ST THOMAS’ CHURCH TOWER, MUSBURY

INVESTIGATION OF MASONRY AND TIMBER CONDITION

JOB NO. 213-66

ST THOMAS’ PCC

11-13 APRIL 2023

Prepared by:	Technical review by:	Administration by:
Kester Banks Robert Branch	Peter Bannister	Tracy Bannister

CONTENTS

Appendices

Hutton+Rostron Environmental Investigations Ltd, Netley House, Gomshall, Surrey, GU5 9QA,
Tel: 01483 203221 Email: ei@handr.co.uk Web: www.handr.co.uk

1 INTRODUCTION

1.1 AUTHORITY AND REFERENCE

Hutton+Rostron Environmental Investigations Limited carried out a timber decay and damp survey of the tower at St Thomas Musbury, Helmshore from 11-13 April 2023 in accordance with instructions received from John Coward Architects by email dated 13 January 2023 on behalf of St Thomas' PCC and order form dated 1 February 2023. Reference was made to drawings supplied by John Coward Architects for the identification of structures. For the purpose of orientation in this report, the building was taken as facing south

1.2 AIM

The aim of this investigation was to undertake a timber and damp survey of the spire/tower and propose a remediation strategy for water ingress

1.3 LIMITATIONS

This survey was confined to the accessible structures. The condition of concealed timbers may be deduced from the reactions or from the general condition and moisture content of the adjacent structure. Only demolition or exposure work can enable the condition of timber to be determined with certainty, and this destroys what it is intended to preserve. Specialist investigative techniques are therefore employed as aids to the surveyor. No such technique can be 100 per cent reliable, but their use allows deductions to be made about the most probable condition of materials at the time of examination. Structures were not examined in detail except as described in this report, and no liability can be accepted for defects that may exist in other parts of the building. We have not inspected woodwork or other parts of the structure which are covered, unexposed or inaccessible and we are therefore unable to report that any such part of the property is free from defect or, in the event that such part of the property is not free from defect, that it will not contaminate and/or affect any other part of the property. Any design work carried out in conjunction with this report has taken account of available pre-construction or construction phase information to assist in the management of health and safety risks. The sample remedial details and other recommendations in this report are included to advise and inform the design team appointed by the client. The contents of this report do not imply the adoption of the role of Principal Designer by H+R for the purposes of the Construction (Design and Management) (CDM) Regulations 2015

1.4 H+R STAFF ON SITE

Peter Bannister
Kester Banks
Robert Branch

1.5 PERSONNEL CONTACTED

Fr David Stephenson
Heather Bickford- Church Warden

2 EXECUTIVE SUMMARY

2.1 WATER PENETRATION OF THE MASONRY

The survey used a range of access methods and investigation techniques. Water penetration of the masonry walls due to the poor condition of mortar joints and wind-driven rain was considered to be the primary moisture source for extensive damp (excess water) contained within the fabric of the spire and tower walls. The southern and western aspects are most severely affected by water penetration, and this has caused more degradation of the mortar joints than elsewhere

Recent repointing all four elevations to the tower is not likely to have provided a beneficial effect since the spire joints have not been repaired and many remain open. The spire masonry will, in effect, be capturing and conducting water into the head of the tower walls

In its current condition, the spire and its supporting tower display evidence of several interventions aimed at mitigating water penetration of the masonry. These include partial repointing of the facades to the spire, relatively recent repointing of the tower facades, and the application of moisture-resisting plaster and paint finishes within part of the ringing chamber within the tower, sheet lead covering the uppermost floor, and numerous repair interventions to address decaying timber floor structures in the tower. Despite these works, the spire and tower masonry structures continue to be subject to a considerable quantity of on-going water penetration

2.2 TIMBER DECAY

The softwood timber floor structures have all been subject to past repairs works due to water penetration and resulting fungal decay. These repairs have generally been constructive but, because of the continuing damp conditions, some decay and vulnerability to further decay was on-going. Nevertheless, in the view of H+R the floors were considered to be economically repairable

A sheet lead covering to the uppermost floor requires further consideration. If it is to be retained, allowance should made for alterations to its drainage arrangements because they are dysfunctional. Corrosion of steel beams and corbels supporting the floors requires further investigation

3 OBSERVATIONS

3.1 WATER PENETRATION OF SPIRE AND TOWER MASONRY

3.1.1 Location and construction

By the nature of its exposed location on the western flanks of the Pennine hills and its single stone thickness, the upper spire masonry is inevitably vulnerable to water penetration. On the southern and western aspects, water from wind-driven rainfall is a significant contributor to this phenomenon. However, findings from the more sheltered northern and eastern aspects also showed water penetration in significant quantities. In this case surface run-off water was the primary moisture source

3.1.2 Building stone

Tactile examination of the stones used to build the tower and the spire indicate it to be consistent with the Millstone Grit; a relatively dense silicaceous sedimentary rock which is generally low in porosity and permeability. Whilst some water absorption by the building stones may be ongoing, it is not likely to be a factor in the deleterious water penetration being experienced and as recorded by this survey

3.1.3 Mortar joints

Water penetration of the joints between stones of the spire and entrapment of water behind recent repointing on the tower was the primary route of ingress. Erosion and degradation of the mortar between stones of the spire and to the tower below was evident from the visual surveys (obtained by drone / mounted camera, MEWP access, and roped access) and by tactile examinations. Missing (void) mortar and saturated, degraded mortar were most pronounced on the southern and western elevations. In places on the spire, rainwater is free to penetrate voids un-checked by the presence of mortar. Furthermore, once mortar is saturated, as it was in many locations, it becomes more susceptible to water penetration than mortar in dry condition

Mortar sampled from masonry joints was ‘wet’ or ‘saturated’ in over 65 per cent of the test locations internally and externally. Original bed mortar is a lime mortar (probably hot mixed lime) with a range of aggregates including coal / coal ash. In the joints of the façade masonry, the mortar condition was variable where it remains. However, the facades have had at least two (and probably more) episodes of repointing works. The most recent of these was to the tower (understood to be 2017) rather than the spire. This work comprised a lime / sand mortar thought to be an NHL (natural hydraulic lime) binder. The repointing mortar was generally reasonably well-placed but, in many places, it has produced a ‘veneer’, concealing joints void of mortar. Rather than preventing water penetration, thin veneers of NHL based mortar appeared to entrap water that was probably percolating down through the tower from the thin-walled open jointed areas of the spire. The spire broach, where the shallower angle of the facades slows the speed of run-off, was particularly vulnerable to water penetration of the masonry joints; and projecting string courses to the tower appeared to provide little beneficial effect. The repointing mortar was, in a small number of locations, un-cured or degraded by salt and/or water action

3.1.4 Condensation cycle

During the survey, hygrothermal measurement showed that indoor surface temperatures of walls at the base of the tower were close (~ 2 ^{o}C) to dew point. Similarly, in the spire surface temperatures were close to theoretical dew point for the conditions at the time of measuring. Whist the volume of water likely to precipitate by this process is relatively small, it will significantly increase the evident symptoms of damp

Given that most masonry structures generally conduct heat far more rapidly when wet than when dry, condensation of atmospheric moisture vapour will also probably contribute to symptoms of damp noted on the interiors

3.1.5 Masonry sampling

Masonry moisture samples were taken on each floor at regular intervals on each wall. Samples were analysed in the H+R laboratory in accordance with the methodology set out in BRE Digest 245. This defines both available moisture and hygroscopic moisture. The results of which are set out in the plans at Appendix F and the table of material moisture contents at Appendix G. The results indicate significant water penetration to the spire above the broach; the wettest samples being taken from the west elevation. This was expected as south west elevations are typically exposed to a significant amount of wind-driven rain. Below the broach, the results showed water penetration had occurred on all aspects and levels of the tower. Samples taken from south west corner, north west corner, and west wall were consistently saturated. Samples taken from the stairwell and adjacent walls confirmed that significant water penetration was occurring via the small roof above

3.2 TOWER STRUCTURAL TIMBER CONDITION

For markups of timber decay and of water penetration of the tower/spire see the Plans at Appendix F

3.2.1 Fourth floor structure

1 Construction: The fourth floor was of softwood construction with joists supporting tongue and groove floorboards. The bearing ends of joists previously bore into the wall but have subsequently been trimmed and were now supported on steel beams. The steel beams were supported on vertical steel posts, which were bolted to the wall. The addition of steels was probably a response to timber decay, caused by water penetration from the tower above. The belfry deck was covered with lead, which had been chased into the walls to create waterproof barrier over the deck. The floor was designed so that water drained via lead channels into 2no. outlets on the north elevation. An opening had been formed in the middle of the floor, to accommodate a vertical spindle for the clock mechanism

2 Condition: Birds were freely accessing the tower, which had caused a significant amount of detritus build up on the floor. This has compromised drainage by blocking the channels and both rainwater outlets. The floor timbers were assessed visually from the floor below. The majority of joists appeared free from decay. The steel repairs ensured that joist bearing ends were not in contact with damp masonry. Localised significant decay from wet rot was detected in the joists and trimmers around the central opening. Timbers in this location had been exposed to ongoing water penetration from the spire above. Localised areas of decay to the floorboards were also noted in the south west corner. However further removal of the lead covering will probably reveal additional areas of localised decay to the floorboards

3.2.2 Belfry floor (Third floor)

The third floor structure was not visible from the ringing chamber due to the boarded ceiling. Above in the belfry, the bells, bell frame and significant bird detritus prevented a detailed inspection of the floor. Furthermore, suspected asbestos material was identified in the void between the bells and the dampening chamber. Therefore, this area was not disturbed

1 Construction: The floor was of the same construction as the fourth floor. The joist bearing ends were re-supported on steels. The beams were supported off the wall by angled steel brackets. Softwood boards were fixed to the underside and topside of the floor joists which created a dampening chamber between the ringing chamber and belfry. The bells were supported on a steel frame above the dampening chamber. Softwood boards spanned the lower flange of the steel frame

2 Condition: The corrosion to the steel beam on the west wall was so significant that a newer steel beam had been added to support the joists. Significant corrosion was also present on to the angle ties supporting the steel beam in this location. The ceiling boards at the centre of the floor were decayed by wet rot, due to water penetration via the central opening in the fourth floor deck. Decay was also present in the ceiling boards along the west wall, particularly in the north and south west corners. The deep moisture content of timbers in the north west corner were >60 per w/w and therefore at risk of decay. Above in the Belfry, there was a significant volume of debris and bird detritus on top of the dampening chamber. Ongoing water penetration and high humidity within the Belfry had caused this material to become damp in areas. As a result of this further decay to floorboards and joists below is probable

3.2.3 Ringing chamber (Second floor)

1 Construction: The floor was of the same construction as those above. Joists had been trimmed and were supported by steel beams. Like the floor above, the original steel beam had corroded and a new steel had been inserted to support the joists. Joists had been notched around the upper flange. The floor had been finished with carpet tiles

2 Condition: Decay was detected in 2no. joists along the west wall. The deep moisture content of timbers along this wall was >20 per cent w/w, leaving them at risk of further decay. The significant corrosion in the older steel on west wall had resulted in expansion of the beams upper flange. Consequently, fissures had formed in joists where they had been tightly notched around the steel's upper flange. There was also evidence of decay to sapwood bands of the floorboards as a result of common furniture beetle activity

3.2.4 First level (First floor)

1 Construction: The floor was constructed from 3no. softwood beams which supported 'mill-board' type (50mm thick) tongue and groove floorboards. Beams had previously bore into the masonry. However, the bearing ends had been trimmed and were now supported on masonry corbels. The beam along the east wall had been cut mid-span, to accommodate the organ pipes. The staircase ascending to the first floor was softwood

2 Condition: Floorboards along the west wall were decayed by wet rot. No decay was detected in the floor beams, however there was some partial decay to smaller trimmer joist in the north west corner. There was significant decay by wet rot and common furniture beetle to floorboards, joists and stringer to the staircase.

Timbers to the quarter landing at the base of the staircase were heavily decayed and partially collapsing as a result of wet rot

3.3 INTERNAL WALL FINISHES

The internal wall finishes varied with floor levels. The walls of the two uppermost floor levels (fourth floor) and (third floor) belfry were bare stone. The walls to the ringing chamber were covered with a hard cementitious plaster, which had been patched in some areas with a gypsum plaster. The use of cementitious plaster in the ringing chamber was trapping moisture within the wall itself. The ground floor level and first floor were partially covered with a lime plaster with a coal / ash aggregate. Damp staining and plaster failure was visible in areas where ongoing water penetration had occurred

4 RECOMMENDATIONS

4.1 WATER PENETRATION AND DAMP

There are several options and combinations of works which may be considered by way of remedial action, e.g.

4.1.1 Re-filling of voids and replacing mortar joints of the spire and tower by pointing and grouting with suitability specified materials -- in the view of H+R this will buy time. However, in isolation, it is not likely to provide a permanent solution

4.1.2 Introducing a waterproof barrier (e.g., a sheet lead tray) through the head of the tower walls

4.1.3 Removal and/or rebuilding of the spire

4.2 TIMBER DECAY MITIGATION WORKS

4.2.1 Fibrous material in the void between the fourth floor and the ceiling over the third floor should be investigated for asbestos content prior to the void being cleared

4.2.2 To reduce the rates of on-going timber decay, floorboards should be raised at intervals and at the perimeters of each floor. The voids should then be thoroughly and carefully cleaned of all dust, debris, and detritus. Alternatively, ceilings, should be taken down. Further detailed investigation of the condition of concealed joists etc should follow. The findings should inform a detailed schedule of timber repairs

4.2.3 Allowance should be made for release of the ground floor staircase, for its repair and reinstatement, isolating its timbers from direct contact with damp masonry

4.2.4 Allowance should be made for investigation and remediation of corroding steel elements associated with the floor structures

4.2.5 Timbers to the south-west corner of the Nave and the Organ loft should be examined where they may be at risk of decay because of their association with damp masonry at the south-east corner of the tower

4.3 TIMBER REPAIRS

4.3.1 Repair of timbers: Structurally decayed timbers as shown on plans at Appendix F should be removed or cut back to sound timber unless required for aesthetic reasons. Timbers should then be partnered or spliced. If steel plates or hangers are used, they should be detailed so as to allow sufficient ventilated air gaps and drainage to prevent moisture build-up due to condensation. Any new timbers should be isolated from the masonry with a damp proof material or ventilated air gap. No timber preservation or remedial treatments should be required

4.3.2 Second floor joists: Allowances should also be made for repair of joists to the second floor that have been structurally compromised due to the expansion of the steel beam

4.4 FOURTH FLOOR LEAD SHEETS

Subject to consideration by the Architect, the lead deck coverings and drainage system to the fourth floor should be redesigned so as to improve the drainage capacity and reduce the risk of blockages

4.5 FURTHER INVESTIGATIONS

4.5.1 Structural steels: The corrosion of structural steels to all floors, including those supporting the bells, should be assessed in detail and the results should inform a schedule of repairs or refurbishments

4.5.2 Third floor: Further investigation of the third floor beneath the Belfry is required. The tongue and groove ceiling over the ringing chamber should be removed to allow for a detailed condition survey of floor structure. Allowances should be to clear all debris and bird detritus within the Belfry itself. Prior to undertaking this work, the suspected asbestos material should be tested by a qualified individual

5 GENERAL RECOMMENDATIONS

5.1 BIRDS

Birds should be prevented from entry to the structure. H+R can give advice on this if necessary

5.2 STRUCTURAL VOIDS

All structural voids within the building should be provided with adequate through ventilation so as to prevent moisture build-up. This must be done with regard to the applicable fire regulations

5.3 PAINT FINISHES

Moisture vapour permeable or 'microporous' paint finishes should be preferred for internal and external surfaces and woodwork. This is especially important on window timbers. To take advantage of the properties of such paints, the complete removal of old alkyd paint systems is recommended. Health and Safety: Special precautions should be taken during surface preparation of pre 1960's paint surfaces as they may contain harmful lead

Appendix A

A.1 DRY ROT

Dry rot (*Serpula lacrymans*) belongs to the same group of fungi as most of the common mushrooms and toadstools. Reproduction is by means of spores which are produced in enormous numbers by the fleshy pancake-shaped fruiting body. These fruiting bodies generally only appear when the fungus is stressed or dying off. A well-established infestation may produce fruiting bodies more than one metre across and be accompanied by thick layers of rust-coloured spore dust. Each minute spore has an outer coat which affords it some protection against heat and desiccation, and germination has been achieved after a twenty-year latent period. Dry rot spores are ubiquitous and there is no domestic or natural environment entirely free of them. They can be found throughout the environment from high up in the jet stream to the middle of the countryside

Spores will germinate and grow in timber with a moisture content of between 20 and 30 per cent. The fine fungal thread (hypha) digests the cellulose and hemi cellulose fractions of the wood, but is unable to attack the structural linings. These remain as a brittle matrix which cracks into cubes under differential stresses. Cuboidal cracking is also a characteristic of many wet rots and does not automatically indicate the presence of dry rot

Fungal hyphae may clump together into a variety of structures known as mycelia which take various forms depending on the surrounding conditions. They may fill a humid cavity as a cotton wool-like mass, or grow across the surface of the timber, as a grey-white skin. Active dry rot has a fresh white or greyish appearance and smells strongly of mushrooms. Distinctive patches of lilac or canary yellow pigmentation are usually present

Some hyphae group together to form conducting strands. These have a fairly impervious outer layer rich in chitin, the major constituent of insect cuticle. The strands, which may reach a centimetre in thickness, are flexible when moist, becoming progressively more brittle as they dry out. Their main function is the conduction of nutrients, through or across inert non-nutrient materials (brickwork etc) to other timbers. Their relatively impervious outer layer, together with an unusual alkaline tolerance, allows them to survive in the mortar layers within masonry and walls. An infested area may be full of dry rot strands. The dry rot fungus may tolerate relatively lower moisture contents and, through this, and other quirks in its biology, is potentially capable of considerable destruction. Realisation of this potential, however, requires a narrow range of environmental conditions and, in practice, several factors restrict growth

Dry rot hyphae may attack timber with a moisture content of about 18 per cent; however, spores would not germinate under these conditions. This moisture content is still 5 to 10 per cent wetter than timber should be in a healthy domestic building, and indicates water penetration or, perhaps, faulty plumbing. There is no evidence that dry rot can 'wet up' timber to any appreciable extent under conditions expected in a healthy building, although this is often claimed. The fine attacking hyphae, unlike the coarse conducting strands, are susceptible to desiccation and dry wood may disperse moisture faster than it can be transported. This means they cannot move through dry masonry and wood or across ventilated cavities

The total breakdown of wood by fungus produces considerable quantities of water. It has been suggested that dry rot can sustain itself on this 'metabolic' water alone. However, in practice, external drying factors disperse the moisture so that favourable conditions can be maintained only in exceptional circumstances such as behind impermeable finishes or in sealed cavities

In order to thrive, dry rot requires a moisture content in timber in excess of 20 per cent, and a relative humidity above 95 per cent. Below these levels the fungus will cease to cause current decay problems. Temperature is also a strong regulating factor, and growth ceases at about 25^{o}C, a temperature frequently exceeded in roof spaces, for example. Large radiators can be particularly lethal to dry rot and measurements of 30^{o}C with 20 per cent relative humidity are not unusual in their immediate vicinity

Dry rot is attacked by many other decay organisms which cause particular damage when the fungus is under stress will eventually destroy it. However, under dry conditions, dead dry rot does not disappear. Strands may eventually darken and the fungal mats may lose their fresh appearance, becoming tinged with brown, and leathery or papery in texture. The decayed wood becomes powdery as it dries, shrinks and distorts, which can be the first sign of decay having occurred behind paint finishes

A.2 WET ROT

Wet rot is caused by a number of basidiomycete fungi of which the most important are *Coniphora puteana* (cellar fungus), *Poria fungi*; *Fibroporia vaillantii*, *Poria placenta*, *Amyloporia xantha*, *Geophyllum trabeum*, *Phellinus contiguus*, *Donkiporia expansa*, *Pleurotus ostreatus*, *Asterostroma* and *Paxillus panuoides*. They attack both softwoods and hardwoods causing a darkening of the timber (brown rot) or bleaching (white rot). Wet rot fungi usually occur in persistently damp conditions, needing an optimum moisture content of 50 to 60 per cent. Unlike dry rot, the conducting strands of wet rot fungi do not extend far from their nutrient wood, hence they cannot travel through masonry and brickwork. The fruiting bodies occur rarely in buildings. Wet rot has been known to hollow out giant beams. Wet rot *Coniphora puteana* is responsible for up to 90 per cent of wood decay within buildings but raises less concern than dry rot, possibly because it is more easily controlled by standard building techniques. Some wet rots are also called soft rots as they destroy both cellulose and lignin, leaving the colour of the wood largely unaltered, but producing a soft felty or spongy texture. Soft rot is caused by *Chaetomium globosum* and a number of other fungi also found growing on wet wood in buildings

A.3 WOOD-BORING INSECTS

The common furniture beetle (*Anobium punctatum*) has a life cycle consisting of four stages - egg, larva (which causes all the damage), pupa and adult. The eggs are laid in end grain or in existing flight holes and hatch in 4 to 5 weeks and the new larvae bore directly into the wood. The larvae feed and grow within the wood creating a network of tunnels closely packed with frass (small ellipsoidal pellets). The larvae are whitish, curved, approximately 6mm in length and have well defined dark-brown jaws. When fully grown the larva excavates a small chamber and pupates producing a beetle after 6-8 weeks which bores through a thin layer of wood producing the characteristic emergence holes 1-2mm in diameter. Emergence usually occurs between May and August. The life cycle depends on the condition of the wood, the temperature and humidity. The life cycle usually takes a minimum of 3 years within buildings. Attack is usually confined to the sapwood of softwoods and hardwoods but may occur in the heartwood in timbers such as beech, birch, spruce or in timbers modified by fungal decay. As sapwood only makes up a small cross section of the majority of structural timbers in older buildings, attack is often of little or no structural importance. In most instances of suspected attack, the infestation has died out long ago due to unfavourable environmental conditions. Careful checking is therefore required to establish that living woodworm are present

In cases of active infestation the environmental conditions are often marginal allowing the life cycle to continue but at a very slow rate. Small changes in the environmental conditions can tip the balance against insects. Woodworm attack is often very localised to small areas of high humidity or especially 'palatable' timber and further spread is highly unlikely

In the British Isles, death watch beetle (*Xestobium rufovillosum*) infestations occur most commonly in oak, probably because this wood used to be extensively employed in construction, but infestation can also occur in elm, walnut, chestnut, elder and beech. The life cycle is similar to that of the common furniture beetle but can take many years to complete from one year under experimental conditions, to ten years or more in a building (Ref 11). The hatched larvae wander over the surface of the timber before burrowing into it. When it is fully grown it pupates and changes into the adult beetle which does not emerge until the spring of the following year producing a 3mm diameter hole

In old buildings severe damage can be caused under favourable environmental conditions. Softwoods are occasionally infested where they are in close proximity to damp infected hardwood. Infestation is confined to fungal decayed or damp affected timbers. Many existing cases probably arose from the reuse of infected timbers from demolished buildings and from the use of unseasoned timbers used in their construction. Attack is not confined to the sapwood and often the heartwood is entirely consumed causing severe structural damage. Damage is most severe where ventilation is poor and where timbers are in contact with damp masonry

Death watch beetles are not active fliers. A localised attack of death watch will not automatically spread to the whole house and infest every timber in the building. Lowering of moisture contents of the timber in conjunction with careful observation to determine the level and extent of activity should provide control of the insects. Some severe cases may merit the use of local insecticide treatments as a first aid measure. However, the chemical must be targeted properly or large quantities of toxic pesticides will be used to little effect

Woodworm and death watch beetle infestation will not flourish if the moisture content of timber is below about 14 to 15 per cent. The risk of infestation of insect attack is slight, in timbers with a moisture content at or below 14 per cent and the insect larvae will desiccate below about 12 per cent moisture content. The infestation will eventually die out if the timber moisture content is maintained below this. Healthy roof timbers should have a core moisture content of between 14 to 15 percent, while suspended floor timbers should be between about 11 and 14 per cent. Installation of a central heating system may reduce these moisture contents to about 9 per cent particularly in exposed timbers

It is absolutely necessary to recognise whether an insect infestation is 'active' or 'dead'. The presence of fresh frass (bore dust) in conjunction with damp timbers may be acceptable evidence of active infestation

Appendix B

B.1 PRELIMINARY INSPECTION AND INVESTIGATION

The basis of any investigation is an understanding of building structures and defects and how these may interact to produce the ecological niches in which various decay organisms can thrive. With experience, an initial visual inspection can give a good idea of the areas that will need further study. A check-list for this preliminary investigation includes building defects, significant timber structures and concealed cavities

The condition of concealed timbers may be deduced from the general condition and moisture content of the adjacent structure. Only demolition or exposure work can enable the condition of timber to be determined with certainty and this destroys what it is intended to preserve. A non-destructive approach is therefore required and to help reduce uncertainty, specialist instrumentation and test equipment can be useful. However, it is important to remember that all tests and instruments are only aids to the surveyor, and must be interpreted with experience and care. A slavish reliance on any technique and failure to take into account its limitations is a recipe for disaster. No technique can be 100 per cent accurate or reliable

The techniques that may be used for preliminary investigation include resistance-based timber moisture meters, capacitance masonry moisture detectors, borescopes and Rothounds

B.2 DETAILED INVESTIGATION

The findings from the initial investigations are followed up by more detailed study. The aim is to determine as far as possible the distribution and extent of all significant decay and organisms in the building, the distribution of micro environments predisposed to timber decay and the building defects that cause them. The extent of significant timber decay should also be determined as far as possible. Active decay organisms may not yet have caused significant timber decay. Conversely, there may be significant decay even when the decay organisms that caused it have been dead for many years. This may seem obvious but many expensive 'treatments' are carried out on insect or fungus damaged timber that has not been infected for tens or even hundreds of years. Key factors that may be noted are species and viability of decay organisms, moisture content of materials, ambient relative humidity, and ventilation. Timber species and previous chemical treatments may also be significant

It is important that the results of the investigation are co-ordinated with the building structure bearing in mind the characteristics of particular periods and methods of building. They should also be carefully recorded and quantified where possible. This allows analysis of the results by other experts, reduces the 'grey' area in which disputes of opinion can arise and forms a basis on which future investigations can build. Photography can be especially valuable and may be used when necessary

B.3 ROTHOUNDS

Rothounds are specialist search dogs trained to help find dry rot (*Serpula lacrymans*) in buildings. Rothounds may indicate areas of active dry rot even before they are visible to the naked eye. This will occur if the dry rot is just developing, is inside the substance of the timber, between the timber and another surface or within porous masonry. Such indications may be confirmed by comparing them with measurements of the moisture content of the structure or by the use of a drilled sample. Rothounds will not indicate the remains of dead dry rot infestations

In areas indicated by Rothounds the significant timber structures should be checked for structural decay or high moisture levels. Even if these are not found steps should be taken to reduce moisture levels and increase ventilation. This may be all that is required to stop a developing problem and all that is then required is to check the area in 6 months. For this purpose Hutton + Rostron again favour the Rothounds

1 Capabilities

a May detect living dry rot (*Serpula lacrymans*) by the scent of the metabolites produced by the fungus

b May detect the scent of dry rot even when hidden behind panelling, under floors, behind plaster or in other concealed cavities

c May detect the scent of dry rot at a distance of several metres depending on scenting conditions

d May detect early dry rot growth before it is detectable by the unaided human eye

e May discriminate between living or dead dry rot and between dry rot and other fungi instantly

f Actively search for dry rot in buildings at high speed, covering 20 to 50 rooms in an hour

g May indicate extent and spread of dry rot infestation

h Will search small inaccessible areas and roof spaces

i Will work in furnished and inhabited buildings

j Totally non-destructive

k Will work 2-4 hours per day

2 Limitations

a Trained only to indicate living dry rot, not wet rot or dead dry rot. Will not indicate fruiting bodies on old dead outbreaks of dry rot

b Indicate the scent of dry rot and the point of maximum scent. This may need interpretation as scent can occasionally be moved by air currents from the point of origin

c Scent will not travel through impermeable surfaces such as neoprene. However, it may be detected at the edge of an impermeable barrier, eg around the edge of a room with a rubber-backed carpet covering an infected floor

d Indicate dry rot infection, not decay. Therefore heavily decayed but inactive outbreaks may give a weaker indication than a recent highly active outbreak that has not yet caused significant decay e May not work if there is a corrosive or choking dust or vapour. However, Rothounds should not be put off by smells and may detect even small amounts of dry rot in the presence of other strong scents

3 Uses

a Survey of properties prior to purchase, renovation, change of occupancy etc, to quickly check for hidden problems

b Preliminary survey of properties with suspected decay problems to determine existence and extent of dry rot infestation

c Survey of properties with known dry rot problems to determine activity and extent of infestation

d Survey of properties undergoing remedial works to check for additional hidden areas of infestation

e Survey of properties after remedial works to check for efficiency of treatment

f Routine survey of properties with past problems thought to be at risk in order to detect recurrence of infestation at an early stage before significant decay can occur

g Periodic survey of properties with known problems awaiting renovation, to detect 'hot spots' of dry rot activity

These can then be dealt with by 'reactive maintenance' allowing outbreaks to be controlled by minor exposure works and environmental controls. This avoids expensive building or remedial works. Further decay is prevented and infection controlled with significant savings on eventual renovation

B.4 FIBRE OPTIC BORESCOPE EXAMINATION

A technique we have found routinely useful over the last 15 years is the use of fibre optics. We use long reach, fixed side view, rigid borescopes and high-power light sources. Although this is comparatively expensive it is essential for getting a clear view across a cavity such as a floor space. It also minimises the time spent and the number of holes drilled. Fibre optic inspection can reveal extensive decay and the consequences of water penetration. However, most wood-destroying fungi will not live on the face of timber which is exposed to air movement because this produces a drying effect. It is always a possibility that a fungus, especially dry rot, is travelling behind a wall plate, for example, and is not detectable from the cavity. Fibre optic inspection may not, therefore, find a minor attack which is developing, but it should indicate where these might be initiated so that faults can be identified and remedied. The siting of inspection holes depends on the points at risk within the room and will usually be located adjacent to balcony floors, flat roofs, cracks in rendering and other points where faults may have resulted in water penetration. Inspection may also be limited in areas of tiled and glued flooring materials and ornate or special wall coverings. Inspection holes are numbered and capped off for future use

B.5 THE MEASUREMENT AND SIGNIFICANCE OF MOISTURE CONTENT

The moisture contents in timber, mortar and plaster are measured by a variety of methods. Timber moisture content might be ascertained by the use of a standard resistance-type moisture probe which measures the moisture content at the surface of the wood. However, this moisture content will be subject to considerable fluctuation, depending on current relative humidity and temperature. A rafter in a roof in summer may, for example, have a moisture content at the surface of 16 per cent which might rise to over 20 per cent in winter. This difference would not necessarily reflect increased water content resulting from a fault in the roof, but might simply be a redeposition of water resulting from a considerable drop in temperature

The condition in the core or subsurface of a timber will remain relatively stable which is why the centre of thick timbers may be preferentially decayed. It is this 'deep' moisture content which must be measured if results are to be meaningful. For this reason, a hammer probe with insulated electrodes or deep moisture probe is used to measure the moisture content within the timber. Healthy roof timbers should maintain a stable core moisture content of between about 12 per cent and 16 per cent, whilst suspended floor timbers (excluding ground floors) should be between about 11 per cent and 14 per cent. Central heating will usually reduce this figure to around 9 per cent

Similarly, surface moisture content readings in plaster and mortar are of limited value except for purposes of comparison. A surface capacitance meter may be used on plastered walls. For further investigation absolute measurements of moisture content may be made on site by means of a carbide-type gas pressure meter

Alternatively, samples are taken back to the laboratory in sealed vials, and the moisture contents are measured by the oven and balance method. For this, mortar samples are obtained by drilling holes in the wall and dust from the first inch of each hole is discarded. Dry mortar and plaster should have moisture contents below about 2 per cent. At levels much above this the moisture content of incorporated timbers will exceed 20 per cent and may easily reach levels at which fungal decay is likely

B.6 OTHER TECHNIQUES

Other techniques that may be used include microscopy, laboratory culture, hot wire anemometry and electronic RH measurement. We have also developed special instruments for measuring 'available' water in materials and for ultrasonic detection of timber-boring insects. More exotic techniques may sometimes be useful such as pheromone insect traps, infra-red thermography, shortwave radar, automatic weather stations and total building monitoring using specialist data loggers

Appendix C

The most critical factors for the environmental control of decay organisms are available moisture and temperature. The former is dependent on such factors as moisture content, relative humidity, micro-ventilation, and salt content. In simplistic terms it is necessary to correct building defects leading to high moisture contents in timber and to increase ventilation around timber at risk

In practice there are two problems; first it is necessary to identify the significant building defects and then the best techniques must be chosen to control the environment at each point. This may be achieved by analysing the building in terms of moisture sources, moisture reservoirs and moisture sinks

It is not possible to prevent moisture entering a building entirely and often attempts to block the movement of moisture through a building structure using impermeable materials are ineffective. They may also be counter-productive as they can prevent moisture being dissipated, resulting in high moisture levels and decay in adjacent materials. The more effective and robust approach is that used in traditional buildings. Here, porous materials are preferred, and every moisture source is balanced by a moisture sink. Thus ground water may penetrate masonry but is evaporated off before it reaches timber structures. Similarly, water vapour is introduced by occupation, but is ventilated out via windows, chimneys and other passive and active forms of ventilation. Failure to balance a moisture source with an appropriate sink may result in moisture moving into vulnerable materials and eventually causing decay and other problems

Moisture reservoirs occur when a moisture 'source' has not been balanced by a 'sink' and water has accumulated in a porous material. Typical examples of this are to be found when thick masonry walls have been soaked by persistent leaks or when chimney breasts have been filled with rain water from uncapped chimneys. Such reservoirs may take years to dry out, even when the source has been dealt with. As a result, they can act as a source of moisture for recurrent timber decay over a long period. A special case of this phenomenon occurs when large quantities of water have been used in fighting a fire

In practice then, each area of decay is associated with a building defect, resulting in an increased moisture source, a blocked or inappropriate moisture sink or a moisture reservoir. The appropriate building measures should then be specified to correct that defect

A common example might be the bridging of a damp proof course by raised ground levels. This will act as a moisture source and may result in decay of timbers in an adjacent floor space. Reducing the ground level will cut off this source and will also provide a sink of moisture by allowing evaporation from the exposed wall. The sub-floor moisture level might also be controlled by increasing the other available moisture sinks. Cleaning pre-existing airbricks or inserting additional sub-floor ventilation would be a common measure. In general, it is important to increase evaporative surfaces and avoid obstructing them during refurbishment

Another common example would be a blocked and overflowing parapet gutter acting as a moisture source. This could wet up gutter soles, joist ends and wall plates as well as any other structure in an expanding cone extending from the leak down through the building. Preventing this moisture source may require a number of measures such as increasing the capacity of down pipes, re-lining the gutters and fitting thermostatically controlled trace heating tape to increase free flow of snow melt water

Any failure in a roof finish, gutter or coping will generally result in significant water penetration into the masonry wall beneath, which will then act as a moisture reservoir. Any timber in contact with this reservoir will be at risk of decay as it will tend to 'wick' moisture from the masonry. Steps must therefore be taken to isolate in-contact timber from the masonry using such measures as DPC membranes or joist hangers producing an air gap. It will also be necessary to ensure the timbers are adequately ventilated so that any moisture that is absorbed can be breathed off. Closed cavities or water-impermeable layers over timbers at risk must therefore be carefully searched out and rectified using knowledge of historic methods of construction. Bricked-in lintels and sealed up emulsion-painted sash windows are typical examples of structures at risk in this way

Having cut off the moisture source to a moisture reservoir and protected the 'at-risk' timbers it is next necessary to provide safe 'sinks' for the moisture. This will ensure that the reservoir is dried out in the long term. In some cases, the reservoir can be removed entirely, for example damp pugging can be dug out and replaced. In most cases it is a matter of promoting ventilation around a wicking surface on the reservoir and ensuring that the moisture-laden air can be vented to the outside. Dry lining systems can be useful for this purpose as can the good old-fashioned chimney. Raising the temperature will promote the process of wicking and evaporation. General house heating can help but care must be taken to ensure that water vapour is not being 'pulsed' into other parts of the building by a sequence of evaporation and condensation down a temperature gradient. Heating can be especially useful if it is possible to heat the reservoir material itself. We have devised special systems for heating large section timbers and masonry for this purpose but again the old-fashioned fire-place and chimney is very useful

In some cases, dehumidifiers can be used in the short to medium term, but care must be taken. They often require special 'tenting' and monitoring so that moisture is removed from the appropriate material and not from the world at large. They also require high air temperatures and high RH's to extract moisture efficiently

In all cases most of the remedial building works that may be required are quite within the capacity of the general contractor. Most are traditional repairs though some may take advantage of new materials or techniques such as dry lining, joist hangers and tanking. New and potentially useful products are coming into the building market all the time, for example, time controlled automatic fans, hollow ventilating plastic skirting boards, plastic masonry drains, roof space ventilating systems and moisture permeable paints. All such products and techniques can be used to help in making the environmental control of timber decay even more efficient and economical. All that is required is careful analysis of each situation and a little scientific understanding

Appendix D

The investigation and building works described in the previous appendices should put a building back into a state of structural and environmental health. The environmental control approach will also mean that a building is less likely to develop problems in the future. This is because the effect of minor building failures should be 'buffered' by the robustness of the systems established. Fortunately, most traditional systems are robust in this way. This is why older buildings may tolerate a considerable amount of neglect and abuse before developing severe problems. However, the long-term health of the building will always depend on adequate maintenance. This is no less true of buildings treated with timber preservatives

A detailed investigation carried out as part of an environmental control policy provides an excellent basis on which to plan the most cost-effective maintenance program. Indeed, the building works required for environmental control are often best integrated into such a program. Short-term 'emergency' measures can be taken to simply halt further decay and measures to replace damaged structures or prevent future problems can be delayed to fit into a longer term plan of works. This flexibility in scheduling work as a result of the environmental approach allows further saving of costs and inconvenience

A maintenance program must also include provision for the routine inspection of all significant parts of the building at appropriate intervals. This should aim to detect and correct problems developing before they cause significant damage. Again the information gained in the investigation can be used to decide on the most cost effective inspection interval

In many cases remote monitoring systems can be very useful in increasing the efficiency and reducing the cost of maintenance programs. They can be especially useful for checking the moisture content of inaccessible timbers in roof spaces, behind decorative finishes and in walls. H+R have developed the Curator building monitoring systems for this proposal

Sensors can be placed at all critical points after the investigation or after the remedial building works. Areas can then be closed up and finishes re-applied, for example sensors may be placed in lintels, joist ends, valley gutter soles or in damp walls to monitor drying. It is important to use enough sensors and to place them with an understanding of the moisture distribution processes because conditions can vary even in a small area. It is these local variations in conditions that produce the environmental niches which decay organisms exploit

If more than 30 sensors are deployed, taking the readings can become onerous and this may result in human error or negligence. In these situations automatic monitoring systems become desirable. H+R have developed a number of specialised 'Curator' data logging systems to do this. With larger systems, the wiring of sensors can also become a problem. For systems requiring 100 or more sensors we can use a 'Curator A' unit working via a single 4-core main cable connecting up any number of nodes, each supporting 4 sensors. This system can be programmed with logging intervals and alarm limits for each sensor and can be read via the telephone system via its own modem. Data from the system can then be analysed using CAD and programs for statistical interpretation on a remote computer

Appendix E

Fig 1:

St Thomas', Musbury—West elevation; showing the tower at the west end of the church

Fig 2:

North elevation of tower; showing a general view

Fig 3:

South elevation of tower; showing a general view

Fig 4:

South and east elevation; showing a general view

St Thomas', Musbury
Photographs
11 April 2023

Fig 5:

East elevation; showing view looking down on the spire

Fig 6:

South-east showing; view of weather vein and finial at the top of the spire

Fig 7:

North-west elevation; showing general view of upper section of spire which is believed to have been rebuilt following a damaging lightening strike

Fig 8:

West elevation; showing example of upper windows

Fig 9:

North elevation; showing detailing around upper windows

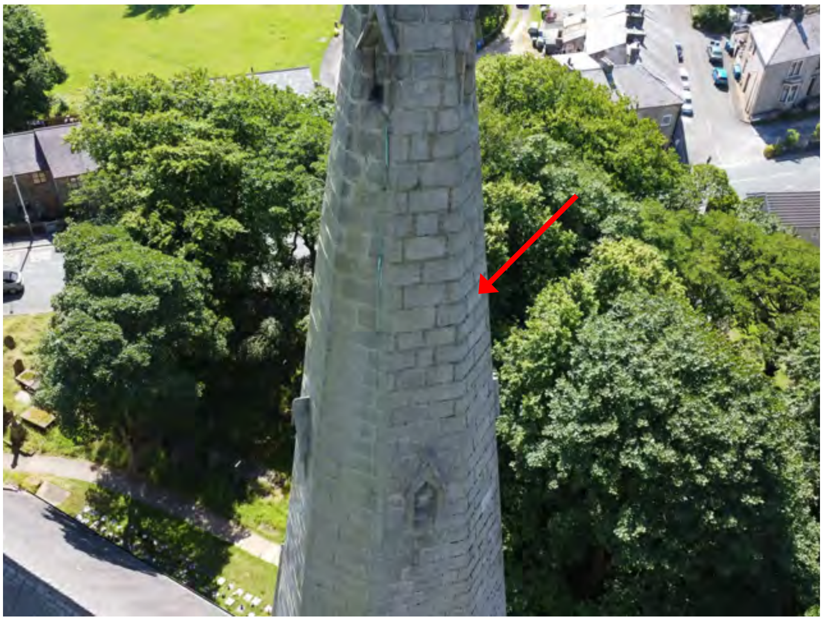


Fig 10:

North-west; showing example of area of spire with erosion to the mortar joints

Fig 11:

North to north-east spire; showing a general view

Fig 12:

North to north-east spire; showing moss growth in heavily degraded mortar joints, some of which are void

Fig 13:

North to north-east spire: showing moss growth in saturated mortar joints at the broach

One of the test holes is arrowed

Fig 14:

West elevation; showing uppermost projecting string course of the tower and the interface of modern NHL repointing work and older pointing of the spire

Fig 15:

North elevation, top of tower; showing an example of saturated mortar clinging to the drill bit. Beyond this 100mm of wet mortar, the joint was void

Fig 16:

North elevation; showing general view of window arch and tracery. Broken glass noted

Fig 17:

North elevation, fourth floor level; showing drainage chute serving internal lead covered deck

Fig 18:

North elevation, fourth floor level; showing plastic drainage pipes discharging (now blocked) into stainless steel chute

Fig 19:

North elevation; showing general view of middle string course

Fig 20:

North elevation; showing general view of roof over stair tower

Fig 21:

North elevation; showing voiding of joints in the stair tower roof masonry

Fig 22:

North elevation, mid-level of tower; showing perished areas of repointing works which were carried out in 2017

There was evidence that water is exuding from these joints

Fig 23:

North elevation; showing test location where joint voiding above the bottom string course was determined by drill

Fig 24:

West elevation; showing general view of the spire

Note the moss growth coincident with the broaches and indicative of moisture reservoirs

Fig 25:

West elevation; showing open and void mortar joints at lower level on the spire

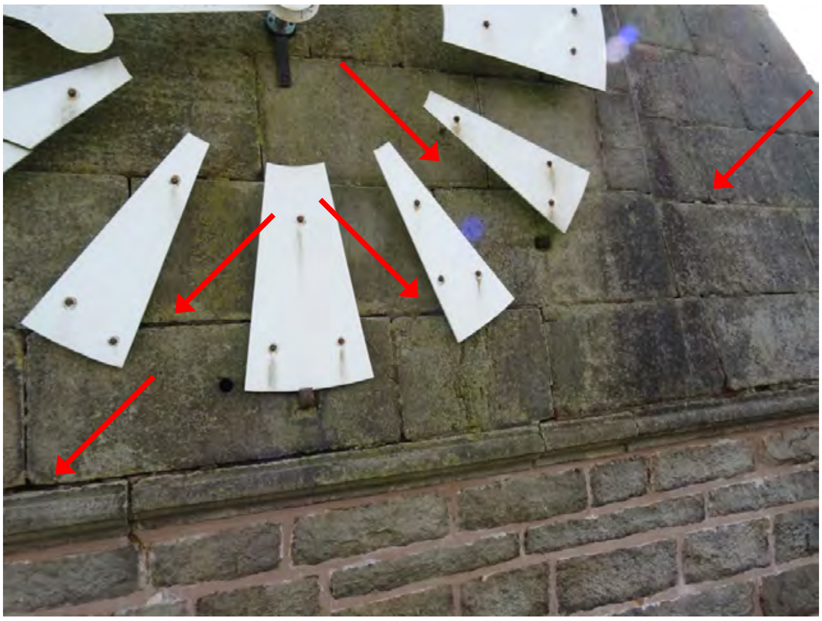


Fig 26:

West elevation; showing open and void mortar joints at lower level of the spire

Fig 27:

West elevation; showing water exuding at the base of window hood detail

Fig 28:

West elevation; showing general view of window tracery at high level of the tower

Fig 29:

West elevation; showing void detection at high level of the tower

Note; the saturated mortar clinging to the drill bit

Fig 30:

West elevation; showing void detection at high level of tower

Note; the saturated mortar clinging to the drill bit

Fig 31:

West elevation; showing void detection at high level of the tower

Note; the saturated mortar/soil compound clinging to the drill bit

Fig 32:

West elevation; showing where voiding and wet mortar where found at high level on the tower

Note; the saturated mortar/soil compound clinging to the drill bit

Fig 33:

West elevation,; showing mid level of tower

Note; the degraded and washed-out mortar repointing of works carried out in 2017

Fig 34:

West elevation; showing mid level of tower

Note; the degraded and washed-out NHL mortar repointing of works carried out in 2017

Fig 35:

West elevation; showing void detection at lower level of the tower

Note; the saturated mortar clinging to drill bit

Fig 36:

West elevation; showing void detection at lower level of the tower

Note; the saturated mortar clinging to drill bit

Fig 37:

South elevation; showing a general view of the spire

Fig 38:

South elevation; showing open and void mortar joints at the broach of the spire

Fig 39:

South elevation; showing open/void mortar joints at base of spire

Fig 40:

South elevation; showing general view of the uppermost window head detail

Fig 41:

South elevation; showing general view of the window head at high level of the tower

Fig 42:

South elevation, upper level of the tower; showing degraded re-pointing and saturated mortar/soil compound clinging to drill bit

Note the lime exudate on the face of the stone; where water (thought to emanate from the spire masonry core) has percolated downwards

Fig 43:

South elevation; showing void detection at mid level of the tower

Note; degraded re-pointing and saturated mortar clinging to drill bit

Fig 44:

4th floor/spire; showing water freely penetrating the south-west aspect of the spire masonry during a period of driving rain

Fig 45:

4th floor (Clock Tower); showing algal growth on the internal wall of the spire

Fig 46:

4th floor (Clock Tower); showing algae on the internal wall of the spire

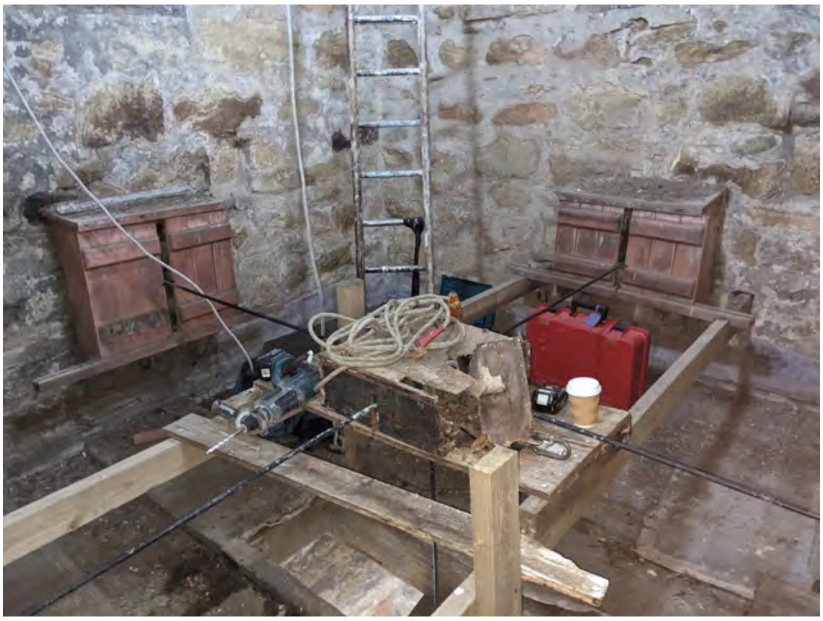


Fig 47:

4th floor (Clock Tower); showing lead covering to deck

Lead had been chased into the wall to form an upstand, with an overlapping flashing

Fig 48:

4th floor (Clock Tower); showing gutter formed in lead deck

Two channels had been formed on either side of the centre to drain water towards the north wall

Fig 49:

4th floor (Clock Tower); showing the outlet from the gutter. The outlet was only approximately 60mm in diameter

Both outlets and drainage channels were blocked by debris and bird detritus

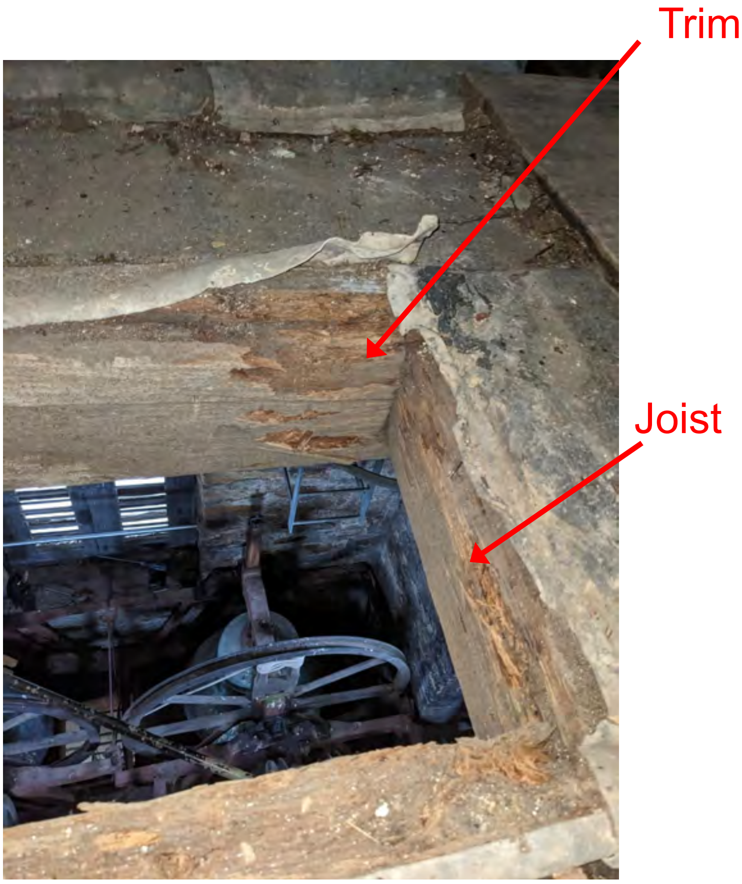


Fig 50:

4th floor (Clock Tower); showing opening in floor deck

The joists and trimmer joists around the opening were wet and structurally decayed by wet rot. Water penetration was occurring from the leaking spire above

Fig 51:

4th floor (Clock Tower); showing mortar sampling for gravimetric testing

Fig 52:

4th floor (Clock Tower); showing mortar sampling for gravimetric testing

Note saturated mortar clinging to the drill bit

Fig 53:

3rd floor (Belfry): showing 4th floor structure

The floor was softwood joists and floorboards. Although joists had originally been supported in the wall; the ends had been trimmed and joists were now supported by steel beams

Fig 54:

3rd floor (Belfry): showing 4th floor structure

Note the area of decay and damp staining to the floorboards, which indicates that water penetration is occurring

Fig 55:

3rd floor (Belfry); showing 4th floor structure steel support

Steel has been added in response to decay in the bearing end of joists. Steels beams were supported on a steel post bolted to the wall

Fig 56:

3rd floor (Belfry); showing 4th floor; showing a former masonry pocket where joists had previously been embedded

Joist bearing ends had been trimmed and timber was no longer in contact with potentially damp masonry

Fig 57:

3rd floor (Belfry); showing opening in 4th floor from below

Fig 58:

3rd floor (Belfry); showing a general view of the bells and bell frame

Fig 59:

3rd floor (Belfry); showing arrangement of bell frame and floor deck

Bells were supported on a steel frame which was supported on a brick plinth

Fig 60:

3rd floor (Belfry); showing example of superficial corrosion to the bell frame

Fig 61:

3rd floor; showing the sound-dampening void between the 4th floor deck and the 3rd floor ceiling

Note: possible asbestos containing material. Inspection or disturbance of this void was not undertaken

Fig 62:

3rd floor; showing the sound-dampening void between the 4th floor deck and the 3rd floor ceiling

Boards had been laid across the lower flange of the steels

Fig 63:

3rd floor, sound-dampening void; showing the floor deck bearing onto the bottom flange of the steel beam

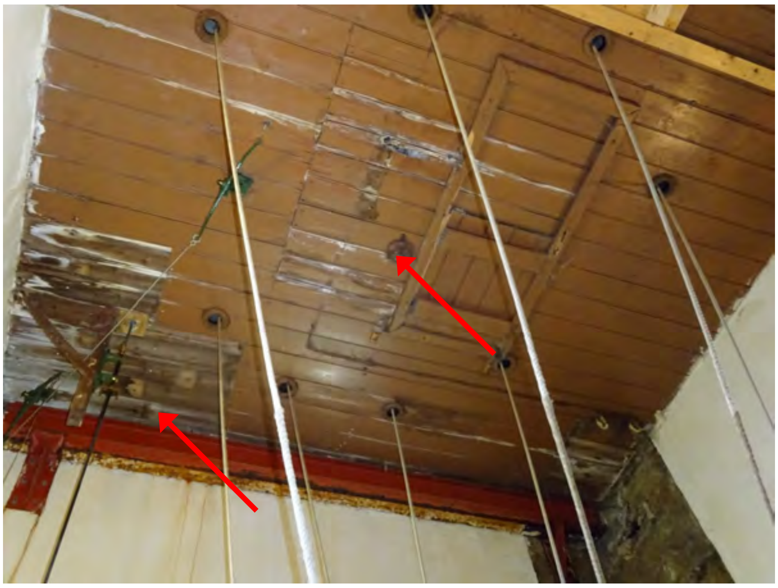


Fig 64:

2nd floor (Ringing Chamber); showing 2nd floor tongue and groove ceiling, which prevented detailed inspection of the floor structure

Water penetration was occurring at the centre of the floor and along the west wall

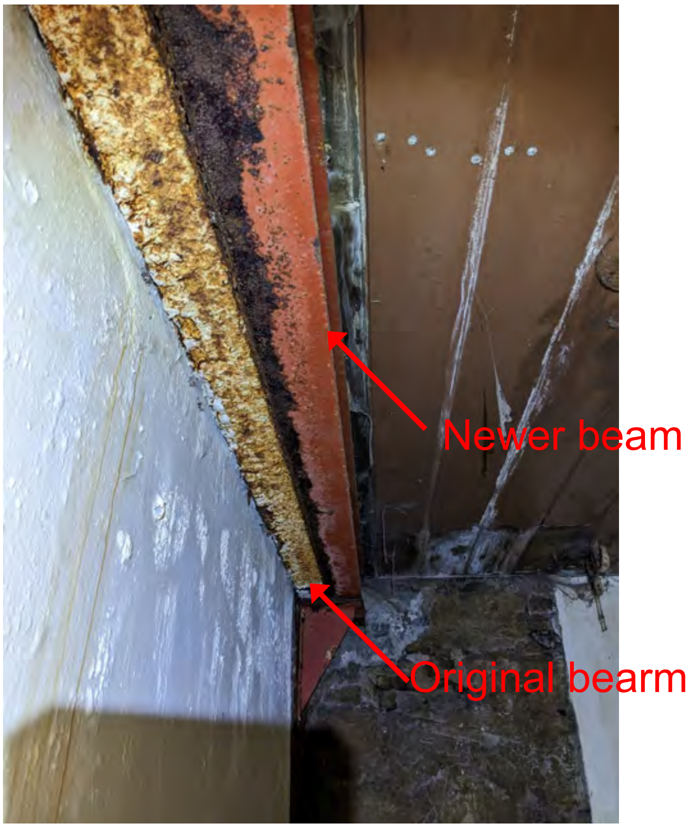


Fig 65:

2nd floor (Ringing Chamber); showing steel beams supporting structure above

Fig 66:

2nd floor (Ringing Chamber); showing steel beams and a close-up of the corrosion to the steels

Steel beams should be further assessed

Fig 67:

2nd floor (Ringing Chamber); showing steel bracket supporting steel beams above

Note corrosion of bracket

The steel brackets should be further investigated

Fig 68:

2nd floor (Ringing Chamber); showing remnants of a wet rot fungus on wall where timber plaque was previously hung

Fig 69:

2nd floor (Ringing Chamber); showing algal growth and area where plaster had failed

Fig 70:

2nd floor (Ringing Chamber); showing the build up of cementitious plaster

The water-resistant plaster was approx. 35mm in depth

Fig 71:

1st floor (Organ Blower Room); showing 2nd floor structure

Floor was a softwood joists and floorboard structure retrospectively supported on steel beams

Fig 72:

1st floor (Organ Blower Room); showing 2nd floor structure and a more recent steel repair to the floor

This steel was the second time the joists had been re-supported. Joists had originally been re-supported in web of an overlying steel beam

Fig 73:

1st floor (Organ Blower Room), second floor structure; showing corrosion and expansion of the upper flange of the older steel beam

Fig 74:

1st floor (Organ Blower Room), second floor structure; showing an example of a horizontal fissure that has occurred in the top third of the joists

Fissure was a result of the expansion of the upper flange of the original steel beam

Fig 75:

2nd floor (Ringing chamber), north west corner; showing an example of a second floor joist decayed by wet rot

Fig 76:

1st floor (Organ Blower Room); showing algae growth on the walls

Fig 77:

1st floor (Organ Blower Room); showing lime-based plaster base coat and finishing coats

Plaster had failed in a number of locations and masonry was visible

Fig 78:

1st floor (Organ Blower Room); showing visibly wet timber floorboards on the west elevation

Fig 79:

1st floor (Organ Blower Room); showing floorboards decayed by wet rot on the west elevation

Fig 80:

Ground floor; showing 1st floor structure

Floor comprised softwood beam with softwood ‘mill board’ type tongue and groove boards

Fig 81:

Ground floor; showing 1st floor structure and an example of the masonry corbel that supported the beams

This was a repair and the beams had been trimmed and re-supported on corbel

This was most probably done in response to decay in the bearing end of the beams

Fig 82:

Ground floor; showing the primary timber beam along the east wall which has been cut

This appears to have been done to accommodate the pipework to the organ

Fig 83:

Ground floor; showing stone corbel which previously supported the end of the beam which has been cut

See also Fig 82 above

Fig 84:

Ground floor; showing decayed timber at the foot of the staircase

Fig 85:

Ground floor; showing wet rot decay of the landing timbers at the foot of the staircase

Staircase timbers in contact with west and south walls in this location are at continuing risk of decay

Fig 86:

Ground floor; showing lime-based mortar, plaster base coat and finishing coats bearing-up in spite of the persistent damp

Fig 87:

Ground floor; showing lime-based mortar, plaster base coat and finishing coats

Fig 88:

Ground floor; showing lime-based plaster base coat and finishing coats

Note pozzolan inclusions of coal/coal ash

Fig 89:

Ground floor, Nave; showing the opposite side of the south-east tower wall from inside the Nave

Note; the extent of the damp-related deterioration of the finishes correlating to the south-east corner of the tower

Fig 90:

Ground floor, Nave; showing the opposite side of the south-east tower wall from inside the main body of the church

Note; the extent of the damp-related deterioration of the finishes

Fig 91:

Ground floor, Nave; showing opposite side of the north-east tower wall from inside the main body of the church

Note; the lesser extent of damp-related deterioration of the finishes

Fig 92:

Interior of the spire during roped access survey

Fig 93:

Interior of the upper spire accessed by roped techniques

Fig 94:

Interior of the spire in the upper third of its height

Daylight is visible through a mortar joint in the single skin stonemasonry

Fig 95:

Interior of the spire

One of the uppermost window openings

Fig 96:

Spire interior

Location of a surface temperature measurement

Fig 97:

Spire interior

Surface temperature measurement at the location shown in Fig 96 above

Condensation was occurring at the time

Fig 98:

Ringing chamber

Location of a surface temperature measurement

Fig 99:

Ringing chamber

Condensation was not occurring at the time but the potential for condensation was high because at mid-day there was less than 3°C separation between surface temperatures and dew point

Fig 100:

Roped access being used to closely examine and test masonry joints

Fig 101:

The highest point surveyed by tactile examination

Above this point, the masonry of the spire had been rebuilt

Fig 102:

The highest point surveyed by tactile examination

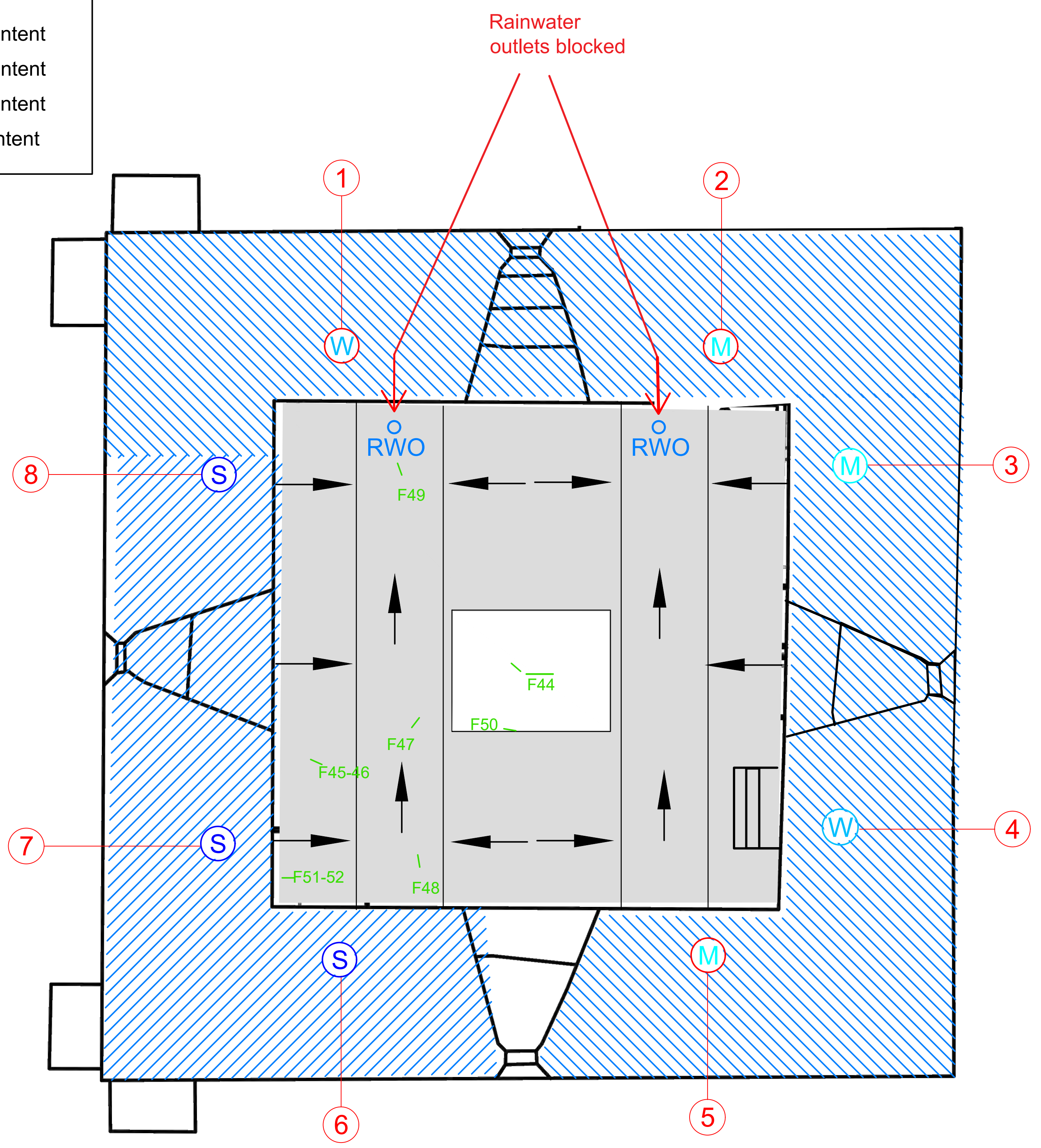
Appendix F

MASONRY SAMPLES TAKEN AT FOURTH FLOOR

①— Masonry sample location

	High salt content	Low salt content	
Dry	Ⓓ	Ⓓ	0-2% w/w available moisture content
Moist	Ⓜ	Ⓜ	2-5% w/w available moisture content
Wet	Ⓦ	Ⓦ	5-8% w/w available moisture content
Saturated	Ⓢ	Ⓢ	8+% w/w available moisture content

N



Typical construction:

The fourth floor deck has been covered with lead to act as a roof over the Belfry. Lead finishes have been laid to fall into two rainwater outlets. These rainwater outlets are dysfunctional and blocked

Key:

▨	Area subject to water penetration
RWO ○	Rainwater outlets
→	Lead covering - direction of fall
— F1	Approximate location of photograph
— F̅1̅	Photograph of underside of roof

H+R

St Thomas', Musbury - Tower, Fourth floor showing fourth floor lead finishes

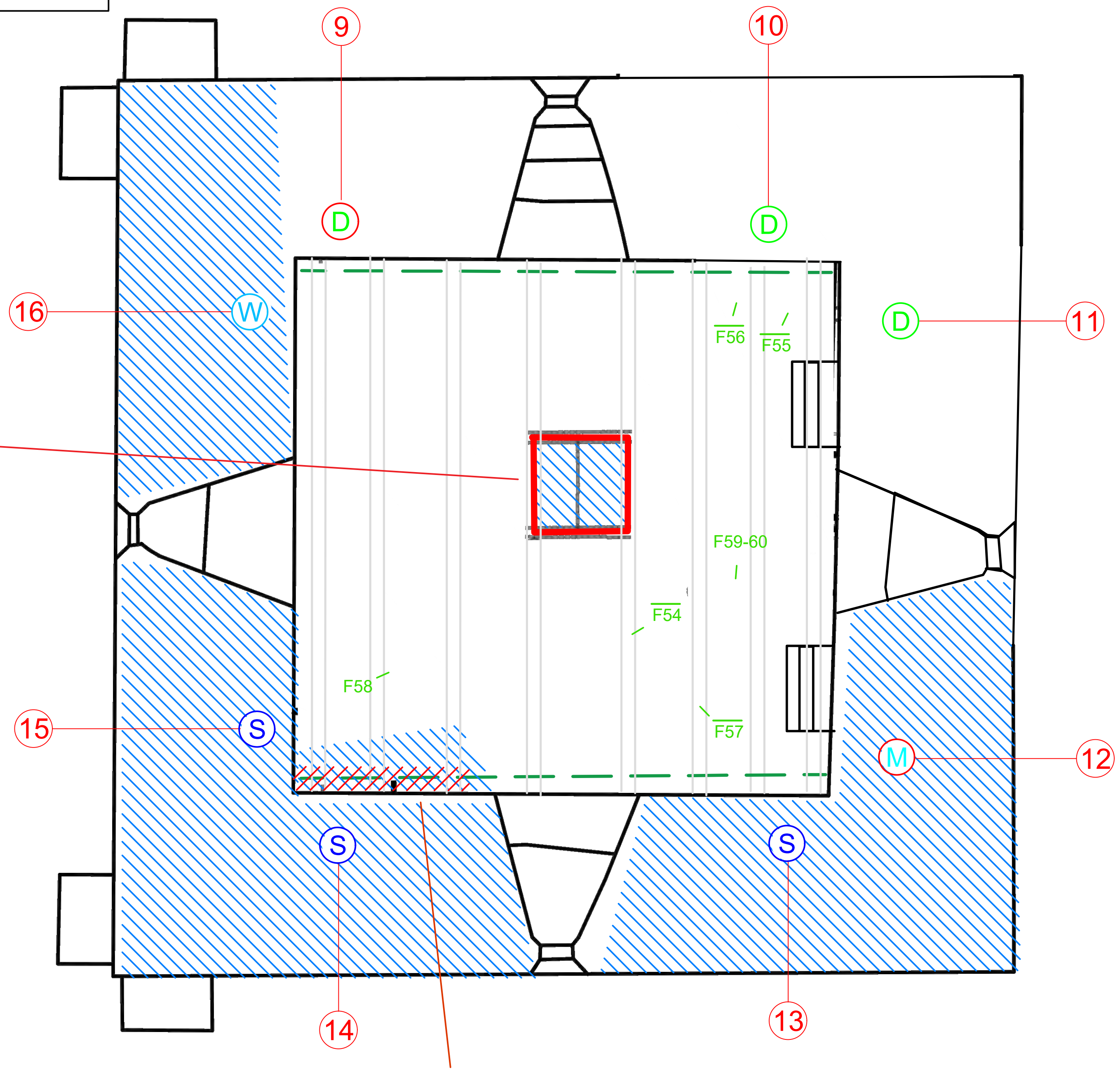
INVESTIGATION OF DAMP AND TIMBER DECAY

11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale- © Copyright Hutton+Rostron 2023

MASONRY SAMPLES TAKEN AT THIRD FLOOR

	High salt content	Low salt content	
	①		Masonry sample location
Dry	Ⓓ	Ⓓ	0-2% w/w available moisture content
Moist	Ⓜ	Ⓜ	2-5% w/w available moisture content
Wet	Ⓦ	Ⓦ	5-8% w/w available moisture content
Saturated	Ⓢ	Ⓢ	8+% w/w available moisture content



Principal and trimmer joists around opening structurally decayed by wet rot.

Appears to be historical decay. Allow for further inspection when floorboards are repaired

Typical construction:

Floor: softwood joists with tongue and groove floorboards supported on steel beams

Wall: stone, base seems to have been re-pointed/ mortar buttered

Bellframe: Cast iron bellframe, which is supported by steel beams which in turn are supported by the masonry

Note:
Access was restricted by the bells and the bellframe

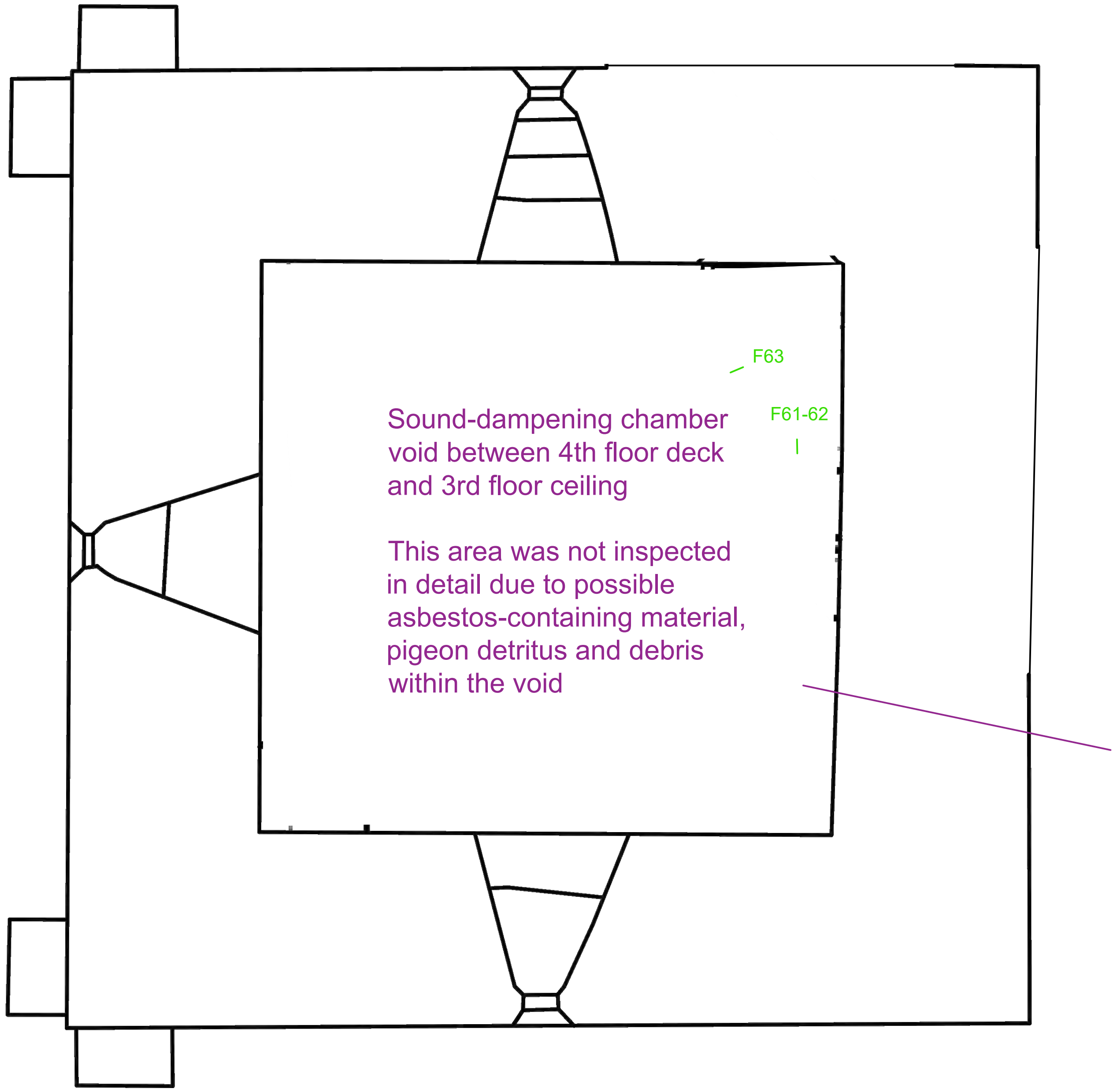
Key:

▬	Structurally decayed timber element
— —	Steel beam supporting joists
▧	Area subject to water penetration
▨	Area subject to timber decay
— F1	Approximate location of photograph
— F1	Photograph of underside of floor

St Thomas', Musbury - Tower, Third floor showing fourth floor structure
INVESTIGATION OF DAMP AND TIMBER DECAY
11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-

N



Sound-dampening chamber void between 4th floor deck and 3rd floor ceiling

This area was not inspected in detail due to possible asbestos-containing material, pigeon detritus and debris within the void

Key:

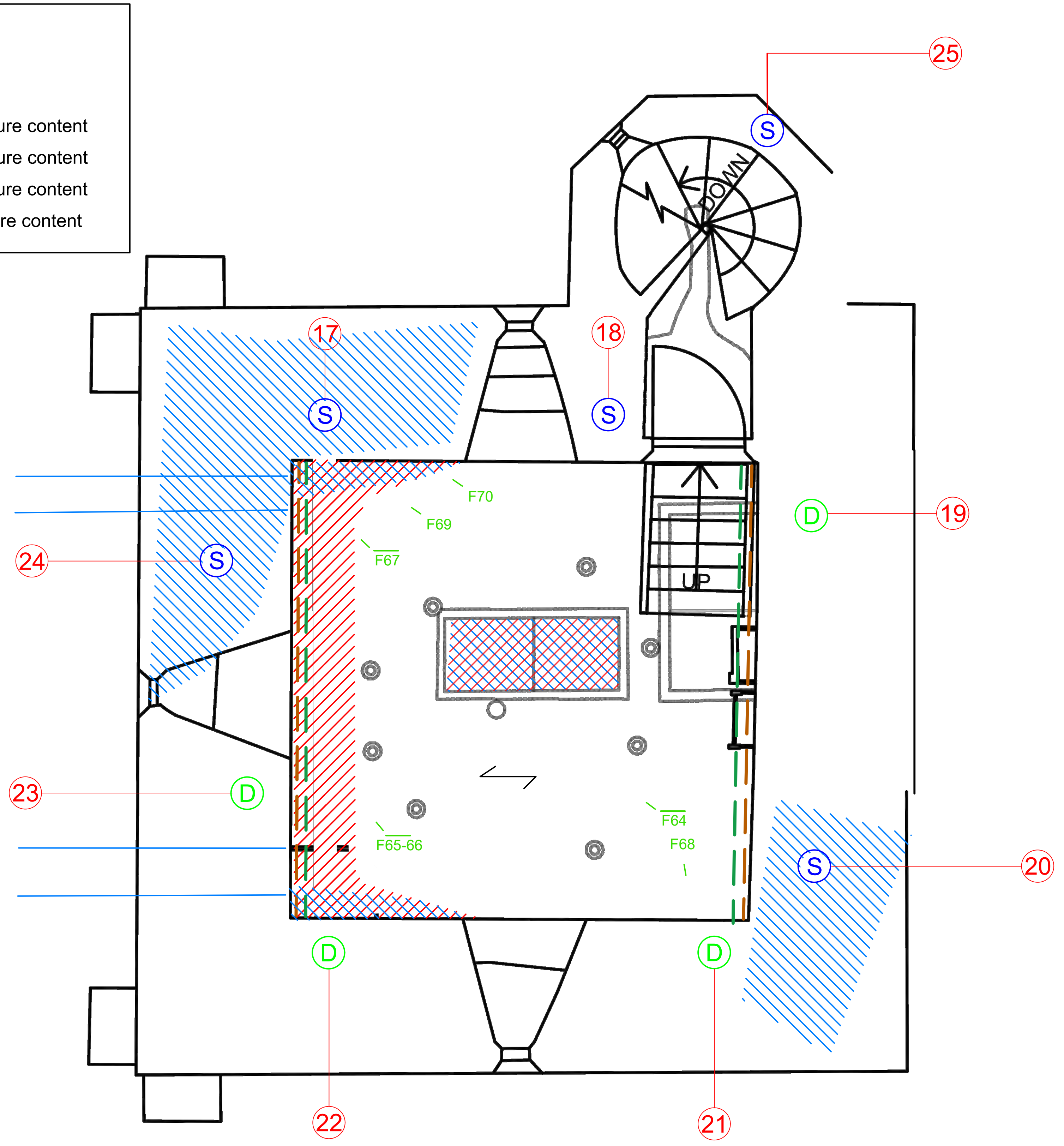
— F1	Approximate location of photograph
— $\overline{\text{F1}}$	Photograph of underside of floor

St Thomas', Musbury - Tower, Third floor damping chamber
INVESTIGATION OF DAMP AND TIMBER DECAY
11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale- © Copyright Hutton+Rostron 2023

MASONRY SAMPLES TAKEN AT SECOND FLOOR

	High salt content	Low salt content	
	①		Masonry sample location
Dry	Ⓓ	Ⓓ	0-2% w/w available moisture content
Moist	Ⓜ	Ⓜ	2-5% w/w available moisture content
Wet	Ⓦ	Ⓦ	5-8% w/w available moisture content
Saturated	Ⓢ	Ⓢ	8+% w/w available moisture content



Typical construction:

Floor: softwood joists with tongue and groove floorboards supported on steel beams

Ceiling: tongue and groove ceiling boards fixed directly to joists (concealing most of structure above)

Walls: stone, cementitous plaster. Areas of wall had been patched up with a gypsum plaster

H+R

St Thomas', Musbury - Tower, Second floor showing third floor structure

INVESTIGATION OF DAMP AND TIMBER DECAY

11-13 April 2023

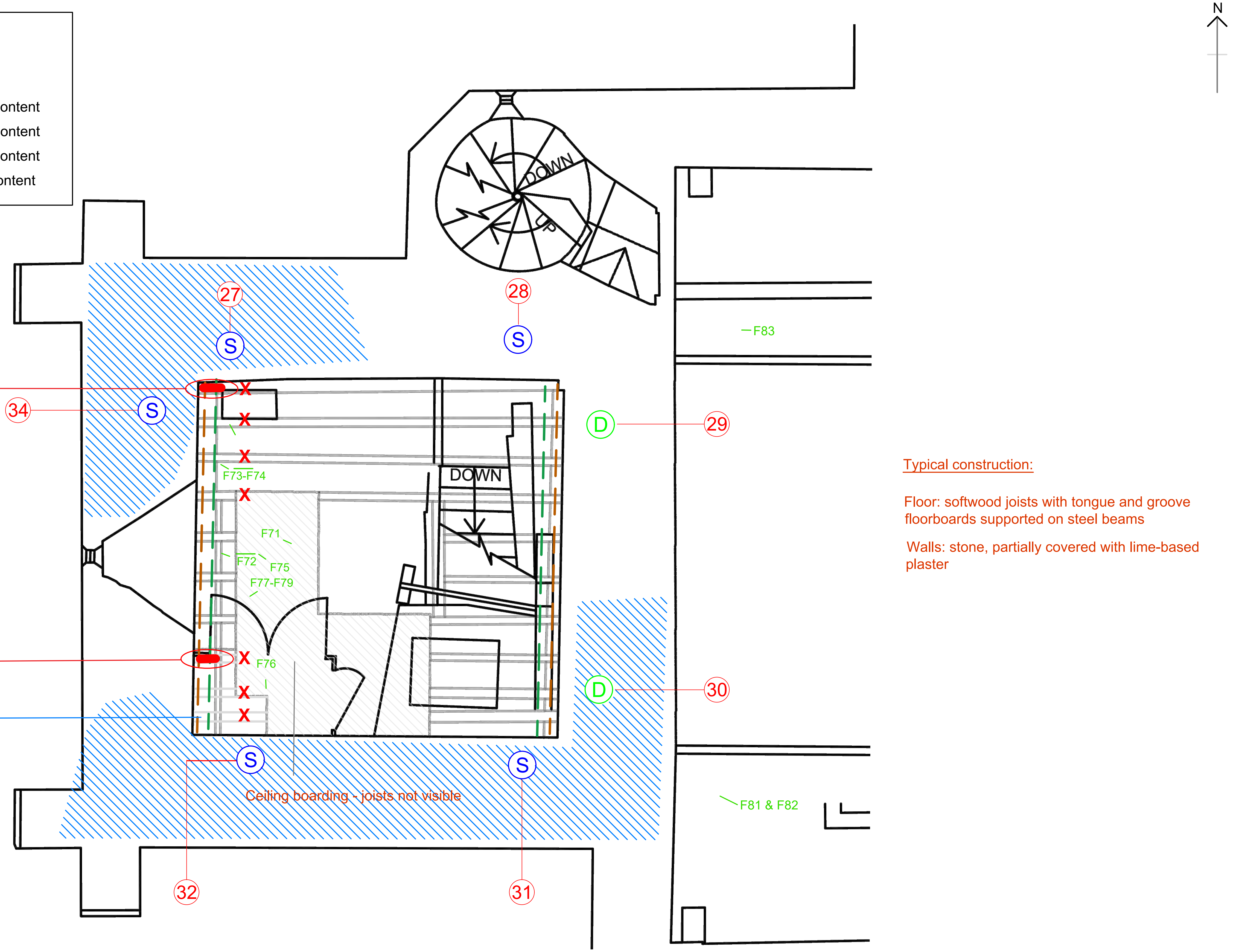
Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale- © Copyright Hutton+Rostron 2023

Key:

▨	Area subject to water penetration
▨	Area subject to timber decay
⇜	Span direction of joists
— —	Old corroded steel beam supporting joist
— —	Newer, less corroded steel beam supporting joists
— F1	Approximate location of photograph
— F1	Photograph of underside of floor

MASONRY SAMPLES TAKEN AT FIRST FLOOR

	① High salt content	Low salt content	Masonry sample location
Dry	Ⓓ	Ⓓ	0-2% w/w available moisture content
Moist	Ⓜ	Ⓜ	2-5% w/w available moisture content
Wet	Ⓦ	Ⓦ	5-8% w/w available moisture content
Saturated	Ⓢ	Ⓢ	8+% w/w available moisture content



Decay to top of joist 140 x 200mm from bearing end
Deep moisture content of bearing end 40% w/w

Decay to 220mm from bearing end
Deep moisture content of bearing end 20% w/w

Deep moisture content of bearing end 20% w/w

Typical construction:

Floor: softwood joists with tongue and groove floorboards supported on steel beams

Walls: stone, partially covered with lime-based plaster

St Thomas', Musbury - Tower, First floor showing second floor structure

INVESTIGATION OF DAMP AND TIMBER DECAY

11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-

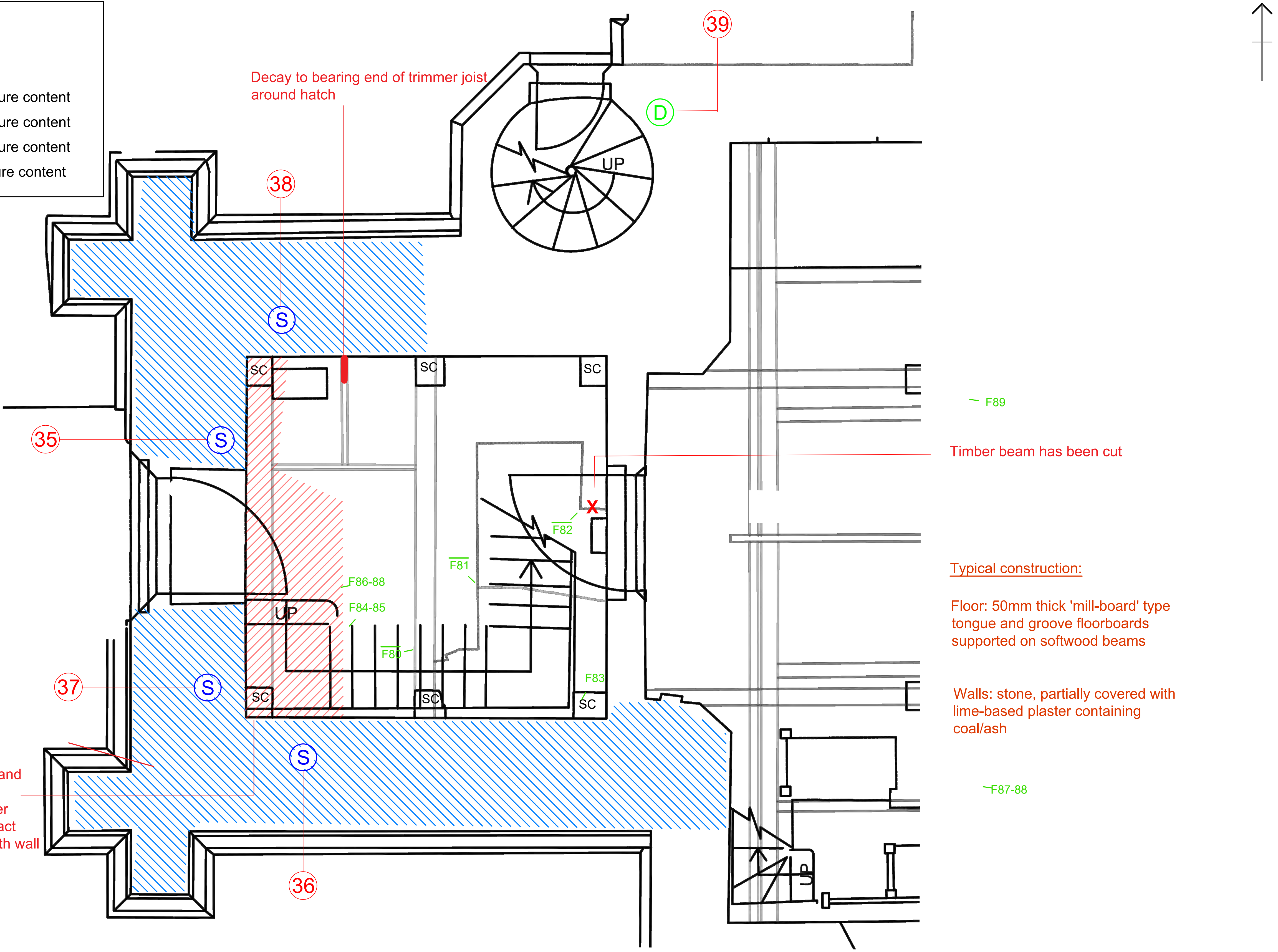
Key:

⬭	Structurally decayed timber element
X	Joist end split where notched over flange of corroded beam
— —	Older corroded steel beam supporting joists
— —	Newer galvanised steel beam supporting joists
— F1	Approximate location of photograph
— F1	Photograph of underside of floor

MASONRY SAMPLES TAKEN AT GROUND FLOOR

①— Masonry sample location

	High salt content	Low salt content	
Dry	D	D	0-2% w/w available moisture content
Moist	M	M	2-5% w/w available moisture content
Wet	W	W	5-8% w/w available moisture content
Saturated	S	S	8+% w/w available moisture content



Decay to bearing end of trimmer joist around hatch

Timber beam has been cut

Typical construction:

Floor: 50mm thick 'mill-board' type tongue and groove floorboards supported on softwood beams

Walls: stone, partially covered with lime-based plaster containing coal/ash

Decay by wet rot to floor joists and floorboards of staircase bottom landing. Decay probably in other staircase timbers in direct contact with damp masonry on the south wall

H+R

St Thomas', Musbury - Tower, Ground floor showing first floor structure

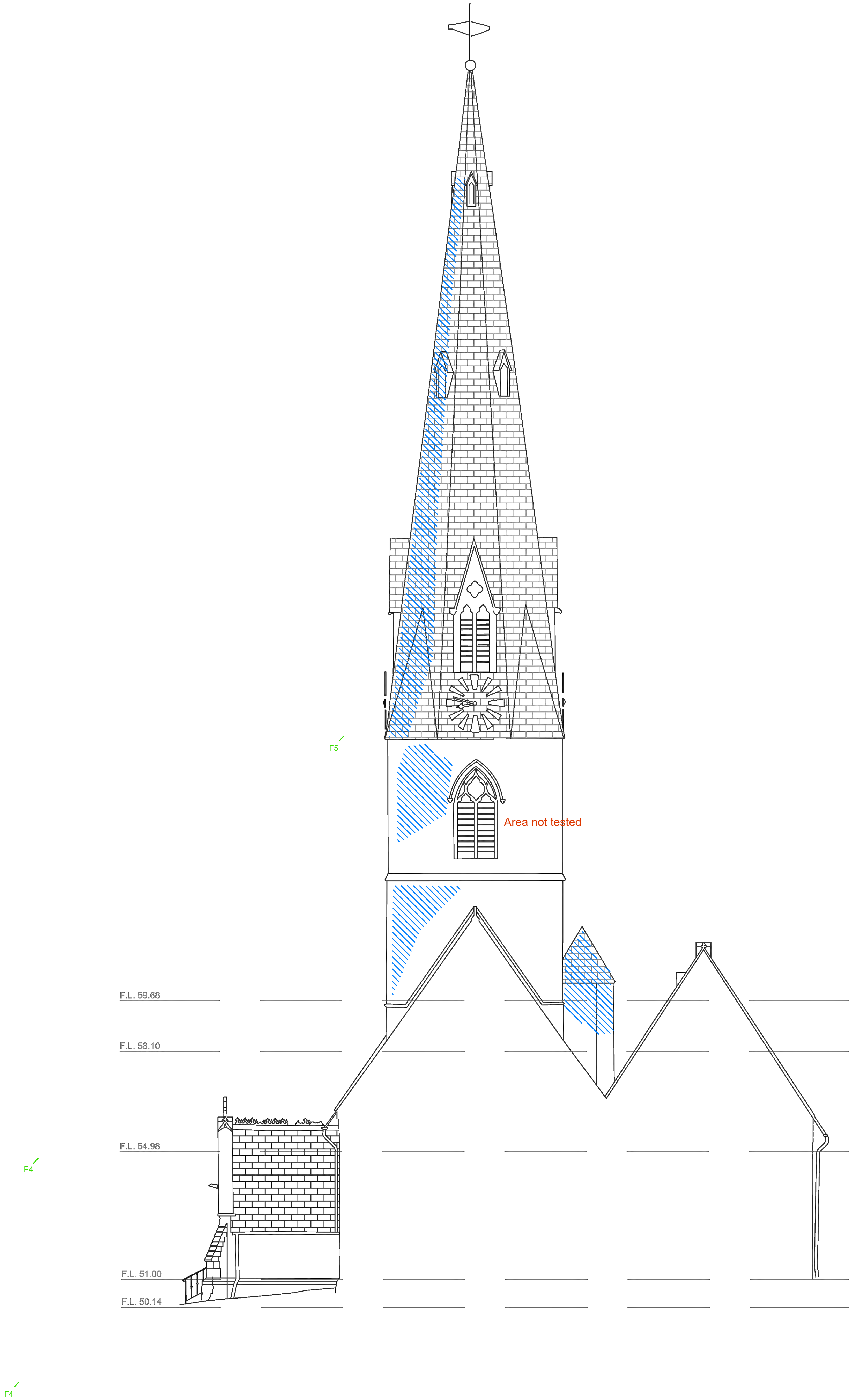
INVESTIGATION OF DAMP AND TIMBER DECAY

11-13 April 2023

Key:

X	Structurally damaged element
////	Area of floorboard decayed by wet rot
—	Structurally decayed timber element
SC	Stone corbel
— F1	Approximate location of photograph
— F1	Photograph of underside of floor

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-



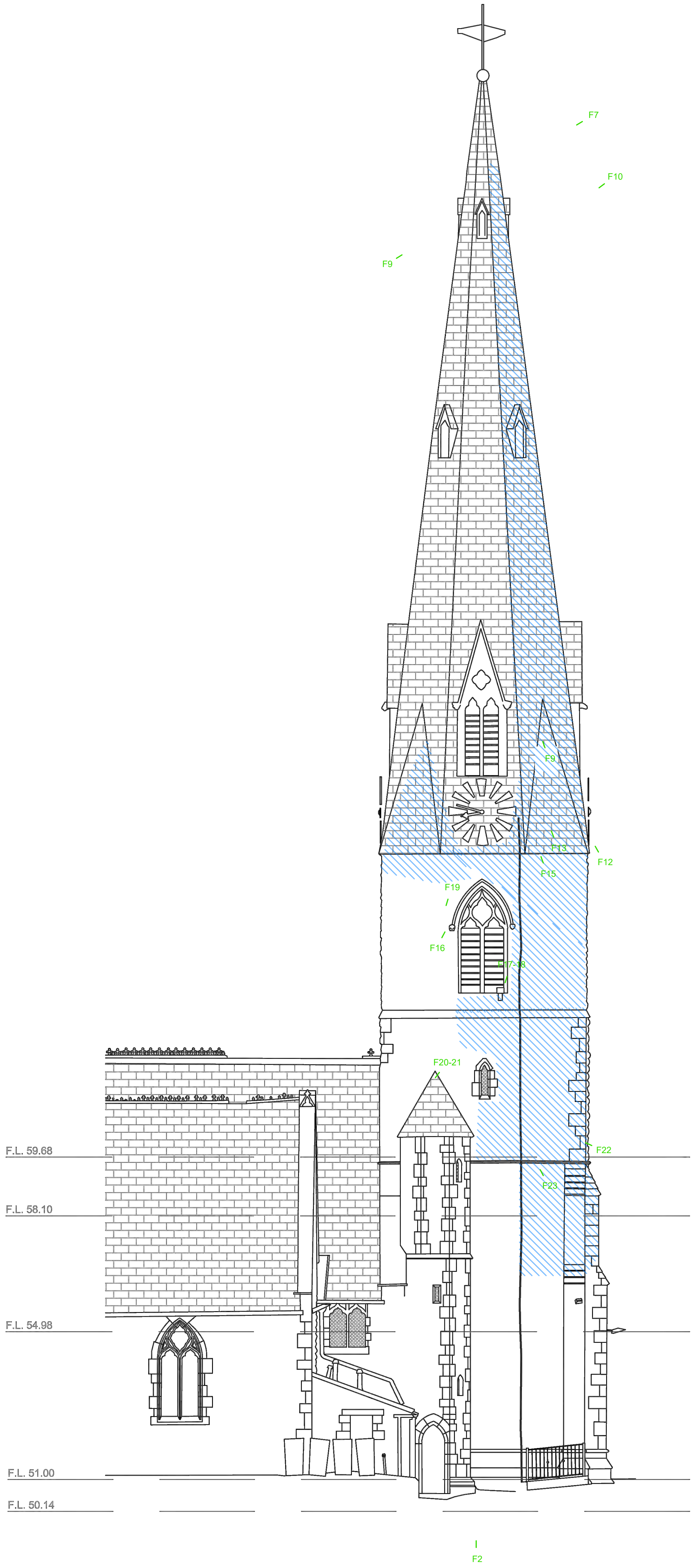
Key:

▨ Area of interstitial masonry voids and high masonry moisture content

— F1 Approximate location of photograph

St Thomas', Musbury- East elevation
INVESTIGATION OF DAMP AND TIMBER DECAY
11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-



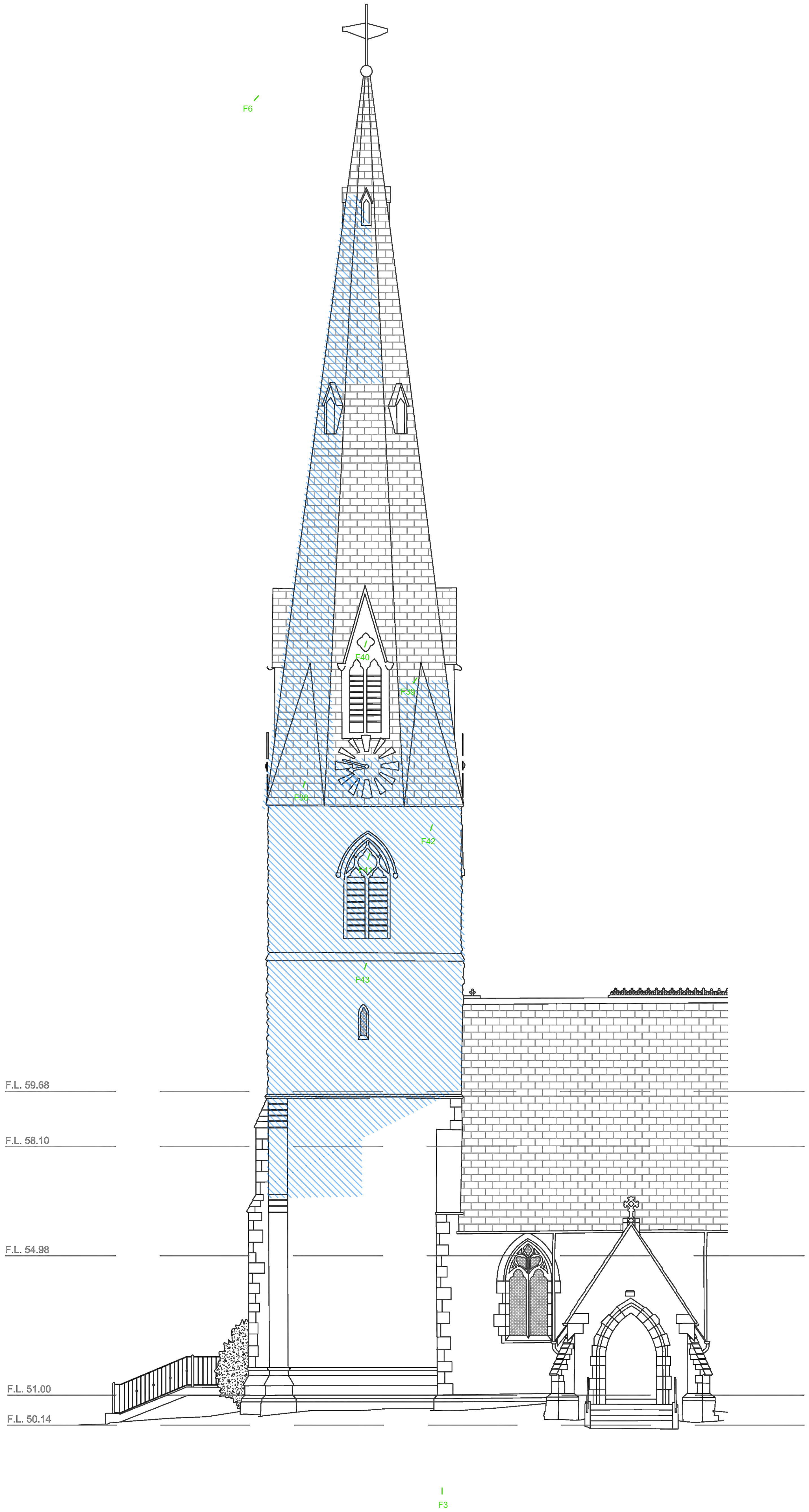
Key: ▨ Area of interstitial masonry voids and high masonry moisture content

— F1 Approximate location of photograph

St Thomas', Musbury- North elevation

INVESTIGATION OF DAMP AND TIMBER DECAY
11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-



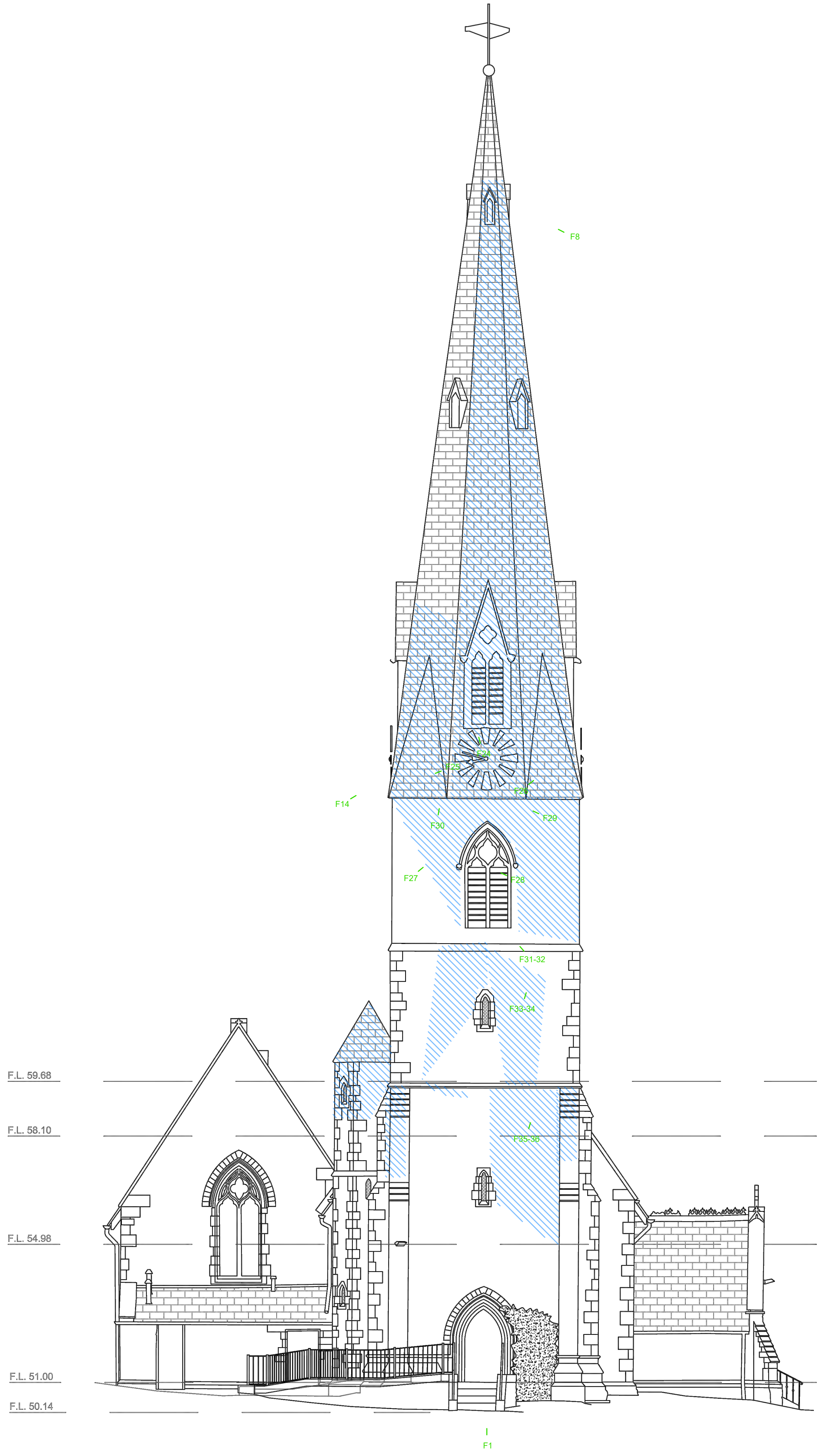
Key: ▨ Area of interstitial masonry voids and high masonry moisture content

— F1 Approximate location of photograph

H+R

St Thomas', Musbury- South elevation
INVESTIGATION OF DAMP AND TIMBER DECAY
11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-



Key: ▨ Area of interstitial masonry voids and high masonry moisture content

— F1 Approximate location of photograph

St Thomas', Musbury- West elevation
INVESTIGATION OF DAMP AND TIMBER DECAY
11-13 April 2023

Hutton + Rostron Environmental Investigations Ltd
Netley House, Gomshall, Surrey, GU5 9QA Tel: 01483 203221
213-66 Report -Not to scale-

Appendix G

TABLE OF MATERIAL MOISTURE CONTENTS **Appendix G**

Samples of masonry by drilling into the fabric and collecting the dust. The masonry samples were placed in sealed containers and tested at the H+R laboratory in accordance with the procedure for gravimetric measurement of moisture content as described in the appendix to BRE Digest 245. The results of which are set out on the Plans at Appendix F and in the table beneath

Notes on the table

Where the 'available moisture content' of the sample is higher than the 'hygroscopic moisture content', there is excess water and a 'damp' condition exists

For ease of interpretation, we have characterised 'damp' materials into:

M=Moist	(2-5% available moisture content)
W=Wet	(5-8% available moisture content)
S=Saturated	(8+% available moisture content)

Dry materials are characterised as:

D=Dry	(0-2% available moisture content)

Hygroscopic moisture content is the moisture content of the sample equilibrated with an atmosphere of 75 per cent relative humidity. This is moisture associated with the surface of a porous material by adhesion of water molecules from water vapour

H = Hygroscopic indicates a relatively high degree of hygroscopicity and can be attributable to salt contamination

Sample ID/Location	**Moisture content % w/w**			**Hygroscopic moisture content % w/w**	**Available moisture content % w/w**
1	8.74	W	H	2.14	6.61
2	5.80	M	H	2.50	3.30
3	3.84	M		0.93	2.92
4	7.34	W		0.48	6.86
5	5.29	M	H	2.12	3.17
6	18.48	S	H	2.35	16.13
7	12.59	S		1.58	11.01
8	18.68	S		1.45	17.23
9	4.52	D	H	2.77	1.75
10	3.28	D		2.00	1.28
11	3.19	D		1.46	1.73
12	5.82	M	H	2.23	3.59
13	12.18	S		1.19	10.98
14	12.61	S		1.85	10.76

15	17.64	S		0.89	16.74
16	7.60	W		1.52	6.08
17	13.84	S		1.10	12.73
18	12.56	S		1.26	11.30
19	1.11	D		0.39	0.72
20	12.66	S		0.39	12.27
21	2.09	D		0.81	1.28
22	0.26	D		0.29	-0.03
23	0.41	D		0.63	-0.22
24	15.93	S		0.83	15.10
25	13.16	S		0.72	12.44
27	17.25	S		0.80	16.45
28	12.69	S		0.58	12.11
29	0.13	D		0.14	-0.01
30	3.13	D		1.44	1.69
31	13.36	S		0.73	12.63
32	18.23	S		0.74	17.50
34	17.25	S		0.79	16.45
35	13.62	S		0.67	12.94
36	14.87	S		0.63	14.24
37	18.11	S		0.81	17.31
38	12.62	S		0.57	12.05
39	1.92	D		0.94	0.98