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## BEYOND THE THEME



## REVIEWS

dossier

Robert James Williamson, Michael Nevell,
Bob Humphrey-Taylor*

# Increasing the resilience of cultural heritage using novel technologies: the perspective from a UK volunteer-led site

Continuing anthropogenic induced climate change poses risks to Cultural Heritage (CH) across the world. In the UK, cultural, natural and built heritage sites are often run by or with the help of groups of volunteers, whether that being at a national level or at a local level. Mellor Archaeological Trust is one such local charity which aims to preserve, maintain and protect the local CH assets. Climate change and its impacts are, therefore, a big concern for the trust as it looks to plan for the future. After a successful pilot of the STORM service, Mellor was able to demonstrate how the use of inexpensive and novel technologies can help small and large volunteer-led organisations in protecting heritage whilst ensuring that correct procedures are followed.
**Keywords:** culture, mitigation, precipitation, volunteers

*Il cambiamento climatico di origine antropica mette a rischio il patrimonio culturale nel mondo. Nel Regno Unito, i beni culturali e naturali sono spesso gestiti da – o con l'aiuto di – gruppi di volontari, sia a livello nazionale che locale. Il* Mellor Archaeological Trust *è una di queste organizzazioni locali che si propone di preservare, mantenere e proteggere il patrimonio culturale locale. Per questo motivo, il cambiamento climatico e le sue conseguenze sono una preoccupazione per il* trust *quando di tratta di pianificare per il futuro. Dopo un progetto pilota con il servizio STORM, Mellor ha dimostrato come l'uso di tecnologie innovative e a basso costo possa aiutare piccole e grandi organizzazioni a proteggere il patrimonio, assicurando nel contempo che siano seguite corrette procedure.*
***Parole chiave:*** *cultura, mitigazione, precipitazione, volontari*

## 1. Introduction

It is widely accepted that climate change, augmented by the rapid increase of anthropogenic greenhouse gas emissions since pre-industrial levels, will have considerable impacts on our environment, society and heritage (Pachauri, Reisinger 2007). The impact of climate change on

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our cultural heritage is receiving much attention, understandably concentrating on coastal areas that will be threatened by sea level change both eustatic (Daly 2010; Croft 2013) and, more recently, isostatic (Pettersson, Jonsson 2017).

This paper outlines the approach of one project to these threats and problems - STORM: Safeguarding cultural Heritage through Technical and Organisational Resources Management, a project co-funded by the Horizon 2020 programme of the European Union, specifically concentrating on the UK pilot site at Mellor, Stockport. The STORM project aims to develop a novel set of tools, models, techniques, and services to aid owners of cultural heritage assets in protecting their sites from the impacts of both climate change and natural disasters amongst other threats.

The Mellor Heritage Project (fig. 1) is one of five pilot sites included in the STORM project, each selected for their unique combination of threats and needs. The other four include: The Roman Ruins of Troia, Portugal; Baths of Diocletian, Rome, Italy; The Historic City of Rethymno, Crete, Greece; and Ephesus, Turkey (Nevell, Williamson, Wit 2019).

### *1.1. The study site*

Mellor Archaeological Trust was formed in 2000 as a result of archaeological discoveries in the village of Mellor, Stockport, UK. The aim was to preserve the archaeology for future generations and has since grown to encompass many sites of archaeological interest in Mellor and the surrounding area.

Three such sites have been selected for inclusion in the STORM project: The Old Vicarage site – a site with other 10,000 years of history but with significant Iron-Age and Roman occupation; Shaw Carin – a Bronze-Age burial cairn; and Mellor Mill – an industrial period mill built in 1790s and destroyed by fire in 1892 (Redhead 2005; Roberts 2011; Hearle 2011).

The Old Vicarage site has been occupied in some capacity for the past 10,000 years, beginning with nomadic hunter-gatherers using the uplands as the climate warmed after the Devensian glacial maximum. Excavations at the Old Vicarage site have revealed an Iron Age site comprising two ditches, defining the boundaries of a hillfort. A small outer ditch encompassed an area of 10ha and a much deeper inner ditch encompassed an area of around 2ha. Many postholes and roundhouse gullies have been uncovered. The position of a Medieval aisled hall has also been discovered at the Mellor Vicarage Site. The site is also home to a recon-

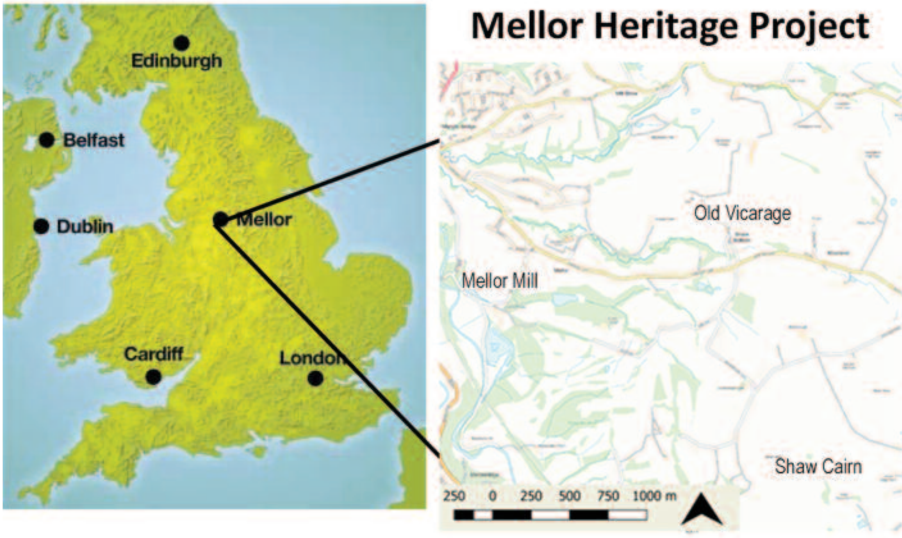


Fig. 1. Study Location – Mellor, Greater Manchester, UK.

structed roundhouse built by local college students as part of a European Community Cultural Project. This roundhouse has been designed, to the best knowledge of experts, to a similar specification as that which would have been used on the site 2000 years earlier (Hearle, Hearle 2005; Noble, Thompson 2005).

The site of a Bronze Age burial cairn first excavated in the 1970s, Shaw Cairn has revealed flints, bones, pottery, and an amber bead necklace associated with a central inhumation grave surrounded by later cremation burials (Hearle, Hearle 2005; Noble, Thompson 2005).

Mellor Mill was an impressive mill built in 1790s by Samuel Oldknow. It was one of the largest cotton spinning mills during its time and became the architectural guide for other mills subsequently built in the region. Oldknow diverted the River Goyt to build two large mill ponds. The Mills was over 120 m long, over 12 m wide and 6 stories high. Burnt down in 1892 and reduced to ground level, the site has been in need of great investment and care and had become overgrown and forested. The Mellor Archaeological Trust and the Canal and Rivers Trust, thanks to heritage lottery funding, are in the process of opening up the mill remains to the public as a mini country park with a CH theme (Redhead 2005; Hearle, Hearle 2005).

### 1.2. Volunteer-led

Mellor, as is the case for many sites across the United Kingdom, relies heavily on volunteers to ensure the day-to-day running and general maintenance. Not only is this true for small cultural heritage site, like Mellor, but in the UK even large cultural heritage organisations such as Historic England, National Trust, Royal Palaces, and Natural England all operate under this volunteer-reliant model. Without large numbers of volunteers cultural heritage preservation in the UK would suffer heavily unless national and regional governments increased their support to offset this loss in workforce. Continental European countries on the other hand have a more top-down approach where governments, both nationally and locally invest in and support their cultural heritage sector and have greater control over their cultural assets. This is significant for STORM, which could be more easily rolled out in such cases. However, the UK-based sites would struggle to train and develop their volunteer-based workforce on such a wide scale. It was vital, therefore, that the STORM platform was simple to use, required minimal training and development, and was accessible to a wide range of needs and abilities. Only this could ensure that the platform and service was useful and applicable to the UK pilot site and future UK cultural heritage sites which may use STORM. Mellor has a workforce almost wholly volunteer-based. The average age of volunteers for the Mellor site is over 55 years old, and this highlights a key issue unique to the UK pilot. Generally, the Mellor volunteers are not trained professionals but rather members of the public with a desire to protect their CH.

### 1.3. Hazards

The environmental threats and the risk multipliers associated with climate change at Mellor are as follows (Nevell, Williamson, Wit 2019):

1. *Wind*: Two of the Mellor Sites are situated at relatively high elevation. Shaw Cairn (~325 m a.s.l.) is extremely exposed to wind, and the Old Vicarage site is situated on a hillside, again exposed to high winds. Winds, and accelerated winds resulting from climate change, could fell trees near-by to the archaeology and infrastructure. Trees and branches could fall onto and subsequently damage the archaeology – which would need to be repaired at a cost to the site owner, Mellor Archaeological Trust. Similarly, the Mill site is heavily tree covered and, although in a valley and shielded from the worse of the winds, any severe wind storms could collapse trees and branches and damage the masonry on site. This also causes a health hazard to visitors.

2. *Precipitation*: Mellor is in the North-West England region of the UK. The North West of England has a very mild and wet climate. This is because the North West is exposed to westerly winds bringing maritime air masses off the Atlantic Ocean. This leads to the North West being one of the wettest areas in the UK. This effect is accentuated as elevation increases. As Mellor is located on the edge of the British Peak District National Park – and at elevation – Mellor receives a lot of rainfall. Intense rains may directly damage the masonry, and archaeology at all three sites. Prolonged rainfall may lead to inundation and landslides – especially at the Mill site – and this would damage, if not destroy, the ruins of Mellor Mill. Overtime, the earth at the Iron Age ditch will erode and intense rainfall may wash away large parts of the ditch. Finally, intense and prolonged rainfall may lead to flooding at Mellor Mill.
3. *Flooding*: Flooding at the Mellor Archaeological site could manifest itself in two ways. Firstly, the Mellor Mill site is in the flood zone of the River Goyt and during a large flood event, this land would be allowed to flood to protect nearby villages and towns, downstream of the site. Heavy precipitation, therefore, could lead to water levels in the River Goyt, close to Mellor Mill, breaching its banks Secondly, the nearby Mill ponds – the Roman Lakes – are dammed close to the Mill Site. Should this dam fail water would inundate the archaeology of the Mill. Therefore, dam failure is a huge risk to Mellor Mill. Should either of the above situations occur, the Mill would be completely inundated with water, masonry and artefacts would be destroyed, and it could lead to irreparable damage.
4. *Change in Freeze-thaw events*: Of high concern for the Mellor site is temperature changes, and how such changes may alter because of climate change. Freeze thaw cycles at Mellor Mill are the main concern here. Presently, freeze thaw is leading to erosion of the Mill remains. The bricks are becoming brittle and disintegrating – which are then washed away by rain, or damaged by human interaction. How freeze-thaw cycles alter in a changing climate will be important for the Mill. Fewer cycles will reduce the erosion of the mill remains, whereas more cycles will speed up the rate of erosion. Temperatures at the Mill site vary more than at the other Mellor sites, with higher temperature maxima and lower minima. Monitoring the number of cold days following wet periods will be vital in understanding the direction that the frequency of freeze thaw cycles is heading.
5. *Mass Movements*: landslides have the potential to cause damage to the archaeology at the mill site. Being at the bottom of a steep valley a large landslide may cut off access to the site and in a worst-case scenario it may lead to damage of the archaeology.

6. *Biological Infestation*: currently, volunteers clear vegetation of the sites multiple times per year. However, due to the climate of North West England, vegetation grows quickly and substantially over the Mill site and Iron Age Ditch. Vegetation growth within the sites can cause damage from roots into the masonry and earth. More frequent maintenance would be necessary to keep vegetation growth to a minimum.

There are also some anthropogenic hazards and threats to the Mellor pilot site and these include:

7. *Tourism related threats*: Thanks to recent funding, the Mellor Mill heritage site is being developed to improve the accessibility of the site for tourists. It is hoped that there will be significant footfall over the coming years. The Shaw Cairn and Old Vicarage sites, as well as surrounding the Mill site, are also public rights of way. As such, many people will pass through the sites – even people who are not visiting the site, but are using the surrounding countryside. The people who are only passing through the sites are much less considerate of the importance of the archaeology and thus, may take less care. This increased footfall risks damaging the site, either the archaeology directly becoming damaged or the footpaths being worn, which would be costly to maintain and replace.
8. *Vandalism*: The Mellor heritage site is not secure. As mentioned, the sites are all located in public areas and therefore many people may gain access to the site and could damage the archaeology, vandalise archaeology/information boards and even steal equipment used by the trust, sensors, and artefacts which could be of importance. Such damage may be caused inadvertently or be caused due to malice.
9. *Dam/levee failures*: Mellor Mill was powered by water. Therefore, mill ponds were needed to hold water upstream of the Mill and three reservoirs were constructed. The three ponds still exist today and are used as a local leisure amenity. One serious anthropogenic threat to the Mill site is failure of the dam from the nearby mill pond. People could damage the dam in such a way that the dam would give way and this would release the water from the three mill ponds which would inundate the mill site. This not only poses a danger to guests at the site but also would severely damage the archaeological remains.

The abundant hazards detailed above were grouped and then used to set out a list of possible scenarios that may be faced by the pilot site and which could be used to test the STORM service and platform. The site, working alongside technical and academic partners developed some use cases that could be linked to the hazard scenarios (fig. 2). This formed the basis for the live drills that were run towards the end of project to assess the usefulness of the service on a per-pilot site basis.

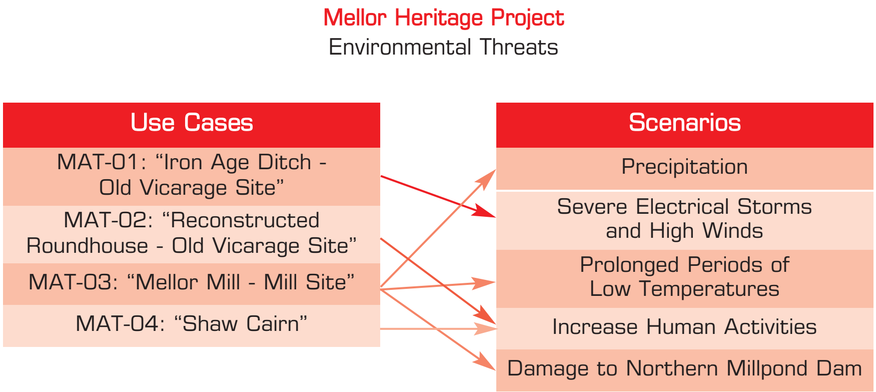


Fig. 2. Linkages between Cultural Heritage assets (Use Cases) and hazard scenarios selected to test the STORM platform and service at the UK pilot site.

## 2. Pre-STORM

As previously mentioned, the Mellor Archaeological Trust was set up in 2000, and maintenance has been carried out by the trust since then. As Mellor Archaeological Trust is a charitable organisation, maintenance work is carried out by volunteers. Recent funding is allowing the Mill site to undergo significant redevelopment, making the site more accessible for tourists. Previous funding, and help from the local government, has led to small-scale infrastructure development at the Iron Age Ditch.

Damage is assessed at all three of the Mellor sites by simple visual inspection which is carried out on weekly basis. This involves members of the Mellor Archaeological Trust together with volunteers walking the three sites and visually identifying issues which are developing. This quick and easy solution allow the Trust to identify issues with the sites' archaeology early and fix issues before they become a larger problem. Moreover, this provides some security to the site, as there is no fixed surveillance or company operating surveillance at the sites.

A qualified archaeologist is employed by the trust. The archaeologist makes assessments of the exposed archaeology on the three sites, looking for damage. Furthermore, qualified archaeologists from local universities are often involved with projects on the site – and the site is often utilised by archaeology students throughout the year.

Throughout the year vegetation growth is removed. On the Mill and Old Vicarage sites, this should ideally be performed multiple times per year. Again, these activities are undertaken by trustees and volunteers, and as such there is not a set agenda for performing this task.Vegetation will be cleared as and when is required.

To prevent damage and destruction of the ground-based archaeology, an annual inspection of trees around the sites is undertaken by an arboriculturist. The arboriculturist removes any dangerous, dying, and diseased trees as required.

The Mellor Archaeological Trust, up until late December 2016, did not have any climate or environmental sensors *in situ* at any of the three Mellor sites. Locally, however, there are many amateur and official weather stations. Data from the official meteorological stations can be accessed through application to the UK Met Office.

Historical meteorological data is available via the Met Office, and was recorded at Manchester Airport (~17 km away from site) between 1960s and 2000s. Since the 2000s the official Met Office weather station has transferred to Woodford and subsequently to Rosthern. Data from the three weather stations could be combined to give a long-time series of historic data relevant to the Mellor site.

There are multiple "amateur" weather stations within the vicinity with current conditions freely accessible via online meteorological "crowd-sourcing" websites such as the Met Office's WOW website. Records from these stations may be available from owners upon request. One such station close to the site is operated, for educational purposes, by Stockport Grammar Secondary School (8.4 km from site). Water levels/Discharge of the river Goyt are monitored, by the environment agency, at Marple Bridge (2.6 km downstream of Mellor Mill) and at Goytside Farm, New Mills (5.9 km upstream of Mellor Mill).

## 3. STORM services and tools

This sections will detail two of the key sensors that were adapted for the Mellor Pilot Site within the context of STORM. It will then chart how a wide range of sensors and tools have been integrated into the STORM platform and how the STORM service as a whole has been utilised at Mellor.

*Automatic Weather Stations*

As the Mellor pilot site consists of three fairly unique sites in terms of their individual "micro-climate" the solution that was used for monitoring the weather was to select three separate weather stations and deploy one at each Mellor site. This ensured that weather data would be collected close to all four of our use-cases, since the sites are located in areas where the localised conditions vary considerably. Shaw Cairn is located high on top of Mellor Moor and is very exposed. Mellor Vicarage

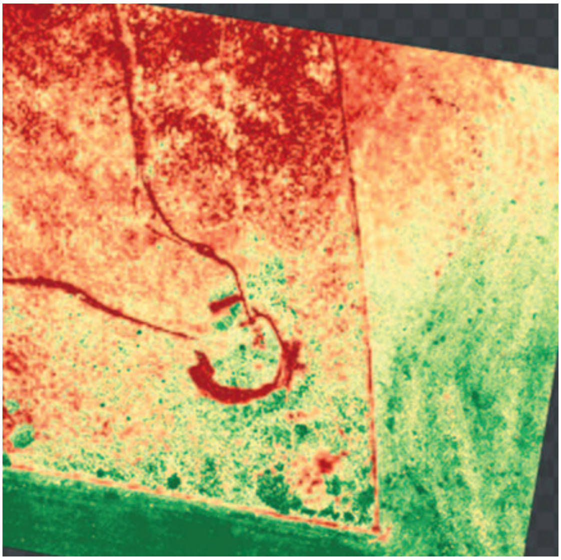

Fig. 3. Processed NDVI false colour image output in the GIS.

is located on a hill top and is less exposed, and Mellor Mill is located in a valley sheltered from much of the harsh weather experienced across the other two locations.

The weather station selected at Mellor was the Davis Vantage Pro 2.

*NDVI Photogrammetry*

A modified Dji X3 camera was purchased where the filters have been modified so that it is able to photograph in the near infrared and red wavelengths (peak wavelength 660 and 850 nm) whilst filtering out the green and blue ends of the spectrum. The camera is attached to a gimble that is suitable for flying with the Dji Inspire 1 drone. The data is collected and stored on a SD card in both .Raw and .JPEG files.The resulting colourised NDVI image is shown in fig. 3. The monument, Shaw Carin, is clearly indicated correctly (dark red - representing soil and rocks), and the fields below the monument (directly south) and to the east of the monument are correctly coloured green (these are rich pastures for grazing sheep). The range of pixel values as a result of the JPEG compression means that much of the north of the image is incorrectly red, especially the area to the north-east which is similar land use to the south-east of the image despite a very different result.

*The STORM Platform*

The sensors installed at Mellor, which include the above mentioned weather stations and drone photogrammetry, but also wireless acoustic


Fig. 4. Volunteer-led use of the STORM platform in action.

networks (for monitoring human activity close to the site, gamification game responses, allowing the site to monitor when and where site footfall is occurring), surveying and diagnosis services that include laser scanners and photogrammetric methods, all provide the site with a vast and rich set of data. This data is, however, not much use to site managers and employees or volunteers, many of whom will not be experienced enough to interpret the large quantity of data. STORM provided a way for sites to take in these vast sums of information and convert this into real-world, real-time, useful information. In the event the weather stations record data in excess of a pre-defined range of values, the STORM service would inform the site that action needed to be taken to mitigate damage or prevent any damage and significantly prevent loss of life. Moreover, the STORM service provided a platform whereby the site manage who received the alert (fig. 4) would be able to pass on responsibility of the first-responder to the nearest available volunteer or staff member. The platform would be pre-loaded with expert advice from the site, CH experts, scientific and technical experts, and regional and local governance and law experts, for which the user of the app would be able to follow clear guidelines and respond, knowing which assets must be protected in the first instance and how they should go about their task. This provides an excellent use-case example for UK based volunteer-reliant organisations where often the person or people who ought to respond to events may not be based in the vicinity of the cultural heritage site. Ordinarily, pre-STORM this would be an issue which would result in response times extending over days, as opposed to hours, damage occurring to the assets and potentially greater costs being incurred by the organisation.

## 4. Feedback and conclusions

The STORM project has brought a number of positives to the management of our volunteer-led Cultural Heritage sites.

Prior to the STORM project climate related risk information was minimal and this led to a reactive approach to both slow and fast onset scenarios. This meant that protective and restorative decisions were often taken without any reference to documented processes. STORM has given site managers the tools, using cutting edge technology, to analyse the situation against predetermined and rehearsed disaster scenarios. STORM has given the volunteers the opportunity to be proactive in their approach, keep accurate records and produce mitigation plans against the effects of Climate Change.

Furthermore, through this project we have been able to share 'best practice' across the five, Europe wide, Cultural Heritage sites and other expert partners involved. We are also now more aware of what new potential disasters may be in store for us as Climate Change progresses.

As managers we have had our eyes opened through a new and innovative approach to the responsible management of our sites and their protection for the generations to come.

Volunteer feedback was also sought about use of the STORM platform and the following conclusions were given:

- Photographs. Useful feature to have available to record key events, but the use of the camera is not as intuitive as it might be. It would ideally work like a smartphone camera and save all images automatically without the need for follow-up actions. This would be especially helpful in a fast-moving emergency when there would not be time to save each image separately. If this is not possible within the app. then the 'save' button in the top right hand corner needs to be much more obvious. Currently it is too small, and white letters on a black background - so not at all obvious as it merges with the image - so is not noticeable. Smartphone screen design would normally place this image in the centre of the image so that you can't move on to the next action without acting (so 'Save Image - Yes/No' placed centrally). If this is not possible then the Yes/No buttons need to be white with black lettering - and larger.

- The notes page was a really useful feature - where the detail of actions (or variations from pre-planned actions) can be recorded. Users should be encouraged to use this feature as fully as possible as it is in these notes that post-event analysis of actions will be reviewed.
- The volunteers acted/reacted well on the day and followed instructions well thanks to the STORM application, and this would not have been achieved without the implementation of the STORM platform.

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