Saltford Brass Mill

Watercourse Inspection and Penstock Repair

Survey Report

(Western Chamber, Penstock W4 and Sealed Culvert W3. 10 October 2018)

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Chair: Saltford Brass Mill Project

Executive Summary

In the summer of 2018, B&NES provided funding to dewater the upstream watercourses of Saltford Brass Mill to enable inspection of the normally flooded structures and repair a penstock gate which had been deteriorating over a number of years. This was an opportune time as B&NES had recently acquired a laser scanning capability for the survey of structures in the city of Bath which they were able to deploy at Saltford. One of the SBMP volunteers also had access to an aerial drone capability, which combined with the laser-scan enabled a thorough survey of the mill to be conducted.

The upstream watercourses had not been dewatered in many years. This opportunity therefore enabled a full survey of the watercourses to be conducted and accurate measurements to be taken of the mill, both above and below ground, by a combination of conventional surveying, laser-scan and aerial scan by drone. An accurate 2D plan of the mill has been produced, drawing upon the 3D point-cloud model of the mill produced by the laser scan. Much potential exists for further analysis of the point-cloud model of the mill.

Two surprising discoveries were the existence of a fifth watercourse (WO) on the eastern side of the mill and a western chamber under the dynamo room.

- Watercourse W0 is a culverted channel, 2.5m wide, running north-east from the road bridge for 4.0m towards the eastern range of the mill. The watercourse was previously unknown and further research is required to determine its age and purpose.
- The western chamber is approx. 6m x 5.75m and covers the head-race to watercourse W4 and the blocked watercourse W3. The reason for such a large chamber is unclear and further research is required to establish its age and the reason for its construction.

The survey identified that:

- The masonry throughout the culverts was in generally good condition with no signs of instability, although there is an overall need for repointing.
- The tail-race leat walls of all four watercourses were in a poor condition, masonry having been displaced, fallen and/or been robbed out. A programme of work is required to stabilise these structures, rebuild were appropriate within the constraints of the scheduling and listed status and generally repoint the structures.
- The lintels supporting the penstock gate W1 operating mechanism were found to be cracked. The mechanism is secured to the lintels by six iron bolts fitted through holes drilled through the stone. The swelling of corrosion products round the iron bolts has caused both lintels to crack. The structure remained stable and was not in danger of collapse but it was considered a wise precaution to install a galvanised steel fabrication to take the load of the operating mechanism off the lintels and transfer that load into the culvert walls.
- There are two longitudinal cracks in the western arch of the southern road bridge, running from east to west along the inner edges of the voussoirs. There is no evidence of movement or instability. A weight limit is imposed on the bridge and the structure should be monitored to assess whether any movement is occurring.

The other major objective of the programme of work was the replacement of penstock gate W1 and inspection of penstock gates W2 and W4.

- Penstock gate W1 had been leaking badly. A replacement structure was designed and constructed by the SBMP using greenheart timber and the gate replaced.
- Penstock gate W2 had been replaced in 2016 with a marine-plywood structure following failure of the earlier gate. The gate was found to be in good condition and the paint coating intact.
- Penstock gate W4 is an iron structure. The gate was in good condition, with the exception of the gooseneck in the operating stock which was found to be seriously corroded. Two galvanised steel inserts were therefore manufactured and bolted to the web of the 'I' beam web to reinforce the structure.

A series of recommendations are made, listed at Section 2.5. The key activities that are recommended are stabilising and repointing of various walls. Of most concern are the walls above the tail-race leats which are in a particularly poor condition.

Contents

Acronyms

AIBT	Avon Industrial Buildings Trust
B&NES	Bath and North East Somerset
BIAS	Bristol Industrial Archaeological Society
CRT	Canal and River Trust
SBMP	Saltford Brass Mill Project

Glossary

The following terminology is used in this report:

Watercourses	
Culvert	An artificially buried watercourse that allows water to flow under a road or pavement. In this report the term is used to denote a watercourse that flows under the mill floor.
Leat	An artificial watercourse dug into the ground, especially one supplying water to a watermill. In this report, the term leat is used to denote an open watercourse as distinct to a culverted watercourse.
Penstock	A sluice, gate or intake structure that controls the water flow to a waterwheel.
Penstock Gate	A water control gate that controls the flow of water to a waterwheel. Penstock gates are also known as sluice gates, slide gates or stop gates. In this paper, the term penstock gate is applied to the gates which control the flow to individual waterwheels as distinguished from the sluice gates at the head of the major leat which control the upstream river level.
Race	A race is the channel conducting water to or from a waterwheel or the current of water that turns a waterwheel. The race leading to the waterwheel is called the head-race, and the race leading away from the wheel is called the tail-race.
Sluice	A watercourse controlled at its head by a gate. A mill race, leat, flume, penstock or lade is a sluice channelling water toward a water mill. From the Dutch “sluis”.
Sluice Gate	A wood or metal barrier sliding in groves, set in the sides of a watercourse, commonly used to control water levels and flow in rivers and canals. Sluice gates are also known as knife gates and slide gates. In this paper, the term sluice gate is applied to the gates at the head of the major leat which control the upstream river level as distinguished from the penstock gates which control the flow to individual waterwheels.
Watercourse	An artificially constructed channel along which a body of water flows.

Masonry	
Ashlar Masonry	Masonry made of large square-cut stones, as distinct to rubble masonry. In ashlar masonry, all the stones are cut and dressed, or worked, so they have the same shape, size and surface texture.
Corbel	A structural piece of stone, wood or metal jutting from a wall to act as a bracket to carry a super-incumbent weight.
Keystone	The centre stone, voussoir or masonry unit at the apex of an arch.
Rubble Masonry	Rough, unhewn building stone set in mortar, but not laid in regular courses. It may appear as the outer surface of a wall or may fill the core of a wall which is faced with ashlar or brick.
Springer	The lowest voussoir on each side of an arch, located where the curve of the arch springs from the vertical support or abutment of the wall or pier.
Voussoir	A wedge-shaped element, typically a stone, which is used in building an arch or vault. Although each unit in an arch or vault is a voussoir, two units are of distinct functional importance: the keystone and the springer.

INTRODUCTION AND BACKGROUND

1 INTRODUCTION

1.1 OBJECTIVES

The objectives of this report are to document the work carried out by the Saltford Brass Mill Project in October 2018, comprising:

- De-watering of the mill's upstream watercourses.
- Survey of the mill's watercourses.
- Repair of the penstock-gate in watercourse W1.

1.2 STRUCTURE OF THE REPORT

The report comprises:

- Section 1: Introduction and background.
- Section 2: The programme of work conducted, including recommendations for future work to conserve the scheduled monument.
- Section 3: The survey report of the brass mill's watercourses.
- Section 4: The survey report of the penstock-gates, including the repair action undertaken.
- Section 5: Conclusions

1.3 BACKGROUND

Saltford brass battery and rolling mill is a Grade II* listed building and scheduled monument located on the River Avon at 'The Shallows', Saltford (Grid Ref ST 68713 67005) [Figure 1], mid-way between Bath and Bristol. The site incorporates a major leat fed from Kelson Weir, which in turn feeds four watercourses, each of which supported a waterwheel driving either a set of battery hammers or a set of rolls. The watercourses are numbered W1 to W4 (Figure 2).

The mill was operational as a brass mill from 1721 to 1925 and a map showing the location of Saltford Mill in relation to the River Avon and Kelston Weir is at Figure 3. This is an extract from the 1903 Ordnance Survey map and shows the key elements of the site which are significant to the survey of the watercourses and repair of the penstock gate in watercourse W1.

Following the closure of the brass company in 1925, the mill was purchased by Eric Butler (a director of William Butler and Company, 'Tar, Rosin and Oil Distillers' of Crews Hole), who lived at the 'The Craig' adjacent to the brass mill. Butler adapted the mill to become a sports-centre; which included the installation of a squash court. Lighting for the squash court was provided by a 10kW dynamo driven by the waterwheel in watercourse W2, installed in 1928. At some point in time, waterwheel W2 was further adapted to provide a belt-drive to a circular-saw for cutting timber. Later in the twentieth century (post WWII?) the squash-court ceased to be used. The mill was later acquired by Charlie Shepard and used for the construction of boats (now Bristol Boats Ltd, based at Saltford Lock) but by the 1970s the mill had fallen into a state of decay.

Following attempts to redevelop the site, the mill building was listed Grade II* in 1975 (Listing Number 1384676) and the site scheduled in 1986 (listing Number 1004607). In 1981, the Avon Industrial Buildings Trust (AIBT) leased the listed building and embarked upon a programme of conservation and restoration. The project proved to be beyond their means and the mill was restored to its current condition in 1995, funded by English Heritage. The maintaining lease on the monument was subsequently taken on by the local council (now the unitary authority Bath and North East Somerset [B&NES]). In 1997, the Saltford Brass Mill Project (SBMP) was formed, a voluntary group who work with B&NES to maintain, interpret and open the building to the public.

A description of Saltford Brass Mill and links to archaeological surveys carried out in the mill can be found on the website of the Saltford Brass Mill Project at www.brassmill.com [Ref 1].

Of the four watercourses:

- The penstock gate in watercourse W1 remains operational to enable flushing of the leat. The waterwheel was left in-situ following closure of the mill as a brass works in 1925 but jacked off its bearings and allowed to deteriorate.
- The penstock gate in watercourse W2 and its associated waterwheel were modified to drive the dynamo in 1928 and remain operational, albeit the dynamo is no longer used to light the building.
- Watercourse W3 was blocked and the waterwheel removed to enable construction of the squash court.
- The penstock gate in watercourse W4 remains operational to enable flushing of the leat. The waterwheel was however removed c.1930 and the associated west battery mill demolished.

Penstock gate W1 had been deteriorating for a number of years and at a joint inspection conducted by members of B&NES, the SBMP and Canal and River Trust (CRT) in 2017 it was recommended that the penstock-gate should be replaced within two years. A joint survey by B&NES and Historic England also recommended that a survey be carried out of the mill's sub-structure to assess its condition and propose an ongoing programme of repair and maintenance.

In 2018, funding was made available by B&NES to carry out the survey and conduct the repair. The SBMP undertook the work; which is described in:

- Culvert inspection and Sluice Gate Repair - Options Study [Ref 2].
- Culvert inspection and Sluice Gate Repair - Schedule of Work [Ref 4].

PROGRAMME OF WORK

2 PROGRAMME OF WORK

2.1 SCHEDULE

The key dates in the schedule were:

Event	Date
Survey of the downstream culverts	09 Jun 18
Advance delivery of timber	12 Sept 18
Construction of penstock-gate W1	15 Sept 18 to 5 Oct 18
Project start-up	18 Sept 18
Portadam installation	28 Sept 18
Removal of old penstock gate W1	29 Sept 18
Survey of watercourses	30 Sept 18 to 25 Oct 18
Installation of new penstock gate W1	11 Oct 18
Repair of penstock-gate W4 stock	18 Oct 18
Portadam removal	30 Oct 18

2.2 PERMISSIONS

In recognition of the mill's scheduled monument status and the potential environmental effects of damming the major leat, a number of permissions were required before work could commence.

Bath & North East Somerset Council

B&NES hold the maintaining lease on the scheduled monument; hence B&NES permission was required to undertake the repair work and survey. B&NES further agreed that the SBMP should undertake the work.

Historic England

Saltford Brass Mill is a Grade II* Listed Building and Scheduled Monument [Ref 2]; hence, Historic England's consent is required before works can be carried out within the boundary of the monument. On 13th Sept 2018, Historic England (Ms Melanie Barge) was informed that penstock-gate W1 was leaking badly and was potentially in danger of collapse. An opportunity existed to de-water the upstream watercourses of the mill by rigging a coffer-dam in the major head-race. The river level was exceptionally low in the late-summer of 2018, hence it was opportune to replace the penstock gate and conduct a full survey of the normally flooded culverts and leats. Notice was provided in writing to Historic England by the SBMP, detailing the works and fully justifying the need (Ref 4).

Class 5 of the Ancient Monuments (Class Consents) Order 1994 enables works that are urgently needed in the interests of health or safety to proceed but such works are limited to the minimum measures immediately necessary to secure health or safety. A Class 5 Consent was approved (Ref 5) noting the SBMP were the responsible organisation for determining what works were the minimum necessary for the purposes of health or safety. If there was uncertainty whether or not the proposed works were covered by the 1994 Order, the project should contact Historic England for advice.

Historic England assessed that the works would have minimal impact on the fabric of the monument. It was also recognised that there may be a need for temporary or emergency repairs to the culverts once the survey was concluded and these were covered by the Consent, but no works other than those notified were to be carried out.

The condition of penstock-gate W2 was also discussed. The gate had failed in 2014 as a consequence of which it had been replaced by a marine-plywood structure as an urgent measure to protect the monument and working waterwheel. As it was proposed to replace penstock-gate W1 with a greenheart timber structure, the question was asked whether gate W2 should also be similarly replaced. It was agreed that gate W2 should be examined only at this time. If its condition was satisfactory for future operation the ply-wood gate should be retained but when next in need of renewal consideration should be given to replacement with a greenheart structure.

Environment Agency

The brass mill's watercourses are part of the Kelston Weir waterway system; hence, damming and/or de-watering of the leat system requires Environment Agency consent. The consent is based upon an assessment of the potential impact on flooding in the vicinity of the waterway system and on wildlife in the waterway system. An exemption was registered for temporary de-watering of the leat and culvert. [Ref 6]

2.3 Coffer-Dam

The Options Study [Ref 3] considered the methods and location of temporary dams in the major leat of the brass mill, the factors determining the type and location of the coffer-dam being:

- The cofferdam must effectively stem to the flow into the watercourses to provide a safe environment in which to conduct survey and repair work.
- The cofferdam must make an effective seal with the bed and banks of the leat.
- The location of the cofferdam must, so far as is reasonably practicable, minimise the impact on the business of Mill Island Moorings.

Method of Damming

Three methods of damming the leat were considered:

- Use of a local coffer-dam, using scaffolding, plywood sheet and tarpaulins, as previously deployed to protect the waterwheel in watercourse W2.
- Installation of a Portadam, a proprietary system designed for use as mobile flood protection barriers and temporary cofferdams for the construction industry, comprising a steel frame and fabric membrane rigged across the full width of the major leat.
- Installation of an Aquadam, a proprietary system designed for use by the construction industry, comprising three or more polyethylene or woven geo-tech tubes and any available water supply. Two 'inner' tubes, contained by an outer 'master' tube, are pumped full of water simultaneously. Counter friction between the master and inner tubes results in a stable, non-rolling 'wall' or aqua barrier of contained water, which adjusts automatically to bottom terrain as the Aqua Dam deploys.

Option b, the Portadam, was selected as most appropriate to the conditions in major leat.

Location of Dam

A number of locations for the dam were considered:

- Close-coupled to the entrance to watercourse W1 inlet culvert.
- Upstream of the watercourse inlets, in the lower reach of the major-leat.
- Upstream of the watercourse inlets in the upper reach of the major-leat.
- In the upper reach of the major-leat, upstream of the river sluices to enable inspection and repair of the river sluices by the Canal and River Trust.

- Upstream and downstream dams to fully de-water the watercourses.

Option b, upstream of the watercourse inlets, in the lower reach of the major-leat was selected as it provided good protection for work conducted in the culverts whilst minimising the impact on Mill Island Moorings [Figure 42 to Figure 46].

2.4 SURVEY

A full survey of the mill and watercourses was carried out by members of the SBMP supported by B&NES officers. The survey comprised a combination of visual inspection, photographic record, conventional measurement, aerial scan using a drone and 3D laser scan. Of particular value was the use of a Leica RTC360 3D laser scanner made available by B&NES (Jeremy Rogers, Senior 3D Imaging Surveyor, Bath & North East Somerset Council).

Water-levels

The watercourses upstream of the penstock gates were dewatered but the downstream watercourses remained flooded to the corresponding river level downstream of Kelston Weir. The river was very low during the period of the survey but the level of water in the downstream culverts was still approx. 0.7m deep, which limited the degree of inspection achievable and prevented use of the laser scan in culvert W2.

Silt

The upstream watercourses were heavily silted. It was possible to sound the depth of the silt using an iron rod and these measurements have been incorporated into survey report.

Laser Scan and 'Point-Cloud'

A laser scanner is a portable device which is set up on a tripod [Figure 4]. When activated, the device automatically scans a 3-dimensional envelope around itself measuring the distance to all structures and objects in line-of-sight. The system then creates a 'point-cloud', i.e. a set of data points in space, a 'point-cloud' being a very accurate digital record of an object or space. It is saved in the form of a very large number of 'points' that cover the surfaces of a sensed object. 'Points' in a 'point-cloud' are always located on the external surfaces of visible objects, because these are the spots where a ray of light from the scanner was reflected from the object. The Leica scanner has a measuring rate of up to 2 million points per second and a coloured 3D 'point-cloud' can be created in under two minutes.

A 'point-cloud' is obtained by visible access to real objects. It is impossible to obtain points on the surfaces that are not visible from the position from which we collect data. This means that to cover all objects it is necessary to combine many scanning positions. The software subsequently interpolates the data-set to create a single 'point-cloud' of the structure and objects within the structure. The brass mill is a complex structure; the mill was therefore scanned from multiple data collection positions and the mill was eventually scanned from approx. 60 data collection positions which created around 300GB of data.

The information recorded for each data-point is not only its position in space but also its colour. An array of data-points can therefore be displayed to create an image of the structure which resembles a photograph. Figure 4 shows an image of the squash court created in this manner.

2D Plan of the Mill

The aerial scan and 'point-cloud' were used to create an accurate 2D plan of the mill and the watercourse system (both within the building and the building's setting within its environs).

An overall view from the aerial scan is shown at Figure 41 and two screenshots from the 'point-cloud' are shown at Figure 42 and Figure 43:

- Figure 41 is an overall aerial view taken by drone.
- Figure 42 is a cut-set of the 'point-cloud' at roof level, showing the overall structure within its environs.
- Figure 43 is a cut-set of the point-cloud at ground level showing the mill's floor-plan and watercourse system.

The colours of the 'point-cloud' screenshots have been enhanced to aid interpretation by use of colour and high contrast. The two cut-sets of the 'point-cloud' have been used to support production of an accurate 2D plan of the mill using Microsoft Visio. The Visio plan is a 'layered' document enabling different drawings to be produced from the same data-set with emphasis on different characteristics of the mill. The Visio plan incorporates not only data from the 'point-cloud', but also data from the 1839 tithe-map of Saltford (Ref 7) and the 2018 Historic England map of the scheduled monument.

The 2D plan shows the location of existing and demolished structures:

- Figure 44 shows the mill within its environs and the boundary of the scheduled monument.
- Figure 45 is a larger scale plan of the mill interior, showing the location of the battery mills, the rolling mill, the squash court and dynamo room, the four waterwheels and the watercourse system.
- Figure 46 shows the watercourse system only.

This has used only a small sub-set of the point-cloud. The data will continue to be used for future research into the mill.

Artefacts

No programme of artefact recovery from the watercourses was carried out but a number of interesting pieces of glass and pottery were recovered for the surface silt. These included a number of glass bottles, pottery jars and ink bottles. One item of particular interest was the remains of a porcelain jug on which was a transfer of Major-General John French [Figure 40]. The jug is likely to be a commemorate piece dating to the Boer War (1899-1902).

2.5 RECOMMENDATIONS

Survey of Downstream Watercourses

Rigging of the coffer-dam in the head-race dewatered the upstream watercourses but left the downstream watercourses at the river level downstream of Kelston Weir. The survey of the upstream watercourses has been very comprehensive but certain parts of the downstream watercourses were flooded to a depth of approx. 0.7m. This was problematical for the laser scan survey of watercourse W2 where the clearance was such that the scanner could not be deployed. A future programme of work should include the rigging of a coffer-dam in the W1/W2 tail-race to de-water the downstream watercourses and enable completion of the laser scan.

Re-Pointing

While the watercourses are in good condition, considering their age, there is a general need to re-point much of the masonry. The repointing packages can be considered in three groups: (1) repointing which can be carried out without de-watering; (2) repointing requiring upstream de-watering; and (3) repointing requiring downstream de-watering.

Direct Access

The areas requiring repointing which are not dependent upon de-watering are:

- Tail-race culvert W1 – upper courses, dependent upon river level.
- Tail-race culvert W2 – upper courses, dependent upon river level.
- Tail-race culvert W4 – upper courses, dependent upon river level.

Downstream De-watering

The areas requiring repointing which are dependent upon de-watering the downstream watercourses are:

- Tail-race culvert W1– lower courses.
- Tail-race culvert W2– lower courses.
- Tail-race culvert W4– lower courses.

Upstream De-watering

The areas requiring repointing which are dependent upon de-watering of the upstream watercourses are:

- Head-race culvert W1.
- Southern road-bridge piers.
- Southern road bridge.
- West wall of the rolling mill, upstream of watercourse W2.
- Penstock W2.
- Western Chamber.

Repair of Leat Walls

The area most in need of stabilisation and repair are the walls of the east and west tail-race leats W1/W2 and W3/W4.

Tail-Race W1/W2

A scheme should be developed to stabilise the structures on the east bank of tail-race leat W1/W2, both within the leat and the standing east annealing shop structure above the leat. The walls should be stabilised, rebuilt where practicable and repointed.

The pier between culverts W1 and W2 should be repointed, and where practicable rebuilt.

A scheme should be developed to stabilise the structures on the west bank of tail-race leat W1/W2. The leat bank should be stabilised to protect the extant masonry and, where practicable, the superstructure re-built.

Tail Race W3/W4

The mill superstructure above the west wall of the W4 wheel-pit is showing signs of instability. There has clearly been some movement of the wall. The pointing is in poor condition. There is evidence of frost damage to some of the stone work. Vegetation has caused further damage to the lime mortar dislodging some masonry. The damaged area is above the watercourses and so can be accessed without de-watering. A programme of work needs to be put in place to stabilise the walls, remove vegetation and repoint the structure.

The west wall of the tail-race leat W3/W4, downstream of the foot-bridge, is suffering from vegetation damage, degradation of the mortar binding and displacement of masonry. A programme of work is required to reduce the amount of vegetation in the bank, stabilise the bank, stabilise the extant structure, rebuild fallen masonry and repoint the wall.

The east leat wall of the tail-race leat W3/W4, downstream of the rising foot-bridge, is in poor condition. The wall has suffered from vegetation damage, degradation of the mortar binding and displacement of masonry. Much of the masonry has fallen or has been being robbed-out and in places stands only just above river level. A programme of work is required to reduce the amount of vegetation in the bank, stabilise the bank, stabilise the extant structure, rebuild fallen masonry and repoint the wall.

The shallow arch through which the leat discharges is laid on a wrought iron plate which is badly corroded. The masonry arch appears stable but should be monitored and action taken if the wall above shows signs of movement.

Culvert W2

Consideration should also be given to repairing the damage in culvert W2, downstream of the wheel-pit where the outer faces of a number of courses of masonry have fallen.

Penstocks

W2 Penstock

The performance of W2 penstock should continue to be monitored. Leakage past the gate and the fixed shuttering should be monitored. If the leakage becomes excessive, a scheme should be developed to replace the gate and/or the shuttering. If this becomes necessary, replacement with greenheart timber should be considered.

W4 Penstock

The performance of penstock W4 should continue to be monitored, in particular the gooseneck which has experienced significant corrosion damage. If the condition of the gooseneck continues to deteriorate, consideration should be given to replacing the stock, possibly with a timber structure, which may in turn require replacement of the gate.

Southern Road Bridge

The damage to the southern road bridge masonry should be monitored. and a future programme of repointing developed when the watercourses are next de-watered.

Repairs to the weather damaged stonework should be carried out. This can be accessed from above and does not require de-watering.

WATERCOURSE SURVEY

3 WATERCOURSE SURVEY

3.1 SALTFORD BRASS MILL

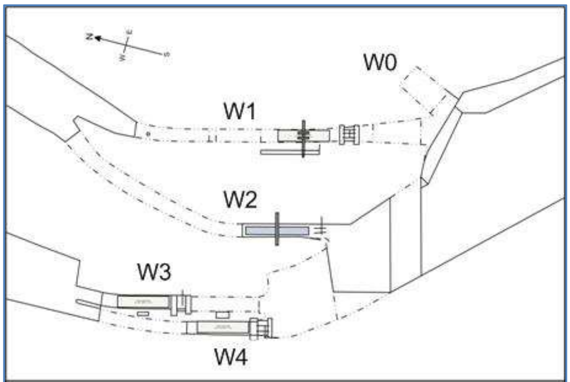
Figure 45 shows the layout of the mill, incorporating the standing super-structures, sub-structure, watercourses and structures demolished following closure of the mill for the manufacture of brass in 1925.

Maps showing the layout of Saltford brass mill between 1839 and 1903 (Refs 7 to 11) [Figure 5] indicate that the layout of the mill did change significantly over this period. The major upstream leat is fed from Kelston weir splitting beneath the road-bridge at the southern end of the mill into four watercourses, each of which supplied a waterwheel.

The bridge has two-spans and is constructed on a shallow bend (Figure 6). The entrance to watercourse W1 is beneath the eastern arch of the bridge and the entrance to watercourses W2, W3 and W4 is under the western arch of the bridge. The entrance to watercourse W2 is beneath the southern wall of the workshop known today as the dynamo room. The entrance to watercourses W3 and W4 is via a wide arch on the western side of the dynamo room, extending from the middle of the dynamo room to the wall of the now-demolished, west battery mill.

The 1932 OS map (Ref 11) shows that by 1932 the west battery mill had been demolished, presumably as part of Eric Butler's conversion of the mill to a sport's facility. The arrangement of watercourses was not however changed with the exception of watercourse W3 which was probably blocked in the late 1920's as part of the conversion.

3.2 WATERCOURSES

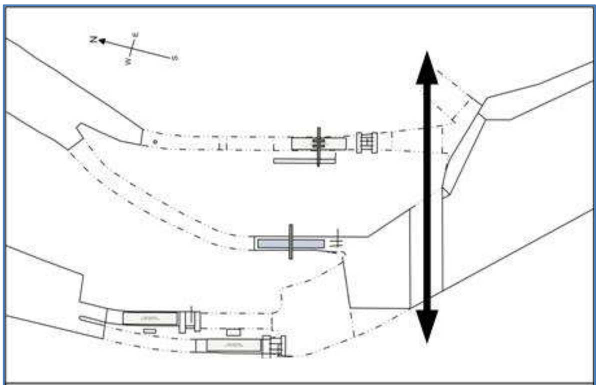


Saltford Brass Mill Watercourses

The survey of the watercourses revealed a number of unexpected features:

- A fifth, previously unknown, watercourse (Watercourse W0) was identified to the east of watercourse W1.
- Watercourse W1 runs as predicted from south to north from the eastern span of the road-bridge, via penstock-gate W1, to the culvert outlet at the north of the mill. The structure is however more complex than envisaged showing evidence of an earlier secondary sluice and two extensions to the bridge.
- The arch through which watercourses W3 and W4 are fed opens onto a large chamber which extends part-way beneath the dynamo room. The entrances to watercourses W3 and W4 are in the north-west corner of this chamber.
- Watercourse W3 is not simply silted up but is sealed by a wall constructed of well-dressed masonry. It is assumed that this culvert was walled-up in the mid-1920s to enable construction of the squash-court.

3.3 Southern Road Bridge



Southern Road Bridge

Length	19.4m
Width	2.75m
Orientation	East-West

<u>Description of the Southern Bridge</u>

The lower reach of the major upstream leat is spanned by a road bridge running east-west and set at a slight angle to the major-leat [Figure 45].

The bridge is contemporary with the main structure of the mill. It features in all maps from 1839 onwards and is probably significantly older. It is constructed from local rubble stone, roughly coursed with lime mortar binding, but with ashlar voussoirs.

The bridge is a complex structure. When viewed from upstream [Figure 6] it appears to have two spans and a central pier. The survey revealed that the bridge has in fact three spans and two piers. The western span crosses open water, spanning the head-races to watercourses W2, W3 and W4. The western pier is a broad irregular quadrilateral in plan. it separates watercourses W1 and W2, supports the roadway and supports the southern wall of the rolling mill. The centre and eastern spans form the entrances to watercourses W1 and W0 respectively and are separated by a narrow eastern pier [0]. The roadway is extended to the south of the two eastern spans above watercourses W1 and W0, the extended roadway being laid on a single shallow arch across the culvert entrances. The extension is triangular in shape, extending from the centre of the western pier to the south-eastern corner of the W0 culvert voussoir, providing an apron to ease carriage access onto and off the bridge [Figure 9].

The dimensions of the arches and piers are:

- The western arch has a span of 8.6m with a rise of approx. 1.5m.
- The western pier is 3.7m long (east-west) x 3.0m wide (north-south).
- The central arch, above watercourse W1, has a span of 2.3m.
- The eastern arch, above watercourse W0, has a span of 2.5 m.
- The southern extension above watercourses W1 and W0 has a span of 7.6m with a rise of approx. 0.75m.

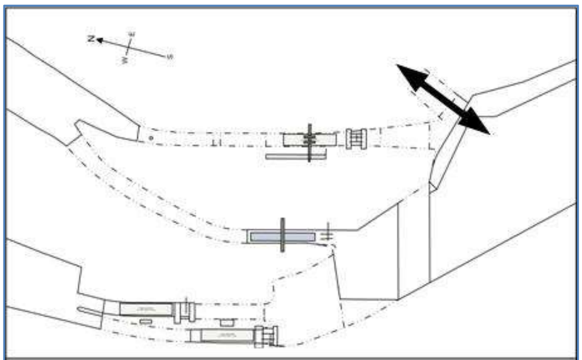
<u>Condition of the Southern Bridge</u>

The bridge structure appears stable and there is no evidence of movement. Two cracks are however visible running east-west along the length of the western arch along the inside of the voussoirs [Figure 8]. The damage is more significant on the northern side of the bridge. The voussoir at the south west springing is also showing signs of freeze-thaw damage to the stone work.

The lime mortar is in reasonable condition but there is evidence of the mortar being washed through the structure resulting in numerous stalactites on the underside of the bridge.

The damage to the stonework should be monitored and a future programme of repointing developed when the watercourses are next de-watered.

3.4 WATERCOURSE W0 – EAST-CULVERT



Watercourse W0

Length	4.0m
Width	2.5m
Orientation	South West – North East

The existence of watercourse W0 was previously unknown, although there were suspicions that an earlier watercourse may exist; Joan Day[1] having verbally expressed the possibility of an earlier watercourse closer to the river that the four known watercourses.

Description of Culvert W0

Watercourse W0 is culverted along its remaining length. The culvert runs from the eastern side of southern road bridge and passes under the road towards the eastern range of the mill (Figure 45). The culvert is of a constant width of 2.5m along its length and runs north-east towards the river for 4.0m at which point the leat is blocked with a well-dressed masonry wall. It is not known if the culvert continued beyond this point.

The culvert is constructed from local rubble stone, roughly coursed, with lime mortar binding, but with well-cut ashlar voussoirs (Figure 11). There is also a well-cut ashlar pier between watercourse W0 and watercourse W1 [0]. The culvert is heavily silted (approx. 1.9 m deep); hence it was not possible to inspect the lower structure. The culvert has vertical walls with a shallow barrel roof. By comparison with the adjacent culvert, W1, it is estimated that the height of the walls is approx. 2.4 m from floor to springing. The rise of the arch is only 0.25 m giving maximum height of the culvert of 2.65 m.

Condition of Culvert W0

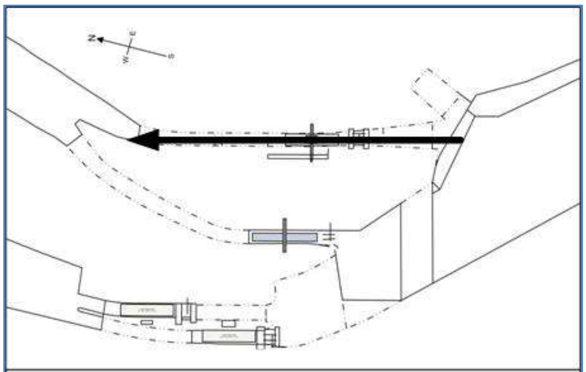
The walls and roof of culvert W0 appear in good condition and there is no evidence of structural damage or instability.

Interpretation of Culvert W0

Culvert W0 and any associated waterwheels are not recorded as part of the 1859 inventory of the rolling or battery mills, when the brass company's works were to be sold by auction [Ref 12]. Nor does culvert W0 appear on any maps after 1839. It is therefore assumed that the structure is pre-1839 and appears to be part of an earlier configuration of the mill. Two possibilities are that it was part of the mill as modified for brass battery in the 1720s, but again modified when the rolls were introduced in the later eighteenth century, or it was part of the mill's pre-1721 use, either as a flour or grist mill, or as a fulling mill. Further research and investigation are required to fully establish the function of watercourse W0.

[1] Joan Day. Author of 'Bristol Brass; the History of the Industry' David & Charles, 1973. First Chair of the SBMP

3.5 WATERCOURSE W1



Watercourse W1

Length	27.0m
Width (Head)	2.3m
Width (Tail)	1.1m
Orientation	South - North

Description of Watercourse W1

Watercourse W1 runs from south to north and supplied water to the eastern waterwheel driving the rolling-mill. The watercourse comprises: an inlet under the southern road-bridge; a culverted head-race; a penstock gate (replaced as part of the 2018 programme of work); the remains of a waterwheel; a culverted tail-race; a culvert outlet adjacent to watercourse W2; and a combined W1/W2 tail-race leat returning to the river.

The watercourse is 27m long and is culverted for much of its length. The inlet is under the central span of the road bridge. The head-race is 6.8m long from the culvert inlet to the penstock gate and the tail-race 18.6m long from the penstock gate to the culvert outlet, being culverted for 11.4m.

Head-Race Culvert W1

The upstream W1 culvert forms a funnel to increase the velocity of water as it approached the waterwheel, reducing from 2.3m wide at its mouth to 1.2m at the penstock gate. The culvert has vertical walls with a shallow barrel roof. The walls are 2.4m high from floor to springing and the rise of the arch is 0.25m giving maximum height of the culvert of 2.65m. The length of the culvert from its inlet to the penstock gate is 6.8m, but the bridge has been widened at this point and now overhangs the entrance by a further 1.6m.

In common with other parts of the mill, the culvert is constructed from local rubble stone, roughly coursed with lime mortar binding, with ashlar employed where structural integrity is important: for the voussoirs at the inlet and outlet from the culverts; in the lower courses of the culvert; around the penstock gate guide channels; and for the gate operating mechanism mounting arrangements.

There is evidence of the culvert being modified at several times in its history. 4.3m upstream from the penstock-gate there is evidence of arrangements for a secondary sluice, comprising ashlar blocks built into the culvert wall into which a channel has been cut and an opening in the roof into which a sluice-gate could be inserted. The aperture, if extended to the surface, would open in the middle of the road-way, however there is no corresponding opening in the road-way, hence it would appear that this facility was not used in the later operating period of the mill.

Penstock Gate W1

Penstock-gate W1 [Figure 14] comprises a lower moveable gate and upper fixed shutter. The fixed shutter is made from wrought-iron, set in a wrought-iron channel mounted at 35^{O} to the vertical, itself set into a section of the culvert wall constructed from ashlar masonry.

The gate is made of timber (originally oak, but now replaced with greenheart) mounted at 45^{o} to the vertical and operated from above by means of a rack-and-pinion mechanism located in the rolling-mill. The angle of the gate acts as a nozzle to further accelerate flow through the gate onto the undershot waterwheel. A fuller description of the penstock gate is given in Section 0.

The operating mechanism is mounted on two lintels set across the leat [Figure 18]. The lintels are separate structures to the culvert barrel roof. The operating mechanism is constructed from a combination of cast and wrought iron and is secured to the lintels by means of six iron bolts fitted through holes driven into the lintels. This fixing method is different to the penstocks in W2, W3 and W4, which use an 'L' shaped key-way cut into the lintel with wedges inserted to hold the mechanisms in position. This suggests that the mechanisms were installed at different times, possibly meaning that watercourse W1 is a later addition. One possibility is that the watercourse was constructed when the mill was adapted for rolling in the late eighteenth century.

The watercourse is more sophisticated than originally thought. There is a step in the culvert floor beneath the foot of penstock gate [Figure 14] and the floor of the culvert downstream of this step is contoured to the shape of the waterwheel. Water is accelerated towards the wheel by the funnelling effect of the head-race culvert and angling of the penstock-gate. Water is directed, not at the base of the waterwheel but around 0.6m above its maximum diameter, projected onto the wheel's paddles. The shape of the culvert floor encourages outflow from the wheel, so reducing the waterlogging effect of the downstream head.

Tail-Race Culvert W1

Tail-race culvert W1 is 1.3m wide x 18.6m long from the penstock-gate to the culvert outlet. In section, the culvert has vertical walls and a shallow barrel roof., the walls being 1.3m high with the barrel roof having a rise of 0.18 m. The culvert, which shows evidence of multiple stages of construction, comprises three distinct sections: the open waterwheel pit; the upper reach of the culvert; and the lower reach of the culvert.

Waterwheel Pit W1

The waterwheel pit is 7.2m long x 1.1m wide and contains a variety of masonry, including ashlar, local rubble stone and brick, dating from several periods of history. The lower courses of the west wall are ashlar which provide a foundation for the mill's superstructure which is built of local rubble stone, roughly coursed with lime mortar binding. The wall has been repaired in a number of places with brick, also dating from a number of periods including the conversion of the mill to a sports facility in the late 1920s and the 1995 restoration. There are also score marks on the wall where the wheel inadvertently made contact with the wall when operational. The remains of a waterwheel, comprising an iron shaft and hub plus the remains of timber spokes, are still in place, as preserved during the 1995 restoration. The shaft has been raised from its operating position, presumed to have taken place in the 1920s, and is supported by brick walls which infill the drive-shaft openings on either side of the pit. The upper walls were shored with timber bracing in the 1995 restoration to stabilise the structure; that shoring remains in place, is in good condition and no movement of the walls has been observed.

Tail-Race Culvert W1 – Upper-Reach

The upper-reach of the culvert runs north from the wheel-pit to a discontinuity in the barrel roof 4.8m downstream. The discontinuity aligns with the east-west wall at the northern end of the battery mill and possibly indicates that the culvert was extended north at some point in the mill's life. The discontinuity possibly supports the theory that the northern range was extended sometime after 1742 [Reference 13, Section 7]. At the downstream end of the upper-reach there are two features of interest: in the roof of the culvert, immediately upstream of the discontinuity, there is a roughly-engineered opening which appears to have given access to the culvert from the eastern wing of the mill. At a similar position but in the western wall of the culvert there is a well-engineered drain which extends to the west under the rolling mill. The purpose of the drains was presumably to drain the mill flowing a flood. Further research is however required to fully establish the purpose and extent of the drains.

Tail-Race Culvert W1 – Lower-Reach

Downstream of the discontinuity the culvert continues north for a further 6.6m under the north-eastern range of the mill. The roof of the lower-reach of the culvert is 0.25 m lower than the upstream section. In the roof of the lower culvert, close to its outlet, there is a discharge shaft from a latrine located in the northern range of the mill, known colloquially as the 'one-holer'.

Condition of Culvert W1

Head-Race Culvert W1

Head-race culvert W1 is silted to a depth of around 0.6 m. Penstock W1 has not been operated for around 5 years; hence there has been a general built up of silt upstream of the gate. In particular there is a large bank of silt close to the inlet to the culvert. Following the installation of the new gate it is planned to open the gate regularly with the aim of reducing the level of silt.

The walls and roof of the W1 head-race culvert appear in good condition and there is no evidence of structural damage or instability. There is however a general need to repoint the masonry. This will require de-watering of the upstream watercourses and will need to be part of a future programme of work.

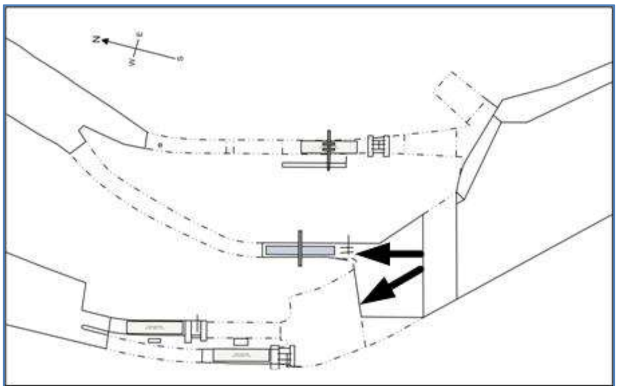
Penstock W1

The two lintels which support the penstock-gate operating mechanism have been damaged by the swelling of corrosion products around the six mounting bolts. The lintels are not in danger of falling but both lintels are cracked. The action of the corrosion has also caused some of the stone to break way, the damage being most severe on the upstream lintel [Figure 18]. It was judged that the lintels could not continue to take the load of operating the penstock-gate and a galvanised fabrication was constructed and installed in October 2018 to relieve the load on the lintels and transfer the load into the culvert walls [Figure 19].

Tail-Race Culvert W1

The downstream culvert is only lightly silted; flow through the damaged penstock-gate having purged the leat. The walls and roof of the culvert appear in good condition and there is no evidence of structural instability. There is a general need for repointing throughout the culvert and some masonry is loose, but not to the extent of structural instability. The downstream leat can be accessed when the river is low; however, the re-pointing programme would benefit from de-watering of the downstream leat to enable the lower-walls to be re-pointed as well as the higher-walls.

3.6 Head-Race W2, W3 and W4



Head Race W2, W3 & W4

Description of W2, W3 and W4 Head-Race

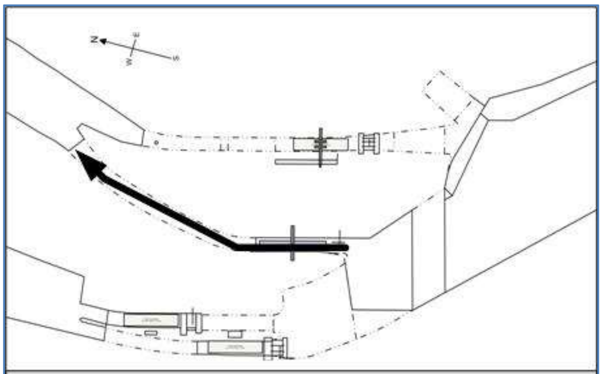
An area of open water exists between the road bridge and southern wall of the mill which is the head race for watercourses W2, W3 and W4 (Figure 25 and Figure 26). The boundaries of the open water are: the road bridge; the west-wall of the upper rolling mill; penstock W2; and a chamber beneath the area now-known as the dynamo room from which watercourses W3 and W4 are fed.

The road-bridge, west chamber and penstock W2 are described separately. The east-wall of the head race performs a number of functions: it is the foundation for the west-wall of the rolling mill; it becomes the western-pier of the road bridge; and it is contoured to direct flow into watercourse W2 (Figure 25). The wall is constructed from a combination of roughly-coursed local rubble stone with lime mortar binding and larger blocks of well-coursed local stone where structural integrity is important, principally at the base of the mill superstructure and around the entrance to watercourse W2.

Condition of W2, W3 and W4 Head-Race

Flow around the east-wall into watercourse W2 has caused significant erosion to the masonry and there is evidence of a cement repair on the corner of the wall as it turns in towards the watercourse. This repair appears to have been made by casting cement using a sheet of corrugated-iron as shuttering. The date of this repair is unknown, but pre-dates the involvement of the SBMP. The wall, including the repair, is stable and does not appear in danger of collapse, but the wall needs extensive repointing. This will require de-watering of the upstream watercourse and will need to be planned into a future programme of work.

3.7 WATERCOURSE W2



Watercourse W2

Watercourse Length	25.60m
Culvert Length	17.6m
Width (Head)	1.45m
Width (Tail)	1.4m
Orientation	South West – North East

Description of W2 Watercourse

Watercourse W2 [Figure 46] comprises: an inlet adjoining the open water to the south of the dynamo-room; a short head-race; a penstock gate (replaced in 2016); a working waterwheel; a culverted tail-race which passes under the squash court and annealing furnace apron; an outlet adjacent to culvert W1; and a combined W1/W2 open leat returning to the river. The watercourse runs from south to north, curving eastwards as it passes under the squash-court to join watercourse W1. The watercourse is 25.6m long from head-race inlet to culvert outlet and supplied water to the western waterwheel driving the rolling-mill. This wheel was adapted by Eric Butler in 1928 to drive a dynamo to light the squash court.

Head-Race W2

Head-race W2 is a short open leat, approx. 1.0m long (by comparison to the 6.9m culvert of the W1 head-race). The east-wall of the leat is coincident with the west-wall of the rolling mill, the curve of the wall acting to channel flow into the watercourse from the open-water of the major head-race leat. The west-wall of the head-race is within the dynamo room and comprises a short, curved, wall, approx. 1m long [Figure 27], creating a funnel at the entrance to the penstock.

A galvanised iron grill is mounted in front of the penstock W2 to protect the waterwheel by preventing large items of debris from entering the penstock. The grill was put in place as part of the 1995 restoration programme, photographic evidence pre-dating the restoration showing that no grill was previously in place. The grill is in reasonable condition, albeit that some rungs have broken as a consequence of corrosion. The grill is otherwise sound and is capable of performing its duty as a defence against large items of debris. The structure is galvanised; hence no further preservation is recommended.

Two lintels are laid across the head-race on which are mounted the penstock operating mechanism. The lintels are well-cut ashlar, of cross-section 0.3m deep x 0.46m wide. The penstock operating mechanism is cast-iron and is mounted in ‘L’ shaped key-ways cut into the stone lintels, two in each lintel, the mechanism being held in position by wooden wedges.

In common with other parts of the mill, the head-race is constructed from roughly-coursed local rubble stone with lime mortar binding, with ashlar employed at locations where structural integrity is important: principally around the penstock gate slide channels and supporting wall for the lintels. The upstream lintel is a complex shape. The eastern end is built into the rolling-mill wall. The western end is built into the south-wall of the dynamo room but overhangs the upstream leat by approx. 30cm to lie perpendicular across the leat necessitating a curved corbel to take the load into the wall.

Penstock-Gate W2

Penstock-gate W2 is accessed from the dynamo room but operated from the rolling mill by means of a shaft which passes through the west-wall of the rolling mill. The penstock gate and fixed shutter are both constructed from timber. A fuller description is given at Section 4.4.

Tail-Race Culvert W2

The W2 tail-race is culverted, the tunnel being 17.6m long from the culvert inlet, downstream of the wheel to the culvert outlet. The culvert is constructed from roughly-coursed local rubble stone with lime mortar binding. The voussoirs of the culvert inlet are constructed from well-cut ashlar but the voussoirs of the culvert outlet are constructed from larger pieces of local stone fashioned to create a stable arch. The culvert turns eastwards, running under the squash-court and annealing furnace apron, to join culvert W1 and discharge into a common W1/W2 tail-race leat to re-join the river to the north.

Condition of Watercourse W2

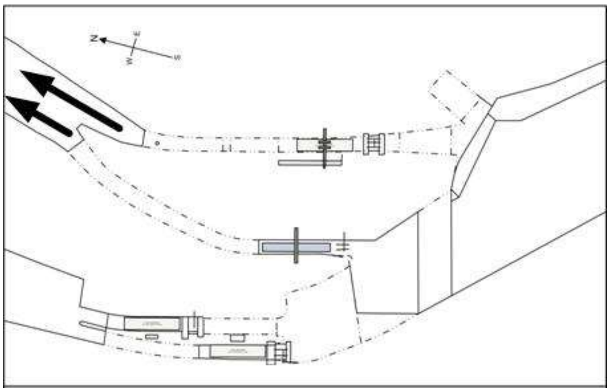
Head-Race W2

The masonry of the W2 head-race is generally in good condition but would benefit from repointing, particularly on the rolling-mill wall.

Tail-Race Culvert W2

Tail-Race Culvert W2 is generally in good condition, although there is an area of damage on the eastern wall of the culvert, beneath the southern wall of the squash-court. The damage extends for approx. 2.5m along the waterline and is 2-3 courses high [Figure 29]. The surface layers of stone have fallen but the rear layers of stone remain in place and are stable. Overall, the culvert is stable and there is no evidence that it is in danger of collapse. The stonework would however benefit from repointing. This will ideally require de-watering of the downstream watercourses to enable repointing to the base of the walls.

3.8 TAIL-RACE LEAT W1/W2



Tail Race Leat W1 & W2

Description of Tail-Race Leat W1/2

The walls of the W1/W2 tail-race leat are constructed from a combination of well-cut ashlar and cast copper-slag blocks [Figure 24] indicating that they are of eighteenth-century construction, laid after the mill was leased by the Bristol Brass Company in 1721.

The west-wall of the leat appears to have been built of cast copper-slag blocks, but much of the wall has collapsed and the masonry robbed-out. The central pier between culverts W1 and W2 is constructed from well-cut ashlar. The east-wall of the leat is constructed from cast copper-slag blocks and forms the foundation of the west-wall of the east annealing workshop; much of the annealing workshop wall has however collapsed. From the elements of the workshop wall that remain standing it is deduced that the workshop wall was built of roughly-coursed local rubble stone with the jambs and sills of a window in the wall being constructed of copper-slag.

Condition Tail Race Leat W1/W2

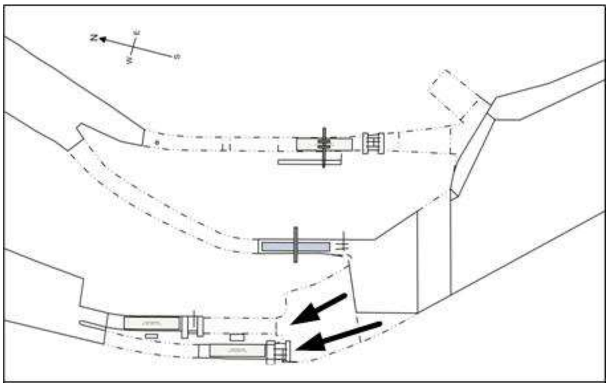
The copper-slag blocks are resilient to weathering and erosion; however, the leat walls have suffered a large amount of displacement and in places have collapsed.

The east-wall of the leat is largely intact, albeit with some displacement of slag blocks. The wall appears stable, however, and no movement has been observed in recent years. The east annealing shop wall has largely collapsed with the exception of a short run in the vicinity of the culvert outlet.

The west-wall of the leat has suffered most damage and much of the masonry above river-level is missing. Parts of the wall's foundations are intact but there is significant erosion of the leat bank.

Future work should be targeted at stabilising the extant structures and re-pointing the standing masonry. Particular attention needs to be paid to the west-wall of the leat, where a scheme should be developed to stabilise the leat bank and protect the extant masonry. Also, the standing remains of the east annealing shop wall adjacent to the tail-race leat W1 need to be stabilised and repointed.

3.9 WESTERN CHAMBER



Western Chamber

Description of Western Chamber

A chamber exists beneath the dynamo room (Figure 45 and Figure 46). This chamber is normally flooded and forms the head-race to watercourses W3 and W4. The chamber extends westwards from the dynamo-room, under the deck above the former inlet to watercourse W3 and the deck above penstock-gate W4. There is southern extension to the chamber beneath the path leading to the southern entrance to the brass mill.

The chamber has two components. The main chamber, running east-west beneath the dynamo room, roughly quadrilateral in plan, approx. 5.75m (north-south) x 6.0m (east-west). The east and west walls are curved to direct the flow of water to watercourses W3 and W4. A secondary, triangular, sub-chamber adjoins the south-western boundary of the main chamber running south to the road bridge. The sub-chamber is 4.7m deep (north-south) and 2.2m wide (east-west) at its widest point.

The main chamber has vertical walls and a shallow arched roof running east-west and having a rise of 0.9m over a 5.75m span. The roof of the adjoining secondary chamber is a shallow semi-arch running north-south and abutting the voussoir of the downstream inlet to the main chamber. The rise of the semi-arch is 0.4 m over a 4.7 m span.

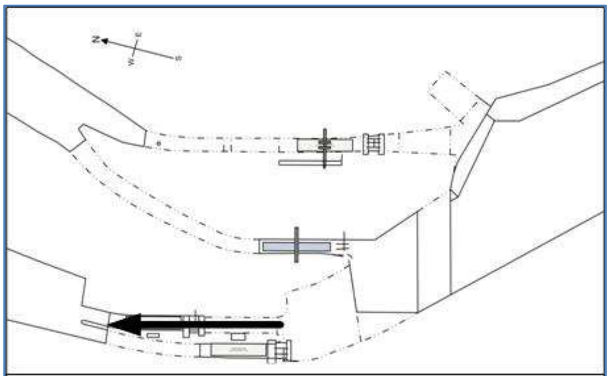
The walls of the chamber are, in the main, constructed from roughly-coursed local rubble stone with lime mortar binding. Ashlar is employed at locations where structural integrity is important: in particular for the voussoirs and entrances to the watercourses.

Condition of Western Chamber

The chamber is silted to a depth of approx. 0.5m but with a channel running from the south-eastern corner of the chamber, adjacent to watercourse W2, to penstock-gate W4, created by flow through watercourse W4 when routinely opened to flush away silt. The area immediately upstream of penstock-gate W4 is only lightly silted.

The masonry appears stable and is in good condition but would benefit from extensive repointing. This will require de-watering of the upstream watercourses and should be planned in to a future programme of work.

3.10 Watercourse W3



Watercourse W3	
Watercourse Length	14.0 m
Culvert Length	6.1 m
Width	1.2 m
Orientation	South – North

Description of Watercourse W3

Watercourse W3 runs from south to north and supplied water to the wheel powering the east battery-mill (converted to a squash-court in 1928). The watercourse comprises: a blocked inlet from the western chamber (presumed blocked in 1928); an in-filled, culverted, head race, 6.1m long; a penstock gate, now removed (presumably removed and blanked in 1928); a waterwheel pit (the wheel is no longer in place, presumably removed in 1928, but the western bearing mounts and eastern drive-shaft arch leading into the battery mill remain); a short tail-race passing under a former exterior wall of the mill adjacent to culvert W4; and a combined W3/W4 tail-race leat returning to the river.

The inlet culvert is blocked with well-cut ashlar masonry. There is an opening in the roof of the western chamber immediately upstream of the culvert inlet, giving access to the chamber from the mill floor (now outside the main building following the demolition of the west battery-mill c.1930). The opening is covered with a metal grill, installed as a safety measure in 1995 as part of the conservation programme.

The head-race culvert is in-filled but the waterwheel pit remains exposed. The walls of the wheel-pit are constructed from large blocks of well-cut ashlar, which contrasts with the roughly-coursed local rubble walls of the mill superstructure above.

The waterwheel is no longer in place but score marks are visible in the leat walls where the wheel inadvertently touched the wall. Two transverse lintels remain in place denoting the location of penstock-gate W3. The mounting arrangements of the operating mechanism are similar to those of penstock-gate W2. The lintels are well-cut ashlar, of cross-section 0.3m deep x 0.46m wide. Four 'L' shaped key-ways are cut into the stone lintels, two in each lintel, which would have supported the operating mechanism. The gate has been removed but the fixed shutter remains in place. The shutter is made of iron and is similar to penstock-gate W4. The gate was operated from the east battery-mill, with the access port for the operating shaft remaining visible.

An arched drive-shaft opening, now blocked, remains in the east leat wall. The opening gave access to the east battery-mill and was blocked to enable construction of the squash court. A hatch, now blocked, remains in the mill wall, located downstream of the position of the former mill-wheel.

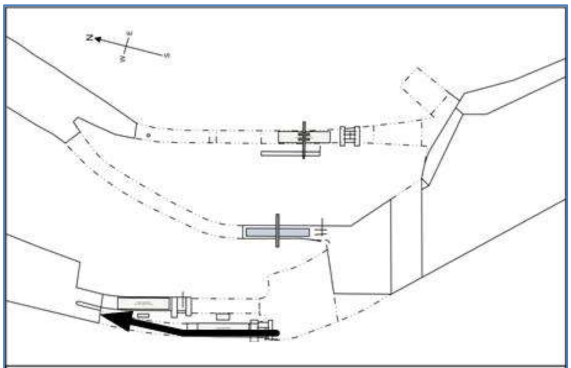
The watercourse discharges beneath a shallow arch in a wall which was formerly the outer wall of the mill accommodating the discharges from watercourses W3 and W4.

<u>Condition of Watercourse W3</u>

The watercourse W3 masonry is in good condition and shows no sign of instability. The mill walls superstructure which use the leat walls as a foundation are however in need of repointing, vegetation growing in the walls has dislodged some masonry and there is evidence of frost damage to some of the rubble composition.

The shallow arch through which the leat discharges is laid on a wrought iron plate which is badly corroded. The masonry arch, however, appears stable.

3.11 WATERCOURSE W4



Watercourse W4

Watercourse Length	14.0 m
Culvert Length	7.9 m
Width	1.1 m
Orientation	South – North

<u>Description of Watercourse W4</u>

Watercourse W4 runs from south to north and supplied water to the wheel powering the west battery mill (demolished by 1932). The watercourse comprises: an inlet from the western chamber; an iron penstock gate (still operational); a waterwheel (now removed, but with the eastern bearing mounts and western drive-shaft mounts leading into the former west battery-mill still in-situ); a culverted downstream tail-race the outlet of which is adjacent to the watercourse W3; and a combined W3/W4 tail-race leat returning to the river.

The penstock-gate is routinely opened to flush the watercourse of silt. The gate is operated from above from a location which may have been open to the west battery-mill when the mill was operational. The operating mechanism is similar to those of penstock-gates W2 and W3, being of wrought and cast-iron construction mounted on two transverse stone lintels. The lintels are well-cut ashlar, of cross-section 0.3m deep x 0.46m wide. Four 'L' shaped key-ways are cut into the stone lintels, two in each lintel, which support the operating mechanism. The penstock gate and fixed shutter are made of iron, by contrast to the timber construction of W2. A fuller description of the penstock gate is given at Section 4.5.

The bearing mounts for the waterwheel remain visible on top of the east waterwheel pit wall cut into an ashlar block. Two large, vertical, wrought-iron, threaded studs remain in-situ on the western wall of the wheel pit which were probably the mounting arrangements for the west battery-mill drive shaft.

The walls of wheel pit W4 are a combination of well-cut ashlar and larger pieces of well-coursed, local rubble stone, with ashlar being used where structural integrity is important such as around the penstock gate guides and culvert voussoirs. Score marks are visible in the leat walls where the wheel inadvertently touched the wall. There are two small openings in the west wall close to the river surface which appear to be drains from the west battery-mill.

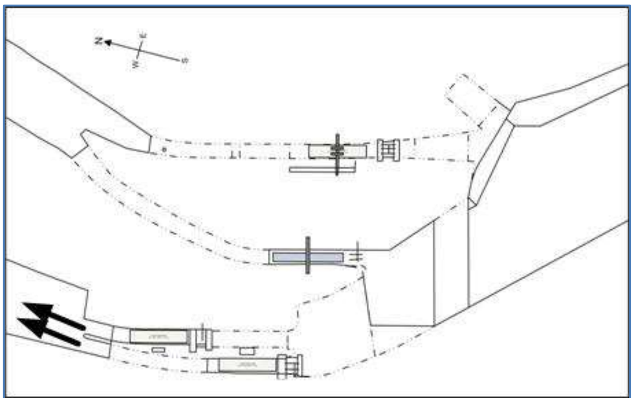
The tail-race is culverted and discharges beneath a shallow arch in a wall that was formerly the outer wall of the mill, the arch accommodating the discharges from watercourses W3 and W4. The culvert walls are constructed from well-coursed local rubble stone with the roof constructed from smaller pieces of roughly-coursed rubble stone.

Condition of Watercourse W4

The watercourse masonry is in reasonable condition but would benefit from repointing. There is some damage to the masonry close to the river water-line but this does not appear to be a threat to the wall's stability.

The mill superstructure above the west leat wall is however showing signs of instability. There has clearly been some movement of the wall. The pointing is in poor condition. There is evidence of frost damage to some of the stone work. Vegetation has caused further damage to the lime mortar binding dislodging some masonry. The damaged area is above the watercourses and so can be accessed without de-watering. A programme of work needs to be put in place to stabilise the walls, remove vegetation and repoint the structure.

3.12 WATERCOURSE W3/W4 TAIL-RACE



Tail Race Leat W3 & W4

Description of Tail-Race Leat W3/W4

Watercourses W3 and W4 discharge into a common tail-race which continues north-east to re-join the river [Figure 37, Figure 38 and Figure 39]. The walls of the leats are constructed from a combination of local rubble stone, ashlar stone and cast copper-slag blocks. The west wall holds back the river bank which is approx. 3.0m high.

The leat is spanned by a lifting pedestrian bridge, built in 1997 by the SBMP to provide public access to the monument without having to cross private land to the south.

Condition of Tail-Race Leat W3/W4

The walls of the W3/W4 tail-race leat are in a generally poor condition, but by contrast, the abutments of the lifting bridge, built in 1997, remain in good condition.

The masonry upstream of the lifting bridge is in reasonable condition but would benefit from repointing. Much of this can be carried out from a scaffolding platform when the river is low, but re-pointing down to the wall's foundation will require de-watering of the downstream watercourse.

The west wall of the leat, downstream of the bridge, has suffered from vegetation damage, degradation of the mortar binding and displacement of masonry. A programme of work is required to reduce the amount of vegetation in the bank, stabilise the bank, stabilise the extant structure, rebuild fallen masonry and repoint the wall.

The east leat wall is in a worse condition than the west wall. The east wall of the leat has also suffered from vegetation damage, degradation of the mortar binding and displacement of masonry. Much of the masonry has fallen or has been being robbed-out and in places stands only just above river level. A programme of work is also required to reduce the amount of vegetation in the bank, stabilise the bank, stabilise the extant structure, rebuild fallen masonry and repoint the wall.

SLUICES AND PENSTOCK GATES

4 SLUICES AND PENSTOCK GATES

4.1 CONFIGURATION

There were four penstock gates in operation in the mill throughout the nineteenth century, two controlling the supply of water to the east and west battery mills and two working in tandem to operate the rolling mill. A fifth sluice was installed in an out-building controlling the supply of water to a grind-wheel and a larger river sluice exists at the head of the major leat adjacent to Kelston Weir. The river-sluice was used to control the upstream river level and, when the mill was operational, would have been used to de-water the mill to enable repair and maintenance of the mill watercourses and normally flooded structures. This survey considers the four penstocks within the mill only.

4.2 PENSTOCK-GATE DESIGN

Penstock gates have a finite life; hence, the mill's penstocks must have been refurbished a number of times in the building's history and their designs have probably evolved over successive generations.

The four penstock-gates within the mill are all of similar design, albeit with differences in their detail. Each penstock-gate comprises a lower rising-gate and upper fixed-shutter. The gate and shutter are both mounted in cast-iron channels set into the leat wall. The gate is mounted at approx. 45^{O} to the vertical and slides beneath the fixed shutter which is set nearer the vertical. The assembly creates a 'funnel' to accelerate the flow as it passes through the gate.

The gate is lifted and lowered by means of a stock bolted to the gate which extends from near the bottom of the gate to above the working-floor of the mill. A cast-iron rack-and-pinion is mounted on the upper stock which is operated from the mill floor using a large detachable spanner. The rack-and-pinion is fitted with a pawl to hold the gate at any intermediate position. This is of particular importance when the leat is dewatered as the gate will shut by gravity without the pressure of water holding the gate against the guide rail.

A variety of stock designs are evident in the mill, being either a single piece of material or a two-piece construction. The materials of construction are also different in each of the penstock-gates.

- Penstock-gate W1 has a timber gate and iron shutter with the stock being made from a single piece of timber.
- Penstock-gate W2 has a timber gate and timber shutter with the stock being made out of two pieces of timber scarf-jointed just above the gate.
- Penstock-gate W3 is no longer operational but an iron shutter remains in-situ and the gate operating mechanism is very similar to Penstock-gates W2 and W4.
- Penstock-gate W4 has an iron gate and iron shutter with the stock being made out of a steel 'I' beam, forged to form a gooseneck just above the gate. However, it is evident that this is a later modification and the setting of the gate and rack-and-pinion suggests that this replaced an earlier timber assembly similar to penstock-gate W2.

4.3 PENSTOCK-GATE W1

2018 Programme of Work

A key objective of the 2018 programme of work was replacement of the W1 penstock-gate which had been deteriorating over several years. The penstock-gate is part of the scheduled monument and listed building, it was therefore important to respect the nature of the building when constructing the replacement gate and stock.

The river-level was exceptionally low in the summer of 2018, it was therefore possible to survey the penstock from the downstream culvert before the watercourses were de-watered [Figure 14]. This enabled timber to be purchased before the coffer-dam was installed and reduced the length of time that the mill would have to be de-watered but carried a risk as parts of the structure would not be visible until after the watercourses were de-watered and their dimensions could be confirmed.

Old Penstock Gate W1

The age of the old W1 penstock-gate is uncertain. There are no records of the gate having been replaced by the Saltford Brass Mill Project (established in 1997) nor are there any records of the gate having been replaced since BIAS conducted a survey of the mill in 1976 (Ref 14). The assumption is therefore that the gate pre-dates 1976 survey.

A comparison of penstock-gate W1 and the river-sluice may offer a clue as to the dating of the structure. The river-sluice has three vertical lifting-gates but no fixed-shuttering. The cast-iron operating mechanism is inscribed 1840 but the two outer gates are inscribed 1948. The centre gate has been replaced more recently and the original 1948 gate is an exhibit in the mill. There are similarities in the method of construction of the 1948 river-sluice gate and the old penstock-gate W1. It is therefore assumed that the old penstock-gate W1 dates either from 1948 (70 years old) or from the 1960s (c.50 years old).

The old gate is constructed of eight, tongue-and-grooved, oak planks [Figure 21] and is 1.15m wide x 1.94m tall x 50mm (original thickness). The aging mechanism of a gate is erosion, caused by flow across the body of the gate or by flow through the joints between the planks. This mechanism is evident in the old gate, erosion of the joints causing substantial leakage. Although there was damage to the gate's tongue-and-groove joints, examination of the gate after removal showed that the planks retained significant strength and were not, as feared, in danger on imminent collapse as experienced with penstock-gate W2 gate in 2012.

The pre-dewatering survey of the penstock and stock indicated that the stock was a single piece of timber 4.1m long, of cross-section 0.185m x 0.155m. This is different to penstock-gate W2 and a defunct gate exhibited in the mill, in which the stock is made from two pieces of timber with a scarf-joint just above the gate.

Once the gate was removed, it was evident that the penstock gate was significantly larger than the penstock opening; the opening being 1.14m tall and the gate 1.94m. The reason for the oversize gate is not evident. It was also discovered that the gate was inset into the stock, requiring a 50mm deep longitudinal cut along the length of the shaft.

New Penstock-Gate W1

A number of options were considered for the design of the new gate, including the choice of materials and the system of joints. The old gate was constructed of oak; however, today's material of choice for river-systems and lock-gates is 'greenheart' timber; a South American hardwood which is resistant to water-damage, rot and insect attack. Replacing the gate with greenheart would not require changes to be made to the physical structure of the mill (so would not be detrimental to the protected monument) and would provide a durable structure for future operation.

Greenheart is a high-density, high-stiffness timber; making it difficult to work, which influenced the design. Creating a series of tongue-and-grooved joints would be problematical. The joints had also been observed to be sources of weakness in the structure, creating leak sites in later-life. It was therefore decided to construct the gate using a series of laminated over-lapping planks [Figure 15].

Examination of the various defunct gates in the mill indicated that, when new, the gates were approx. 50mm thick, the thickness being determined by a large margin for in-service erosion rather than strength. The gates slide in cast-iron guide-channels set into the leat wall and in the pre-dewatering survey it was estimated by feeler-gauge that the guide was 57.5mm deep. The total thickness of the new gate was therefore set at 45mm to ensure an adequate clearance in the guide channel recognising the difficulty of working the greenheart timber should adjustments need to be made during the on-site construction.

The new gate is comprised of two layers of greenheart, one 25mm thick and the second 20mm thick, giving a total thickness of 45mm. The timbers were coated with standard black coal-tar solution on their mating surfaces to form a seal and bolted together using 32 x M8 stainless steel bolts. The bolts were counter-bored on the down-stream face to provide a flat surface making the sliding seal with the fixed shutter when operated,

Consideration had been given to re-using the old stock; but it was found to be significantly eroded and the decision was taken to replace both the gate and the stock. The inset in the stock was not discovered until the watercourses had been de-watered. This also posed a problem as cutting such an inset in greenheart would be difficult with the tools available in the mill. Removal of the old gate and stock in one piece was also challenging due to the space constraints in the mill. It was therefore decided to cut the new-stock just above the gate and join the two parts using a scarf joint, as observed on other stocks in the mill. This had two benefits; the joint could be off-set to create the inset, negating the need for a large longitudinal cut; and the gate could be assembled in-situ in two parts, so easing re-construction [Figure 16].

The lower stock was bolted to the gate using 14 x M12 stainless steel bolts. The scarf joint was secured using 4 x M12 stainless steel bolts.

A length of aluminium angle bar was fitted to the foot of the gate to protect the gate on shutting the penstock.

Fixed Shutter

The survey of the fixed-shutter indicated that it was in good condition. The decision was therefore taken not to disturb the structure.

Gate and Shutter Guide Channels

The iron guide channels were found to be in good condition and required no restoration work.

Gate and Stock Removal

The old gate and stock were removed as a single assembly. The assembly had to be lifted vertically clear of the leat, turned sideways through 90^{O} to clear the mill walls and roof and rotated bodily through 90^{O} to lay flat on the mill floor for inspection. The challenges posed by this operation were: the weight of the structure; the height of lift required to raise the structure clear of leat; the clearance between the assembly when raised, the mill walls and the roof; and the need to manoeuvre the assembly around the working floor. The most significant challenge was the height needed to clear the leat, the gate being 1.94m tall.

Consideration was given to constructing a scaffolding frame above the leat to provide a high-point from which to lift. The alternative was to employ mobile engine-lifts. Two engine lifts were identified, one of 2-tonne and a second of 1-tonne capacity [Figure 17]. The 2-tonne engine lift was considered to be very versatile as it provided a high lifting-point when raised to its maximum elevation (2.45m). Use of the two engine-lifts in conjunction with two 2-tonne chain hoists was adopted, the 2-tonne engine lift to provide a high-point to raise the assembly clear of the leat and the 1-tonne engine lift to suspend the assembly to enable the lifting point to be adjusted to enable manoeuvring.

Penstock-Gate Installation

A new gate was constructed from greenheart, the stock was cut and the scarf prepared and pre-drilled, and the lower stock bolted to the gate. The lower gate assembly was lifted using the 2-tonne engine lift, lowered into the leat and suspended vertically from two bars laid across the leat opening so that the lower scarf was above the level of the working floor. The upper stock was lifted using the 2-tonne engine lift, manoeuvred into position and the two parts mated and bolted together in-situ. The complete gate and stock assembly was then lifted from its balance point and swung around the pivot to locate the gate in the guide channel. The assembly was then lowered and allowed to slide down the guide in a controlled manner. With the gate fully inserted, the new fabrications were installed and the operating mechanism re-assembled. The correct operation of the gate was proven before re-watering the watercourses.

Penstock Operating Mechanism

Operating Mechanism

The penstock operating mechanism was found to be in good condition, requiring a light removal of surface rust, de-greasing of old packed grease in the bearings and re-greasing only.

Mounting Lintels

There was significant damage to the two lintels supporting the penstock operating mechanism. The mechanism was secured to the lintels by iron bolts fitted in holes drilled through the stone lintels. Expansion of corrosion products had caused both lintels to crack and parts of the lintels to break away, in particular on the upstream lintel. A decision was made to construct two galvanised-steel fabrications which would take the load off the lintels and transmit that load into the leat walls (Figure 19) but in all other respects not to change the scheduled structure of the mill. The fabrications are an obvious addition to the mill's structure to alleviate degradation of the original building.

Deck-Plates

When operating as a brass mill, evidence suggests that the culvert around the operating mechanisms was open, which by modern-day standards poses a health and safety hazard. In recent years, the culvert above penstock-gate W1 has been covered by a crudely cut deck-plate. This was clearly not original, was inadequate to protect visitors to the monument and hid much of the operating mechanism from view. Three open-web galvanised-steel deck-plates will therefore be manufactured and inserted into the culvert opening before the next open-season to protect people from falling into the leat while giving visibility of the operating mechanism. A guard-rail is also being constructed around the culvert to enable visitors to see the operating arrangements while ensuring their safety.

4.4 PENSTOCK-GATE W2

Background

Penstock Gate W2 - 1999

Penstock-gate W2 had been replaced in the 1990s to enable operation of the working waterwheel as an interpretation display. The gate was constructed of 10, tongued-and-grooved, oak panels, clamped by two steel rods fitted in holes bored through the length of the gate. The thickness of the timber was only 30mm, significantly thinner than the 50mm observed on other gates in the mill.

In 2012, a section of the timber gate broke away (second plank from the bottom), jamming the wheel and allowing limited but uncontrolled flow of water through the gate. A temporary repair was carried by bolting an 12mm thick sheet of Lloyd's Grade marine-plywood over the upstream face of the gate, covering the broken plank, however, in 2014 the bottom plank of the gate fractured, jamming the wheel and the penstock-gate. The gate was therefore replaced in 2016.

Penstock-Gate W2 Removal - 2016

In 2014 and again in 2016, a coffer-dam was erected around the inlet to watercourse W2 to protect the monument structure and working waterwheel. This proved adequate to stem the flow through the watercourse and the decision taken to effect a repair recognising that the repair would be carried out from above and as there was no access into the watercourse. Scaffolding bars were rigged across the two leat walls above the penstock-gate, which rise approx. 2.0m above the working floor, to provide a high point for lifting the gate and stock assembly.

Penstock-Gate W2 - 2016

In view of the urgency, options were considered about the most practicable way of replacing the gate in a timely manner. Ideally, a new oak gate would have been constructed, using tongue-and–groove jointing and 50mm thick. An alternative was proposed using Lloyd's Grade marine-ply wood. The material was available in 18mm thick sheets. A new gate was therefore fabricated using two thicknesses of 18mm marine-plywood, bolted together with 10 x M8 stainless steel bolts and coated in standard black coal-tar solution. Although showing signs of age, the stock was considered serviceable and the new gate was bolted onto the old stock. The gate was thereby replaced with a 36mm thick marine-plywood assembly which has since proven adequately serviceable to enable operation of the penstock-gate and waterwheel.

Fixed Shuttering

The fixed timber shuttering was also found to be leaking badly in 2012. The structure is not however subject to the same loads as the gate being set at a shallower depth of water. A repair was therefore effected by constructing a backing plate of 12mm marine ply wood.

2018 Inspection of Penstock W2

A further objective of the 2018 survey was to inspect penstock gate W2 and stock to assess its performance in-service. No deterioration of the gate was observed and the standard black coal-tar solution coating remained intact. Consideration was given to replacing the gate with a greenheart assembly mirroring penstock-gate W1 but the decision was taken not to replace the gate at this time but consideration should be given to its replacement with a greenheart structure when next in need of replacement.

Fixed Shuttering

The fixed timber shuttering is performing reasonably well but there is some leakage around the timber within the guide channel. This will continue to be monitored and plans should be made to replace the fixed shuttering when the mill watercourses are next de-watered if required.

Deck-Plates

The culvert around the operating mechanisms is open, which poses a potential health and safety hazard to people in the vicinity of the penstock. Penstock W2 is shut-off from the dynamo room by a stable door when visitors are in the mill, so protecting them from harm. There are occasions when volunteers need to enter the space above the penstock when carrying out repair or maintenance on the waterwheel.

Since 2016, plywood boards have been placed over the openings which provide protection to volunteers but limits visibility for visitors. Three open-web galvanised-steel deck-plates, similar to penstock-gate W1, will therefore be manufactured and inserted into the culvert opening to protect people from falling into the leat while maintaining visibility of the operating mechanism.

4.5 Penstock-Gate W4

Design of Penstock Gate W4

Penstock-gate W4 [Figure 35] is fabricated from iron and steel, having an iron lifting gate, iron fixed shuttering and a steel stock. The operating mechanism and iron guide-rails are of similar design and dimensions to the penstocks W1 and W2 suggesting that the assembly was originally made of wood. There are no records of the penstock being modified; hence the current gate could date from the 1960s, the 1920s (when Eric Butler adapted the mill to become a sports centre) or the 1880s (when attempts were made to modernise the brass mill).

The penstock gate is constructed from a single piece of iron, 1.2m wide x 1.65m tall x 10 mm thick. Two 20mm thick edge-runners are attached to each wing of the gate to create a 50mm sandwich (mirroring the 50mm thickness of timber on other gates in the mill) which slides in the iron channel let into the leat wall. This reinforces the idea that the iron gate is an adaptation of an earlier timber gate.

The upper fixed-shutter is a single sheet of cast iron, with stiffeners cast into its upstream face, set into a cast-iron channel let into the leat wall.

The stock is a single galvanised rolled steel 'I' beam, of web-height 100mm (4") and flange width 65mm (2.5"), bent just above the gate to create a swan-neck. The gate is bolted to the lower stock with a 20mm packing plate sandwiched between the stock and the gate to enable alignment with the rack-and-pinion. The rack-and-pinion is mounted on lower flange of the upper stock but with two packing pieces, a 30mm thick timber board and 10mm steel plate, between the stock and the gearing. The packing presumably mirrors the positioning of an earlier timber stock.

The difference in alignment between the assumed position of an earlier timber gate and the rack-and-pinion is 50mm which equates to the step observed on gate W1, adding further weight to the argument that the iron assembly replaced an earlier wooden structure.

Survey and Repair

The W4 penstock gate and shuttering are in good condition, there being no indication of degradation which could affect their performance.

The stock was generally in good condition with the exception of the goose-neck. The working of the metal to create the goose-neck, which would have required significant heat, has clearly affected the properties of the steel and/or the galvanising as a result of which there was severe corrosion in the region of the goose-neck. The alignment of the gate and rack-and-pinion is also such that the stock bends laterally when the penstock is cycled subjecting the stock to fatigue. A repair was effected by the manufacture of two galvanised-steel inserts which were bolted to the 'I' beam web to reinforce the structure.

The state of the goose-neck should be routinely checked to monitor any further degradation. Consideration may also be given to replacing the gate at some time in the future with a wooden gate but this is not an urgent requirement.

Deck-Plates

A fence prevents public access to the open culvert above penstock-gate W4 but the area must be accessed by volunteers when operating the gate. The culvert around the operating mechanisms has to-date been covered by two iron plates. These have, however, corroded and were in danger of collapse posing a health and safety hazard to volunteers when operating the penstock-gate. Two open-web galvanised-steel deck-plates will therefore be manufactured, similar to penstock-gate W1, and inserted into the culvert opening to protect people from falling into the leat but maintain visibility of the operating mechanism.

CONCLUSIONS

5 CONCLUSIONS

The consent and funding provided by B&NES in the summer of 2018 presented a timely opportunity to dewater the upstream watercourses of Saltford Brass Mill, inspect the normally flooded structures and repair the degrading penstock gate in watercourse W1. The timing was fortuitous as the river levels were particularly low, exposing large areas of masonry without the need to de-water downstream of the penstock gates. It was also an opportune time as B&NES has recently acquired a laser scanning capability for the survey of structures in the city of Bath which they were able to deploy at Saltford. Additionally, one of the SBMP volunteers had access to an aerial drone to enable conduct of an overhead survey, which combined with the laser-scan enabled a thorough survey to be undertaken.

This was the first time that the upstream watercourses had been dewatered in many years, the last time that this occurred possibly being as long ago as 1948. The opportunity enabled a full survey of the watercourses to be conducted and accurate measurements of the mill, both above and below ground, to be taken by a combination of conventional surveying techniques, use of the laser scanner and aerial scan using a drone. This has enabled an accurate 2D plan of the mill to be produced, drawing upon the 3D point-cloud model of the mill produced by the laser scan. Much potential exists for further analysis of the point-cloud model of the mill.

No programme of artefact recovery from the watercourses was carried out but a number of interesting pieces of glass and pottery were recovered for the surface silt. These included a number of glass bottles, pottery jars and ink bottles. One item of particular interest was the remains of a porcelain jug on which was a transfer of Major-General John French. The jug is likely to be a commemorative piece dating to the Boer War (1899-1902).

Two surprising discoveries were the existence of a fifth watercourse (WO) on the eastern side of the mill and a western chamber under the dynamo room.

- Watercourse W0 is a culverted channel, 2.5m wide, running north-east from the road bridge for 4.0m towards the eastern range of the mill. The leat is blocked at its eastern end by a well-dressed masonry wall. The watercourse was previously unknown and further research is required to determine its age and purpose.
- The western chamber is approx. 6m x 5.75m and covers the head-race to watercourse W4 and the blocked watercourse W3. It was known that the head-races to penstocks W3 and W4 were culverted but the extent of the chamber was unknown. The reason for such a large chamber is unclear and further research is required to establish its age and the reason for its construction.

The survey identified that:

- The masonry throughout the culverts was in generally good condition with no signs of instability, although there is an overall need for repointing. This will need to be planned into a future programme of work and will require de-watering of the watercourses.
- The two lintels supporting the penstock gate W1 operating mechanism were found to be cracked and parts of the

upstream lintel had broken away. The mechanism is secured to the lintels by six iron bolts fitted through holes drilled through the stone. The swelling of corrosion products round the iron bolts had caused both lintels to crack. The structure remained stable and was not in danger of collapse but it was considered a wise precaution to install a galvanised steel fabrication to take the load of the operating mechanism off the lintels and transfer that load into the culvert walls.

- The tail-race leat walls of all four watercourses were in a poor condition, much masonry having been displaced, fallen and/or been robbed out. A programme of work is required to stabilise these structures, rebuild were appropriate within the constraints of the scheduling and listed status and generally repoint the structures.
- An area of the mill wall immediately upstream of the entrance to watercourse W2 was observed to have been subject to a crude repair using a sheet of corrugated iron as shuttering for a concrete patch to the wall. The repair is stable and not normally visible when the leat is flooded.
- The survey of the southern road-bridge, which provides the only vehicle access to the island, revealed two longitudinal cracks in the western arch, running from east to west along the inner edges of the voussoirs. There is no evidence of movement or instability. A weight limit is imposed on the bridge and the structure should be monitored to assess whether any movement is occurring.

The other major objective of the programme of work was the replacement of penstock gate W1 and inspection of penstock gates W2 and W4.

- Penstock gate W1 had been leaking badly. It is not certain when the gate was last changed, two possibilities being 1948, when the river-sluices were replaced or in the 1960s. The old gate was constructed of tonged-and-grove oak planks which had deteriorated such that there was high leakage through the gate. A replacement structure was designed and constructed by the SBMP using greenheart timber, and the gate replaced. It was observed that although the gate had been leaking badly, the structure retained significant strength which prevented complete collapse of the gate, as had been experienced with gate W2 in 2012.
- Penstock gate W2 had been replaced in 2016 with a marine-plywood structure following failure of the earlier gate. The gate was found to be in good condition and the paint coating intact. Consideration was given to replacing the gate with a greenheart assembly mirroring penstock-gate W1 but the decision was taken not to replace the gate at this time but consideration should be given to its replacement with greenheart timber when the gate is next in need of replacement.
- Penstock gate W4 is an iron structure. The gate was in good condition, with the exception of the gooseneck in the operating stock which was found to be seriously corroded. Replacement of the stock would have been a complex operation. Two galvanised steel inserts were therefore manufactured and bolted to the web if the ‘I’ beam web to reinforce the structure. The performance of the stock will be monitored and a plan for further repair action formulated should further deterioration be observed.

A series of recommendations are made, listed at Section 2.5. The key activities that are recommended are stabilisation and repointing of various walls. Of most concern are the walls above the tail-race leats which are in a particularly poor condition. A programme of work should be developed to stabilise the structures, rebuild those structures where practicable within the constraints of the buildings scheduling and repoint the structures.

6 References

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7 Tithe Map – Saltford - 1839

8 Ordnance Survey Map – Saltford – 1883

9 Ordnance Survey Map – Saltford – 1886

10 Ordnance Survey Map – Saltford – 1903

11 Ordnance Survey Map – Saltford – 1932

12 Particulars and Conditions of Sale. Harfords and the Bristol Brass Battery and Wire Company's Works. 7th July 1859

13 Saltford Brass Battery Mill. City of Hereford Archaeology Unit. Second Interim Report. September 1994.

14 The Old Brass Mills, Saltford. Joan Day and the BIAS Survey Group. Journal of the Bristol Industrial Archaeological Society. Vol 9 1976

7 List of Figures

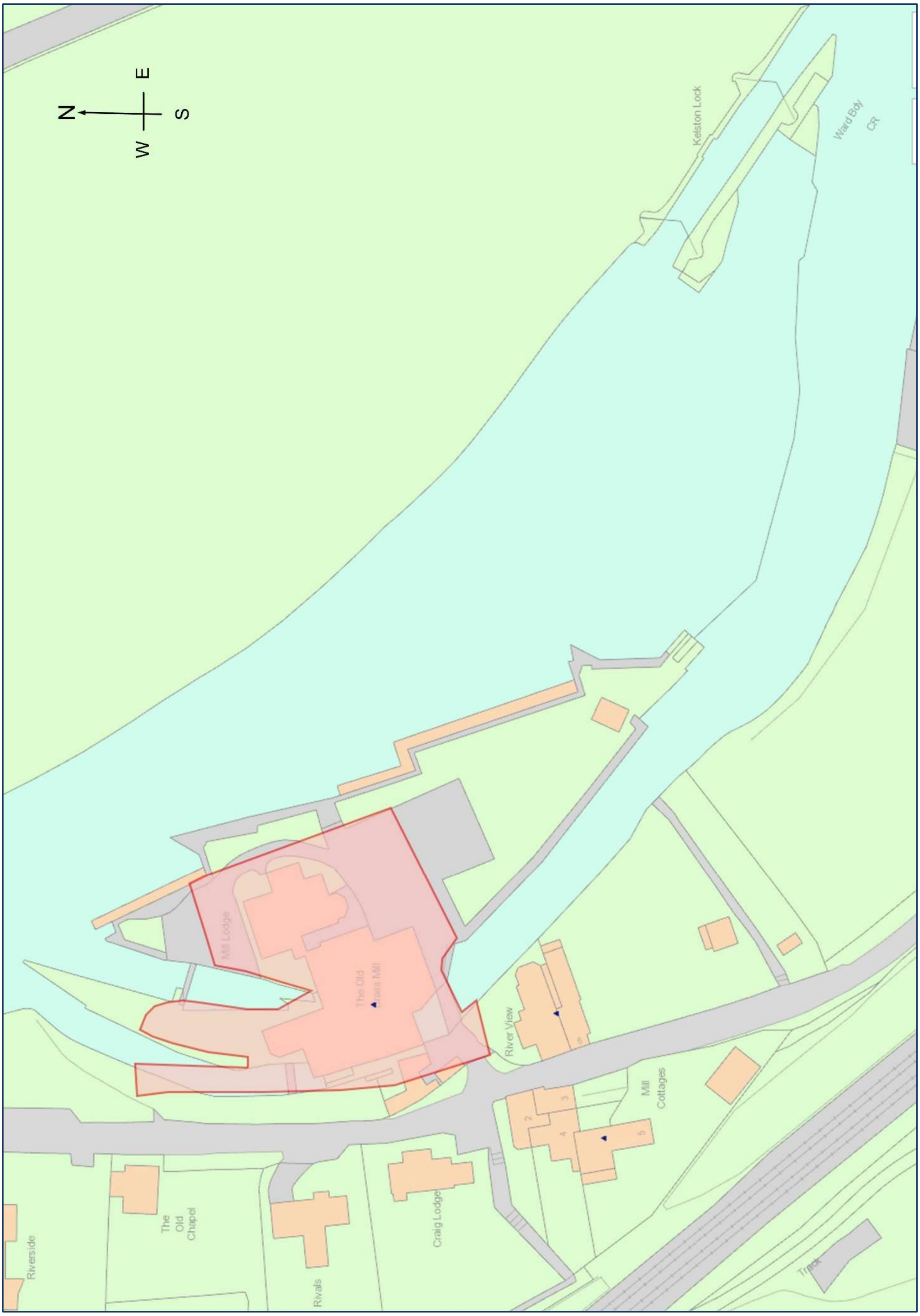


Figure 1 Saltford Brass Battery & Rolling Mill - Scheduled Monument Boundary

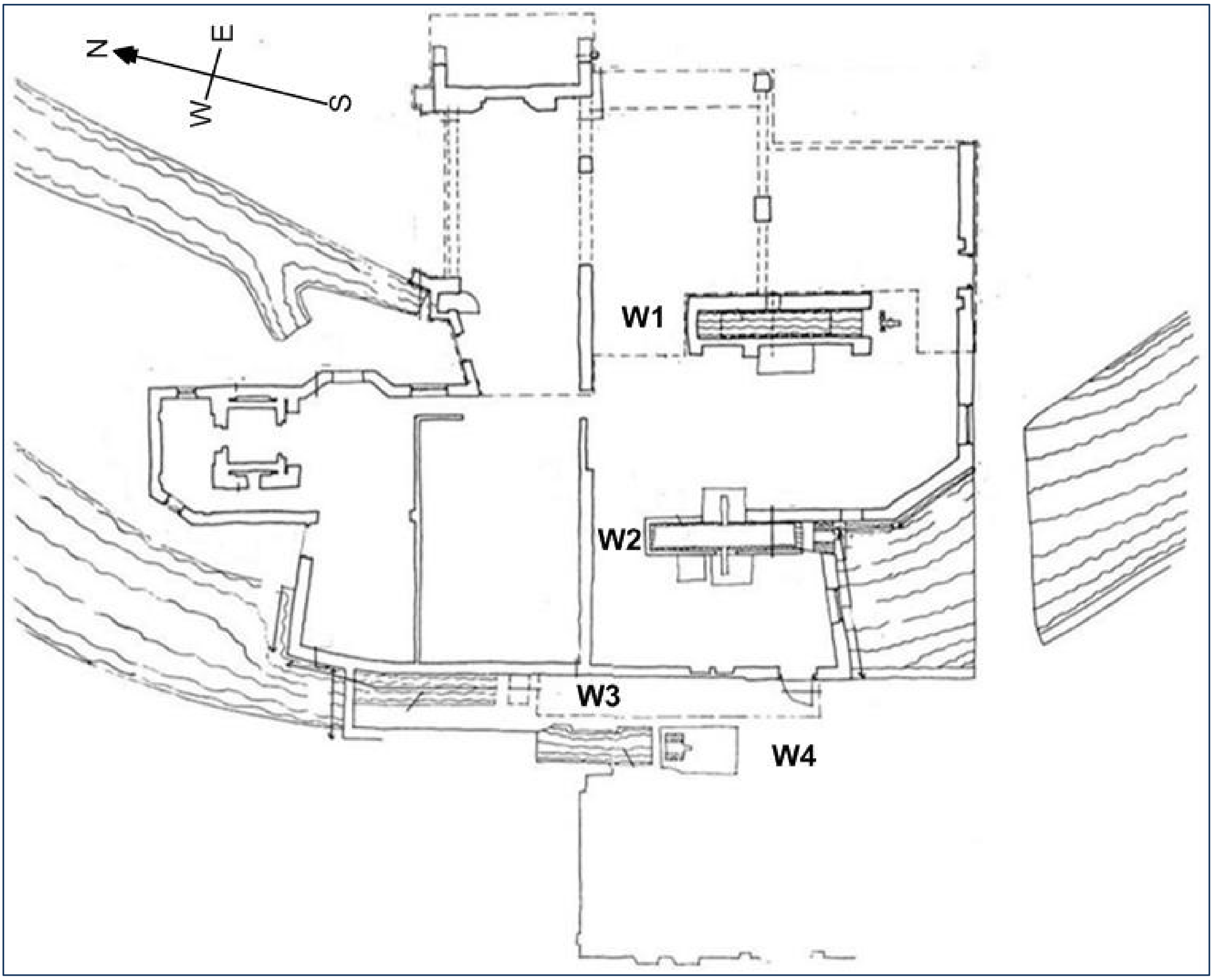


Figure 2 Saltford Brass Mill – Plan of Watercourses

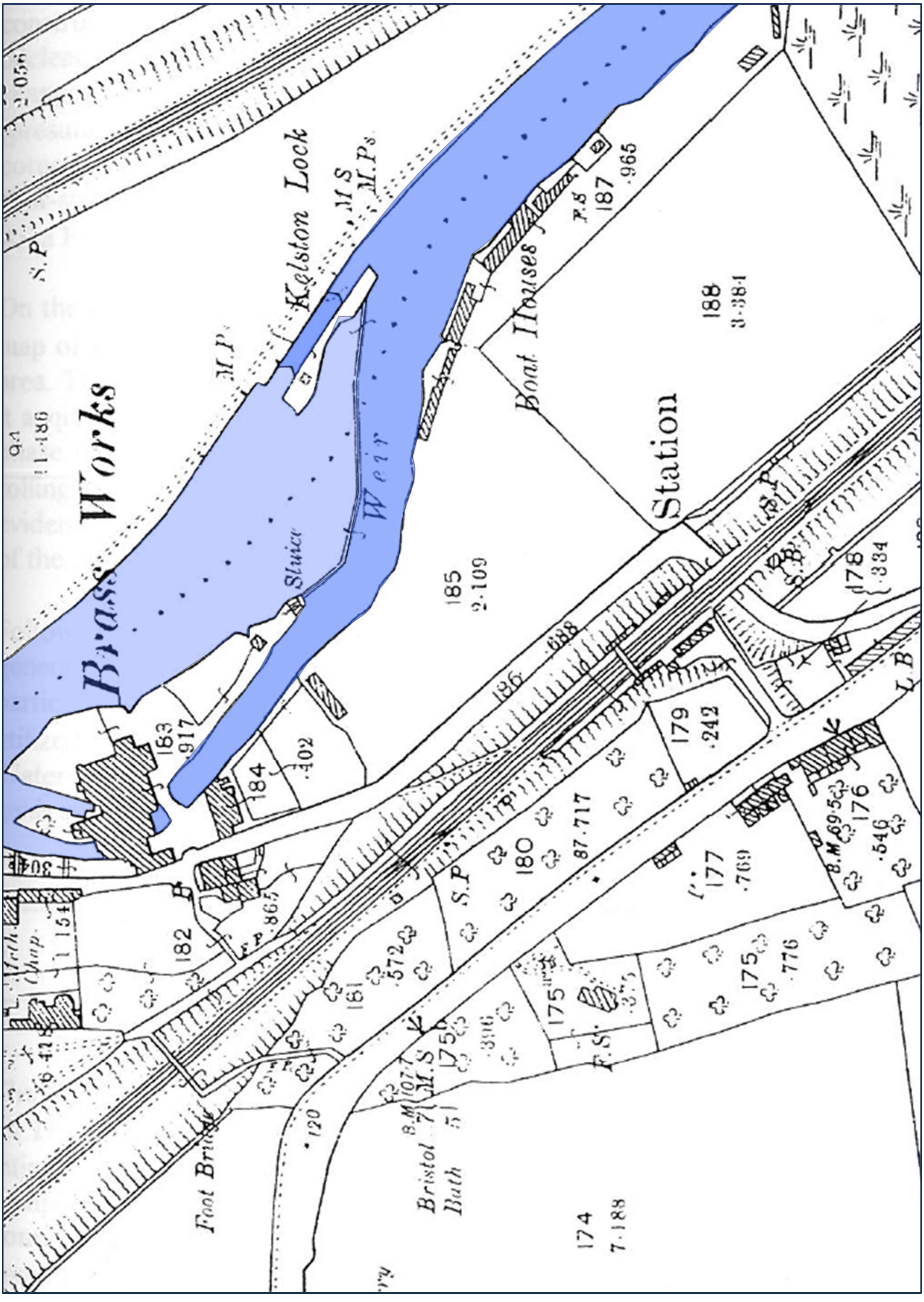


Figure 3 Saltford Brass Mill & River Avon - OS 1903

Laser Scanner

'Point-Cloud' image of Squash-Court / Battery Mill

Figure 4 Leica RTC360 Laser Scanner

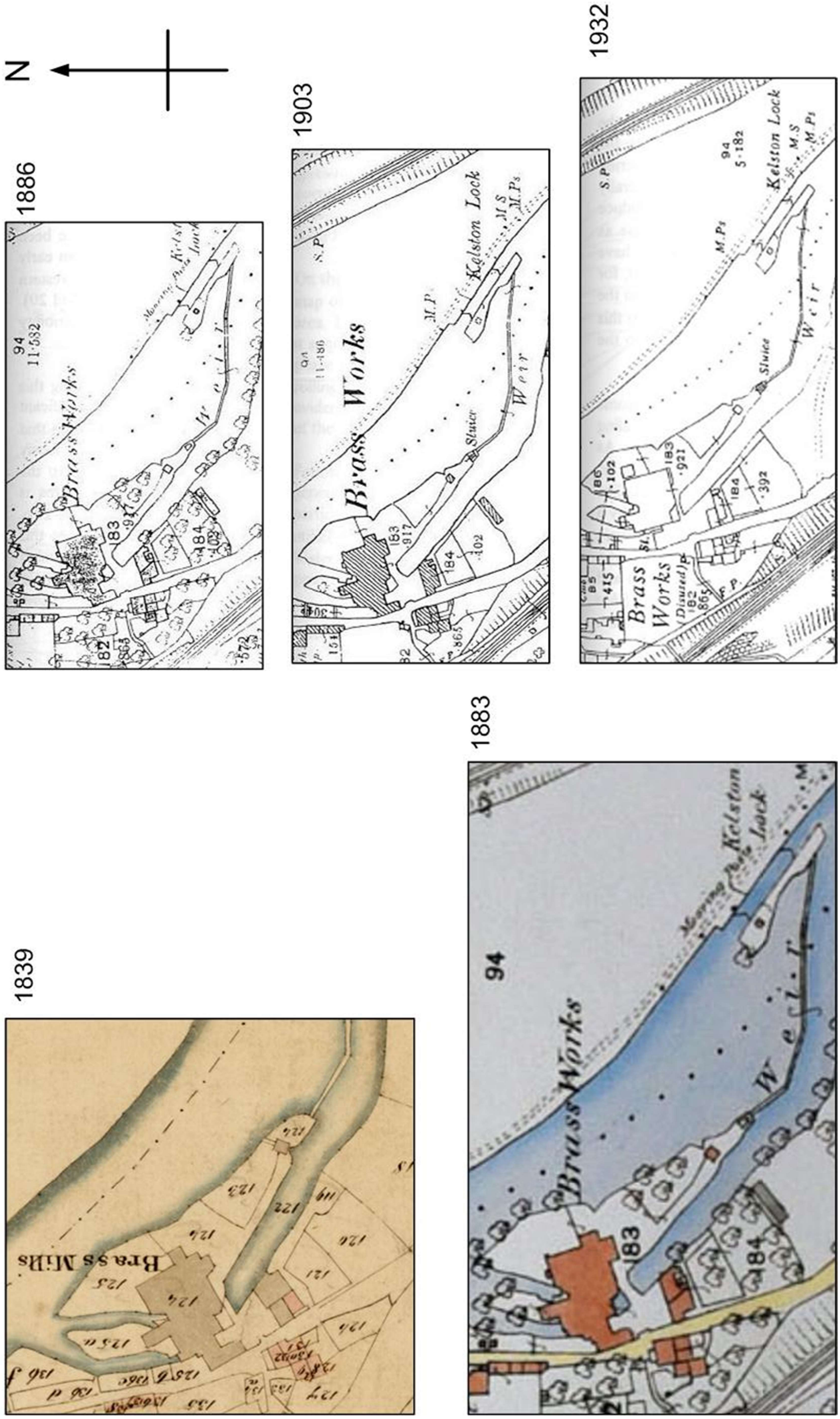
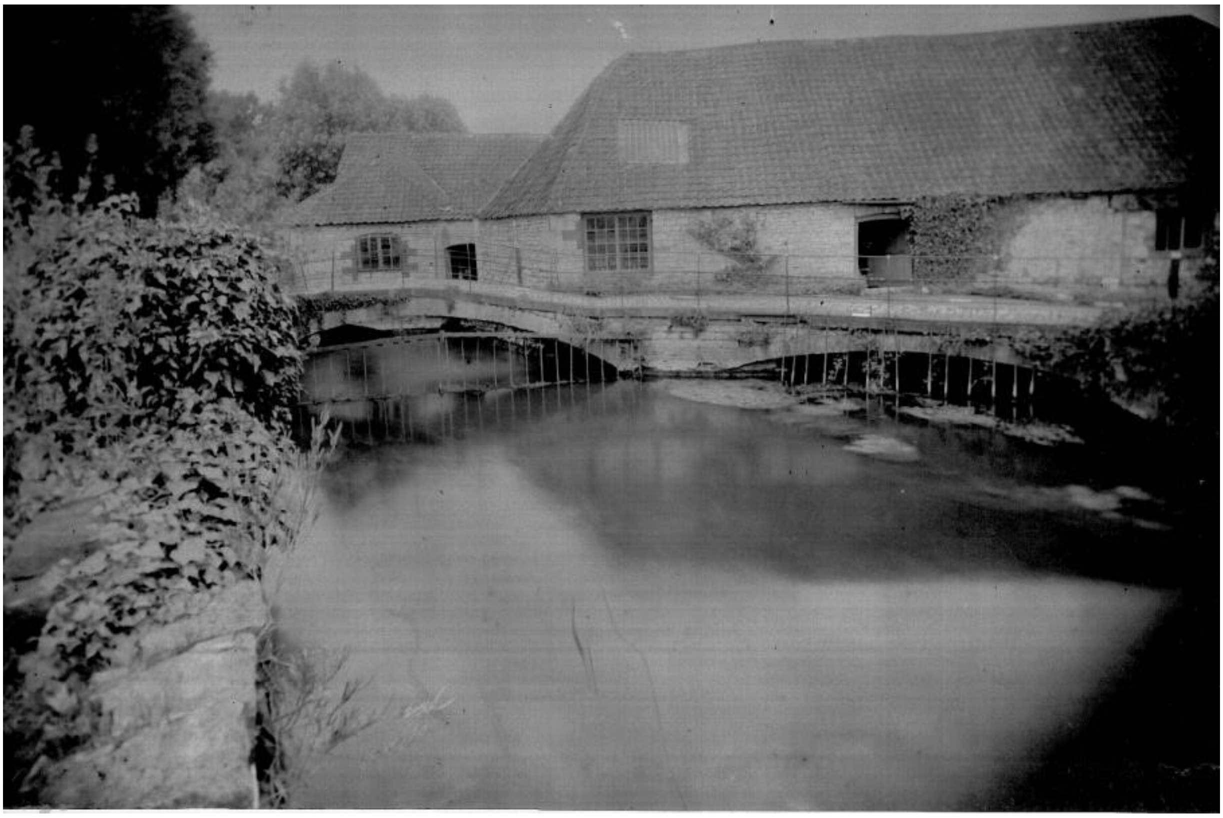


Figure 5 Evolution of Saltford Brass Mill – 1839 to 1932



Saltford Mill – c.1930

Saltford Mill – September 2018

Figure 6 Major Upstream Leat looking North

Coffer-Dam – during installation

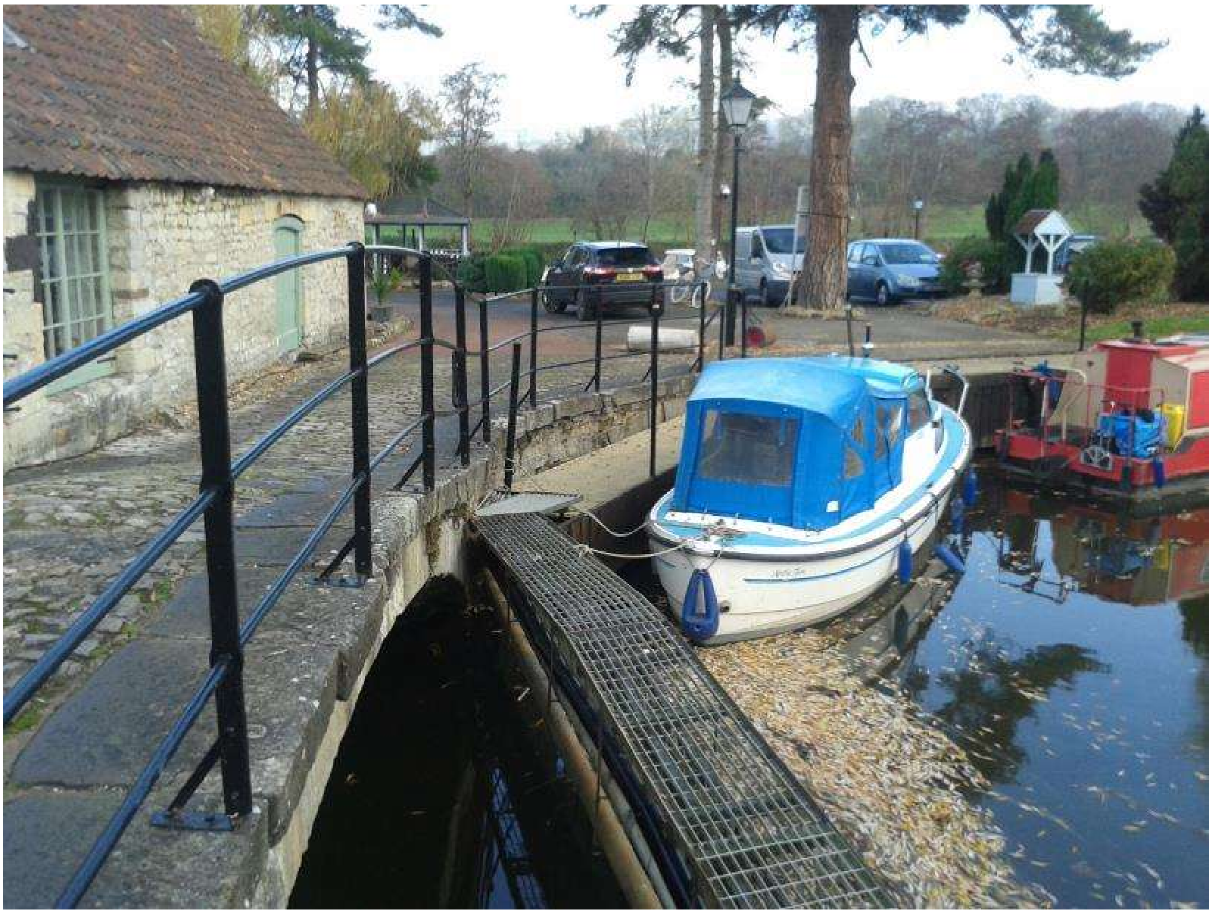
Coffer-Dam – in-situ

Figure 7 Coffer Dam

Western span of road bridge showing springing from western abutment and cracking along voussoirs

Western span of the road bridge showing springing from central pier

Figure 8 Southern Road Bridge - Watercourse



Western Span of road bridge and apron extension

Figure 9 Southern Road Bridge – Deck

Central Pier and Entrance to Watercourse W1

Pier between Watercourse W0 and Watercourse W1atercourse W0/W1 Upstream Entrance

Figure 10 Watercourse W0/W1 Upstream Entrance

Entrance to Watercourse W0 showing southern extension to the roadway

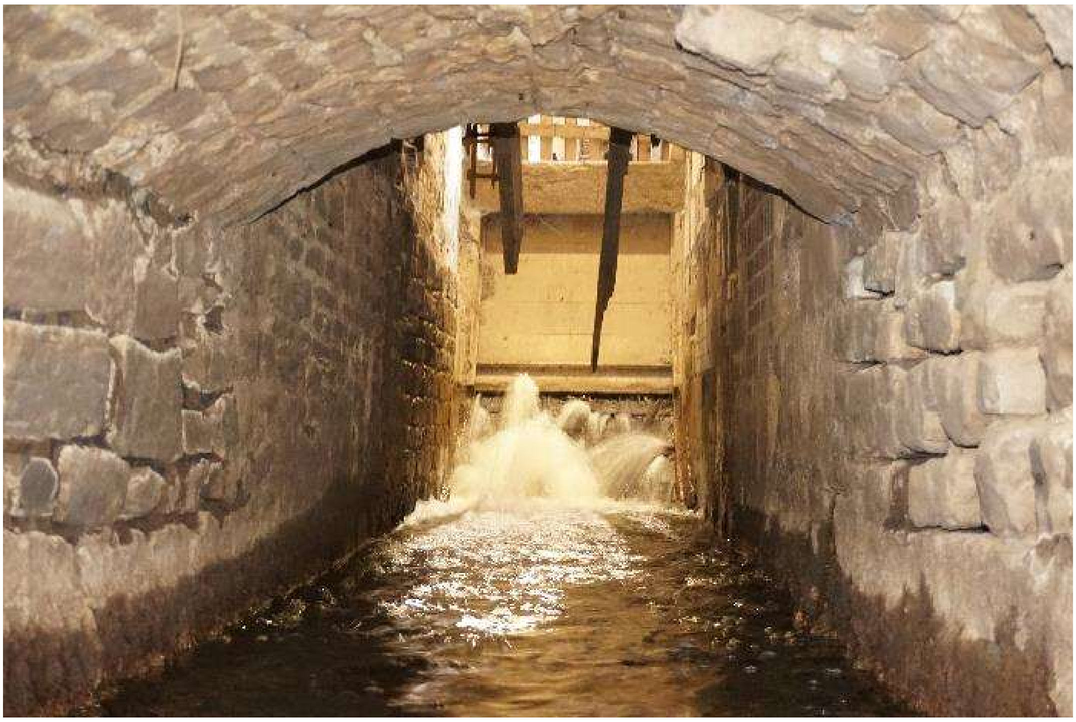
Watercourse W0 showing heavy silting and sealing wall

Figure 11 Watercourse W0

View from penstock-gate W1 looking upstream

View from Watercourse Entrance looking downstream – New Gate installed

Figure 12 Upstream Watercourse W1



Downstream Watercourse W1 - Old Gate – Before Removal showing Leakage

Derelict Waterwheel -Watercourse W1

Figure 13 Downstream Watercourse W1 – Upper Reach

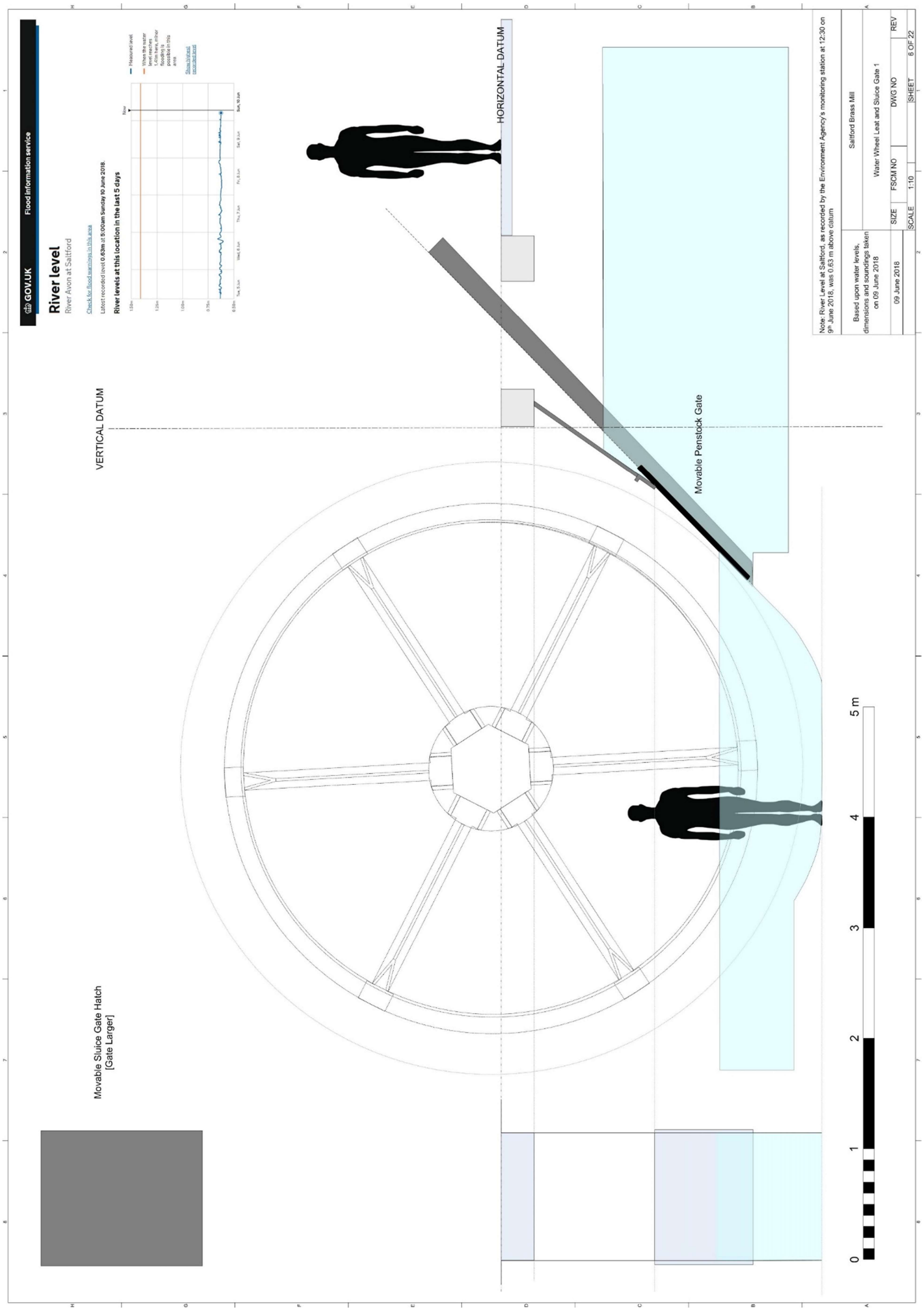


Figure 14 Penstock Gate W1

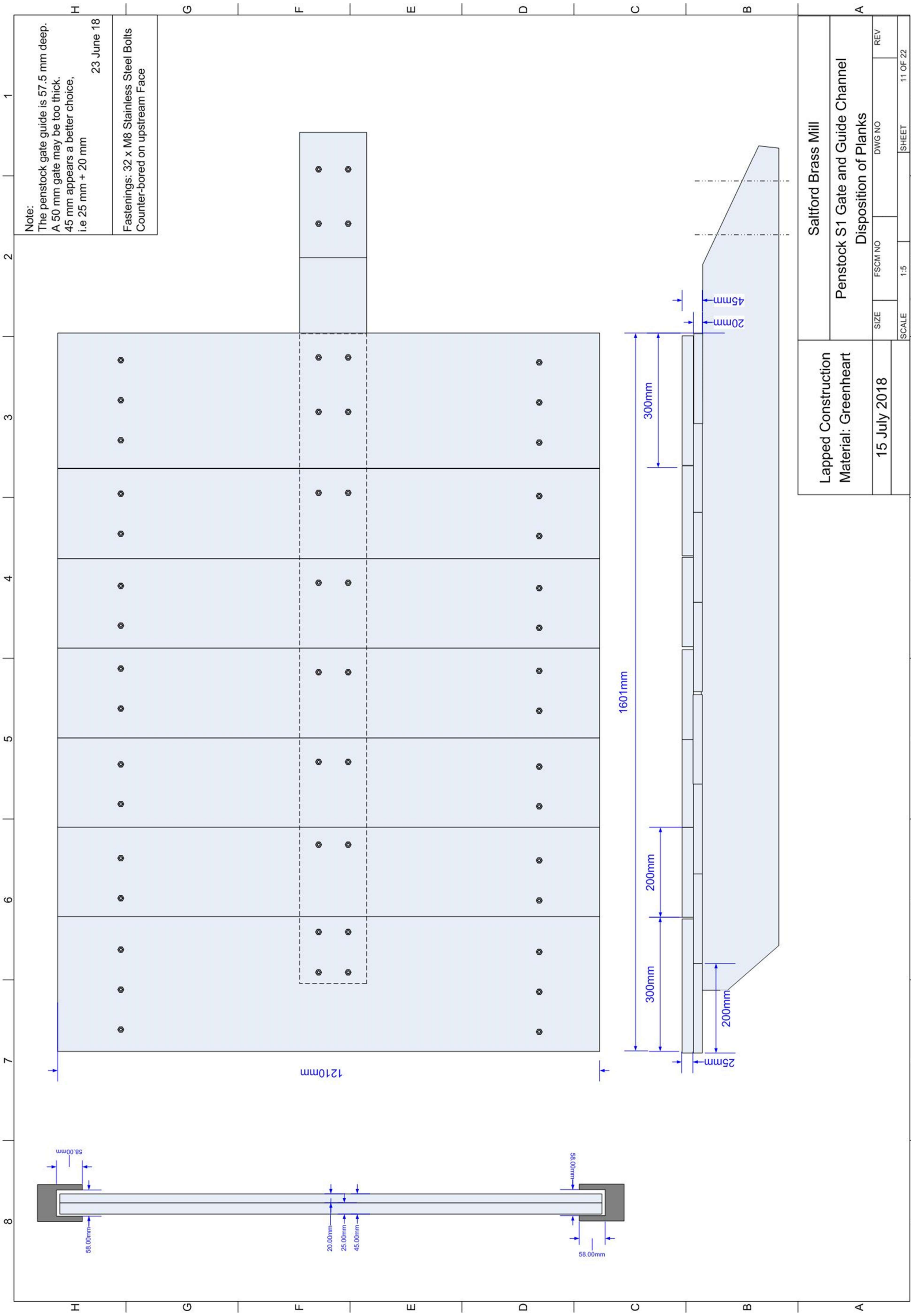


Figure 15 Penstock Gate W1 - Gate – Lapped Construction

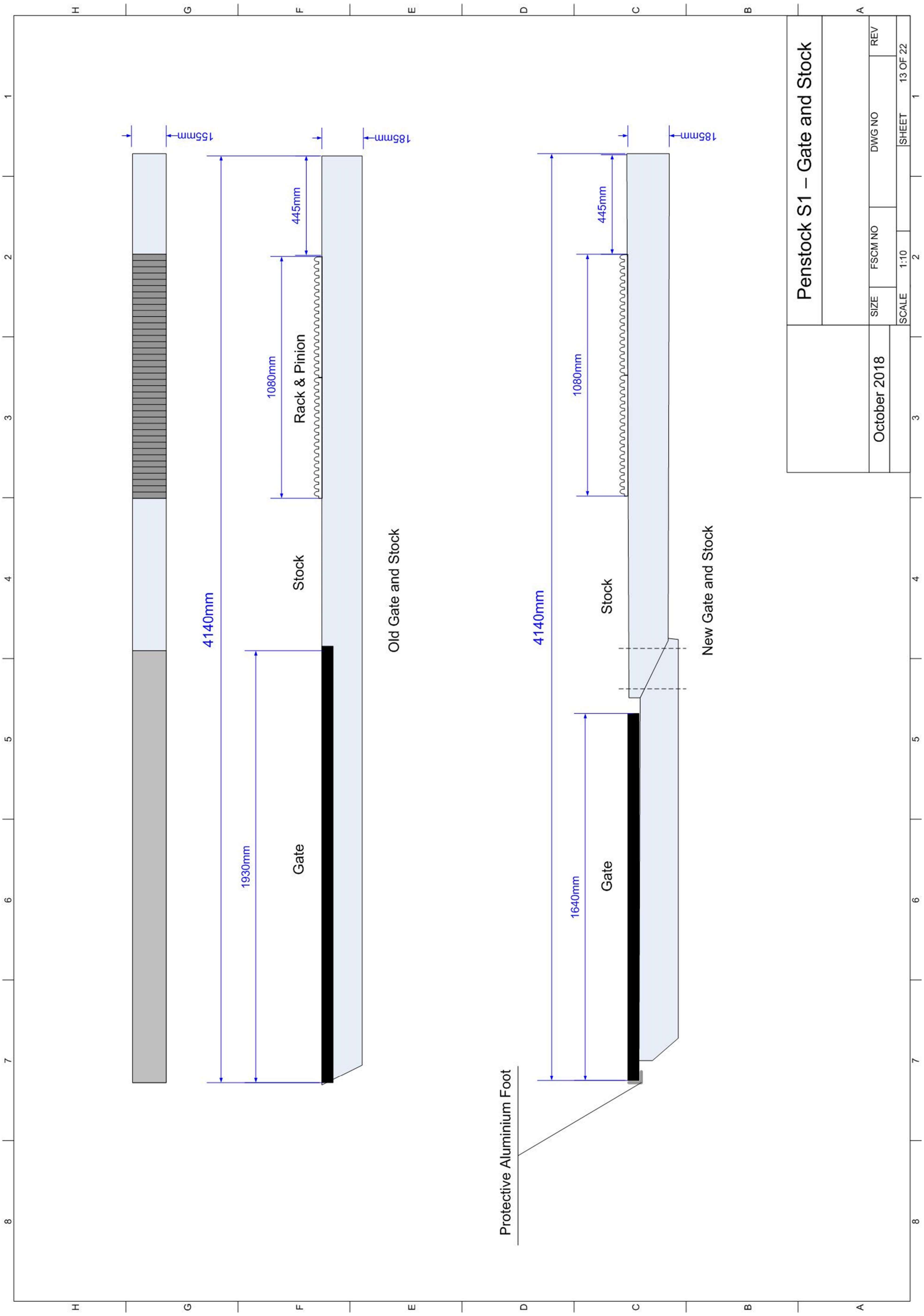
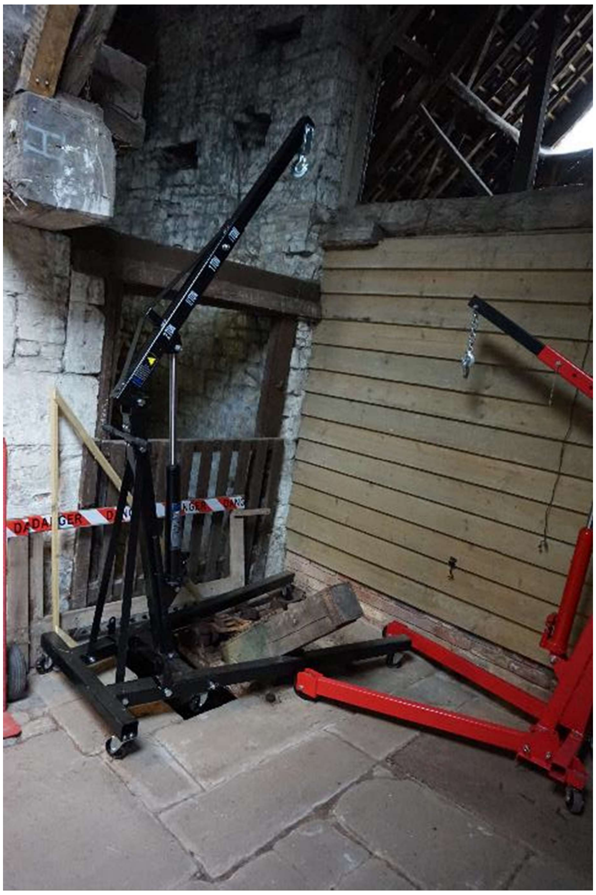


Figure 16 Penstock Gate W1 - Stock



2 Tonne Engine Lift

1 tonne engine lift

Figure 17 Lifting Arrangements

Mounting arrangements of Penstock W1 operating mechanism cut into supporting lintels. Gate and operating mechanism removed. The damage is evident to the lintels caused by corrosion of the securing bolts.

Penstock W1 operating mechanism restored with the new gate and stock in place.
Note fabrications installed to relieve the load on the damaged lintels.

Figure 18 Penstock Gate W1 – Operating Mechanism

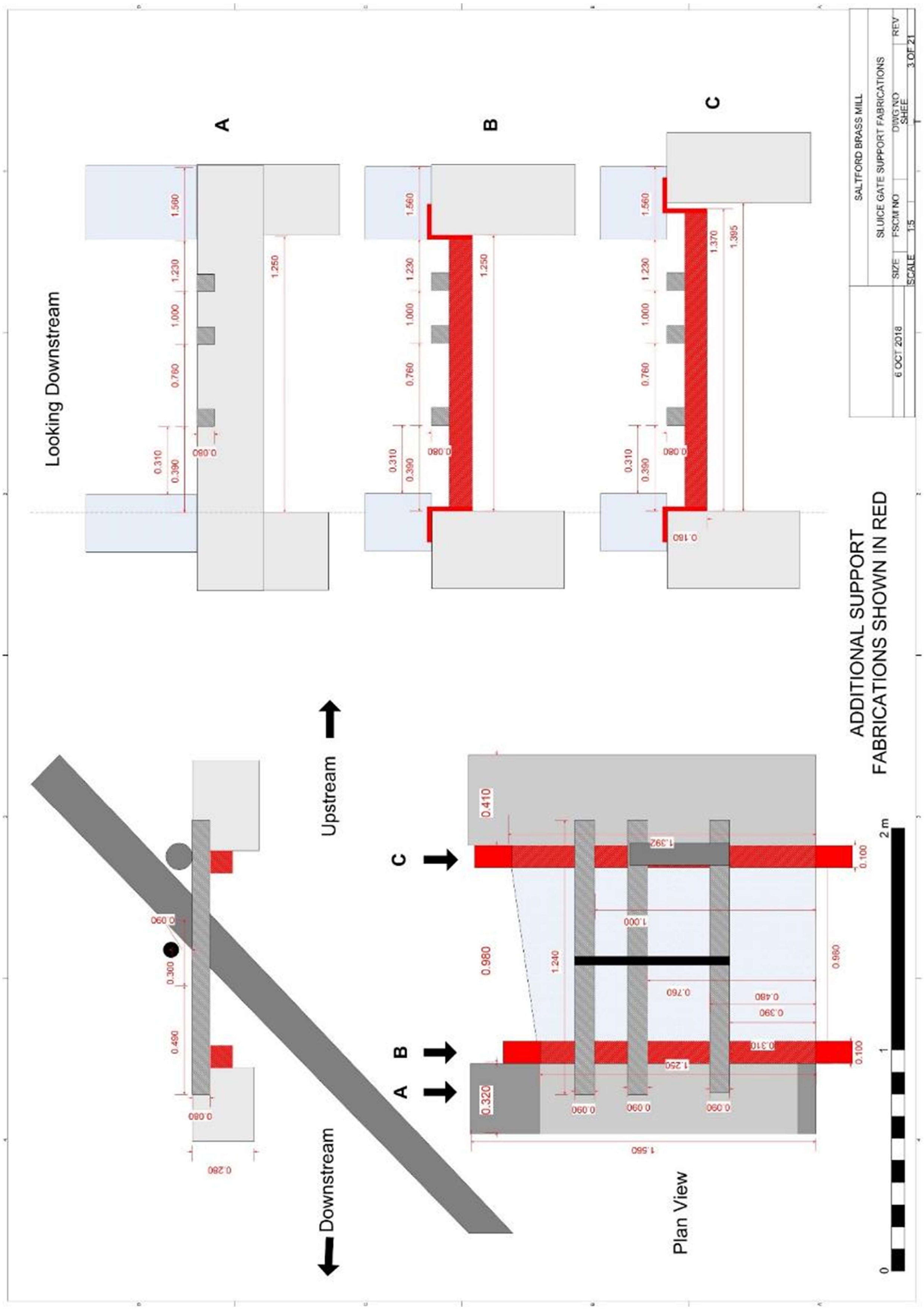


Figure 19 2018 Repairs to Penstock Gate W1 Operating Mechanism

Old Gate – Following Removal

Figure 20 Old Penstock Gate W1

New gate – Scarf Joint and Laminated Gate

New Gate and Lower Stock

Figure 21 New Penstock Gate W1

Discontinuity and opening in upper culvert

View looking upstream from the Culvert Outlet

Figure 22 Watercourse W1 – Lower Reach

Latrine – from below

Latrine – from above

Figure 23 Watercourse W1 – Latrine-

Figure 24 Watercourse W1/W2 Tail-Race

Exterior wall of upper rolling mill, mill watercourses, road bridge and western pier

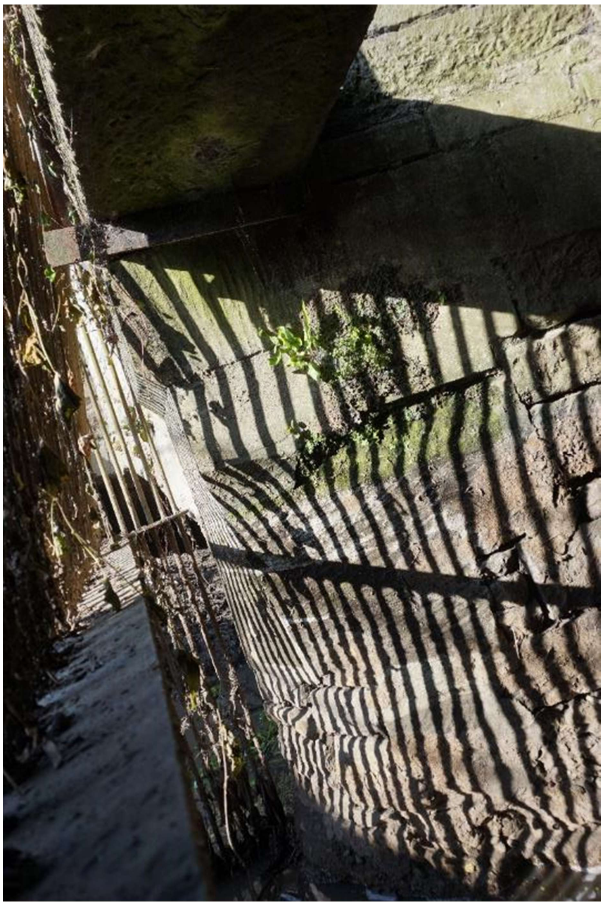
Exterior wall of upper rolling mill and southern wall of dynamo room

Figure 25 Head Race - Watercourse W2, W3 & W4

W3/W4 western Chamber and Watercourse 02 inlet

W3/W4 Western Chamber - Flooded

Figure 26 Watercourse W3/W4 Head Race



Watercourse Inlet – West Wall

Penstock W2

Watercourse Inlet – East Wall

Figure 27 Watercourse W2 – Inlet

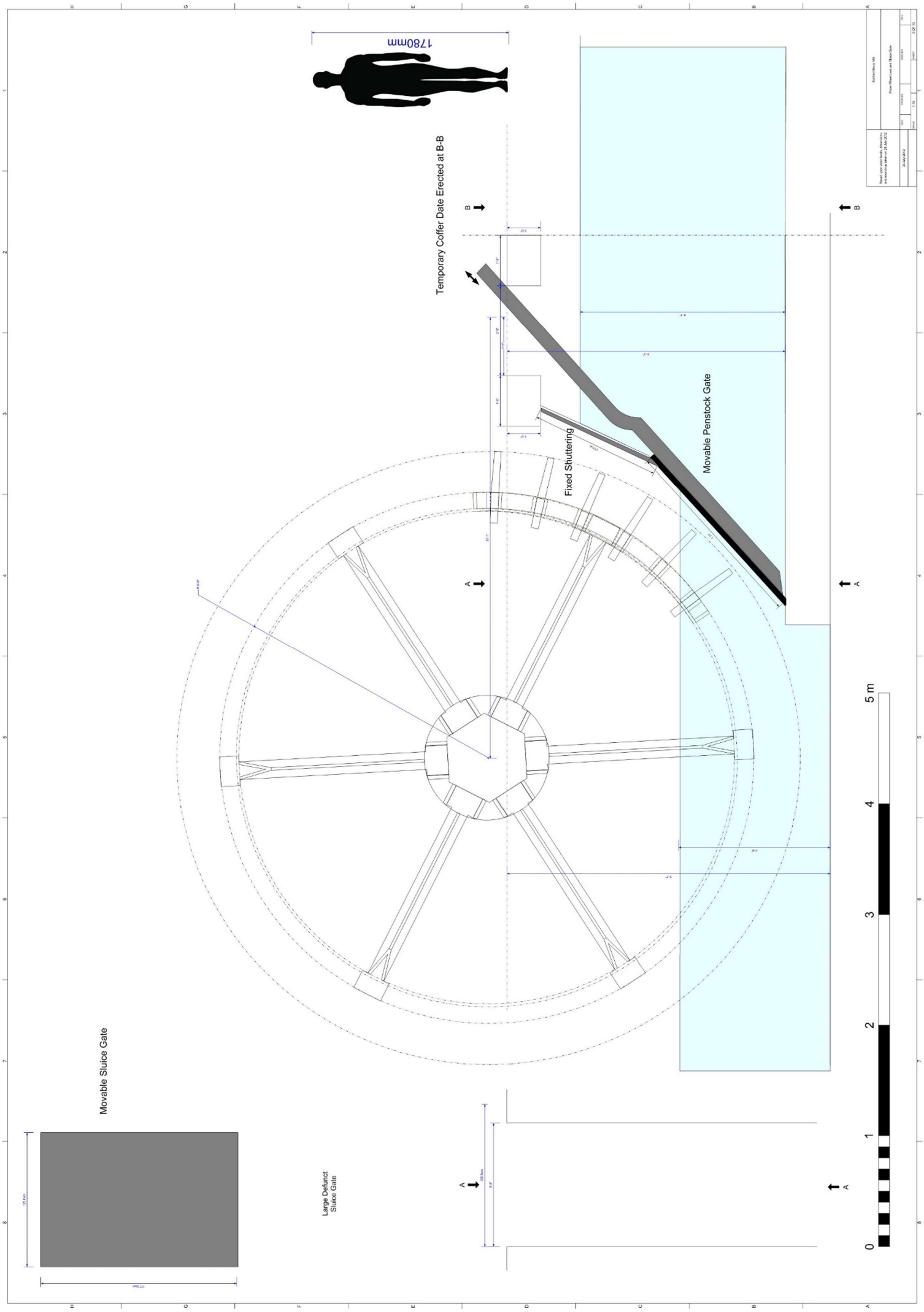


Figure 28 Penstock Gate W2

Culvert W2 outlet – looking upstream

Culvert W2 looking downstream from waterwheel

Figure 29 Watercourse W2

North Aspect - showing blanked culvert W3 and penstock W4

North Aspect – penstock W4, pier and blanked entrance to watercourse W3

Figure 30 Western Chamber

Eastern Aspect

Western Aspect

Figure 31 Western Chamber

Blanked entrance to watercourse W3

Figure 32 Western Chamber – Pier between W3 and W4

Southern sub-chamber

Figure 33 Western Chamber – Southern Extension

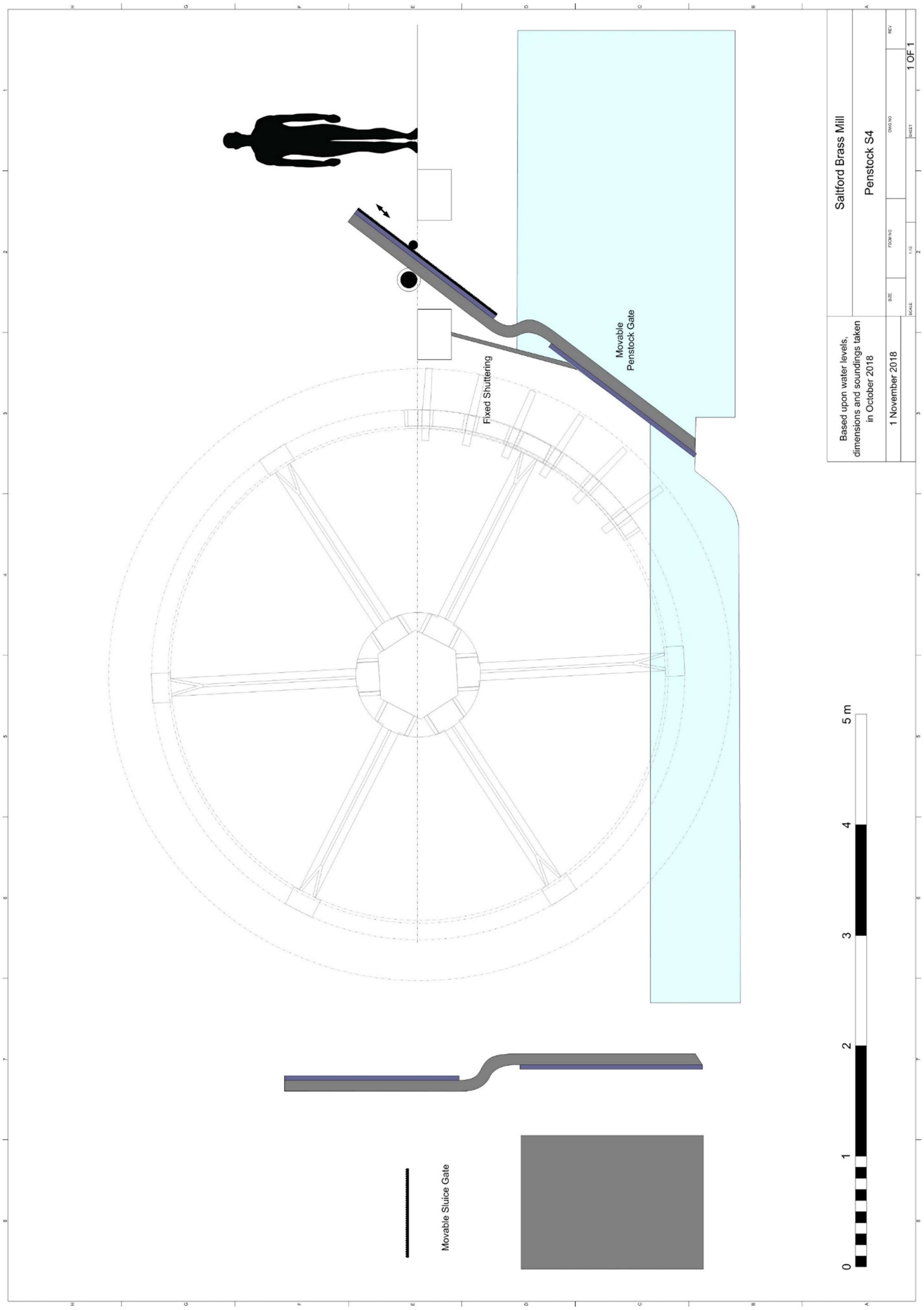


Figure 34 Penstock Gate W4

Figure 35 Penstock Gate W4

Goose-neck Insert plate

Damage to goose-neck

Figure 36 Penstock Gate W4 – Goose-Neck

W3 and W4 Outlets

W3 Tail Race – looking south

Figure 37 W3/W4 Tail Race Leat

W4 Tail-Race Culvert – looking South

W4 Culvert – looking North

Figure 38 W4 Tail-Race Culvert

West bank

East Bank

Figure 39 W3/W4 Tail Race Leat

Pottery bottle and Boer War commemorative jug

Figure 40 Artefacts found in the surface layer of silt in the upstream leat

Figure 41 Saltford Brass Mill – Drone Survey – January 2019

Figure 42 Saltford Brass Mill – Laser Scan – Screenshot – Roof-Level

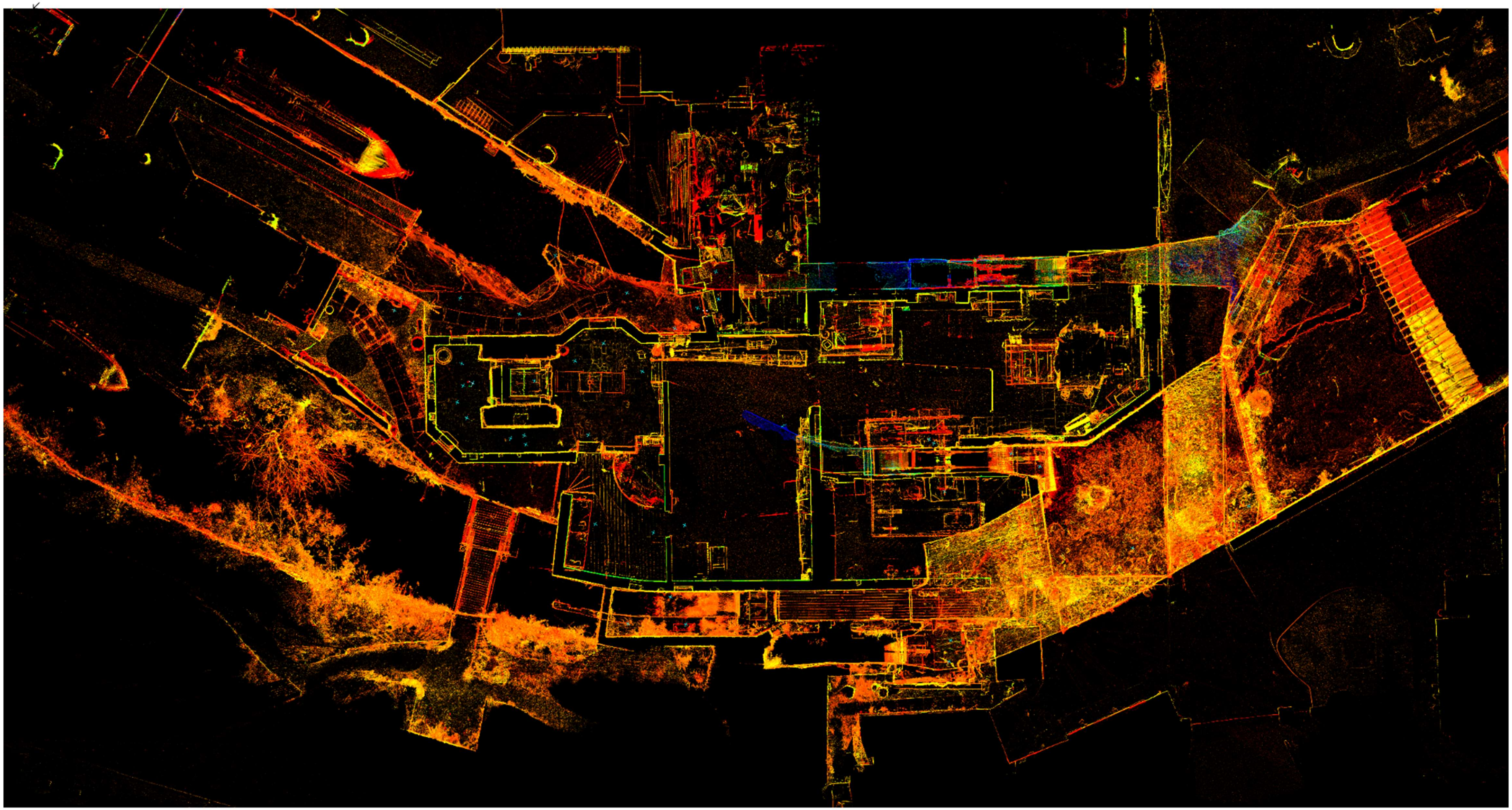


Figure 43 Saltford Brass Mill – Laser Scan – Screenshot – Ground level and Watercourses

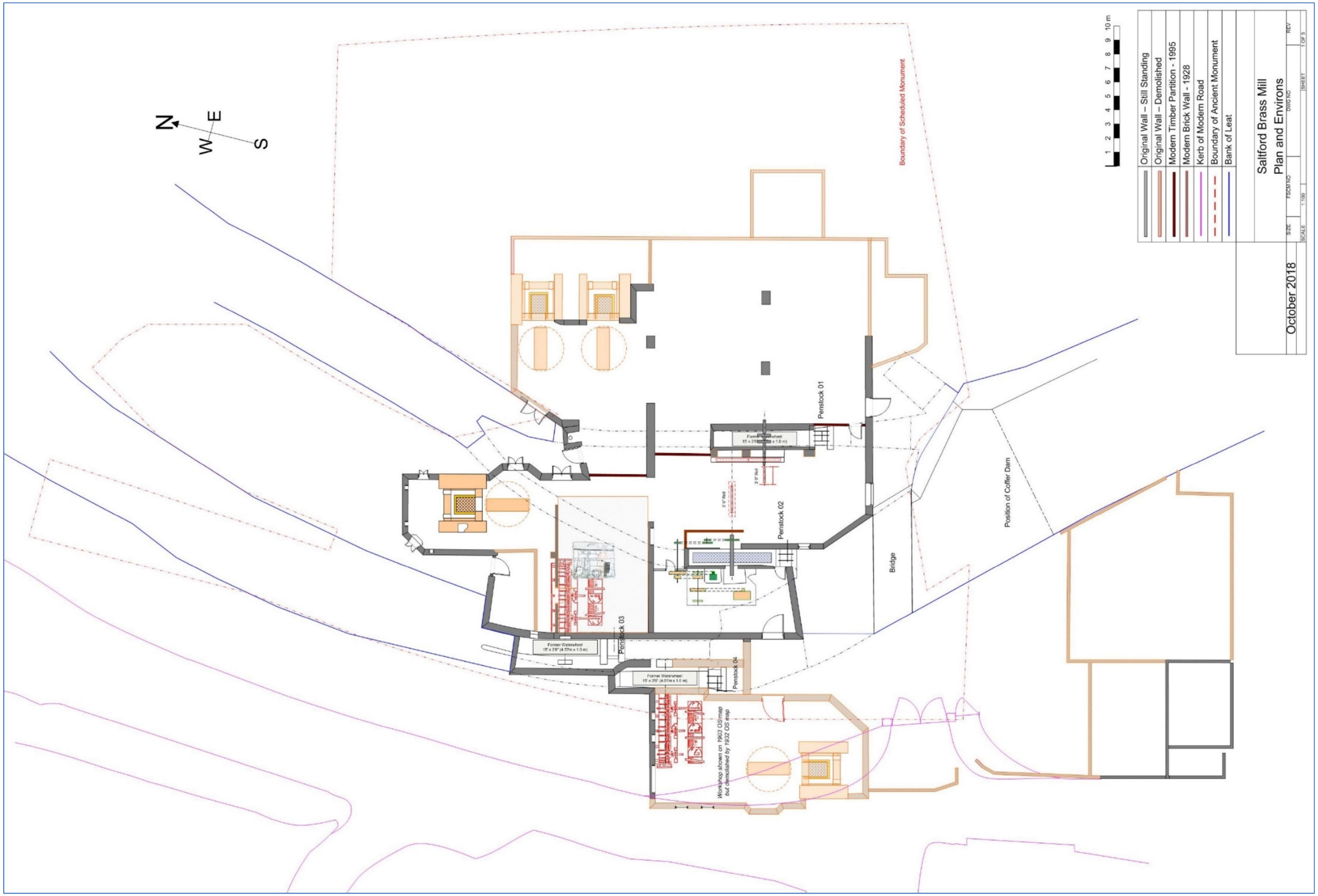


Figure 44 Saltford Brass Mill – Plan and Environs

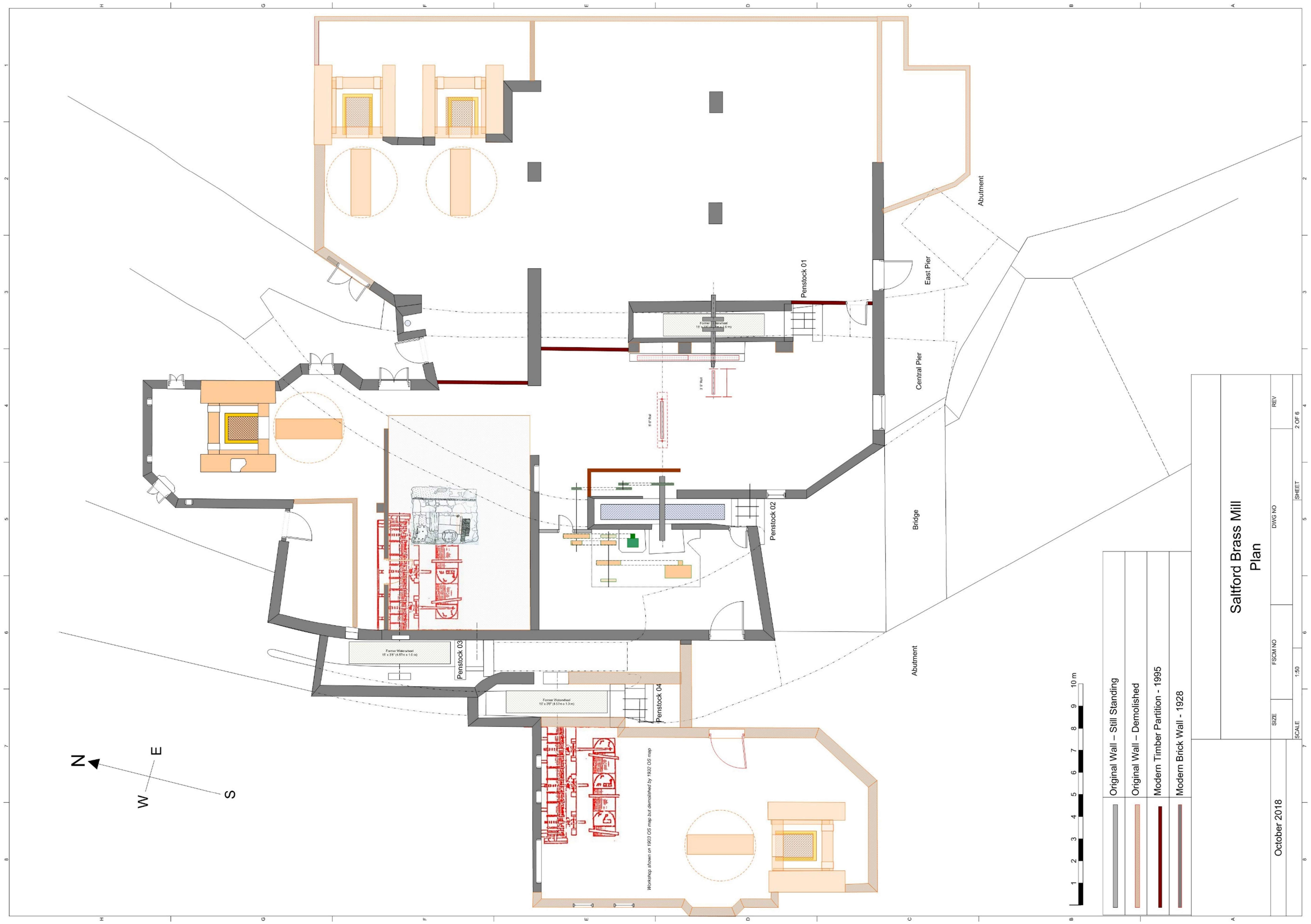


Figure 45 Saltford Brass Mill – Existing and Demolished Structures

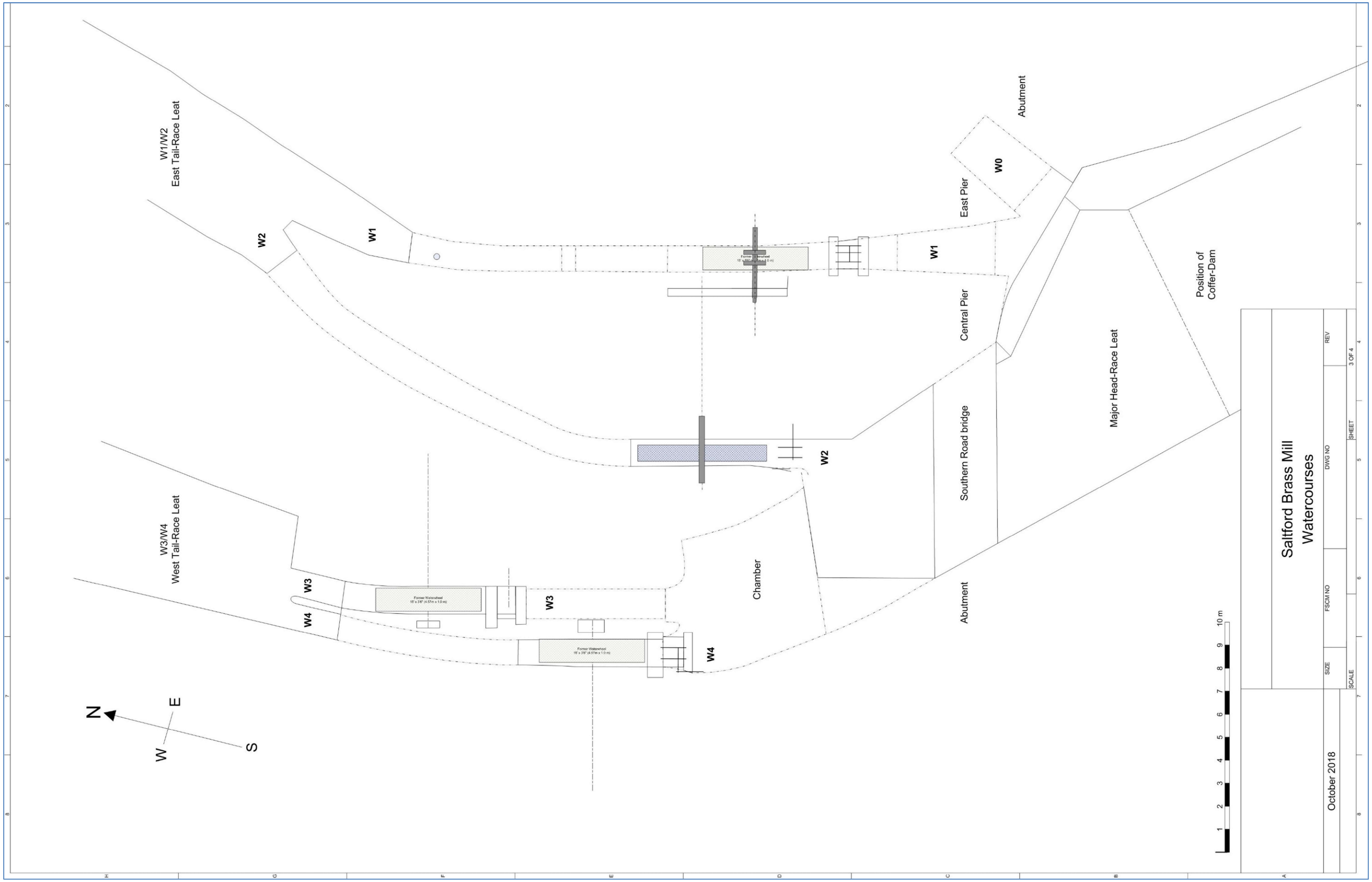


Figure 46 Saltford Brass Mill – Watercourses

Saltford
Brass
Mill
Project