Hinguar Primary School: Design for Future Climate Study

Technology Strategy Board - Project Number: 400259 - Final Report Revision A - December 2012
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EXECUTIVE SUMMARY

The aim of this study is to investigate the risks posed by the predicted future climate change to the Hinguar Primary School project and to describe the potential adaptation measures investigated and analysed by the Design Team.

The Team consisted of Space Craft Architects, Norman Bromley Partnership (M&E consultants) and Marstan BDB (cost consultants), with structural advice from Eckersley O’Callaghan.

Section 1 introduces the building project, which is for a new build primary school on an exposed maritime greenfield site in Shoeburyness for Southend-on-Sea Borough Council. The site is located in a 3(a) floodzone. This study coincided with the construction on site of the first phase of the school, which was completed in August 2012. The school has been fully operational since September 2012.

The construction of the Phase 2 extension is planned to take place in 5-10 years time. The report investigates both possible adaptation works to the Phase 1 build, as well as design changes for the Phase 2 extension.

In Section 2 of the study the likely risk to the school during years 2030, 2050 and 2080 are evaluated under the three ‘climate change headlines’:

- Impact on comfort and energy performance through hotter summers & warmer winters;
- Impact on construction / structural integrity of the building;
- Impacts arising from water shortages and at the same time increase rainfall rates;

Overheating of the teaching spaces was identified as the dominant risk, due to its direct impact on the learning, health and behaviour of the pupils and staff. Using the overheating criteria set out in Building Bulletin 101 (guidance for school design), the existing spaces were assessed through thermal modelling using the 90% probability / high emissions climate data. A Thermal Modelling Report has been included in Appendix 2.

A range of potential adaptation measures were reviewed in Section 3, which are then valued against the installation of air conditioning in a cost benefit analysis.

The analysis lead to the following adaptation measures being proposed:

- 2030: Installation of electrical fans to support natural ventilation and extension of existing louvers.
- 2050: Installation of ASHP or GSHP to provide reverse cooling using the underfloor heating system.
- 2080: Possible installation of ‘thermal battery’ cooling system to support the reverse cooling.

Other adaptation measures analysed include the following:

- Review of school timetable, including introduction of a ‘siesta’ to shift peak temperatures in classrooms;
- Increasing thermal mass was shown as having a significant impact on internal temperatures. Unfortunately this had to be dismissed as an option due to the structural limitation of the existing building (two storey lightweight structure raised on top of a concrete transfer slab to mitigate flood risk);
- ‘Dry-proofing’ of sensitive ground floor spaces. Due to extensive flood risk mitigation measures already developed during the design stage (habitable rooms raised above flood level, Flood Evacuation Plan in place, etc), the residual risk was considered low. However, the impact of a fluvial or tidal flood event would be significant, so the Team recommended that ‘dry-proofing’ should be reviewed in future in line with the available flood data at the time;
- Installation of a below ground tank as part of the Phase 2 construction works for rainwater harvesting to serve WC’s. Although the cost analysis showed that this measure has an extremely long payback period, it was recommended to address water as a valuable resource;
- Review of plant selection for landscaping in view of longer dryer summers. The research showed that this would require the installation of a full drainage layer to ensure plants are kept dry during the wetter winters on a site with already relatively high ground water levels.
During the progress of the study, it became apparent that the ‘adaptation measures’ could be divided into four categories:

1. Measures which were already implemented in the Phase 1 design and which the study had shown to be effective in mitigating future climate change risks, such as flood risk mitigation measures, existing solar shading, etc.

2. Future retro-fitting measures to the completed Phase 1 building (2030-2080).

3. Changes to the design of the Phase 2 extension, which would facilitate future adaptation measures (next 5-10 years).

4. Future adaptation measures to the Phase 2 building elements (2030-2080).

A summary of the adaptation measures analysed during the options appraisal can be found on page 26/27 in figure 31.

Section 4 contains a summary of our approach, the resources, tools and methodologies we used - and what we learned from carrying out this study.

The overall findings of the study were presented to Southend Council in October 2012. In addition to the client for the Hinguar School project, the workshop was also attended by other Project Managers and Electrical & Mechanical Engineers working within Southend Council’s Property & Regeneration department, as well as the Sustainability Officer. Whilst there was generally a keen interest within the council to push the climate change adaptation agenda, budget restraints were considered the biggest hurdle. A second issue which emerged in the presentation was a very varied view on the long term performance of some of the suggested services measures, which involve ‘relatively new’ technology, such as GSHPs.

Due to timing of the study within the construction project, the opportunities of directly influencing the Phase 1 built were limited. With the current budget restraints on education projects and changes in demographic prediction in Shoeburyness (combined with increasing pressure on school places within Southend central), it was not possible to get a firm commitment from the client on any specific adaptation measure to be implemented at this stage.

We therefore felt that the most useful application of our findings would be to focus on adaptation measures in categories 1 and 3 identified above (which are of course closely linked to 2 and 4) and establish a ‘Design Toolkit’ of initial adaptation measures which could / should be considered in the early design stages of any future project and which would facilitate the more onerous (and often costly) adaptation measures in the future. This approach, which is described in Section 5, also provided us with a tool which could be applied to other building projects.

A cost analysis of the measures in the toolkit showed that most of them are likely to be achievable with little or no extra cost, both in new build (e.g. the Phase 2 extension) or refurbishment projects.

A copy of the ‘Design Toolkit’ has been included in Appendix 4 and was distributed to Southend Council as part of the final presentation.

Whilst the emphasis of the study has been on mitigating overheating in schools, the proposed measures within the toolkit are not limited to educational buildings.

However, the forecasts by the Department of Education show a rise in pupil numbers in maintained nursery and state-funded primary school by 20% (about 820,000 pupils) by 20201, which has triggered additional funding being made available by the Secretary of State for Education2. As many of these additional spaces will be delivered as part of extensions or refurbishments of existing buildings as well as new builds with limited budgets, looking into options of future proving education projects now seems to be a sensible strategy to prepare for the future challenges posed by climate change - and to reduce costs long term.
0.0 INTRODUCTION

This report summarises the findings of a study carried out by Space Craft Architects [SCA], Norman Bromley Partnership [NBP] and Marstan BDB [MBDB] on behalf of the Technology Strategy Board [TSB]. The study investigates the potential impact of future climate change on the Hinguar Primary School project in Shoeburyness, Essex and proposes a series of adaptation measures.

The report has been developed with assistance from Dr Matthew Eames at the Centre for Energy and the Environment, University of Exeter, who prepared the weather data for the site and Ray Hoyte from Eckersley O’Callaghan, who provided structural and drainage advice. The project client, Southend-on-Sea Borough Council, and the end-users, Hinguar Primary School, also provided valuable input and commentary. Further collaborators are listed in the bibliography.

The latest issue climate change projections by the Met Office do not show the climate stabilising this century and so climate change must be regarded as an ongoing phenomenon. In the future we will need to change the way we design, construct, upgrade and occupy buildings to accommodate the expected changes – this is the challenge of adaptation. Within the realm of this report we will examine how the predicted climate change will affect the Hinguar School project and what might be done to mitigate this.

With the current restrictions on budgets for education buildings, we feel this is an important opportunity to investigate how schools might be ‘future proved’ within economical means. As the study has shown, there are a number of adaptation measures which can be included in the construction of new buildings or refurbishments/ extensions today at little, or at times no extra cost, and which facilitate the implementation of more extensive climate change mitigation measures in the future.
1.0 THE BUILDING PROJECT

1.1 THE BRIEF & THE SITE

The proposal for the Hinguar Primary School project for Southend-On-Sea Borough Council comprises a new school building (about 2,877 m² gross internal accommodation in Phases 1 & 2) and associated playgrounds, landscaping, on site car parking and vehicular / pedestrian accesses. The building has achieved a BREEAM rating of “very good” for the Design Stage with the Post -Construction assessment currently underway.

Initially the building provides accommodation for 300 pupils aged 4 - 11 years and 26 nursery school. It has been designed as a phased development to allow for four additional classrooms to be constructed in Phase 2 to accommodate a further 120 pupils.

Drawings of both phases have been included in Appendix 1, together with construction photographs.

The new school is located in Shoeburyness, Essex. The site is in an exposed costal location, approximately 500m away from the Thames Estuary (see figure 1).
1.2 PROGRAMME & INTEGRATION OF THE D4FC STUDY

The construction of the first phase of the building was completed in August 2012 and teaching commenced in September 2012. The main part of the study ran in parallel with the construction of Phase 1 on site.

A date for the construction of the second phase has not yet been set, but it is likely to be within the next 5-10 years, depending on the demand in the Shoeburyness area. The Phase 2 extension has, as far as possible, been conceived as a modular copy of the classroom arrangement in Phase 1 (see Figure 5 - a full set of drawings has been included in Appendix 1).

During the progress of the study however it became apparent that the ‘adaptation measures’ could be divided into four categories:

1. Measures which were already implemented in the Phase 1 design and which the study had shown to be effective in mitigating future climate change risks, such as flood risk mitigation measures, existing solar shading, etc.
2. Future retro-fitting measures to the completed Phase 1 building (2030-2080).
3. Changes to the design of the Phase 2 extension, which would facilitate future adaptation measures (next 5-10 years).
4. Future adaptation measures to the Phase 2 building elements (2030-2080).

On the basis of this we put together a ‘Climate Change Design Tool Kit’ which incorporated the measures identified under (1) and (3) above. This will be used to influence the design of the Phase 2 when this is developed in detail, but also allow the Council to apply the results of the study to other future construction projects.

1.3 BUILDING SYSTEMS

Low energy use has been an important factor in the design of the Hinguar School building. During the early design stage and linked to the Primary Capital funding, the project had aimed at achieving a 60% reduction in CO2 emissions when compared with the requirements of the 2002 Building Regulations. Due to the overall financial climate, this funding was considerably cut during the planning stage, which meant that the majority of the construction cost had to be met by Southend-on-Sea Borough Council. In order to keep the project alive, the team had to look at significant value...
engineering, including the replacement of the GSHP with gas boilers, omitting the wind turbine on the school grounds (which was also considered a potential noise issue by the neighbours) and installing less photovoltaic panels on the roof. This resulted in a decreased CO2 emissions reduction rate of 38 % above Building Regs 2002. A 10% reduction in carbon emissions from a renewable energy source will still be achieved in the form of the photovoltaic panels.

Underfloor heating is being provided throughout the building to meet the heating load, with a centralised gas boiler. During the design stage the installation of a ground source heat pump was considered and planned out, but later omitted due to value engineering.

Mechanical cooling has so far been kept to a minimum in the building. Two roof mounted air conditioning units (cooling loads of 4.1 kW and 5.2 kW respectively) provide cooling to the IT Server Room and the Fridge Room, which forms part of the school kitchen. All other cooling is provided through natural ventilation via rooflights / windows with actuators, mechanical louvers and mechanical windcatchers, generally in accordance with BB 101. All rooms are equipped with CO2 and temperature sensors linked to the BMS. The cross section of the building has been developed to maximise natural ventilation and daylight throughout the teaching spaces.

Services are strategically metered to allow energy use to be monitored. A digital display showing the energy generated by the roof mounted photovoltaic panels will be mounted in the central Atrium space, allowing the school to engage and use the building as an educational tool.

1.4 STRUCTURE

The superstructure for the building comprises a two storey steel frame with precast concrete plank floors. This is raised on top of a reinforced concrete transfer slab at First Floor level on concrete columns and pile foundations.

1.5 FLOODING

The school site is located within Flood Zone 3(a) and despite the existence of flood defences is subject to a residual risk of tidal flooding during an extreme tide event. The risks connected to flooding and mitigation measures already in place are discussed in more detail in chapter 2.1.3.
2.0 CLIMATE CHANGE RISKS

In order to develop a focused agenda of potential adaptation measures, it was critical for the team to understand and assess up the risks posed to the Hinguar School project by the changing climate, as well as the data available to quantify these risks. A risk register has been included in Appendix 2A.

This chapter discusses the main climate change risks relevant to the Hinguar School project, split into sections covering the main ‘climate change headlines’:

- Impact on comfort and energy performance through hotter summers and warmer winters;
- Impact on construction / structural integrity of the building;
- Impacts arising from water shortages and at the same time increased rainfall rates / rising water levels;

In early discussions within the design team and with the end-users (school and council), a rise in internal temperatures and the resulting overheating of teaching spaces emerged as a dominant risk. Providing a suitable internal environment for learning and teaching (in terms of temperature, acoustics, day-lighting, etc), whilst retaining the flexibility of the spaces, is essential for any education project - but in particular primary schools, which cater for the youngest learners. This is discussed in more detail later on in this section.

The focus on temperature was reinforced by the availability of specific weather data for the site, which could be fed into a thermal model and would allow for possible adaptation strategies to be tested in detail. The Thermal Modelling report has been included in Appendix 2B.

Data available on UKIP 09 for other risks including rainfall and wind patterns tended to cover a wider area and therefore did not lend itself to similar specific investigations.

2.1 ASSESSMENT OF RISK EXPOSURE TO THE PROJECTED FUTURE CLIMATE

2.1.1 COMFORT & ENERGY PERFORMANCE

Prometheus weather data was provided for the project site by Dr Matthew Eames at the Centre for Energy and the Environment, University of Exeter. Using IES Virtual Environment Modular Software this data was used to produce internal temperature and solar gain predictions within the school and will allow possible adaptation measures to be tested – both for the Phase 1 areas already under construction and the Phase 2 extension. A detailed analysis of the thermal model and the modelling results has been included in NBP’s Thermal Modelling report in Appendix 2B.

Four specific areas were identified for investigation: the main hall, the south-facing classrooms, the north-facing classrooms and the south-facing library. As outlined in more detail in NBP’s Thermal Modelling report, the criteria set out in Building Bulletin (BB) 101 have been used to assess the quantitative likelihood of the risk (i.e. whether the classroom will be “overheating”):

- a) There should be no more than 120 hours when the air temperature in the Classroom rises above 28°C
- b) The average internal to external temperature difference should not exceed 5°C.
- c) The internal air temperature when the space is occupied should not exceed 32°C.

![Graph showing thermal model data for a typical day in July for a South-facing classroom](image-url)
The modelling results show that the current construction and ventilation strategy, which have been designed to meet building regulations and BB101 in our current climate, could already struggle to provide an adequate teaching environment in 2030.

It is also interesting to note that in our workshop of the report findings to Southend Council in November 2012, the Council’s M&E consultants reported that the Council have had problems with new build schools getting to 26-27 deg in the summer which does comply with BB101, but the schools are unhappy with these temperatures and the council are introducing cooling. This seems to indicate that it might become necessary to review both BB101 and our adaptability to temperature in the near future.

2.1.2 CONSTRUCTION & STRUCTURAL INTEGRITY

Movement in soil due to clay shrinkage was identified as a possible risk to the building structure. However, whilst Bill Gething’s report shows the site generally located in an area with a ‘significant’ risk of soils being subject to clay shrinkage, the site specific soil investigation report confirms the sub-soil to contain sand and describes the silty clay as ‘stiff’ to ‘very stiff’. This, together with the pile foundations, which have been taken down well below the zone where changes in moisture content within the clay may lead to shrinkage, means that the residual risk to the building structure is likely to be low.

Owing to the location of the site in an exposed coastal environment, consideration has been given to the durability and resistance of external materials throughout the design stage (e.g. marine grade finish to a galvanised and powder coated elements, durable UV stable cladding materials, etc).

Due to the exposed location of the site, the structural calculations are based on a wind load of 22m/s, which equates to a ‘strong gale’ (Force 9 on the Beauford scale).

The specification for external windows / screens requires a water-tightness of 600 Pa. Window systems without water leakage at more than 600 Pa are classified as Class E [exceptional], which was felt to be outside the budget and performance requirements for a school building. Threshold details were developed to ensure maximum water tightness, though this had to be compromised at glazed doors to allow for level access. At the most exposed south-elevation, windows/doors have been partially sheltered by overhanging balconies / louvers.

The risk posed to the building construction by an increase in the frequency and severity of wind driven rain, severe gales and UV radiation on the building was therefore considered to be relatively low.
2.1.3 WATER CONSERVATION, DRAINAGE & FLOODING

Water shortages and increased rainfall
Shoeburyness is located in an area of ‘serious’ water stress. Climate change predictions point to a general trend of water shortage becoming an increasingly severe problem especially during summer months, whilst at the same time heavy storm rains during winter months are likely to increase.

Water shortages would affect the school on a number of levels. Locally, increasing droughts during the summer would impact on the planting of the external spaces, which form an intrinsic part of the school curriculum (e.g. the vegetable area, habitats & pond, sports grounds) and are of importance for the school environment.

Regionally increased water stress could impact on water costs for the school and ultimately on the availability of potable water for pupils and staff. Bearing in mind that the school caters for a very young and vulnerable student population, drinking water is essential and important for learning & teaching through pupil and staff concentration and well-being.

A shortage of water could also result in the school not being able to maintain their swimming pool, which would impact on their revenue (for community use) but also take away the potential health benefits for pupils of cooling down in the pool during hotter summers.

Rise in sea water, surface water and ground water levels
A full Flood Risk Assessment (FRA) for the site was prepared by Entec UK as part of the planning process. As the table below shows, the potential flood sources have been identified as tidal and fluvial.

<table>
<thead>
<tr>
<th>Source of Flooding</th>
<th>Risk Identified</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal</td>
<td>Yes (Quantified)</td>
<td>Within tidal flood zone 3</td>
</tr>
<tr>
<td>Fluvial</td>
<td>Potential</td>
<td>No fluvial flood zone exists for Barge Pier Cliffs. The Shoebury Garrison Mixed Use Area PPG25 Flood Risk Assessment WSP (2004) identified a potential risk. Flood risk management infrastructure has since been engineered to manage this risk.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>No</td>
<td>No risk identified</td>
</tr>
<tr>
<td>Sewers</td>
<td>No</td>
<td>No risk identified</td>
</tr>
<tr>
<td>Surface Water</td>
<td>Yes</td>
<td>There is always a potential risk of surface water run-on despite there being no documented issues, as such the risk cannot be discounted.</td>
</tr>
</tbody>
</table>

Tidal flood risk
The flood defences already in place which are running along the Shoeburyness coastline include a primary bund at 6m AOD, which protects the site against the 1 in 1000 year tidal flood event and a secondary bund at 4m, which would contain any overtopping of the primary bund (although this is unlikely) and also provides a holding tank for fluvial run-off at times of very high tide. As part of the FRA, Entec used a model to analyse the effects of a 200m breach in the primary bund combined with a 1 in 200 year flood and investigated the residual risk posed by this lower section of the defences.

Figure 11: Summary of Flood Risks

Figure 12: Water levels during a 1 in 200 year flood event with breach of the outer flood defence bund
The flood levels derived in this manner already include an allowance for climate change (1m for the next 100 years), based on data predictions for the year 2109. John Rampley from Entec had explained that this data is currently being superseded and refined within the UKCP 09 study, but he felt that this was unlikely to have a major impact on the current design scenario, especially as an additional 0.3m “freeboard” (or safety) margin has already been added to the predicted flood levels for the site.

A number of possible mitigation measures were reviewed at planning stage, resulting first and second floor of the school being raised above the 1 in 1000 year water level plus climate change allowance. All habitable rooms are situated on these upper floor providing a safe refuge from the flood, with car parking, playareas and secondary non-habitable spaces (WC’s, changing rooms, stores) remaining on the Ground Floor.

However, as the FRA modelling showed, there would be a period of time during which escape routes along New Garrison Road would be cut off, before flood waters receded enough to allow safe dry exit. It was not deemed to be acceptable by the Environmental Agency (EA) to retain the pupils within the school during this period and therefore an Emergency Evacuation Strategy was developed between the school, the EA, Southend Borough Council and the Design Team, which sees all pupils and staff safely evacuated to a nearby school outside the flood zone when a flood warning is issued.

The team felt that these mitigation measures already address most of the potential risk posed to the school by a flood event. Following consultation with the Core Group in December 2011 as part of the D4FC project, the Council has advised that, should the frequency and severity of flood events increase beyond the predicted levels, it is likely that steps would be taken to reinforce the flood defences by increasing the lower section of the bund. This would result in the flood risk for the school site being reduced even further. It should be noted though, that the impact of a flood event affecting the school would be significant and likely to result in a temporary school closure and considerable repair costs.

**Fluvial flood risk:**
As noted in Entec’s FRA, the risk associated with the fluvial outfalls being tide locked (where the watercourses cannot discharge if the tide level is higher than the fluvial outfall) was assessed as part of the masterplan for the overall area.

This risk was to be mitigated by providing an area wide alleviation scheme including works to the existing ditches and the creation of sufficient storage for the volume of water likely to be attained in the event of a 1 in 100 year fluvial event during one high tide cycle.

The risk is therefore reduced, but a remedial risk remains. Due to the habitable spaces of the school being raised on the first and second floor (see more detailed description below), fluvial flooding would mainly affect the landscaping, including the sports pitch, and the services equipment located in the Ground Floor spaces.
2.2 CLIMATE CHANGE SCENARIOS & CLIMATE DATA USED

2.2.1 CLIMATE & WEATHER DATA FOR THERMAL MODELLING

Site specific climate data for years 2030, 2050 and 2080 produced by the Prometheus Project from Exeter University was used in NBP’s thermal model to simulate the different predicted climate scenarios. The weather files were based on a high emission scenario, which assumes a high increase in future green house gas and pollutant levels, population, etc.

Each weather file also contains different probability projections for each of the test years. Due to the severity of the risk of overheating to the school, the Team decided to use the 90% ('worst case') projections. This means that it is 90% likely that the temperatures in the critical years will not exceed the predicted data.

It is important to make the client aware of the choice of data to ensure that they understand that what the projections relate to, when assessing the benefits and costs of the proposed adaptation measures. Solutions designed to cope with the 90% data are covering some of the levels of uncertainty and are highly likely to mitigate the projected risks - on the other hand they could also be over-engineered.

Climate predictions are becoming increasingly less precise the further we are looking into the future and it is difficult to persuade a Client to invest for possible events taking place in over 70 years, which is a long time in the life of a building. Analysing the weather data it was noted that the 2050 90% scenario is very similar to the 2080 50% scenario. Therefore, any adaptation measures performing well during 2050 90% high emissions weather data would also perform well during the 2080 50% high emissions weather data and might therefore be a solution to address both timescales.

2.2.2 RAINFALL DATA

Flooding
A model using TuFLOW software had been produced by Entec UK to carry out a simulation for the 1 in 200 year flood event with simultaneous breach of the outer flood defence bund. This takes into account peak tide levels up to year 2110, provided by the Environmental Agency. The determination of the period and shape of the tidal cycle was based on tidal records from the Sheerness gauge.

Water conservation & drainage
As noted before, we felt that the school was likely to be affected both locally and regionally by changes in precipitation patterns and the associated droughts / heavy rain showers.

Whilst the availability of specific climate data for the site in conjunction with a thermal model to test the different scenarios made the use of precise, daily or even hourly information useful, we felt that our research in to the risk around water would benefit more from an understanding of general trends. We decided that the 50% probability (the 'central estimate') and medium emission scenario would give a good general understanding.

Water supply – regional data
The potable water supply to the school is provided by Essex & Suffolk Water. Their area of supply lies within the Anglian river basin area. Obviously the school could change supplier in the future or the delivery structure of water as a resource could become inter-regional, but we felt that this offered a useful starting point.

The UKCP 09 data for the Anglian basin shows a clear reduction in rainfall during the summer months, which is likely to result in more droughts and 'hose pipe bans'. The annual data seems to suggest that the yearly rainfall will remain the same or even increase slightly (due to heavier rain showers in winter months).
### CHANGE IN PRECIPITATION [Anglian basin]

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SUMMER</th>
<th>ANNUAL AVERAGE</th>
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<tbody>
<tr>
<td>2030</td>
<td>- 8.5%</td>
<td>+ 0.4%</td>
</tr>
<tr>
<td>2050</td>
<td>- 18.5%</td>
<td>+ 0.15%</td>
</tr>
<tr>
<td>2080</td>
<td>- 21.5%</td>
<td>+ 0.5%</td>
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Projections for the water supply-demand balance (as published in the DEFRA Climate Change Risk Assessment for the Built Environment Sector) also indicate that the area will experience significant deficits in water supply by 2050.

### Direct impact on site:

We then carried out a similar investigation using the closest 25km grid available near the site. The data output for the site was very similar to the river basin.

As the river basin data already suggested, this confirmed that the site would experience much less rain during summer months (a reduction of up to 23% in 2080), but increased levels of precipitation in winter.

An analysis of the ‘change in precipitation on the wettest day’ gave an idea of a likely change in intensity of heavy showers, though it only gives an approximation of the overall water volume and does not directly translate into the intensity of the rainfall / storm. As discussed before, the overall SUDS strategy has been designed to include a climate change allowance, but specific areas of the school grounds, in particular the sports pitch, could be directly affected.

### CHANGE IN PRECIPITATION ON WETTEST DAY [25KM grid]

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AUTUMN</th>
<th>WINTER</th>
<th>SPRING</th>
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<tbody>
<tr>
<td>2030</td>
<td>+ 6%</td>
<td>+ 8.5%</td>
<td>+ 1.5%</td>
</tr>
<tr>
<td>2050</td>
<td>+ 7%</td>
<td>+ 13%</td>
<td>+ 4%</td>
</tr>
<tr>
<td>2080</td>
<td>+ 10%</td>
<td>+ 16%</td>
<td>+ 5%</td>
</tr>
</tbody>
</table>

### 2.3 OTHER FEATURES SIGNIFICANT TO THE ADAPTATION STRATEGY

As mentioned at the start of this chapter, a main focus of this study became the issues relating to overheating of teaching spaces and the immediate impact on the pupils and staff, both in relation to general well-being and ‘learning performance’.

A review of related research papers reinforced the importance of comfort on learning and teaching. As noted in a report carried out by the Design Council "it has been shown that physical elements in the school environment can be shown to have discernible effects on teachers and learners. In particular, inadequate temperature control, lighting, air quality and acoustics have detrimental effects on concentration, mood, well-being, attendance and, ultimately, attainment”.

In his study into criteria for ‘school building adequacy’ Earthman identifies “Human Comfort – i.e., temperatures within the human comfort range” as the criteria, which most impacts on student achievement. Earthman’s paper also includes a range of interesting case studies relating classroom temperature to student performance and also student behaviour. It should be noted that Earthman seems to assume the installation of an AC cooling system as the only solution to provide the right temperature environment. This report on the other hand aims to investigate alternatives to AC units, both for health and ecological benefits.

During workshops and meetings with the Hinguar School teaching staff and students it also became clear that the qualitative impact of possible overheating was already very present for the school who reported that during spells of hot weather over the recent years, pupils have been less able to concentrate, more ‘hot-headed’ and more difficult to engage and control (“The please and thank you’s are out of the window”).
The teaching staff are also affected by heat stress and additional pressure caused by the pupils underachieving and misbehaving. This is aggravated by thermal discomfort at home, leading to pupils sleeping less during the night and thus being over-tired.

In a workshop with the Hinguar Eco Warriors (a group of pupils from all years, focussing on sustainability issues) the Team asked the pupils for their experience of the heat wave impact. The responses (see figure 16 below) showed that the pupils were aware of temperatures affecting them, both with regards to learning performance: “My brain is too hot – I can’t work” and behaviour: “If it is hot in the playground, we get more angry and spiteful.”
3.0 ADAPTATION STRATEGY

This chapter contains the strategies used by the team to review, appraise and develop a number of potential adaptation measures for the Hinguar School project. Supporting information including sketches, correspondence and product information, has been included in Appendix 3_A.

After an introduction to the overall methodology, this chapter outlines the measures investigated by the team and explains which measures were chosen for further development and recommendation to the client. The options are structured under the main climate risk headings, allowing them to be compared more easily and relating them back to the Checklist 3, which has been included in Appendix 3. This is followed by a cost benefit analysis and implementation timeline, which were used to further rate the various options and provide information to the client. The chapter concludes with an introduction to the monitoring period which will take place in spring/summer 2013.

3.1 METHODOLOGY

The Team adopted a two stage approach:

In the first stage the Team collated a range of potential ideas for adaptation measures, structured under the main climate change design challenges of Thermal Comfort, Water and Construction. The design opportunities identified in Checklist 3 (see Appendix 3) were a useful tool in reviewing the current design and instigate discussions about potential measures. This process also incorporated issues raised by the School and Southend-on-Sea Borough Council during the consultation workshop in November 2011.

The opportunities identified were discussed at the Design Team Workshop in January 2012 and ranked into ‘likely,’ ‘possibly’ or ‘unlikely’ measures to be taken forward as part of the options appraisal. This took into account the weighting of the climate risks, an initial assessment of the financial cost to the project, the likely effectiveness of the measure, potential negative impacts on the building / school and other project specific issues.

In the second stage further research, detail development, costing and modelling was carried out on all potential adaptation measures previously rated as ‘likely’ or ‘possible’ (with some options merged or adapted). Each potential mitigation strategy was reviewed and, where appropriate analysed using a SWOT template developed by the team. Summaries of the SWOT template and workshop discussions have been included in Appendix 3_E.

As noted in the previous chapter, the team focused on the risk of overheating of teaching spaces, which had emerged as a dominant issue during the risk assessment stage. Proposed adaptation measures were tested by NBP in the thermal IES model against the guidelines set out in BB101. Please refer to Section 2.1.1 of this study and NBP’s Thermal Modelling Report in Appendix 2 for more details. A number of other significant risks such as for example as water shortages / rainwater recycling were also pursued.

3.2 ADAPTATION STRATEGY & OPTIONS APPRAISAL

3.2.1 OVERHEATING OF INTERNAL TEACHING SPACES

Overheating had been identified as the dominant risk during the risk assessment stage, due to its direct negative effect on pupils and staff. The different mitigation strategies investigated can be split into four sub categories:

- Keeping the heat / sun out of the building (e.g. through additional shading, improved glazing, planting etc.) -> Options A1 & A2.
- Changes to the building envelope/ structure to increase thermal mass -> Options A3 & A4.
- Enhancing ventilation strategy to mitigate the future installation of AC units -> Options A5, A6, A7 & A10.
- Reviewing changes to user behaviour / management -> Options A8 & A9

Figure 18: Initial sketches for roller shutter option (A1).
OPTION A1: This option investigates the possible introduction of additional shading to south-facing classrooms (including external balcony spaces) and the south-facing library.

(A) External shading to South-facing classrooms
Various arrangements were investigated which are shown in Appendix 3_A with the associated thermal model information included in section 3.1.1 of the Thermal Modelling Report in Appendix 2. A solution using flexible fabric roller blinds was chosen as the most appropriate and effective proposal and is discussed below.

Strengths:
- Big impact on external teaching as additional shading will allow balconies to be used as integral part of the teaching environment.
- Flexible use thus no loss of solar gain in winter which would lead to increase in heating requirements.
- Easy to operate by school. No obstruction to doors for access to balcony.
- Can be integrated in phase 2.

Weaknesses:
- Structural review established that blinds could not be fixed to brise soleils structure. As a result the roller shutters would require a sub frame supported of the podium deck and only laterally supported of he balcony structures. Vertical supports which might be seen as a H&S issue by the school (climbing opportunity).
- Durability issues of moving parts need to be assessed.
- Exposed site location (strong wind) might make operation at times difficult and fabric vulnerable. A ribbonised / perforated fabric could be used to reduce the wind loads.
- Thermal model has shown that any additional shading is unlikely to have a large impact on the internal temperatures. It could though lead to an increase in light loads (reduction of daylight) and thus energy use.

Opportunities:
- Development of a partly fixed (existing louvers), partly flexible (roller shutters) shading system seems to address the necessary balance between reduction of internal heat gain in summer and retention of (positive) solar gain and light levels in winter and could be used on future education projects.

Threats:
- Visual change to elevation might require discussion with planners (both for phase 1 & 2). Due to flexible nature of rollershutters impact is likely to be minimal.

(B) Alterations to external shading to Library
This involved extending the existing brise soleil to the Library curtain walling with a vertical element.

Strengths:
- Thermal model shows good solar gain reduction in autumn, winter & spring months.
- Heating demands in winter only marginally affected (monthly increase of approx. 1%).
- Manufacturer has confirmed that extension in principle possible.
- Adaptation measure could be implemented without causing much disruption to school (scaffold tower on decking).

Weaknesses:
- Structural review suggests that the introduction of tie back wires could lessen the load on the existing louver brackets (which are fixed back to the curtain walling), but this would need to be confirmed by the manufacturer.
- Additional fixed shading could have an impact on daylight levels and thus result in an increased energy use for lighting.

C) Additional planting (deciduous trees) to provide shading
Thermal modelling showed that, in order for trees to provide effective shading in summer, they would need to be placed very close to the building (see Thermal Modelling Report section 3.1.1.), resulting in restrictions to views and potential problems with leaves on balconies, root damage to surfacing as well as possible damage to the building in high winds.

PROPOSED ADAPTATION MEASURE:
Extension of existing brise soille to Library & installation of external fabric roller blinds to Phase 1 (retro-fitted) and Phase 2 (change to design).
OPTION A2: Review of solar performance of glazing specification and possible improvement.

Strengths:
• If g-value performance of glazing was improved, this would have an impact on solar gain and internal temperatures in summer.

Weaknesses:
• Current requirement for control of solar gain within the glazing specification for south-facing teaching spaces is already quite onerous at a g-value of 0.36. It is unlikely that with current technology this could be improved significantly without high cost implications (e.g. triple glazing, which cannot be accommodated in the installed window frames).

Opportunities:
• Future developments in material technology / manufacture might provide new glass technologies.

MEASURE PROPOSED FOR FUTURE REVIEW
Solar Performance of glazing specification.

OPTION A3: This option investigates increasing the thermal mass by exposing the existing structural floor soffits or a change in construction for Phase 2. As the pre-cast concrete slab ceiling construction used in Phase 1 does not lend itself to being exposed, this option would require the floor construction to change to an in-situ slab (see sketch in Appendix 3_A for floor build up).

Strengths:
• Increase of thermal mass likely to have significant impact on stability of internal temperatures (both in summer and winter) as shown in section 3.1.2 of the Thermal Modelling Report.

Weaknesses:
• The weight of insitu concrete is a lot heavier than precast due to the spans involved.
• The First Floor transfer slab, which will be supporting the Phase 2 extension, has been designed to take point loads applied by a steelframe. The use of load bearing masonry will be heavier and place loads away from where the transfer deck has been designed to support them. A structural review has established that sufficient strengthening of the structure would be difficult retrospectively. At present shear heads below some columns have been introduced to stop the punching shear problem. If the load on the slab was increased in order to be able to take a structure which could support exposed floors and heavyweight walls, this would have required an increase in the depth of the transfer slab at construction stage. Due to the site levels the design had to accommodate (e.g. the car park ramp / road levels and the entrance ramp levels to the front), this would not have been possible.
• Suspended acoustic panels will be required to meet BB93. This will have an implication on the services & sprinkler installation.
• Costings show a RC floor construction for Phase 2 as about 2.5 times more expensive compared to the pre-cast plank construction installed in Phase 1.

Opportunities:
• Opportunities for thermal mass should be reviewed early on in future projects.

Threats:
• Precast concrete planks on a steel frame is a quick and light form of construction, changing to in-situ could result in a longer construction period. Construction programmes for schools are often restricted in time as they need to work within term times and minimise disruption to the school. This will be particular relevant for the Phase 2 extension.

Measure not proposed.

OPTION A4: Increase in insulation properties of flat roofs through increase in insulation thickness or introduction of sedum roof (see sketch in Appendix 3_A & section 3.1.3 of the Thermal Modelling Report).

Strengths:
• The introduction of a sedum roof could provide additional thermal insulation and also deal with increased run-off rates during predicted heavier rainstorms / showers.
• Bauder Roofing have advised that a sedum roof could be retrofitted on top of the single-ply membrane roof currently installed.
• Adaptation measure could be integrated in Phase 2 construction.

Weaknesses:
• Parapet height / rooflight up stands might need to be increased in height for roof above hall if sedum layer is installed.
• Thermal modelling has shown that even an increase from the current 120mm insulation to 250mm thickness would only result in a small reduction in u-values.
• The roovescape already accommodates a large amount of upstands for rooflights etc and services elements (PV’s, extracts, windcatchers, etc), which would make it difficult to retrofit a continuous sedum roof.

Opportunities:
• Outcome of further investigations could be relevant to future projects.

Threats:
• UKCP 09 data shows that summers will be increasingly dry, which might require the plants / concept of sedum roofs to be reviewed in order to avoid a need for artificial irrigation (e.g. leaky pipe).

PROPOSED ADAPTATION MEASURE:
Installation of sedum roof as part of Phase 2 works.

OPTION A5: Fine tuning of BMS for ventilation in collaboration with the school

Strengths:
• Low cost impact as no additional equipment required from School & Council.
• The headteacher noted that staff involved might be less likely to attempt to override the BMS settings manually in the classrooms to suit their individual preferences during the acclimatisation to the new building.

Weaknesses:
• Might be difficult to precisely test and compare different scenarios (e.g. night time cooling on weekends through louvers only, etc) due to fluctuations in weather during monitoring period.
• Cost of monitoring equipment.

Opportunities:
• Involvement of pupils and staff during the 12 month monitoring period.
• Useful feedback for future education projects and educational opportunities for pupils.

PROPOSED ADAPTATION MEASURE:
Monitoring period in spring/summer 2013 to be used to fine-tune BMS and maximise performance, in collaboration with school.

OPTION A6: Introduction of electrical fans to support natural ventilation strategy.
Please refer to section 3.1.4 of the Thermal Modelling Report and Appendix 3_A.

Strengths:
• Significant impact on internal temperatures in classrooms.
• Can be retro-fitted in Phase 1 and included in design for Phase 2.
• Relatively low cost for individual fans, compared with installation of full air conditioning (see section 3.3.2.1).

Weaknesses:
• Possible impact of fan noise on classroom environment has been discussed with the Acoustic Consultant. Internal noise levels within classroom need to comply with BB93. As a result it is likely that a roof mounted fan with attenuator will be required.
• Thermal modelling shows that this option is only adequate to deal with the predicted temperature increase up to 2030. Additional measures will be required for future years, with the electrical fans only being of minimal impact in conjunction.
• Increase in energy use.
• Additional roof trimmers might be required depending on final fan weight. Fan to be supported on a collar to spread additional load evenly.

Opportunities:
• Airscoop manufacturer’s Passivent are currently looking into developing a retro-fitted fan option for the Airscoop product installed.

Threats:
• Guidelines for overheating might become more onerous and require installation of full air conditioning rendering this adaptation obsolete.

PROPOSED ADAPTATION MEASURE:
Installation of electrical fans in Phase 1 (retro-fitted) and Phase 2 (change to design).
OPTION A7: Introduction of ground source heat pump (GSHP) or air source heat pump (ASHP) for reverse cooling in summer through under floor heating (UFH). Refer to section 3.1.5 of the Thermal Modelling Report.

Both systems would be suitable, with the ASHP being less efficient but more economic in terms of capital costs (see section 3.3.2.1 for cost analysis). A GSHP system using vertical boreholes was discussed as a less disruptive alternative, compared to a coils system, which would require a large area of the school grounds to be excavated.

Strengths:
- The thermal model shows that a reduction in floor temperatures by 2-3 degrees could be achieved, which would have a significant impact on the internal room temperatures in 2050 and 2080.
- Significant lower cost and CO2 emissions compared to AC unit installation (see section 3.3.2.1).

Weaknesses:
- Some works to existing UFH system required, as discussed with heating manufacturer.
- Acoustic ventilated enclosure on school ground required to accommodate ASHPs. This will need to be agreed with the Planning Authorities, to ensure noise output levels are within the allowable limits.
- Restriction to what cooling output can be achieved using the UFH system due to the number of pipe coils in the floor and the risk of condensation forming on the floor if cooled too much.

Opportunities:
- More efficient GSHP technology developed in future might decrease space requirements, reducing impact on landscaping.
- Outcome of further investigations could be relevant to future projects.
- The GSHP/ASHP’s proposed have been sized to provide the cooling outputs only. However, if gas supplies diminish further in the energy costs escalate, a portion of the school’s heating needs could be met by the GSHP/ASHP (this would require additional alterations to services). Alternatively a larger GSHP could be installed to replace the gas boilers.

Threats:
- Disruption to school curriculum (external activities) as remedial works to landscaping will take time to establish.

PROPOSED ADAPTATION MEASURE:
Installation of GSHP or ASHP for reverse cooling using UFH system.

OPTION A8: Organisational changes to daily school timetable, including introduction of siesta / ‘relax’ time during hottest period of the day.

The breakdown of daily summer temperatures shows peak temperatures occurring about 2.30pm. The proposed scenario introduces a 2 hour siesta from 1pm to 3pm with all pupil / staff vacating the relevant teaching spaces.

Strengths:
- Thermal modelling shows that the introduction of siesta shifts the temperature peak to about 5pm which roughly coincides with the children finishing the revised school day. (Refer to section 3.1.6 of the Thermal Modelling Interim Report).
- Further benefit might be gained from an earlier start to the school day.

Weaknesses:
- School timetable would need to be adapted to start earlier and offer outside / alternative activities outside classrooms during siesta time (e.g. relax time in Hall?)

Threats:
- Impact on parents (pick up / drop off) as school day is shifted or if parents need to look after pupils during siesta time.
- Cost to council if alternative activities / facilities / supervision are required during siesta time.

MEASURE PROPOSED FOR FUTURE REVIEW:
Review of school timetable to avoid peak temperatures in summer.
**OPTION A9:** Maximise impact of use of flexible teaching spaces and class sizes on internal temperatures: (Refer to section 3.1.7 of the Thermal Modelling Report.)

**Strengths:**
- Some of the opportunities provided by the flexible room layout (see Appendix 3_A) could have a positive impact on internal temperatures (e.g. extended north-south cross ventilation, increase m² per pupil, etc).
- No additional cost impact, as already in place.

**Weaknesses:**
- Restrictions on certain room arrangements during hotter months will reduce the teaching flexibility for the school.

**Opportunities:**
- Findings could impact on classroom layouts for future education projects.

**Threats:**
- Option would rely on ongoing user involvement, which cannot be guaranteed.

**PROPOSED ADAPTATION MEASURE:**
Monitoring period in spring/summer 2013 to be used to investigate impact of flexible arrangements. Include flexible layout in future school design.

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**OPTION A10:** Installation of mechanical cooling using a ‘thermal battery’ (Monodraught CoolPhase system—see product information in Appendix 3_A).

The system introduces a small but efficient element of thermal mass to the spaces in form of ‘phase change material,’ which is located within the ventilation installation.

**Strengths:**
- Low energy system (compared to air conditioning). Manufacturer claims the system uses up to 90% less energy compared to a conventional cooling system.
- Lower cost than AC installation (but higher than ASHP or GSHP).
- System can be used in winter to trap heat and warm up any cool air entering the building for ventilation. This would have a positive effect on the heating demands.

**Weaknesses:**
- Phase 1 retrofitting; alterations to external façade, soffit and lowering of internal ceiling heights required.
- Impact on ceiling layout, including sprinklers and lighting.
- Current system requires individual units for each space, multiplying any alteration works to external envelope.
- Potential interface issues with BMS already installed due to different manufacturers.
- Thermal model shows system struggling to meet BB101 requirements in 2080.

**Opportunities:**
- Manufacturer has been co-operative in investigation (providing thermal modelling of building for future years), might be scope to develop a more specific, flexible system with them.
- Other similar products using ‘thermal batteries’ might be available in the future, making the market more competitive.

**Threats:**
- New material - how will phase change material perform in future?
- No long term projects yet to provide precedents. (Manufacturers warranty for 5 years only).

**PROPOSED ADAPTATION MEASURE:**
Installation of CoolPhase system to teaching spaces.
3.2.2 OVERHEATING OF EXTERNAL SPACES

OPTION B1: Review adaptability of covered external areas to accommodate sports and teaching activities.

As part of this study, the team carried out a study amongst member of staff at the existing Hinguar Primary School to investigate which ‘external classroom elements’ were considered to be of most importance to the teachers. Six staff including the head teacher took part and the results are shown below (see also Appendix 3).

The diversity of the responses and further discussion with the school made it clear that further much more detailed development would be required to successfully define the brief for an ‘external classroom kit’ and to ensure that it becomes a useful tool to deliver teaching and learning outside. Apart from designers this would need to involve the Council’s education department and more teaching staff and was felt to be outside the realms of this study.

| 1 | Acoustic division to the surrounding spaces (e.g. in form of acoustic screens etc). | 2 | 4 |
| 2 | Visual division from the surrounding spaces (e.g. in form of visual screens etc). | 2 | 4 |
| 3 | A permanent clear definition of the ‘teaching space’, for example a change in floor finish, a painted line, a defined enclosure. | 4 | 2 |
| 4 | Fixed seating, such as permanent benches. | 2 | 2 | 2 |
| 5 | Flexible / mobile seating for pupils and staff. | 3 | 3 |
| 6 | Writing surfaces for pupils (e.g. tables, ledges to seats). | 3 | 3 |
| 7 | Mobile storage units to contain teaching equipment. | 3 | 3 |
| 8 | Wireless ICT connection. | 4 | 1 | 1 |
| 9 | Larger ICT equipment for shared use (i.e. interactive whiteboard/screen). | 2 | 3 | 1 |
| 10 | Mobile ICT equipment for individual use (e.g. laptops, tablets). | 3 | 3 |

Strengths:
- IT provision installed in school has recently been adapted to allow for WIFI coverage of all external areas in collaboration with the council’s IT advisor (additional outlets were fixed to underside of covered play area softfit), making external use of IT devices possible.
- Adding back the ‘tree house’ which was omitted during an earlier VE exercise would offer an additional external classroom.

Weaknesses:
- Initial discussions with the school and staff have shown that further development would be needed to establish a ‘brief’ for an external classroom kit.
- Potentially high cost risk as concept will need to be trialed to establish how well it can be integrated into teaching curriculum.

Opportunities:
- Advances in technologies will increase flexibility (e.g. more affordable handheld devices which can be read in daylight such as Kindles).
- Could additional funding be available as this might be a generic investigation?
- Could be developed as a kit of parts to be employed in other schools.

Threats:
- Statutory guidance for teaching spaces (acoustics, ergonomics, lighting, etc) might not be fulfilled. Will this keep the external classroom from becoming an ‘official’ teaching space and restrict its use?

PROPOSED ADAPTATION MEASURE:
Development of standard ‘external teaching kit’ for schools to encourage external teaching activities.
OPTION B2: Review of plant selection and gradual replacement with more drought resistant species:

The selection of currently specified plants (including native plants) might need to be adjusted in the future to respond to water shortages and higher external temperatures.

Judging the adaptability of the currently specified plant has proved difficult. Space Craft Architects has visited the Dry Garden project set up by RHS Garden Hyde Hall and consulted with Ian Bull, the Garden Manager looking after this area. Of the plants specified for the Hinguar project, only three (Cictus scoparius, Clematis vitalba and Rosa canina) are of the same genus of plants listed in the Dry Garden Plants A-Z published by RHS Hyde Hall. Sketch SK_011 shows areas which might be suitable for re-planting. From our research it has become clear that an adequate drainage layer would need to be installed as drought resistant plants tend not to cope well with sudden increase in ground moisture (e.g. increasingly frequent heavy rain showers), especially as we are already dealing with a generally very wet site. This does not make this option very viable for the school. However, the specification of drought resistant plants should be considered for other future projects.

Strengths:
- Gradual replacement could be integrated into the landscape maintenance cycles.
- Drought resistant plants require less maintenance, leading to decrease in water used for upkeep in summer or loss of plants during school summer holidays.

Weaknesses:
- Installation of a drainage layer would require extensive alterations to landscaping.
- Most drought resistant species require high solar gain (generally south-facing areas), limiting the areas of potential application.

Opportunities:
- Findings could be applied to plant selection in future projects.

Measure not proposed.

3.2.3 DAMAGE TO BUILDING STRUCTURE & FOUNDATIONS DUE TO CLAY SHRINKAGE

OPTION C1: Review of current foundation design to predict and minimise any impact of change in soil conditions, such as shrinkage of clay rich soils due to reduced rainfall.

This problem has already been addressed through the use of a pile foundations. The 350mm diameter piles have been taken down well below the zone where changes in moisture content within the clay may lead to shrinkage.

The clay subsoil found on site contains sand and is unlikely to be susceptible to ground movement associated with clay heave or shrinkage. (The site investigations report notes the ground as ‘stiff’ to ‘very stiff’ silty clay with fine sand.)

Measure not proposed as already implemented as part of design.

OPTION C2: Review of potential impact of clay shrinkage on retaining walls & sloped landscape along New Garrison Road.

The structural engineer advised that there is a potential risk. However the makeup of the subsoil of the bank shows a lot of gravelly sandy clay subsoil which has less of a problem with shrinkage associated with drying out.

Option not to be taken forward as adaptation measures could not be developed in time to be implemented in the ramp construction which was already underway at the time of writing.

3.2.4 IMPACT OF INCREASE IN FREQUENCY / SEVERITY OF WIND DRIVEN RAIN & OF INCREASE IN UV INTENSITY ON MATERIALS

OPTION D1: Review of external cladding materials with regards to increased wind loads / heavy rainfall / UV exposure and replacement of these as part of the school maintenance cycle.

The external materials specified already have a good durability to UV exposure and wind driven rain (35 year lifespan guarantee for terracotta tiles, 50 years for fibre cement and laminated rainscreen cladding). It is likely that by the end of their lifetime cycle technological changes will offer a different range of materials which might be even more adept at addressing these challenges.

MEASURE PROPOSED FOR FUTURE REVIEW:
Review of materials available should be included as part of the maintenance cycle.
3.2.5 REDUCTION IN RAINFALL AND WATER TABLES PUT STRAIN ON POTABLE WATER SUPPLIES

OPTION E1: Upgrading of sanitary fittings specified for phase 1 and review of phase 2 fittings to reduce water usage. Sanitaryware for Phase 1 has already been specified to minimise water usage (low-flush volume, delay action inlet valve, etc). Touch free sensors taps are provided to pupil WC’s where trough basins are used, but not to standard basins.

Strengths:
- Retrofitting of touch-free sensors to all Phase 1 wash basins would reduce water wastage.

Weaknesses:
- Additional cost might outweigh benefit as these are located in WC’s used by staff/visitors/older pupils who are more likely to turn taps off anyway.

Opportunity:
- Might be an opportunity to recommend this as a standard for council schools.

PROPOSED ADAPTATION MEASURE: Retrofitting of touch-free sensors to all wash basins.

OPTION E2: Introduction of rainwater harvesting for external landscaping/vegetable patch and grey-water recycling in phase 2. Please also refer to section 3.3.2.2.

As discussed in section 2.1.3, water shortages would have a significant impact on the school. In addition the cost of water is likely to increase with the resource diminishing, which could put a strain on the school budget.

(A) Installation of rainwater butts for irrigation of landscape / school vegetable garden
Due to the habitable rooms of the building being raised onto the transfer slab, rainwater pipes are running exposed in the car park and covered play area. Individual rainwater butts for use by pupils and staff could be placed in strategic locations to collect and store water for irrigation during the increasing dry summer months. (See Appendix 3_A for potential locations.) This would also provide a learning resource for pupils.

(B) Installation of rainwater harvesting to serve WC’s in phase 1 and phase 2
Both above and below ground tank options were considered.

An above ground tank located in the stair core 2, which will be freed up during the Phase 2 construction works, was initially looked at as the more economic and less disruptive option. It was proposed that the tank would link into the existing RWP’s running along the transfer slab soffit. However, this would limit the ‘harvestable’ roof area and result only in sufficient water for 8-10 pupil WC’s. The option was discarded when a structural review flagged up that the location of the tank would put significant strain on the existing pile caps, resulting in expensive and disruptive foundation works.

The proposed adaptation measure therefore assumes an underground tank within the school grounds linked to the existing drainage runs. Any overflow from the tank during the increasingly heavy rainfall in winter months could be discharged into the SUDS drainage already installed and continue to the attenuation pond / ditches.

Figure 27: Sketch showing proposed location of below ground tank for rainwater harvesting.
Strengths:
- Reduction in potable water used for WC flushing.
- Underground tank can be installed without much disruption to school / existing building, apart from, where the rising main is redirected.
- Works could be carried out during phase 2 construction works, when this area will need to be excavated and re-landscaped to provide foundations for the new playdeck above.
- Initial calculations of rainfall figures suggest that the equivalent of about 24-30 toilet cisterns could be served by the rainwater harvested.

Weaknesses:
- Interfaces with services to WC’s and roof areas for grey-water recycling already installed would need further consideration.
- Access requirements to tank, pump and filter will need to be addressed as part of the phase 2 detail design, especially as these would be located within areas accessible to the pupils.
- Long payback period (see section 3.3.2.2).

Threats:
- UKCP data shows significant decrease of rainfall during summer months, which might make use of rainwater for WC’s during this period not possible.

3.2.6 INCREASE IN RAINFALL MIGHT PUT STRAIN ON SUDS DRAINAGE SYSTEM

OPTION F1: Adaptation of the currently installed SUDS strategy to ensure this can deal with an increase in heavy rainfall.

The current SUD system installed in the school grounds provides 266m3 of storage within gravel filled trenches and french drains before discharging into the existing surface water ditch at a discharge rate of 2.15 l/s, as agreed with the Environmental Agency (see details of attenuation pond shown in figure 28).

The system already allows for climate change rainfall for a 1 in 100 year storm with a 30% additional allowance for climate change increase. Any additional hard standing introduced as part of phase 2 will need to be porous to allow for thunderstorm rainfall water to pass through.

A more onerous SUD strategy providing 450m3 of storage (see Appendix 3_A) had originally been developed during the design process and could be re-introduced, though this would cause disruption to landscaping. Costs for this item are included in Appendix 3_B.

The current build up for the raised playdeck area features a ‘green roof’ drainage layer. When a new playdeck is constructed in Phase 2, the storage and discharge of the deck could be reviewed in line with further data on rainfall, which might be available then.

MEASURE PROPOSED FOR FUTURE REVIEW:
Future review of SUDS strategy recommended if more detailed rainfall data available in the future suggests this is required.

OPTION F2: Develop strategy for use of external spaces as part of the curriculum to make sure external activities are maintained (‘wellies & raincoats approach’). How could learning & teaching be adapted to the changing climate?

On further discussion the Team decided that this option was outside the scope of this study as it will need to be developed by the school / council as part of their school and borough wide curriculum vision.

Measure not proposed.
OPTION F3: Adaptation works to sports pitch to ensure continuous use during wetter winter months.

An increase in heavier rain showers, as indicated by the UKCP09 data, could put strain on the drainage installed in the existing grassed sports pitch and result in an increase in days when the pitch will not be usable by the school. This could be aggravated by an increase in fluvial flooding.

Due to the school site being located in a flood zone, raising the sports pitch would require an equal volume of soil to be displaced elsewhere on the site, which is not viable. Due to the high groundwater levels, lowering another part of the site would render this area unusable. Improving the existing drainage through the installation of a thicker gravel drainage layer and reseeding of the pitch would require extensive ground works and might not fully address the issue caused by high groundwater table and potential flooding from the nearby ditch.

The installation of an artificial pitch with integrated drainage was considered the most efficient method to address any potential future issues (albeit an expensive option). An artificial pitch would also reduce the impact of hotter dryer summers on the pitch and the demand for water for irrigation. On the other hand it would result in a loss of vegetation on the school site. Cost for this option need to be confirmed yet.

Whilst the UKCP09 data clearly shows an increase in precipitation on wetter days by 2080, it is difficult to assess at this stage if the increase in rainfall will become an issue for the pitch.

PROPOSED ADAPTATION MEASURE:
Artificial sports pitch to be installed in lieu of current grass pitch.

3.2.7 INCREASED RISK OF FLOODING DUE TO RISE IN SEA LEVELS

OPTION G1: Ongoing review of the Evacuation Strategy to adapt to potentially more frequent flood warnings.

The flood risk strategy from which the an Emergency Evacuation Plan was developed is based on rising sea level predictions up to the year 2100, thus already encompassing the timescale covered by this study.

As shown in figure 30, all teaching facilities and the main plant room are located above the predicted '1 in 200 years & defences breech' flood level.

If future flood level predictions show an increased likelihood of flooding beyond what has been allowed for, it is likely that the council will address the issues in the current flood defences (i.e. raising the lower section of the bund). Essentially this would make the school site less prone to flooding.

It might be necessary to adjust the ‘evacuation trigger level’ in line with rising sea levels to find the right balance between a suitable safety thresholds and not causing too much disruption to the school. The team will suggest that this is included in the regular review of the Emergency Evacuation Plan, but decided that implementation was beyond the scope of this study.

Measure not proposed, but should be included in the regular review of the Emergency Evacuation Plan.
OPTION G2: Post flood recovery measures - to minimise the impact of a flood event on teaching facilities /delivery of teaching.

This measure was considered outside the scope of this study by the team as it will involve mainly organisational issues, which need to be addressed by the school and the Council. The likelihood of a flood event occurring is too low to make permanent features (e.g. stand-by generator, temporary classroom strategy, etc) viable. In the event of a bund breech the First and Second Floor containing all teaching facilities, will remain above flood level, so the main disruption will be to incoming services and access at Ground Floor level.

The team will recommend to the school / council that a review of post flood recovery measures is included in the regular Emergency Evacuation Strategy review.

Measure not proposed, but should be included in the regular review of the Emergency Evacuation Plan.

3.2.8 INCREASED RISK OF FLOODING DUE TO RISE IN GROUND WATER LEVELS AND / OR FLASH FLOODING FROM ADJACENT SITES

OPTION H1: ‘Dry-proofing’ of sensitive rooms at Ground Floor level in case of flooding. Refer to sketch SK_005 for possible mitigation measures which have been investigated together with potential issues raised.

Strengths:
• Dry-proofing of rooms containing equipment (e.g. meter room, sprinkler tank room, etc) would reduce costs and time required for school to re-inhabit the building following a flood event.
• Replacing of plasterboard walls with painted exposed block work / concrete walls would reduce damage to finishes in case of a flood event. (But: services currently behind plasterboard would need to be changed to surface mounted.)

Weaknesses:
• Dry-proofing measures only likely to mitigate against fluvial / ground water flooding, not tidal. (Most proprietary measures (such as flood barriers/ shutters) are developed for a flood level of about 1m above FFL. In the unlikely event of a 1 in 1000 year flood event and simultaneous bund breech, the ground floor will be flooded to about 2.9m above FFL.)

• The r/c concrete walls were designed to withstand hydrostatic pressure in a flood event, but not to be fully ‘watertight’ in such a situation. Designing the walls as fully watertight is achievable but likely to be difficult retrospectively. Depending on levels of fluvial flooding (not available) this might not be an issue.
• Gulleys in Sprinkler Room and Pool Plant Room would need to be filled in and relocated externally to avoid water ingress. Mobile sump pumps would be required to deal with occasional flooding of rooms during maintenance.

Threats:
• Statutory requirements for protection of services could change resulting in a requirement to relocate the equipment to the First Floor or raise it on plinths.

PROPOSED ADAPTATION MEASURE:
‘Dry-proofing’ of sensitive rooms at Ground Floor.

3.3 SUMMARY OF ADAPTATION MEASURES INVESTIGATED

Figure 31 on the following pages shows a summary of the potential adaptation measures and which of the measures were selected as ‘proposed adaptation measures’ and ‘measures proposed for future review’ following the SWOT analysis. Further potential measures had been discussed and discarded during the initial design team work shops. This process has been documented in for of Design Team Workshop ‘Option Matrix’ documents, which are included in Appendix 3_E.
<table>
<thead>
<tr>
<th>Description of potential adaptation measure</th>
<th>Measure proposed for implementation in future</th>
<th>Changes to Phase 2 design would aid implementation of measure in future</th>
<th>Measure proposed for future review</th>
<th>Measure not proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RISK: OVERHEATING OF INTERNAL SPACES DURING HOTTER SUMMERS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1 (a) Introduction of additional external shading devices to provide shading.</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1 (b) Introduction of additional planting (deciduous trees) to provide shading.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>A1 (c) Adaptation of external shading (to library).</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>A2 Review of solar performance of glazing specification and possible improvement.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3 Increasing thermal mass by exposing of Phase 2.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>A4 Increase in insulation properties of flat roofs through increase in insulation thickness or introduction of sedum roof (phase2)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>A5 Fine tuning of BMS for ventilation in collaboration with the school.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A6 Introduction of electrical fans to support natural ventilation strategy.</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>A7 Introduction of ground source heat pump or air source heat pump for reverse cooling in summer through under floor heating</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A8 Organisational changes to daily school timetable, including introduction of siesta during hottest period of the day.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A9 Maximise impact of use of flexible teaching spaces and class sizes on internal temperatures.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>A10 Installation of mechanical cooling using a ‘thermal battery’ (e.g. Monodraught CoolPhase system).</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>RISK: OVERHEATING OF EXTERNAL SPACES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1 Review adaptability of external areas &amp; develop ‘external teaching kit’ to encourage teaching activities.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2 Review of plant selection and gradual replacement with more drought resistant species.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>RISK: DAMAGE TO BUILDING STRUCTURE &amp; FOUNDATIONS DUE TO CLAY SHRINKAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1 Adapt of foundation design to minimise any impact of change in soil conditions, such as shrinkage of clay rich soils.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2 Review of potential impact of clay shrinkage on retaining walls &amp; sloped landscape along New Garrison Road.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>RISK: IMPACT OF INCREASE IN WIND DRIVEN RAIN &amp; UV INTENSITY ON MATERIAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1 Review of external cladding materials as part of maintenance/replacement cycle (increased wind loads / rainfall / UV exposure).</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Description of potential adaptation measure</td>
<td>Measure proposed for implementation in future</td>
<td>Changes to Phase 2 design would aid implementation of measure in future</td>
<td>Measure proposed for future review</td>
<td>Measure not proposed</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
<td>-----------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>RISK: REDUCTIONS IN RAINFALL &amp; WATER TABLES PUT STRAIN ON POTABLE WATER SUPPLY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1 Upgrading of sanitary fittings to reduce water usage.</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E2 (a) Installation of rainwater butts for irrigation of landscape / school vegetable garden</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E2 (b) Installation of rainwater harvesting to serve WC’s in phase 1 and phase 2</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RISK: INCREASE IN RAINFALL MIGHT PUT STRAIN ON SUDS DRAINAGE SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 Adaptation of the currently installed SUDS strategy to ensure this can deal with an increase in heavy rainfall.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2 Develop strategy for use of external spaces as part of the curriculum.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>F3 Adaptation works to sports pitch to ensure continuous use during wetter winter months.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RISK: INCREASED RISK OF FLOODING DUE TO RISE IN SEA LEVELS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1 Ongoing review of the Evacuation Strategy to adapt to potentially more frequent flood warnings.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>G2 Post flood recovery measures - to minimise the impact of a flood event on teaching facilities / delivery of teaching.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RISK: INCREASED RISK OF FLOODING DUE TO RISE IN GROUND WATER / FLASH FLOODING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1 ‘Dry-proofing’ of sensitive rooms at Ground Floor level in case of flooding.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4 COST BENEFIT ANALYSIS AND RISK MITIGATION OF IMPLEMENTING THE SHORTLISTED MEASURES

We took two different approaches to the cost analysis of the adaptation measures:

The first part of this chapter contains a list of cost estimates for each measure, limited to overall installation costs only. This communicates a general idea of cost to the Client and will be an important tool in assessing budgets for retrofitting/maintenance as well as the construction budget for the Phase 2 extension. A summary of (installation) costs for the proposed adaptation measured in shown in figure 32. More detailed cost break downs have been included in Appendix 3_B.

The team felt however that these figures only gave a limited pictures, as they do not take into account any long term benefits (financially and otherwise) which the Council/School might incur from the individual measures.

In the second part of this chapter we have therefore tried to establish 'benchmark' scenarios to assess the 'value' (financially and otherwise), which can be used to compare the various proposed adaptation measures against.

This has been carried out for the risk associated with overheating of internal teaching spaces and the various ventilation strategies as well as rainwater harvesting/water shortages.

3.4.1 COST ANALYSIS FOR ADAPTATION MEASURES

Figure 32 (see next page) provides a table of cost estimates for the proposed mitigation measures identified in section 3.0 of this report. All costs within the table are at 4Q2012 prices.

The explanation below should be read in conjunction with Figure 32.

**Measure A1:** The costs provided in this section relate to the additional external shading options for the south facing classrooms and library.

Cost option A1a is to retrofit additional louvres to the library. This option was selected as it offers the most economic shading solution as it involves extending the existing louvre.

Option A1a relates to the installation of blinds to the phase 1 classrooms. Alternative blinds and other shading systems were considered but were dismissed on the basis of cost, practicality of fitting, flexibility of use, robustness or the risk of climbing by school pupils. Flexible external blinds are relatively simple to retrofit with little disruption to the existing structure. Costs for phase 1 (the existing building) are higher due to the need to replace and adapt existing finishes. For the phase 2 extension the balconies and deck areas can be designed to suit.

**Measure A2:** This relates to future technology and cannot be costed at present.

**Measure A4:** This option is for the introduction of a sedum roof to the existing roof finish. The school is finished with a flat roof membrane which is suitable for the further installation of a green roof system. Costs for phase 1 and phase 2 would be similar as no adaptation of the existing roof is necessary.

**Measure A5:** This looks at the refining of the existing BMS technology over time. No capital expenditure is anticipated for this.

**Measure A6:** This considers the use of electrically powered fans to assist and expand the effect of the natural ventilation system. Costs for the existing building are higher as the works involve adapting the existing ventilation shafts, constructing enclosures and forming louvres for fans connected to the roof lights. Phase 2 works assume that the building is constructed to suit the fans and that no adaptation is necessary in the future.

**Measure A7:** This measure is split into two separate options:

A7a looks at the installation of Ground Source Heat Pumps (GSHP) utilising the existing (and proposed) underfloor heating circuits installed within the school. Costs would be significantly higher had the existing building not had underfloor heating already installed. Costs allow for vertical boreholes rather than horizontal pipework for the ground source pipework as this alleviates disruption and the cost of excavating and reinstating the sports pitch or playgrounds.

A7b looks at an alternative to the GSHP; Air Source Heat Pumps (ASHP). These have a significantly lower capital cost and cause less disruption in their installation.

Performance comparisons of these two options are considered in figure 33.

**Measure A8:** This adaptation is concerned with alterations to the school timetable and does not have any capital cost implication.
Measure A9: This adaptation is concerned with alterations to the way the school is used and does not have any capital cost implication.

Measure A10: Adaptation measure A10 provides a cost alternative for the GSHP and ASHP by looking at a Monodraught Cool-phase. Costs include the structural alterations and additional works necessary for the installation of the system.

Comparative benefits of this system are considered in figure 33.

Measure B1: Measure B1 is concerned with the creation of an external teaching space for use during warmer weather. At the phase 1 design stage the creation of a treehouse was considered. Costs for adding this back have been included. This would be separate from the main building and would not cause disruption or result in works to existing buildings.

Measure D1: This measure looks at the replacement of the external cladding material in the future. This assumes that alternate better performing products will become available and is therefore not possible to price at this time.

Measure E1: Option E1 is to retrofit touch free sensors to all of the first phase taps. Costs allow for power supplies and adjustments to existing services as well as replacing taps where necessary. Touch free taps are designed to reduce water consumption.

Measure E2: This option considers reuse of rainwater within the site. The first option considers the use of above ground rainwater storage tanks for use as irrigation for the school gardens and grass areas. The tanks would be linked directly to existing down pipes so additional works are mitigated. The second option looks at the use of below ground water storage tanks and reuse for flushing WCs. This would require some adaptation to the above ground drainage system and changes to the supply pipework and this all forms part of the capital cost. With this option there would be ongoing charges for electricity and maintenance on the pumps.

Measure F1: Measure F1 looks at increasing the on site storage provision for surface water run off based on the increased levels of rainfall anticipated. The option is significantly more expensive than a new scheme with larger storage built in as it involves extending the additional drainage system, replacing pipework and making good surfaces of play areas disturbed.

Measure H1: This option reviews the strategy of the building in times of significant flood. The current building has all of its key accommodation at first and second floors with some ancillary space as well as car parking at ground floor. The strategy designed is that in the case of significant flooding (due to the sea wall being breached) the ground floor areas will flood. These are designed so that any flood will cause minimal damage however some damage is inevitable. H1 considers the use of additional dry proofing measures to the ground floor rooms and the cost is shown for providing fully sealed doors to this space.
<table>
<thead>
<tr>
<th>PROPOSED ADAPTATION MEASURE</th>
<th>INSTALLATION COST ESTIMATES</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1a Extension of existing louvers to Library</td>
<td>£6,600.00</td>
<td>Includes scaffolding costs.</td>
</tr>
<tr>
<td>A1b Installation of fabric roller shutters retrofitting in Phase 1 integration into Phase 2 design</td>
<td>£12,100.00</td>
<td>£9,724.00</td>
</tr>
<tr>
<td>A2 Review of solar performance of glazing</td>
<td>N/A</td>
<td>Costs for potential future technologies not available.</td>
</tr>
<tr>
<td>A4 Introduction of sedum roof</td>
<td>£61,400.00</td>
<td>Cost for installation to Phase 1 &amp; Phase 2 roof areas.</td>
</tr>
<tr>
<td>A5 Fine-tuning of BMS system for ventilation</td>
<td>N/A</td>
<td>System already in place.</td>
</tr>
<tr>
<td>A6 Introduction of electrical fans to support natural ventilation strategy</td>
<td>£39,200.00</td>
<td>See section 3.3.2.1 for details and cost benefit analysis.</td>
</tr>
<tr>
<td>A7a Installation of GSHP for reverse cooling through UFH. Phase 1</td>
<td>£212,800.00</td>
<td>£199,584.00 Based on 2050 figures &amp; vertical GSHP - see section 3.3.2.1 for details. Cost for remedial works to landscaping not included.</td>
</tr>
<tr>
<td>A7b Installation of ASHP for reverse cooling through UFH. Phase 1</td>
<td>£33,264.00</td>
<td>£26,880.00 Based on 2050 figures - see section 3.3.2.1 for details.</td>
</tr>
<tr>
<td>A8 Review of school timetable / introduction of ‘siesta’</td>
<td>N/A</td>
<td>Organisational issue. Potential cost for additional staff or spaces required during siesta period?</td>
</tr>
<tr>
<td>A9 Using opportunities offered by flexible teaching spaces to reduce internal temperatures</td>
<td>N/A</td>
<td>Organisational issue. Flexible partitions already in place.</td>
</tr>
<tr>
<td>A10 Install Monodraught system for cooling. Phase 1</td>
<td>£143,584.00</td>
<td>£88,325.00</td>
</tr>
<tr>
<td>B1 Introduce ‘external teaching kit’ to encourage increase use of Treehouse as external teaching space</td>
<td>N/A</td>
<td>Further investigation required to establish final brief.</td>
</tr>
<tr>
<td>D1 Replacement of external cladding materials</td>
<td>N/A</td>
<td>Costs for potential future materials not available.</td>
</tr>
<tr>
<td>E1 Retrofitting of touch free sensors to all Phase 1 wash basins.</td>
<td>£9,200.00</td>
<td></td>
</tr>
<tr>
<td>E2 Rainwater harvesting installation of rainwater butts linked to RWP’s for irrigation</td>
<td>£5,600.00</td>
<td>£3,210.00</td>
</tr>
<tr>
<td>F1 Increase in SUDS strategy storage capacity.</td>
<td>£105,800.00</td>
<td>Based on original drainage scheme with higher storage capacity.</td>
</tr>
<tr>
<td>F3 Replacing of sports pitch with artificial pitch.</td>
<td>TBC</td>
<td></td>
</tr>
<tr>
<td>H1 Introduction of 'dry-proofing' measures to sensitive Ground Floor spaces.</td>
<td>£118,560.00</td>
<td>Cost for fully sealed doors only.</td>
</tr>
</tbody>
</table>

Figure 32: Estimates for installation costs of proposed adaptation measures (based on MBDB’s costings)
3.4.2 COMPARATIVE COST BENEFIT ANALYSIS

3.4.2.1 ADAPTATION MEASURES TO MITIGATE OVERHEATING OF INTERNAL TEACHING SPACES.

The thermal model indicates that the teaching space will fail to meet the BB101 criteria from 2030 onwards. With no other adaptation measures in place, this would be likely to result in the installation of AC units to avoid overheating. Using the thermal model and climate information, Norman Bromley Partnership [NBP] established the cooling requirements for the years 2030, 2050 and 2080 (data included in Appendix 3 C).

This information was used as the ‘benchmark’ for the cost benefit analysis carried out by Marstan BDB [MBDB], which is shown on the following pages (figure 33). This analysis expands on the alternative heating and cooling solutions costed in table 32. It also considers cost in use and environmental impact of each solution.

The following criteria were analysed:

- Installation Cost, including associated works and alterations to the existing Phase 1 building
- Energy Usage per year
- Running Costs (based on a constant electricity cost)
- Maintenance Cost
- CO₂ Emissions per year.

It was felt that other benefits or negative impact on the school had already been covered in the SWOT analysis in section 3.2, which had been updated as the detail design developed.

To provide a comparison on the impact of each solution three scenarios have been costed based on the climate change data for 2030, 2050 and 2080. It has been assumed that the lifespan of the equipment will cover each of the periods and that a new installation has been made at the start of each period. This fits with the manufacturers’ expected life cycles of each of the solutions.

**2030:**
The costs and thermal model indicate that the most efficient and simplest model for this period would be the installation of the additional fans. Air Conditioning units and the Cool Phase product are both ruled out in terms of cost. Air Source Heat Pumps may present an alternative solution in terms of cost and offer a slightly lower carbon dioxide emission.

**2050:**
By 2050 the fans are working much harder to control temperatures and with that their carbon dioxide emissions increase by 37%. However it is of interest to note that both the AC units (95%) and Cool Phase (52%) emission level increases are expected to exceed this. The thermal model indicates that without additional cooling in the building assisting the fans the BB101 maximum temperatures would be exceeded. The Air Source Heat Pumps solution offers the second lowest total cost, the lowest overall emissions and would meet the cooling criteria.

**2080:**
The thermal model for the final phase of the study up to 2080 shows that additional cooling will be needed to support the fans if temperatures are to be controlled to satisfactory levels. Again the Air Conditioning and Cool Phase solutions represent the highest overall cost and emissions. Air Source Heat Pumps continue to offer the best overall solution on a cost and emission basis.
<table>
<thead>
<tr>
<th>Mitigation Measures</th>
<th>Installation Cost (£)</th>
<th>Energy Usage per Annum (kWh)</th>
<th>Electricity cost per kWh (£)</th>
<th>Running Cost (£)</th>
<th>Maintenance Cost (£)</th>
<th>Total Cost (£)</th>
<th>CO2 Emissions per year (kg)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2030 Climate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC units Ph 1</td>
<td>146,289.92</td>
<td>10,682.00</td>
<td>0.14</td>
<td>37,400.00</td>
<td>25,000.00</td>
<td>£208,689.92</td>
<td>5,523</td>
<td>Assumes no UFH in phase 2 as AC units used for heating.</td>
</tr>
<tr>
<td>AC units Ph 2</td>
<td>43,966.72</td>
<td>4,597.00</td>
<td>0.14</td>
<td>16,100.00</td>
<td>12,500.00</td>
<td>£72,566.72</td>
<td>2,377</td>
<td></td>
</tr>
<tr>
<td></td>
<td>190,256.64</td>
<td>15,279.00</td>
<td></td>
<td>£53,500.00</td>
<td>£37,500.00</td>
<td>£281,256.64</td>
<td>7,900</td>
<td></td>
</tr>
<tr>
<td>Cool Phase Ph 1</td>
<td>143,584.00</td>
<td>4,188.00</td>
<td>0.14</td>
<td>14,700.00</td>
<td>12,500.00</td>
<td>£170,784.00</td>
<td>2,165</td>
<td></td>
</tr>
<tr>
<td>Cool Phase Ph 2</td>
<td>68,325.60</td>
<td>2,443.00</td>
<td>0.14</td>
<td>8,600.00</td>
<td>5,000.00</td>
<td>£81,925.60</td>
<td>1,263</td>
<td></td>
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<td>3,836.00</td>
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Figure 33: Cost benefit analysis of adaptation measures to address overheating (carried out by MBDB)
<table>
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<tr>
<th>Mitigation Measures</th>
<th>Installation Cost (£)</th>
<th>Energy Usage per Annum (kWh)</th>
<th>Electricity cost per kWh (£)</th>
<th>Running Cost (£)</th>
<th>Maintenance Cost (£)</th>
<th>Total Cost (£)</th>
<th>CO2 Emissions per year (kg)</th>
<th>Comments</th>
</tr>
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<td><strong>2080 Climate</strong></td>
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<td><strong>£245,200.00</strong></td>
<td>2,945</td>
<td>Excludes disruption, enabling works &amp; reinstated landscaping.</td>
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**Assumptions:** 1) 3% inflation year on year; 2) 25 year product life

**Note:** GSHP/ ASHP have been sized to provide reverse cooling. They could though probably be used to support the heating in winter months, reducing the heating requirement on the gas boiler. These potential savings are not included above.
The Team felt that the cost benefit analysis brought a number of interesting results, which we communicated to the client and which might be of importance on only to this but other future projects:

- As predicted, the installation of AC units resulted in the highest emission of CO$_2$ per year, for all three year bands. The costings also showed this to be the most expensive option, despite the fact that the AC units could be used for heating the Phase 2 extension thus not requiring UFH installation in Phase 2. This illustrates the consideration of alternative cooling methods to have both financial as well as sustainable advantages.

- Data for the Monodraught CoolPhase ‘thermal battery’ was difficult to obtain due to this being a relatively new product. Overall the installation of CoolPhase units performed better in terms of cost and CO$_2$ emissions compared to the AC units, but still proved to be an expensive option. The thermal model had also indicated that the units would struggle to keep classrooms to BB101 levels, resulting in a recommendation that the CoolPhase units could be installed in 2080 to support the reverse cooling if necessary. Bearing in mind that our modelling was based on the ‘worst case scenario weather data (90% probability, high emissions) and due to the high costs of these units this is not very likely.

- Based on the findings of the thermal model, it was recommended that electrical fans to support natural ventilation could be installed in 2030 as an initial adaptation measure, as they will be suitable to address the predicted climate change for this year band. As we are working with the 90%/ high emissions climate data, the fans might also be sufficient for year 2050 based on the lowest change rates. The retrofitting of the fans would also cause little disruption to the school and could be carried out during a holiday period. However, the analysis shows the cost of the fans to be close to the overall costs for the ASHP, so the client might want to consider an installation of a ASHP (or even GSHP) with reverse cooling straight away, which would be able to mitigate the predicted climate change for 2050 and to a large degree 2080.

- The option of installing an ASHP was shown to be about 50% cheaper than a GSHP, though CO$_2$ emissions for the former option are slightly higher (but still much below the AC units!). Both systems have advantages and disadvantages (e.g. disruption to mature landscaping through GSHP installation, requirement for acoustic enclosure within school playground for ASHP, possible noise planning issues, etc), which will need to be considered in detail by the Client and School.
3.4.2.2 ADAPTATION MEASURES TO MITIGATE REDUCTION IN WATER SUPPLY

Water is a commodity with a fixed cost to the School. Any savings achieved by water saving measures could be compared against the costs associated with implementing and running the measures.

The future cost of water is difficult to assess. As with any resource, the cost tends to increase in relation to a reduction in availability – but there are no clear indications to the extent of the increase. The UKCP09 river basin data (see figure 30) shows that the water supply – demand relationship in the region is likely to change from a surplus in 2010 to a significant deficit in future years.

When carrying out an Environmental Profit and Loss Account for Puma, Trucost Plc established a correlation between water scarcity and cost. In areas where the consumptive use of water accounts for 50% of the renewable supply, the value Trucost attach to m$^3$ of water is about 3.5 times higher than in areas where only 30% of the renewable water are used. It should be noted that the Puma study is not directly applicable to our study, as it valued the loss of ecosystem services that depend on water for their provision (other than direct provision of freshwater) - often termed the ‘indirect use value’ of water. It did not include the lost value associated with reduced water availability for direct consumption (the opportunity cost of water), as this was deemed already be included in the costs charged by water companies. The ‘water scarcity’ relates to water availability in different locations that Puma manufactures in, rather than a reduction in water resources over time. Nevertheless, the resulting analysis shown in graph form below gives an interesting (and concerning) indication of the relationship between water scarcity and a significant increase in value.

We do not have sufficient data to predict water costs in the future, especially as the costs paid by the consumer might not directly reflect the ‘value’ of water. The cost analysis for the rainwater harvesting was therefore based on current water rates of 0.98/m$^3$, taking into account inflation of 3%. The costs do not take running costs for the associated pumps into account.

**Base & Running costs for Below Ground Rainwater Harvesting:** £33,100.00.

**Payback period based on current water rates:** 741 years.

(This is based on the tank serving 24 WC’s, i.e. about 200 pupils with a daily water usage of 3 x 4 litres. Based on 190 statutory school days this results in an overall water saving of 456,000 litres (45.6 m$^3$). The costs do not include running cost for the pump associated with the below ground tank. Refer to Appendix 3.C for more details and cost breakdown.)

As the above analysis shows, the extremely long payback period for a below ground rainwater tank does not make this an economically viable options, even if water costs were to increase by a large percentage in the future. However, bearing in mind that water is a limited resource which needs to be preserved, the Team would still recommend the installation to the Client, should the funds be available. Furthermore the installation of a tank would provide a water resource for the School during increasingly dry summers, enabling them to use less of their drinking water provision on WC flushing.

Figure 34: Water supply-demand balance across river basin regions (assuming to sharing of water across regions)
### 3.5 TIMESCALES FOR IMPLEMENTATION

<table>
<thead>
<tr>
<th>PROPOSED ADAPTATION MEASURE</th>
<th>APPLICABLE YEARS</th>
<th>COMMENTS</th>
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<td>2050</td>
</tr>
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<td>A1a Extension of existing louvers to Library</td>
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</tr>
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<td>A1b Installation of fabric roller shutters</td>
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<tr>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>A2 Review of solar performance of glazing</td>
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<td>X</td>
</tr>
<tr>
<td>A4 Introduction of sedum roof</td>
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<td>X</td>
</tr>
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<td>A5 Fine-tuning of BMS system for ventilation</td>
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<td>X</td>
</tr>
<tr>
<td>A6 Introduction of electrical fans to support natural ventilation strategy</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>A7 Using UFH system for reverse cooling in summer</td>
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Figure 35: Timescales for implementation of proposed adaptation measures.
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<th>COMMENTS</th>
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</thead>
<tbody>
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<td></td>
<td>2030</td>
<td>2050</td>
</tr>
<tr>
<td>A8 Review of school timetable / introduction of ‘siesta’</td>
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<tr>
<td>A9 Using opportunities offered by flexible teaching spaces to reduce internal temperatures.</td>
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<td>X</td>
</tr>
<tr>
<td>A10 Install Monodraught CoolPhase system for cooling.</td>
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</tr>
<tr>
<td>B1 Introduce ‘external teaching kit’ to encourage increase use of external teaching areas.</td>
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<td>X</td>
</tr>
<tr>
<td>D1 Replacement of external cladding materials</td>
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<tr>
<td>E1 Retrofitting of touch free sensors to all Phase 1 wash basins.</td>
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<td>X</td>
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<tr>
<td>E2 Rainwater harvesting</td>
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<td>X</td>
</tr>
<tr>
<td>F1 Increase in SUDS strategy storage capacity.</td>
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<td></td>
</tr>
<tr>
<td>F3 Replacing of sports pitch with artificial pitch.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H1 Introduction of ‘dry-proofing’ measures to sensitive Ground Floor spaces.</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 35 (cont.): Timescales for implementation of proposed adaptation measures.
3.6 MONITORING PERIOD

As part of our study the Team will be monitoring the environmental performance of the school during the first school year. This will enable us to compare the actual data collected within the building against the thermal model and establish if the current building is performing as well as envisaged. We will also interrogate the collected information to see if our findings could be applied to future modelling in order to provide more accurate building performance predictions.

The results and analysis of the monitoring period will be issued in summer 2013 as an addendum to this report.

3.6.1 TEMPERATURE DATA COLLECTION

To allow for the most direct comparison, we are focusing our monitoring on the four areas which were investigated in the thermal model (south-facing classroom, north-facing classroom, library & main hall), as well as the external temperature around the building.

The focus of our thermal modeling has been the peak months May to July, which relate to the criteria set out in BB101. The team decided that it would be useful for the monitoring period to stretch beyond this and encompass the full academic year from October 2012 to July 2013.

Four Tiny Tag data loggers were installed in September 2012 to record the hourly internal and external temperatures, which will be compared to the outputs from the thermal model. A building plan showing logger locations has been included in Appendix 3_G.

After some initial setting up difficulties with the heating and ventilation, the overall building system appears to be running well now (December 2012). The data recorded can be manually downloaded via a laptop in 3 month intervals, with the first data collection taking place in January 2013.

3.6.2 SPECIFIC SCENARIOS

In addition to monitoring the overall performance of the building, we are also hoping to utilize the data collection to enable us to test some specific ‘scenarios’, using the paired classrooms as comparative spaces:

- Different natural ventilation options, to aid fine-tuning of the BMS;
- Different classroom layout options;

This would take place during the summer months (May to July) and a more detailed timetable will be developed. The principle of setting up different scenarios has been discussed with the school, which is interested and keen to participate though the full details will need to be finalised.
3.6.3 PUPIL/SCHOOL INVOLVEMENT

In additional to the recorded data, we have proposed that the pupils (possibly the Hinguar Eco Warriors) are actively involved in producing a second set of data. This would involve the pupils recording an external temperature reading using a standard thermometer, as well as an observed weather record (e.g. ‘overcast’, ‘sunny’) and a ‘perceived temperature’ in the room at a fix time each day.

On one hand this will allow pupils to understand some of the connections between weather, temperature, solar gain and internal climate, but also provide us with some further information to what degree the comfort guidelines set out in BB101 overlap with the user experience.

3.6.4 OTHER DATA COLLECTION

In additional to the temperature data, we are also collecting monthly readings of the water consumption and electricity generated by the photovoltaic panels. As the BSM does not have a remote facility, these readings are taken manually.
4.0 LEARNING FROM WORK ON THIS CONTRACT

4.1 A SUMMARY OF OUR APPROACH TO THE ADAPTATION DESIGN WORK

Our approach was to set up a number of questions to structure our adaptation design work. At the heart of this process was a close collaboration of the design team for the study with various workshop meetings.

The questions we asked were:

(1) What is ‘climate change’, what are the current future predictions and what data is available for us to work with?
- Research into current literature about climate change, in particular Bill Gething’s report.
- Research into future weather data (provided by Exeter University), decision on climate scenarios to be used;
- Review of data available on rainfall, flooding, soil stability, etc. using UKCP09, of various reports already prepared for the scheme during feasibility stage and discussions with other consultants which had been part of the wider project team (e.g. flood risk consultant);
- Review of reports / fact sheet of previous Design for Future Climate case studies, to establish how other teams had structured their approach;

(2) How is climate change likely to impact on our project in future, both on the building itself as well as its occupants?
- Preparation of a thermal model of the existing phase 1 scheme and phase 2 extension and review of how this will perform under the predicted weather data for 2030, 2050 & 2080;
- Research into impact on overheating on teaching / learning, review of current guidelines (e.g. BB101 Ventilation in Schools);
- Workshop with Design Team to discuss how other climate risks can be assessed, both quantitatively (selection of data) and qualitatively;
- Meetings with School (staff & pupils) / Council to discuss where they feel the biggest risks for the operation of the building would lie;
- Preparation of a Risk Register;

(3) What could be done to mitigate the risks and adapt the existing Phase 1 / new Phase 2 extension and how can we assess the overall ‘value’ of the proposals?
- Two step approach to option appraisal, leading to a short list of mitigation measures to be investigated in detail;
- Detail development, including drafting of drawings, discussions with manufacturers, consultation with other consultants (e.g. acoustic consultant) and planners;
- Testing of the impact of proposed measures through the thermal model;
- Assessment of the overall ‘value’ of the options where possible by comparing different scenarios (incl. cost modelling & energy consumption);

(4) How can we influence the Client’s decision making in relation to Phase 1 and 2 of the Hinguar School project and other future construction projects?
- Get the client involved from the outset, in particular when reviewing the potential impact of future climate change. Where possible, set up comparisons between the predicted future climate scenarios with past events, which the end-user can relate to. During our early discussions with the School and Council ‘overheating’ was identified as a dominant risk - the School felt strongly about this issue, as they had already experienced the negative effect on pupils performance and well-being during the recent short summer heat waves;
- Cost and budget restrictions are at the heart of most construction projects. We felt that by compiling a cost benefit comparison (see Figure 33 in section 3.4.2.1) which takes into account long term running, maintenance and energy costs, we could communicate to the client that options with initial high installation costs (e.g. GSHP vs gas boiler) might be a worthwhile investment, in particular in view of future climate change. It might be useful for future projects to suggest to the client that similar cost-benefit analyses are carried as part of the design stage cost estimates.
- Even though current climate predictions show climate change is here to stay, the timescales associated with some of the risks make it difficult to convince a client to implement costly adaptation measures today, which might not be required for another 30 years. However, often elements can be integrated or design in at early project stages for little or no cost which will allow for an easier installation of adaptation measures in the future, when they become necessary. The ‘Design Tool Kit for Climate Change Future Proofing’ which the Team compiled as part of this study and which is described in more detail in section 5.4 of this study lists a range of such initial measures, which the client might be more willing to consider.
Throughout our work on the Hinguar School project, Southend Council have shown a very collaborative approach to decision making, which involved the end-user (the School), the education department, the property department, the design team and any other specialists within the council.

During our presentation to the Council in November 2012 a healthy discussion ensued between the Council’s in-house M&E consultants and NBP, the M&E consultant involved in this study. This emphasised the importance of encouraging discussion and collecting information on other case studies and projects using similar ‘relatively new’ technologies, in order to address any concerns at an early stage.

Some of the main points discussed are listed below:

1. How effective is night time cooling (using outside air to naturally cool classrooms at night during the summer) in a light-weight building construction, where thermal mass is limited? The thermal modelling report proves nighttime cooling to have a significant impact on the day-time temperatures, though this would be more effective on a heavy weight building.

2. What are the Pro’s and Con’s of using UFH for reverse cooling? As the council have had a bad experience with underfloor cooling on a previous project, the benefits and possible challenges were debated. This then broke into a discussion on mean radiant temperature and its effectiveness on the comfort condition with underfloor cooling. Underfloor cooling was one of our most effective solutions in combating overheating, which was demonstrated in our thermal modelling.

3. Are the overheating criteria set out in BB101 adequate? As outlined in section 2.1.1, the three criteria for overheating in classrooms where used as the bench mark for assessing overheating during our study. However, the Council reported that they have had problems with new build schools getting to 26-27°C in the summer which does comply with BB101, but the schools are unhappy with these temperatures and the council are introducing cooling.

(5) How can we share our findings and who do we share them with?

- The Team identified four (partially overlapping) interest groups, with whom we felt it would be beneficial to share the findings of this study. These are outlined below, together with an explanation why we pinpointed these groups and what the possible methods for suitable dissemination could be.

The project team for the Hinguar Primary School project, focusing on the School and Council

Why?

During the study:

- Ongoing feedback throughout the study on the end-users view/valuation of the main risks posed by climate change and initial views on the proposed mitigation measures.
- Influence the construction process for Phase 1
  (Due to the quick programme and tight budget at the end of the project, this did not prove to be feasible.)
- Following completion of the study:
  - Influence the design of the Phase 2 built to include some of the initial measures and (depending on the timing of the second phase) larger interventions proposed in the study, such as the installation of a GSHP.
  - Raising awareness of Climate Change issues by getting the School and Pupils involved and working together with them.
- The School and Council will remain involved during the Monitoring Period.
How?
- Setting up dissemination events with the Council’s project team & the School: We have kept the School and Council involved through a series of meetings, which were coordinated with the regular construction project meetings, and a number of emailed updates. Workshops held with the pupils (e.g. ‘Eco Feature Hunt’ with Year 6 students, climate change workshop with ‘Hinguar Eco Worriers’).
- Issue of the final report to the School and Council, including costings (please refer to ‘how we can influence the client below), so these documents can be referred to for reference.

The wider team within Southend Borough Council, who will be involved in other construction projects
Why?
- As discussed in section 5 of this report, we felt that many of the investigations carried out as part of this study would be beneficial to other construction projects within the Council, both within education and other sectors. Southend Borough Council has a strong commitment to sustainability and was very interested in learning from this study for other future projects.

How?
- As described earlier on, the Team presented the findings of our study to Southend Council in form of a lunchtime CDP on 14th November. The workshop was attended by a variety of members of the department of Property & Regeneration, comprising of project managers, building surveyors, electrical and mechanical engineers as well as Southend’s Sustainability Officer. (A full list of attendees has been included in Appendix 4_B).

Colleagues / co-workers within our own organisations
Why?
- To ensure that the knowledge we have gained as individual practices and a design team is not restricted to a small group of people but can become an integral part of our projects -and an additional service we can offer to future clients.

How?
- We have organised internal presentations within our offices.

Other professionals / students outside our own organisations.
Why?
- Heighten awareness of risks posed by future climate change throughout the construction industry professions.

How?
- We have established contact with Southbank University and Brighton University’s architecture departments, who both expressed an interest in hosting an evening lecture on our study and the building project.
- We are currently investigating other options for dissemination events, such as the RISC, as well as publications.

4.2 WHO WAS INVOLVED IN THE STUDY & WHAT THEY BROUGHT TO THE PROJECT

The ‘Core Team’ for the D4FC study comprised of Space Craft Architects, Norman Bromley Partnership and Marstan BDB, all of which had been part of the Design Team for the Hinguar Primary School construction project throughout. Their roles and input have been outlined below.

Additional advice and input was provided by other consultants who had been involved in the construction project, such as Structural Engineer Ray Hoyte at Eckersley O’Callaghan (Ray previously worked for Dewhurst Macfarlane on the Hinguar School project), John Rampley at Entec UK (flood risk assessment) and Keith Lodder at NBP (below ground drainage). Southend Council’s project manager Michelle Fishlock, Alastair Robertson (SBC Department of Children & Learning) and Vivienne Stevens, headteacher at Hinguar Primary School were also involved throughout the study and provided valuable advice on the impact of the potential climate change risks on the school and feedback on the proposed mitigation options.

Architects / Landscape Designers / D4FC Project Manager:
Space Craft Architects
Key Personnel: Laura Irving – Education Director
Sophie Ungerer – Project Architect

Key input:
Lead Designer
Climate & Weather Research
Landscape Research
Input into mitigation option development, discussions, ideas, etc.
Product & alternative solution research and appraisal
Integration of proposals into building details
Main Report
Main line of communication with School & Council
Quantity Surveyor:  
**Marstan BDB**

Key Personnel:  
James Woricker - Partner  
Alex Howden - Quantity Surveyor

Key input:  
Input into mitigation option development, discussions, ideas, etc.  
Cost advice and options appraisal  
Cost benefit analysis  
Alternative solution research and appraisal

Building Services and Environmental Engineer:  
**Norman Bromley Partnership**

Key Personnel:  
Mark Roskilly - Partner  
Matthew Nicoll – Associate Mechanical Engineer  
Ben Campbell – Mechanical Engineer

Key input:  
Climate & Weather Research  
Input into mitigation option development, discussions, ideas, etc.  
Thermal Modelling & Thermal Model Report  
SBEM calculations  
Analysis of data during monitoring period  
M&E concept & strategy development  
Product research

Structural Engineer:  
**Eckersley O’Callaghan**

Key Personnel:  
Ray Hoyte – Project Director

Key input:  
Foundation & site stability  
Structural advice on interfaces with existing structure  
Drainage & SUDS strategy research

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Figure 39: Team Onanogram
4.3 THE INITIAL PROJECT PLAN AND HOW THIS CHANGED THROUGH THE COURSE OF THE PROJECT

Overall the study was carried out in line with the initial project plan (after a slow start) and most of the outcomes which we had set ourselves to date have been achieved. It had always been the intention to follow the main study with a monitoring period, which will be added as an addendum or revision to this report.

It had been difficult to assess the time requirements from each member of the group at the outset, and one of the difficulties was to channel the time we had for detail development into focussed studies, which inevitably mean that some areas (such as for example material behaviour in extreme weather) were decided not to be reviewed in depth as part of this study.

The areas which took longer than expected were:
- Collaborative processes where information/research, which was carried out by one member of the design team, needed to be passed on to others for further processing (e.g. thermal modelling of AC unit size & energy consumption and integration into building design needs to be fed into cost comparison), to then finally be discussed and assessed again by the team as a whole.
- Report production and coordination, to ensure that all team members had a chance for sufficient input.
- Decision making on the extent of the study and research required. As this was an unusual way of working for the design team, it took a while to establish the best working strategies and to judge how our time would be most efficiently spent. It was a learning curve for all involved and has prepared us well for future projects.
- Preparation of information for dissemination to the client. We had been ambitious in assuming that we will be preparing the final presentation to the stakeholders in parallel to the Final Report. Whilst we have been having ongoing communication with the Council and School throughout, we felt that, due to the nature of our project (construction of phase 1 now complete, phase 2 extension not likely to take place in next 5 years), it would be most beneficial to wait with our final presentation to the Council until September 2012, when the full report has been completed and everyone is back from their summer holidays.

4.4 WHAT WORKED WELL & WHAT DIDN’T WORK IN OUR APPROACH

Whilst our team comprised of less members than some of the other D4FC studies, we felt it was a very productive collaboration. Team workshops in particular were very successful and allowed all members to contribute from their various angles of expertise and experience. We felt that the study has allowed us to build on our strengths and we will be looking for further opportunities as a team to offer and apply our ‘climate change’ consultancy knowledge.

The opportunity presented by this study to investigate and research climate change issues in detail, but within the structure of a project plan and report outputs was unique and important for the whole team. A lot of vital lessons have been learned which we will aim to re-invest in future projects.

As we worked with a partially completed project, it was interesting to see which design features already in place (e.g. insulation, brise soleil) would play a crucial role in effectively addressing the climate change challenges. This will give the team more confidence to advise future clients of the importance, value and viability of these features, which too often fall prey to value engineering.

Although the stakeholders (School and Council) were not directly members of the design team for this study, we were able to keep them engaged throughout, using the already establish Core Group meetings for the construction project as a vehicle. Bringing the pupils on board through some shorter presentations and activities was also useful, especially as a number of the issues raised in our study are related to user management or might require minor adaptation which the school could take on board as ‘projects’. We hope that this collaboration will continue well during the monitoring stage.

We felt that getting the site specific Prometheus weather data to use in our thermal model was extremely useful in fully investigating options – and also in discussing them with the client. This highlighted the importance of careful data selection and the need to constantly keep reviewing and extending the software skills in this field.

The option appraisal process was difficult as it was not possible to fully investigate and cost all options in detail prior to deciding which areas we would focus on. This meant that some of our SWOT analysis was based on our experience and we might have missed an opportunity to look into some important issues. As a team we decided that this was regrettable, but that it would be of more benefit to all those involved to keep focused on some areas than to only touch the surface of many.
Setting benchmarks and carrying out cost-benefit analysis to assess the different mitigation options against (e.g. installation of GSHP with reverse UFH cooling vs. Installation of AC units) was a very useful tool, which helped us to weigh up the different measures and communicate them to the council/school.

As the end of our study coincided with the completion of the construction project and final account negotiations, as well as the summer holiday period, it was slightly difficult to get the other construction project team members engaged in the final stages and in particular discussions regarding the implementation of some of the measures. In hindsight it might have been beneficial to involve a representative of the client as a team member for the study, as this would have given us a more regular and direct link for feedback and decision making process. Due to the changes in birth-rate predictions in Shoeburyness, there are no immediate plans for Phase 2. However, we are confident that many of the findings in this study will be very valuable in influencing the final detail design of the extension and considered for implementation by the client.

As reported in section 4.1, the Team organised a presentation of the study to a wider audience within the Council, including project managers, M&E engineers and sustainability officers. We felt that this was generally successful and a good opportunity to involve ‘decision makers’ within different areas if the council and extend the relevant of the study beyond the Hinguar School project. We had to realise that the allocated hour (CDP luncheon slot) was a very short timespan to introduce the full scope of the study, especially as not everyone present was familiar with the Hinguar School scheme. Maintaining the balance between providing sufficient detail for an informed discussion without focussing too much on specific and often specialist areas proved challenging and is something we will need to refine for the further dissemination events. The presentation did seem to trigger interest and we will be circulating a copy of this report to all participants to allow them to review the results in more detail.

During the presentation and the ensuing discussion regarding the proposed adaptation measures to address the risk of overheating, it became clear that the views on some of the proposals such as using UFH for reverse cooling, differed greatly between all present. One of the Council’s engineer’s reported that they had experienced problems with GSHP’s and UFH on a recent project. In order to convince the client to implement the more onerous strategies, especially those using more recent technologies, it might have been useful to include precedent studies and research on similar schemes.

4.5 RESOURCES & TOOLS USED IN THIS STUDY

4.5.1 PROMETHEUS WEATHER DATA & UKCP09 DATA
The modelling process incorporated predicted weather data for the site location, Shoeburyness, Southend-on-Sea. The predicted weather data was produced by the Prometheus Project from Exeter University for years 2030, 2050 and 2080. The predicted whether data was invaluable to the study, enable all the proposed mitigation strategies to be explored and determined there effectiveness in the future climates. Additional data was extracted from the UKCP09 website (e.g. precipitation changes).

4.5.2 THERMAL MODELLING - IES
The thermal modelling and simulations was undertaken using the IES Virtual Environment 6.4 software package. The IES software allowed for all aspects of the building design to be incorporated into the model, including building fabric U-values, brise soleil, natural ventilation strategies, building services strategies and profiles related to building occupancy and building services.

The IES is a fully dynamic thermal modelling software package, although, there were limitation within the package on modelling external spaces, and plants and foliage used for shading devices.

4.5.3 BUILDING REGS & SBEM
SBEM calculations were used to establish the natural ventilation scheme and U-values for the phase 1 design. The calculations are based on 1990 weather and do not include a requirement or ‘safety margin’ for climate change, unlike for example flood risk assessments and modelling. Having looked at the performance of the building under the predicted 2030 weather data, we are interested to see if the monitoring period planned for spring/summer 2013 will offer an idea of how well a building designed to 2010 Building Regulations performs.

4.5.4 BUILDING BULLETIN 101: VENTILATION IN SCHOOLS
The building bulletin gives three specific criteria to assess overheating in teaching spaces. These were used by the team to assess the effectiveness of the various potential mitigation measures. Whilst this gives a clear set of data, it is likely though that these criteria will need to be reconsidered in future years, as our adaptability to warmer summers as a country increases. This will require further consideration.
4.5.5 TSB DESIGN FUTURE CLIMATE REPORTS & CONFERENCE
We found that the review of other Design for Future Climate studies (both as the final reports and during the Conference in June 2012) was very helpful and gave us ideas how our specific research can be applied to other building projects. It was in particular interesting to see which climate scenarios other teams had picked and how this might have influences their decisions.

4.5.6 PASSIVE DESIGN ASSISTANT
This free software developed by TSB, ARUP, MPA and AHMM is a useful tool in helping architects carry out initial investigations using a basic thermal model. Whilst limited in its complexity, we feel this will come in useful for future design projects, but also to introduce designers to the principles of solar gain, thermal mass, etc.
5.0 EXTENDING ADAPTATION TO OTHER BUILDINGS

5.1 ASSESSMENT, HOW THE STRATEGY RECOMMENDATIONS AND ANALYSES IN THIS STUDY MIGHT BE APPLIED TO OTHER BUILDINGS AND BUILDING TYPES

Whilst this study took the team to new areas of research it also reinforced our view that the principles of sustainable design, which we are already pursuing as a design team must form the core of any climate change adaptation work: building a structure which maximises its passive performance in terms of natural ventilation, daylight and resource preservation by ensuring that solar orientation, building form, insulation and glazing ratio are optimised whilst still meeting the brief and user requirements. What we have learned from the study though, is that in future we will need to push all these issues much further than what is required today to meet statutory compliance and create healthy, enjoyable environments – and that we need to get the stakeholders alert and involved now to be prepared.

It is difficult and arguably also not always sensible to design for 2080 today, bearing in mind the uncertainty of the data we have for this time, potential unforeseeable improvements/developments in modern technology and the lifespan of buildings designed today - at least in their original function. Within this study we have therefore aimed at identifying a series of ‘initial measures’ which can be considered/applied to building projects today in order to facilitate future adaptation work. This information has been presented in form of a Design Tool Kit for Climate Change Future Proofing, which is described in more detail in section 5.4.

The forecasts by the Department of Education show a rise in pupil numbers in maintained nursery and state-funded primary school by 20% (about 820,000 pupils) by 2020. Figure 40 illustrates the changes in pupil numbers, which have taken place over the last 40 years as well as the projected increase in pupils by 2020. This increase in pupils would equal about 27,000 additional classrooms or 3,900 new/remodelled 1FE primary schools and nurseries (each accommodating about 210 pupils) over the next 15-20 years. Whilst some of the increase will of course be accommodated in existing (and possibly under-used) school buildings, a significant amount of new education buildings are likely to be required.

In November 2011, the Secretary of State for Education explained that £500 million funding would be made available to local authorities to provide pupil places.

As many of these additional spaces will be delivered as part of extensions or refurbishments of existing buildings as well as new builds with limited budgets, looking into options of future proving education projects now seems to be a sensible strategy to prepare for the future challenges posed by climate change - and to reduce costs long term, as has been demonstrated in section 3.4.2.1. Reducing long term running, electricity and maintenance costs (including such costs incurred through possible adaptation works in future), will allow schools to spend more of their annual budgets on the provision of teaching and pupil support.

The measures proposed in the toolkit are relevant to both refurbishments/extensions to existing building stock and we have included a costs indication for both scenarios.

Whilst the emphasis of the study has been to investigate measures to mitigating overheating in schools, the proposed measures within the toolkit are not limited to educational buildings. The intention is for this document to be updated and added to by the Design Team as a wider range of projects is investigated.
5.2 DESCRIPTION OF THE LIMITATIONS OF APPLYING THIS STRATEGY TO OTHER BUILDINGS

- The general principles of this study can be applied to a range of building types. However, the specific research and analysis is of most direct use to other education buildings. The thermal model data is measured against BB101 criteria, which assumes a limited building occupation (i.e. not overnight, the weekend and during school holidays). On the other hand it also caters for a high occupancy rate during school hours and needs to create the right criteria for successful teaching and learning.

- Whilst parallels in the occupancy patterns can be drawn to office buildings, there is a significant difference in the use and functional requirements of predominantly residential buildings.

- A number of adaptation measures we reviewed are specific to a quiet greenfield site and might need to be approached differently for a busy urban site (e.g. noise issues in relation to natural ventilation, integrating landscape, etc).

- Our study is based on local climate data. Whilst general UK wide trend predictions exist, any meaningful study will need to review the particular weather in the site area and design for the specific building location.

5.3 AN ANALYSIS OF WHICH BUILDINGS ACROSS THE UK MIGHT BE SUITABLE FOR SIMILAR RECOMMENDATIONS

As noted above, some of the analysis included in this study is particular to education buildings with a similar occupation pattern. This would include primary and secondary schools, nurseries and early years centres, higher education and adult learning centres, etc. As noted in section 5.1, there is an urgent need to provide a significant amount of teaching accommodation over the next 15-20 years within a tight budget.

In our view it will be very important that the current research on climate change and future adaptability of education buildings is fed into any review of the government’s ‘design guidance’. From the information currently in the press, there is a concern that the ‘baseline information’ due to be issued this summer will focus on providing ‘budget’ standardised school designs for now, rather than allowing sufficient flexibility for the future.

Standardisation and the use of pre-fabricated elements to provide high quality education spaces offers a lot of opportunities and it’s potential benefits may be particularly important in the current financial climate. Space Craft Architects has developed a system for standardised construction (QES) whereby performance, cost and programme are predictable, bug flexibility is also achieved. As a result of this study we will review internally which of the principles and methods outlined in this study could be integrated into this system.

Many of the principles developed in the study could be applied to other non-residential buildings with similar occupation patterns, such as libraries, community centres and offices, but also public external spaces.

Residential buildings will also benefit from a sensitive and carefully considered approach to climate and comfort, water preservation, etc. It is important to remember that our overall wellbeing is influenced by all the spaces we pass through during the course of a day. As the headteacher of Hinguar pointed out, if a pupil arrives at school tired and tense after a restless sleep in an overheated home, he or she will struggle to keep up concentration, no matter how well designed the school building is.

Design for climate change will need to impact all parts of architecture and urban design.
5.4 RESOURCES, TOOLS AND MATERIALS WE DEVELOPED THROUGH THIS STUDY FOR PROVIDING FUTURE ADAPTATION SERVICES

The main ‘resource’ we have developed within this study is the design team itself and the specific skills and knowledge we have all been able to acquire over the last months. This will be passed on within our offices in form of CDPs to ensure that everyone has a good understanding and awareness of potential climate risks.

Whilst the nature of Design Teams is often changing and project specific, we have also noticed a trend towards client looking for applications by full design teams, with a lead consultant as a single point of contact . (This was for example the case at Hingaur School, where the structural and M&E consultants acted as sub-consultants to Space Craft.) This offers an opportunity to build on our combined skills as a team.

The client has already explained that the integration of remedial adaptation measures to existing buildings is very important to them. We will aim to utilise this document as a framework of further climate change consultancy advice on future projects.

When comparing the adaptation of some measures to the Phase 1 (essentially retro-fitting) and Phase 2 (integration at design stage), the Team soon realised that significant long term cost savings could be achieved by adding small ‘future proofing’ elements during the design stage (e.g. slightly higher roof parapet upstand and stronger roof structure), which would then facilitate the retrofitting of the adaptation measure when this becomes necessary (e.g. installation of sedum roof to attenuate more frequent rainfall and increase insulation to mitigate overheating).

On the basis of our findings, we developed a ‘Design Tool Kit for Climate Change Future Proofing’, in which possible initial measures has been structured into the following project components: Structure, Building Construction & Detailing, Building Services & Below Ground Drainage, External Spaces & Management and External Spaces /Lanscaping. A copy of the tool kit has been included in Appendix 4_B.

The toolkit aims to provide project teams with the beginnings of a ‘compendium of measures’ which can be integrated into the design at an early stage and often at no or limited additional cost, in order to facilitate adaptation in the future. The tool kit is not intended as a complete document but has been developed as a ‘working paper’, which can be added to and extended further research and development is collected.

A range of initial measures are listed under each project components, which could be reviewed / taken on board during the design stage of a future project, together with the following information:

- Which future adaptation strategy would this initial measure facilitate;
- Which climate change risk is being addressed;
- What is the likely timescale for the future adaptation;
- What is the likely cost impact on the project cost during the design stage, both for new build and refurbishment projects.

5.5 FURTHER NEEDS WE HAVE IN ORDER TO PROVIDE ADAPTATION SERVICES

- BIM based projects will soon become the standard. As we are trying to adapt to this as a design team, it would be useful to establish an understanding how some of the research / analysis we carried out could be integrated into a BIM project.

- Integration of climate change research into legislation. Maybe a review of BREEAM? This is a rather time consuming process at the moment, which is very prescriptive but does not include enough emphasis on ‘future proofing’.

- Involved clients, who are aware of the risks posed by climate change.

- Client incentives / funding for projects – the deadline for the feed in tariff for the PV’s was cut back half way throughout our construction process.

- A comprehensive and growing list of case studies (such as the D4FC reports), to be able to show clients similar schemes and installed technologies, which they can use as reference points.

- Flexible budgets and cost allocation - as the cost benefit analysis in section 3.3.2.1 showed, running costs and maintenance play an important role in the overall budget. Often client budgets for ‘capital costs and ‘running costs’ are held in separate departments, which might influence the decisions at design stage in favour of options with the least ‘capital costs’ when a longer term view would bring greater benefits and economies. This was discussed at the presentation to the client, and is certainly an issue the Council is aware off and looking into.
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PUMA’s Environmental Profit and Loss Account for the year ended 31 December 2010 (prepared by Trucost Plc for Puma)

(B) CORRESPONDENCE & DISCUSSIONS:

Email correspondence with James Hammick, Design Manager, Passivent Ltd.

Email correspondence with Graham Cross, Halsted Rain Ltd.

Email correspondence with Mike Jones, Regional Manager, Bauder Ltd.

Email correspondence and meeting with Ian Bull, Garden Manager [RHS Hyde Hall Garden], including visit to Hyde Hall Dry Garden.

Email correspondence with Margaret Leo, Levolux.

Email correspondence with Chris Baldock at Trucost.

Email correspondence with Vincent Shapland, Design Engineer, Monodraught Ltd.

Correspondence with Graham Bowland, Principle Consultant - Hepworth Acoustics

(C) EVENTS AND VISITS:

Meetings with Viv Stephens, Headteacher & Adam Judge, Business Manger [Hinguar Primary School] and Alastair Roberts & Michelle Fishlock , Project Manager [Southend-on-Sea Borough Council]

Material Considerations – Sustainable Design in Housing @ The Concrete Centre seminar at New London Architecture Centre, London, 1st May 2012

Design for Future Climate Showcase Conference 2012 @ New London Architecture Centre, London, 12th June 2012

Ecobuild @ Excell London, 20th March 2012.

TSB Low Impact Building Open Session @ House of Barnabas, 8th November 2012
FOOTNOTES:


3 Gething, B. Design for Future Climate: Opportunities for Adaptation in the Built Environment


5 Ibid, p.32.

6 Rampley, J. Hinguar Primary School Flood Risk Assessment, pp 15-16.


10 Quotation from Stevens, Viv; Headteacher Hinguar Primary School.

11 PUMA’s Environmental Profit and Loss Account for the year ended 31 December 2010 (prepared by Trucost Plc for Puma), p. 22.


PICTURE CREDITS:

Figure 1: Composite image based on images extracted from http://maps.google.co.uk

Figure 11: Rampley, J. Hinguar Primary School Flood Risk Assessment, p.15.

Figure 12: Ibid, p.15.

Figure 15: LEFT: Essex & Suffolk Water ‘Areas of Supply’, extracted from www.eswater.co.uk

RIGHT: UKCP09 map of Anglian river basin area, extracted from www.ukcip.org.uk.

Figure 34: UKCP09 data, taken from Capon, R. and Oakley, G. Climate Change Risk Assessment for the Built Environment Sector, p.79.

Figure 40: Department of Education data, taken from “National Pupil Projections: Future Trends in Pupil Numbers”, p. 14.

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Other images and photos by Space Craft Architects, Norman Bromley Partnership & Eckersley O’Callaghan.