PARSONS BRINCKERHOFF

November 2014

DINAH'S HOLLOW STABILISATION OPTIONS REPORT

Dorset County Council

285400AF-HLT/1

Issue 2

Dinah's Hollow Stabilisation Options Report

285400AF-HLT/1

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LIST OF ABBREVIATIONS

BGS	British Geological Society
BHC	Boyne Hollow Chert
BS	British Standard
CS	Cann Sand
DCC	Dorset County Council
EA	Environment Agency
ESG	Environmental Services Group
GI	Ground Investigation
mbgl	Metres below ground level
mAOD	Metres above Ordnance Datum
MS	Melbury Sandstone
OS	Ordnance Survey
PB	Parsons Brinckerhoff Ltd
SS	Shaftesbury Sandstone
UGS	Upper Greensand

EXECUTIVE SUMMARY

	This report relates to the area named Dinah's hollow located on the C13 at Melbury Abbas. Following landslips on the slopes of the hollow, Brody Forbes were commissioned to investigate the slopes and concluded that there was a risk of large quantities of materials slipping, sufficient to bury a passing small vehicle. Subsequently the C13 has been closed to traffic at this location. Following closure of the road Parsons Brinkerhoff were commissioned to carry out a geotechnical investigation and produce an options report to mitigate the risk of landslip in the hollow. The objectives of this report are to: • Describe the desk studies as undertaken; • Describe the ground investigation as undertaken; • Provide details of the ground conditions; • Provide a preliminary ground model and present preliminary geotechnical parameters; • Discuss options and provide a recommendation for stabilisation measures (including provisional cost estimates); and • Develop a geotechnical risk register to be developed for the future works. The solid geology comprises the Upper Greensand Formation. No superficial deposits have been observed on the site. It is recommended to stabilise the slopes using soil nailing techniques and appropriate facing (soil panels on the lower, steeper slopes and flexible high-tensile wire mesh on the upper slopes), which can be re-vegetated to minimise any visual impact. Drainage measures in the form of long hole drainage, crest drains, kerbing with gullies and a collector pipe should also be installed. Although preliminary discussions have been held with specialist geotechnical contractors, it is strongly recommended that early contractor involvement, including a site visit, is sought to confirm any potential site constraints which may affect the potential stabilisation measures detailed in the report.
This sheet is intended as a summary only	

1 INTRODUCTION

1.1 Scope and Objectives of Report

1.1.1 This report will focus principally upon the Dinah's Hollow site and all proposed options are relevant for this site only. However due to the geographical proximity of the two locations, there are anticipated to be similarities between the ground conditions and existing information for the two sites; Dinah's Hollow and the smaller Melbury Abbas church site.

1.1.2 Following landslips on the slopes of Dinah's Hollow, Brody Forbes were commissioned to investigate the slopes and concluded that there was a risk of large quantities of materials slipping, sufficient to bury a passing small vehicle. Subsequently the C13 has been closed to traffic at this location.

1.1.3 Following closure of the road Parsons Brinkerhoff were commissioned to carry out a geotechnical investigation and produce an options report to mitigate the risk of landslip in the hollow.

1.1.4 The GI was scoped by Parsons Brinkerhoff (PB) and comprised intrusive investigations undertaken at Dinah's Hollow, including the Melbury Abbas church site. This was undertaken in order to supplement the information obtained from the previous GI undertaken by Brody Forbes, particularly with regards to the eastern slope and groundwater monitoring information. The GI was subsequently undertaken by Environmental Scientifics Group (ESG), with the investigation at Dinah's Hollow taking place in July and August 2014.

1.1.5 The objectives of this report are to:

- Describe the desk studies as undertaken;
- Describe the GI as undertaken;
- Provide details of the ground conditions;
- Provide a preliminary ground model and present preliminary geotechnical parameters;
- Discuss options and providing a recommendation for stabilisation measures (including provisional cost estimates); and
- Develop a geotechnical risk register to be developed for the future works.

1.1.6 This Geotechnical Options Report is based upon information contained within the ESG Factual Report which is presented in Appendix A and the Brody Forbes Report presented in Appendix B, as well as the other appendices in this report.

1.2 Description of Project

1.2.1 The site is located approximately 3km south east of Shaftesbury, National Grid reference [88266X 20506Y].

1.2.2 The site area comprises a single carriageway road approximately 450m long trending in a north to south direction, and two slopes located on each side of the carriageway. The slopes dip towards the highway such that it is located in a valley known locally as a 'hollow', and are steep, of varying height and densely vegetated. This is discussed in further detail in Section 3 of the report.

1.2.3 Dorset County Council (DCC) is the highway authority responsible for maintaining the highway in the base of the hollow, with the surrounding land owned by local farmers. The land beyond the hollow is divided into fields with crops planted to the east of the hollow and fields and a vineyard to the west.

Project Brief

1.2.4 PB has been asked by DCC to provide the following services:

- Review existing information including previous GIs and any previously recorded movements on the slopes;
- Provide a list of technical requirements for fieldwork scheduling laboratory testing, and determine an on-going groundwater monitoring regime including part time presence on site whilst the GI was being undertaken;
- Undertake back analyses of the stability of the hollow slopes;
- Review all possible stabilisation options and make recommendations based on completion of preliminary design; and,
- Provision of an Options Report.

Project Options

1.2.5 Several stabilisation options for improving the design life of the hollow to 120 years have been put forward, and are summarised below:

- Reprofiling the slope;
- Installing soil nails with either flexible or rigid facing;
- Use of vegetation i.e. bioengineering;
- Raising the level of the existing highway; and,
- Other retaining structures such as sheet piling and contiguous bored piled wall.

1.2.6 These options are discussed in detail within Section 4 of this report.

1.3 Geotechnical Category of the Project

1.3.1 The scheme has been categorised as a Geotechnical Category 2 project. This is defined in BS EN 1997-1 [Ref. 1] as:

1.3.2 *"Projects which include conventional types of geotechnical structures, earthworks and activities, with no exceptional geotechnical risks, unusual or difficult ground conditions or loading conditions".*

2 SUMMARY OF EXISTING INFORMATION

2.1 Topographical Maps

2.1.1 An extract of the Ordnance Survey (OS) Explorer Map 118 (Shaftesbury & Cranbourne Chase) [Ref. 2] is presented below:

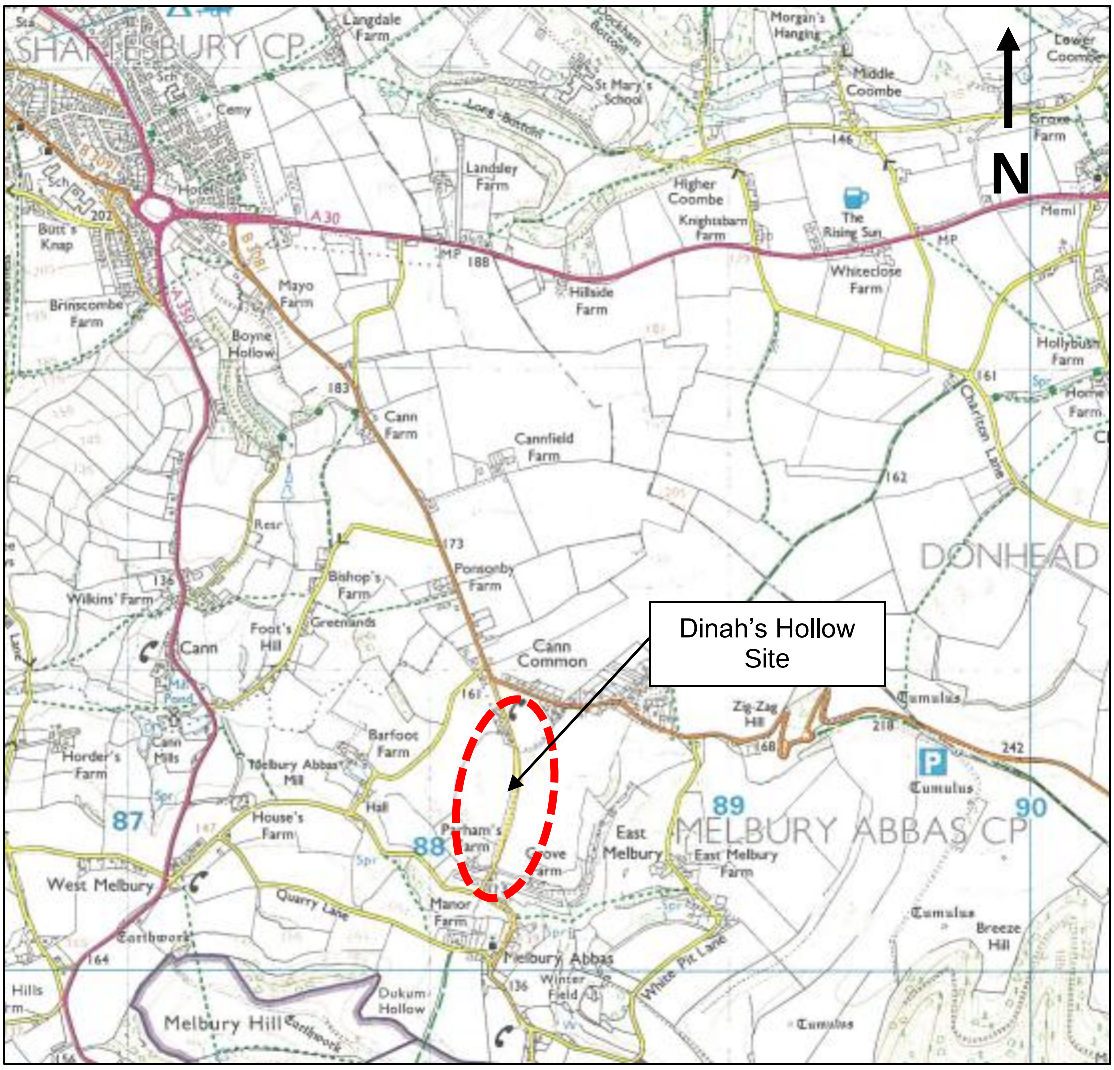


Figure 1: Extract of Ordnance Survey Map

2.1.2 The OS map indicates the natural topography to rise from 120 mAOD at the sites southern extent to 150 mAOD at its northern. South of the site, the valley bottom is approximately 115 AOD where a stream runs perpendicular to the road and is crossed by a bridge. North of the site, the incline slackens considerably at 155 mAOD and the land continues to rise gently in a northern direction.

2.1.3 Information regarding the adjoining land is discussed in greater detail in Section 3.1.2.

2.2 Geological Maps and Memoirs

2.2.1 An extract of the British Geological Survey (BGS) geological sheet 313 (Shaftesbury) [Ref. 3] is presented below:

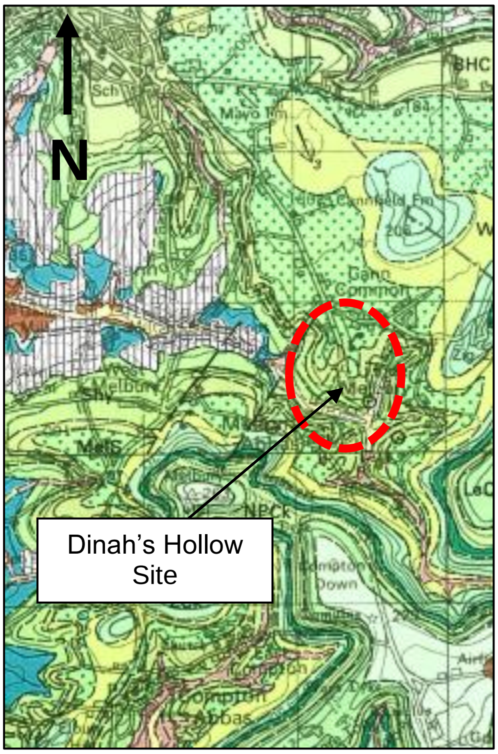


Figure 2: Extract of British Geological Map

2.2.2 No superficial deposits are recorded on the geological map within the site area.

2.2.3 The site is underlain by the Upper Greensand Formation (UGF) which comprises the following members: the Melbury Sandstone (MelS), Boyne Hollow Chert (BHC), the Shaftesbury Sandstone (SS) and the Cann Sand (CS).

2.2.4 Descriptions of the members have been sourced from the BGS geology of the country around Shaftesbury Memoir [Ref. 4] as follows:

Table 1: Descriptions of Upper Greendsand Members

Melbury Sandstone (MS)	*"A pebbly, shelly, phosphatic bed"* [overlain by] *"shelly calcareous sandstone and clayey sand"*
Boyne Hollow Chert (BHC)	*"Glauconitic quartz sand and weakly glauconitic sandstone with cherty and siliceous concentrations, and in places beds of chert up to 0.6m thick"*
Shaftsbury Sandstone (SS)	*"Alternating beds of glauconitic sand and weakly calcite-cemented, glauconitic sandstone in the lower part, and hard, shelly, calcite cemented, glauconitic sandstone (ragstone) in the upper part"*
Cann Sand (CS)	*"Fine grained sand and very weakly cemented Sandstone"*

2.3 Aerial Photographs

2.3.1 Recent aerial photographs released into the public domain by GoogleEarth [Ref. 5] were reviewed for the project. A satellite image showing the site area and surrounding extents is presented below.

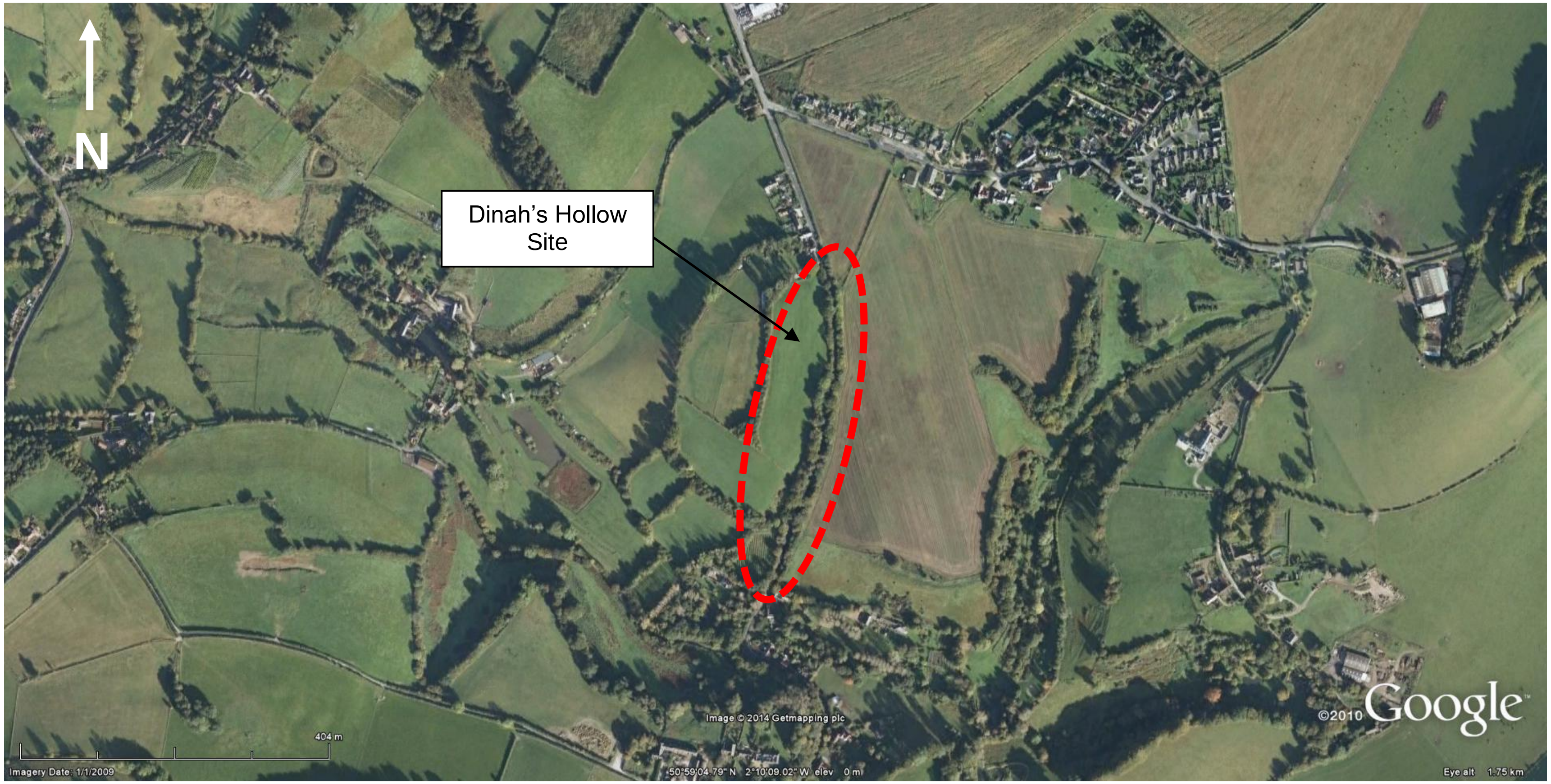


Figure 3: Aerial Photograph

2.3.2 Aerial photographs show vegetation lining the upper slopes of the hollow. Mature trees are present on the slopes both sides of the carriageway, with larger trees noted to the west of the road.

2.3.3 The surrounding land comprises fields planted with barley to the east and fields and a vineyard to the west. There are two farms in close proximity to the site; Parham's Farm is located to the west; Higher Barn Farm and Grove Farm to the east of the site area. The farms are located near the base of the natural valley and north of the stream.

2.3.4 The village of Melbury Abbas is located approximately 200m south of the site.

2.4 Historical Development

2.4.1 A review of historical maps of the site has been undertaken using the Old Maps online resource [Ref. 6] and is discussed below:

Table 2: Historical Development

Date	Site Area	Surrounding Land
1887 – 1891	A track is located on the current site of Dinah's Hollow. The track is flanked by trees on both sides.	The surrounding land is divided into fields. Parham's, Higher Barn and Grove Farm are visible in their current locations. There is an orchard to the west of Parham's Farm. There is a post office on the corner of the intersection with the access road to Grove Farm. There is a Methodist Chapel on the road north of the hollow extents.
1901 – 1902	No significant changes from previous.	The post office is no longer visible.
1929 – 1931	No significant changes from previous.	Buildings have been constructed to form a small village to the north east of the site.
1962 – 1965	No significant changes from previous.	The small quarry on the western slope is visible in its current location.
1983 - 1987	No significant changes from previous.	The size of the village north east of the site has increased.

2.5 Previous Ground Investigations

2.5.1 A total of 1 No. historical exploratory hole within the site extents was located using the online BGS GeoIndex [Ref. 7].

2.5.2 The exploratory hole is located at the northern end of the site at the crest of the eastern slope. It is reported as having been formed in 1987 on behalf of DCC, and was undertaken using a Cable Percussive rig. The log is included in Appendix C of this report.

Brody Forbes Report

2.5.3 A GI was undertaken by Structural Soils on behalf of Brody Forbes to assess the stability of the hollow slopes. The investigation comprised 4 No. dynamically sampled boreholes to the west of the hollow and 1 No. to the east. The information collated from the boreholes was supplemented by *in situ* testing with the use of Dynamic Cone Penetrometer (DCP) tests on both slopes.

2.5.4 A copy of the Brody Forbes Report is included in Appendix B.

2.6 Other Information

Hydrology

2.6.2 The watercourse at the base of the valley has not been identified or assessed on the Environment Agency (EA) Water Framework Directive – River Basin Management Plan presented on their online map resource –'what's in your backyard' [Ref. 8].

2.6.3 It is noted that the watercourse is an 'ordinary watercourse' and that DCC, as the Lead Local Flood Authority, have the regulatory powers for consenting any alterations and controlling activities on the watercourse that might have an adverse flooding impact, e.g. such as controlling surface water runoff.

2.6.4 Information requested from the Environment Agency indicates that there are no recorded abstraction from surface water licenses within a 1km radius of the site.

Hydrogeology

2.6.5 Information requested from the EA indicates that there are 2 No. abstraction from groundwater licenses within a 1km radius of the site. These are listed in Table 2 below, and the full details are included in Appendix D.

Table 3: Local Groundwater Abstraction Licenses

Location	Distance from Site	Use
Grove Farm House	550m (South East)	Feeding a pond and household use
Melbury Abbas	480m (South)	Feeding a fish farm and cress pool, general farming and domestic use.

2.6.6 A copy of the groundwater abstraction license information provided by the Environment Agency is included in Appendix D.

2.6.7 A drainage survey was carried out by DCC in October 2014, the results of which are presented in Appendix E. It should be noted that there is a well immediately north of the junction between Dinah's Hollow and the driveway of Parham's Farm.

Ecology

2.6.8 An ecology survey undertaken at the site has been commissioned and undertaken by Dorset County Council during May and July 2014. The report produced as a result of the survey is included in Appendix F.

2.6.9 The survey was undertaken in order to identify protected species present in the site area, and assess the impact upon wildlife and local flora as a result of the proposed works. The report also provides recommendations which will mitigate the impact of the proposed works upon protected species.

2.6.10 The ecological impact of the works upon protected species has been considered when evaluating the options in Section 4, and is discussed where relevant in the appropriate section. The recommendations provided by DCC will be used at the detailed design stage to minimise the ecological impact of the preferred solution.

<u>Tree Survey</u>

2.6.11 A tree survey was carried out by DCC between May and July 2014, and is included in Appendix G.

2.6.12 The results of the tree survey will be taken into account when developing the preferred solution during the detailed design stage.

3 FIELD AND LABORATORY STUDIES

3.1 Topographical Survey

3.1.1 A topographical survey was undertaken at the site by Merrett Survey Ltd in June 2014, and is included in Appendix H.

3.1.2 The survey shows the depth of the hollow varies between 5.2m and 13.2m to the west of the road, and between 5m and 10m to the east.

3.1.3 The depth of the hollow generally increases towards the south and is deepest approximately midway down as the carriageway slope is at its steepest here.

3.1.4 The slope angle is typically greatest on the lower section of the slopes, reaching a maximum of 70° at a location on the west slope and 73° at a location on the east.

3.1.5 The 'chainage' discussed in the following sections is defined as the distance along the centre of the road from a fixed point south of the hollow extents. The chainage is increased from south to north and is recorded on the topographical survey in 10m increments. The point the chainage has been measured from has been specified by Dorset County Council, and is intended to provide a standard point of reference for all published information concerning the hollow.

3.1.6 While evaluating the results of the survey, it was noted that the topography of the east and west slopes can be typically divided into two sections;

- the overly steep lower section with a slope angle of typically 60° to 70°, but at some limited locations as low as 53^{o}; and,
- the upper section with a slacker slope angle of typically between 30° and 45°.

3.1.7 There is local variation in slope angles as the hollow slopes are not engineered and also potentially from both historic and recent movements.

3.1.8 Given the difference in slope angle, it is therefore considered likely that the best solution may vary for the upper and lower sections. This is discussed in further detail where relevant in Section 4.

3.2 Walkover Survey

3.2.1 An initial site visit was undertaken with representatives from DCC and PB present on 16th April 2014. Further subsequent site visits by a PB engineer were undertaken on 10th June, 8th July and 16th July during the GI. A further site visit on 3rd September was undertaken by a PB drainage engineer to discuss appropriate drainage surveys and discuss potential drainage options.

Dinah's Hollow

3.2.2 The single carriageway in the hollow descends from Cann Common in the north, into a valley with a watercourse at the base in the south. The steep slopes increase in height as the road descends.

3.2.3 The slopes themselves are mainly heavily vegetated, with small shrubs, brambles, nettles and ferns on the lower slopes and mature trees to the top of the slopes. Erosion occurring towards the toe of the slope has resulted in loss of vegetation in this area.

3.2.4 The majority of the angle of the slopes range from 60° to 70°, slackening off to 45° or 30° in the upper parts, as mentioned when previously discussing the topographical survey.

3.2.5 A small section of the eastern slopes towards Cann Common are known to have been re-graded to an angle of approximately 30° as shown in the figure below. This may have been due to previous instabilities of the slopes.

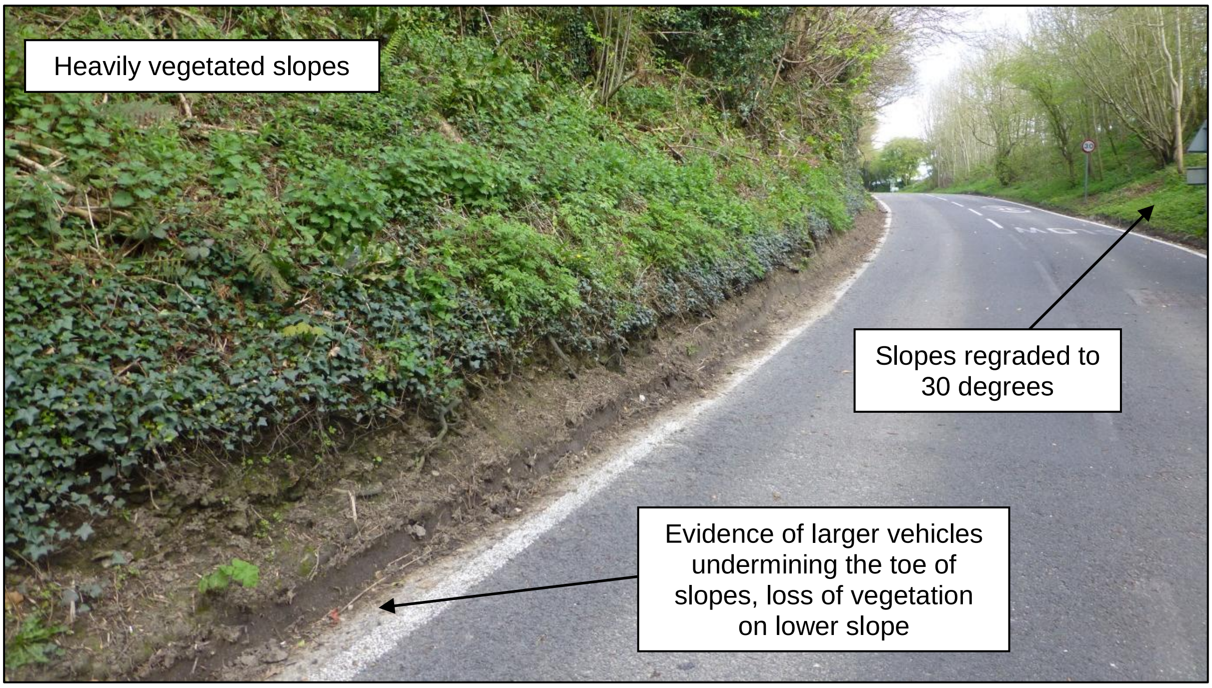


Figure 4: Western Slopes showing Signs of Undermining

3.2.6 Heavy goods vehicles encroaching on the toe of slopes when passing each other have resulted in the slopes becoming undermined.

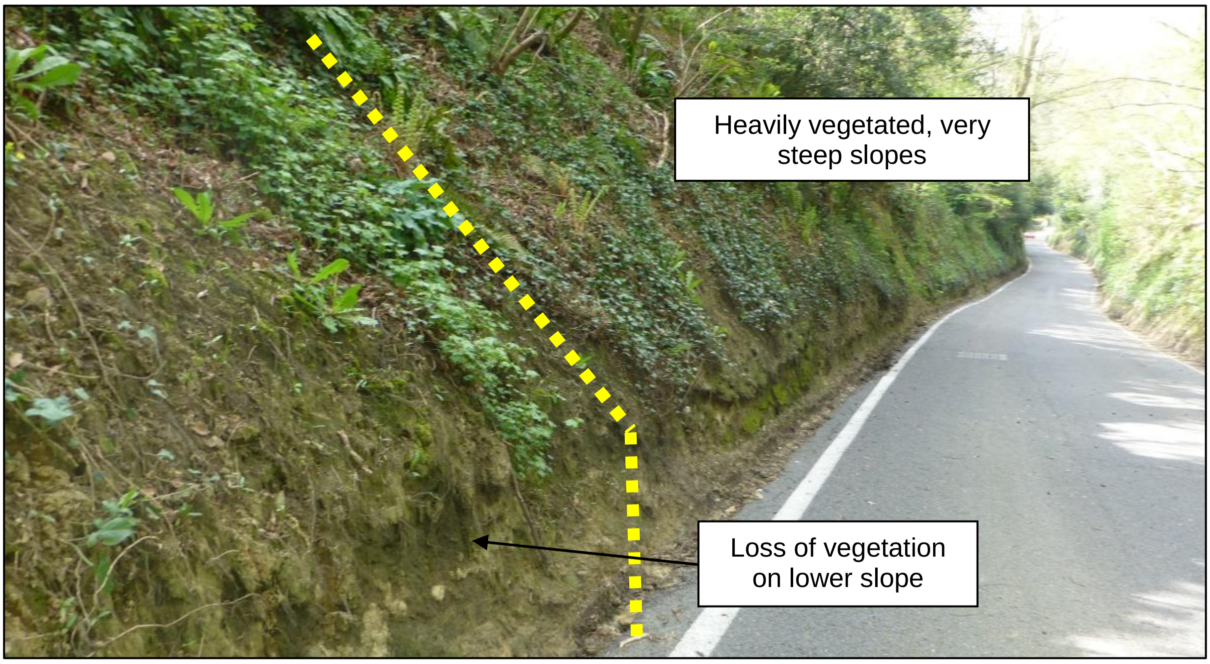


Figure 5: Eastern Slopes showing Signs of Undermining

3.2.7 It was seen that surface water run-off down the edges of the carriageway has also caused some erosion at the toe of the slope.

3.2.8 The anecdotal evidence seems to be that surface water runoff comes down the road from as far distant as Cann Common. The current camber of the road within Dinah's Hollow sheds the surface water to both edges of the road.

3.2.9 There was evidence of shallow, localised slips which will be discussed in further detail further on in this report within the Geomorphological section. Records of highway maintenance callouts have shown these to occur on a fairly regular basis. The material appeared to be extremely weakly cemented sandstone.

3.2.10 Records of the callouts can be found in Appendix I.

Figure 6: Shallow, Local Instabilities on Eastern Slope

3.2.11 The material making up the slopes shows signs of erosion due to surface water travelling down the slopes, presumably during periods of very heavy rain.

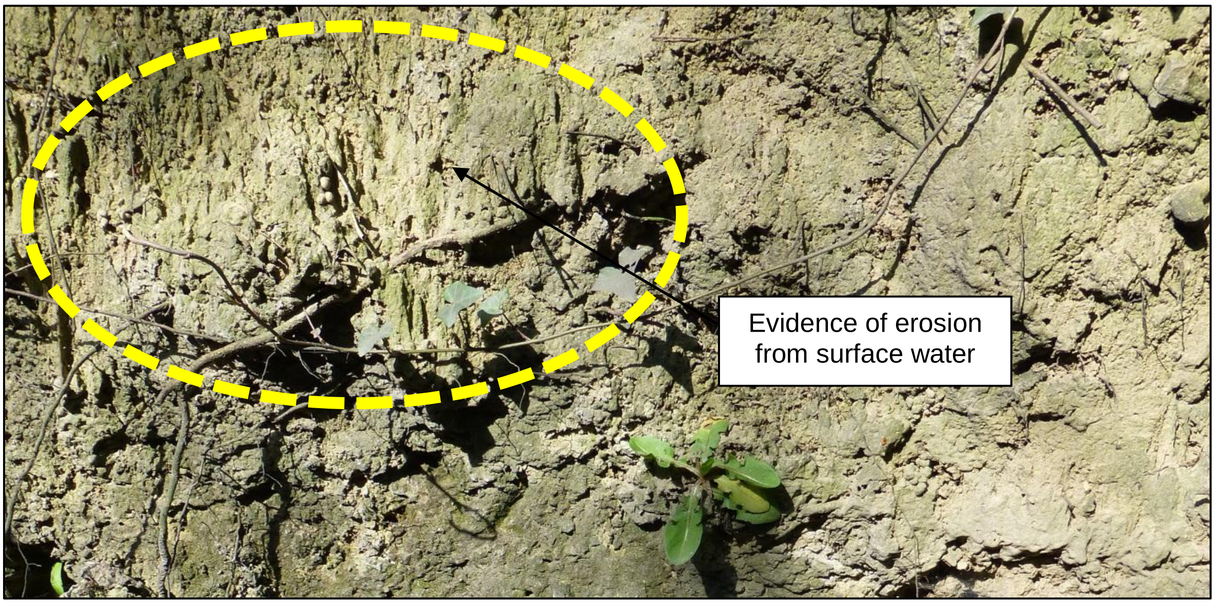


Figure 7: Upper Greensand, Evidence of Surface Erosion

3.2.12 A rock outcrop was evident in the location of the historic quarry on the western slopes as shown below and further rock outcrops were observed adjacent to the road north of the quarry. The material is believed to be the BHC.

3.2.13 The rock observed in the quarry and rock exposures to the north along the carriageway is described as: Weak to medium strong thinly to medium bedded yellow grey medium grained SANDSTONE. Some thin beds are extremely weak. Distinctly weathered. Medium to wide spaced, wide to very wide aperture discontinuities some of which may be as a result of quarrying or excavation for the road.

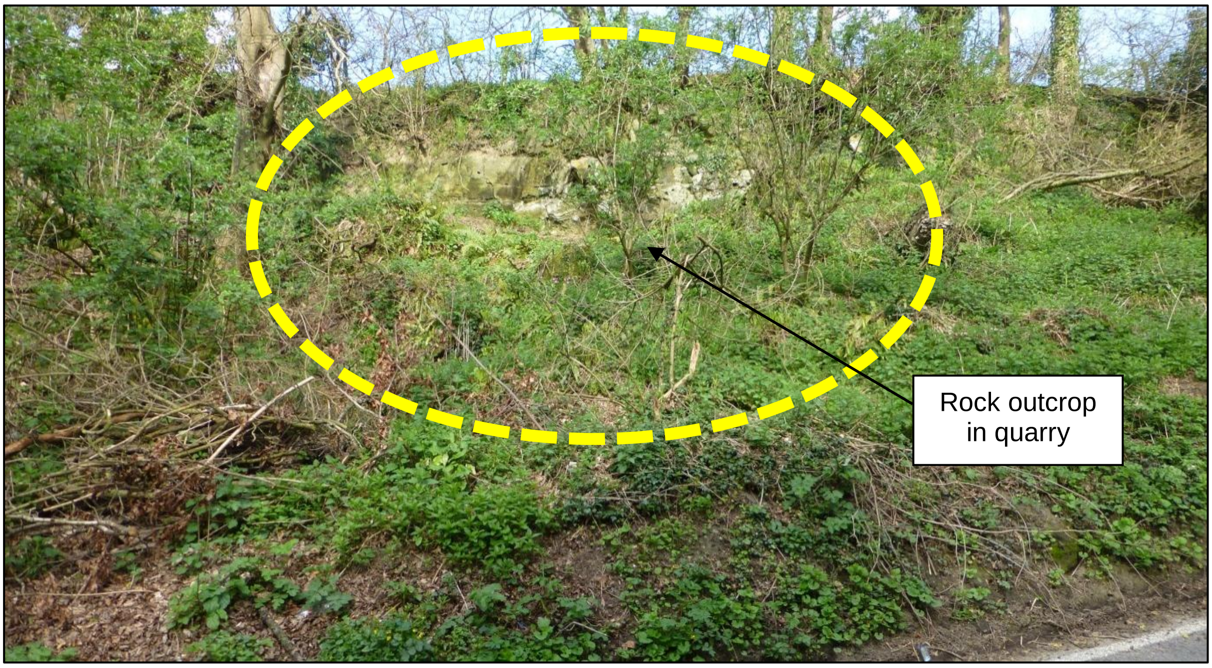


Figure 8: Historic Quarry on Western Slopes

<u>Highway Drainage</u>

3.2.14 The minimal highway drainage noted during the walkover, was observed to be blocked up with large amount of material assumed to have washed off the slopes, as shown below.

Figure 9: Blocked drain within Carriageway

3.2.15 A drainage survey has been carried out by DCC to establish the amount and type of highway drainage within Dinah's Hollow and the immediate vicinity. This includes the outfalls shown below, situated next to the watercourse at the base of the valley and Spring Cottage.

Figure 10: Drainage Outfall near Spring Cottage

Land to the East

3.2.16 The land to the east is predominantly arable land, owned by Higher Barn Farm, the farmhouse of which is located to the north at Cann Common.

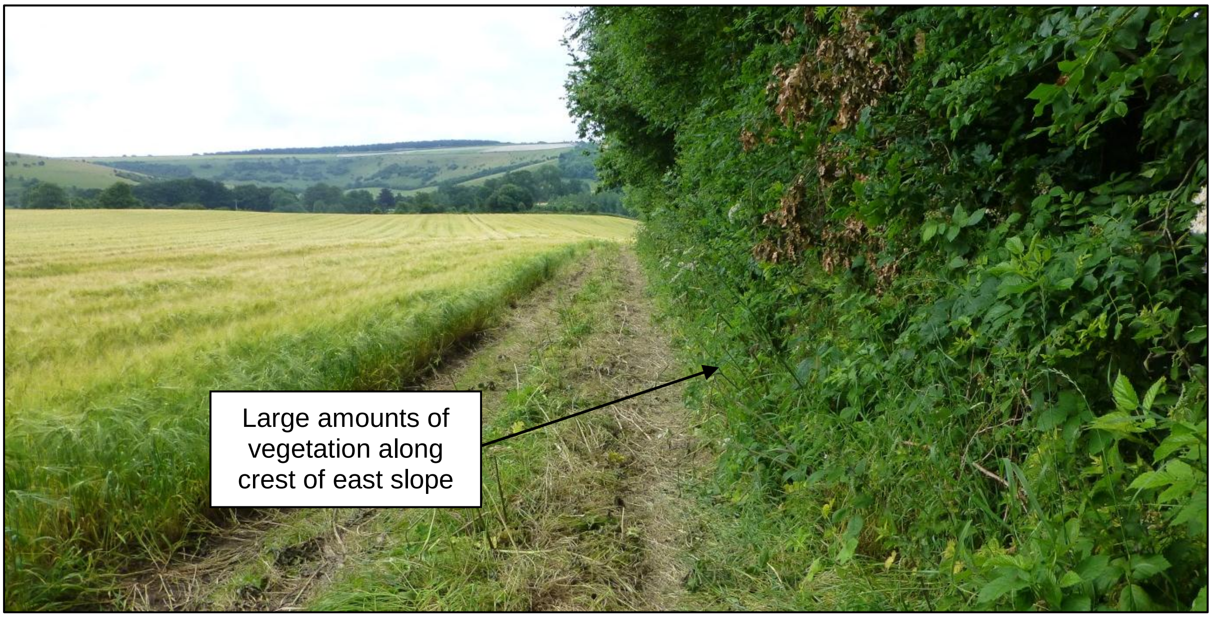


Figure 11: Barley Growing in the Field to the East of Dinah's Hollow

3.2.17 The topography of the land is sloping towards Dinah's Hollow and the valley in a south westerly direction.

3.2.18 Evidence of soil erosion assumed to have been caused by surface water run-off is apparent in the south-west corner of the field, where deposits of sediment have been "trapped" by the fencing.

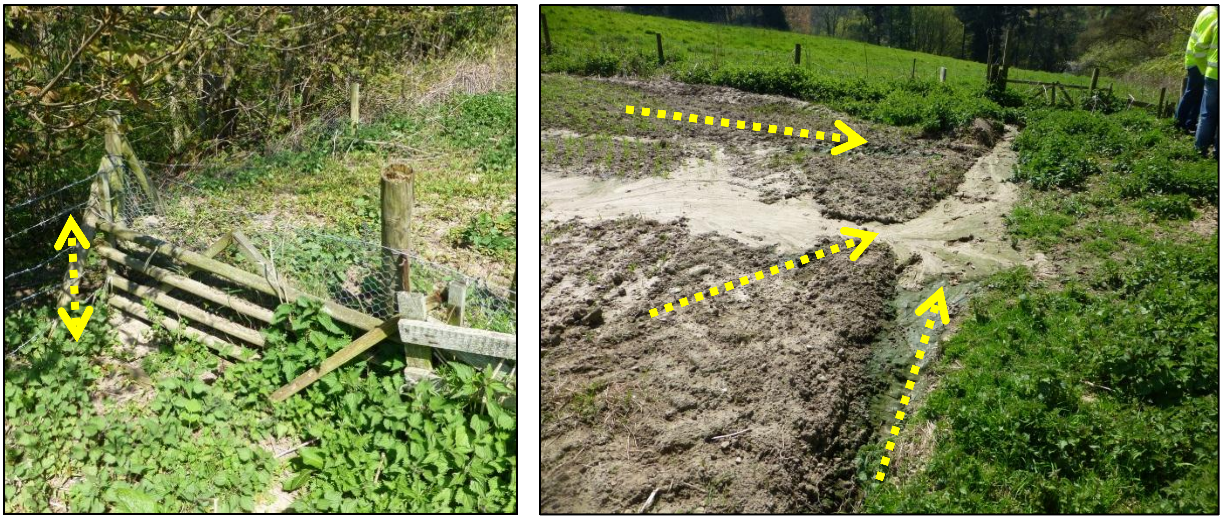


Figure 12: Accumulated Sediment at crest of Eastern Slope

3.2.19 Groundwater seepage was noted on the eastern slopes almost immediately below the accumulated sediments discussed above.

Figure 13: Seepage Running along Eastern side of Carriageway

Land to the West

3.2.20 The land to the west is split into a vineyard to the south and fields to the north, owned by Parham's Farm, the farmhouse of which is located in the south, near the base of the valley.

Figure 14: Vineyard

3.2.21 The topography of the land is sloping towards Dinah's Hollow and the valley in a south easterly direction, but with a considerably smaller surface water catchment area that on the eastern side.

Figure 15: Field with Track Leading to the Vineyard And Parham's Farm

3.2.22 A spring line was noted along the edge of the driveway to Parham's Farm and a potential artesian water flow was present in one of the drainage outflows as shown below in the photos.

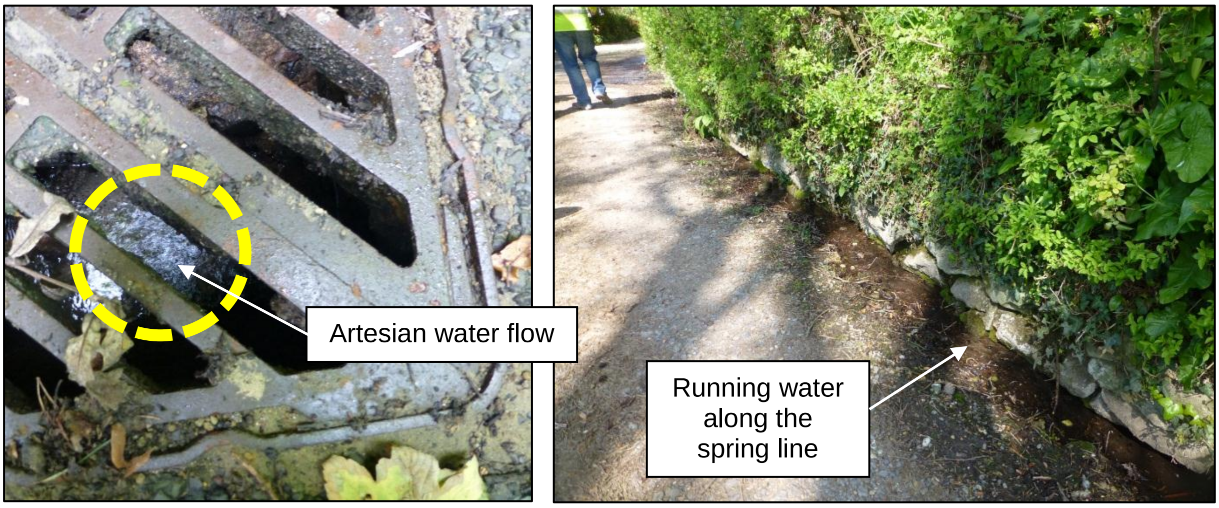


Figure 16: Artesian Water Flow and Spring Line

3.2.23 An old well was noted in the area where there had previously been a milk churn stand immediately north of the junction between Dinah's Hollow and the driveway to Parham's Farm. This well has been picked up on the Drainage Surveys, the results of which are presented in Appendix E.

<u>Geomorphological / Geological Survey</u>

3.2.24 Geomorphological mapping of the slopes along Dinah's Hollow was undertaken by a PB Engineering Geologist on 8th July 2014.

3.2.25 The mapping was undertaken from road level since access up the slopes was considered un-safe and it was determined on site that due to the significant vegetation cover on the slopes there would be limited benefit in undertaking the mapping with the use of a cherry picker.

3.2.26 The purpose of the geomorphological survey was to identify features that may adversely affect, or be related to, the stability of the slopes and included the following:

- Rock band outcrops;
- Slips, both historical and recent;
- Oversteepened slopes;
- Water; and
- Vegetation;

3.2.27 The findings of the geomorphological survey are presented on PB Drawing number DH/002A and DH/002B and a summary is given below. This is presented in Appendix J.

Rock Band Outcrops

3.2.28 Despite the anticipated geology of the site, limited rock bands were observed on the slopes of Dinah's Hollow.

3.2.29 A significant rock outcrop was observed within the historic quarry on the western side of the Hollow and extending north from here to chainage 405.

3.2.30 Evidence of previous block failure was noted both within the historic quarry and on the exposure adjacent to the carriageway, north of the quarry.

3.2.31 In addition, a low level rock outcrop was observed on both sides of the carriageway from approximately chainage 190-220. The rock was evident from road level to a maximum height of 1.3m above road level. The rock can be described as extremely weak to very weak weathered sandstone.

Slips

3.2.32 The majority of the slips, both historic and recent, were observed on the eastern slopes of the hollow. One possible historic slip was noted on the western slopes at chainage 165-180 in the form of what was thought to be an old back scar.

3.2.33 The slips were generally shallow surface slips with the exception of what was interpreted to be a large historic circular slip on the eastern slopes at chainage 270-282. It is possible that the feature observed is a man made one.

Oversteepened Slopes

3.2.34 Oversteepened faces at the toe of the hollow slopes were observed at various locations on both the eastern and western slopes.

3.2.35 These faces were found to be standing at over 70º with heights ranging from 0.5-1.8m. The faces were generally comprised of poorly cemented yellow grey sandstone which broke down to a coarse sand when handled.

3.2.36 At some locations evidence that the tyres of HGV's are further eroding these faces was noted.

Surface Water

3.2.37 Limited higways drainage was seen within Dinah's Hollow with gullies only observed between chainage 80 and 145.

3.2.38 A large area of sediment was observed on the road at the southern extent of the hollow. It is thought that this sediment is as a result of water run off from the fields and slopes surrounding the carriageway.

3.2.39 Several erosion gullies were noted on the eastern and western slopes which were considered to be as a result of erosion caused by concentrated surface water flow.

3.2.40 The erosion gully at chainage 159 on the western slopes coincides with the top corner of the vineyard where it is understood, from discussions with the landowner, that during heavy rain earlier in the year large volumes of water issued over the face.

3.2.41 Much hydrophilic vegetation was seen to be growing on the slopes, particularly on the eastern slopes.

Vegetation

3.2.42 Several previously felled trees were observed on the slopes of Dinah's Hollow. The concern regarding these trees is that future decomposition of these stumps may lead to a loss of soil support and subsequent slope failure.

3.2.43 A couple of trees were also noted to be leaning over the carriageway. Leaning trees can be a sign of slope instability.

3.2.44 Loss of soil support was observed beneath a number of trees on the slopes. This will make these trees at a greater risk of falling and may also increase the risk of slope instability.

3.2.45 Below the midpoint of the slopes the vegetation is lighter with some bare sections. Loss of topsoil is evident on the lower section of the slope, with loose material visible at the edges of the road and blocking the highway drainage systems.

3.3 Ground Investigation

3.3.1 The intrusive GI for Dinah's Hollow was undertaken from the 4th July 2014 to the 3rd August 2014. The GI was undertaken in accordance with the following British and European Standards:

- BS EN 1997-1:2004 'Eurocode 7: Geotechnical Design. General Rules' +A1:2013 (incorporating corrigendum February 2009) [Ref. 1];
- UK National Annex+A1:2014 to BS EN 1997-1:2004+A1:2013 [Ref. 9];
- BS EN 1997-2:2007 'Eurocode 7. Geotechnical Design. Ground Investigation and Testing' (incorporating corrigendum June 2010) [Ref. 10];
- UK National Annex BS EN 1997-2:2007 [Ref. 11];
- BS5930:1999 + A2:2010 'Code of Practice for Site Investigation' [Ref. 12];
- BS1377:1990 'Soils for Civil Engineering Purposes' Parts 1 to 9; [Ref. 13];
- BS EN ISO 22475-1:2006 'Geotechnical investigation and testing. Sampling methods and groundwater measurements. Technical principles for execution'[Ref. 14];
- BS EN ISO 14688-2:2004 'Geotechnical investigation and testing. Identification and classification of soil. Principles for a classification' [Ref. 15];
- BS EN 14688-1:2002 'Geotechnical Investigation and Testing — Identification and Classification of Soil — Part 1: Identification and Description' (+A1:2013) (incorporating corrigenda Nos. 1 and 2) [Ref. 16];
- BS EN 14689-1:2003 'Geotechnical Investigation and Testing — Identification and Classification of Rock — Part 1: Identification and Description' (incorporating corrigendum No. 1) [Ref. 17]; and,
- 'Specification for Ground Investigation', Second Edition (ICE Publishing, 2012) [Ref. 18].

3.3.2 The purpose of the 2014 intrusive GI was to confirm the ground conditions encountered by the 2013 GI designed by Brody Forbes, and to obtain additional data pertinent to the scheme in particular:

- Ground information regarding the eastern hollow slopes;
- Undisturbed samples for effective stress testing; and,
- Groundwater monitoring information.

3.3.3 A summary of the 2014 GI is presented in Table 3 and includes the depth reached by the exploratory holes, the excavation method and any additional information considered relevant to the scheme.

Table 4: 2014 Ground Investigation Summary

Exploratory Hole	Location	Ground Level (mAOD)	Depth (mbgl)	Instrumentation	Response Zone* (mbgl)
BH2-1	East Slope	147.38	7.95	Piezometer	3.80 – 7.95
BH2-2	East Slope	140.87	7.50	Piezometer	3.10 – 8.95
BH2-3	East Slope	134.58	10 .95	Piezometer	3.00 – 3.30
BH2-4	East Slope	131.12	11.95	Piezometer	7.50 – 11.95
BH2-5	East Slope	124.70	10.95	Piezometer	10.00 – 10.95
BH2-6	West Slope	148.0	16.0	Piezometer	5.00 – 16.00
BH2-7	West Slope	131.30	17.0	Piezometer	2.00-17.00
*: The response zone is the section of the borehole that is open to the host strata					

3.3.4 The locations of these exploratory holes are presented in a location plan included in the ESG Factual Report. This is included in Appendix A.

Copies of Test Results

3.3.5 The exploratory hole logs and laboratory test results are included in Appendix A of this report.

Ground Model

3.3.6 There was very little differentiation between the geological members encountered within the boreholes sunk (which were previously described in Section 2.2) therefore it was decided to assign one set of geotechnical parameters to all.

3.3.7 The geotechnical parameter selection was undertaken primarily using the results of the laboratory and *in situ* testing undertaken during the two phases of GI and corroborated using information gathered from a literature review and the undertaking of a back analysis. All evidence utilised to produce the derived parameters is included in Appendix K.

3.3.8 The back analysis indicates that for the current slopes to have a Factor of Safety of 1.0, with an effective angle of friction of 35°, the material would need to have an apparent cohesion of in excess of 10kPa or as discussed previously for the granular materials to possess a degree of cementation. A Factor of Safety of 1.0 is also less than would be required to comply with current standards.

3.3.9 Given the essentially granular nature of the natural ground this is unlikely and any cementation could in general be broken down by finger pressure, thus neither cohesion nor cementation can be relied upon in the long term. This is confirmed by the fact that there was little coring as such required during the ground investigation and as shown in the data in the Appendix A; the *in situ* field testing confirmed the assessment made from the laboratory tests.

3.3.10 The proposed geotechnical parameters are presented below:

Table 5: Derived Geotechnical Parameters

Stratum	Unit Weight γ' (kN/m^3)	Effective Cohesion c' (kPa)	Angle of Shearing Resistance ϕ' (kPa)
Upper Greensand Formation	21	0	35

<u>Groundwater</u>

3.3.11 Groundwater was not encountered within any of the boreholes formed by ESG during the 2014 site works.

3.3.12 Following conclusion of the works, the groundwater levels within the boreholes were checked on a fortnightly basis. The results of this are summarised in table 6 below, and full details are contained in Appendix A.

Table 6: Groundwater Levels Observed

Borehole No.	Water Level Observed (m below ground level)		
	4th August	19th August	3rd September
BH2-1	Dry	Dry	Dry
BH2-2	Dry	Dry	Dry
BH2-3	Dry	Dry	Dry
BH2-4	Dry	Dry	Dry
BH2-5	8.37	8.5	8.45
BH2-6	Dry	Dry	Dry
BH2-7	Dry	14.45	Dry

3.3.13 It should be noted that both the GI and subsequent monitoring took place during the summer, when rainfall is generally anticipated to be lower. The groundwater will therefore be assumed to be at the level of the toe of the slopes for the design purposes.

<u>Geo-Chemical Properties</u>

3.3.14 Geo-chemical testing was undertaken as part of the ground investigation laboratory testing as recommended by BRE Special Digest [Ref. 19].

3.3.15 Mobile groundwater conditions have been assumed as a worst case scenario due to the permeability of the essentially granular nature of the natural ground.

3.3.16 The Design Sulphate (DS) class and Aggressive Chemical Environment for Concrete (ACEC) class have been determined in accordance with BRE Special Digest 1 [Ref. 19].

3.3.17 Characteristic values for the sulphate content and the pH have been assessed in accordance with the BRE standard. Using these values a DS-1 and ACEC-1 class can be considered appropriate for the Upper Greensand. These classes indicate generally benign conditions, and should be taken into account during detailed design of steel or concrete buried elements of the solution.

4 STABILISATION OPTIONS

4.1 General

Vegetation Clearance and Preliminaries

4.1.2 Recommendations regarding the removal of vegetation and other ecological aspects, including bats and badgers, are included in the Ecology Report presented in Appendix F.

4.1.3 Further information regarding the trees can be found in the Tree Survey presented in Appendix G.

4.1.4 An indication of provisional costs of installation for each option based on the preliminary discussions is also included below.

4.1.5 The estimated cost for preliminaries (including site establishment, welfare facilities and any required Quality Assurance testing) is in the region of £148,500.

4.1.6 A provisional cost for the removal of vegetation is in the order of £49,300. This is discussed in further detail with regards to each of the options.

Drainage

4.1.7 Due to the extremely limited drainage measures existing on site the following drainage measures are to be installed whichever stabilisation option is chosen.

4.1.8 It is proposed to install crest drains where they are deemed to be appropriate to intercept surface water flows that could be detrimental to the stability of the slopes by allowing water to flow down the slopes.

4.1.9 The existing camber of the road would require kerbs and gullies (or perhaps channels) on both sides of the road. Kerbs will be installed on either side of the carriageway, with gullies spaced approximately 20m apart. These gullies will feed into a pipe of approximate diameter 300mm running underneath the centre of the carriageway via connect pipes of approximate diameter 150mm.

4.1.10 This is to facilitate drainage at the sides of the road, so that the potential for eroding the toe is reduced / removed.

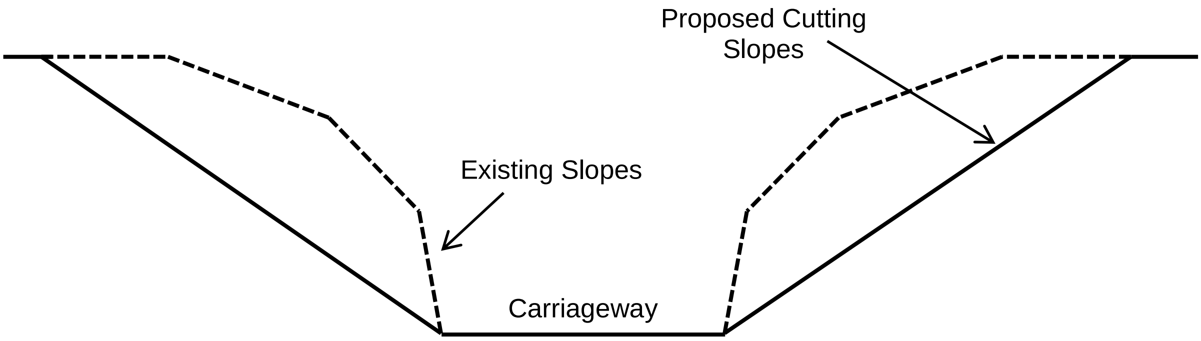
4.1.11 The preliminary cost estimate of installing the drainage measures is as follows:

Crest drain	£16,000
Kerbs and gullies along length of road with connector pipes to central highway pipe (including manhole covers)	£136,200
Reinstatement of Carriageway	£68,100
Total	**£220,300**

4.2 Re-grading of the Slope

4.2.1 Re-grading the hollow slopes to an acceptable reduced slope angle from the toe of the slopes has been considered as a solution.

4.2.2 Without additional reinforcement techniques, the maximum slope angle allowable according to current standards has been calculated to be 28°. This re-grading option results in an estimated volume of material requiring removal of around 42,200m^3.



4.2.3 The preliminary cost estimate of re-grading the slopes and the transporting and dumping of material is shown below:

Cost of removing material to re-grade at 28° from toe	£1,150,000
Cost of transportation* and dumping of material	£4,280,000
Total	**£5,430,000**

*: This is based on transportation to a disposal facility 15km away

4.2.4 In addition, slackening of the slopes would require land purchase from the landowners and would result in the loss of the 'sunken road' aesthetic.

4.2.5 The technique would have a detrimental impact on the habitat and a large visual impact on the hollow from surrounding land and would require full vegetation clearance including all trees.

4.2.6 The advantages and disadvantages are summarised below:

Advantages	Disadvantages
• Hollow slopes are at acceptable slope angles, without reinforcement.	• Removal of large volumes of material which will then require transporting and dumping. • Removal of all vegetation from proposed new hollow slopes, including all trees. • Detrimental effects to the aesthetics of the hollow itself and surrounding land. • Land purchase required.

4.2.7 As a result of these factors, this solution has been discounted.

4.3 Soil Nailing

4.3.1 Soil nails with the option of either a flexible or hard facing have been considered as a stabilisation technique.

4.3.2 Vegetation will need to be cleared from the slopes: all vegetation including trees from the steeper, lowers slopes and some from the upper slopes. Extensive consultations with an arboriculturist and ecologist will be held in order to preserve as many trees as practicable on the upper slopes. However is should be stressed that any trees compromising the integrity of the soil nailed solution and facing will be removed.

4.3.3 For the purposes of this Options Report, taking into account recommendation from CIRIA 637 [Ref. 20] and BS 8006-2 [Ref. 21] a spacing of 1m has been assumed, installed at an inclination of 10^o to the horizontal. This spacing is likely to be increased during detailed design on upper slopes after rigorous analysis has been undertaken.

4.3.4 The properties of Dywidag R-32 280 bars or equivalent have been initially considered for use following their successful implementation at Beaminster Tunnel, a site with similar geotechnical properties. The length and spacing of soil nails required was assessed for a slope angle of 45°, 60° and 70°, the assumption being that the actual slope will either be re-profiled to the lower angle, or assumed to be the higher angle on a case by case basis during the detailed design.

4.3.5 The results of the analysis indicate that soil nails of length 8m are appropriate for stabilising the length of the site. As previously discussed with regards to the spacing, this length could be locally altered during detail design.

4.3.6 Long hole drainage, in the form of slotted pipes with geotextile surround to prevent fines ingress, should also be installed at the base of the slopes at 5m intervals, at the same length as the soil nails installed.

<u>Hard Facing</u>

4.3.7 The hard facing installed on the lower slopes, i.e. those above 45°, would comprise soil panels, which are steel boxes filled with growing medium or stone. It is recommended that a growing medium is used which can then be hydro-seeded to allow vegetation to proliferate.

4.3.8 These are also pinned to the slope using soil nails, which reinforce the global stability of the slope while the facing provides an effectively rigid restraint across the whole face.

4.3.9 For the purposes of providing an estimation of the costs involved, it has been assumed that the hard facing would be used on slopes greater than 45^o. This will be reviewed during detailed design.

4.3.10 Limited excavation of the hollow slopes will be required in order to install these soil panels and ensure there is no encroachment beyond the existing slope and onto the existing carriageway.

4.3.11 The benefit of this solution is that it can be utilised on steeper slopes than what is possible from flexible facing, discussed below, up to vertical. It would also provide some protection to the slopes from any impact from heavy good vehicles.

Flexible Facing

4.3.12 Flexible facing installed on the upper slopes would comprise high tensile strength mesh, pinned to the slope using soil nails at a specified length and spacing. The soil nails reinforce the global stability of the slope, while the mesh supports the soil between nail locations and prevents any local losses of material.

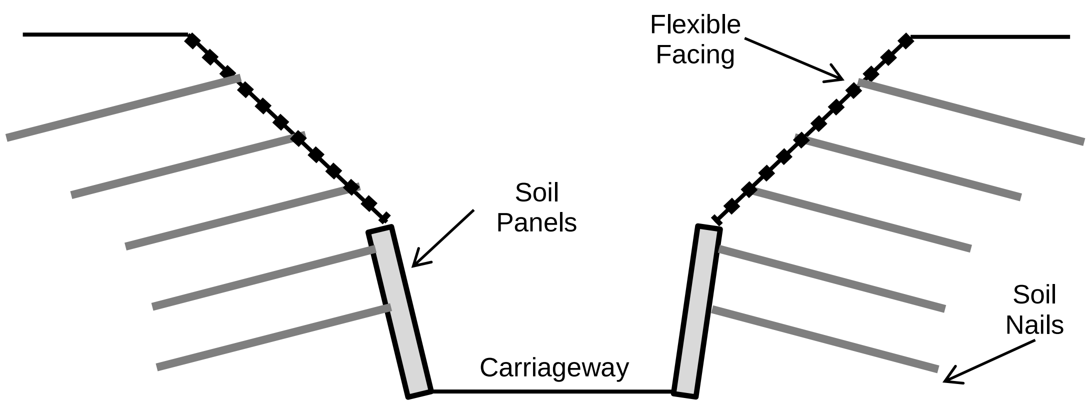
4.3.13 For the purposes of providing an estimation of costs, it has been assumed flexible facing would be used on slopes up to 45°. The potential use of flexible facing applied to slopes greater than 45° will be reviewed during detailed design.

4.3.14 An example of this type of facing is TECCO mesh. Erosion protection matting could also be installed underneath the mesh and the slopes hydro-seeded to promote vegetation growth which would reduce the visual impact of this stabilisation measure.

4.3.15 As the existing topography would be unchanged, trees at the existing crest lines have the potential to be preserved, thus reducing the visual impact of the stabilisation measures from the surrounding land. The meshing of the slopes may also be locally designed to avoid any trees which are specified to remain during the works. Appropriate measures will be taken to preserve trees, as far as practical without compromising the effectiveness of the remedial measures. This will require detailed and careful consideration at the design stage.

4.3.16 The preliminary cost estimate of installing soil nails and the appropriate facing as the stabilisation measure is as follows:

Soil nailing	£1,620,000
Flexible Facing for Upper Slopes	£175,500
Soil Panels for Lower Slopes	£472,500
Testing	£13,500
Long hole drains along the stabilised section	£53,000
Total	**£2,334,500**



Quarry Area

4.3.17 Within the historic quarry and on the rock exposure adjacent to the road north of the quarry Individual rock anchors could be installed, as necessary, to prevent the failure of discrete blocks. The number, dimensions and location of any rock anchors will be considered further at detailed design stage.

4.3.18 Fully bonded untensioned anchors or bolts are best suited where no movement of the block has yet occurred. The bolts are stiff enough to prevent movement across the discontinuities. Rock bolts are quick to install and are cheaper than tensioned rock anchors.

4.3.19 Tensioned rock anchors are generally required where blocks have already moved and require stabilisation to prevent full failure. The anchors are installed across the discontinuity and grouted into sound rock beyond. The tensile force, transmitted to the rock by a reaction plate modifies the normal and shear stresses on the slide surface eliminating the risk of failure.

4.3.20 Tensioned rock anchors are slower and more expensive to install and require testing and subsequent monitoring (albeit at longer intervals).

4.3.21 The use of anchors, untensioned or tensioned, on this face would be appropriate on any blocks where the probability of failure is high but they are too large, or not currently loose enough, to be removed by scaling.

4.3.22 It is recommended that scaling, the removal of loose rock or blocks at an increased probability of failure, generally using hand tools is undertaken prior to the installation of any rock anchors or bolts. Care must be taken when scaling to ensure that overhangs are not created leaving material above unsupported and at an increased risk of failure.

4.3.23 Although preliminary discussions have been held with specialist geotechnical contractors, it is strongly recommended that early contractor involvement, including a site visit, is sought to confirm any potential site constraints which may affect the potential stabilisation measures detailed in the report. This would also finalise the amount of material to be removed and if this could potentially be reused within the facing panels.

Advantages	Disadvantages
• Minimal removal of material (only that required to install soil panels). • Vegetation can be re-established on the slopes minimising the visual impact, although it is recommended that this is not trees. • Minimal effects to the aesthetics of the hollow itself and surrounding land. • Stabilisation measures can be designed for the required 120 design life.	• Removal of vegetation in preparation for the soil nails to be installed.

4.3.24 As a result of these factors, this solution has been chosen and is discussed further in Section 5.

4.4 Bio-Engineering

4.4.1 The following guidance and sources of information have been consulted with regards to the use of bio-engineering as a stabilisation measure:

- BS6031:2009, Code of Practice for Earthworks [Ref. 22];
- ICE Manual of Geotechnical Engineering [Ref. 23];
- CIRIA C780, Effect of Vegetation on Soil Slopes [Ref. 24];
- CIRIA C591, Infrastructure Cuttings condition appraisal and remedial treatment [Ref. 25];
- CIRIA Project Report 81, Bioengineering: the Longham Wood Cutting Field Trial [Ref. 26];
- Norris & Greenwood, Assessing the role of vegetation on soil slopes in urban areas, Paper No 744 [Ref. 27];
- Slope Stability and Erosion Control: Ecotechnological Solutions [Ref. 28]; and,
- TRL Report 508, Report on the use of Live Willow Poles for stabilising Highway Embankments [Ref. 29].

4.4.2 The sources listed above indicate that the presence of certain types of vegetation on slopes has an observable, but unquantifiable, positive effect on the stability of the earthwork. This is achieved by the roots of the vegetation adding mechanical reinforcement to the soil, the area of influence typically concentrated within 1.0m of the surface. Some tree roots have been recorded to extend up to 3.0m below the surface.

4.4.3 It should be noted that the positive effect of the vegetation is lost if the depth of the slip is greater than the extents of the root network. Failures reaching a depth greater than 1.0m below ground level were consistently observed in the back analysis, and depths greater than 3.0m were also noted.

4.4.4 Vegetation has also been noted to reduce the proportion of precipitation that reaches the soil, and reduce the moisture content of the ground due to transpiration. This also has a positive effect on the slope stability, although to a lesser extent than the mechanical reinforcement. It should be noted that transpiration rates are highly variable and seasonal in deciduous trees. These rates are lowest in winter, which is also the period when the risk of landslips is greatest.

4.4.5 The vegetation currently present on the slopes of the hollow is likely to be providing some increase to the ground stability, accounting for the overly steep slope angles observed at present. The extents of this reinforcement are likely to be highly variable across the site extents due to the large variety in types and maturity of the vegetation, and areas of the hollow without vegetation coverage will not receive the benefit. It is therefore impossible to quantify and guarantee its effectiveness in the long term lifespan of the site.

4.4.6 The location of the vegetation is also important, as the vegetation at the toe of the slope is likely to provide more benefit that at the crest of the slope. The weight of the larger, more mature trees is likely to be providing a detrimental effect to the stability of the slope. There is also a risk of trees falling during periods of strong wind, which could cause a further failure of the hollow slopes due to pressures exerted by roots wrenched loose. This risk is exacerbated by large mature trees, the failure of which would cause greater damage to the slopes due to the increased range, size and density of roots.

4.4.7 It is however strongly recommended that suitable vegetation is reintroduced to the slope post construction of any additional stabilisation measures. This will enhance the slope stability by assisting in the retention of superficial material, and will also preserve the aesthetics of the area.

4.4.8 The advantages and disadvantages are summarised below:

Advantages	Disadvantages
• Minimal removal of material. • Minimal effects to the aesthetics of the hollow itself and surrounding land.	• Cannot quantify and guarantee effectiveness or vegetation as a stabilisation measure. • The area of influence for the bio-engineering typically limited to within 1.0m of the surface, which is insufficient if a slip is greater than this depth. • Large areas with no trees are effectively "unreinforced". • Stabilisation measure cannot be designed for the required 120 year design life.

4.4.9 As a result of these factors, this solution has been discounted.

4.5 Vertical Realignment

4.5.1 Consideration has been given to raising the vertical alignment of the road at the lower end of the hollow as a potential option.

4.5.2 BT ducts run through the hollow therefore BT would need to be consulted with respect to altering the vertical alignment of the carriageway. Laying new empty ducts at a higher level for future maintenance whilst maintaining the existing cables at their existing levels may be possible but this should be confirmed with BT.

4.5.3 The gain in vertical height of the carriageway would be up to 1.76m in places (please see PB Drawing number DH/001 in Appendix L). Although it would have a beneficial effect on the stability of the slopes, it would not solve the issue of the instability of the hollow slopes themselves, therefore should only be used in conjunction with the chosen stabilisation measure if required.

4.5.4 The new alignment would be subject to a road safety audit and the detailed design would need to consider visibility further, which may require vegetation / tree clearance on the re-profiled slope

4.5.5 The preliminary cost estimate for vertical re-alignment of the road is as follows:

Preliminaries	£21,300
Ducting	£7,600
Earthworks	£97,000
Pavements	£88,000
Signs and Road Markings	£3,700
Landscaping	£500
Total	**£218,100**

4.5.6 The cost estimates are based on the following assumptions:

- Carriageway is 6.0m wide throughout scheme and 40mm surface course, 60mm bind course, 100mm base course, 150mm sub base;
- Fill above existing road to be Class 6F5 granular material;
- 35m of tie in to existing carriageway which would require milling and re-lay of surface course;
- 2 way duct between chambers and 2 intermediate chambers for duct (for the BT ducts);
- No traffic management required as road is currently closed; and,
- Existing carriageway to be broken up and left *in situ*.

4.5.7 The advantages and disadvantages are summarised below:

Advantages	Disadvantages
• Will provide a beneficial effect to the stability of the slopes, however will need to be used alongside another stabilisation measure. • Would reduce the amounts of materials used for additional stabilisation solutions	• Consultation with BT regarding the ducting that runs along the carriageway. • Relatively expensive to import the required volumes of materials. • Will not solve the issue of the slope instability as a stand-alone solution.

4.5.8 The vertical re-alignment of the carriageway cannot be used as a stand-alone solution as although the heights of the hollow slopes will reduce, and therefore it is providing a beneficial effect; the instability of the hollow slopes themselves is not addressed.

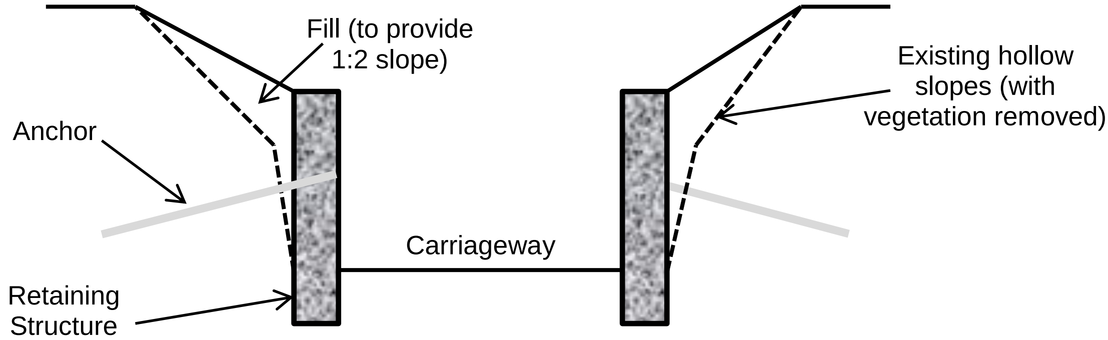
4.5.9 The vertical re-alignment could be considered in conjunction with the chosen stabilisation solution and this option should be discussed during detailed design. However, it is thought that no net saving would be obtained by implementing this solution.

4.6 Other Retaining Structures

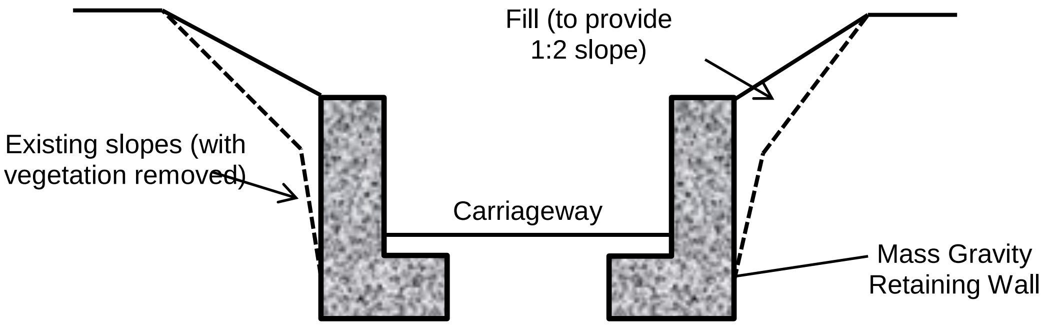
4.6.1 Some different types of retaining structure were considered as potential stabilisation options for Dinah's Hollow.

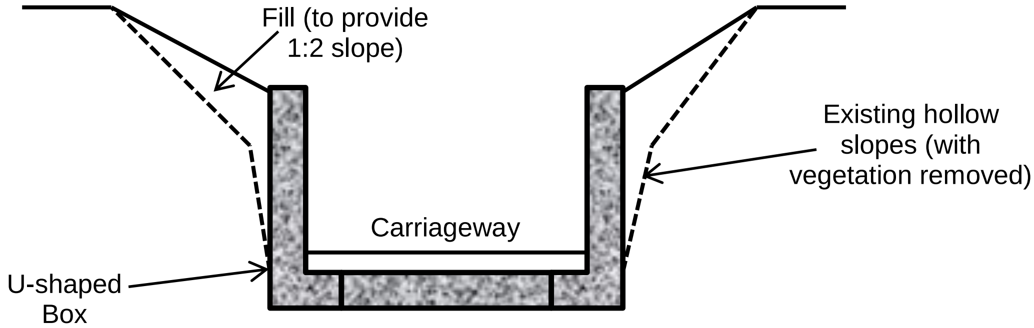
4.6.2 A sheet piled wall or bored pile wall would ensure there was no unnecessary removal of material but the installation of the wall to the required depth would be problematic. If this were the case, the sheet piled wall would need to be anchored back.

4.6.3 The construction and temporary works such as piling platforms (which would require the filling of the hollow) and casting of the piles would also be impractical.



4.6.4 Another retaining solution would be either a single mass gravity retaining wall on each side or a U-shaped box. Installation of both of these retaining structures would require large amounts of excavation, in order to either ensure the toe of the retaining wall did not encroach onto the existing carriageway or for installation of the box and subsequent reinstatement of the carriageway.





4.6.5 The temporary works associated with this size of excavation would be excessive as the excavated cut faces will require temporary support whilst the retaining structures were installed.

4.6.6 Weep-holes would be installed to control any potential build-up of groundwater behind the structure.

4.6.7 The retaining wall solutions above would also be aesthetically unsympathetic to the environment of Dinah's Hollow and therefore have been discounted as potential stabilisation solutions.

4.6.8 The advantages and disadvantages are summarised below:

Advantages	Disadvantages
• Minimal removal of material associated with the sheet pile solution. • Stabilisation measures can be designed for the required 120 design life.	• Detrimental effects to the aesthetics of the hollow itself and surrounding land. • Importing of fill and large amounts of concrete and steel to be used. • Problematic construction associated with the sheet or bored pile wall. • Removal of large volumes of material associated with the gravity or U-shaped retaining wall, which would then require transporting and dumping. • Excessive temporary works associated with the mass gravity or U-shaped retaining wall.

4.6.9 As a result of these factors, this solution has been discounted.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Preferred Engineering Option

5.1.1 The preferred stabilisation option is to soil nail the slopes and use a hard facing on the steeper, lower slopes and flexible facing on the upper slopes, as discussed in Section 4.4. For the purposes of providing an estimation of the costs involved, it has been assumed that the hard facing will be used on slopes greater than 45^{o} however this will be reviewed during detailed design.

5.2 Outline Costs

5.2.1 As stated previously, although preliminary discussions have been held with specialist geotechnical contractors, it is strongly recommended that early contractor involvement, including a site visit, is sought to confirm any potential site constraints which may affect the potential stabilisation measures detailed in the report.

5.2.2 Table 8 below presents estimated costs of the preferred engineering option. Costs will be subject to change following detailed design.

Table 7: Cost Estimate

Engineering Option	Estimated Cost
Preliminaries, including removal of vegetation	£197,800
Soil Nailing, including installation of facing	£2,334,500
Drainage Measures	£220,300
Total	**£2,752,600**

5.2.3 The costs presented above do not cover the following:

- Detailed design including any Health and Safety requirements and production of drawings and specifications; and
- Site supervision of any works by a Geotechnical Engineer or Engineering Geologist.

5.2.4 It should be noted that the vertical re-alignment could be used alongside the chosen stabilisation solution and this option should be discussed during detailed design. However, it is thought that the potential cost savings incurred by reducing the area of hollow slopes to be stabilised by implementing this solution would be minimal.

6 GEOTECHNICAL RISK REGISTER

6.1.1 A geotechnical risk register has been compiled. As this is a live document, this will be regularly updated and guidance will be sought from all parties involved in the design and implementation of the works.

6.1.2 Residual geotechnical risks will be highlighted on the construction drawings.

6.1.3 The scoring system used in the register below is as follows:

Probability (P)		Impact/ Consequence (I)		Risk Rating	Risk (PxI=R)	Response
Very likely	5	Very high	5	Intolerable	17 to 25	Unacceptable
Probable	4	High	4	Intolerable	13 to 16	Unacceptable
Likely	3	Medium	3	Substantial	9 to 12	Early attention
Unlikely	2	Low	2	Tolerable	5 to 8	Regular attention
Negligible	1	Very low	1	Trivial	1 to 4	Monitor

Feature	Hazard	Before Control			Risk Control Measure (RCM)	After Control		
		P	I	R		P	I	R
Geotechnical	Local, superficial failure including surface soil and vegetation.	4	3	12	Appropriate stabilisation measures to be designed and constructed to control both any deep seated and superficial failures.	1	3	3
	Deep seated failure of the slopes.	4	5	20		1	5	5
Vegetation	Falling of mature trees on the slope as result of inclement weather (heavy rain and / or wind).	3	4	12	Targeted and appropriate vegetation clearance to be undertaken with the guidance of an arboriculturist.	1	4	4
Heavy Goods Vehicles	Erosion of the slopes as a result of heavy good vehicles encroaching on the toe of the slopes.	4	4	16	Measures to prevent the heavy good vehicles from hitting the sides of the hollow slopes and encroaching on the toe.	1	4	4
Hydrology	High water levels within the hollow slope.	2	4	8	Groundwater encountered significantly below the road level during subsequent monitoring of the exploratory holes. Appropriate drainage measures to be installed on the slope and the installation of highway drainage.	1	4	4
	Surface water flows removing material from slopes.	4	3	9		1	3	3
	Surface water flows along highway carriageway resulting in erosion of the toe.	4	3	12		1	3	3
Historical	Archaeological finds made during works causing delays to programme.	2	4	8	No indication of archaeological features or materials in the site vicinity.	1	4	4

7 REFERENCES

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12. BS5930:1999 + A2:2010 'Code of Practice for Site Investigation'
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APPENDIX A – GROUND INVESTIGATION FACTUAL REPORT (ESG)

APPENDIX B – BRODY FORBES GEOTECHNICAL REPORT

APPENDIX C – OTHER HISTORICAL BOREHOLES (BGS)

APPENDIX D – ENVIRONMENT AGENCY RECORDS

APPENDIX E – DRAINAGE SURVEYS

APPENDIX F – ECOLOGICAL SURVEY REPORT

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APPENDIX I – HIGHWAY CALL OUT RECORDS

APPENDIX J – GEOMORPHOLOGICAL MAP

APPENDIX K – DERIVATION OF GEOTECHNICAL PARAMETERS

APPENDIX L – VERTICAL REALIGNMENT