Building and Collection Survey

Leicestershire Church

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1. Aims and Objectives

The aim of this report is to present recently gathered data on the current internal and external environment and condition of the church and the collection it houses, and to assess the efficiency of the building in providing a suitable environment for that collection.

A brief history of the building and its collection is presented to give an understanding of its historical and local significance. The condition of the collection is reviewed with consideration given to damage that has likely occurred as a result of the internal environment. The condition of the building fabric is assessed with consideration given to the effect of the external environment on its material and the internal climate that this in turn creates. The external and internal climate of the building and its effect on the collection are presented followed by an assessment of the risks and vulnerabilities present to the collection in the building.

Finally recommendations for practical and manageable alterations that can be pursued to affect the internal climate are made to provide more sustainable conditions for the objects of the collection.

2. The Building : History and Context

Figure 1 –

The Church is situated in the village of ……, four and a half miles north west of ……. The village was first recorded in the Domesday Book in 1086 as ….. and the church is believed to have been built about 1190. (Gregory, 2012) It was probably 'smaller then but already had the bellcote'. It is built of local sandstone with limestone dressings, most likely quarried from the former village stonepit in the lowest point of the church field. (W. 2005 p4) It is recorded as 'impressive and important' by Pevsner, who states that 'its importance lies in the S. arcade....In the arches a great deal of original ornamental painting in red with a variety of motifs.' (Pevsner, 2001, p419).

It is probable that the entirety of the internal walls of the church would have been plastered and painted originally, but all plaster has since been removed from the walls most likely during renovations in 1867-8 when 'the church was re-roofed and 'the walls cleared' (W. 2005 P7). This was common practice at this time as 'learned architects and historians were developing views that held that painted decoration was not part of the original appearance of medieval buildings' and this led to 'a fetish of Victorian and later restorers for stripping plaster from the walls to show the beautiful stonework – which was not meant to be seen' (Budge, 2018, p2).

3. The Building : Collection

The collection of the church is a mixed media, ecclesiastical Collection whose importance in many cases is literally tied to the building and its location. The main items of historical significance within the collection are the medieval wall paintings and the 15^{thC} wooden pews. There are many items of local significance that were donated or commemorate donations and contributions by members of the local community such as the altar, pews, organ, lectern, and memorial plaques. The remainder of the collection consists of other working items that are part of the church activity. A brief condition report was carried out using the Suzanne Keene survey format (Table 1).

Material	Objects	Condition
Wall Painting	Medieval wall painting - directly on stone.	2
Wood	C15th pews, 19th and 20th C pews, lecterns, wall mounted memorial boards (2no.), wall mounted bell brace, alter, hymn board, candlestick, bookshelf, wooden paneling	2
Metal	C19th brass monument, candlesticks, crucifix, service regalia	2
Stone	Wall mounted memorial plaques (5no.) floor memorial stones, font, carved capitols, historic graffitti, witch marks (?)	2
Paper	Bible, prayer books, visitor book, framed print (with handblown glass, air bubbles : late 1800 - early 1900's?)	3
Textile	Alter cloth, cushions, gallery curtain	2
Other	Organ, Stained glass windows, plain glass windows (varied colour shades of clear glass) quarried tiles	2
Notes		
Wall Painting	Spalling of stonework in arch above wall painting worrying. Area where paint appears eaten away/ preferential flaking. More vibrant paint on north face of arcade where out of direct sunlight.	
Wood	Wall mounted wooden memorial plaque is cracked - possibly result of direct contact with wall	
	C15th pews show considerable woodworm damage, but no apparent recent activity. Monitoring required. Are positioned next to damp floor and walls and directly across from south facing window	
Stone	Stone memorial plaques fixed to the wall with cement, could possibly cause future damage.	
	Carved capitol and witch marks in belfry in danger of loss of detail from spalling and biological damage from mould	
Paper	Bible shows yellowing of pages, active mould, fading of leather, spine cracked and loose, binding loose.	
Textile	Embroidered kneelers stored on benches, while leather kneelers on the floor and more prone to moisture damage from	
Other	Crack in pane of stained glass. Possibly damaged came causing water ingress. Condensation common internally.	
	Irrisdescence evident on plain glass quarries, build up of accretions on exterior. Condensation common internally.	
	Victorian quarried tiles showing staining and tide marks from continual salt efflorescence.	

Table 1 Collection condition survey

Figure 2 – Preferential flaking of paint on medieval wall painting

The medieval wall painting is only present on the dressed stone of the south arcade arches. The decoration is painted in shades of red and black, and the black appears to be a more fragile pigment than the red. The black fades more than the red, in some places barely visible as a very pale grey, while in other areas it has preferentially stripped away "leaving the formerly black painted areas as patches of yellow stone showing the basic form the decoration against the white ground of the surrounding whitewash" (Fig.2)(Budge 2018 P38).

The paint itself appears to be stable, however there is an ongoing damp problem along the west of the arcade that is resulting in the spalling of the ironstone which if it continues to spread will result in the crumbling away of the stone substrate beneath the paint. (See Section 5.b.2 for more). The paint on the north side of the arcade is more vibrant and less faded than that on the south facing indicating that repeated exposure to the sunlight and UV damage has taken its toll over the years. (See 5.b.1)

The paper and leather objects of the collection, particularly the leather bound 19^{thC} bible on the lectern are displaying mould growth on the pages and textile bindings while the leather binding is suffering from mechanical damage from repeated use, brittleness and cracking resulting in loss of some of the spine, as well as fraying and red rot at the headband (Fig.3)(Fig4). This is likely a result of the high RH of the building as well as its storage location on the lectern in front of the south facing windows. (Vandyke-Lee 1979) (5.b.2).

Most of the wooden objects of the collection are all in tolerably good condition considering the high relative humidity (RH) and damp problems within the building. There is past woodworm damage to the 15^{thC} pews but they are not displaying any current signs of activity. The timber items mounted directly against the west wall do not have a barrier layer between the stone and the objects and have cracked along stress points in places as a result of repeated fluctuations in moisture content (Fig.5) (Ankersmit 2009 P55).

Figure 3 – Mould growth on bible

Figure 4 – Damage to leather binding

The textiles of the collection are in surprisingly good condition considering the high RH and the mould growth found in the paper collection. They are however working objects within the collection and most likely items such as the altar cloth and vestry curtain are rotated and removed for cleaning by local volunteers on a regular basis. The embroidered kneelers are stored at the back of the pews and as such are afforded some protection from light and moisture damage (Fig.6).

Figure 5 – Crack to wall mounted timber

Figure 6 – Storage of embroidered kneelers

4. The Building : Condition

4.a. External Condition

4.a.1 Walls

Overall the external walls of the church are in good structural condition, they are sound, and show no obvious structural damage or movement.

The walls are of ironstone, with dressed limestone window openings, cornerstones and copings. The ironstone is severely weathered and spalling from moisture movement and there are areas of obvious stone repair and replacement (Fig.7). Areas of very extreme spalling are obvious around the belfry, which is believed to be the oldest part of the exterior surviving (W. 2005).

A white efflorescence can be seen in many areas around the exterior, caused by the evaporation of moisture from the stone (Fig.8). As moisture evaporates it causes crystallised salt deposits to be left behind. In cases where the rate of evaporation of the moisture is higher than the supply of moisture, as in the case where there is wind on the exterior of a building, this evaporation will take place beneath the surface of the stone instead of on the surface. The formation of these salt crystals as they dry will cause an increase in volume which results in the crumbling, cracking and spalling of stone. (Ankersmit 2017 p101). Areas where this efflorescence is more abundant on the building include the west walls and belfry, as well as the eastern buttress at the back of the building.

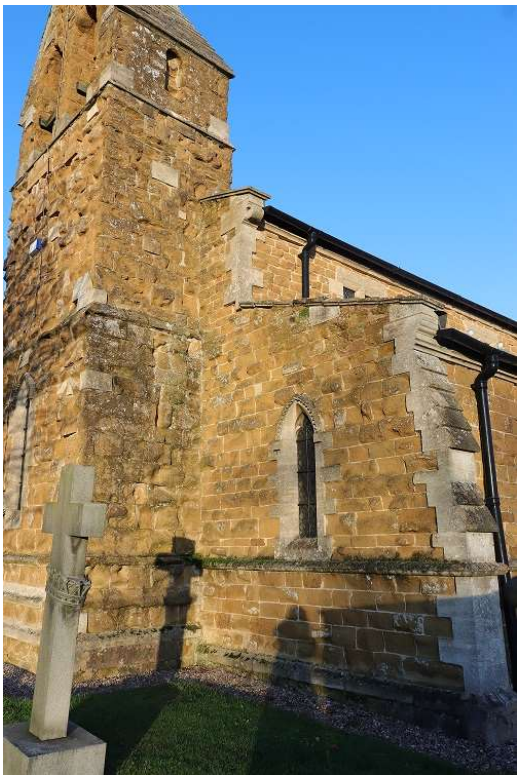


Figure 7 – Spalling to west wall

Figure 8 – Efflorescence causing spalling on north wall

Along the protruding drip course on the west and east of the building there is vibrant moss and lichen growth (Fig.9). This keeps moisture on the surface of the stone, which can cause frost damage through causing spalling and cracking of the stone when the volume of water expands when freezing. Damage from secretion of organic acids is also likely (Watt 2006) (Watt 2004).

Figure 9 – Moss growth on drip course of west wall

Moss growth can be seen just beneath the coping stones of the western wall indicating a regular presence of moisture to these locations (Fig.10). There is missing mortar between the coping stones above the window, as well as between the belfry wall and the western wall and between the copings stones themselves on the north side (Fig.11). These allow easy access for rainwater to soak directly into the walls of the building. Internally there is evidence of previous water drips from above the window (see section 4.b.1).

Figure 10 – Moss growth and gap in mortar of coping on west wall

Figure 11 – Gap between coping and belfry

4.a.2 Roof

It was only possible to make a visual inspection of the roof from ground level. The roof of the nave, the south aisle and the porch are clad in lead, while the chancel and belfry are slated. In recent years there has been considerable work undertaken to the lead roofs to discover pinhole leaks in the lead flashing, evidence of the damage can be seen internally where white mould has bloomed in the effected roof rafters. (W. 2005, p14). Internally there is considerable evidence of water dripping from above on metal items; organ pipes, memorial brass plaques and the brass monument, while there are discoloured areas of dripping on the west wall. It is unclear whether the majority of these occurred before the roof repair or more recently (Fig.12 & 13).

Figure 12 – Drip marks on organ pipes

Figure 13 – Drip marks on west wall

On the last visit to the building there was fresh dashed droplets of water from above obvious on the glass of the framed print inside the door. There was a dark patch, as well as white mould between the boards on the interior ceiling which may indicate a new pinhole leak to the south aisle lead roof. There had been rain the previous evening (Fig.14) (Fig.15).

Figure 14 – Darkening between ceiling timbers

Figure 15 – Droplets of water on glass

There appears to be either a missing or possibly shattered slate on the south side of the belfry roof, unaided visual inspection from ground level was not very clear. Beneath this there appears to be a darkening of the stone and a patch of efflorescence visible, which if not just a trick of the eye would indicate rainwater is soaking into the building here (Fig,16). The shaded north side of the belfry roof displays an impressive growth of moss across the slates which can cause damage as described in 4.a.1, but which could also be concealing other cracked or damaged slates here also (Fig.17).

Figure 16 – Missing slate on south side of belfry roof

Figure 17 – Moss growth on north side of belfry roof

4.a.3 Drainage

Drainage facilities around the church are very well organised with gutters along all the eaves and downpipes leading to grated gullies positioned within reasonable distances to accommodate any heavy downpour. There is a frenchdrain running around the entirety of the building that helps drain surrounding groundwater away from the foundations, and hopefully prevent rising damp internally.

At the front of the building the drain is kept in perfect condition, free of debris and vegetation, however the drain at the back has a build-up of recently fallen leaves covering most of the gravel drain and plant growth has started in the gravel also, particularly by the eastern buttress beside the chancel (Fig.19). These both keep moisture against the back wall counteracting the purpose of the drain. The gully grates under the downpipes here were covered with the autumn leaves also making it more likely for water to pool in this area (Fig.18).

Figure 18 – Leaves and vegetation blocking drain gulley

Figure 19 – Vegetation growth in frenchdrain at rear of church

As the building is positioned down from a slope, the groundwater that will accumulate at the back walls will be higher; groundwater from the slope will all be flowing down towards the church wall (Fig.20). The frenchdrain in this part of the building is particularly useful and should be kept clear to allow best functioning.

Figure 20 – Sloping of ground to the rear of the church

4.b. Internal Condition

4.b.1 Walls

The interior walls are bare rough-cut stonework in most places with dressed stone around the window, door and arch openings likely inserted during the renovations in 1867. There is significant spalling of the ironstone throughout the interior of the church, most likely due to many years of moisture migration and evaporation through the soft stone. (see 4a.1). Areas of particularly severe spalling include the entirety of the walls of the Belfry from the base to the top, the adjoining western wall, and the top of the arches of the aisle. Particularly worrying is the spalling that is present on the west arch as should it continue to spread the medieval wall painting remnants will crumble away also (Fig.21) (Fig.22).

Figure 21 – Spalling of stone of west arch

Figure 22 – Medieval wall painting

The stonework has been re-pointed with cementitious mortar in large areas, most likely during further renovations in 1948. Moisture readings taken throughout the interior walls using a GE Protimeter Mini© surprisingly show acceptable levels of moisture in these areas (25 – 35% WME – see section 5.b.3 for more) despite the presence of an unbreathable and inflexible mortar that can trap moisture within the porous soft stone. (Hindle 2019) (Survey Express Services 2015)

Moisture readings of the west wall and the belfry however show high moisture content in the stone from the base of the wall up to 2metres. WME : 45 – 55% (Hindle 2019). The walls within the Belfry retain traces of many layers of paint or limewash over which a green mould thrives and active spalling of the stonework is evident in the dust and crumbled stone visible on the floor. There are tide marks in the base of the pillars of the belfry and the westernmost of the south aisle (Fig.24). As mentioned in *4.a.1,* there are drip marks and cracks in the stonework above the west window of the south aisle (Fig.23).

Figure 23 – Dripmarks on west window

Figure 24 – Tidemarks and spalling of west pillar

These serious moisture issues could be the accumulated result of a number of colluding factors on the exterior: the missing/damaged slate on the belfry roof, the gaps between the coping stones, the accumulated moss growth on the drip course, and vegetation debris in the frenchdrain. Drip marks on the stonework and brass plaques of the adjacent nave wall also suggest possible faults in the flashings of the nave roof where it meets the belfry.

There are significant tidemarks as well as areas of green mould surrounding and beneath the pulpit (Fig.25). Further examination with a moisture reader confirmed dampness in these areas and in the plaster in the east wall of the chancel behind. The frenchdrains and gulley to the exterior of this area are also clogged with vegetation debris and growing plants (Fig.26). The presence of the two blocked gulleys in this area and the moisture reading suggest the debris may be the cause of the dampness here.

Figure 25 – Tidemarks and green mould at base of pulpit

Figure 26 – Leaves blocking the frenchdrain and gulley at rear of chancel

4.b.2 Ceiling/ Roof

The interior roof of the church consists of three separate open timber truss roofs for the nave, south aisle and chancel, all most likely rebuilt in the 1867 renovations. There is evidence of past leaks in areas of white mould growth on the timbers in places.

As discussed in 4.a.2, there are many residues of splash marks on the metalwork objects in the building as well as drip marks on the stonework of the west wall. Some of these could have been caused during the previous leaks or from condensation. There is however a small area of green mould growing on the stone above the eastern arch of the south arcade (Fig.27) adjacent to the splash marked organ pipes which suggests consistent moisture in the area currently.

Figure 27 – Green mould growth above easternmost arch

Figure 28 - IR Thermometer reading of westernmost arch

When reviewed with a FLIR ® TG165 IR Thermometer at sunset on a sunny day a small area of heat can be seen between the stone and the sun heated timber beams under the lead possibly indicating a thermal bridge of moisture and a new pinhole leak (Fig.28).

4.b.3 Windows

There are ten windows at ground level, predominantly lanceted single glazed quarried leadlights. There is a Victorian triple light stained glass in the east wall of the chancel with a mullioned square headed quarried window in the south wall. In the clerestory on the south face there are three similar square headed mullioned quarried windows.

There are considerable drip stains on the stonework beneath the stained glass in the chancel (Fig.29) and during one survey water was seen to seep in from the lead cames of the central light (Fig.30), there was light rain outside. There is a cracked pane currently repaired with a clear adhesive tape. And a slight bow in the stained glass and the west chancel leadlights that appear stable currently but may need attention in the near future.

Figure 29 – Drip marks on stone and residue paint.

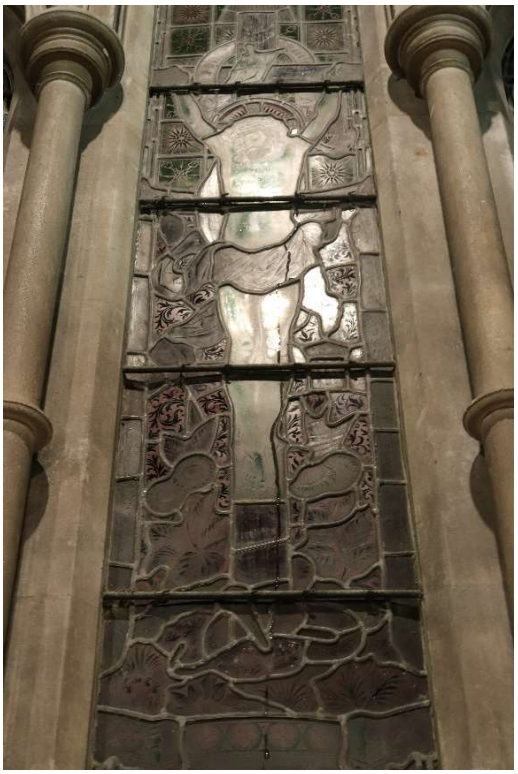


Figure 30 – Drip on central stained glass window

The rest of the windows appear in good condition with no evidence of leaks despite two or three cracked panes. There is a build-up of dirt and encrustations on the exterior of the clear quarries that will aid the corrosion of the glass (Fig.31). There is already an iridescence weathering crust on the exterior indicating active corrosion (Fig.32) (Romich, 2004) (Van Giffen, 2014).

Figure 31 – Encrustations on window exterior

Figure 32 – Irridescence on glass exterior

4.b.4 Floors

The floor of the nave and aisle is tiled with plain Victorian quarry tiles arranged in a geometric diamond and cross pattern. There are encaustic patterned tiles in the chancel, currently covered with a carpet and plastic underpad. There are two memorial stones laid in the floor in the nave also, both in good condition and largely concealed by the wooden pews.

Figure 33 – Efflorescence on floor tiles

There is salt efflorescence evident in the floor tiles of the nave, particularly around the edges of and beneath the pews. There is also the previously mentioned tidemarks and green mould growth at the base of the pulpit. As discussed in 4.b.1 this is likely a result of the build-up of vegetation in the drains to the exterior of these walls. In the below image displaying the moisture readings of the pulpit floor however it is possible to see how this excess water is moving through the stone of the floor and the tiles.

Figure 34 – GE Protimeter Mini© readings along tidemarks at base of pulpit

Moisture and IR thermometer readings taken of the 15^{thC} pew and the floor tiles beneath it show that a certain amount of moisture is rising up through the timber from the floor. The adjacent plaster also displays a high moisture reading for its material. (Hindle, 2019)

Figure 35 - GE Protimeter Mini© readings of pew

Figure 36 - Flir® TG165 IR Thermometer reading of pe

4.b.5 Main Services

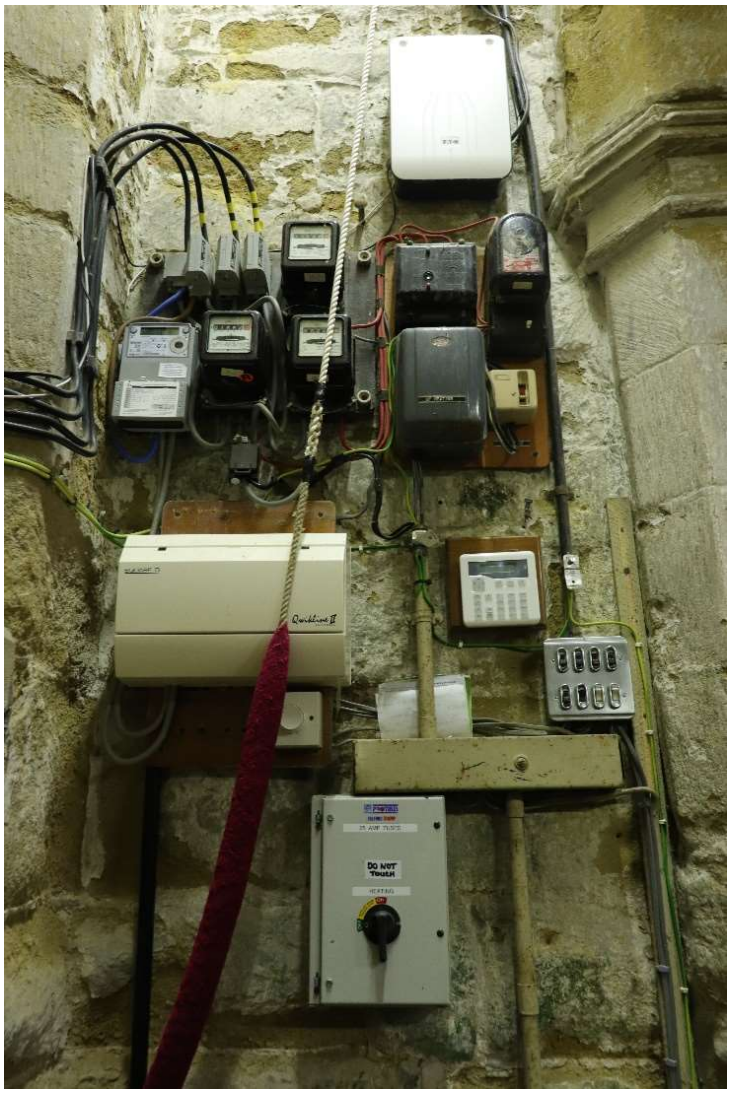


Figure 37 – Mains services in belfry

Electric light was first used in the church in 1947 and was rewired in 1990 by a locally resident electrician. Indirect incandescent downlights were added at this time to the nave and chancel and are noted to have 'greatly improved the internal appearance of the church'. (W. 2005) (Further discussion in 5.b.1 about their effect on the collection).

The church is heated by two electric radiators mounted on the north wall and turned on by switch in the belfry and four electric fan heaters (further discussion in section 5.b.2). While the electrical supply boards at first sight appears worryingly jumbled and old, a new meter was installed in 2015 at which point it was deemed up to date and fit for purpose.

4.b.6 Security

There does not appear to be a fire alarm or smoke detector installed in the building though there are two fire extinguishers. Foam and carbon dioxide suitable for extinguishing solid fuel, liquid fuel and electric fires. There is an alarm system rigged to the lead roof, notices advertising the presence of the alarm in the porch, and a visible alarm box on the belfry wall facing the road. All windows at ground level have iron support bars or grilles to protect against intruder entry.

Figure 38 – Metal grille over stained glass window

Figure 39 – Iron bar on south window

There is a sturdy internal rim lock on the entrance door.

Access to the church is by foot along a paved path through a field visible to residents. The church is screened from the view of the narrow lane which gives access to this field by mature trees. The lane itself is a cul-de-sac.

5. Environmental Conditions

5.a External Environment

The climate in the locality is warm and temperate. The average annual temperature is 9.1 °C while rainfall averages at 675 mm. The driest month is February, with 47 mm of rain. Most precipitation falls in December, with an average of 63 mm. There is a difference of 16 mm of precipitation between the driest and wettest months.

Annually the temperature ranges from 2 - 21°C and RH from 74 – 86%. July is the warmest month of the year averaging at 16.4 °C while January has the lowest average temperature of 2.3 °C.

It receives an average of 1511hrs of sunlight annually, approximately 126 hours monthly. The building is south facing with the majority of windows south facing also. There is one 10m tall holly tree at the church yard entrance and a number of large oak and chestnuts in the adjoining field to the southwest however the south face of the church receives full exposure to the sun all day.

Predominately winds blow from the west, with an average windspeed of 12 – 21kmph. The presence of some mature trees at a distance of 10 – 50m provide some shelter for the structure to the west of the building while remaining far enough away to avoid danger of damage from falls. (Merkel, A. 2012)

5.b Internal Environment

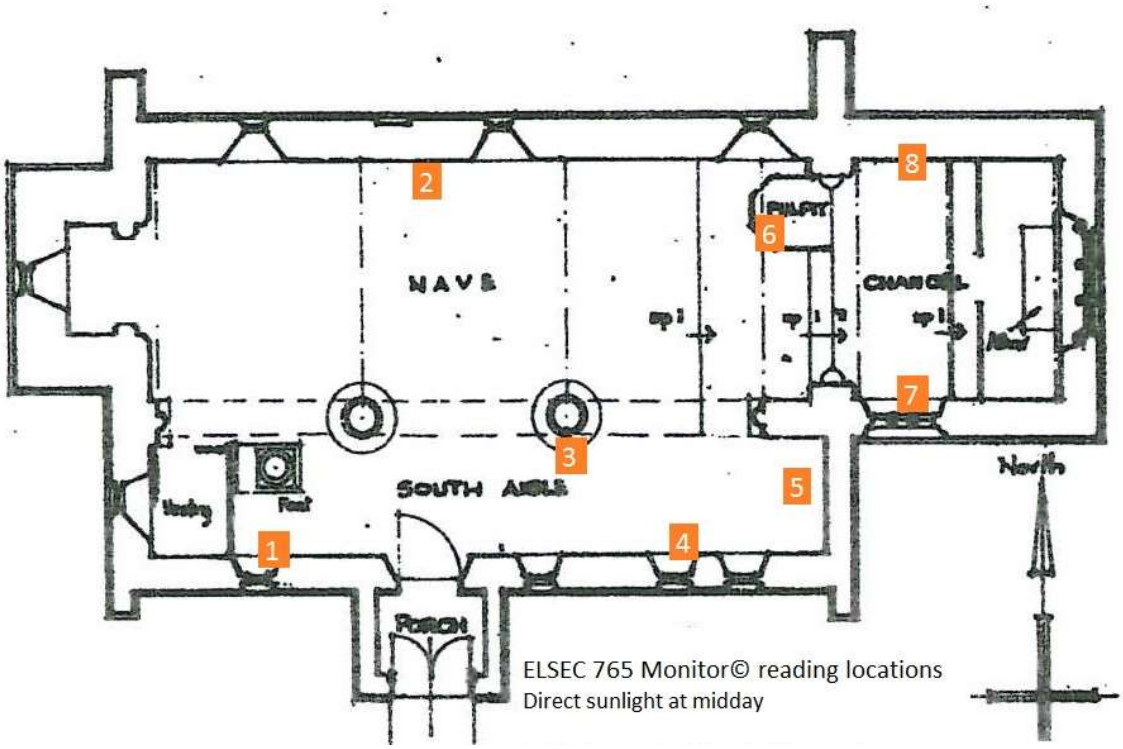
5.b.1 Light

Lux and UV readings were taken on two occasions using an ELSEC 765 Environmental Monitor. Once in the evening with full church lighting and once at midday in direct and indirect sunlight. Special attention was given to locations where sunlight was likely to pass daily in front of sensitive objects of the collection.

The recommended lux levels for the materials within the church collection can be seen below in the table. It proved difficult to locate exact recommended lux levels for medieval wall paintings, however considering the recommended levels for 'thinly coloured paint on canvas' and 'oil and tempera paintings' fall within 50 – 200 lux, a conservative estimate of 50 – 100lux might be recommended for the already faded wall paintings of this collection.

Material	Recommended Lux
thinly coloured painting on canvas	50 - 100
leather	50 - 100
paper	50 - 100
textile	50 - 100
oil and tempera paintings	100 - 200
wood	100 - 200
stone	200+
metal	200+
glass	200+

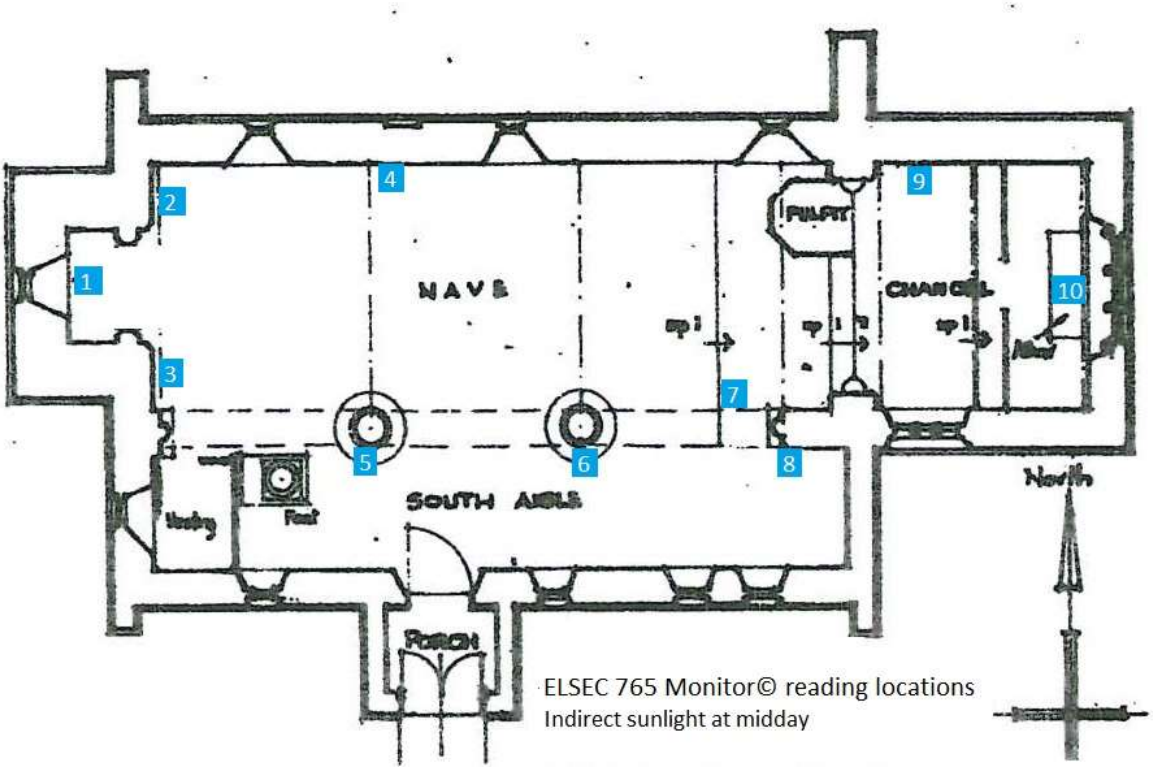
Table 2 – Recommended light levels for materials (Stolow 1987 p20)



Direct Sunlight

Location		µW / lumen	Lux
1	In front of south window	43	4057
2	North wall Nave	24	1475
3	On pillar below capitol	48	2184
4	In front of south window	106	2358
5	On organ pipes	61	987
6	On pulpit	51.5	322
7	In front of south window	25	1501
8	North wall Chancel	24	1475

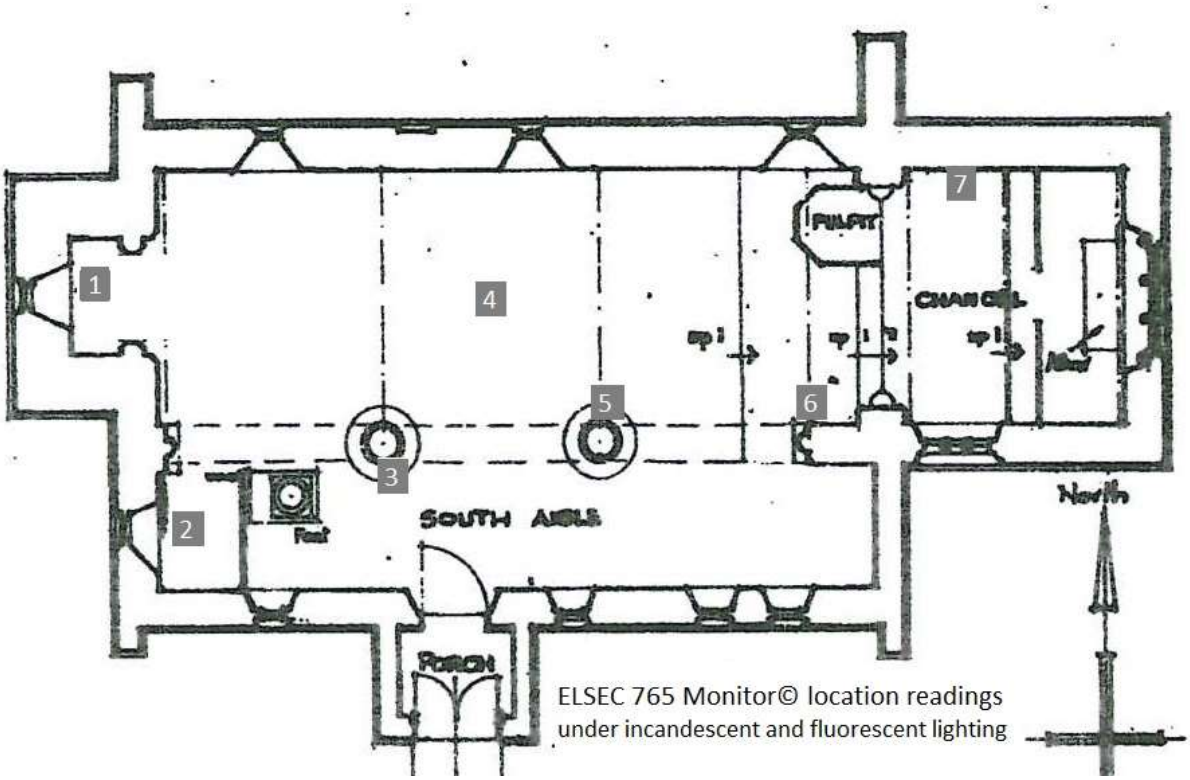
Figure 40 – Floor plan showing ELSEC 765 Monitor© direct sunlight readings



Indirect Sunlight

Location		µW / lumen	Lux
1	In front of Belfry window	63.6	151
2	In front of Bell yoke	181	13.1
3	Above pillar capitol	70.4	33.8
4	North wall Nave	226	16.6
5	Above pillar capitol	172	12.7
6	Above pillar capitol	152	30
7	In front of bible on lecturn	145	142
8	Above pillar capitol	168	19
9	On wooden pew	38.8	220
10	On altar cloth	156	20.5

Figure 41 – Floorplan showing ELSEC 765 Monitor© indirect sunlight readings



Incandescent and fluorescent lighting

Location		µW / lumen	Lux
1	In Belfry	25	9
2	In Vestry	108	53.2
3	Above pillar capitol	109	65.9
4	Centre of Nave	66.9	93.7
5	Above pillar capitol	0	41.1
6	Above pillar capitol	92.4	70.8
7	On wooden pew	0	59.4

Figure 42 – Floorplan showing ELSEC 765 Monitor© incandescent and fluorescent readings

Reviewing the readings it is obvious the lux levels in direct sunlight are far beyond recommended levels (Fig.40) and make it very apparent why the wall paintings have survived better on the north face of the south arcade. The levels in indirect sunlight are far more moderate and almost all fell within recommended levels excepting objects in close proximity to south facing windows (Fig.41). The incandescent and fluorescent lighting of the church also falls within recommended levels (Fig.42).

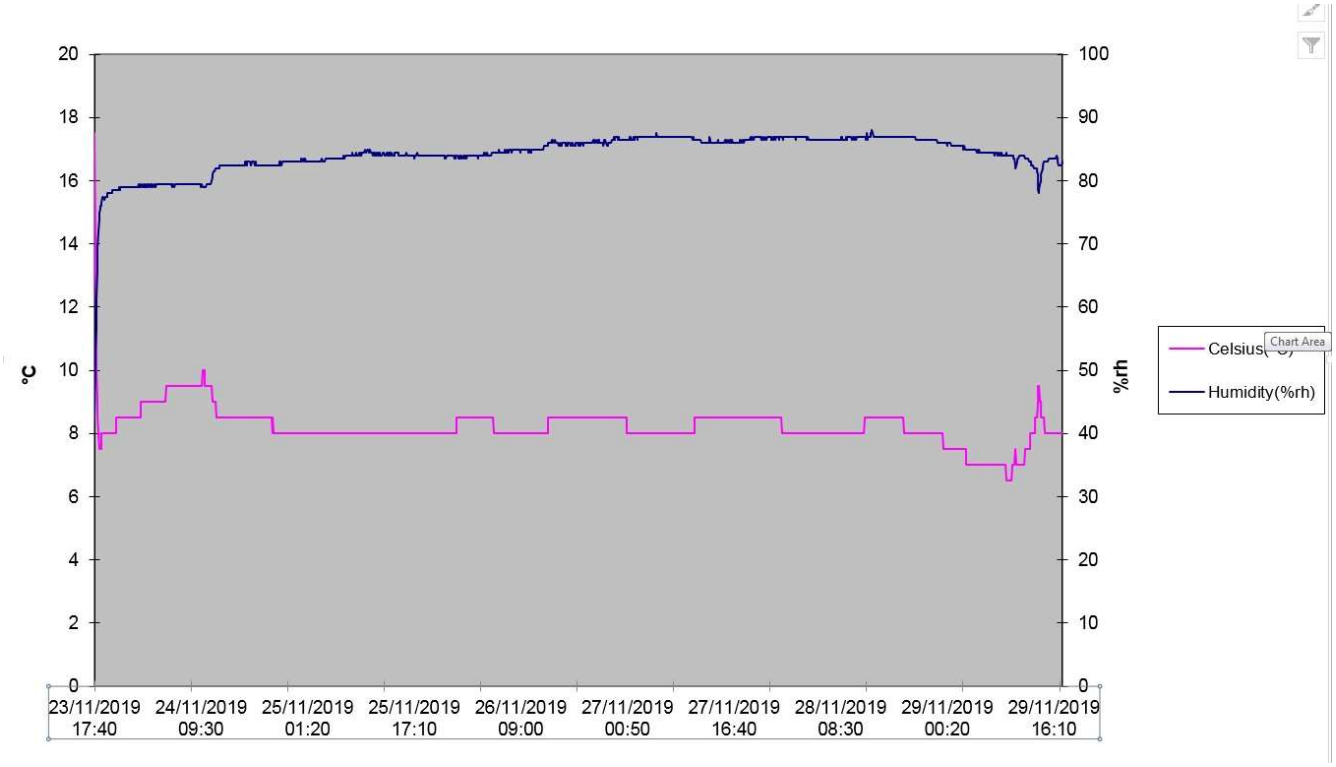
Many of the more sensitive materials within the collection are likely to fall within the path of direct sunlight: the wall paintings, leather and paper, and the woodworm damaged 15^{thC} pew.

5.b.2 RH and Temperature

Figure 43 – Datalogger© positioned above capitol in front of painting

The Datalogger© recording the relative humidity (%RH) and temperature (°C) at 5-minute intervals was positioned above the capitol of one of the south arcade arches in front of the medieval painted decoration and recorded for 19 days.

The external RH during this time ranged from 70 – 100% with an average of 99% while external temperatures ranged from -3 – 12°C with an average of 6°C. (Customweather© , 2019) Within the building the RH generally ranged from 76 - 93% with an average of 85% while temperatures generally ranged from 5.5 - 8.5°C with an average of 7°C showing that the building provided some insulation against the outside conditions.



– Graph displaying results of Datalogger© 23.11.2019 - 29.11.2019

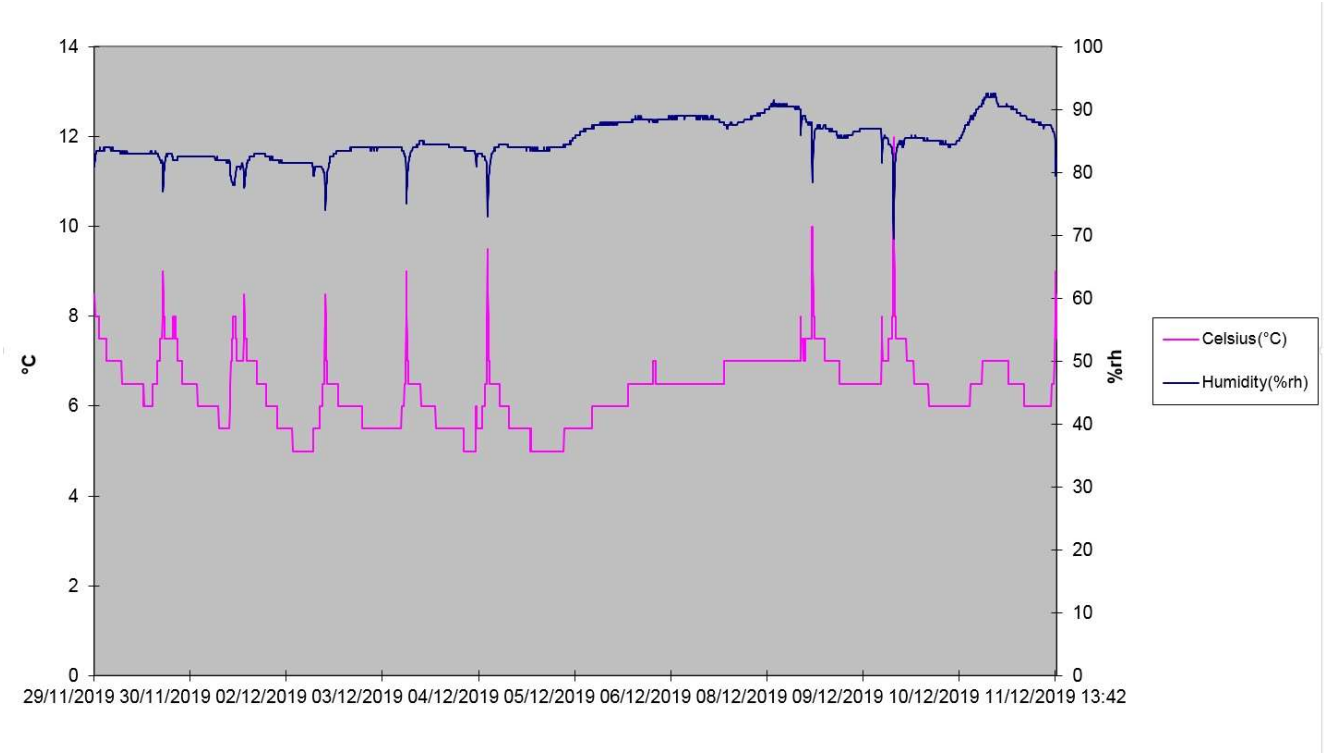


Figure 45 – Graph displaying results of Datalogger© 29.11.2019 - 11.12.2019

There were repetitive lower peaks of RH and higher peaks of temperature recorded outside of these ranges (Fig.44 & 45) These occurred only on clear days and are likely the result of solar gain when direct sunlight fell across or close to the meter around midday.

The most drastic of these instances was on 09.12.2019 when RH dropped by 15% to 69.5% about midday and temperature increased by 4.5°C to 12°C. The image below displays the residual heat retained in a wooden pew an hour after direct sunlight had shone through the three south facing lancet windows at sunset on the 29th November (Fig.41).

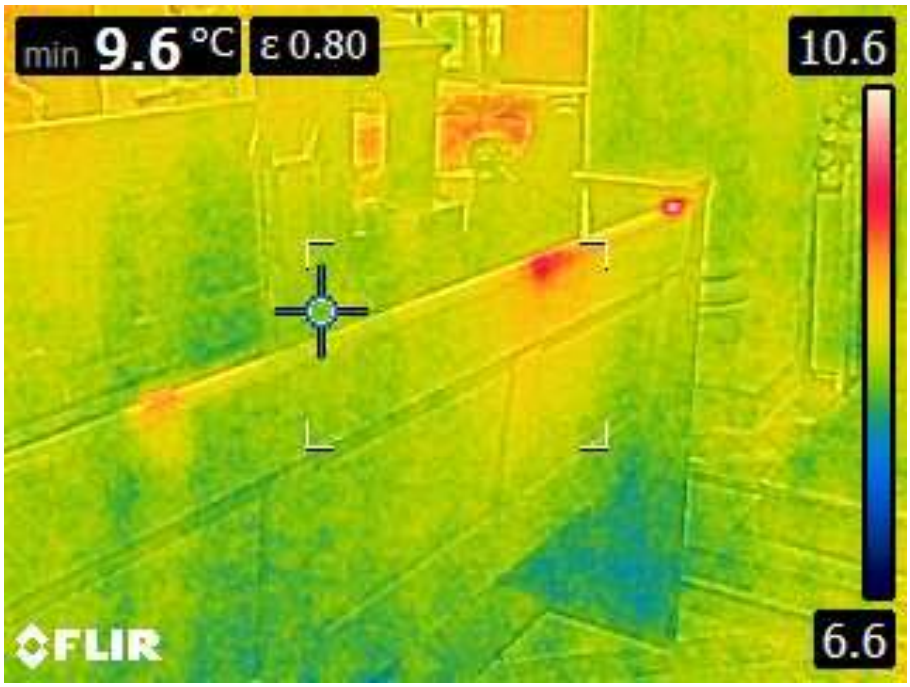


Figure 46 - Flir® TG165 IR Thermometer reading solar gain on wooden pews

Such fluctuations where direct sunlight is passing over the wall painting are particularly worrying. There is already evidence of salt efflorescence in the stonework of the building (detailed in 4.a.1 and 4.b.1). Fluctuations in the RH can "activate moisture transfer between the wall and the internal atmosphere causing soluble salt crystalisation cycles" (Henry & Stewart, 2011 p498) which can cause spalling of the stone surface and as such, loss of the painting.

The bi-monthly services only caused small changes in internal environment by comparison. The fluctuations that resulted from heating of the church prior and during these services on 24.11.2019 and 01.12.2019 only resulted in a maximum rise of 2.5°C in temperature and 2% in RH over 17hours and 3 hours respectively.

The recommended maximum hourly variations for the preservation of plaster are 1.5°C/h and 2%RH/h (Zarzo, 2013). While the fluctuations that result from services extend this range it is at a more gradual rate that is unlikely to cause adverse damage to the painting. The midday solar gain however does fall outside these levels and should be addressed speedily.

Overall the RH of the building is well beyond the museum recommended levels for collections at normal temperatures, 40 – 60 %RH as well as for historic buildings, 60 – 70 %RH. (Stolow 1987 p16), (Larsen 2018 p164)

Material	Recommended Relative Humidity (%RH)	Temperature (°C)
Metals	15 - 40	16 - 20.
Ceramic, Tiles, Stone	20 - 60	16 - 20.
Textiles, Rugs	30 - 50	16 - 20.
Furniture, Wood	40 - 60	16 - 20.
Paper	40 - 60	16 - 20.
Leather	45 - 60	16 - 20.
Frescoes	45 - 60	06 - 25.
Glass	40 - 60	16 - 20.

Table 3 – Recommended levels of RH% for collections (at normal temperatures) (Stolow 1987 p20) (Zarzo 2013)

Above are the recommended RH levels for the preservation of materials of the church collection. (Table 3) RH related damage is evident in many objects of the collection as already described in section 3. Beyond 75% RH mould growth begins, the higher the RH the faster the growth and spread of mould. (Ankersmit & Stappers, 2009, p49)

The paper and leather are the most vulnerable to mould growth currently as it has already taken hold in many objects of the collection. Green mould has begun to grow on the stone in areas where there is persistent moisture as detailed in 4.b1, 4.b.2 and 4.b.4. should it continue to spread and reach the wall paintings it would damage the fragile paint surface.

5.b.3 Moisture Readings

Moisture readings were taken using a pronged GE Protimeter Mini© by placing the two prongs against the material surface (as opposed to pressing into the material).

The Protimeter takes measurements based on a Wood Moisture equivalent – "a quantitative moisture content if they were taken from timber". It is not based on actual moisture content but the electroconductivity of the material, therefore readings for different materials need to be interpreted differently. Applying standards used by building surveyors, readings of above 25% in plaster or stone indicate moisture content '*worth investigating*' (Hindle, 2014)

Also worth taking into consideration while reviewing the data is that the presence of salts, which are evident in the efflorescence visible throughout the building can often cause electric moisture meters to over-read moisture levels (York Survey Supply Centre 2019).

As such these moisture readings should not be taken as guaranteed indications of actual moisture content by themselves unless used in conjunction with other methods of interpretation such as an IR Thermometer in 4.b.4. Below they are used in conjunction with a map of the RH% and temperature to show the elevated moisture levels along the western wall in comparison to the north wall, as well as a slightly higher elevation of moisture on the plastered north wall of the chancel confirming the visual interpretations in 4.a.1 and 4.b.2.

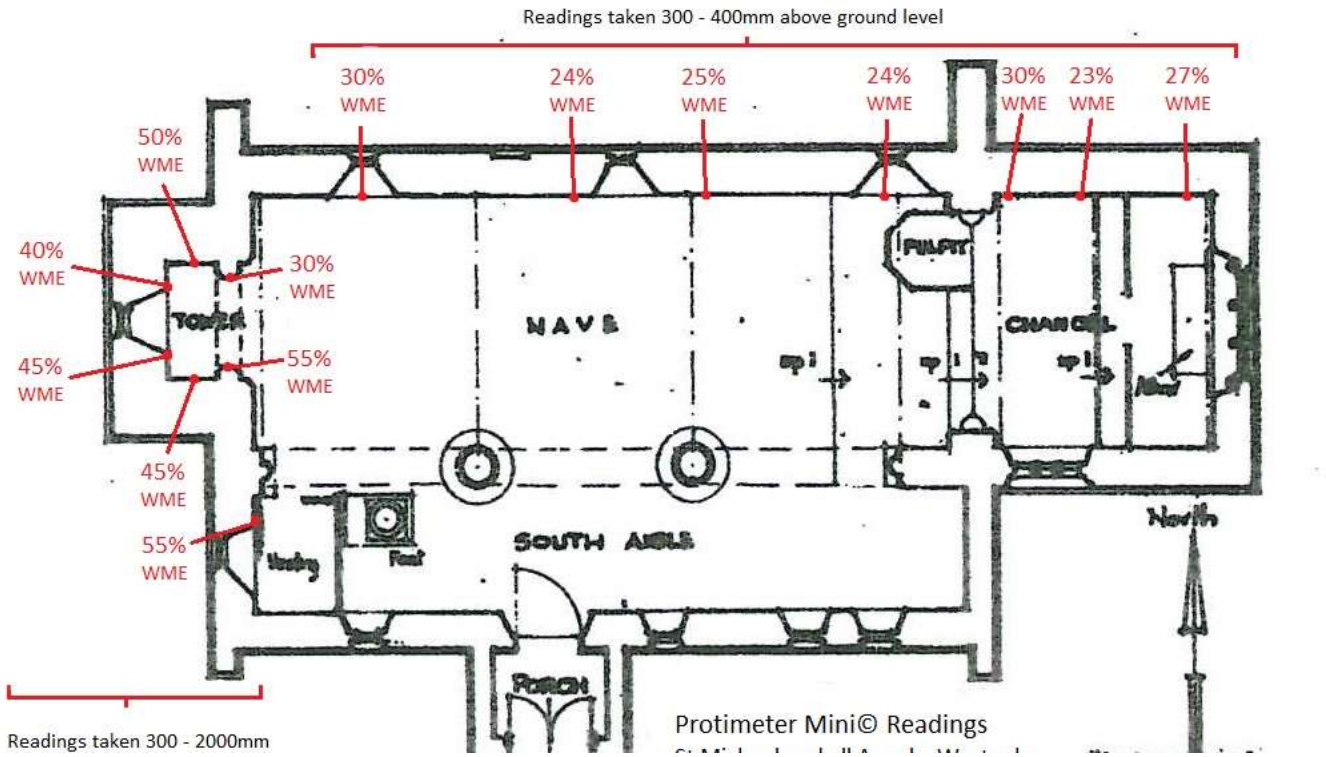


Figure 47 – Floorplan showing Protimeter Mini© Readings

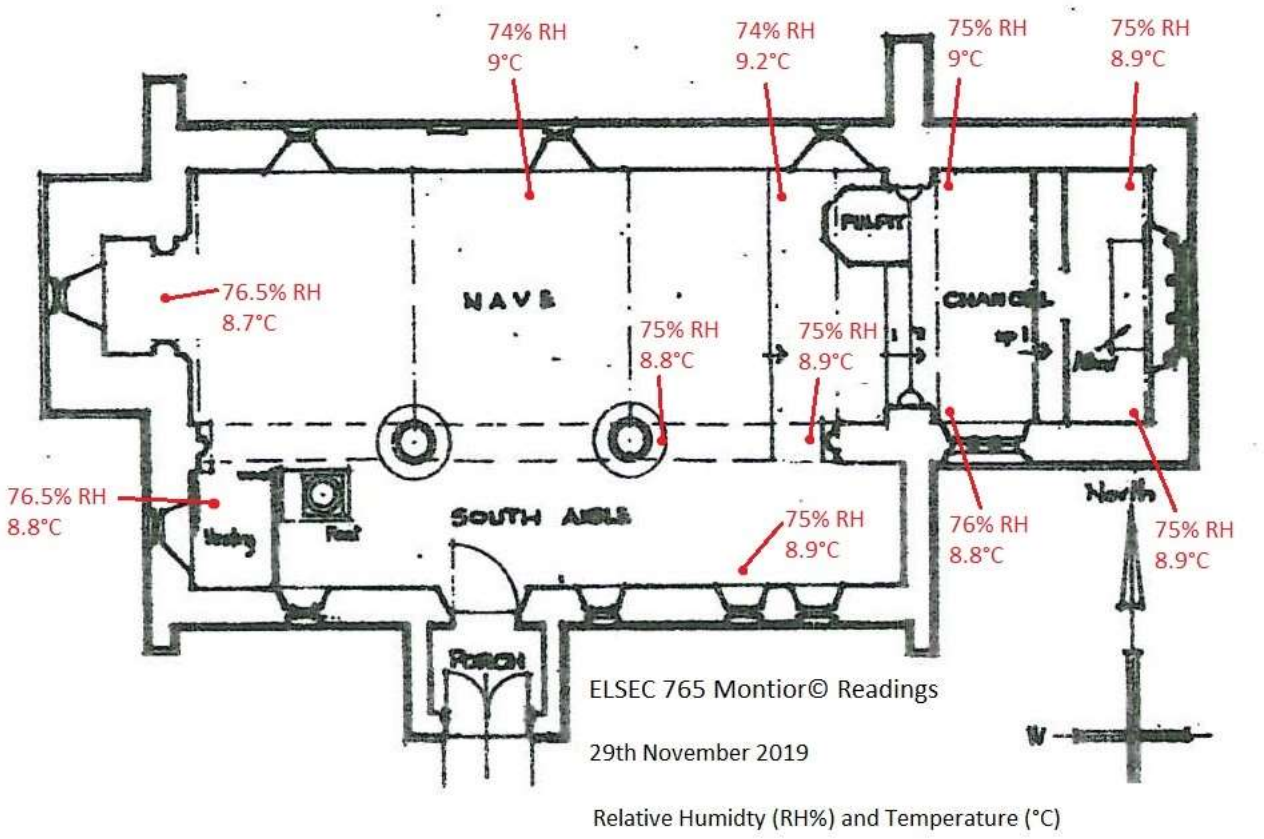


Figure 49 – Floorplan showing ELSEC 765 Monitor© RH% and temperature readings

The below interpretation of the south arcade as viewed from the Nave shows readings displaying the increased moisture content of the westernmost pillar adjacent to the west wall and a slightly higher content in the easternmost arch beneath the area of green mould mentioned in 4.b.2. giving an indication of how moisture may be moving through the arches (Fig.50).

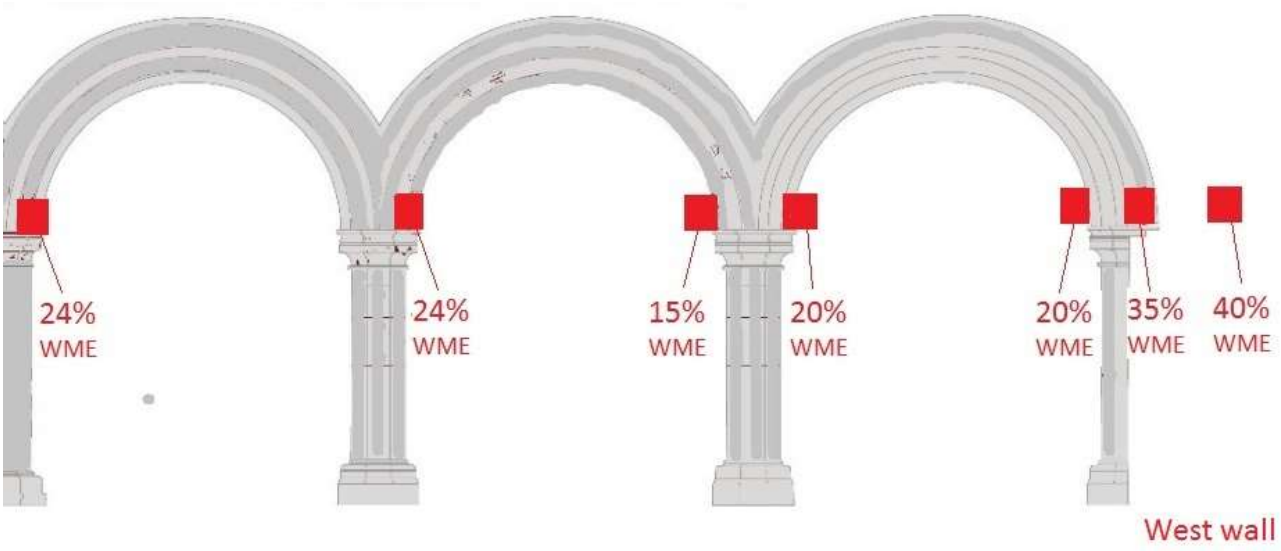


Figure 50 – Elevation drawing of south arcade showing Protimeter Mini© moisture readings (Budge 2018)

6. Risks and Vulnerabilities

The largest risk to the structure of the church currently comes from the persistent moisture penetration into the walls, this is aiding the further migration of soluble salts through the walls and the continued erosion of the stone fabric from efflorescence, and frost damage as detailed in 4.a and 4.b. The moisture in turn adds to the largest risk to the collection within the church, the conditions of the internal climate, as discussed in 5.b.

Irregular monitoring of the conditions within the building coupled with a lack of formal documentation of the collection and its condition make it difficult to determine if there is on-going deterioration in action.

Lack of a collections care and management plan, disaster management plan, or integrated pest management programme similarly leave the collection vulnerable. Currently the church is maintained admirably by the goodwill of local volunteers undertaking general housekeeping and maintenance as need appears. The quinquennial inspections, one of which is soon approaching do allow for a regular assessment on the condition of the building structure but no such inspection is made regularly of the collection within.

7. Recommendations

The recommendations outlined in the table below aim to improve the care of collections by addressing three areas.

Through external improvement of building maintenance in order to improve the internal environment.

Internally to arrange the collection in such a way as to minimise hazardous effects of the internal environment on the objects of the collection.

And finally to improve monitoring and management of the collection in order to prevent damage to the collection as opposed to only actively treating it when it has already occurred.

External
Removal of all vegetation debris and growth from the drains and gulleys Removal of moss and lichen growth from drip courses and stone surfaces Inspection of nave roof with particular attention paid to the coping stone and flashing on the western side. Inspection of coping stones of easternmost buttress at the rear. Inspection of the belfry roof and condition of slates. Removal of moss from north face of roof while access is available. Inspection of south aisle roof with particular attention to possible locations of leaks indicated in 4.a.3 Continued maintenance of church grounds
Internal
Regular monitoring of any moisture ingress from roof during times of rain to aid in external roof inspections. Consideration of installing a stand dehumidifier to reduce RH until west wall damp problems solved. Installation of protective blinds on south facing ground floor windows, particularly in the south aisle to reduce light damage and RH% and temperature fluctuations. Relocation away from north chancel wall or elevation / insertion of barrier layer between 15th C pew and ground to protect against rising moisture. moisture in the wall. Insertion of barrier layer beneath all timber pews to reduce contact with moisture rising from the floor Storage of leather kneelers on the pews alongside embroidered kneelers to reduce moisture damage. Removal from the building and treatment of mould damaged books. Continual housekeeping within the church
Monitoring and Management
Formal documentation of church collection and regular condition audits to assess deterioration. Formation of a collections care and management plan. Creation of a disaster management plan. Creation of an integrated pest management programme. Annual / bi-annual monitoring of environmental conditions within the building to determine if any improvement is being achieved to the internal climate.

Table 4 – Recommendations to improve care of collections

8. Discussion

The aim of this report as stated in section 1. was to assess the efficiency of the building in providing a suitable environment for its collection. This was to be achieved through evaluation of the accumulated data about the internal and external environment as well as the condition of the building itself.

The historical context of the building and the items within its collection and their historical and local significance were discussed briefly. A cursory condition survey of the collection was reviewed.

A detailed survey of the internal and external condition of the building fabric was presented along with plausible considerations for the effect of the internal and external environment on the building fabric, and in turn the internal environment that this has created.

An evaluation of the internal and external environment was presented with consideration given to the effect on the collection that this has already had and may have in the future. Overall many of the items within the collection are withstanding the undesirable environmental conditions within the church without any adverse signs however there are initial signs of deterioration in some of the items which if left unchecked will continue to spread and ultimately damage and destroy some of the more valuable assets of the collection. The vulnerabilities and risks to the building and collection were highlighted and recommendations were made to improve the current condition of the church and its environment as well as to improve monitoring and management of the collection to prevent deterioration of this historic collection in the long term.

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