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Swanage Town Council

SWANAGE SEAFRONT

Ground Stabilisation Feasibility Study

70094760-GEO-REV001
SEPTEMBER 2022

CONFIDENTIAL

Swanage Town Council

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EXECUTIVE SUMMARY

0.1.1. WSP UK Ltd (WSP) was commissioned by Swanage Town Council (STC), 'The Client', to complete a Ground Stability Feasibility report for a section of Swanage Seafront (Dorset), where areas of ground instability have been identified over a number of years.

0.1.2. The scope of this report is to develop high level ground engineering proposals to address areas of potential instability and assess with respect to future potential uses for the following areas:

- The Spa;
- Spa Beach Huts;
- Weather Station Field; and
- Sandpit Field.

0.1.3. A desk study for the site has been undertaken in Section 2 prior to assessing potential remedial solutions. The desk study includes a review of information sources including geological maps, existing ground investigations (see Appendix A), hydrogeology and hydrology, potential ground hazards, historical development and unexploded ordnance records.

0.1.4. Based on geological and historical maps, the anticipated strata at the site consist of Made Ground overlying mudstones (and potentially sandstones) of the Wealden Group. In addition, Marine Beach Deposits are expected along the eastern extents of the site overlying the mudstones. The ground conditions identified in previous ground investigations at the site are generally in line with the geological maps.

0.1.5. The desk study has been complemented with a site visit undertaken by two WSP Geotechnical Engineers on the 24th of May 2022. During the site visit it became quite evident that some of the cracks affecting the retaining walls, footpaths and slopes have deteriorated further when compared with the 2016 survey undertaken by Smith Foster Limited report. The findings and photographs are included in Section 3 and Appendix B.

0.1.6. The risks associated with the geotechnical aspects of the scheme have been identified in a Geotechnical Risk Register (GRR) in Section 4. The geotechnical risks listed in the GRR are as follows:

- Failure of existing structures if no remedial solutions are adopted;
- Unexpected ground conditions;
- High groundwater levels and/or perched water underlying the site;
- Instability of excavations in granular materials, including potential of blowing/running sands;
- Unknown location and depth of slip planes affecting the slopes;
- Build-up of pore water pressure due to blocked drainage systems behind retaining walls;
- Encountering contaminated materials during the remedial works;
- Aggressive ground conditions and sulphate attack on concrete, steel and other buried structures;
- Unexploded Ordnance (UXO); and
- Construction works compromising the stability of the existing structures.

0.1.7. A preliminary engineering assessment has been conducted in Section 5. This section contains a discussion on likely types of landslide(s) and potential cause(s) of the instabilities, and gives recommendations on potential remedial solutions.

0.1.8. The identification of a shallow soft/loose stratum (maximum depth ≈2.5 m) is suspected to be the main reason causing the ground instabilities. Shallow ground movement (possibly soil creep) affecting this upper stratum is considered the more likely failure mechanism at the site. No evidence of deep seated failure planes has been observed although this cannot be fully discounted, and should be continually reviewed during ongoing monitoring of installations.

0.1.9. Deficiencies affecting the drainage system are likely to be contributing to the instabilities as well. During the site visit it was noticed that various drains and weep holes were blocked with vegetation and sediment impeding groundwater flow. This accumulation of water reduces the soil shear strength, which in turn, brings about further down-slope ground movement.

0.1.10. The potential remedial solutions and budget estimation have been presented in Section 5.2. The proposed potential solutions are as follows:

- Option 1 – Do Minimum (across site);
  *This option **should be adopted as a 'do minimum' and will be required for all** further proposed options. Noted as the lowest cost option although not a permanent solution.*
- Option 2 – Slope regrading and/or granular replacement;
- Option 3 – Soil nails/anchors of slopes and/or existing retaining walls;
- Option 4 – Full reconstruction of existing retaining walls as gravity walls; and
- Option 4a – Full reconstruction of existing walls as embedded retaining walls.

0.1.11. A preliminary estimate of the construction budget for each of the options have been provided in Table 5-1.

0.1.12. It should be noted that this report does not constitute detailed design and only provides outlines of potential remedial solutions.

0.1.13. Remedial solutions will need to be developed alongside the planning and development proposals for future potential uses for each of the areas of the site, to ensure the application of robust and cost-effective engineering solutions.

1 INTRODUCTION

1.1 SCOPE AND OBJECTIVES OF THE REPORT

1.1.1. WSP UK Ltd (WSP) was commissioned by **Swanage Town Council (STC), 'The Client', to** complete a Ground Stability Feasibility report for a 280 m long section of Swanage Seafront (Dorset), where areas of ground instability have been identified over a number of years.

1.1.2. The scope of this report is as follows:

- Review of all available information provided, assess proposed ground models and summarise findings;
- Undertake a site visit to assess the current condition of the features present within the study area;
- Develop a geotechnical risk register;
- Develop high level ground engineering proposals to address areas of potential instability and assess with respect to future potential uses for the following areas:
  - The Spa
  - Spa Beach Huts
  - Weather Station Field
  - Sandpit Field
- Prepare drawings of ground engineering proposals by areas; and
- Prepare preliminary budget estimates for the ground engineering proposals.

1.1.3. Complementary information is provided in the appendices of this report as indicated below:

- Appendix A – Relevant geotechnical information provided by the Client and Preliminary Unexploded Ordnance Threat Assessment;
- Appendix B – Site visit photographs; and
- Appendix C – Drawings.

1.2 DESCRIPTION OF THE PROJECT

1.2.1. The site forms a coastal transition zone between the town of Swanage and the beach. The site is centred on National Grid Reference E403025, N79297. See Figure 1-1.

1.2.2. The overall site comprises a linear parcel of land trending north-south between De Moulham Road to the west, Shore Road to the east, and is split by Walrond Road, which runs east-west through the centre.

1.2.3. The site can be subdivided into four definable sections by various land uses as follows:

1) **Northernmost section (The Spa)**. It comprises a gently sloping grass area (west to east), with a combination of steps and retaining walls which work their way down to Shore Road below. The slope shows signs of gradual instability, including cracks within the footpaths and tilting of paving stones.

2) **Northern central section (Spa Beach Huts)**. It comprises a largely terraced hillside upon which timber holiday cabins are situated. The slope has been extensively modified and terraced to accommodate the holiday cabins with steps and small (1 to 2 m) to medium (2 to 3 m) retaining walls. The whole section displays signs of slope instability with the stone wall along the western

boundary tilting down slope. Several of the retaining walls exhibit cracks with sections of blockwork repaired and rebuilt towards the south of the section.

There is evidence of significant seepage through the two large retaining walls towards the east of this section, with calcite deposition encountered at <1.5 m up to the wall. There is also seepage along the eastern boundary of the retaining wall and an adjacent blocked drain along Shore Road.

3) **Southernmost part of northern section (Weather Station Field)**. It is bounded to the south by Walrond Road, to the east by Shore Road and to the west by De Moulham Road. The northern boundary is defined by a stone wall with holiday cabins. This section comprises a partly terraced grassed area that slopes gently down from the west to the east. The eastern boundary is defined by a ≈2 m high retaining wall that has seepages and cracks visible towards the south of the wall. Generally the ground surface is hummocky or uneven.

   A footpath runs north to south approximately ten metres from the eastern boundary with tension cracks that have been filled in with concrete towards the north of this section. A weather station is located in the south western corner.

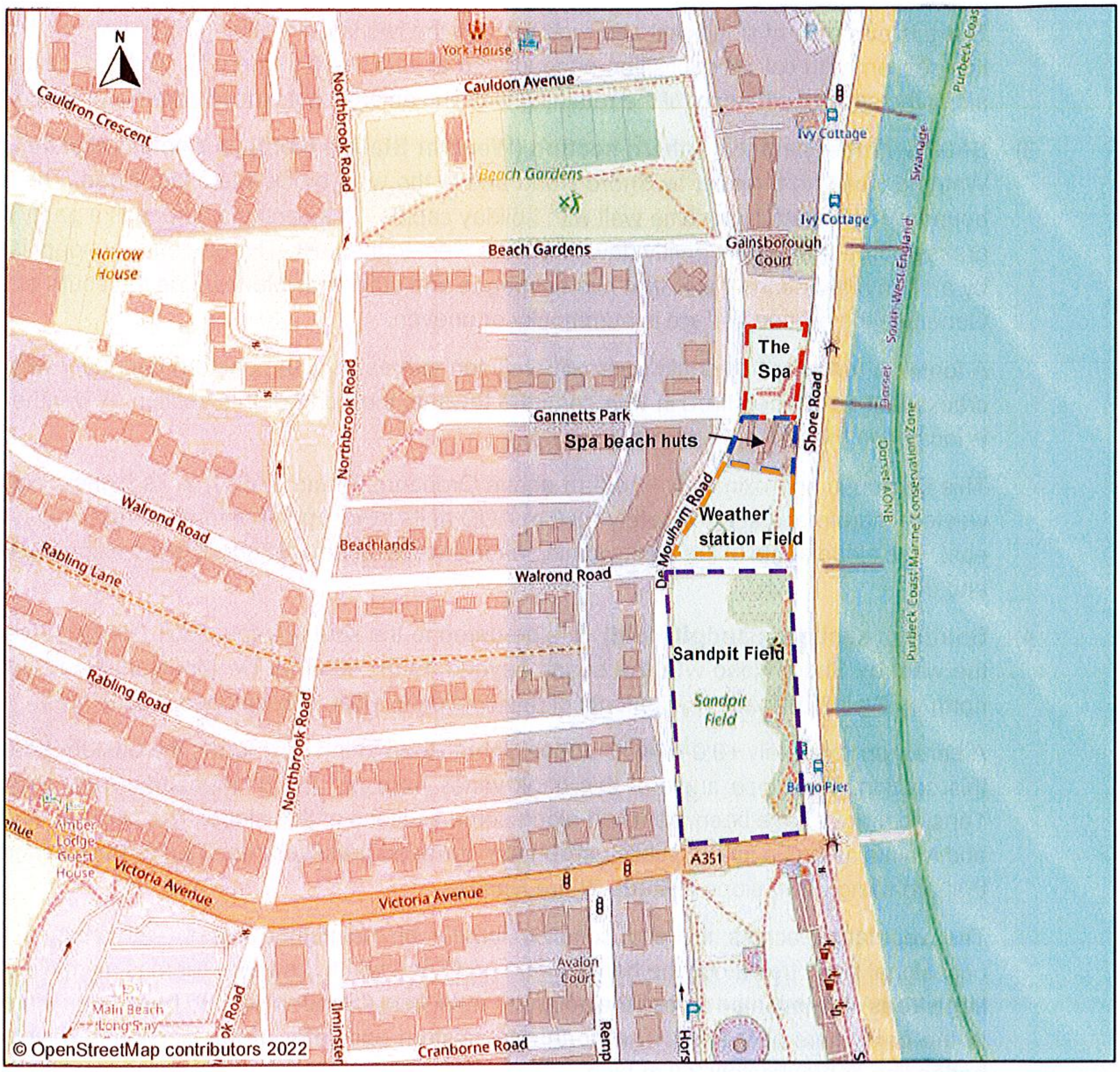
   This section is approximately +14.5 m above Ordnance Datum (AOD) at its highest point at the western margin and approximately +3.0 m AOD at its lowest point before the retaining wall in the east. The slope angle of the banks joining each terrace differ throughout this section between 15° and 28°.

4) **Southern section (Sandpit Field)**. It is bordered to the south by the A351 (Victoria Avenue), to the west by Shore Road with the beach beyond, to the west by De Moulham Road and to the north by Walrond Road. The majority of this section is a flat undeveloped grassy area.

   A bank approximately +9.0 m AOD above Shore Road to the east forms the eastern boundary of this section. The slope angle of this bank varies from 26° to 40° measured from crest to toe. Tension cracks have been identified along some sections of this slope. The slope is landscaped and maintained as a formal public garden with terraced grassed areas and formally planted beds that are tilting down slope towards Shore Road.

   The vegetation across the site consists largely of maintained grass, with bushes and the occasional small tree along the banks in the north and south, however there is a small number of large trees disseminated across the southern most field ('Sandpit field.') These trees are confined to the perimeters of the site. The north and western perimeter of this section is bounded by a hedge line approximately 2.0 m high.

Figure 1-1 - Site location plan



1.3 EXISTING GEOTECHNICAL INFORMATION

1.3.1. Table 1-1 provides a summary of the existing available reports / documents which have been provided by the client. These documents have been included in Appendix A.

Table 1-1 - Existing geotechnical information

Report / Document title & reference	Summary of content	Author	Publication year
Ground Investigation Report, Shore Road, Swanage, Dorset, ref. GE8143/GIR [1]	This corresponds to land immediately south the site. Ground Investigation Report to support a geotechnical assessment of slope stability and consideration of remedial options.	Geo-Environmental Services Ltd	August 2011
Beach Huts Typical Single Module Drawing, ref. 12150.103 [2]	This corresponds to land immediately south the site. Swanage Town Centre, Recreation Ground.	Morgan Carey Architects	July 2013
Drainage Plan drawing no. 21120/100 [3]	This corresponds to land immediately south the site. Swanage Town Centre, Recreation Ground, Sea Front Development.	Smith Foster Limited	August 2013
Swanage Sea Front Interim Report, ref. 21120/48261 [4]	This corresponds to land immediately south hf the site. Relocation of the War Memorial to facilitate reprofiling the slopes to a shallower angle. Description of the works undertaken so far.	Smith Foster Limited	February 2014
Swanage Seafront Topo, Topographical Survey, drawing no. DB648-100, (Layouts 1 & 2) [5]	Topographical Survey.	DesignBase Ltd	April 2014
Preliminary Geo-Environmental and Geotechnical Assessment, ref. no. 5951, Version 1 [6]	Desk study, findings and interpretation of results from a ground investigation, environmental assessment, and geotechnical recommendations on ground engineering proposals.	South West Geotechnical	April 2014
Supplementary Survey Report, ref. no. 11063/58315 [7]	A supplementary condition survey of the public amenity areas fronting Shore Road, Swanage and to identify any significant deterioration compared to conditions recorded in the Smith Foster Partnership survey dated October 2000.	Smith Foster Limited	June 2016
Geotechnical Assessment, ref. no. 12660, Version 1 [8]	Desk study, findings from a ground investigation including proposed ground conditions, and geotechnical assessment & conclusions on ground engineering proposals.	South West Geotechnical	June 2021
Swanage Seafront Monitoring, ref. no. GR001, Version 1 [9]	Further to the completion of the additional inclinometer and groundwater monitoring at Swanage Seafront by South West Geotechnical. The purpose of the works was to monitor the slopes over the winter period to determine whether any more significant ground movement would occur during the wetter months, and to determine whether groundwater levels change significantly.	South West Geotechnical	April 2022

1.4 GEOTECHNICAL CATEGORY

1.4.1. In accordance with BS EN 1997-1 [10], the scheme has been classified as a Geotechnical Category 2 project. A Geotechnical Category 2 scheme includes conventional types of structures and foundations with no exceptional risk or difficult ground or loading conditions, this is considered to be appropriate with the current scope of works, and assessment of currently available ground information.

1.5 LIMITATIONS

1.5.1. WSP have prepared this report for the sole use of Swanage Town Council, in accordance with generally accepted consulting practices and for the intended purposes as stated in the agreement under which this work was completed.

1.5.2. This report may not be relied upon by any other party without the explicit written agreement of WSP. No other third party warranty, expressed or implied, is made as to the professional advice included in this report. This report must be used in its entirety.

1.5.3. WSP does no assume liability for misrepresentation of information or for items not visible, accessible, or present at the time of any site reconnaissance.

2 DESK STUDY

2.1 GEOLOGICAL MAPS AND MEMOIRS

2.1.1. The following geological information has been sourced from the British Geological Survey (BGS) Onshore GeoIndex [11], BGS Lexicon [12], BGS Sheet 342 (Swanage) Scale 1:50,000 [13].

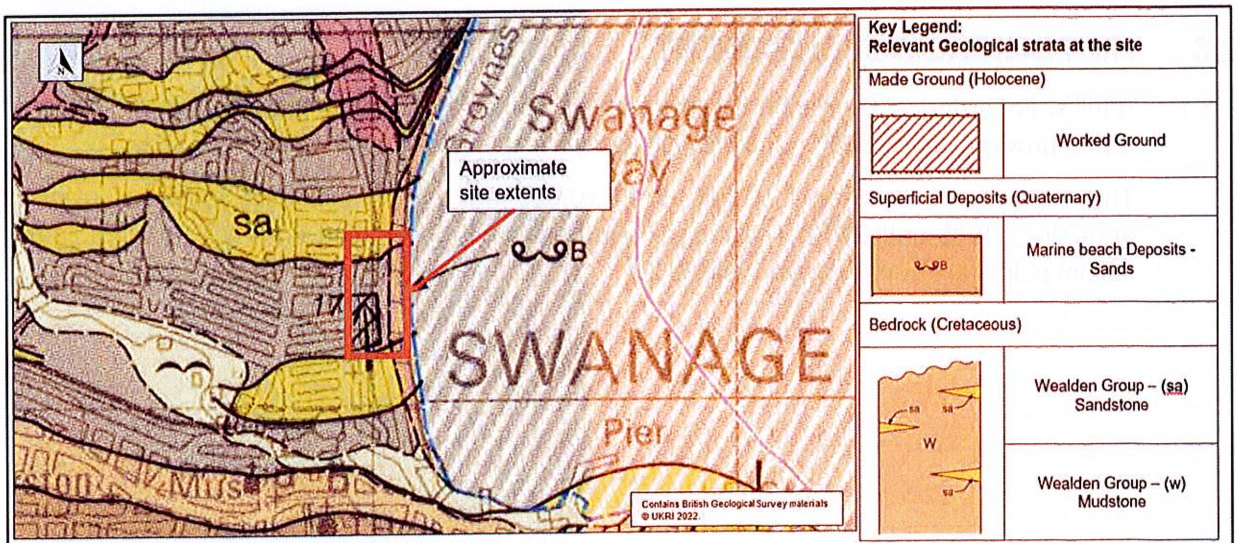
2.1.2. Figure 2-1 is an extract from the BGS Sheet 342 [13] showing the geological information collated for the site. The site is anticipated to be underlain by Mudstones of the Wealden Group (Solid Geology, Cretaceous Period). Sandstones of the same geological group are recorded only at the northern part of the site (The Spa area). Marine Beach Deposits (Superficial Deposits) forming Swanage beach are mapped along the toe of the eastern slopes.

2.1.3. Made Ground **('worked ground')** is observed on the maps along the western extents of the Sandpit Field. This is probably associated with a historic sandpit which gives name to this area. In addition, historical mapping suggests that the site has been developed and landscaped, therefore Made Ground and reworked natural ground are anticipated.

2.1.4. BGS Lexicon of named Units [12] describes the anticipated materials/strata at the site as follows:

- Worked Ground (Holocene Epoch): *'an area where land surface (natural or artificial) has been lowered as a result of man-made excavations.'*
- Marine Beach Deposits (Quaternary Period): *'Shingle, sand, silt and clay; may be bedded or chaotic; beach deposits may be in the form of dunes, sheets or banks; in association with the marine environment.'*
- Wealden Group – Mudstone & Sandstone (Cretaceous Period): *'Interbedded thick sandstones, siltstones, mudstones ("shales"), limestones and clay ironstones of predominantly non-marine facies. Divided into formations and members.'* As shown in Figure 2-1, the strata of the Wealden Group are dipping 17° northwards, with the strike approximately perpendicular (east-west) to the slope. Based on this, the general slope orientation is considered favourable.

Figure 2-1 - Regional geology and site location



(Sheet 342: Solid and Drift, Swanage. Published 2000. Geological Survey of England and Wales 1:50,000 geological map series, New Series).

2.2 HISTORICAL BOREHOLES

2.2.1. No available historical boreholes have been found within a 500 m radius surrounding the site.

2.3 HYDROLOGY AND HYDROGEOLOGY

2.3.1. The hydrology and hydrogeology at the site have been assessed using information from the Groundsure report reference EMS-247852_332984 provided within the Preliminary Geo-Environmental and Geotechnical Assessment, ref. no. 5951, Version 1 [6].

2.3.2. The closest surface water feature to the site is a culverted tertiary river that runs along Victoria Avenue (A351), immediately south of the Sandpit Field. In addition, Swanage Bay is approximately 25-30 m east of the site.

2.3.3. The eastern extents of the site are located in areas of extreme flooding risk from rivers or sea without defences (the latter in this case), Flood Zone 2. This corresponds to locations with high probability of flooding and are likely to need a flood risk assessment.

2.3.4. It should be noted that sea level rise due to climate change is likely to increase the coastal flood risk in the coming years, therefore the design for the proposed works should include this scenario.

2.3.5. The underlying strata are classified by the Environment Agency (EA) as a Secondary Type A aquifer, described as *'permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.'*

2.4 GROUND STABILITY HAZARDS

2.4.1. The Groundsure report provided in the SWG report [6] indicates that running sands are a high risk along the eastern site extents across site. This corresponds to the areas where Marine Beach Deposits are present.

2.4.2. The risk of landslides is recorded as moderate, also in association with the Marine Beach Deposits.

2.4.3. The risk of other ground stability hazards such as shrink-swell clays, soluble rocks, compressible deposits is recorded as low to negligible.

2.5 HISTORICAL DEVELOPMENT

2.5.1. A full set of historical Ordnance Survey maps of the site were obtained as part of the Groundsure report provided in the SWG report [6] following significant points relating to the site.

The maps scales between 1:1:2,500 and 1:10,560 indicate the historical development of the study area since 1889 until 2012. The maps have been reviewed based on SWG 2014 findings and the salient points are summarised in Table 2-1.

Table 2-1 - Summary of historical development

Map date	Significant observations
1889	The site and surrounding areas are shown to be undeveloped, comprising agricultural land. Only the eastern site boundary is defined by a road (current Shore Road). A 'sand pit' is shown in the southern section where within the Sandfield Pit area.
1902	The 'sand pit' workings have been extended inland to the west, approximately 10-15 m. Some residential development is shown to the south of Sandfield Pit. De Moulham Road (south of Sandfield Pit) is first recorded on this map edition, at the current location.
1928	Most of the current boundaries of the site are shown on this map edition. The eastern slope of the Sandpit Field is shown to comprise formal gardens, and the 'sand pit' feature is no longer shown. A circular feature, possibly indicating lower ground, is shown in the central area of the Sandpit Field. Walrond Road is first recorded on this map, and it separates the southern and northern sections of the site. The Weather Station area, immediately north of Walrond Road, is noted as 'Recreation Ground'. The holiday chalets of the Spa Beach Huts area are also shown. The land south of the Sandpit Field has been landscaped not a war memorial gardens and recreation ground.
1954	The Spa area has been landscaped and a footpath and is shown. A rectangular feature is shown in the south wester corner of the Weathered Station area. A series of groins have been installed in the beach. Significant developments are shown in the site surroundings.
1962/63	No significant changes recorded.
1974/75	No significant changes recorded. Carrie hotel has been built to the west of the Weathered Station. Continued development of the surrounding area noted. An electric substation is shown in the northwestern corner of The Spa area.
1985/86	No significant changes recorded.
1995	A breakwater has been constructed in the foreshore area to the southeast of the site. The hotel to the west of the site is no longer shown.
2012	The 'works' to the west of the site has been redeveloped for residential housing. The former hotel to the west of the site has been redeveloped.

2.6 UNEXPLODED ORDNANCE

2.6.1. A preliminary review for Unexploded Ordnance (UXO) has been undertaken using Zetica risk maps [14] whereby the site has been classified as having a moderate risk of encountering UXO. This means that there is a density potentially between 15 and 49 bombs per 1000 acre.

2.6.2. A Preliminary Unexploded Ordnance Threat Assessment (PDSA) prepared by Zetica UXO in May 2022 indicates that '*it is recommended that a detailed desk study is commissioned to assess, and potentially zone, the Unexploded Ordnance (UXO) hazard level on the Site*' (Appendix A).

2.7 REVIEW OF EXISTING INFORMATION

2.7.1. A review of the information provided by the client, included in Appendix A and summarised in Table 1-1, has been undertaken.

2.7.2. This review is focused on the assessment of the proposed ground models and ground engineering proposals recommended by South West Geotechnical (SWG) and Smith Foster Limited as part of the provided documents.

2.8 GROUND INVESTIGATION REPORT, SHORE ROAD, SWANAGE (AUGUST 2011)

2011 GROUND INVESTIGATION FINDINGS

2.8.1. A ground investigation (GI) was carried out by Geo-Environmental to the land immediately south of the site to support a geotechnical assessment of slope stability and consideration of remedial options.

2.8.2. No specific development was proposed other than potential remedial options to stabilise the slope along the eastern boundary.

2.8.3. This parcel of land included an easterly facing slope, areas of grassed lawn, footpaths, and a war memorial.

2.8.4. According to Geo-Environmental, the southern portion of the slope was characterised by hummocky ground which was thought to be indicative of shallow seated slope failure. This has been found to be very similar to the situation currently present in the land immediately north, at the site.

2.8.5. The ground conditions encountered by Geo-Environmental were comprised of shallow areas of Made Ground, overlying firm becoming very stiff clay with depth, and dense sand/poorly cemented sandstone. The soils plasticity of the clay was predominantly low.

2.8.6. No groundwater was encountered during the GI or monitoring wells installed within the boreholes according to Geo-Environmental. This could be due to the GI and monitoring being undertaken during the summer season when groundwater levels would be lowest. However, groundwater strikes at 4.0 m bgl (in WS7) and 4.3 m bgl (in WS9) were recorded during the GI.

2.8.7. Geo-Environmental indicated that whilst hummocky ground was evident in some areas of the slope, no evidence of failure planes was noted in the soils recovered from any of the boreholes.

2.8.8. A summary of the geotechnical test results taken from the GIR [1] has been presented in Table 1 of the report. The findings of the laboratory testing indicated that buried concrete should be designed using BRE Class DS-2, AC-2.

GEOTECHNICAL ASSESSMENT – GEOENVIRONMENTAL SERVICES LTD

Excavations

2.8.9. Geo-Environmental Services Ltd. (GSL) recommended to excavate into the existing slope as part of the remedial works. However, they indicated not to carry out long trench excavations across the slope since this could cause catastrophic slope failure.

2.8.10. Excavations beneath the groundwater table would probably require the use of dewatering and trench support.

Slope stability analysis

2.8.11. The slope stability analysis conducted by GSL indicated that the southern portion of the slope was unstable.

2.8.12. The assessment was undertaken for three sections across the unstable slope. The results generally confirmed the slopes to be unstable (i.e. factors of safety <1.0, except for one section).

Remedial Options

2.8.13. A summary of the slope stability remedial options proposed by GSL has been presented as follows:

- Do nothing – Lowest cost option but risk of future harm or damage. Regular footpath maintenance.
- Monitoring and alarm system – Installation of extensometers, piezometers and inclinometers to provide continual and real time data connected to an alarm system to warn of the onset of slope failure. It would only potentially provide early warning of potential slope failure, but would not solve the slope instabilities and structural damage.
- Move the footpaths – Relocation of footpaths further back from crest of slope. As the previous option, it does not address the existing stability problem.
- Structural integrity checks on the existing retaining wall – A structural examination of the existing wall would be critical to development of remedial options.
- Assuming the existing retaining wall is structurally sound, replace or refurbish drainage through the wall at the toe – Improve of drainage behind walls, which would improve slope stability.
- Construction of a new retaining wall – Option to be adopted when the structural integrity of the wall has been breached. This could be combined with re-profiling the slope to a shallower angle to improve stability. The new probably higher wall would have to be constructed in short sections to prevent slope failure during construction. Examples of retaining walls could include masonry walls, crib walls or gabion walls.
- Excavate and replace – Excavation of failed material and replacement with engineered fill, compacted in layers as per an earthworks specification. Potential need for geogrid reinforcement.
- Terracing the slope – Creating a series of terraces up the slope, making the slopes shallower. This could be combined with new drainage, vegetation and/or shallow retaining structures. Deep drainage and possible deep foundations for the retaining walls may be required.
- Construction of deep drainage down through the slope – Such as French or Counterfort Drains, constructed through the slope to reduce pore water pressure in the slope. This option may not prevent further ground movement but would improve the slope stability.
- Piled structures – Secant bored pile wall constructed along the slope would intercept existing slope failures, in combination with a capping beam to facilitate reprofiling of the slope.
- Soil nailing – GSL undertook a preliminary modelling of soil nails. The analysis indicated that two rows of nails in the lower row being 20 m long and nails in the upper row being 15 m long would make the slope stable.

2.9 PRELIMINARY GEO-ENVIRONMENTAL AND GEOTECHNICAL ASSESSMENT, SWG (APRIL 2014)

2014 GROUND INVESTIGATION FINDINGS

2.9.1. A GI was carried out at the site by South West Geotechnical (SWG) in March 2014 to obtain geoenvironmental and geotechnical data to assist the site management and future development.

2.9.2. The GI comprised nine window sample boreholes, ten dynamic cone penetrometer tests (DPSH), five Dynamic Cone Penetrometer (DCP) tests, and chemical and geotechnical laboratory testing. The exploratory hole location plan is provided within Figure 2 of the SWG report.

2.9.3. The ground conditions encountered during the 2014 GI are summarised in Table 2-2. This table should be used in combination with the ground conditions encountered in the 2021 GI by SWG presented in Table 2-3.

2.9.4. The ground conditions described in the logs were generally characterised by Topsoil overlying firm becoming stiff clay with depth. The presence of a soft clay layer is only noted in WS1 (in Weather Station Field) from 0.2 to 1.0 m bgl.

2.9.5. Cohesive overlying granular Made Ground was encountered in WS3 (in Sandpit Field). The maximum proven thickness of the Made Ground was 3.0 m.

2.9.6. It was noted that the ground conditions presented in Table 2-2 were not entirely consistent with the log descriptions, and probably SWG based these descriptions mainly on the in-situ DPSH results.

2.9.7. Groundwater was not encountered during the 2014 GI, except for seepage in WS3 at 1.5 m below ground level (bgl). No groundwater monitoring was conducted in this GI, hence this results may not be fully representative of the groundwater conditions at the site.

2.9.8. Standard Penetration Tests (SPT) were only conducted in WS1 (in Weather Station Field). The SPT N values (uncorrected) ranged between 1 and 21, increasing with depth, and showing consistency with the log descriptions.

2.9.9. Hand Shear Vane (HSV) tests were conducted within the cohesive strata of WS1, WS2, WS4, WS5, WS6, WS8 and WS9. The HSV values ranged between 11 and 90 kPa and were found to be in line with the log descriptions as well.

2.9.10. The results of the DPSH tests generally showed N100 values (i.e. number of blows per 100 mm penetration) ≤ 2 from ground level to 2-3 m bgl. Then, a steady increment to N100 of ≈ 5 and above was registered below the 2-3 m depth. The soft layer identified by the DPSH testing was not recognised in the window samples logs except in WS1.

2.9.11. The investigation found low concentrations of contaminants on the site indicating that the site could be fit for use in a commercial context.

GEOTECHNICAL CONSIDERATIONS

2.9.12. SWG concluded that the slope along the eastern boundary of the site may be prone to soil creep, translation and / or circular slope failures.

Slope stability

2.9.13. The SWG report indicated that most of the slopes at the site comprised of soft to firm clay to depths of around 2 m, overlying stiff to very stiff clay, becoming a weak mudstone at the depths.

2.9.14. However, WSP noticed that this assessment was not entirely in accordance with the log descriptions. As shown in Table 2-2 (based on log descriptions and HSV results), the soft layer was only identified in WS1. The presence of a 'weak mudstone' stratum was not recorded in any of the log descriptions.

2.9.15. The report did not include any overall slope stability analysis, but based on site observations SWG concluded that the slopes were marginally stable (i.e. Factor of Safety (FoS) ≈1.0). It was also suggested that installation of a deep land drainage system would increase the FoS above 1.0, hence making the slopes stable.

2.9.16. With regard to the existing retaining walls and other structures present on site, SWG suggested that soil nails anchored into the deeper mudstone would be the simplest solution.

2.9.17. Finally, the report indicated that anchored or piled structures into the deeper mudstone should be considered for future new structures.

2.9.18. WSP considers that the adoption of soil nails/anchors or piles requires further assessment since these remedial measures may be overly costly compared with other simpler solutions.

Foundations

2.9.19. SWG indicated that shallow foundations fully penetrating the soft soil and/or Made Ground into the firm underlying clay could be a reasonable solution for some of the new structures. This could involve excavations to depths up to 2.5 m depth. SWG indicated that a safe nett allowable bearing pressure of 100 kN/m^2 could be placed on the firm clay. WSP considers this appropriate for all areas, provided that foundations are clearly placed below soft soil and/or Made Ground (i.e. materials with undrained shear strength ≤ 40 kPa).

2.9.20. Adoption of vibro piling foundations through the shallow soft material down into the firm to stiff clays was also suggested by SWG. However, WSP thinks that the effectiveness of this ground improvement method (suitable in granular soils such as sands) may be limited given the anticipated cohesive nature of the soils underlying the site.

2.9.21. SWG recommended using **'uni-directional trench fill type'** spread foundation rather than piled solutions at areas with signs of shallow soil instabilities. These would involve casting of deep mass or reinforced concrete footings parallel to the slope contours with ground beams spanning between them.

Aggressive Ground Conditions

2.9.22. SWG indicated that no special precautions to protect buried concrete from sulphate attack were required, however no sulphate classes were suggested.

2.9.23. Based on the laboratory test results, a design sulphate class (DS) of DS-1 and an Aggressive concrete environment class (ACEC) of AC-1 could be adopted.

Road pavement design

2.9.24. According to SWG, the results of five or six (not clear in the report) DCP tests indicated a California Bearing Ratio (CBR) design value of 2% for use in road pavement design.

Table 2-2 - Summary of ground conditions, 2014 GI

Stratum	Depth from top to base of stratum (m)								
	WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9
Topsoil / Made Ground[(1)]	0.0 - 0.2	0.0 - 0.3	0.0 - >3.0	0.0 - 0.1	0.0 - 0.1	0.0 - 0.2	0.0 - 0.5	0.0 - 0.3	0.0 - 0.2
Soft Clay	0.2 - 1.0	-	-	-	-	-	-	-	-
Firm becoming stiff Clay	1.0 - 3.0	0.3 - ≥4.0	-	0.1 - ≥3.0	0.1 - ≥2.5	0.2 - ≥3.5	0.5 - ≥3.0	0.3 - ≥4.0	0.2 - ≥3.0
Stiff becoming very stiff Clay	3.0 - ≥5.0	≥4.0	-	-	-	-	-	-	-

(1) Made Ground was encountered to full depth of WS3 at 3.0 m below ground level (bgl). It was described as silty sandy gravelly clay from 0.2 to 1.0 m bgl and as silty gravelly clayey sand from 1.0 to 3.0 m bgl. SWG indicated that this could represent backfilling to a former sandpit.

2.10 SUPPLEMENTARY SURVEY REPORT, SMITH FOSTER (JUNE 2016)

2.10.1. A supplementary condition survey to establish the current condition, features and defects at the site, was carried out in May 2016 by Smith Foster. It should be noted that the original survey conducted by Smith Foster in October 2000 was not available.

2.10.2. The following recommendations for the existing structures and slopes at the site were suggested by Smith Foster:

Sandpit Field

- Replacement of missing stone of retaining wall;
- Point up stone treads at the south steps;
- Consider adding handrail on upslope side of staircase;
- Repair/replace damaged stone treads to north steps; and
- Rake out and repoint cracks in perimeter of retaining walls.

Weather Station Field

- Consider installation of ground anchors through southeast corner retaining wall;
- Rake out and repoint cracks;
- Clean out weep holes of retaining walls; and
- Provide improved edging restrain to footpath and resurface.

Spa Village

- Consider installation of ground anchors through wall adjacent to north entrance steps or installation of ground anchors/soil nails within the bank to reduce loading on the wall;
- Clean out weep holes of retaining walls; and

- Monitor deterioration of the public footpath where affected by ground movement along upper retaining wall to De Moulham Road.

2.11 GEOTECHNICAL ASSESSMENT, SWG (JUNE 2021)

2021 GROUND INVESTIGATION & GEOMORPHOLOGICAL SUVEY

2.11.1. SWG was commissioned by the Client to carry out a slope stability assessment and a GI with associated geotechnical testing, installation and monitoring of inclinometers and groundwater monitoring standpipes in boreholes.

2.11.2. The GI was conducted in December 2020 and included 17 window sample boreholes, six of which were followed on using a rotary percussive method; nine inclinometer installations, five standpipe piezometers and three standpipes. The exploratory hole location plan was included as Appendix C of the report.

2.11.3. The ground conditions encountered consisted of Made Ground overlying cohesive residual soils of the Wealden Group, tending to extremely weak, highly weathered siltstone of the Wealden Group in the deeper boreholes.

2.11.4. The ground conditions encountered during the 2020 GI were summarised in Table 2-3.

2.11.5. In addition to the GI, SWG conducted a site walkover geomorphological survey in December 2020. The findings suggested that the majority of the mapped geomorphological features were indicative of shallow creep and / or translational ground movements, rather than deep seated landslides, which concurs with the conclusions from the 2014 assessment. The type and location of the identified geomorphological features were presented in Appendix B of the SWG report.

2.11.6. The geomorphological survey also suggested that several of the retaining walls, especially around Sandpit Field were associated with inadequate drainage and poor condition. A series of cracks were noted in the tarmac footpath adjacent to De Moulham Road (in Weather Station Field) to the rear of the stone boundary wall. The walls were noted to be tilting downslope.

2.11.7. Significant quantities of both surface and groundwater were observed issuing at several locations across the site by SGW. A historic aerial photograph from 1950 showed the potential presence of a historic landslip at the location of the Spa Beach Huts. Based on the scale of the photograph this is difficult to confirm, although some form of soil exposure / slope erosion seemed to be present.

2.11.8. The drainage system along the seafront (Shore Road) was found to be blocked, full of water or sediment.

Made Ground

2.11.9. It was observed that the Made Ground near the ground surface was affected by fissuring, which according to SWG could be a sign of downslope movement. According to SWG the fissures were particularly evident in the exploratory holes near the crest of the slopes. Alternatively, WSP suggests the origin of this fissures may also be related to soil desiccation near the surface.

2.11.10. Using SPT correlations (Stroud and Butler, 1975), SWG derived the undrained shear strength of the Made Ground to be between 20 and 95 kPa, which was in line with the log descriptions. The results were scattered probably due to the variable nature of this material as indicated by SWG. It is noted that the correlation used is most suitable when applied to natural overconsolidated fissured clays, hence the values should be use with appropriate caution.

2.11.11. Based on Atterberg Limit tests, the Made Ground was classified as an intermediate to high plasticity clay. This means that this material may develop excessive/inadmissible long term settlements when loaded. Seasonal Shrinking-swelling (i.e. volume change variations when groundwater is present or absence in the ground) could contribute to further development of settlements.

2.11.12. A peak angle of shearing resistance of 29° and an effective cohesion of 24 kPa were obtained from a drained shear box test. Similarly, a residual angle of shearing resistance of 26° and a residual effective cohesion of 12 kPa were obtained for the same sample. By comparison, using correlations with the Plasticity Index (BS 8002 method), a constant volume angle of shearing resistance of 24° was obtained.

Stiff (locally firm) Silt/Clay (weathered Wealden Group)

2.11.13. Fissuring was also identified within the weathered Wealden Group in various exploratory holes. This was especially obvious in the positions located near the crest of the slopes, thus suggesting potential downslope movement.

2.11.14. The clays/silts of the weathered Wealden Group were classified as intermediate to high plasticity soils.

2.11.15. The undrained shear strength of the strata was derived using the same SPT correlation described for the Made Ground. The values ranged between 40 and 165 kPa, generally increasing with depth.

2.11.16. Four drained shear box tests were undertaken on samples of the weathered Wealden Group with results peak angle of shearing resistance and effective cohesion of between 22-27°, and 8-14 kPa respectively. Residual parameters of 17-26° and 6-10 kPa were recorded.

Very dense Sand (Wealden Group)

2.11.17. A very dense sand layer with occasional clay pockets was only encountered in BH09, BH10 and BH17, within the Sandpit Field. It should be noted that open hole drilling methods were used by SWG through this layer, therefore the log descriptions were assumed by SWG.

2.11.18. Only two SPTs were conducted on the layer, with N values of 62 and 75, which were in accordance with the log descriptions ('very dense sand').

2.11.19. A shear box test gave an angle of shearing resistance and an effective cohesion of 31° and 1.5 kPa respectively. Given the high fines content identified for this stratum in the particle size distribution analysis (PSD) (24% and 31% in BH09 and BH17, respectively), these results seem reasonable. Alternatively, this could correspond to highly weathered bedrock with its structure destroyed during sampling activities.

Extremely weak Siltstone/Mudstone (Wealden Group)

2.11.20. The siltstones/mudstones of the Wealden Group formed extremely weak rocks of the Solid Geology. It is noted that due to its highly fractured nature potentially combined with induced drilling disturbance, the material was recovered as stiff silts/clays.

2.11.21. The SPT N values ranged between 30 (hard clays) and 90 (extremely weak siltstones/mudstones) (average of 50).

Groundwater

2.11.22. Significant groundwater was observed issuing through the retaining walls adjacent to Shore Road (eastern end of the site) during the GI.

2.11.23. The exploratory holes recoded groundwater strikes at between 5.3 m AOD (0.9 m bgl) and 8.5 m AOD (7.0 m bgl).

2.11.24. SWG monitored the groundwater levels between January and June 2021 and noticed that groundwater levels were affected by the weather conditions with changes of between 3 and 7 m across the site.

2.11.25. Figure 5 of the report showed the groundwater levels decreasing during a dry period of mid-March to early May 2021, with a sharp increase soon after that.

2.11.26. Groundwater was recorded at ground level in BH13 (in Sandpit Field), during the initial site visits, however the protective cover was damaged and monitored was interrupted.

Inclinometers

2.11.27. Inclinometers to monitor ground movements were installed in The Spa area (BH01 and BH03), the Weather Station Field area (BH06 and BH07), and the Sandpit Field area (BH10, BH12 and BH16).

2.11.28. SWG indicated that the inclinometer readings confirmed that the slopes were moving, however WSP considers that this interpretation needs further examination.

2.11.29. The inclinometer in BH01 recorded approximately 2 mm of maximum deflection near the ground surface over the five month monitoring period. It also recorded <1.0 mm movement at approximately 12.0 m bgl. The inclinometer in BH03 recorded a maximum deflection of 1.7 mm between ground level and 2.5 m bgl. The other inclinometers registered smaller amounts of ground movement.

2.11.30. It should be noted that the accuracy of inclinometers is typically around ± 0.2 mm per meter length, therefore the observed readings fell within the accuracy of the equipment and as such, 'true' movement may not have been registered.

GEOTECHNICAL CONSIDERATIONS

Stability assessment

2.11.31. SWG undertook a limit equilibrium slope stability analysis using Rocscience Slide software, based on the Morgenstern Price method. The British Standard approach based on an overall factor of safety of 1.2 to 1.3 was adopted.

2.11.32. The analysis considered a higher and a lower groundwater levels to account for the groundwater variations observed during the monitoring period.

2.11.33. The geotechnical design parameters used in the analysis were summarised in Table 4 of the report. The angle of shearing resistance was taken for the residual condition, i.e. assuming existing slip planes due to failure of the slopes.

2.11.34. This approach is considered appropriate for the shallow Made Ground and potentially the underlying residual soil. However, WSP opine that the parameters adopted for the siltstone/mudstone (Wealden Group) may have been underestimated since it is not certain that residual conditions (i.e. slope failure) are representative of the strata at depth.

2.11.35. Due to the adoption of residual geotechnical parameters, all sections analysed by SWG showed potential shallow failure circles with a FoS <1.0.

2.11.36. The results of the stability analysis were summarised by SWG in Table 5 of the report. These results were used to create a Hazard Map for the site which was provided in Appendix I. The Hazard Map classified most of The Spa and Spa Beach Huts areas as high risk due to ground instabilities; the Weather Station Field area was medium risk; and the Sandpit Field area was low (western section) to medium risk (eastern section).

Foundations

2.11.37. SWG recommended piled foundations for any new structures and replacement of retaining walls in the area of the Weather Station, and along the slopes on the northern and eastern elevations of the Sandpit Field.

2.11.38. SWG considered that secant bored pile retaining walls would be the preferred option for new retaining structures. This type of wall could improve drainage at the site.

2.11.39. Soil nails were recommended to provide additional support to the slopes.

2.11.40. The following foundation types were briefly discussed in the SWG report:

- **Piles/Piled walls**. These were considered by SWG as the most appropriate solution to transfer structural loads into competent ground at depth. Bored piles or percussively formed ODEX piles were suggested.
- **Shallow Foundations**. SWG indicated that shallow foundations may be appropriate in some areas of the Sandpit Field, although the depth of the anticipated made Ground (up to 2.6 m) would make this option more expensive than piling solutions.

2.11.41. WSP recommends having special consideration to issues related to blowing/running sands (i.e. loose sand/silt layers becoming fluidised by groundwater flowing through them), especially when pling works may be required.

2.11.42. Open bore auger techniques such as continuous flight auger (CFA) or rotary bored piling may be problematic without some kind of support system, e.g. risk of over-flighting, base softening and collapse of excavation. A driven piled solution may therefore offer a more practical alternative both in terms of construction and performance, although this will generate more disruption for local stakeholders (noise, vibration etc.). WSP recommends that a piling contractor is consulted early in the design process.

Groundwater and excavations

2.11.43. Shallow groundwater was found to have a significant impact on the stability of the slopes. therefore, installation of a new drainage system would be greatly beneficial.

2.11.44. SWG suggested installation of horizontal drains drilled along the eastern retaining walls of the site, with most benefit as a dewatering method to the north of Walrond Road.

2.11.45. It was also mentioned that deep drainage could be installed south of Walrond Road down to Shore Road level, although this would involve significant earthworks. The slopes would require installing some form of temporary support prior to or during excavation to make sure deep seated failures do not occur.

2.11.46. SWG advised to give appropriate consideration to the length of excavations and construction sequencing together with temporary or permanent support to make sure the stability of the slopes is maintained.

Table 2-3 - Summary of ground conditions, 2021 GI

General description / Stratum	Depth/level from top to base of stratum (m bgl) / (m AOD)					
	BH01	BH02	BH03	BH04	BH05	BH06
Soft to firm Clay/Silt (Topsoil)	0.0 - 0.2 (16.0 - 15.8)	0.0 - 0.3 (15.5 - 15.2)	0.0 - 0.2 (14.0 - 13.8)	0.0 - 0.2 (13.6 - 13.4)	0.0 - 0.2 (11.2 - 11.0)	0.0 - 0.3 (11.7 - 11.4)
Soft to firm clay/Silt (Made Ground[(1)])	0.2 - 1.2 (15.8 - 14.8)	0.3 - 1.7 (15.2 - 13.8)	0.2 - 1.9 (13.8 - 12.1)	0.2 - 1.6 (13.4 - 12.0)	0.2 - 2.2 (11.0 - 9.0)	0.3 - 3.1 (11.4 - 8.6)
Stiff (locally firm) Silt/Clay (weathered Wealden Group)	1.2 - 2.3 (14.8 - 13.7)	1.7 - 2.7 (13.8 - 12.8)	1.9 - 3.5 (12.1 - 10.5)	1.6 - 4.9 (12.0 - 8.7)	2.2 - 4.5 (9.0 - 6.7)	3.1 - 3.9 (8.6 - 7.8)
Very dense Sand (Wealden Group)	-	-	-	-	-	-
Extremely weak Siltstone/Mudstone recovered as stiff silt/clay. (Wealden Group Siltstone)	2.3 - ≥13.5 (13.7 - ≥2.5)	2.7 - ≥15.0 (12.8 - ≥0.5)	3.5 - ≥5.5 (10.5 - ≥8.5)	4.9 - ≥5.5 (8.7 - ≥8.1)	4.5 - ≥8.0 (6.7 - ≥3.2)	3.9 - ≥9.0 (7.8 - ≥2.7)
Groundwater (m bgl) / (m AOD)	-	7.0 (8.5)	-	-	-	1.0 (10.7)
Stratum	**Depth from top to base of stratum (m)**					
	BH07	**BH08**	**BH09**	**BH10**	**BH11**	**BH12**
Soft to firm Clay/Silt (Topsoil)	-	0.0 - 0.3 (7.5 - 7.2)	-	0.0 - 0.4 (8.4 - 8.0)	0.0 - 0.1 (9.0 - 8.9)	0.0 - 0.1 (9.0 - 8.9)
Soft to firm clay/Silt (Made Ground[(1)])	0.0 - 0.8 (7.4 - 6.6)	0.3 - 2.2 (7.2 - 5.3)	0.0 - 1.5 (8.4 - 7.0)	0.4 - 2.9 (8.0 - 5.5)	0.1 - 1.3 (8.9 - 7.7)	0.1 - 1.3 (8.9 - 7.7)
Stiff (locally firm) Silt/Clay (weathered Wealden Group)	0.8 - ≥4.5 (6.6 - ≥2.9)	2.2 - ≥5.5 (5.3 - ≥2.0)	-	-	1.3 - 3.1 (7.7 - 5.9)	1.3 - 3.1 (7.7 - 5.9)
Very dense Sand (Wealden Group)	-	-	1.4 - ≥2.5 (7.0 - ≥5.9)	2.9 - ≥3.4 (5.5 - ≥5.0)	-	-
Extremely weak Siltstone/Mudstone recovered as stiff silt/clay. (Wealden Group Siltstone)	-	-	-	-	3.1 - ≥4.5 (5.9 - ≥4.5)	3.1 - ≥4.5 (5.9 - ≥4.5)
Groundwater (m bgl) / (m AOD)	-	-	-	-	-	-

Stratum	Depth from top to base of stratum (m)					
	BH13	BH14	BH15	BH16	BH17	-
Soft to firm Clay/Silt (Topsoil)	0.0 - 0.2 (6.2 - 6.0)	0.0 - 0.2 (6.2 - 6.0)	0.0 - 0.2 (8.4 - 8.2)	0.0 - 0.2 (8.6 - 8.4)	0.0 - 0.2 (10.0 - 9.8)	-
Soft to firm clay/Silt (Made Ground[(1)])	0.2 - 0.9 (6.0 - 5.3)	0.2 - 0.9 (6.0 - 5.3)	0.2 - 2.1 (8.2 - 6.3)	0.2 - 2.6 (8.4 - 6.0)	0.2 - 0.8 (9.8 - 9.2)	
Stiff (locally firm) Silt/Clay[(1)] (weathered Wealden Group)	0.9 - ≥3.5 (5.3 - ≥5.5)	0.9 - ≥3.0 (5.3 - ≥3.2)	2.1 - ≥5.5 (6.3 - ≥5.9)	2.6 - ≥4.0 (6.0 - ≥4.6)	-	
Very dense Sand (Wealden Group)	-	-	-	-	0.8 - ≥7.0 (9.2 - ≥3.0)	
Extremely weak Siltstone/Mudstone recovered as stiff silt/clay. (Wealden Group Siltstone)	-	-	-	-	-	
Groundwater (m bgl) / (m AOD)	0.9 (5.3)	0.9 (5.3)	3.0 (5.4)	2.0 (6.7)	-	
(1) Occasional fissures encountered within this material in some exploratory holes.						

SWANAGE SEAFRONT MONITORING, SWG (APRIL 2022)

2.11.47. Additional inclinometer and groundwater monitoring was conducted by SWG at the site in April 2022. The main objective was to monitor the slopes over the winter period to determine whether significant ground movement would occur, and to assess whether groundwater level would change significantly during the wetter months.

2.11.48. BH01 recorded a maximum deflection of approximately 4.0 mm at the surface for a period of 14 months, possibly associated with the over steep soils on the crest of the slope. SWG also indicated that <1.0 mm movement was recorded in this exploratory hole at 12.0 m depth.

2.11.49. All other boreholes registered similar or lesser amounts of ground movement.

2.11.50. As previously indicated, considering the accuracy of the inclinometers is around ± 0.2 mm per meter length, it is not certain true ground movement was registered by the inclinometers.

2.11.51. The groundwater levels were relatively stable with an anticipated increase over the winter wetter months, except for BH04. This exploratory hole registered significant groundwater fluctuations following periods of intense rain. BH04 was located closed to a potentially damaged drain which was observed to be leaking.

3 WALKOVER SURVEY

3.1.1. A walkover survey of the site was carried out on the 24th of May 2022 by two WSP Geotechnical Engineers. The purpose of the walkover was to assess the current condition, features and defects and make comparisons with surveys previously undertaken on site.

3.1.2. Site photographs, brief description of defects and relevant geomorphological features identified during the assessment are presented in Appendix B. The photographs taken were organised as follows:

- The Spa, photographs P1 to P16;
- Spa Beach Huts, photographs P17 to P28;
- Weather Station Field, photographs P29 to P38; and
- Sandpit Field, photographs P39 to P50.

3.1.3. It is noted that no significant deterioration of the defects and geomorphological features recorded in the 2020 survey by SWG [9] have been observed in the 2022 survey by WSP.

3.1.4. However, it is quite evident that some of the cracks affecting the retaining walls, footpaths and slopes have deteriorated further when compared with the 2016 survey undertaken by Smith Foster Limited report [7]. Clear examples of this are photographs P8, P9 (The Spa) and P38 (Weather Station Field).

4 GEOTECHNICAL RISK REGISTER

4.1.1. The risks associated with the geotechnical aspects of the scheme have been identified and addressed in the geotechnical risk register (GRR).

4.1.2. As this is a live document, this should be regularly updated as the scheme progresses and guidance shall be sought from all parties involved in the design and implementation of the works.

4.1.3. Below are provided the hazards, their inherent consequences and proposed solutions to eliminate or mitigate the risks.

The Risk Matrix

Risk level	
High Risk	Overall Risk = Impact x likelihood
Medium High Risk	
Medium Low Risk	
Low Risk	

Severity ↑					Likelihood →				
Cost as % of Project cost (not just fees)	Time	Quality	Overall IMPACT	Score	Negligible Very Low <5% 1	Unlikely Low 6-20% 2	Possible Medium 21-50% 3	Probable High 51-80% 4	Almost Certain Very High >80% 5
>5%	<20%	Major	Very High	5	5	10	15	20	25
3 to 5%	10% to 20%	Large	High	4	4	8	12	16	20
1 to 3%	5 to 10%	Moderate	Medium	3	3	6	9	12	15
0.5 to 1%	1 to 5%	Minor	Low	2	2	4	6	8	10
<0.5%	<1%	Minimal	Very Low	1	1	2	3	4	5

Cost / time and quality may be affected differently by a single risk. If overall risk is required, use the most severe affected component or give consideration to managing each separately.

Table 4-1 - Geotechnical Risk Register

Risk ID	Hazard	Consequence	Likelihood	Severity	Risk	Mitigation	Likelihood	Severity	Residual Risk
1	Failure of existing retaining walls if no remedial measures are adopted, especially the retaining walls already failing.	Serious injury and/or fatality of pedestrians and road users nearby. Road closures and/or footpath closures. High construction costs to repair the retaining walls as emergency works. Significant disruption to traffic until repair works have been completed.	4	5	20	Various ground investigations have been undertaken to establish the ground profile and derived geotechnical properties and to identify the main cause(s) influencing in the development of defects affecting the slopes and retaining walls stability. Recommendations provided in this report should be considered further and progressed at design stage. It is recommended to undertake CCTV drainage surveys and follow recommendations.	1	5	4
2	Unexpected ground conditions.	This can lead to inadequate geotechnical design, further deterioration and failure of slopes and retaining walls, programme delays, and H&S issues.	4	4	16	Various ground investigations have been undertaken to establish the ground profile and derived geotechnical properties and to identify the main cause(s) influencing in the development of defects affecting the slopes and retaining walls stability. Geotechnical design to be undertaken using the ground model and derived geotechnical parameters obtained from the ground investigations, in combination with following progressing the recommendations given in this report.	4	1	4
3	High groundwater levels and/or perched water underlaying the site	Water ingress into excavations during construction works. Additional cost managing groundwater.	4	3	12	Various ground investigations have been undertaken to establish the ground profile and derived geotechnical properties and to identify the main cause(s) influencing in the development of defects	4	1	4

		Collapse/instability of temporary excavation works. Collapse/instability of the retaining walls and/or slopes.				affecting the slopes and retaining walls stability. Designer to communicate the risk on drawings and to consider suitable design groundwater levels in the stability analysis during the design stage. Temporary stability to be addressed in the temporary works design. Contractor to implement monitoring of groundwater during construction works and implement suitable measures to control the groundwater levels and promote the stability of the earthworks. It is likely that standby pumping equipment will be required during site works, in case of breakdown of the main pumps			
4	Instability of excavations in granular materials, including potential of blowing/running sands/silts.	Temporary excavations undertaken may become unstable leading to complete or partial collapse, programme delays and serious H&S issues.	4	3	12	Correct design and design check procedure should be initiated for all temporary works. Use of trench boxes and supports if appropriate, to minimise the likelihood of collapse. Consideration of temporary works and de-watering during construction Site personnel not to enter unsupported excavations.	4	1	4
5	Unknown location and depth of slip planes affecting the slopes.	Inadequate design of areas with instabilities. Slope failure, programme delays and serious H&S issues.	4	4	16	Geotechnical software to be utilised in the detailed design stage to identify the location of the most critical slip surfaces. Potential additional GI at specific locations could be required, depending on chosen remedial options. Conservative design approach may be necessary if there are uncertainties.	4	4	4

6	Build-up of pore water pressure due to blocked drainage system behind retaining walls.	It would lead to further instabilities, potential failures of existing retaining walls, programme delays and serious H&S issues.	4	3	12	Adequate remediation and/or maintenance of existing drainage system to reduce pore water pressure. It is recommended to undertake a CCTV drainage surveys and follow recommendations.	4	1	4
7	Encountering contaminated materials during the remedial works	Exposure of site workers. Exposure of members of the public. Removal of contaminated material / water to licensed facilities.	3	3	9	Establish site procedures to identify and dispose of contaminated materials. in case these were encountered during construction. The 2016 SWG GI found low concentration of contaminants on the site and confirmed that the site was fit for use in a commercial context.	3	1	3
8	Aggressive ground conditions and sulphate attack on concrete, steel and other buried structures.	Aggressive ground conditions encountered which could lead to chemical attack on concrete and other buried materials.	3	3	9	SWG 2014 ground investigation included chemical analysis to inform the design of buried concrete. See Section 2.9 of this report. Designer to implement all recommendations of BRE Special Digest 1 during detailed design of buried structures.	3	1	3
9	Unexploded Ordnance (UXO).	Encountering UXO during construction. This can lead to programme delays, disruption to ground investigation and construction and serious injury to personnel and/or road users.	4	4	16	Zetica Unexploded Bomb (UXB) risk map indicated that the site is in an area of moderate risk. A Pre-Desk Study Assessment (PSDA) from Zetica prepared in May 2022 indicated that a detailed desk study is recommended prior to any works and/or GI on site. A detailed report should be commissioned by the Client. Designer should follow and adopt all recommendations given in the PSDA prior to any work being undertaken on site.	4	1	4
10	Construction works compromising the stability of the existing structures.	Failure of existing structures such as retaining walls, huts and steps.	4	4	16	Adoption of suitable ground model and geotechnical properties based on GI undertaken at the site. Suitable construction sequence to be	4	1	4

						undertaken to minimise the risk of destabilising existing structures. Requirement for temporary works to allow for construction of remedial solutions to be assessed at detailed design stage.			

5 PRELIMINARY ENGINEERING ASSESSMENT

5.1 DISCUSSION

5.1.1. Based on the information collected from past investigations and the site visit undertaken by WSP Engineers in May 2022, it is reasonable to assume that shallow ground movement, possibly soil creep, is affecting the site.

5.1.2. Soil creep is a type of slope movement that involves the slow and gradual movement of a soil mass down a slope. Soil creep is typically greatest near the ground surface and decreases with depth. The soil ripples (such as the cracks along footpaths), the hummocky terrain along the eastern side of the site, and tilted retaining walls are features typically associated with this type of slope failure.

5.1.3. No clear evidence of deep seated failure planes has been observed at the site, although this cannot be fully discarded. Further ground monitoring using the inclinometers and standpipe piezometers installed by SWG would be highly beneficial to better understand the ground and groundwater behaviour in the long term.

5.1.4. In addition, there are defects in the drainage system which is in poor condition with various of the drains and weep holes blocked with vegetation and sediments. This prevents both groundwater and surface water run-off from exiting the slopes during rainfall events, contributing to water ingress into the ground. This is followed by pore water pressure build-up, which reduces the soil shear strength and brings about further down-slope ground movement.

5.1.5. Vegetation growth may have also contributed to the generation of structural defects (e.g. some of the cracking affecting retaining walls), however this can be considered a localised factor.

5.1.6. Although no information on the original retaining walls foundations is available, it is suspected that these old structures (potentially ≈90 years old based on historical maps information), may not have robust foundations. Therefore, any shallow ground movement such as soil creep and seasonal shrink/swell of cohesive soil could have a significant impact on their integrity.

5.1.7. Furthermore, poorly compacted fill may have contributed to the formation of cracking at some locations, for example below the pavement next to the retaining walls defining the western site extents which support De Moulham Road.

5.2 REMEDIAL OPTIONS, RECOMMENDATIONS & BUDGET ESTIMATES

5.2.1. This section includes a high level ground engineering remedial proposals to address areas of potential instability and assess with respect to future potential uses for the following areas:

- The Spa;
- Spa Beach Huts;
- Weather Station Field; and
- Sandpit Field.

5.2.2. This section should be read in conjunction with the following drawings (see Appendix C), which illustrate the extents of each of the options presented:

- 70094760-GEO-001 – Plan with potential options southern area.
- 70094760-GEO-002 – Plan with potential options northern area.

5.2.3. This report does not constitute either preliminary or detailed design, it is intended to provide outlines of potential remedial solutions.

5.2.4. The options presented in this section should be discussed with the Client.

5.2.5. A summary and a budget estimation for remedial options have been provided in Table 5-1.

Option 1 – Do Minimum (across site)

5.2.6. This option should be adopted as a 'do minimum' and will be required for all options. This option includes the following elements:

- CCTV drainage surveys & drainage repairs based on the survey recommendations. This should include all drainage within the site boundaries and water main pipes behind the crest of the slope.
- Detailed UXO desk survey.
- 3D Topographical survey.
- Periodic visual inspections of slopes and structures by a suitably qualified Geotechnical Engineer, taking photographs of affected areas to compare with previous years. This could include structural integrity checks on the existing retaining walls.
- Localised repairs, e.g. repairs/replacement of missing blocks from retaining walls, minor crack repairs etc.
- Monitoring and/or alarm system. Continue ground and groundwater monitoring using existing inclinometers and standpipe piezometers. This would require implementation of an alarm system to warn of the onset of slope failure.

5.2.7. Lowest cost option although not a permanent solution. The risk of future slope failures which could cause harm to pedestrians and road users is still present. Further damage to existing structures which could collapse still exist. Therefore, the options suggested below should be implemented in combination with Option 1.

Option 2 – Slope regrading and/or granular replacement

5.2.8. This option, if chosen, should be adopted in combination with Option 1. This option includes one or a combination of the following elements:

- Slope regrading of steep slopes and where evidence of ground movement has been recorded (i.e. presence of cracks, uneven/hummocky terrain, loose/soft lobes of soil etc). This may typically be from the ground surface to a maximum depth of 2-2.5 m bgl. The exact extents and depth of this measure needs to be assessed during construction by a suitably qualified Geotechnical Engineer. Slope angles should be regraded to ≈16 degrees (≈1V:3.5H), and in some instances, this may require installation of geogrid reinforcement.
- Granular replacement of soft/loose ground, targeting specific unstable areas, and/or inclusion of counterfort trenches filled with free draining granular material at a regular spacing (e.g. ≈10 m spacing). This measure would improve the slope stability by removing part of the soft unstable material and would also improve drainage, by removing groundwater from the slopes more efficiently. The granular replacement would be engineered fill, compacted in layers and in accordance with an earthwork specification.
- Terracing the slope by creating a series of terraces up the slope, which would make the slopes shallower. This could be combined with new drainage, vegetation and/or shallow retaining structures.

- The measures proposed in this option are likely to require full or partial reconstruction (and often re-location) of the footpaths.

Option 3 – Soil nails/anchors of slopes and/or existing retaining walls

- Soil nailing/anchoring of failing slopes and/or existing retaining walls with defects. Based on the preliminary assessment undertaken by GSL for the land south of the site, the nails required may be in the order of 15-20 m long.

Option 4 – Full reconstruction of existing retaining walls as gravity walls

5.2.9. This option, if chosen, should be adopted in combination with Option 1. This option includes the following elements:

- Full reconstruction of existing retaining walls and other existing structures.
- Complete demolition of existing structures possibly including the structure foundations. Examples of retaining walls types could include masonry walls, crib walls and gabion walls. Use of local natural stones and/or recycling stones from demolition to reduce waste and improve aesthetics in the case of masonry walls. Crib and gabion walls have become highly popular for use in landscaping projects and can blend into natural surroundings, due to the sites coastal location they will require due consideration of the durability of materials used to construct them.
- If new foundations are required, the new structures should be founded on firm stratum (anticipated at depths >1-2.5 m depth), using for example shallow reinforced concrete footings.
- This option should also consider installation of a new drainage system, such as horizontal slotted PVC drain pipes across the new structure.
- Recommended option to be adopted when the structural integrity of the structures has been reached. The new retaining walls would probably be higher, therefore, construction should be conducted in short sections to prevent slope failure. This option would require temporary relocation of the beach huts to allow demolition and removal of the failed wall and construction of the new structure.
- The measures proposed in this option may require full or partial reconstruction (and sometimes re-location) of the footpaths.

Option 4a – Full reconstruction of existing walls as embedded retaining walls (only for Spa Beach Huts)

5.2.10. This option, if chosen, should be adopted in combination with Option 1. This option includes the following:

- Complete demolition of existing retaining walls and construction of embedded retaining walls such as contiguous/secant pile walls.
- This option should also considered installation of new drainage system, such as horizontal slotted PVC drain pipes across the new structure.
- Recommended option to be adopted for the Spa Beach Huts when the structural integrity of the structures has been reached. This option would require temporary relocation of the beach huts to allow demolition and removal of the failed wall and construction of the new structure. Although this is the most expensive option, it may be the most suitable due to the limited available space at this location.
- The measures proposed in this option may require full or partial reconstruction (and sometimes re-location) of the footpaths.

Table 5-1 - Remedial options & construction budget estimate

Option	Construction budget	Assumptions/considerations
Option 1 – Do Minimum (across site)		
Option 2 – Slope regrading and/or granular replacement		
Option 3 – Soil nails/anchors of slopes		
Option 4 – Full reconstruction o existing retaining walls as gravity walls.		
Option 4a – Ful reconstruction c existing retaining walls as embedded walls.		

6 REFERENCES

[1] Geo-Environmental Services Ltd , "Ground Investigation Report, Shore Road, Swanage, Dorset ref. GE8143/GIR," Sussex, August 2011.

[2] Morgan Carey Architects, "Beach Huts Typical Single Module Drawing, ref. 12150.103," Wareham, July 2013.

[3] Smith Foster Limited, "Swanage Town Centre, Recreation Ground, Sea Front Development. Drainage Plan drawing no. 21120/100," Poole, August 2013.

[4] "Swanage Sea Front Interim Report ref. 21120/48261," Poole, February 2014.

[5] DesignBase Ltd, *Swanage Seafront Topo, Topographical Survey, drawing no. DB648-100, (Layouts 1 & 2),* 2014.

[6] South West Geotechnical Ltd, "Preliminary Geo-Environmental and Geotechnical Assessment, ref. no. 5951, Version 1," April 2014.

[7] Smith Foster Ltd, "Supplementary Survey Report, ref. no. 11063/58315," June 2016.

[8] South West Geotechnical, "Geotechnical Assessment, ref. no. 12660, Version 1," June 2021.

[9] South West Geotechnical, "Swanage Seafront Monitoring, ref. no. GR001, Version 1," April 2022.

[10] British Standards Institution, BS EN 1997-1:2004+A1:2013 Incorporating corrigendum February 2009 'Eurocode 7: Geotechnical Design- Part 1: General Rules', London: BSI Standards Limited, 2014.

[11] B. G. Survey, "GeoIndex," BGS, [Online]. Available: https://www.bgs.ac.uk/GeoIndex/. [Accessed 25 05 2022].

[12] British Geological Survey, "BGS Lexicon of named Units," [Online]. Available: https://www.bgs.ac.uk/lexicon/lexicon. [Accessed 25 05 2022].

[13] British Geological Survey, "Geological Map: Swanage. Sheet 342, Geological Survey of England and Wales 1:50,000, Solid and Drift," BGS, London, 2000.

[14] ZeticaUXO, "Risk Maps," [Online]. Available: https://zeticauxo.com/downloads-and-resources/risk-maps/. [Accessed 31 05 2022].

Appendix A

RELEVANT GEOTECHNICAL INFORMATION PROVIDED BY CLIENT AND ZETICA PDSA

ZETICA PDSA

Pre-Desk Study Assessment	
Site:	Land off Swanage Beach, Swanage, Dorset
Client:	WSP
Contact:	Alvaro Delgado-Alvarado
Date:	24th May 2022
Pre-WWI Military Activity on or Affecting the Site	None identified.
WWI Military Activity on or Affecting the Site	None identified.
WWI Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: ▪ Swanage Harbour. ▪ Transport infrastructure and public utilities. ▪ Military camps and training areas.
WWI Bombing	None identified on the Site.
Interwar Military Activity on or Affecting the Site	None identified.
WWII Military Activity on or Affecting the Site	Readily available records have been found to indicate that during WWII several anti-invasion defences, including Light Anti-Aircraft (LAA) batteries, gun emplacements, barbed wire entanglements, and minefields were established on or in close proximity to the Site.
WWII Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: ▪ Swanage Harbour. ▪ Transport infrastructure and public utilities. ▪ Military camps and training areas. ▪ Anti-Aircraft (AA) and anti-invasion defences.
WWII Bombing Decoys (within 5km of Site)	None.
WWII Bombing	During WWII the Site was located in the Urban District (RD) of Swanage, which officially recorded 44No. High Explosive (HE) bombs with a bombing density of 15.9 bombs per 405 hectares (ha). Readily available records have been found to indicate that several HE bombs fell in close proximity to the Site.
Post-WWII Military Activity on or Affecting the Site	None identified.
Recommendation	It is recommended that a detailed desk study is commissioned to assess, and potentially zone, the Unexploded Ordnance (UXO) hazard level on the Site.
Further information	For information about Zetica's detailed UXO desk studies and other UXO services, please visit our website: www.zeticauxo.com. Details and downloadable resources covering the most common sources of UXO hazard affecting sites in the UK can be found **here**. If you have any further queries, please don't hesitate to get in contact with us at uxo@zetica.com or 01993 886 682.

This summary is based on a cursory review of readily available records. Caution is advised if you plan to action work based on this summary.

It should be noted that where a potentially significant source of UXO hazard has been identified on the Site, the requirement for a detailed desk study and risk assessment has been confirmed and no further research will be undertaken at this stage. It is possible that further in-depth research as part of a detailed UXO desk study and risk assessment may identify other potential sources of UXO hazard on the Site.

Appendix B

SITE VISIT PHOTOGRAPHS

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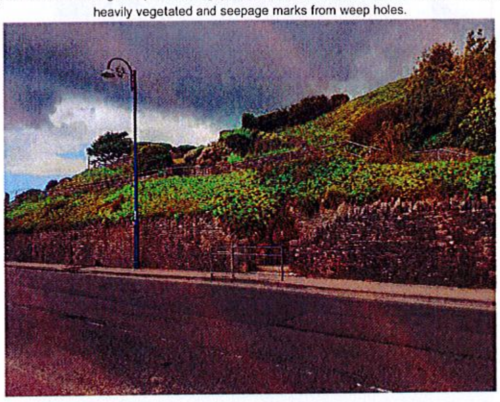
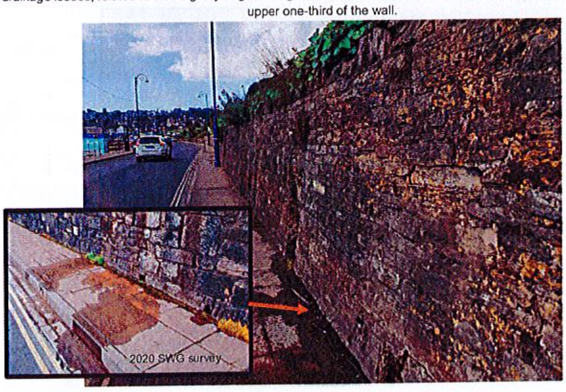
APPENDIX B: SWANAGE SITE WALKOVER 24/05/2022

P1: The Spa. Eastern retaining wall (≈1.5-2m high) and steps looking southwest from Shore Road. Note slopes heavily vegetated and seepage marks from weep holes.

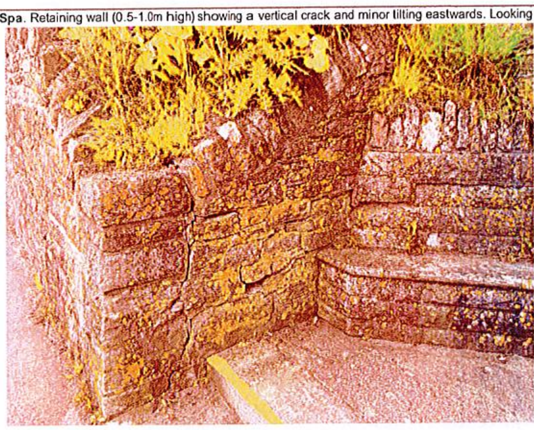


P2: The Spa. Eastern retaining wall (≈1.5-2m high) and steps looking west from Shore Road. Northern site boundary at centre of photograph. The retaining wall on the right hand side (yellowish-light brown colour) is outside the site boundary.

P3: The Spa. Eastern retaining wall (≈1.5-2.0m high) looking south from Shore Road. Retaining wall showing evident drainage issues, related to blockage by vegetation growth and/or sediments. Horizontal cracking is noted along the upper one-third of the wall.



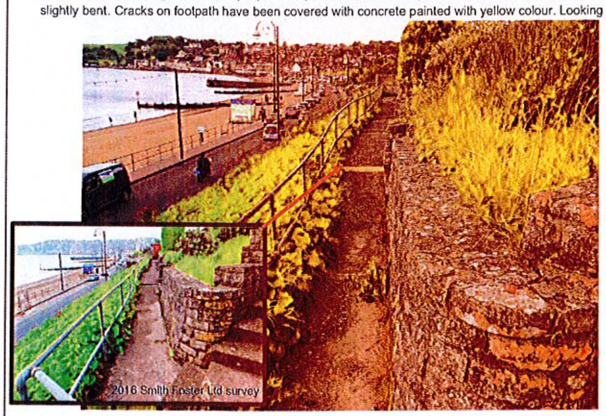
P4: The Spa. Retaining wall (0.5-1.0m high) showing a vertical crack and minor tilting eastwards. Looking sothwest.



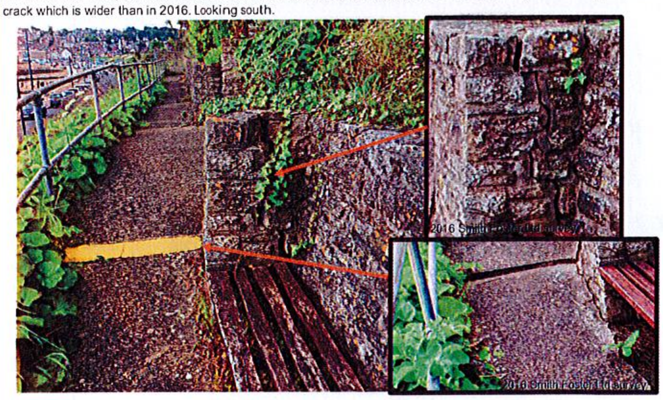
P5: The Spa. Retaining wall (1-1.5 m hig) showing a subhorizontal becoming oblique crack along the upper portion. Heavely vegetated area behind and over the wall. Looking northeast.

P6: The Spa. Leaning retaining wall (westwards) and cracks in steps. Looking south.

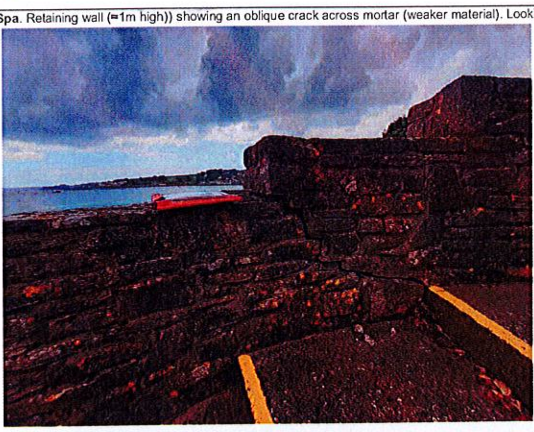
P7: The Spa. Steep vegetated bank (left) and displaced concrete footpath with uneven surface. The hand rail is slightly bent. Cracks on footpath have been covered with concrete painted with yellow colour. Looking south.



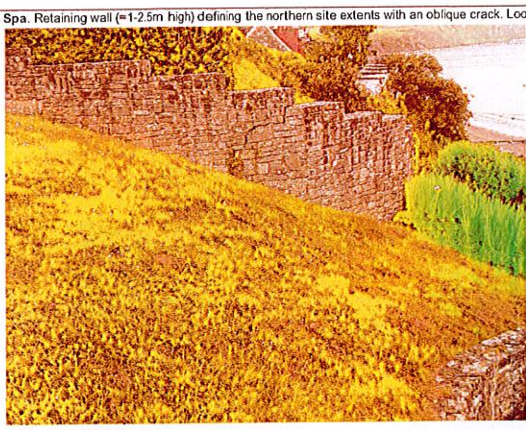
P8: The Spa. Steep vegetated bank (left) and displaced concrete footpath with uneven surface. The hand rail is slightly bent. Cracks on footpath have been covered with concrete painted with yellow colour. Retaining wall showing a vertical crack which is wider than in 2016. Looking south.



P9: The Spa. Retaining wall (≈1m high)) showing an oblique crack across mortar (weaker material). Looking south.

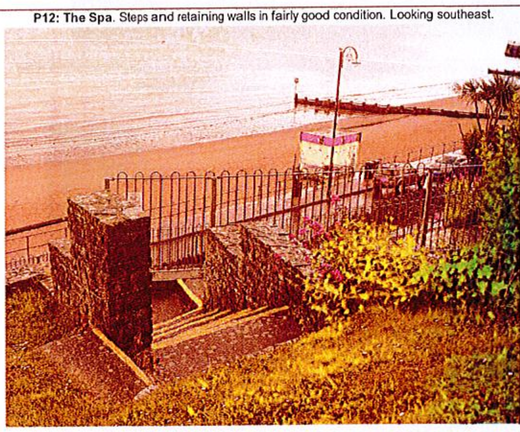


P10: The Spa. Retaining wall (≈1-2.5m high) defining the northern site extents with an oblique crack. Looking north.



P11:The Spa. Steps and retaining walls showing some minor cracking. Looking northeast.

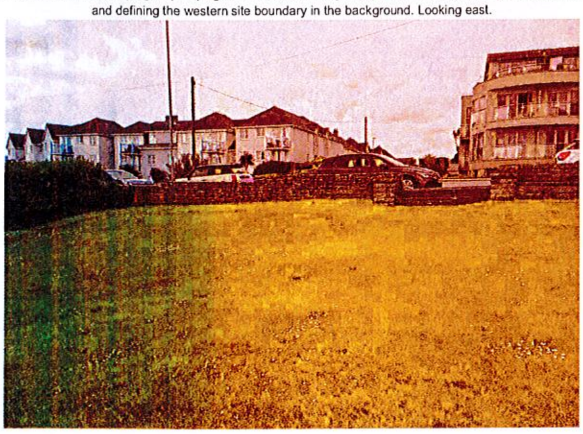
P12: The Spa. Steps and retaining walls in fairly good condition. Looking southeast.



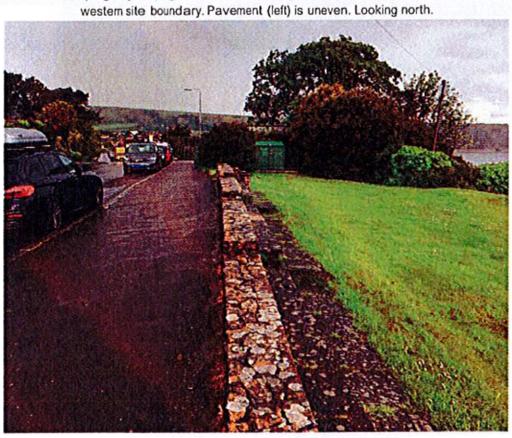
P13: The Spa. Grassed slope gently sloping eastwards. Electric substation and borehole BH01 (SWG 2020) headworks in the background. Looking north.

P14: The Spa. Retaining wall supporting De Moulham Road and defining the western site boundary. Evidence of recent pavement repairs and/or services installation. Looking south.

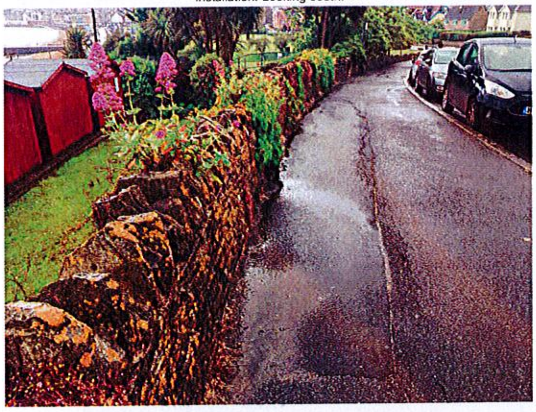
P15: The Spa. Grassed slope gently sloping eastwards. Retaining wall (≈0.5m high) supporting De Moulham Road and defining the western site boundary in the background. Looking east.



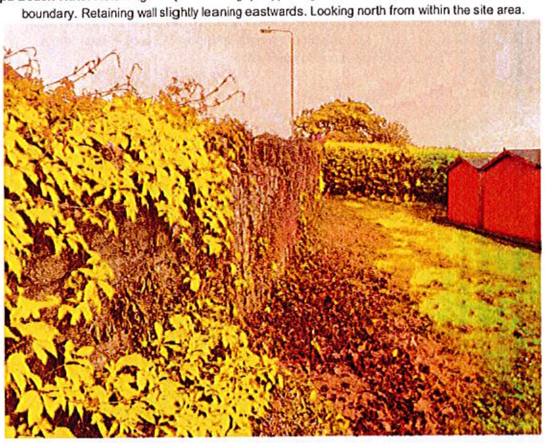
P16: The Spa. Grassed slope gently sloping eastwards. Retaining wall supporting De Moulham Road and defining the western site boundary. Pavement (left) is uneven. Looking north.



P17: Spa Beach Huts. Retaining wall (≈**1.5**-2m high) supporting De Moulham Road and defining the western site boundary. Retaining wall clearly leaning eastwards and evidence of recent pavement repairs and/or services installation. Looking south.



P18: Spa Beach Huts. Retaining wall (≈1.5-2m high) supporting De Moulham Road and defining the western site boundary. Retaining wall slightly leaning eastwards. Looking north from within the site area.



P19: Spa Beach Huts. Grassed slope between huts gently sloping eastwards.

P20: Spa Beach Huts. Concrete slabs with repairs sloping eastwards and supported by a retaining wall (≈2-2.5m high). Presence of steel railings across perimeter. Concrete repairs evident on the lower level (right). Looking northeast.

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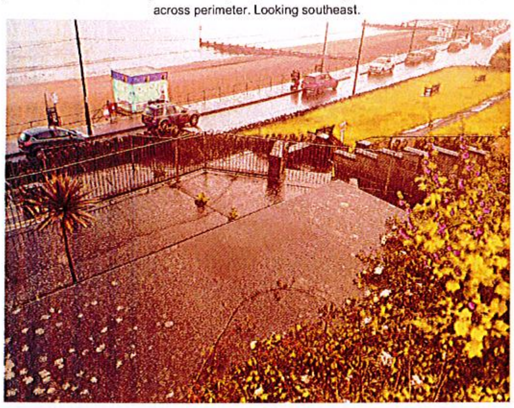
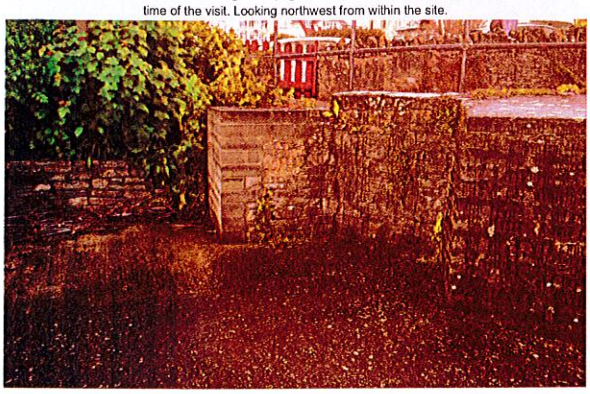
P21: Spa Beach Huts. Concrete slabs with cracks and some minor repairs covering the ground surface on lower level (left). A concrete block retaining wall with steps is present to the right hand side. Presence of steel railings across perimeter. Looking southeast.

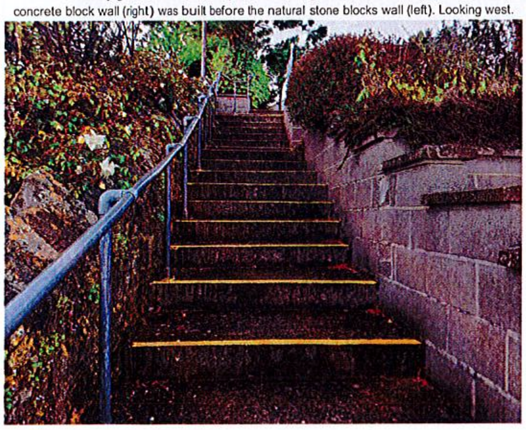


P22: Spa Beach Huts. Concrete slabs with cracks and construction joints, and some minor concrete repairs. A retaining wall (≈2-2.5m high) is supporting the slope in front of the huts. Presence of steel railings across perimeter. Looking northeast.

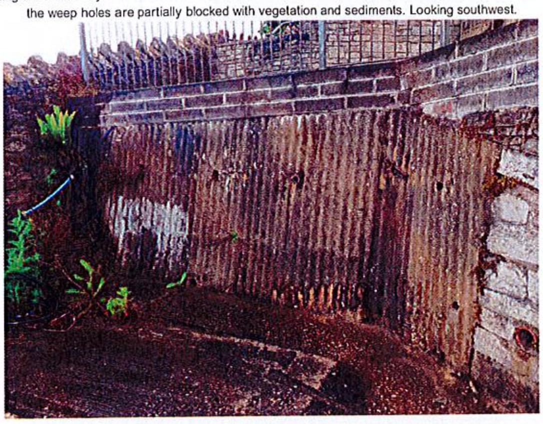
P23: Spa Beach Huts. General aspect of retaining walls with various retained heights (≈0.5-1.5 m high) along the western section. Partial reconstruction of existing masonry wall made of natural stone blocks using prefabricated concrete blocks noted at the centre of the image. Seepage on the walls is due to heavy down pour occurring at the time of the visit. Looking northwest from within the site.



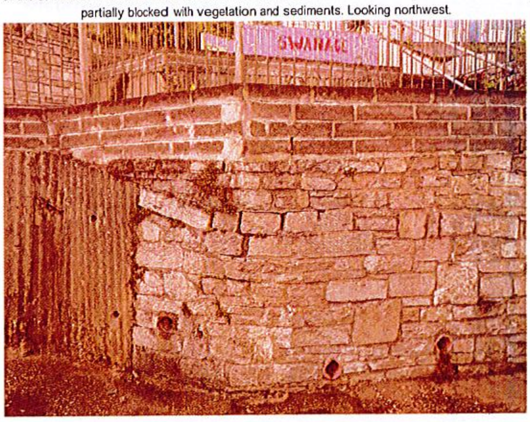
P24: Spa Beach Huts. Fairly good condition of steps and retaining walls. It can be assumed that the prefabricated concrete block wall (right) was built before the natural stone blocks wall (left). Looking west.



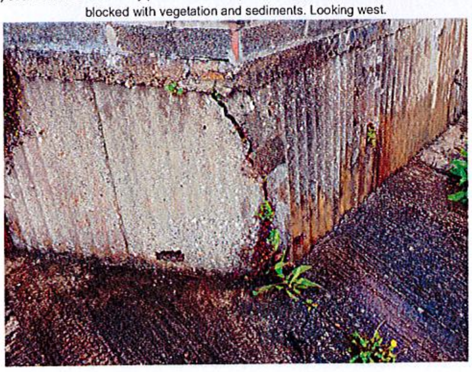
P25: Spa Beach Huts. Retaining wall (≈2-2.5 m high) located in front of the huts. The wall is comprised of prefabricated concrete blocks (top) natural stone blocks (right), and concrete with wavy patterns vertically oriented (left) forming the main body of the structure. This is indicative of different construction and/or repair stages. Some of the weep holes are partially blocked with vegetation and sediments. Looking southwest.



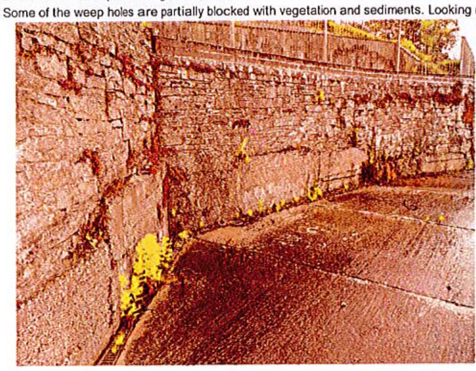
P26: Spa Beach Huts. Retaining wall (≈2-2.5 m high) located in front of the huts. The wall is comprised of prefabricated concrete blocks (top) natural stone blocks (right), and concrete with wavy patterns vertically oriented (left) forming the main body of the structure. This is indicative of different construction and/or repair stages. Some of the weepholes are partially blocked with vegetation and sediments. Looking northwest.



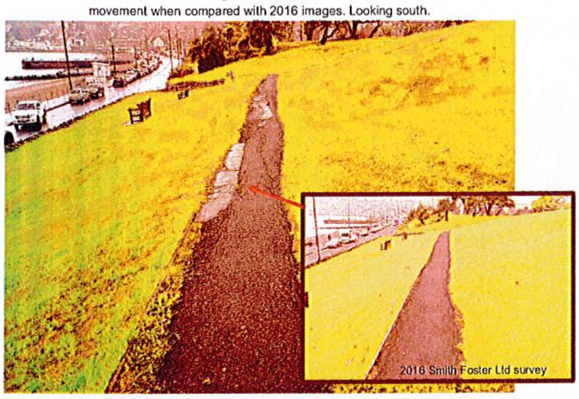
P27: Spa Beach Huts. Detail of vertical crack across the base of the retaining wall comprising prefabricated concrete blocks (above) over concrete with wavy patterns vertically oriented (below). Some of the weep holes are partially blocked with vegetation and sediments. Looking west.



P28: Spa Beach Huts. Retaining wall (≈2-2.5 m high) located in front of the huts. Natural stone blocks forms the main body of the wall with concrete repairs along its lower section. This is indicative of different construction and/or repair stages. Some of the weep holes are partially blocked with vegetation and sediments. Looking northwest.

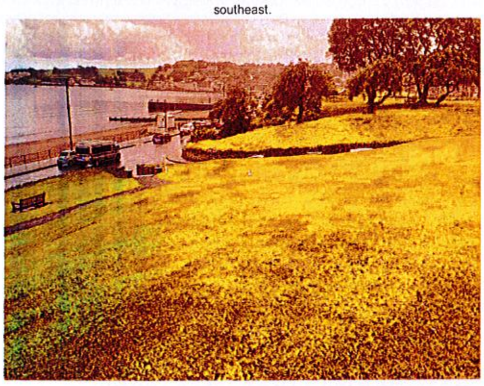


P29: Weathered Station Field. Uneven/hummocky terrain, sloping eastwards. Footpath with extensive cracking along tarmac and recent concrete repairs. This image shows clear evidence of eastwards (probably shallow) ground movement when compared with 2016 images. Looking south.

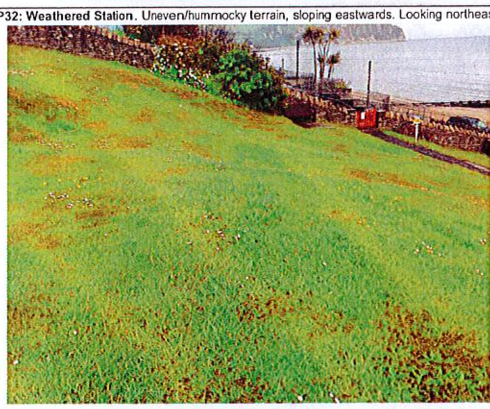


P30: Weathered Station Field. Footpath with extensive cracking along tarmac and recent concrete repairs. Clear evidence of further deterioration when compared with 2016 images. Looking south.

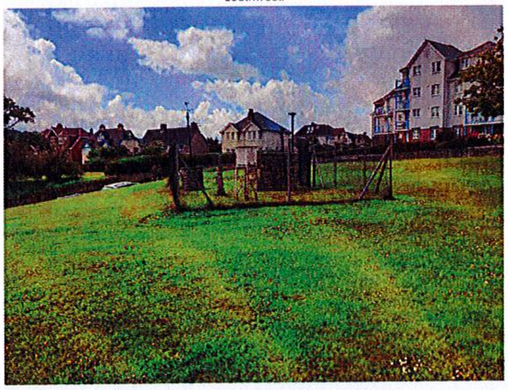
P31: Weathered Station. Uneven/hummocky terrain, sloping eastwards. Sandfield Pit in the background. Looking southeast.



P32: Weathered Station. Uneven/hummocky terrain, sloping eastwards. Looking northeast.

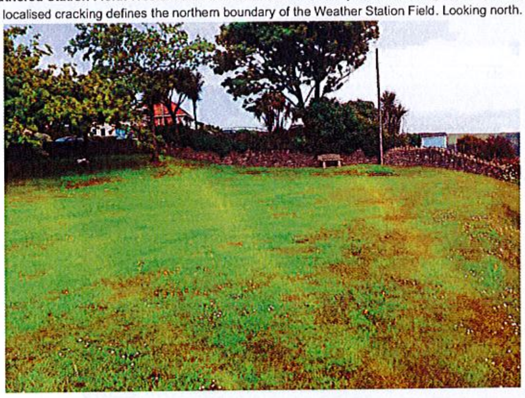


P33: Weathered Station Field. The weather station is on relatively flat ground, gently sloping eastwards. Looking southwest.

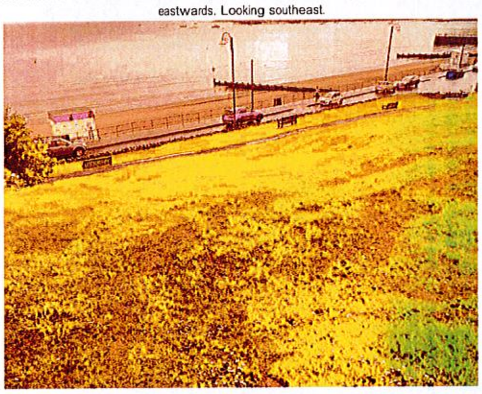


P34: Weathered Station Field. Western retaining wall (≈0.5-1.0m high) supporting De Moulham Road. The walls is in fairly good condition although localised minor cracking is present. Looking northwest.

P35: Weathered Station Field. Western area of this section is relatively flat. A retaining wall (≈0.5-1m high) with localised cracking defines the northern boundary of the Weather Station Field. Looking north.



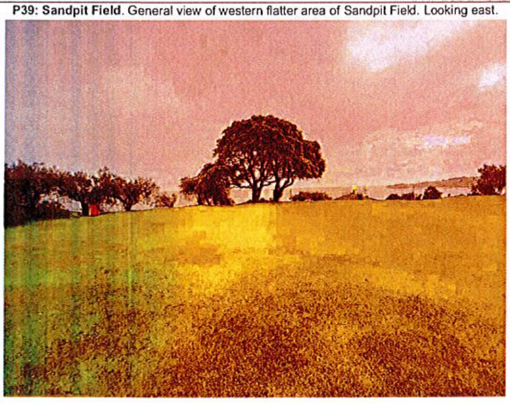
P36: Weathered Station Field. General view of the Weather Station Field slope. Uneven/hummocky terrain, sloping eastwards. Looking southeast.



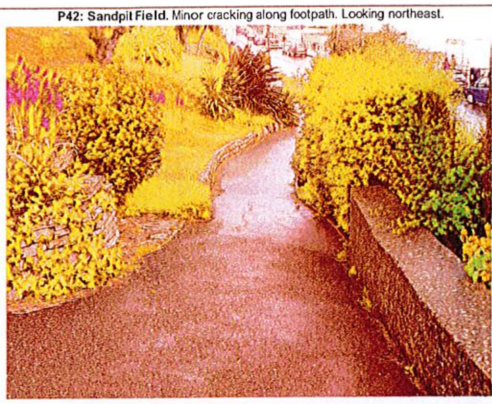
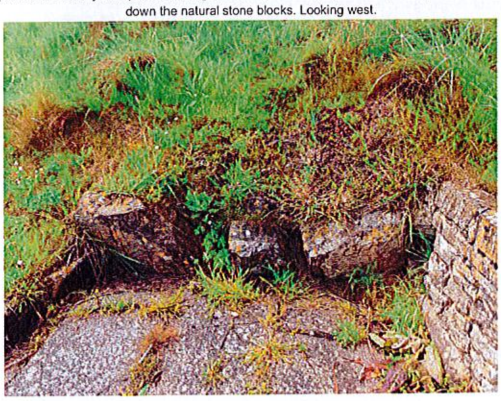
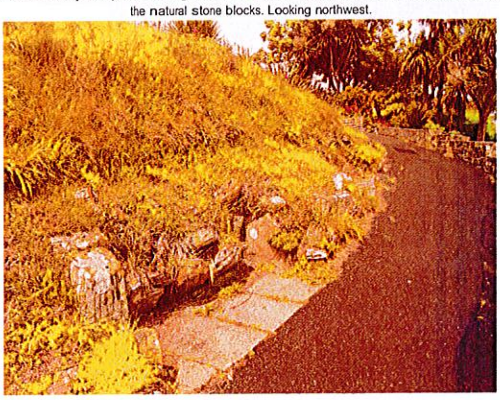
P37: Weathered Station Field. General view of the Weather Station Field from Sandfield Pit. Uneven/hummocky terrain, sloping eastwards. It shows the flatter western area (left), and the steeper and unstable slopes to the east and south of this area. Looking north.

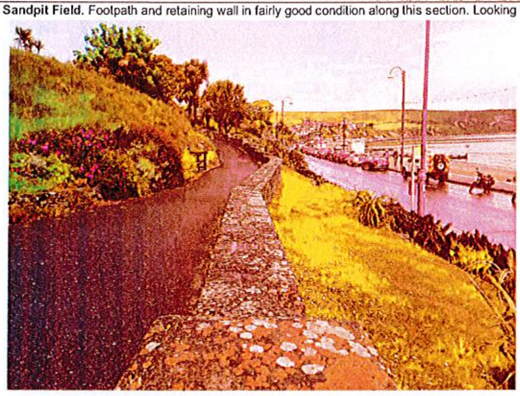
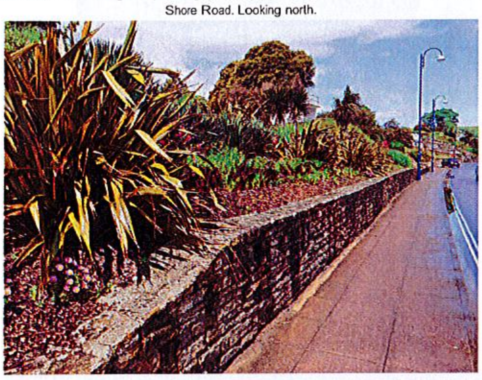
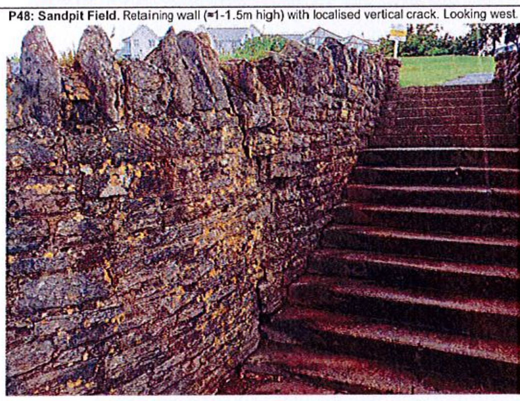
P38: Weathered Station Field. Detail of localised vertical cracking (≈1-15cms wide) across the eastern retaining wall (**≈1.5m high)**. The defect is located at the southeastern corner of the Weathered Station Field. Various stone blocks along the crack are missing. Looking northwest.

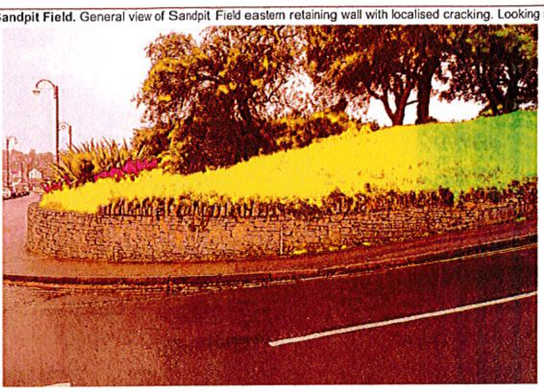
P39: Sandpit Field. General view of western flatter area of Sandpit Field. Looking east.



P40: Sandpit Field. General view of western flatter area of Sandpit Field. Looking southeast.

P41: Sandpit Field. Cracking, subsidence and repairs along footpath. Clear evidence of eastwards shallow ground, pushing the retaining wall. Looking southeast. 	**P42: Sandpit Field.** Minor cracking along footpath. Looking northeast. 
P43: Sandpit Field. Partially collapsed retaining structure (≈0.5m high). Backfill pushing eastwards has knocked down the natural stone blocks. Looking west. 	**P44: Sandpit Field.** Partially collapsed retaining structures (≈0.5m high). Backfill pushing eastwards has knocked down the natural stone blocks. Looking northwest. 

P45: Sandpit Field. Footpath and retaining wall in fairly good condition along this section. Looking north. 	**P46: Sandpit Field.** Eastern retaining wall (≈1m high) in fairly good condition at this location. Drainage blockage along Shore Road. Looking north. 
P47: Sandpit Field. Retaining wall (≈1-1.5m high) with cracking. Looking west. 	**P48: Sandpit Field.** Retaining wall (≈1-1.5m high) with localised vertical crack. Looking west. 

P49: Sandpit Field. General view of Sandpit Field eastern retaining wall with localised cracking. Looking west. 	**P50: Sandpit Field.** General view of Sandpit Field eastern retaining wall with localised cracking. Looking south. 

Appendix C

DRAWINGS

KEY LEGEND - POTENTIAL REMEDIAL OPTIONS

(green) REMEDIAL MEASURES UNLIKELY TO BE REQUIRED.

(yellow) POTENTIAL OPTIONS TO BE CONSIDERED:

OPTION 1 – DO MINIMUM (ACROSS SITE)

- CCTV DRAINAGE SURVEYS & DRAINAGE REPAIRS BASED ON THE SURVEY RECOMMENDATIONS. THIS SHOULD INCLUDE ALL DRAINAGE WITHIN THE SITE BOUNDARIES AND WATER MAIN PIPES BEHIND THE CREST OF THE SLOPE.
- DETAILED UXO DESK SURVEY.
- TOPOGRAPHICAL 3D SURVEY.
- PERIODIC VISUAL INSPECTIONS OF SLOPES AND STRUCTURES BY A SUITABLY QUALIFIED GEOTECHNICAL ENGINEER, TAKING PHOTOGRAPHS OF AFFECTED AREAS TO COMPARE WITH PREVIOUS YEARS. THIS COULD INCLUDE STRUCTURAL INTEGRITY CHECKS ON THE EXISTING RETAINING WALLS.
- LOCALISED REPAIRS, E.G. REPAIRS/REPLACEMENT OF MISSING BLOCKS FROM RETAINING WALLS, MINOR CRACK REPAIRS ETC.
- MONITORING AND/OR ALARM SYSTEM. CONTINUE GROUND AND GROUNDWATER MONITORING USING EXISTING INCLINOMETERS AND STANDPIPE PIEZOMETERS. THIS WOULD REQUIRE IMPLEMENTATION OF AN ALARM SYSTEM TO WARN OF THE ONSET OF SLOPE FAILURE

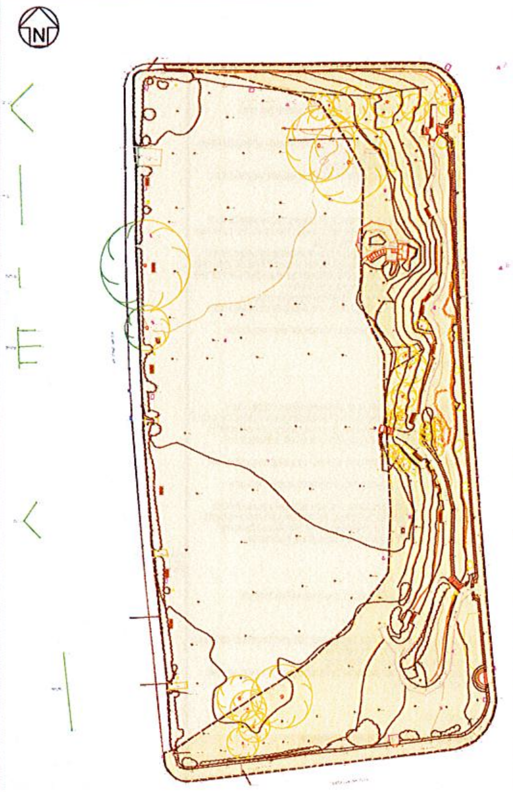
OPTION 3 – SOIL NAILS/ANCHORS OF SLOPES AND/OR EXISTING RETAINING WALLS

- SOIL NAILING/ANCHORING OF FAILING SLOPES AND/OR EXISTING RETAINING WALLS WITH DEFECTS.

OPTION 4 – FULL RECONSTRUCTION OF EXISTING RETAINING WALLS AS GRAVITY WALLS

- FULL RECONSTRUCTION OF EXISTING RETAINING WALLS AND OTHER EXISTING STRUCTURES.
- COMPLETE DEMOLITION OF EXISTING STRUCTURES POSSIBLY INCLUDING THE STRUCTURE FOUNDATIONS. EXAMPLES OF RETAINING WALLS TYPES COULD INCLUDE MASONRY WALLS, CRIB WALLS AND GABION WALLS. USE OF LOCAL NATURAL STONES AND/OR RECYCLING STONES FROM DEMOLITION TO REDUCE WASTE AND IMPROVE AESTHETICS IN THE CASE OF MASONRY WALLS. CRIB AND GABION WALLS HAVE BECOME HIGHLY POPULAR FOR USE IN LANDSCAPING PROJECTS AND CAN BLEND INTO NATURAL SURROUNDINGS, DUE TO THE SITES COASTAL LOCATION THEY WILL REQUIRE DUE CONSIDERATION OF THE DURABILITY OF MATERIALS USED TO CONSTRUCT THEM.
- IF NEW FOUNDATIONS ARE REQUIRED, THE NEW STRUCTURES SHOULD BE FOUNDED ON FIRM STRATUM (ANTICIPATED AT DEPTHS >1-2.5 m DEPTH), USING FOR EXAMPLE SHALLOW REINFORCED CONCRETE FOOTINGS.
- THIS OPTION SHOULD ALSO CONSIDER INSTALLATION OF A NEW DRAINAGE SYSTEM, SUCH AS HORIZONTAL SLOTTED PVC DRAIN PIPES ACROSS THE NEW STRUCTURE.
- RECOMMENDED OPTION TO BE ADOPTED WHEN THE STRUCTURAL INTEGRITY OF THE STRUCTURES HAS BEEN REACHED. THE NEW RETAINING WALLS WOULD PROBABLY BE HIGHER, THEREFORE, CONSTRUCTION SHOULD BE CONDUCTED IN SHORT SECTIONS TO PREVENT SLOPE FAILURE. THIS OPTION WOULD REQUIRE TEMPORARY RELOCATION OF THE BEACH HUTS TO ALLOW DEMOLITION AND REMOVAL OF THE FAILED WALL AND CONSTRUCTION OF THE NEW STRUCTURE.
- THE MEASURES PROPOSED IN THIS OPTION MAY REQUIRE FULL OR PARTIAL RECONSTRUCTION (AND SOMETIMES RE-LOCATION) OF THE FOOTPATHS.

File name C:\USERS\INVM03944\ONEDRIVE - WSP O365\SWANAGE TC - GROUND STABILISATION FEASIBILITY STUDY\06 07 2022\70094760-GEO-001.DWG, printed on 06 September 2022 10:03:08, by Mani, Varalakshmi



NOTES:
1. DO NOT SCALE THIS DRAWING. ALL DIMENSIONS ARE APPROXIMATE AND SUBJECT TO DETAILED DESIGN.
2. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH DRAWING NO. 70094760-GEO-002 AND THE GROUND STABILISATION FEASIBILITY STUDY REF. 70094760-GEO-REV001, PREPARED BY WSP IN JULY 2022.
3. TOPOGRAPHICAL SURVEY INFORMATION WAS PREPARED BY DESIGNBASE SURVEYING & ARCHITECTURE IN APRIL 2014.

REV	DATE	BY	DESCRIPTION	CHK	APP
P02	06-09-2022	VM	FOR APPROVAL	BW	LB
P01	04-07-2022	VM	FIRST ISSUE	BW	LB

DRAWING STATUS: APPROVED

wsp

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CLIENT: SWANAGE TOWN COUNCIL

ARCHITECT: -

PROJECT: SWANAGE TC - GROUND STABILISATION FEASIBILITY STUDY

TITLE: PLAN WITH POTENTIAL REMEDIAL OPTIONS SOUTHERN AREA

SCALE @ A3	CHECKED	APPROVED
NTS	BW	LB

PROJECT No	DESIGNED	DRAWN	DATE
70094760	ADA	VM	July-2022

DRAWING No	REV
70094760-GEO-001	P01

KEY LEGEND - POTENTIAL REMEDIAL OPTIONS

REMEDIAL MEASURES UNLIKELY TO BE REQUIRED.

POTENTIAL OPTIONS TO BE CONSIDERED:

OPTION 1 – DO MINIMUM (ACROSS SITE)

- CCTV DRAINAGE SURVEYS & DRAINAGE REPAIRS BASED ON THE SURVEY RECOMMENDATIONS. THIS SHOULD INCLUDE ALL DRAINAGE WITHIN THE SITE BOUNDARIES AND WATER MAIN PIPES BEHIND THE CREST OF THE SLOPE.
- DETAILED UXO DESK SURVEY.
- PERIODIC VISUAL INSPECTIONS OF SLOPES AND STRUCTURES BY A SUITABLY QUALIFIED GEOTECHNICAL ENGINEER, TAKING PHOTOGRAPHS OF AFFECTED AREAS TO COMPARE WITH PREVIOUS YEARS. THIS COULD INCLUDE STRUCTURAL INTEGRITY CHECKS ON THE EXISTING RETAINING WALLS.
- LOCALISED REPAIRS, E.G. REPAIRS/REPLACEMENT OF MISSING BLOCKS FROM RETAINING WALLS, MINOR CRACK REPAIRS ETC.
- MONITORING AND/OR ALARM SYSTEM. CONTINUE GROUND AND GROUNDWATER MONITORING USING EXISTING INCLINOMETERS AND STANDPIPE PIEZOMETERS. THIS WOULD REQUIRE IMPLEMENTATION OF AN ALARM SYSTEM TO WARN OF THE ONSET OF SLOPE FAILURE.

OPTION 2 – SLOPE REGRADING AND/OR GRANULAR REPLACEMENT AND/OR TERRACING

- SLOPE REGRADING OF STEEP SLOPES AND WHERE EVIDENCE OF GROUND MOVEMENT HAS BEEN RECORDED (I.E. PRESENCE OF CRACKS, UNEVEN/HUMMOCKY TERRAIN, LOOSE/SOFT LOBES OF SOIL ETC). THIS MAY TYPICALLY BE FROM THE GROUND SURFACE TO A MAXIMUM DEPTH OF 2-2.5 m bgl. THE EXACT EXTENTS AND DEPTH OF THIS MEASURE NEEDS TO BE ASSESSED DURING CONSTRUCTION BY A SUITABLY QUALIFIED GEOTECHNICAL ENGINEER.
- SLOPE ANGLES SHOULD BE REGRADED TO ≈16 DEGREES (≈1V:3.5H), AND IN SOME INSTANCES, THIS MAY REQUIRE INSTALLATION OF GEOGRID REINFORCEMENT.
- GRANULAR REPLACEMENT OF SOFT LOOSE GROUND, TARGETING SPECIFIC UNSTABLE AREAS, AND/OR INCLUSION OF COUNTERFORT TRENCHES FILLED WITH FREE DRAINING GRANULAR MATERIAL AT A REGULAR SPACING (E.G. ≈10 m SPACING). THIS MEASURE WOULD IMPROVE THE SLOPE STABILITY BY REMOVING PART OF THE SOFT UNSTABLE MATERIAL AND WOULD ALSO IMPROVE DRAINAGE, BY REMOVING GROUNDWATER FROM THE SLOPES MORE EFFICIENTLY.
- THE GRANULAR REPLACEMENT WOULD BE ENGINEERED FILL, COMPACTED IN LAYERS AND IN ACCORDANCE WITH AN EARTHWORK SPECIFICATION.
- TERRACING THE SLOPE BY CREATING A SERIES OF TERRACES UP THE SLOPE, WHICH WOULD MAKE THE SLOPES SHALLOWER. THIS COULD BE COMBINED WITH NEW DRAINAGE, VEGETATION AND/OR SHALLOW RETAINING STRUCTURES.
- THE MEASURES PROPOSED IN THIS OPTION ARE LIKELY TO REQUIRE FULL OR PARTIAL RECONSTRUCTION (AND OFTEN RE-LOCATION) OF THE FOOTPATHS.

OPTION 3 – SOIL NAILS/ANCHORS OF SLOPES AND/OR EXISTING RETAINING WALLS

- SOIL NAILING/ANCHORING OF FAILING SLOPES AND/OR EXISTING RETAINING WALLS WITH DEFECTS.

OPTION 4 – FULL RECONSTRUCTION OF EXISTING RETAINING WALLS AS GRAVITY WALLS

- FULL RECONSTRUCTION OF EXISTING RETAINING WALLS AND OTHER EXISTING STRUCTURES.
- COMPLETE DEMOLITION OF EXISTING STRUCTURES POSSIBLY INCLUDING THE STRUCTURE FOUNDATIONS. EXAMPLES OF RETAINING WALLS TYPES COULD INCLUDE MASONRY WALLS, CRIB WALLS AND GABION WALLS. USE OF LOCAL NATURAL STONES AND/OR RECYCLING STONES FROM DEMOLITION TO REDUCE WASTE AND IMPROVE AESTHETICS IN THE CASE OF MASONRY WALLS. CRIB AND GABION WALLS HAVE BECOME HIGHLY POPULAR FOR USE IN LANDSCAPING PROJECTS AND CAN BLEND INTO NATURAL SURROUNDINGS, DUE TO THE SITES COASTAL LOCATION THEY WILL REQUIRE DUE CONSIDERATION OF THE DURABILITY OF MATERIALS USED TO CONSTRUCT THEM.
- IF NEW FOUNDATIONS ARE REQUIRED, THE NEW STRUCTURES SHOULD BE FOUNDED ON FIRM STRATUM (ANTICIPATED AT DEPTHS >1-2.5 m DEPTH), USING FOR EXAMPLE SHALLOW REINFORCED CONCRETE FOOTINGS.
- THIS OPTION SHOULD ALSO CONSIDER INSTALLATION OF A NEW DRAINAGE SYSTEM, SUCH AS HORIZONTAL SLOTTED PVC DRAIN PIPES ACROSS THE NEW STRUCTURE.
- RECOMMENDED OPTION TO BE ADOPTED WHEN THE STRUCTURAL INTEGRITY OF THE STRUCTURES HAS BEEN REACHED. THE NEW RETAINING WALLS WOULD PROBABLY BE HIGHER, THEREFORE, CONSTRUCTION SHOULD BE CONDUCTED IN SHORT SECTIONS TO PREVENT SLOPE FAILURE. THIS OPTION WOULD REQUIRE TEMPORARY RELOCATION OF THE BEACH HUTS TO ALLOW DEMOLITION AND REMOVAL OF THE FAILED WALL AND CONSTRUCTION OF THE NEW STRUCTURE.
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OPTION 1 – DO MINIMUM (ACROSS SITE)

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- SOIL NAILING/ANCHORING OF FAILING SLOPES AND/OR EXISTING RETAINING WALLS WITH DEFECTS.

OPTION 4 AND/OR 4A – FULL RECONSTRUCTION OF EXISTING RETAINING WALLS AS GRAVITY WALLS OR AS EMBEDDED RETAINING WALLS
FULL RECONSTRUCTION OF EXISTING RETAINING WALLS AND OTHER EXISTING STRUCTURES.

OPTION 4:

- COMPLETE DEMOLITION OF EXISTING STRUCTURES POSSIBLY INCLUDING THE STRUCTURE FOUNDATIONS. EXAMPLES OF RETAINING WALLS TYPES COULD INCLUDE MASONRY WALLS, CRIB WALLS AND GABION WALLS. USE OF LOCAL NATURAL STONES AND/OR RECYCLING STONES FROM DEMOLITION TO REDUCE WASTE AND IMPROVE AESTHETICS IN THE CASE OF MASONRY WALLS. CRIB AND GABION WALLS HAVE BECOME HIGHLY POPULAR FOR USE IN LANDSCAPING PROJECTS AND CAN BLEND INTO NATURAL SURROUNDINGS, DUE TO THE SITES COASTAL LOCATION THEY WILL REQUIRE DUE CONSIDERATION OF THE DURABILITY OF MATERIALS USED TO CONSTRUCT THEM.
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OPTION 4A:

- COMPLETE DEMOLITION OF EXISTING RETAINING WALLS AND CONSTRUCTION OF EMBEDDED RETAINING WALLS SUCH AS CONTIGUOUS/SECANT PILE WALLS.

BOTH OPTION 4 AND 4A:

- THESE OPTIONS SHOULD ALSO CONSIDER INSTALLATION OF A NEW DRAINAGE SYSTEM, SUCH AS HORIZONTAL SLOTTED PVC DRAIN PIPES ACROSS THE NEW STRUCTURE.
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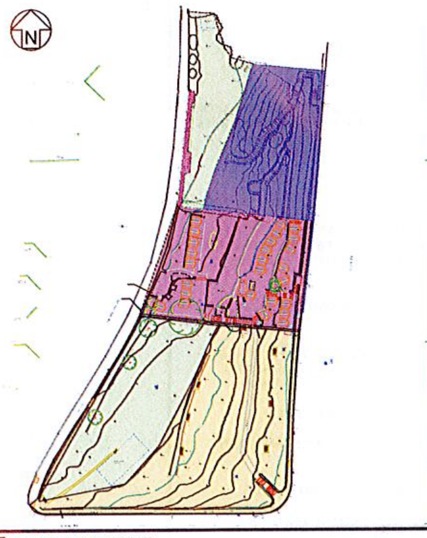

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REV	DATE	BY	DESCRIPTION	CHK	APP
P02	06-09-2022	VM	FOR APPROVAL	BW	LB
P01	04-07-2022	VM	FIRST ISSUE	BW	LB

DRAWING STATUS: APPROVED

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CLIENT: SWANAGE TOWN COUNCIL

ARCHITECT: -

PROJECT: SWANAGE TC - GROUND STABILISATION FEASIBILITY STUDY

TITLE: PLAN WITH POTENTIAL REMEDIAL OPTIONS NORTHERN AREA

SCALE @ A3: NTS	CHECKED: BW		APPROVED: LB
PROJECT No: 70094760	DESIGNED: ADA	DRAWN: VM	DATE: July-2022
DRAWING No: 70094760-GEO-002			REV: P01

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