CAMBORNE SCHOOL OF MINES

Could Helston have historically been a port settlement? : *An analysis of available evidence and LiDAR remote sensing data cross referenced with a survey of the lower Cober/Loe valley*

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05/09/2013

Submitted by Peter Nicholls to the University of Exeter – Camborne School of Mines as a dissertation towards the degree of Master of Science by advanced study in Surveying, Land Environmental Management, September 2013

I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has previously been conferred on me.

Abstract

The aim of this dissertation was to investigate the factual basis of the commonly held belief that Helston was historically a port town with access to the sea. This aim was successfully achieved through rigorous primary data collection cross referenced with available remote sensing information, as well as interpretation of large amounts of secondary evidence. Secondary evidence involved consulting with private contractors who had undertaken work within the area of interest, as well as publically available historical and geological information. Primary data collection was undertaken in the summer of 2013 using topographical surveying apparatus, including both optical and GNSS equipment made available through Camborne School of Mines. Remote sensing LiDAR (5m resolution, carried out in 2006) data was sourced from the Landmap Service, a JISC (Joint Information Systems Committee) funded project between Mimas (centre of excellence based at Manchester University) and the University College London Dept. of Geomatic Engineering. Results show that the LiDAR elevation data for the area matches that of independent primary data gathered, and as such can be deemed reliable and analysed further. With the elevations of the remote sensing data for the valley floor lowered by 6 metres – an approximate amount to represent the build-up of alluvium and increased sedimentation which has taken place over time, as suggested in secondary evidence – an illustration of how the valley might have looked historically is given. The paper concludes that because the Loe Bar might likely have allowed sea-water access to fill the valley, albeit infrequently and sporadically (because of the fluctuating topography of the bar over the course of centuries), the valley has the topographical composition to support a tidal creek/estuary system if sea access were to be maintained.

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Acknowledgements

I would like to take this opportunity to thank several key people for their kind help, support and participation throughout the progression of this dissertation project. Firstly, I would like to thank my personal tutor and advisor Neill Wood, for his advice and council on the subject at hand. I would also like to thank Mr Martin Matthews, former curator of the Helston folk museum, for his valuable input and advice on available literary sources, as well as Robert Miles, Vieri Green and Jack Burns for their kind assistance during the data collection phase of the project.

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1. Introduction

The town of Helston is located some 3km inland from the coast of Mount's Bay on the North West tip of the Lizard peninsula in Cornwall. The town can trace its extensive history back to the sixth century when it was inhabited by the Saxons and gained its name, although the 18th century Cornish poet and historian Richard Polwhele suggests in his1816 'History of Cornwall, civil, military, religious…' that Helston was not unknown as a small settlement as early as the landing of Cesar upon British shores (around 55BC). Many reputable sources proclaiming to possess knowledge of the towns extended history make the common claim that during its former years the town was a thriving port settlement situated amongst the banks of the then substantially larger River Cober. Sources that make this claim include the 18th century celebrated English author and travel writer Daniel Defoe, the early 20th century historian and antiquarian of Cornwall Charles Gordon Henderson, the Encyclopaedia Britannica, the '*Visit Cornwall'* website and the Helston Folk Museum, as well as a variety of other bases for tourist information and local history. Whilst the theories surrounding this claim differ on a number of more specific points and unambiguous interpretations, the general consensus is that Helston was once a port, and at some point (usually stated as around the beginning of the 13th century), the barrier was created stretching the width of the mouth of the Cober, cutting the town's access to the sea. It remains however, that there is a great deal of convincing geomorphological evidence that suggests otherwise, and that in fact the bar was more than likely formed by rising sea levels after the last ice age (thus blocking the river and creating a barrier beach system much earlier). It is apparent that these two hypotheses, (both of which are recognised and respected by a multitude of literary sources respectively), cannot simultaneously hold the truth, with one or the other, (or both) being potentially flawed.

1.1. The Project

The purpose of this project is to investigate the commonly held theory that Helston could have historically been a port settlement, and that the Cober River was once a navigable tidal creek for sea faring ships. This will be done primarily by analysing readily available LiDAR (Light Detection And Ranging) remote sensing GIS information used in conjunction with and backed up by primary data collected on site (in the form of spot height data obtained during an extensive traverse of the area using Leica 1200 series TPS and GNSS equipment). This will allow an approximate (yet verified) 3d topographical map of the lower valley and marsh area to be used to analyse the credibility of the theory. From this an idea of the viability of seawater reaching Helston will be reached and cross referenced with secondary data obtained through extensive desk-based research. This will help demystify the theory and shed light on the validity of historical claims by using information obtained from previously undertaken investigations in the area i.e. historical borehole drilling operations. An approximation of the sediment accumulation and deposition rates within the river valley will also be explored, since the valley has undergone excessive transformation from the time when the port/tidal creek is supposed to have been in existence. Core samples taken from borehole drilling as part of the work carried out during planning for the New Cattle Market in 2005, as well as other data relating to ground content will be analysed for evidence of saltwater underneath the alluvial deposit layers. By combining the primary data and the remote sensing information, as well as the extensive desk based research, a conclusion will be sought to determine whether or not Helston could have been a port town.

1.2. The study area

The area of interest for this investigation stretches from Loe Bar in the South West (grid reference SW 64357 24120), north through the Penrose estate, and up into the Cober/Loe Valley and the southern part of Helston town to the site of the Helston Cattle Market. As will be discussed in more detail later in this chapter, the area outlined in red (see figure 1.2a) will be surveyed in particular detail, since this is the area (due to its raised elevation according to the LiDAR remote sensing data) that is most important when determining whether the valley could have once been a tidal creek. The area of investigation is made up of a mixture of rich woodland (which in turn is made up of mixed vegetation, established trees, small shrubberies) (NT, 2002) and dense wetland within the river valley and around the Loe Pool. Surrounding farmland makes up the vast majority of the hinterland to the site. Loe Pool is a eutrophic coastal lake (the largest freshwater lake in Cornwall) and is a significant ecological habitat, which is reflected in its designation as a Site of Specific Scientific Interest (SSSI). The land immediately around the Loe Pool is owned by the National Trust, and lies within the Cornwall Area of Outstanding Natural Beauty. It is also part of the Cornwall Heritage Coast and holds significant aesthetic value. Indeed the attractiveness of the area has led to it becoming a prominent feature of the local tourist economy as well as providing an important recreation amenity for the local people of nearby Helston and Porthleven.

Figure 1.2a: Location map of study area

Source: *Edina Digimap.* (OS, 2012)

1.2.1. Key sections of the study area

The angled Landsat images below aim to highlight the key features and notable regions within the study area. Figure 1.2.1a gives a useful holistic overview of the whole study area, whilst figure 1.2.1b focuses on the features where the more detailed section of the survey will be carried out.

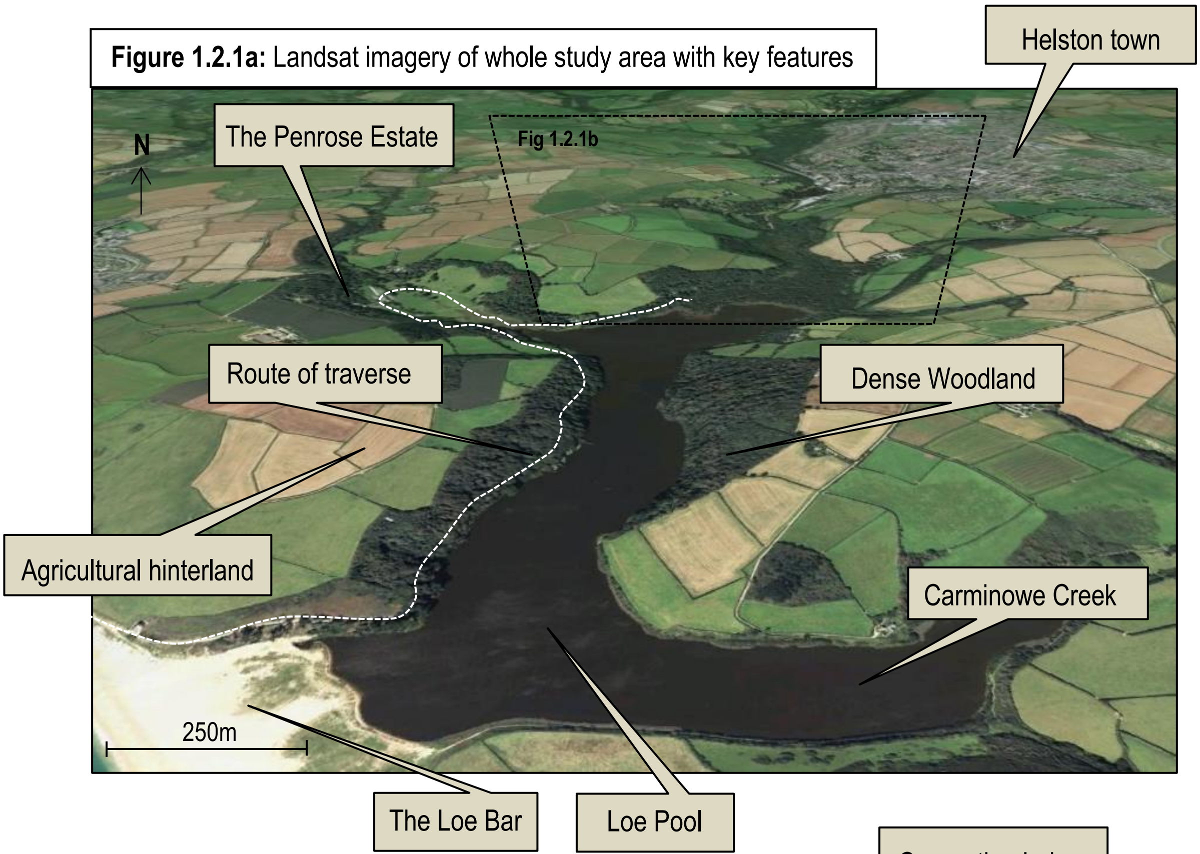


Figure 1.2.1a: Landsat imagery of whole study area with key features

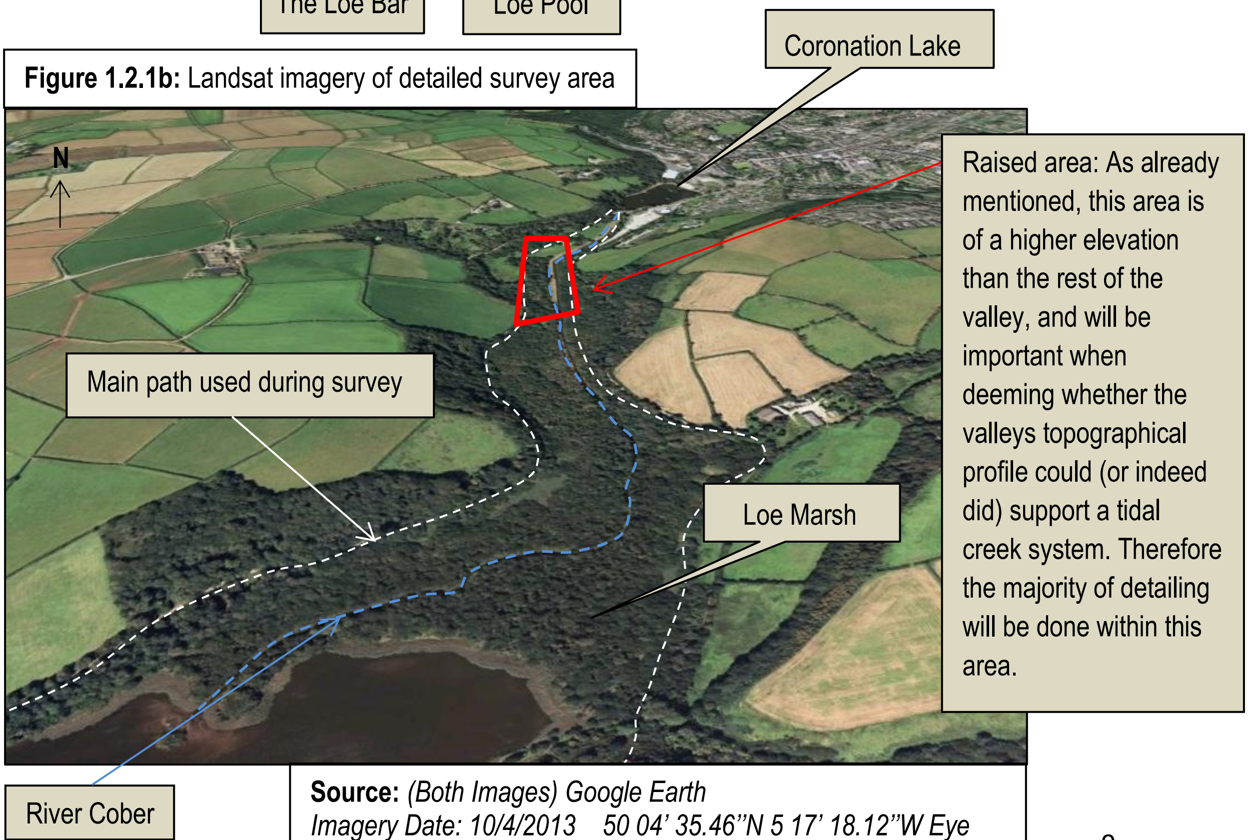


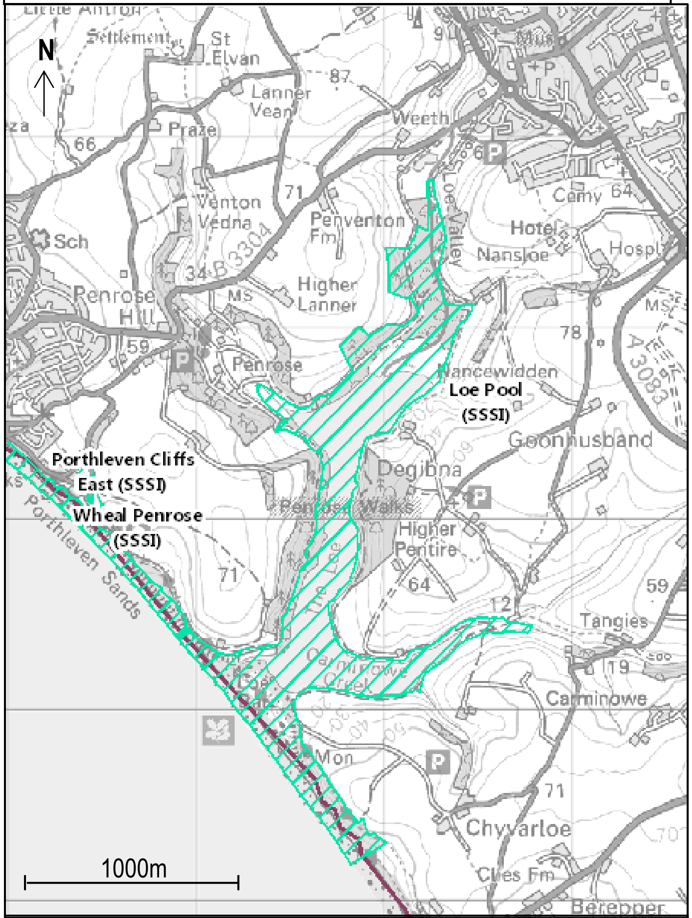
Figure 1.2.1b: Landsat imagery of detailed survey area

Source: *(Both Images) Google Earth Imagery Date: 10/4/2013 50 04' 35.46''N 5 17' 18.12''W Eye altitude 747m Data SIO, NOAA, U.S. Navy, NGA, GEBCO 2013 Infoterra Ltd & Bluesky*

1.2.2. Notable features and characteristics of the site

The area of investigation has a number of notable features and characteristics that are significant to this investigation. It is practical to outline these during this preliminary descriptive chapter.

Figure 1.2.2a: Environmental designation map

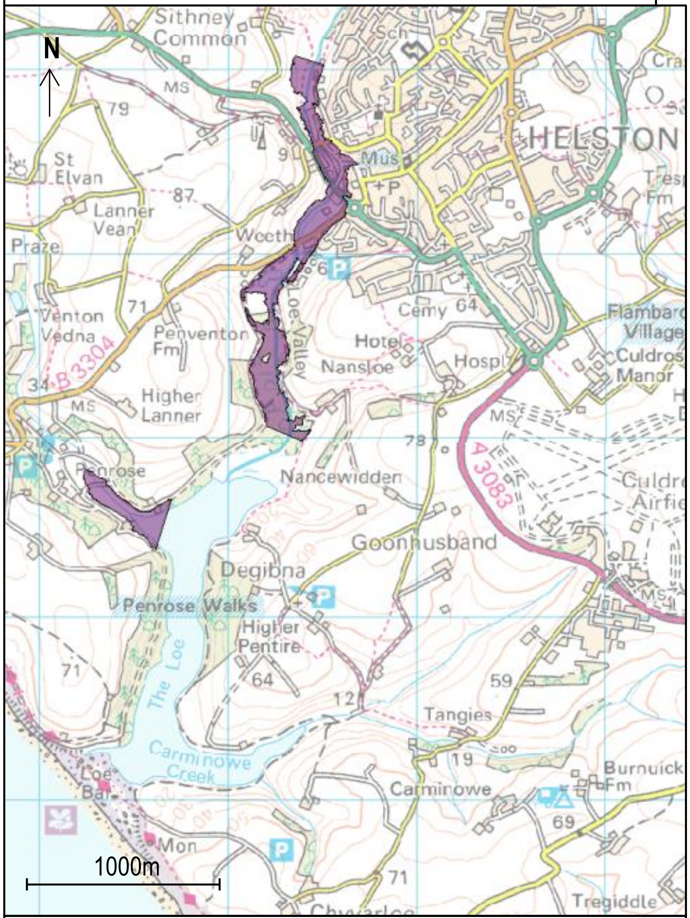


Key

Site of Special Scientific

Source: *MAGIC. Defra*

Figure 1.2.2b: Environment Agency flood warning areas



Key

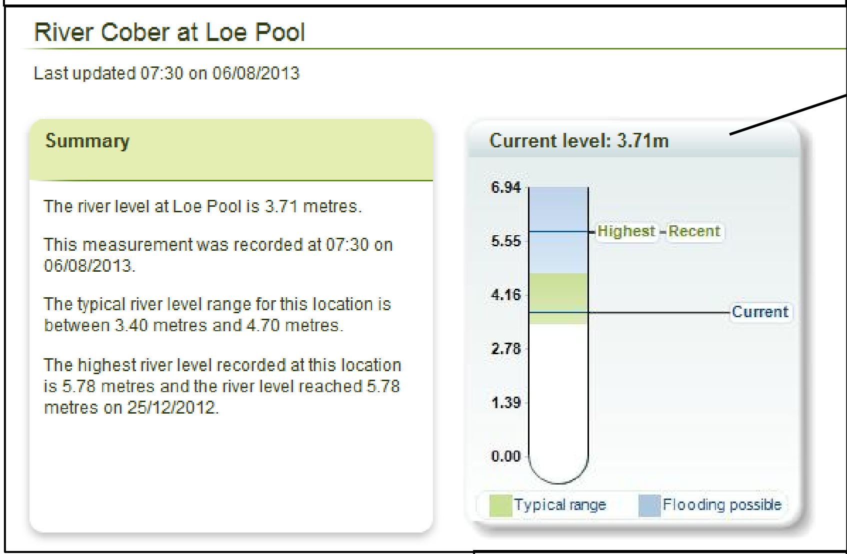
Areas where flood warnings are issued

Source: *Environmental Agency*

Figure 1.2.2a shows the area is a listed SSSI designation. It is noted that the area is also home to other designations (both statutory and non-statutory), including featuring in the Geological Conservation Review (GCR) because of the geomorphological significance of the Loe Bar. Loe Bar is also the only British site of the Cornish sub-species of Sandhill Rustic Moth (*Luperina nickerlii leechi*) and holds conservation value. The site is also located within the Cornwall Area of Outstanding Natural Beauty (AONB) as well as being part of the Cornwall Heritage Coastline (NT, 2002).

Figure 1.2.2b reveals the area is prone to flooding (with figure 1.2.2c detailing the most recent flood levels) and shows the sections most susceptible to risk. Interestingly enough this gives clues towards the topography of the river valley and shows the natural path the floodwaters take, suggesting it is feasible for significant levels of water to build up in these areas because of the geography of the terrain. Figure 1.2.2d gives us an understanding of the topography of the Cober valley leading north into Helston.

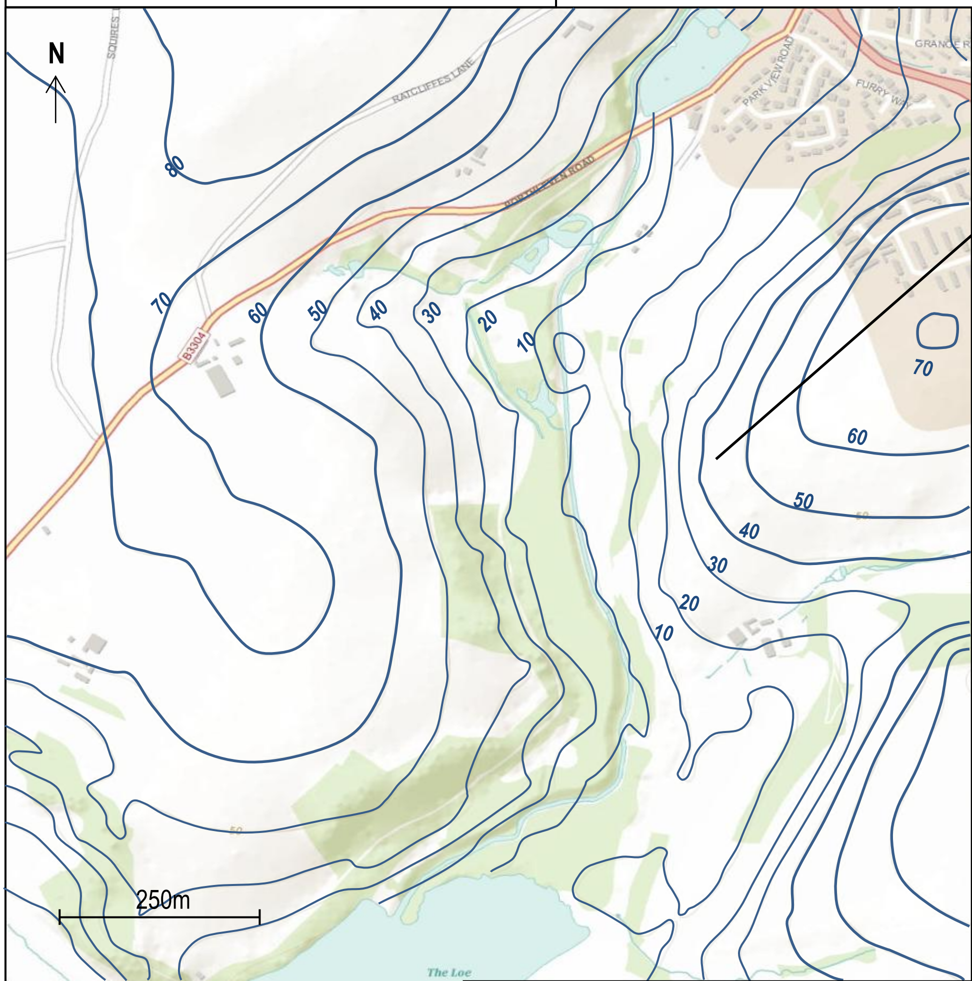
Figure 1.2.2c: Environment Agency recent flood information – River Cober



Source: *Environment Agency*

In an effort to help reduce this flooding upstream from the Loe Pool, actions were taking including the channelization in 1946 of the river, and subsequent reprofiling in 1988 (Coard et al, 1987, p185). This engineering would have resulted in vast amount of earth matter being displaced within the valley, in an attempt to minimise the flood risk. However, figure 1.2.2c shows us that the river is still susceptible to extensive flooding, such as those witnessed in December 2012.

Figure 1.2.2d: Topographical map of the valley



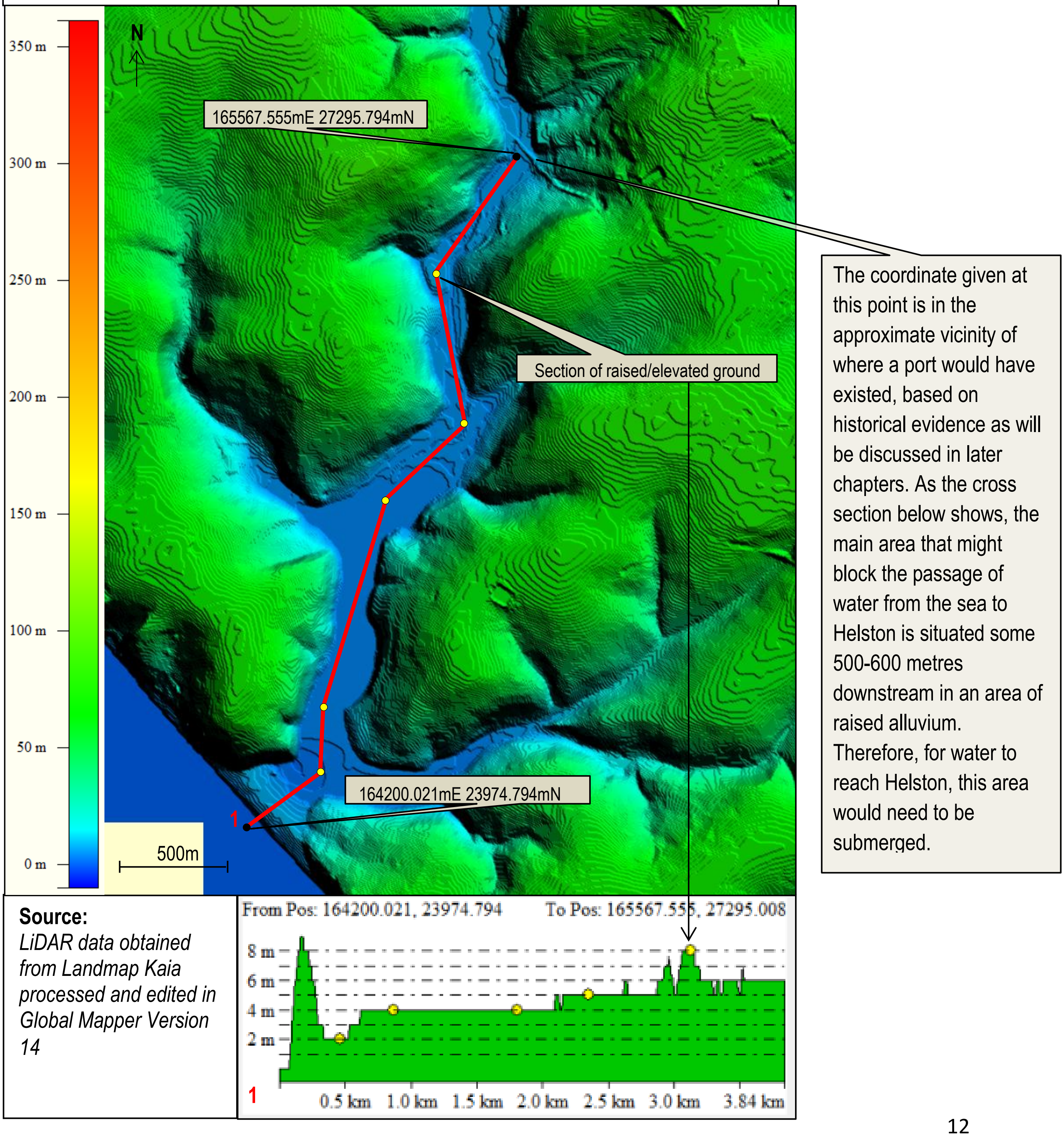
Source: *ArcMap 10 Topographic Basemap*

Figure 1.2.2d helps give a useful preliminary understanding of the topography of the Cober valley area leading into Helston. Whilst we can deduce from this the rough elevation of the valley floor, the LiDAR remote sensing data will be used to gain a more detailed understanding of whether the valley has (or indeed did have) the topographic make-up to support a tidal creek/estuary system.

1.2.3. LiDAR

The use of airborne LiDAR sensors for topographic mapping is rapidly becoming a standard practice in the aero service community (Hodgson & Bresnahan, 2004, p331), and is well suited for the needs of this project. As can be deduced from the cross section below (see figure 1.2.3.a), there is an area of raised elevation approximately 200-300m in length roughly 3km inland from the sea, following the probable route through the valley that sea faring ships would have navigated along.

Figure 1.2.3a: Digital terrain model LIDAR (5m resolution) – With elevation cross section of probable sea faring route from St Mount's Bay in to Helston



Source:
LiDAR data obtained from Landmap Kaia processed and edited in Global Mapper Version 14

This area is approximately 2-3 metres higher than the rest of the valley and could be an anomaly caused by the presence of the valley's dense vegetation affecting the accuracy of the LiDAR. Indeed, the process through which LiDAR data is obtained can make it exceptionally difficult to define ground height levels in areas where thick and dense ground vegetation prevents laser penetration to the ground surface (ASPRS, 2004). However, if the ground is indeed of a raised topographic make up, and the content of the ground beneath the surface suggests the presence of seawater at some point in the valleys history, then the build-up of alluvium (particularly in this section of the valley and likely related to the historic mining within the region) could be a viable explanation for the ceasing of sea access for Helston along this valley. Therefore, the chief aim of the primary data collection phase of this project is to give credibility to this data by analysing and cross referencing spot height data collected on site with this remote sensing data to find a correlation that can go some way to confirm its accuracy. Simultaneously to this, the prospect of whether such a significant amount of sediment build up could have occurred within this area over a relatively short geological time span will be investigated.

1.3. The aim, objectives and scope of the project

This section looks to outline the key aim of the project together with the key objectives and scope/components of the project. This will allow for a more focused approach to completing the project, and thus helps form the 'barebones' of the assignment.

1.3.1. The aim

The overriding aim of this project is to come to a sound conclusion as to whether a sea port could have existed in Helston at some point during the town's extensive history. Note – without archaeological evidence, it is impossible to prove beyond doubt that the port did indeed exist, therefore with this in mind this project merely looks to prove whether the theory is feasible.

1.3.2. The objectives

By analysing the Cober/Loe valley through an extensive site survey, as well as further secondary research, the key objectives of the project (as stated below) will be achieved:

- To undertake a holistic site survey, comprising of an open traverse - paying particular attention to the raised section of the valley, (where LiDAR remote sensing shows an area of significantly elevated ground).
- To establish whether the LiDAR remote sensing data is dependable and consistent with the independently gathered primary data.
- To establish how far up the valley (in its current topographical state) seawater would reach in the hypothetical scenario of the Loe Bar being removed.
- To establish roughly how much sediment may have accumulated over time in the river valley as a result of extensive mining within the catchment.
- To explore secondary data and investigate whether there is evidence of saltwater within the valley underneath these layers of deposited sediment.
- To come to a sound conclusion (drawing upon all aspects of evidence/data collection) as to whether or not there could have been a port at Helston.

1.3.3. The scope

To achieve the objectives as stated above a holistic site survey (incorporating an open traverse) will be undertaken with particular focus given to the lower section of the river valley, since this area is of raised elevation and would therefore ‘block’ the access to the sea the most significantly. The expected outcome is that the traverse will show (from elevations of points along the valley) that the river valley in its present day form does not have the topographical make up for a tidal creek/estuary to exist with the hypothetical removal of the Loe Bar. Assuming that the LiDAR data is dependable (by cross correlating with primary data collected on site with independent surveying equipment), it will be utilised in software such as global mapper, so to analyse how much lower the valley would need to be, (and therefore how much sediment would need to have accumulated over time), for the port theory to be viable. With this in mind, the secondary sources of information in the form of core sampling data and any other geological data will be analysed for evidence of salt water at the applicable depth, underneath the alluvial strata. Historical documentation, literary sources and other relevant evidence will all be explored in an attempt to gain as in-depth understanding of the area as possible. Taking all these aspects into consideration, an education and well informed opinion will be formed.

1.4. Justifying the research

Because there is such a divide in opinions and attitudes surrounding the theories that make up the backbone of this investigation, the subject at hand can make the claim to be in need of interpretation and clarification. This is summed up by the considerable lack of any real historical evidence to support the theory that Helston was once a thriving port town, as well as any significant evidence to disprove this concept. This project aims to fill gaps found within the previous literature and to generate some closure on whether or not the generalised theory holds any weight. As well as this, as already mentioned, the site is of considerable ecological and environmental significance, making the research important in helping understand the history of such an important area, and the processes that have created the habitat there today. The viability of this project is justified by utilising equipment and technologies made available through Camborne School of Mines (CSM), i.e. Leica TPS 1200 series, GNSS etc. Through CSM, a detailed analysis and survey can be undertaken cheaply and effectively, which might otherwise be economically unfeasible to a commercial organisation.

1.5. Structure of Report

This initial section of this project in Chapter one aims to portray the meaning, significance and background behind the project. Chapter two makes up a considerable percentage of the paper, and aims to provide an in-depth literature review exploring sources of information including previous publications and literary bases that are significant to the project at hand. The review is broken down in to additional sections each discussing a noteworthy component of the project – e.g. the origins of Helston, local geology etc. Chapter three will provide a thorough and in depth description of the methodology employed when undertaking this research project – particularly the data collection phase. Techniques are discussed as well as problems encountered and the associated mitigation methods. Chapter four is a discussion of the results and findings from the data collection phase, and aims to use models and figures to visually display results in a suitable format. Chapter five aims to summarise and conclude the project, bringing together the key and suggests areas of suggested future investigation.

2. Literature Review

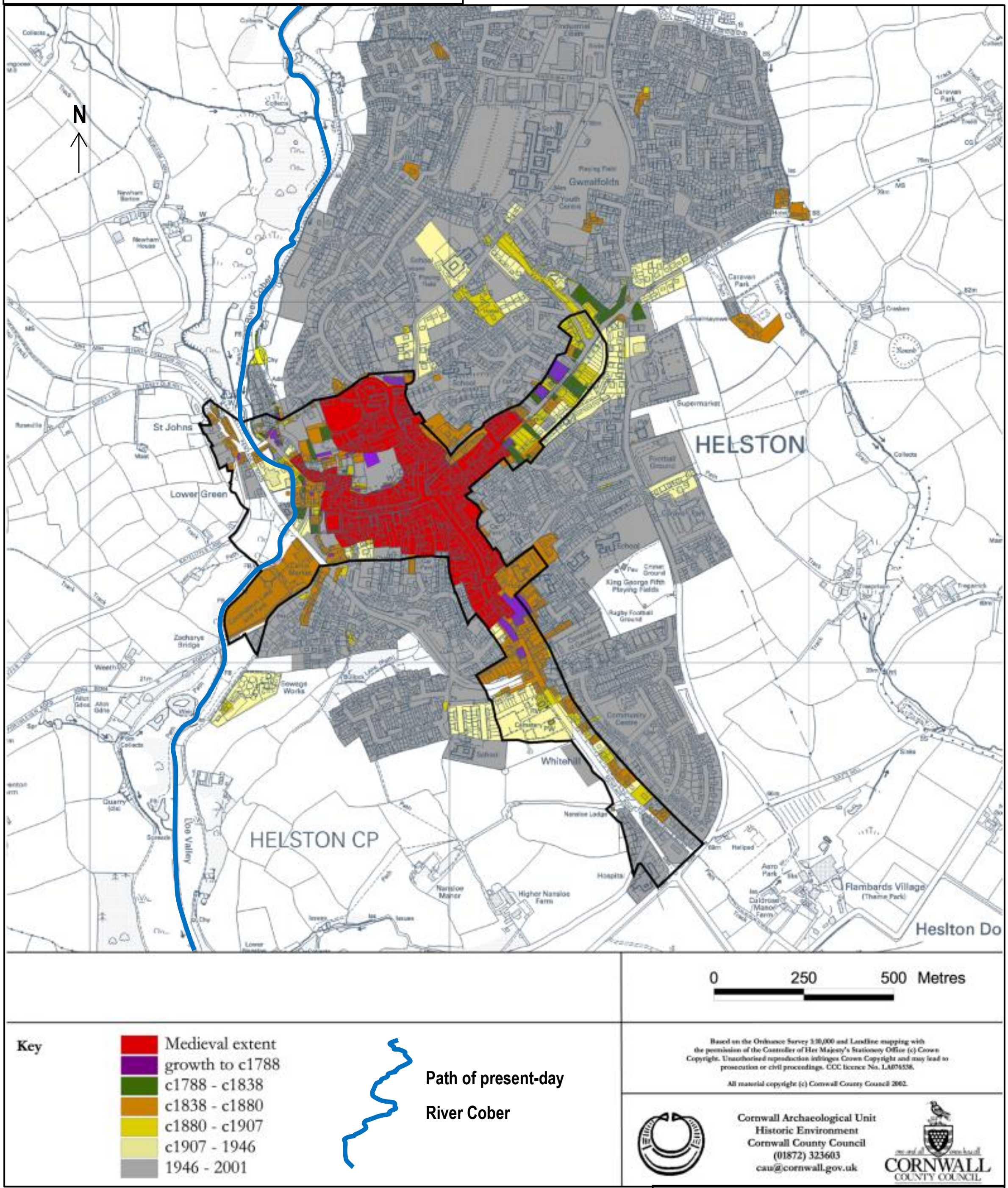
The purpose of this chapter is to provide an overview of the subject and theory in consideration i.e. that Helston was once a port town at some point during its history, with a tidal creek/estuary navigable by sea faring ships. This will be done using a select analysis of existing research and appropriate documentation relevant to my study area. The chapter will attempt to divide the works under review into different categories, (i.e. those in support of this theory, those against, and those which offer alternative theses entirely). Furthermore, this chapter will look to explain how each contributing source of information is similar to, as well as how it varies from, the other pieces of work. Some conclusion will be given as to which pieces are then best considered in their argument (in terms of the convincingness they offer) together with which pieces make the greatest contribution to the understanding of this investigation into whether Helston was indeed once a port town.

2.1. The origins of Helston town

Before embarking on a lengthy discussion around the key components surrounding the hypothesis of the project (i.e. the local geology of the valley, sedimentation rates for the River Cober, ground content above bedrock, the formation of the Loe Bar, etc.), it is first pragmatic to consider the early origins of Helston as a settlement, which Fortesque Hitchins Esq describes as just as 'equally uncertain' as the question surrounding whether or not the town was once a port settlement (Hitchins, 1824, p.316). Early evidence of Helston being a significant settlement can be found in domesday manuscripts, notably the entry in the Exeter domesday that Earl Harold held the manor at the time when the then king (Edward the Confessor) died on 5th January 1066. Prior to this era – the town was known as 'Henliston' or simply 'Henlis' (Henderson, 1935 p.67) – with the syllable 'ton' being added by the Anglo Saxons when they emerged in the tenth century and established the manorial system which the Normans were able to complete some one hundred years later. However, as aforementioned in the introductory chapter, there is evidence to suggest Helston was already established as a small settlement long before it was ever given its Anglo-Saxon name, perhaps even as early as the first century AD. With this in mind, the timespan during which Helston could have theoretically had a port stretches back approximately 2000 years; an important component in understanding how much the landscape could have changed. Figure 2.1a shows the historical development of Helston, with some of the medieval extent of the town located within close proximity to the course of the present day river, suggesting it had some significance to the pattern of development. There is plenty of evidence to show

Helston's development as a medieval settlement, with the town's first charter, granted on 15th April 1201 by King John Lackland, creating the borough of Helston. Indeed, by 1305 Helston was a 'coinage town' (as a result of a charter granted by King Richard), where the tin ingots from the region were taken to be weighted to assess the duty payable to the Duke of Cornwall. The form which Helston exhibited as a town in its medieval extent represented a cross (as shown in Figure 2.1a), with the principle streets meeting at a common centre. However for the town to have been a port settlement, sections of the town in ancient times would have needed to stand adjacent to the banks of the Cober, which would have then been a navigable river, and not the meandering stream it has become today. Hitchins confirms that 'whether Helston was ever a sea port, seems very uncertain' (Hitchins, 1824, p.316), and Polwhele states 'that Helston was once a port, I have before stated as a trafitional tale' (Polwhele, 1816, p.16). Both authors go on to state that the presence of the Loe Pool 'from time immemorial' and the untraceable origins of the customary 'breaking of the bar' (a local tradition in which the lord of the manor at Penrose is presented with leathern purses containing three halfpence, before the bar of sand can be broken) is proof enough of these claims.

Figure 2.1a: Historical development of Helston



Source: *Cornwall County Council*

Considering this information, it is safe to assume Helstons existence as a settlement predates the 13th century, the historical era suggested by many as that when the town lost its access to the sea. The problem herein is that any reliable, consistent and trustworthy information relating to pre-13th century Helston is extremely scarce and thus a concrete opinion on whether or not a port could have existed is hard to establish. This gap in reliable information offers a significant challenge in researching this dissertation topic, but allows for an open minded hypothesis and presents an opportunity for noteworthy and significant conclusion to be obtained.

Figure 2.1b: Map by J.Warburton (1682-1759) of Penrose and Trelevan *(undated)*

Source: *Helston Folk Museum*

It remains that there is no archaeological evidence of a port existing within the area, despite local claims (ranging from rumours of ancient mooring posts still being present within the town, and engraved masonry on old custom house buildings). It could be argued that these reports have a somewhat limited factual basis and are more likely local anecdotes encouraged by this lack of any real evidence either way. As aforementioned there is only an extremely limited and somewhat dubious amount of primary evidence to shed any light on the theory. However, there are glimpses of activity suggesting the presence of a port. For example those seen in the financial Pipe Roll records of Helston, scribed during the time of Henry II. Henderson (1935, p.70) points to these rolls, and specifically the 1182 record of Godric of Helleston paying a fine of ten marks for exporting his corn out of England from Helston without a licence. This could be considered the most significant piece of documentary evidence signifying Helstons former port days; however it is not without question in its reliability. Henderson also points to the likely existence of a ‘castle or fortified manor house at the head of an estuary’ as proof that the town once lay adjacent to a tidal creek. This castle listed under monument number 425399 (English Heritage) was recorded as being in ruins by William or Worcester in 1478, its location is documented as SW 6565 2739 (now occupied by the town bowling green). From this we can gain a generalised understanding of where the estuary might have extended up into the settlement, and as such focus the search for evidence. Figure 2.1b, a depiction of the valley by J.Warburton, most likely completed in the early 18th century shows the valley extending up into Helston, and gives credit to the Henderson’s theory.

It is important to remember that these examples of primary evidence already mentioned do not hold any sound scientific basis, and as such must be taken with an element of scepticism in mind. Consequently we must examine the other core areas of this project in an attempt to gain a more rigid and sound understanding of the history of this region. Therefore, having discussed in brief the origins of Helston’s history, and established that the town predates the 13th century; it is only pragmatic to give some attention now to the origins of the geological feature that is so important to this project – The Loe Bar.

2.2. Local geology and the origins/geomorphology of the Loe Bar

Figure 2.2b shows the local geology of the area, with the superficial deposits of alluvium distinctly following the valley of the Cober. As mentioned in the attached annotations, this suggests some form of transportation and deposition having been present at one time, and could give clues as to the scale and presence of a former river system, more substantial than today's river Cober. However, whilst a more pronounced river, or perhaps even estuary may have existed as this geological evidence supports, it still remains unclear as to whether this likely river system could have existed during Helstons former years.

At the crux of this investigation are questions surrounding the origin of the Loe Bar, since theories around its formation and the subsequent ceasing of Helston as a port town are by their very nature fundamentally interconnected. With various differing opinions and theories to be considered, the origins of Loe Bar will be discussed analysing theories surrounding its formation that both discredit, or conversely support the prospect of the Cober/Loe valley as a historical tidal creek. As previously mentioned, most of the theories purporting Helstons existence as a port town suggest the ceasing of sea access occurred during the early 13th century with the formation of the Loe Bar. Herein lies a problem, since the geomorphology of the bar and geological explanation for its formation puts its formation long before this era.

Whilst the Loe Bar has often in the past been referred to as a 'textbook example' of the relatively rare case (in the U.K.) of a sand/shingle bar entirely blocking a lake from the sea (e.g. Wooldridge and Morgan, 1937; Barnes, 1977), its origins and creation have never really been adequately explained (Steers, 1981). The geological evidence points towards a formation of the Loe Bar approximately 3000-4000 BC, which can be attributed to the sea level change. Bird and Schwartz (1985, p.364) define the Loe Bar as a beach made up of flint shingle 'washed up from the sea floor (there being no flint sources in the adjacent cliffs or hinterland areas)'. This presence of a high proportion of chalk flint in the beach make-up (86 per cent, according to the National Trust & Haynes,1972 – see figure 2.2a), gives significant credibility to formation theories based around the gradual movement onshore of seabed materials during the rising sea levels that have occurred throughout the Holocene geological epoch. May (2007, p.754) states the most likely origin of the aforementioned flint is the 'drowned terraces of the former river flowing down the English Channel'. This suggests a formation of the bar taking place thousands rather than hundreds of years ago (most likely dating from the time when sea levels around the county reached their present height), and thus significantly earlier than any settlement at Helston

Figure 2.2a: Composition of Loe Bar materials

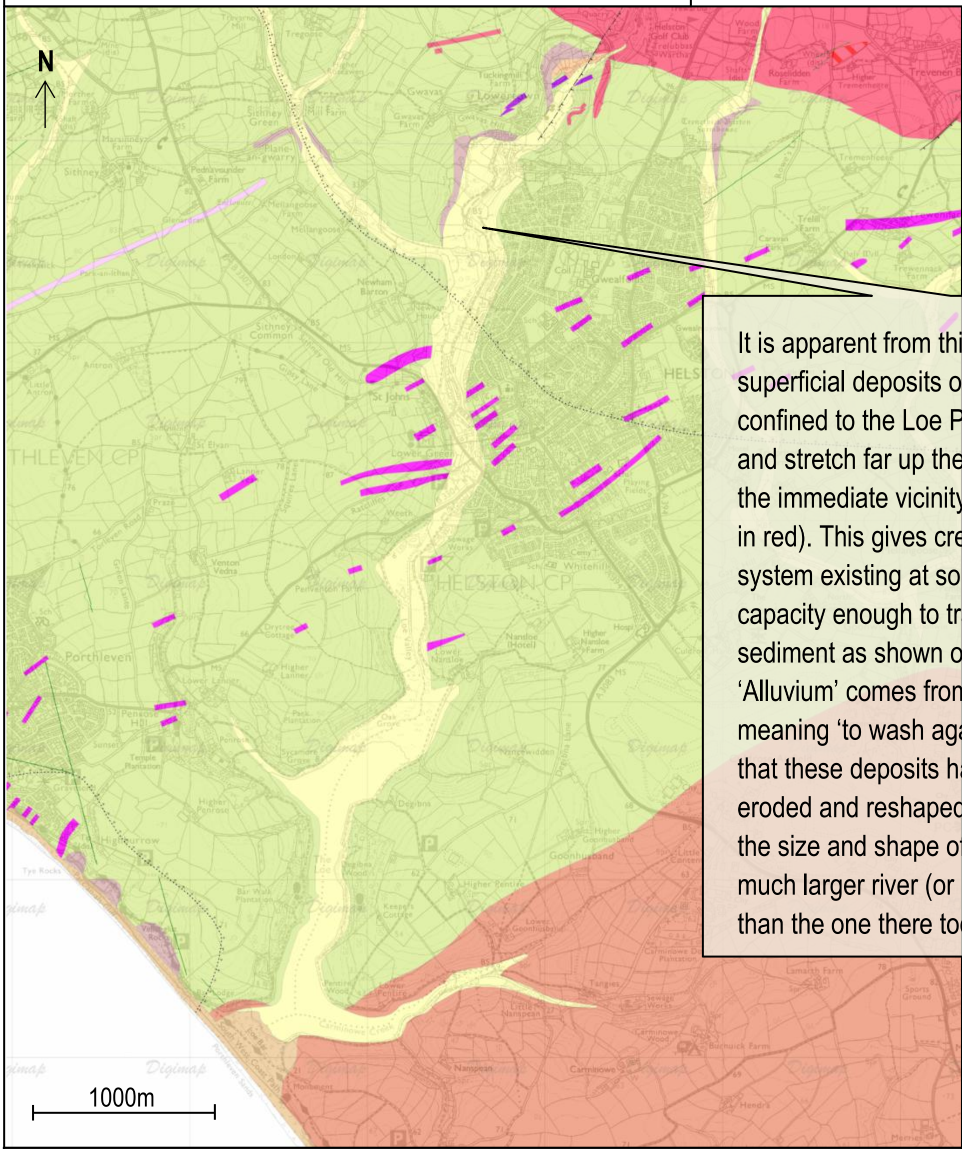
Chalk flint	86 %
Greensand chert	2 %
Quartz	9 %
Grit	2.5 %
Serpentine	0.5 %

Source: Haynes (1972)

being established. If this geological evidence is to be considered indisputable then the theories suggesting a formation during the 13th century must be flawed.

However, it is also distinctly possible that whilst the initial formation of the Loe Bar may have taken place some millennia ago, the Loe Bar may have undergone significant transformation during its extensive existence and the presence of the bar and a simultaneous tidal creek system should not be ruled out as impossible. Indeed, Martin Matthews, former curator of the Helston Folk Museum and President of the Helston Society believes this to have been the case. Mr Matthews, in a telephone interview with the author, states that he believes storms and freak weather occurrences may have breached the bar from time to time, and caused its shape and profile to change sporadically, which could have provided enough of an inlet for boats to gain access into the Cober valley, if only periodically. The historical evidence behind this concept will be discussed and analysed holistically within the next section of this chapter.

Figure 2.2b: Geological map of study area with annotation



It is apparent from this geological map that the superficial deposits of alluvium are not just confined to the Loe Pool and lower valley area, and stretch far up the valley of the Cober, beyond the immediate vicinity of the study area (outlined in red). This gives credit to the theory of a river system existing at some point with carrying capacity enough to transport and deposit the sediment as shown on the map. Indeed the word 'Alluvium' comes from the Latin *alluvius* – meaning 'to wash against'. It is distinctly likely that these deposits have, at some time, been eroded and reshaped by the flow of water, and the size and shape of the pattern indicates a much larger river (or perhaps estuarine system) than the one there today.

Key

Bedrock

- Carnmenellis Intrusion (CAIN)
- Mylor Slate Formation (MRSL)
- Unnamed Dyke, Permian (UDP)
- Unnamed Igneous Intrusion, Devonian (UIID)
- Unnamed Igneous Intrusion, Devonian To Carboniferous (UIIDC)

Superficial Deposits

- Alluvium (ALV)
- Head (HEAD)
- River Terrace Deposits (Undifferentiated) (RTDU)

Source: *Edina Digimap (OS, 2013)*

2.3. The breaking of the Loe Bar – The Bar as an intermittent feature

The 18th century Cornish geologist William Borlase described the bar in 1758, stating that from time to time the people of Helston were known to excavate a channel through the bar in order to reduce the risk of flooding from the lake (Borlase, 1758, pp.51). It is also certain that the breeching of the Loe Bar would have occurred naturally from time to time, although this has not been recorded since the 1830s, with the last known artificial breaching taking place during the winter of 1867-1868 (JNCC, 2007). There is evidence enough to suggest that centuries prior to this the Loe Bar may have, from time to time, been broken naturally and more frequently, thus allowing seagoing ships an access that would usually be otherwise impossible. Indeed, the Bar itself was described by the 16th century English poet, antiquary and 'father of English local history' John Leland, so long ago as the reign of Henry VIII, as having a tendency to be regularly breached by the River Cober. Leland goes on to state 'if this Bar might always be kept open, it would form a goodly haven up to Helston'. Furthermore, Hitchins (1824) states that 'nothing however, but the earth and sand, and other loose materials which now choke the vale, prevents it from becoming a spacious harbour that would rival many of high repute'. This statement gives some credibility to the suggestion that it is exclusively the presence of the bar that denies a tidal estuary from forming up to Helston, and that the deposition of sediment over time has blocked the creek. Hitchins statement infact forms the crux of this dissertation study, since this is the hypothesis that the site survey will test. The 'Geography and geology', Magna Britannia: volume 3: 'Cornwall', published in 1814, states that whilst in the summer the Pool has dimensions of '*about two miles long, and a furlong wide . . . in the winter the whole valley is frequently overspread with water, from the town of Helston to the sea'*. This again, suggests the possibility of a more sporadic presence of the bar as a whole feature, a concept supported by the documentations of Leland, who wrote in the reign of King Henry VIII:

'Lo Poole is a 2.Miles in length, and betwixt it and the Mayn Se is but a Barre of Sand. And ons in 3. or 4. Yeres, what by the wait of the fresch Water and Rage of the Se, it brekith out, and then the fresch and salt Water metyng makith a wonderful Noise. But sone after the Mouth is barrid again with Sande.'

Here Leland's description suggests that the Bar was broken naturally from time to time, perhaps at a more frequent rate and more substantially during earlier eras. This theory is supported by Carew's declaration made in his 'Survey of Cornwall' in 1602 (2012, p.152) that the Bar was not a permanent barrier:

'The foreremembered bank (the Loe Bar) serveth as a bridge to deliver wayfarers with a compendious passage to the other side; howbeit, sometimes with more haste than good speed: for, now and then, it is so pressed on the inside, with the increasing rivers waight, and a portion of the utter sand, so wasted downe by the waves, that, at a sudden, out breakest the upper part of the poole and away goeth a great deal of the sand, water and fish.'

It is imperative to consider these statements not as a form of scientific evidence that was deliberately intended by the writers; however it is nonetheless feasible that these events of spontaneous breaking of the Loe Bar as mentioned in both accounts, were fewer in Carew's time than in Leland's – going by the language used (In Leland's time the Bar gave way once in '3 or 4 years' whereas in Carew's only 'now and then).

Daniel Defoe the renowned author and travel writer, writing in the early 18th century, seems to give the distinct impression that ships were able, and indeed did, trade up the River Cober and into Helston during this period of history;

'Quitting Falmouth Haven from Penryn West, we came to Helston, about seven miles, and stands upon the little River Cober, which, however, admits the sea so into its bosom as to make a tolerable good harbour for ships a little below the town. It is the fifth town allowed for the coining tin, and several of the ships called tin-ships are laden here'.

This extract taken from Defoe's 'From London to Land's End' detailed travelogue, written in 1722, suggests access in to the valley for sea faring ships. However, it is also distinctly probable that this statement is perhaps the origin and precursor to other documented sources suggesting the existence of a port within the vicinity of the town during its former years (Russell, 2002, p.16). Therefore it must be taken with some element of ambiguity.

However, as will be discussed below, Loe Pool is referred to in an early 14th century document, which implies the existence of Loe Bar in some form or other from at least this date, and thus barring the passage of ships up the valley of the River Cober. This evidence can be found in Spencer Toy's Vol.83 No.1 of 'The Geographical Journal: The Loe Bar near Helston, Cornwall' where the writer states that at 'an Eyre (circuit court in medieval England) held in Cornwall in 1302 it was stated that 'William of Trevelle held a Cornish acre of land at Degibna and Eglosderry', with the following extract taken from the Assize Roll (number 117).

'Per seriaunciam inveniendi vnum batellum et rethia ad piscandum in lacu de Hellestona'

Translated as *"by the serjeanty of supplying a boat and nets for fishing in the lake of Helston"*

(Toy, 1934, p.44)

It is possible to conclude from this (without interpreting the word 'lake' in its strictest sense), that in 1302 the Loe Pool was indeed inaccessible by sea, with the obvious explanation to this being the presence of the already formed bar. However, it is not unconceivable that the Loe Bar has changed in shape and size over time, which during earlier times could have allowed the occasional or sporadic access for vessels as a result of the aforementioned natural breakages that occurred. Indeed, according to Goudie and Gardner (1985, p.177) the bar has moved inland since the mid-19th century and may have increased in height considerably. This point is confirmed when analysing historical mapping of the site and comparing areas of the exact same section of the bar from 1870 to those of 1970 (see figures 2.3a and 2.3b)

Figure 2.3a: 1870 historical map of the Loe Bar

Source: *Digimap EDINA Historical Roam*

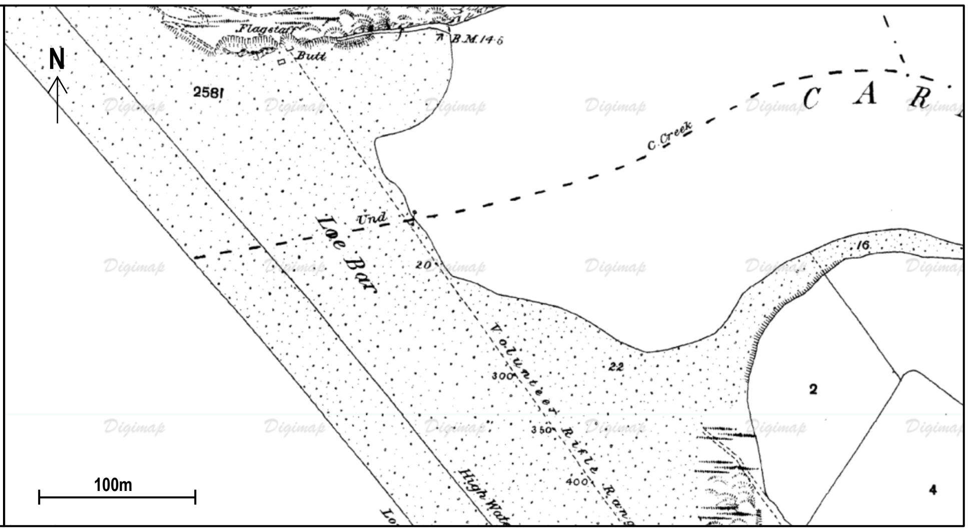
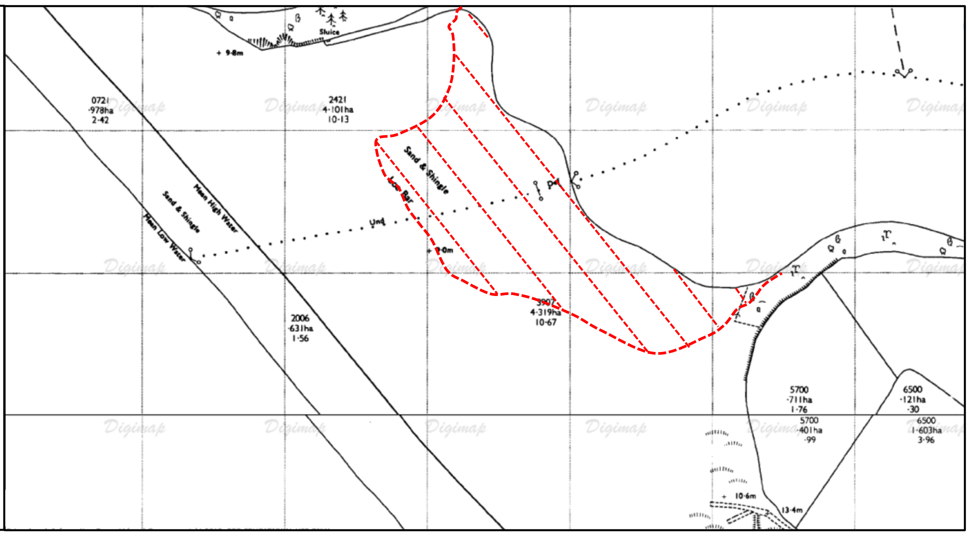


Figure 2.3b: 1970 map showing the same area with red shading overlay illustrating the area of sand and shingle added over the course of 100 years.

Source: *Digimap EDINA Historical Roam*



With this in mind, it is not an implausible assumption to make that the Loe Bar might have grown substantially in size since the time period during which the tidal creek/port access is associated. Actually, it may be anticipated that the whole of the valley has undergone some significant topographical change over the centuries, and indeed it is extremely likely that the valley has undergone its most dramatic transformation since the area was used as a waste disposal mechanism for mines further upstream. This industrial activity within the river catchment area would have had significant impacts on the sedimentation rates, and could account for significant changes in the topography of the river valley over time.

2.4. Sedimentation of the Cober

Toy (1936, p.383) states that 'in addition to the alluvium usually brought down by rivers, the Cober must have carried enormous quantities of silt into the valley from the tin works'. This accumulation of alluvial stratum through mining waste takes place at a much faster rate than any other normal kind of river system sediment accumulation brought about by the natural processes of denudation. This therefore makes comparisons to the carrying capacity of other natural river systems difficult (for purposes of gaining an understanding of the time periods involved for such a sediment accumulation). It is fair to assume however, that mining has hugely increased the rate of sedimentation within the Cober Valley to such an extent that it could have drastically transformed the valley over a relatively short period of time. Toy (1936, p.382) quotes 'the alluvial strata are very pronounced in the lower part of the Cober valley' a statement confirmed by the LIDAR remote sensing, and one that will be tested with more detailed surveying of this specific area. It is not absurd to assume that this is a direct consequence of the extensive mining that has occurred within the catchment area over time. For example, in 1925 when the United Tin Mines located at Wendron were reopened, with a new shaft, (known as Jan Tar) sunk, the 5 years of operation (up until its closure in 1930) meant huge quantities of silt were discharged from it into the Cober river system, with Toy (1936, p.384) stating that 'the whole length of the lower valley was rapidly being filled'. This statement is confirmed when analysing historical mapping for the northernmost section of the Loe Pool, and observing the dramatic change over relatively short periods of time (see figures 2.4a and 2.4b). Binns (1955, p.197) goes further and states that 'the silting up of rivers certainly had a decisive effect on the careers of many towns. A good example is Helston which ceased to be a port owing to the formation of Looe Bar'. Indeed, more than thirty mines have been documented within the Cober catchment since 1700, with the main intense tin mining periods being between 1845-1889 and 1908-1938 (Archer, 2012, p.15).

Figure 2.4a: 1870 map showing the northernmost section of the Loe Pool

Source: *Digimap EDINA Historical Roam*

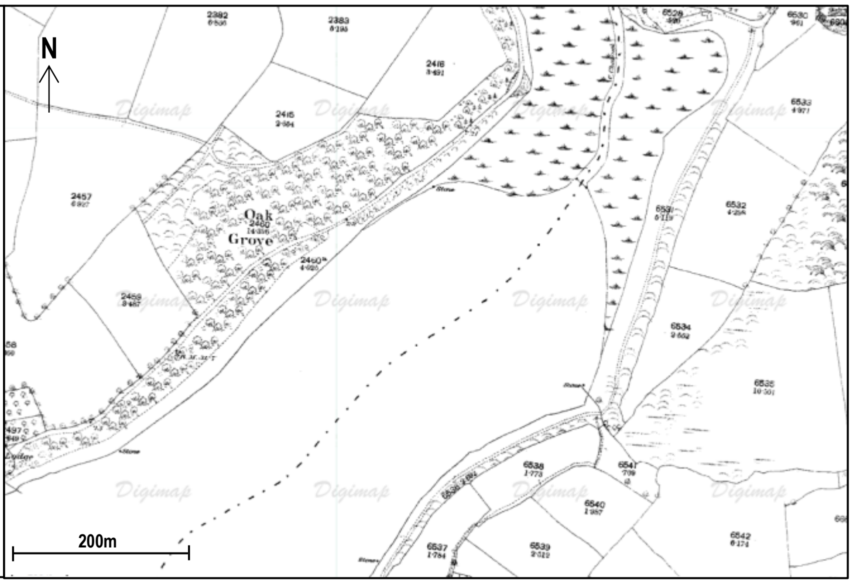
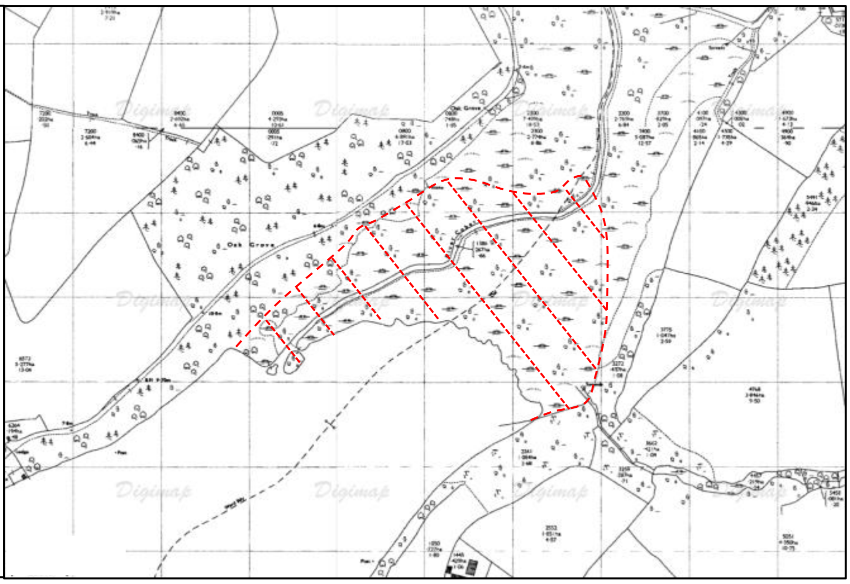


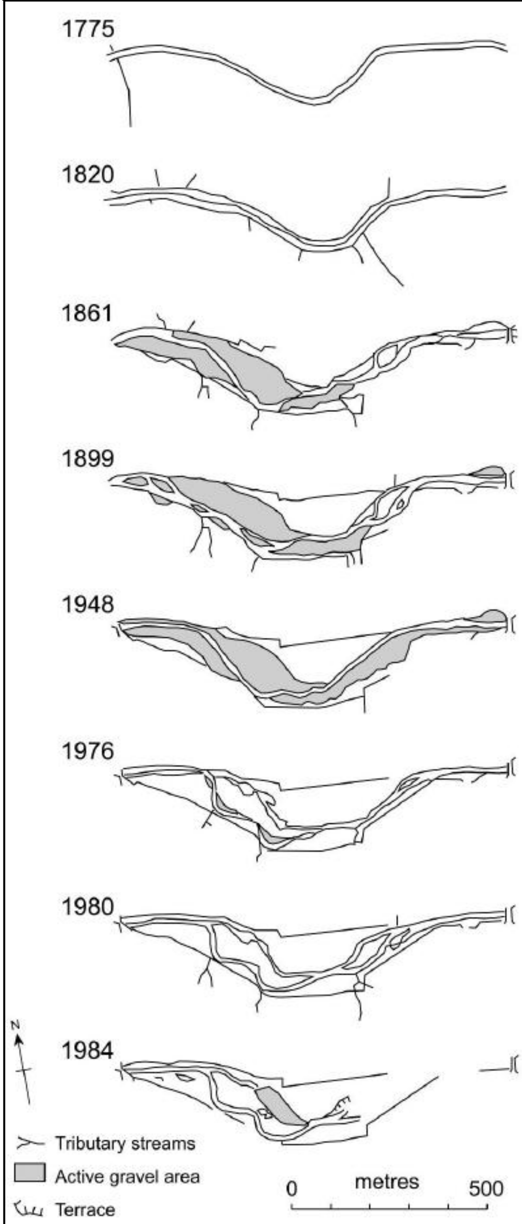
Figure 2.4b: 1970 map showing the same area with red shading overlay illustrating the area of sand and shingle added over the course of 100 years.

Source: *Digimap EDINA Historical Roam*



Since the usual rates of sedimentation do not apply to such a catchment area so heavily influenced by artificial undertakings, the alluvial stratum that has accumulated within the valley would have done so at a significantly speedier rate than usual. Consequently it is extremely likely the floor of the Cober valley would have been considerably lower than it is today only a few centuries ago as a result of such mining within the catchment, a statement that Professor Chris Caseldine (Professor of Quaternary Environmental Change at The University of Exeter) confirms wholly. As mentioned, it is difficult to generate an understanding of how quickly the valley of the Cober might have changed topographically over time by observing the carrying capacity and sedimentation rate of other river systems, since the historical mining that has taken place within its catchment, and thus affected it, is so unique. However, it is possible to observe other river systems that have been influenced significantly by past mining, and thus allow a generalised understanding of the effect mining can have on sedimentation rates and build-up of alluvial strata within river valleys. Figure 2.4c shows the active transformation of the river channel on the River Nent in North East England as a result of the deposition of fine-grained mining wastes. According to Whitley (1881) the River Kennal in Cornwall experienced rapid siltation with sediment accretion rates within the Restronguet Creek area reaching up to 8cm per year. Stapleton and Pethick (1996) estimate an average siltation rate for this area of 5cm per year for the period 1500-1995.

Figure 2.4c: Channel changes between 1775 and 1984 on the River Nent



Source: *Environment Agency – Science Report: SC030136/SR4, p.9*

These testimonies support the feasibility and prospect of this supposed rapid build-up of alluvium within the valley of the Cober over the course of hundreds, rather than thousands of years as a result of mining. They could also help explain why sections of the valley are raised and help in gaining an understanding of whether these raised areas could have caused the demise of the supposed tidal creek.

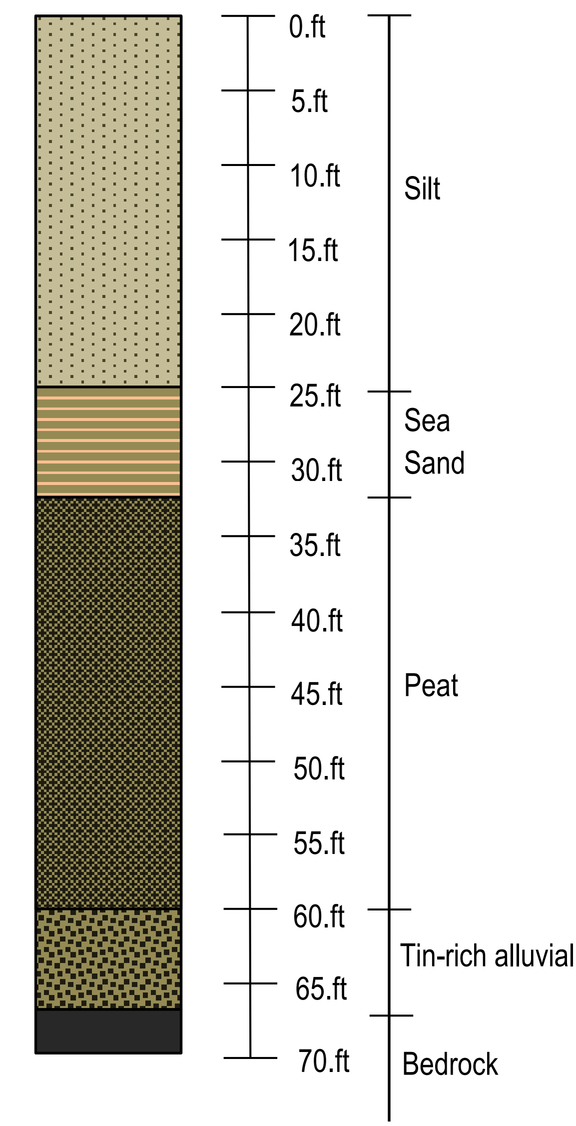
Propositions that Helston once had its own port within a tidal creek system, with the accumulation of sediment bringing to an end, include that of Charles Woolf who suggests that the location of Helstons church offers clues. Woolf claims that the church would have once been a church 'sited on the river estuaries which have been the main entrances to the county by sea for thousands of years' (Woolf, 1970, p93). He goes on to state that allowing for silting of estuaries many of these estuary churches appear inland today, but must have been estuary churches at one time, citing the church at Helston as a prime example. This recognition that extensive mining activity could have a substantially detrimental impact on the environment, (through extensive deposition of sediment) was recognised very early on. In 1356, Abraham le Tynnere was found guilty of, and charged with having caused 'damage to the prince and haven of Fowey' due to the siltation in the estuary that had occurred as a direct result of the tin streamworks he owned upstream of the Fal estuary (Gerrard, 2000)

Because the river received so much mine waste, both accidentally and deliberately, during this main period of operation of the mining industry, parts of the Loe have undoubtedly been silted up i.e.

the Loe Marsh area dominated by willow and alder. Conservational researchers (O'Sullivan et al., 1982) have studied sediment layers in the Loe Pool and calculated that rates of erosion within the catchment reached as much as 421 t km^2 during the final, most intensive period of mining. Furthermore, these authors also measured the then-current rates (in 1982) of erosion as approximately 12 t km^{2}- still a significant amount. This difference in sedimentation rates between these two dates goes some way to help understand how influential the mining activity within the catchment could have been in changing the landscape of the lower valley area. As such, the changing landscape could have had such a major impact on the topography of the terrain that any evidence of sea water being present within the area would be found underneath the surface within the content of the ground above bedrock. The next section of this chapter aims to draw upon information from a variety of sources in an attempt to gain a better understanding of this sub-surface composition within the area.

2.5. Ground content above bedrock

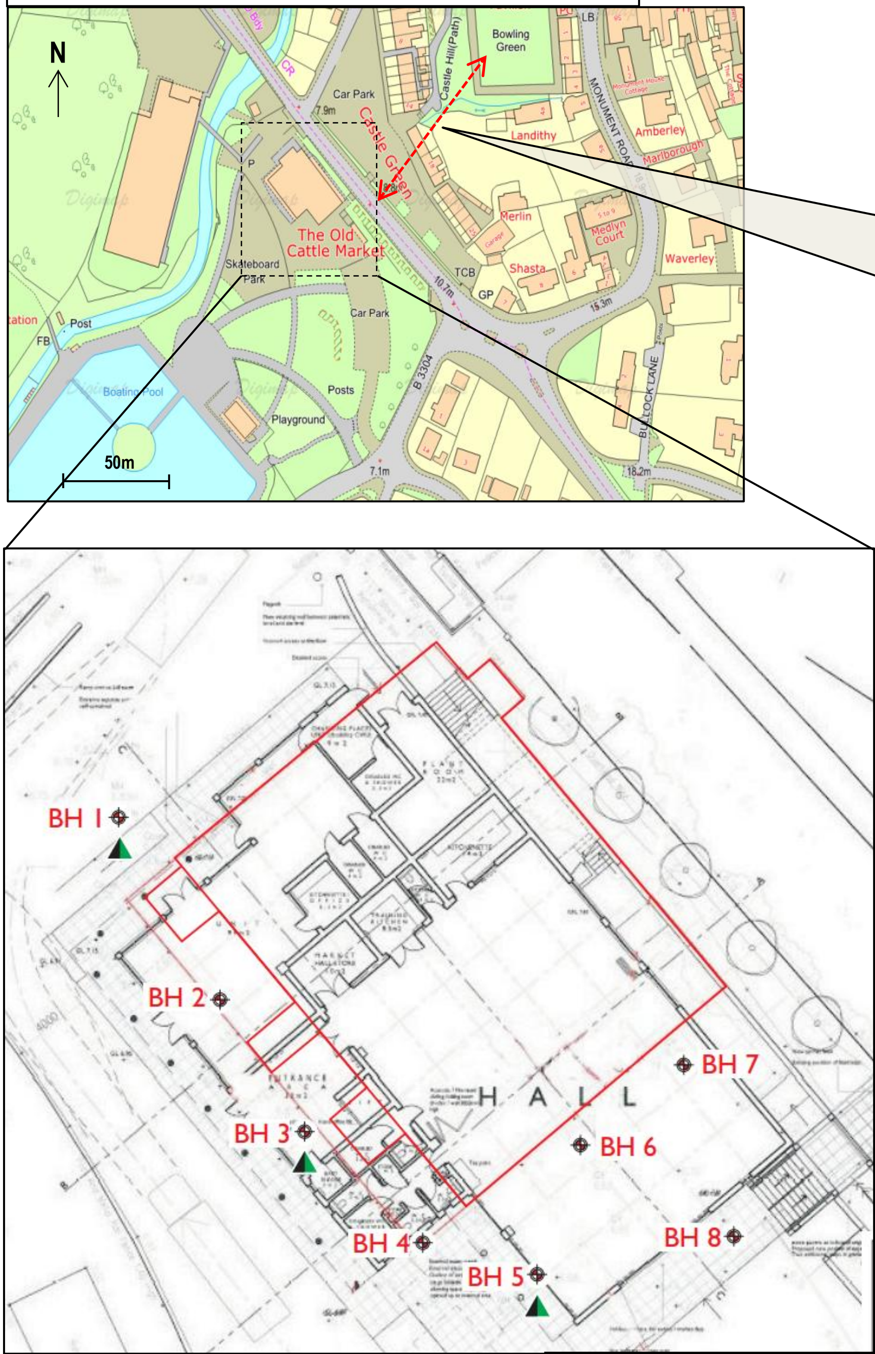
Figure 2.5a: Ground content within area between Helston and Loe Pool showing horizons



Source: *Adapted by the author from data obtained in Brooke, 1994, pp.70*

As already discussed in brief earlier on in this chapter, there is substantial evidence of alluvium stratum build-up within the valley over the centuries where mining was a significant industry within the river catchment. This section aims to examine the contents of the ground within the area of interest, in an attempt to understand how substantial this mining-silt sediment build-up is and what the implications on the topography could be – since this in turn would have implications on the feasibility of a ports existence. As previously noted, the bedrock makeup of the area is Lower Devonian slate in the Pool and Carnmenellis granite in the upper catchment. Gaining an understanding of the depth of this bedrock within the valley is critical in proving or disproving the theory at the heart of this investigation. Furthermore, for Helston to have ever been a port there must be evidence of sea water within ground content of the valley above the bedrock. Perhaps the biggest clues towards the presence of sea water at some point during the valleys history (as well as the depth of bedrock) can be found by analysing the results of previously undertaken site investigations. Brooke (1994, p.70) claims that in the summer of 1912, when boring operations were carried out between Helston and the Loe Pool by a 'well-known company', their drilling revealed evidence of seawater in the form of 7 feet of sea sand underneath 25 feet of mining silt, which according to the Mining Journals report in February 1913, had evidently come from the Wendron and neighbouring mines. This description has been adapted into a cross section revealing the horizons of each of these distinct zones (see figure 2.5a). This 7.620m of silt deposited as a result of mining within the catchment is a significant but nonetheless plausible amount, as discussed in the previous section of this chapter. The exact location of these boring operations is not divulged within the document, and as such it is impossible to cross reference with any of the primary data to be collected regarding topography. Rogers (1859) describes an even earlier boring made within the area in 1834, that extended down 22m (which equates to 9m below the low-water mark) without hitting the underlying bedrock, giving further credit to theories based around sediment build up.

Figure 2.5b: Location map of New Cattle Market with blueprint of structure and borehole locations



Source: *Moreton (2011)*

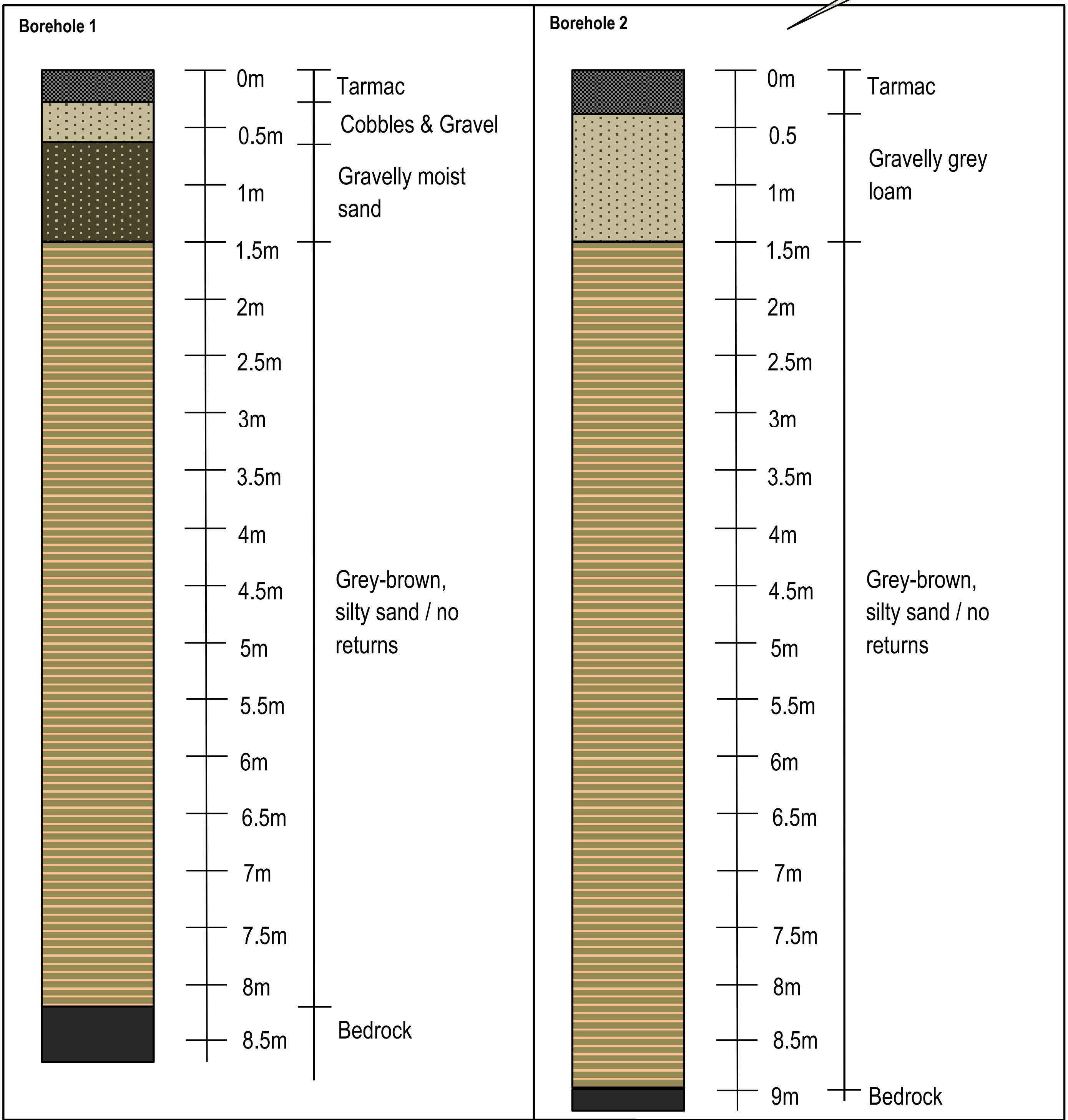
As previously mentioned, there is historical evidence to suggest that the tidal estuary purported to have been in existence would have reached as far in to Helston as the site of the present day Bowling Green (seen here in figure 4.1b – red arrow). The location of the site of the New Cattle Market is roughly 75 metres from this area, suggesting there should be evidence of seawater in the ground beneath the surface here.

Borehole data obtained as part of the Phase 2 intrusive site investigation of the Helston Farmers Market (New Cattle Market) carried out in February 2011 by '2M Research & Survey Ltd' (Moreton, 2011) gives an insight into the ground content at a location within close proximity to the supposed port area. According to English Heritage, The New Cattle Market building is located roughly 75 metres from the site of the old castle (which was situated adjacent to the estuary). As such it is useful to analyse the content beneath ground surface level here, to see whether there are signs of seawater (sands/shells etc.) having ever been present- as would be expected if the theory is to be deemed as having any consistency.

Figure 2.5c: Borehole data with attached horizons - taken from intrusive site investigation of Helston Cattle Market (2011)

Borehole Number	Ground Level (m)	Coordinates	Horizons
Borehole 1 (BH1)	6.79 AOD	E 165555.40 N 27335.23	0 - 0.3m Tarmac 0.3 - 0.7m Angular/sub angular cobbles and gravel 0.7 – 1.5m Gravelly moist sand 1.5 – 8.2m Grey-brown, silty sand / no returns **8.2m Rock** 8.2 - 9.5m Rock, borehole called off
Borehole 2 (BH2)	6.77 AOD	E 165556.53 N 27328.50	0 - 0.4m Tarmac 0.4 – 1.5m Gravelly grey loam 1.5m – 9.0m Grey-brown, silty sand / no returns **9.0m Rock** 9.0 – 10.5m Rock, borehole called off

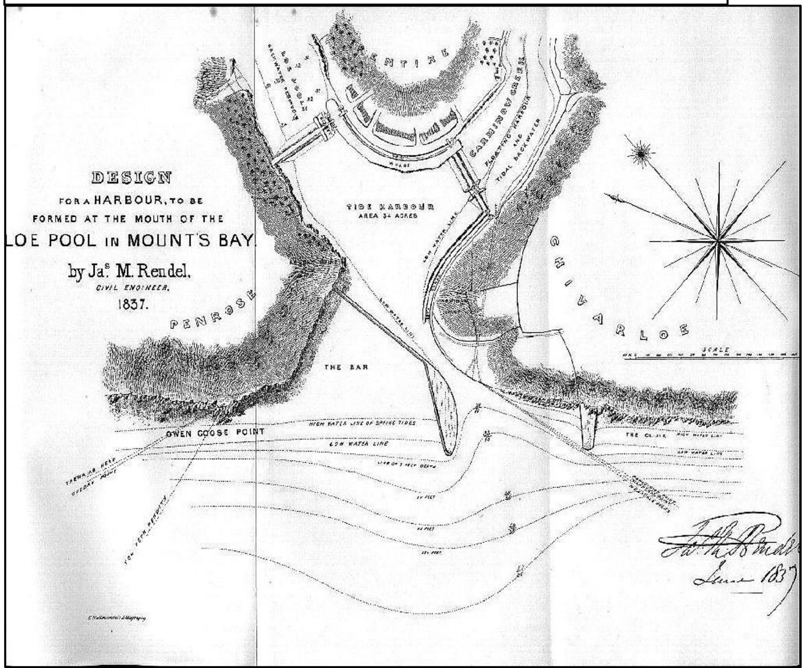
The horizons from Boreholes 1 and 2 have been illustrated below to show the different layers. It is noteworthy that both show evidence of vast amounts of silty sand.



Source: *Adapted by the author from data obtained from Moreton (2011)*

The two core samples show evidence of a vast amount of sand and silt beneath the first foot and a half, which could be interpreted loosely as evidence in favour of the port theory. For example, the depth of the bedrock certainly implies that the valley floor could have been much lower prior to the increased deposition of silt within the region. Furthermore, these core samples give some limited credibility to the theories around seawater being present in this location, since layers of unconsolidated clay as well as sand and silt would have been left behind as the sediment eventually silted the valley above the level of seawater.

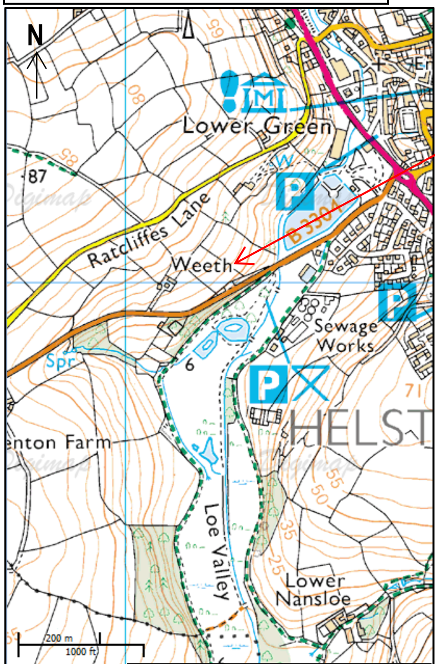
Figure 2.5d: J.M.Rendels 1837 Helston Harbour proposal plan



Source: *Toy, 1936. p382*

When analysing the content of the ground within this area, it is also pragmatic to consult the works of 19th century British civil engineer James Meadows Rendel who in 1837, to gain a better understanding of the practicability of constructing a harbour at the site of the Loe Bar/Pool (see figure 4.1D), conducted numerous intrusive site investigations.

Figure 2.5e: Location of Weeth



Source: *Digimap Edina*

These site investigations included, most notably for this project, borehole drillings at a number of locations within the immediate vicinity of the bar. The results of these borings can be interpreted and used to help determine the content of the ground in an attempt to better understand the likelihood of a ports existence. Rendel states of the first borehole drilling that '*The boring was carried down sixty-eight feet or to thirty feet under the low water level, without finding anything indicating the neighbourhood of rock'.* (taken from J.M.Rendels letter to the Rev.Canon Rogers of Penrose, 30th May 1837).

Another extract taken from Rendel's work gives further clues as to the content above bedrock within the area around Weeth – See figure 2.5e. '*In boring a hole in the Weeth Green, where several alternate layers of mud and sand occupied the first fifteen feet in depth, several rotten trees and pieces of wood were cut through. A layer of granite sand about eighteen inches in thickness covered the surface of the killas, which was twenty-eight feet below the level of the surface'. – Rendel, 1837*. The presence of 'rotten trees and pieces of wood' amongst the layers suggests a lower ground level in the past, and sand/granite sand could be interpreted as proof of historic sea water presence. The depth of underlying bedrock at Weeth according to Rendel (nearly 9m – and matching that of the intrusive investigation further up the valley at the New Cattle Market) goes some way in helping to entertain the theory that prior to significant sedimentation, the valley might have been significantly lower.

3. Methodology

This chapter will aim to give a descriptive outline of the techniques and analytical methods used during the data collection phase of this research project. The content will aim to be of sufficient explanation and depth so as to hypothetically allow an exact repeat of the task by another individual using the methods as outlined in this chapter. Alternative approaches, as well as the explanations behind opting for certain particular methods will be discussed. Furthermore, the chapter will aim to discuss in brief any problems encountered and the ways and means of dealing with them, as well as suggestions on how the approach could have been bettered.

3.1. Desk-based study

Since it was necessary to generate a comprehensive understanding of the fieldwork prior to data gathering commencing, the initial stages of the investigation were based around an extensive phase of information gathering. It was necessary to contact the National Trust at the Penrose estate and inform them of the nature of the project and gain their permission to undertake fieldwork. The secondary evidence, much of which already discussed in the previous chapter was drawn from sources researched during this preliminary assessment phase, for example the content obtained from the Helston Folk Museum and New Cattle Market borehole drilling data. The health and safety considerations, which will be discussed in further detail later on in this chapter, were analysed during this preliminary stage, so to ensure a safe and responsible undertaking of fieldwork and data collection.

3.2. Fieldwork - The open traverse: High water mark at Loe Bar – the New Cattle Market Helston

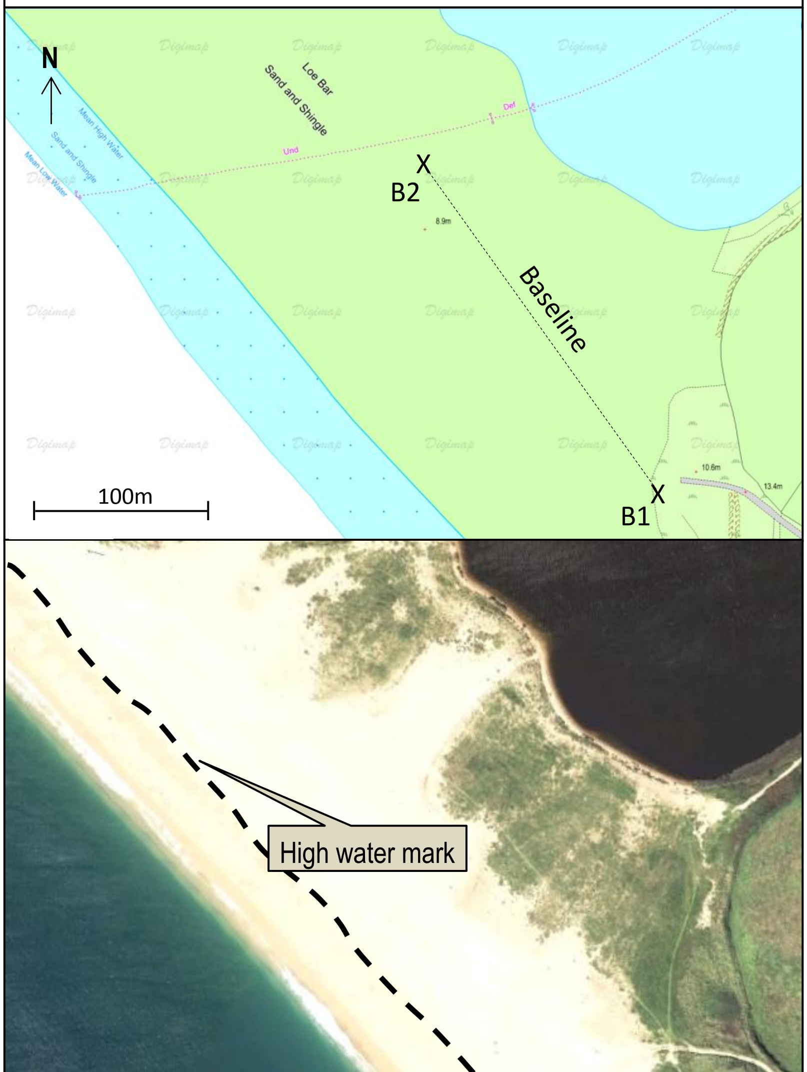
In an attempt to minimise any unwanted anthropogenic hazards The National Trust (Penrose Office) were contacted prior to commencement, with details of the project attached. Permission was granted shortly after for fieldwork to be undertaken within the area. Due consideration was given to ensure that the activities whilst undertaking fieldwork would not affect or encumber the rangers or any members of the public. For example, non-permanent marker pens were used in unobvious locations when marking control points to minimise aesthetic impact. Furthermore full and extensive risk assessment was carried out (discussed in more depth further on in this chapter) prior to fieldwork commencing, with protective PPE and appropriate clothing/footwear worn whilst in the field. Fieldwork was carried out intermittently over the course of 6 weeks starting on 10th July. Weather conditions ranged from sunny/overcast/light rain with temperatures ranging from roughly 17/18 – 25/26°c over the course of the 5 weeks. The weather did not have any significant/notable influence or impact on the methodology adopted. To record the location of the control stations for future reference when returning to site after time away, a Garmin Colorado Series 300 handheld GPS unit was used (see figure 3.2a). Whilst the unit has an error ellipsoid of roughly +/- 3m, it offered a useful way of navigating around the site to locate established control points when returning to them after time. The unit was used exclusively as a means of navigation around the site and, due to its associated error, was not used for data collection purposes.

Figure 3.2a: Photograph of handheld GPS

Source: *Author*

In order to obtain an understanding of the difference in elevation at specific points within the valley of the River Cober (relative to the height of the high water mark on the Loe Bar) it was deemed necessary to undertake an open traverse stretching from the high water mark on the Loe Bar to the supposed site of the port in Helston, (around Coronation Lake and the New Cattle Market). The traverse was undertaken as a means of obtaining accurate spot height and coordinate data, so to help gain an understanding of the topography of the

Figure 3.2b: Location map of baseline with satellite imagery overlay showing the position of the high water mark relative to the Loe Bar

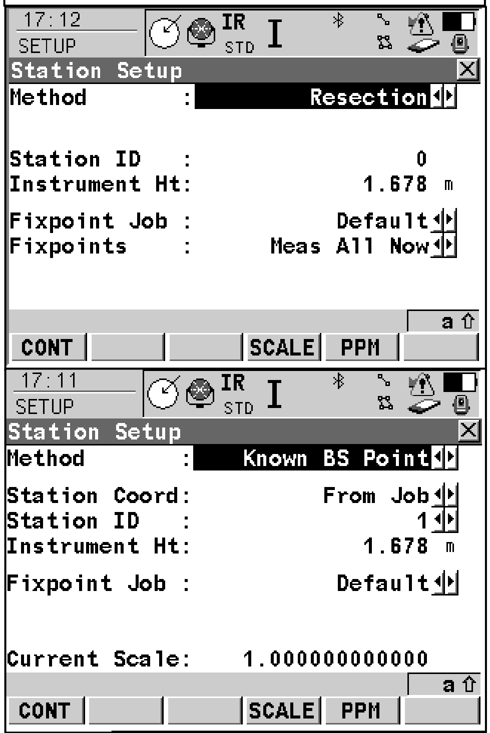


Source: *Edina Digimap (OS, 2013)*

valley. As well as this, the traverse was undertaken to help establish an idea of the feasibility of whether or not the valley, in its current state, could be used as a tidal route for ships in the hypothetical scenario of the Loe Bar not being present. Furthermore, the traverse was chosen as a means of scrutinising the LiDAR remote sensing data already obtained, so to confirm (or otherwise) it's accuracy and thus reliability. All coordinate data was recorded relative to the British National Grid False Origin.

It was deemed necessary to begin the traverse at the high water mark on the Loe Bar (so as every other point taken during the traverse would be referenced to this initial set of elevations), and since there are no known reference points on the Loe Bar, a baseline was established using GPS. Note – The location for the baseline was dictated hugely by the availability of satellite coverage, and thus the baseline was established towards the south eastern section of the bar, away from the steep ridges that overlook the bar at the north western edge (see figure 3.2b). This way, maximum GPS coverage was obtained giving a guarantee of increased accuracy. The instrument used to obtain the baseline was a Leica Geosystems 1200 series GPS base setup and left to receive observations for 90 minutes at each point either end of the baseline. The decision not to use RINEX corrections on the data was made, since the desired accuracy for the fairly sizeable survey at hand (a 3 mile open traverse with GPS data accurate to roughly 250mm without RINEX) was achieved irrespective by allowing a substantial number of observations.

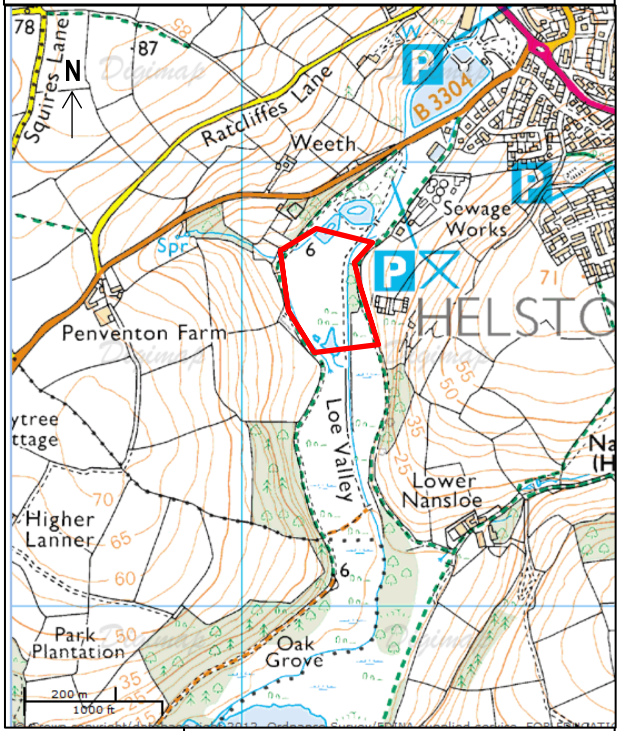
Figure 3.2c: Leica Geosystems 1200 series TPS station showing setup screen for 'Resection' & 'Known back sight point' modes



Source: *TPS 1200 Simulation*

Once the baseline was in place, the Loe Bar was surveyed extensively so as to generate a rough understanding of its topography and to be able to create a profile later on indicating the relative average height of the high water mark. This was done using a Leica 360° prism mounted on a detailing pole at 1750mm, which was placed at rough intervals along the bar, to allow for a good spread of data. Once this had been accomplished, the traverse began by orientating a Leica Geosystems 1200 series TPS (using the already established baseline), atop the North Westerly ridge overlooking the bar to create Control Point 1. The location of Control Point 1 was established through method of resection (see figure 3.2c). The traverse then followed the footpath around the western edge of the Loe Pool by making foresights to establish the next instrument set-up point in sequence and using subsequent known back sights (from the newly established point to the previous point) as a means of orientating the equipment (see figure 3.2.1b). At each setup, the instrument height was recorded with a tape measure and confirmed by a second individual to minimise the risk of any error. This process was repeated along the traverse of the footpath until the main section of the survey was reached. Control points were established along the way at intervals and marked clearly on the ground (large immoveable rocks or boulders) with marker pen. The traverse aimed to focus detailing primarily on the area of the site within the lower section of the Cober/Loe valley (see figure 3.2d), since this was the area identified by LiDAR as being most critical and significant (due to its elevation) when looking at the valley's viability as a tidal creek. During the course of the data collection the principle of working from the whole to the part was used, by establishing and marking the control points along the traverse before going back to carry out detailing where possible using the relevant established control points and branching out. Furthermore, the range of foresights were aimed to be roughly similar to the distance of the instrument from the back sight point - so that refraction and curvature effects are cancelled out. By following these principles his any slight error was localised for each section of the detailing and did not intensify over the whole survey. Although this was deemed an open traverse (as opposed to a closed traverse, which would allow for easy miss closure calculations/corrections), the same GNSS equipment used to establish the baseline was centred and levelled over the final control point adjacent to the New Cattle Market. This allowed the overall accuracy of the 3 mile traverse to be calculated – though exact correlation would be impossible because of the limited accuracy of the GPS equipment. Data was then collated and processed using Leica Geosytems Geo Office software and AutoCAD Civil 3D 2012. LiDAR elevation data was sourced directly from Landmap-Spatial Discovery, a free of charge service provided to the UK academic community via Open Geospatial Consortium standards for maximum interoperability.

Figure 3.2d: Location map of lower Cober/Loe valley and the area to be surveyed in particular detail



Source: *Edina Digimap (OS, 2013)*

3.2.1. Accuracy of the Traverse

Coordinates of final Control Point of traverse within amenity area adjacent to Coronation Lake and the New Cattle Market – Independently checked against GPS coordinates given at same location (after compensating for instrument setup height).

Total Station (Traverse)	GPS (Independent check)	Difference
165539.132mE	165538.659mE	0.473m
27268.197mN	27268.595mN	0.398m
6.869mAOD	6.736mAOD	0.133m

Since the open traverse coordinates were based upon the initial baseline established on Loe Bar with GPS, they will automatically carry some associated slight error (because of the small error ellipsoid associated with the GPS), and as such the accuracy of the traverse is compromised to an extent. The precision of the GPS used in the independent check is therefore not of sufficient quality to be deemed first order accuracy. Indeed the sole purpose of this final check on the last control point was to establish that the coordinates obtained were of an acceptable accuracy and not grossly inconsistent. Furthermore, the length of the open traverse would induce some sources of slight error which would increase and exacerbate over the length of the survey. As already mentioned however, this associated error was deemed acceptable since it would not affect the reliability of the data in determining the accuracy of the remote sensing data, and correlations between the two sets would still be possible.

3.3. Problems encountered

During the initial detailing phase on the Loe Bar, the high water mark was followed only roughly using the distribution of flotsam and debris as an indication of where the sea water reached. This basic method employed, means the precision and accuracy of the high water mark will be backed up with independent secondary research. This will be considered when looking at the hypothetical scenario of the Loe Bar being removed, as will be done in later chapters. The sporadic large areas of dense foliage and woodland found within the lower river catchment made the detailing component of the fieldwork difficult, since access into these areas (to enable as wider and well-spaced spread of 'valley height' data) was impossible with the equipment. This resulted in 'gaps' of information where certain areas were inaccessible, which effects the generalisation of height within the valley. Figure 3.3a shows an example of where a sighting could be made through a gap in the vegetation, however in many cases the foliage was so condensed and concentrated that detailing was impossible.

Figure 3.3a: Site photograph illustrating denseness of vegetation and the difficulty it posed for surveying

(Location: 165231.001mE 26671.3597mN)

Source: *Author*

During the traverse from the Loe Bar it was not uncommon for the instruments to lose their level over their already coordinated point, thus losing correct orientation. Whilst every attempt was made to arrange the instrument and tripod over firm ground, ensuring that the tripod leg screws were fastened tightly to guarantee minimal movement, as well as ensuring only slight and necessary contact with the machine was made, there were occasions when the legs would move slightly and the level would be lost midway through a sighting. This resulted in having to re-level and centre above the most previously used coordinated control points marked on the ground. Whilst it is impossible to fully alleviate the source of these problems, the issue was mitigated effectively by establishing frequent control points along the route of the traverse so to ensure a minimum amount of backtracking to re-establish the instruments correct orientation.

The sheer scale of the data collection phase, over the large area proved a problem in that the initial preliminary timescale that was planned and predicted was grossly underestimated. The time to undertake the fieldwork (compared to initial estimations and plans) was greater by a factor of nearly 2. This led to a decrease in time available for the secondary data collection as well as the write-up phase of the project. This could have been mitigated with a more comprehensive preliminary on site exploration or reconnaissance, as opposed to relying primarily on initial desk based research for the initial phase of my fieldwork.

3.4. Alternative methodologies

Additional methodologies involving different approaches towards the data collection were considered before opting for this particular method of traverse. For example it was contemplated to assume the water level of the Loe Pool was a constant and to traverse to the watermark at the southern edge of the pool once the bar had been detailed, then pick up the traverse again at the same elevation at the northern edge of the pool, thus removing a lengthy section of the traverse and keeping the height the same. Whilst this would provide a quick way of calculating the elevation of points, the option was deemed unviable since it would prove too difficult to re-orientate the instrument in its new position, as there would be no option of resection or known-back sight to the previously plotted known points (too far). It was also considered to begin in the traverse in Helston, at the site of the supposed port, and work in a southern direction towards the Loe Bar and the high water mark. However, this was deemed unviable since the Loe Bar represented a far better option for setting up the initial baseline with good open space for GNSS coverage.

Another methodology deemed unviable was the use of the GPS TOPCON or other GNSS base and rover technologies within the lower sections of the valley. This option was deemed impractical because of the poor coverage the area offers and the high level of vegetation shelter. Indeed, the primary aim of the survey within this area was to give credibility to the remote sensing data because of stipulations around vegetation coverage, therefore a method of data collection that was not impacted by this needed to be chosen.

3.5. Health and safety considerations

To minimise risk and to ensure safe practice during data collection and fieldwork, a full and comprehensive risk assessment was undertaken prior to the undertaking of research on site. The 5 x 5 risk matrix technique/tool was used to analyse a wide range of the foreseeable risks, plotting their likelihood vs. impact to gain a tangible value which helps to indicate suitable mitigation methods.

Figure 3.5a: 5x5 risk matrix for fieldwork to be undertaken

Likelihood	**Consequence/Severity**				
	Insignificant : 1	Minor : 2	Moderate : 3	Major : 4	Severe : 5
Almost Certain : 5	5	10	15	20	25
Likely : 4	4	8	12	16	20
Possible : 3	3	6	9	12	15
Unlikely : 2	2	4	6	8	10
Rare : 1	1	2	3	4	5

Likelihood of Occurrence	**Consequence/Severity of Impact**
1 : Rare – Rarely Occurs	1 : Insignificant – Has no noteworthy effect
2 : Unlikely -	2 : Minor – Has little effect
3 : Possible – Possible but uncommon	3 : Moderate – May pose a problem
4 : Likely – Commonly occurs	4 : Major – Will pose a problem
5 : Almost Certain – Occurs frequently	5 : Severe – Immediate action required

1: Risk Inherent to site – Roadside/Traffic					
Likelihood :	2	Consequence :	5	Overall :	10
Whilst the majority of the site is not adjacent to any major roads, the North Western edge of the Cober Valley meets the B3304 as it approaches Coronation Lake. Therefore, care and consideration will be given whilst undertaking fieldwork activities around this area of the site. Furthermore high visibility vests will be worn at all times on site, so to make public aware of presence in times of poor visibility.					

2: Risk Inherent to site – Cliffs/rock falls					
Likelihood :	1	Consequence :	5	Overall :	5
The North Western edge of Loe Bar meets the boundary of the Penrose estate at Owen Goose Point and Rogers Point. Whilst the cliffs here are of relatively shallow incline with large amounts of brush and minimal exposed rock, the risk these faces pose in terms of potential rock falls and falling from height will need to be militated against. Although this area will not be included in the survey, it is worth bearing in mind the risk it poses. Protective headwear as well as appropriate footwear will be worn in areas of significant risk.					

3: Risk Inherent to site – Sea/Seashore-dangerous waves, rip tides					
Likelihood :	2	Consequence :	5	Overall :	10
The waves and tides at Loe Bar are renowned for being extremely treacherous, having claimed several lives over the years. Whilst it will not be necessary to go directly to the seas edge at the bar, the fieldwork will be carried out in pairs to ensure maximum vigilance and attentiveness.					

4: Risk Inherent to site – Extreme weather occurrence					
Likelihood :	2	Consequence :	2	Overall :	4
Extreme weather such as heavy rain or strong winds might pose a minor threat in terms health and safety and practicability of data collection. Coupled with the risk of the sea, it becomes even more noteworthy. Appropriate clothing and footwear should go some way to mitigate against this risk, furthermore forecasts will be attentively monitored prior to the site visit.					

5: Risk Inherent to site – Anthropogenic hazards					
Likelihood :	2	Consequence :	5	Overall :	10
The majority of the area being surveyed is open to public access, however areas adjacent to and including the site are privately owned. i.e. the Penrose estate. Loe Pool is also a SSSI, and thus must be deemed a sensitive habitat. Whilst the work being undertaken is unlikely to cause suspicion or resentment of the public or the private land owners (in this case the National Trust), it is still pragmatic to take matters into consideration. Therefore, contact with the appropriate bodies will be made to ensure their familiarity with the project, and to ensure permission is granted to work on site.					

6: Risk Inherent to site – Bog/Swamp trip/fall hazards					
Likelihood :	3	Consequence :	4	Overall :	12
Large areas needing to be surveyed are wet boggy marshland areas. This may cause risk in terms of unstable ground whilst navigating around site. This risk is not unique to a health and safety risk to myself but also poses risk to the equipment. Because of this, the need to wear waterproof ankle supporting footwear as well as appropriate trousers is important.					

7: Risk Inherent in the work – Environmental Impact					
Likelihood :	1	Consequence :	4	Overall :	4
No significant impact on the environment is predicted as a result of this fieldwork. Control stations will be marked at certain points of the terrain in an inconspicuous manner, however all evidence of these will be removed after the fieldwork stage of the project is completed. Personal waste i.e. food wrappers etc will also be removed from site and disposed of appropriately. No disturbance of eco-systems is predicted.					

8: Risk Inherent in the work – Heavy Equipment – health risk					
Likelihood :	1	Consequence :	4	Overall :	4
Whilst much of the surveying equipment to be used does not weigh a significant amount, the tripods as well as the TPS equipment are near 10kg combined. This will be considered when arranging to carry them on site. Correct heavy lifting technique will be employed and no more than two tripods with one TPS box shall be carried at once.					

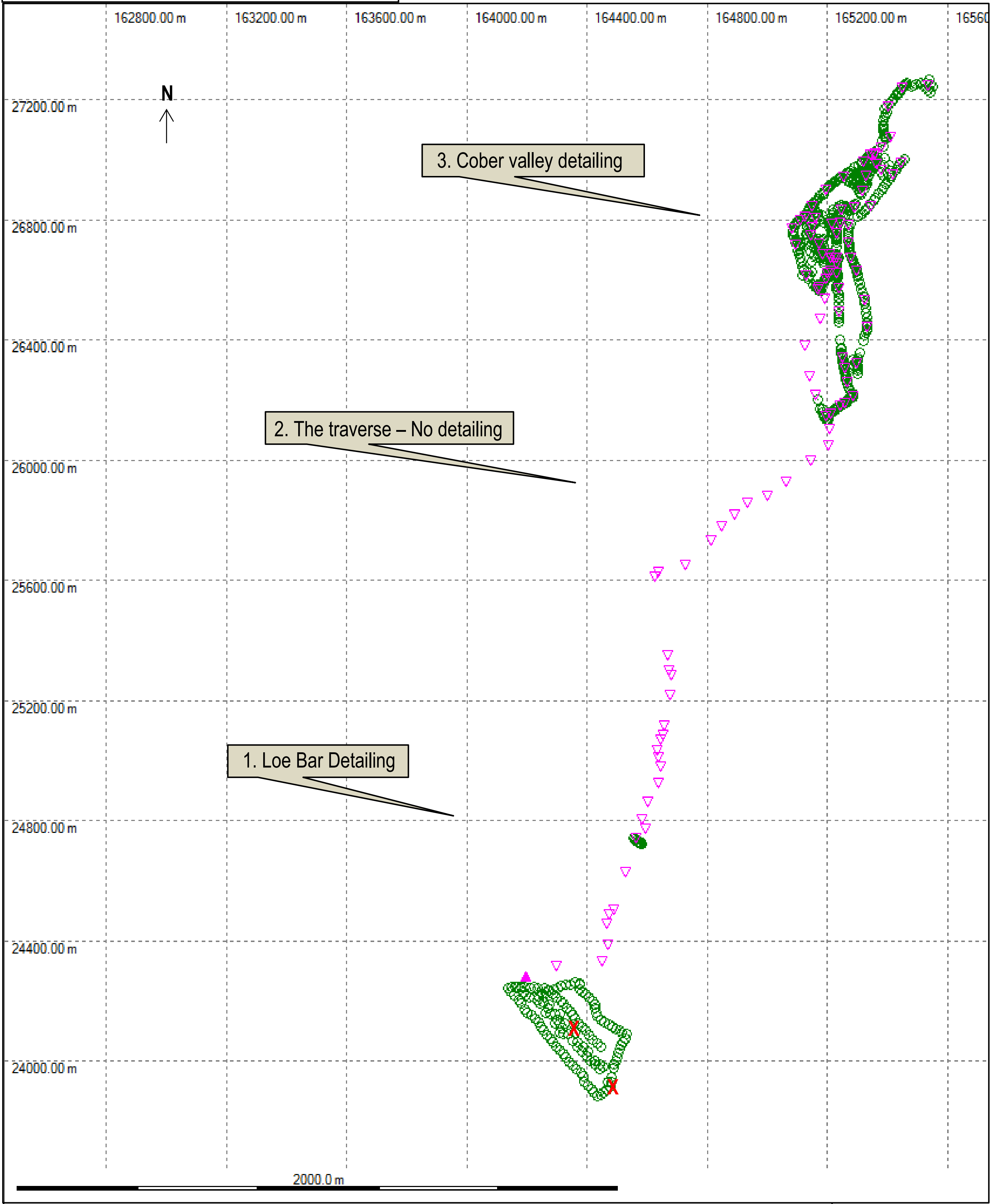
4. Results and discussion

The main intent of this investigation is based around the interpretation of primary data collected on site as well as secondary LiDAR remote sensing data, to help draw a conclusion as to whether Helston could have once had a port with sea access. This chapter aims to summarise the findings of the practical component by giving a descriptive analysis and comparison of the two datasets. This will be done by first presenting the key findings of the primary on-site fieldwork undertaken, then discussing and interpreting the meaning by bringing referring to elements of the secondary research. This presentation and discussion represents the heart of the technical report and offers the chance to obtain a holistic summary of the investigation. Results are displayed using screenshots captured from AutoCAD (Civil 3d 2012) and Leica Geo-Systems Geo Office as well as Global Mapper V14.

Figure 4a gives a useful holistic illustration of the entire site survey area together with all data collected on a geo-referenced grid. The figure shows each point (X, Y, Z) as was recorded during the primary data collection and is a good starting point when interpreting the results of the data collected. This overview of the survey site illustrates the full extent of the fieldwork, with each particular phase being broken down. It illustrates the Loe Bar in the South West area of the survey site, where the original baseline was established using GNSS equipment to gain an understanding of the elevations of the Bar and a point from which to begin the traverse. Since there was no detailing undertaken during the traverse it consists purely of instrument set up points. The Cober River valley area was detailed extensively (with over 800 spot heights recorded) and can be seen here. However, there are gaps in the data with some sections of the area too densely covered with foliage to use the optical equipment for detailing. These gaps can be seen as blank areas within the detailed 'Cober valley detailing survey section area. The site survey was concluded at the amenity area north of Coronation Lake and adjacent to the New Cattle Market building by using GNSS to check the coordinates as previously discussed.

Figure 4b shows the next stage of processing as the raw spot height data for each point is interpreted into a contour surface model using AutoCAD, to help understand the physical characteristics of the area. By taking this unedited raw spot height data for the fieldwork (as seen on the left in Leica Geo Office) from the lower valley area, it is possible to construct a surface layer model giving height contours using AutoCAD (see on the right). From this a good understanding of the topography of this section of the valley and pick out key features can be gained and subsequently compared with the LiDAR data. As mentioned previous, there are some sections of the area that were lacking in spot height data, as a result of the limitations caused by using the optical equipment within areas of dense vegetation and foliage. However, the section was covered in sufficient detail, as Figure 4b shows, so to generate a fairly accurate interpretation of the main physical characteristics. The next stage, having extracted the data is to make correlations between the primary data collected on site using the optical and GPS surveying equipment, and the LiDAR.

Figure 4a: Overview of survey / fieldwork data



Key

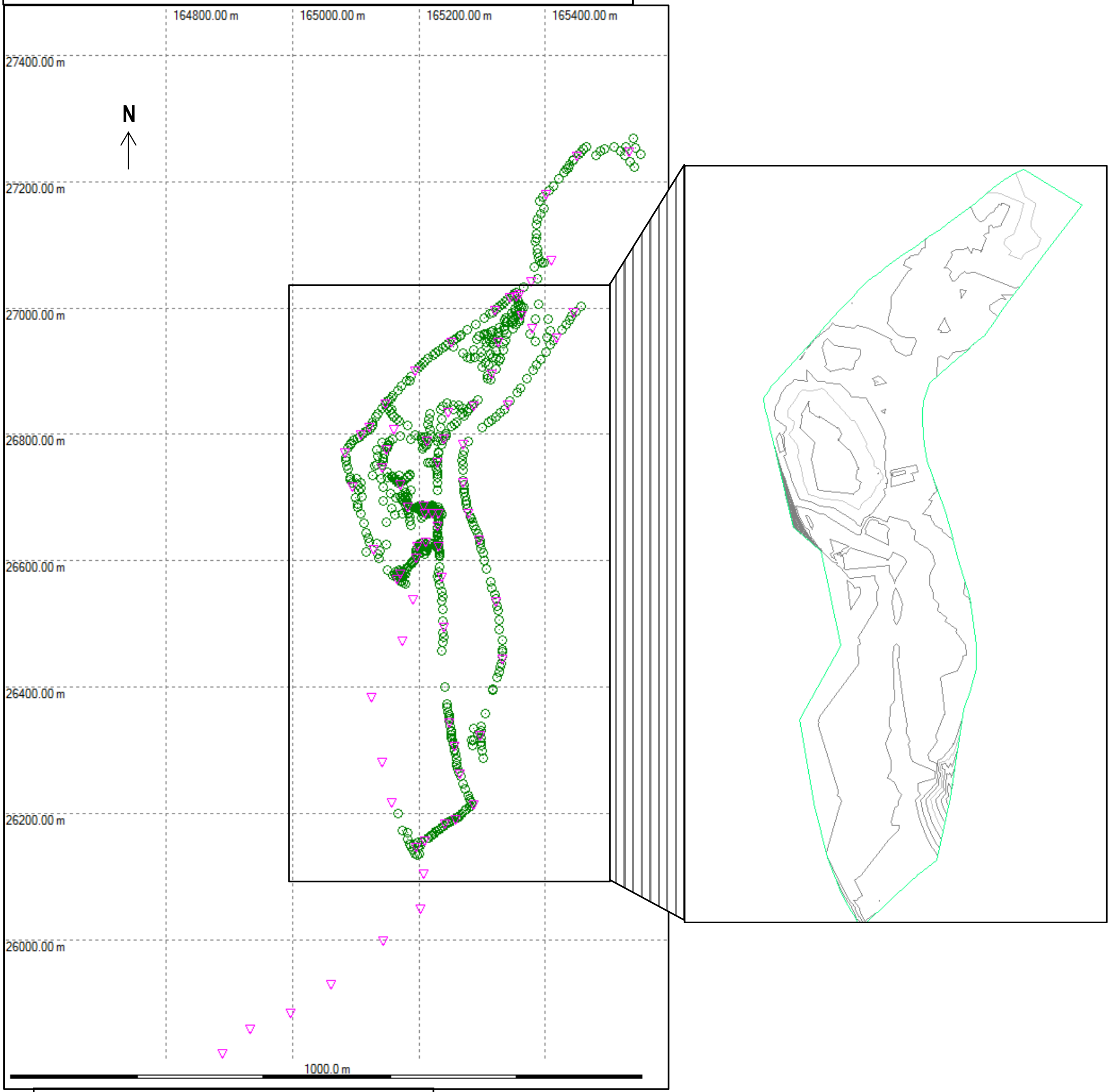
Source: *Data collected on site, processed in Leica Geosystems Geo OfficE*

▽ Instrument setup positions/ control points

○ Detailing elevation/spot height points

X GPS established baseline points

Figure 4b: Converting spot height data of detailed survey area into contour lines

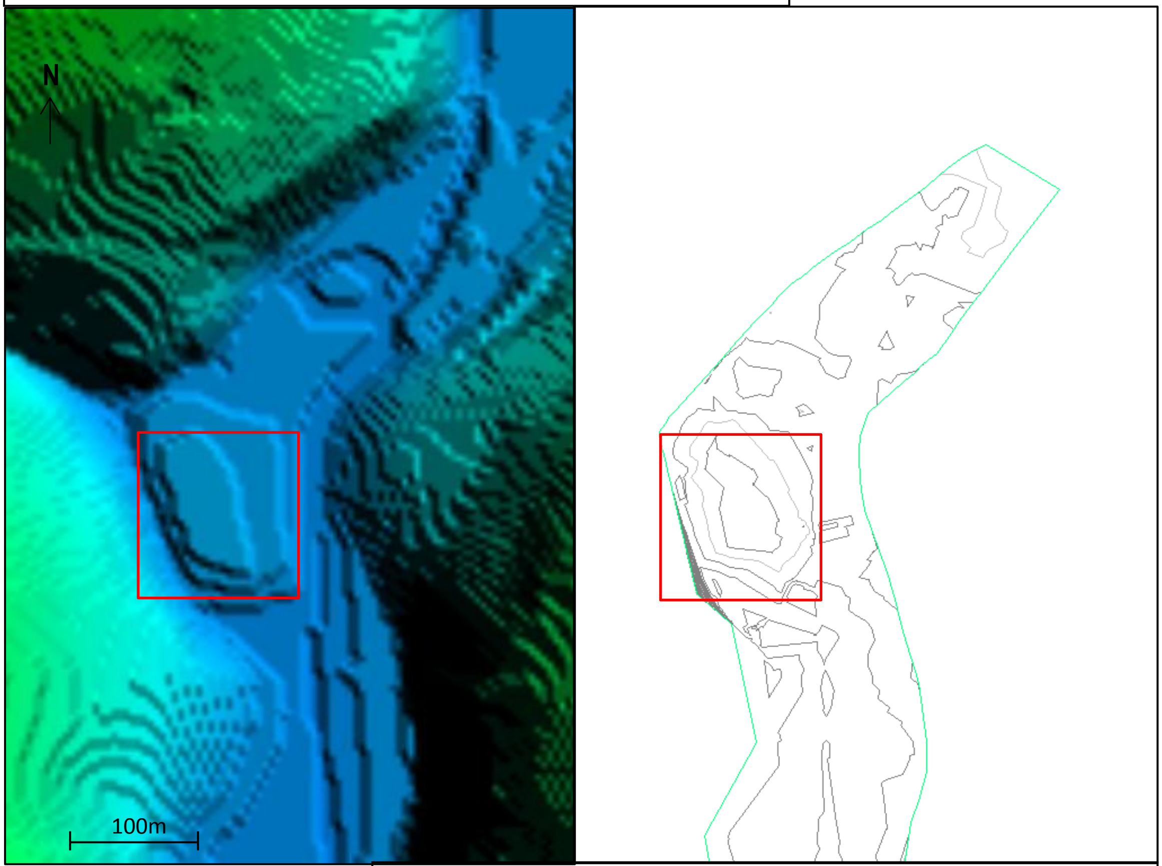


Source: *Primary data gathered on site – Processed in Leica Geosystems Geo Office (left) AutoCAD Civil 3d 2012 (right)*

4.1. Correlation between LIDAR and survey data collected on site

In order to scrutinise the reliability of the available LiDAR datasets obtained, correlations between the primary data collected on-site and the remote sensing data will be analysed and discussed in this section.

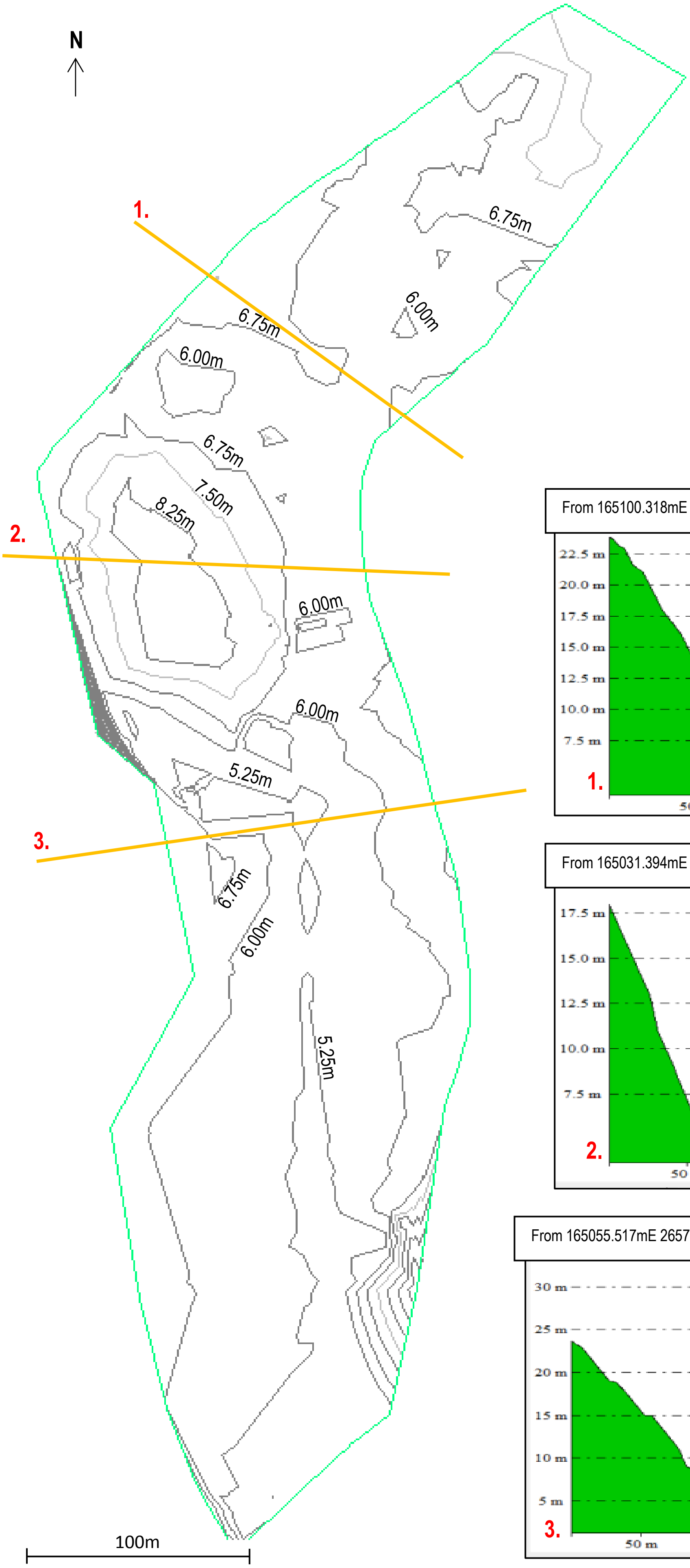
Figure 4.1a: Comparison of LiDAR elevation data (left) and primary data gathered on site and processed in AUTOCAD (right)

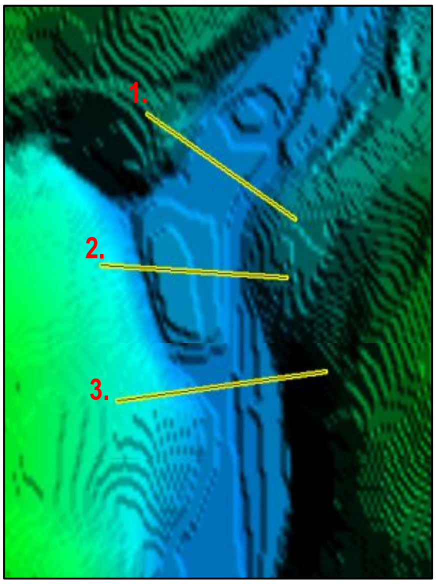


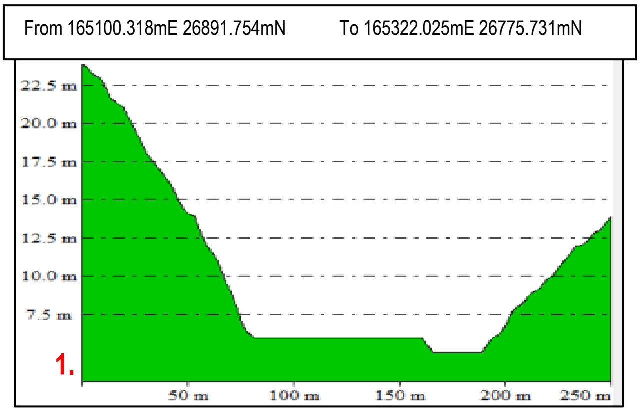
Source: Comparison of LiDAR elevation data (left) and primary data gathered on site and processed in AUTOCAD (right)

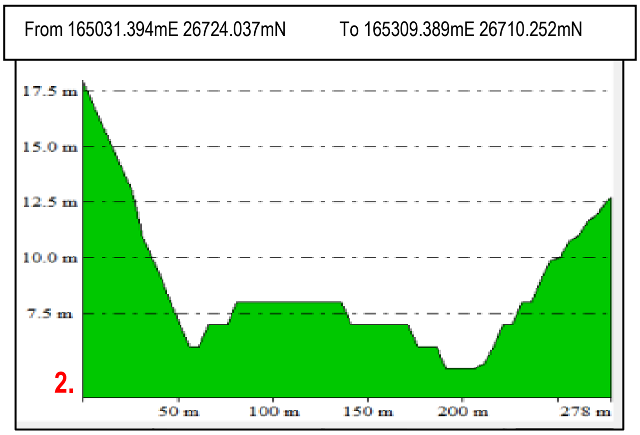
Figure 4.1a shows a close up the same section of elevated valley floor using both the LiDAR remote sensing data as well as the other independently sourced primary data gathered on site with the surveying instruments. Obvious correlations can be made, with the area of raised elevation being present on both (highlighted in red). Essentially, correlations such as this prove the LiDAR data collection was not hindered by the dense vegetation in such a way as to be unsupportive for use in this project - as was previously stipulated it could be. Figure 4.1b shows that the elevations for this area are the same – whether the data is taken from either LiDAR (inset top right) or the primary optical instrument-gathered data (left of page). This is tested by observing cross sections (labelled 1,2 and 3) between sets of coordinates, to ensure the same area is being observed. Cross section 2 perhaps shows the most significant correlation, with the elevated area (raised alluvium) showing maximum heights of approximately 8.25m (using the primary data collected on site). The LiDAR cross section gives the same height for the area - suggesting the desired accuracy has been achieved.

Figure 4.1b: Contour map (left) of Loe Bar taken from spot height data obtained during fieldwork with cross section comparisons with LiDAR of area of dense vegetation/raised elevation









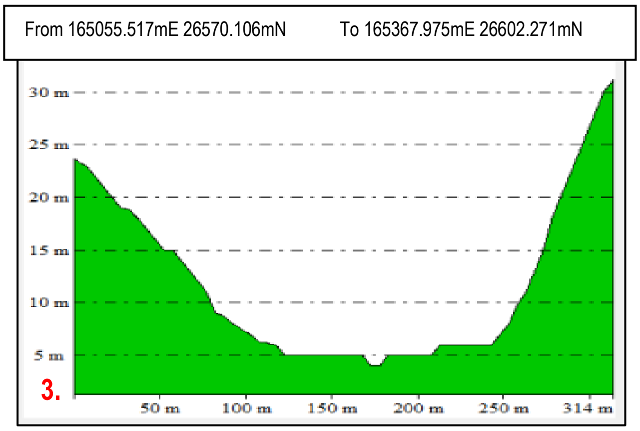
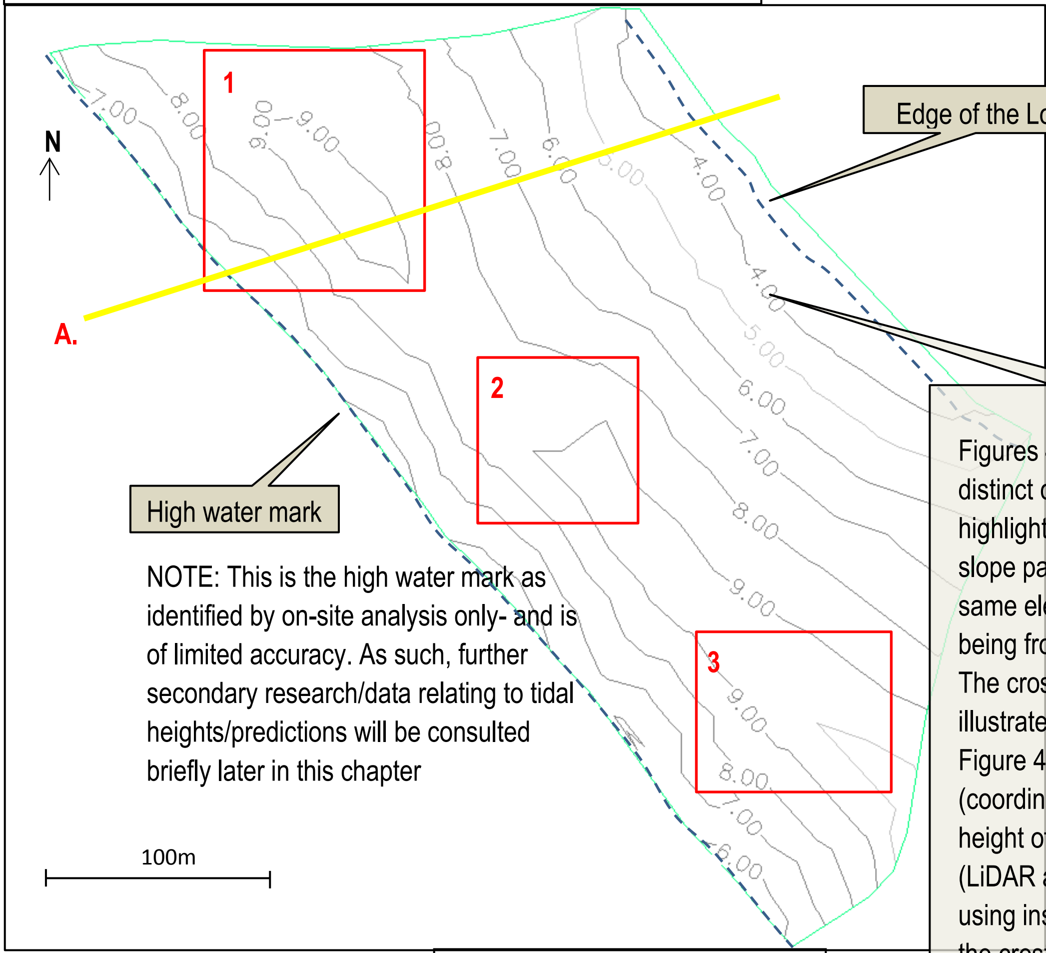


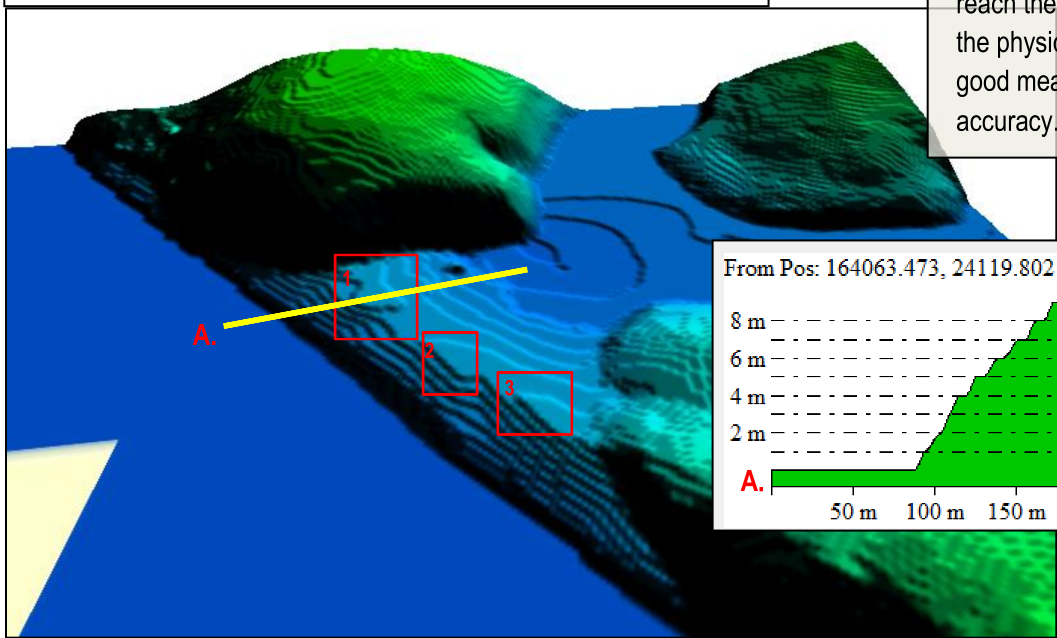
Figure 4.1c: Contour map (m) of Loe Bar taken from spot height data obtained during fieldwork

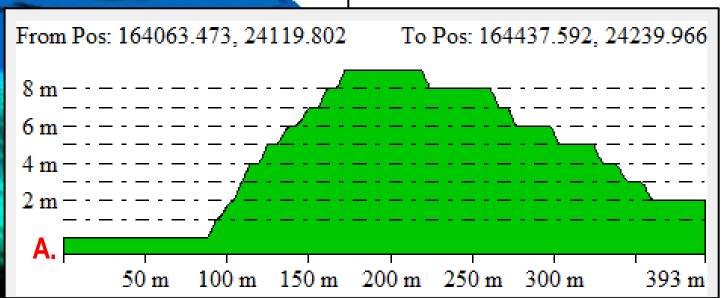


Source: *AutoCAD Civil 3d 2012*

Figures 4.1c and 4.1d show some distinct correlations. The 3 areas highlighted in red follow the same slope pattern and maintain the same elevations irrespective of being from two different datasets. The cross section labelled 'A' is illustrated on the following page in Figure 4.1e. Cross section 'A' (coordinates given) reaches a height of 9m in both datasets (LiDAR and primary data collected using instruments) as it crosses the crest of the Loe Bar. Again, as previously noted, the fact that these two data sets (both independent from each other) reach the same conclusion as to the physical characteristics, is a good means of proving their accuracy.

Figure 4.1d: 3d Digital Terrain Model (5m resolution) elevation of the Loe Bar (vertical exaggeration scale factor x 2)





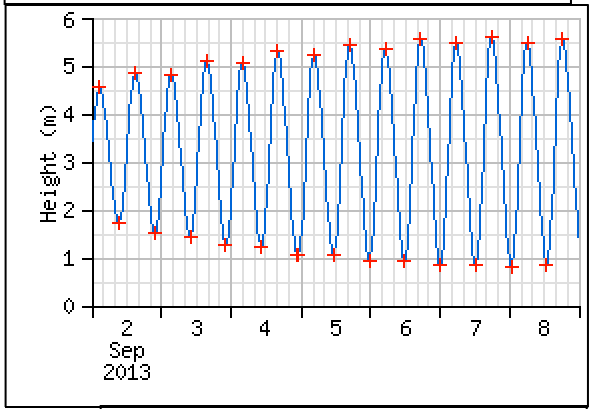
Source: *Dataset - Landmap Kaia*

Modelled in - Global Mapper

4.2. Analysis of LiDAR

Having established that the LiDAR remote sensing data set is of an acceptable accuracy and unaffected by the vegetation cover within the lower section of the valley, it is now pragmatic to analyse the data to answer some of the key aims and objectives as outlined in chapter 1. Global Mapper 14 is a GIS data processing application which has been used in conjunction with the spatial remote sensing data set in order to act out hypothetical scenarios, such as the impacts of flooding the Cober valley by lowering ground level. By hypothetically flooding the valley, it is possible to emulate as close as possible the topographical conditions that might have existed prior to the build-up of alluvium over time.

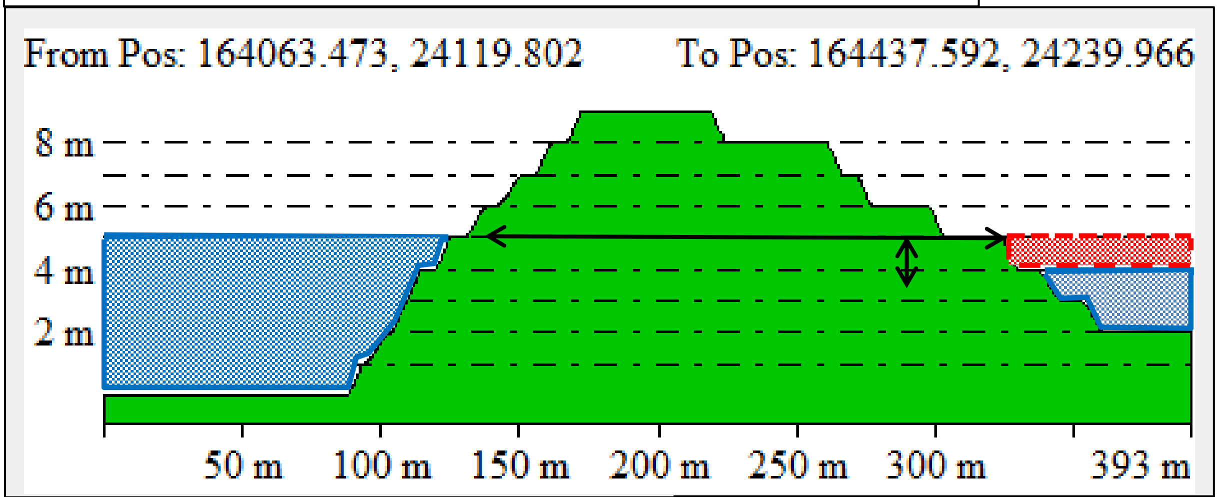
Figure 4.2a: High and Low Water predictions for Mounts Bay, Cornwall - over period of early September 2013



Source: *National Oceanography Centre*

Firstly, the high water mark on the bar must be established with some confidence, and as already discussed; this will involve consulting additional sources of information – since measuring by observation has potential for error. This will be done by utilising data obtained from the National Oceanography Centre, as shown in Figure 4.2a. The figure shows that the rough average elevation of high water is approximately just over 5m (similar to that observed during the site survey). Taking this into consideration, and knowing the height of the edge of the Loe Pool (which was easier to determine without stipulation since the water's edge could be followed directly), it is possible to calculate the difference and thus an approximate estimate of how much sea water would be subject to the valley if allowed passage.

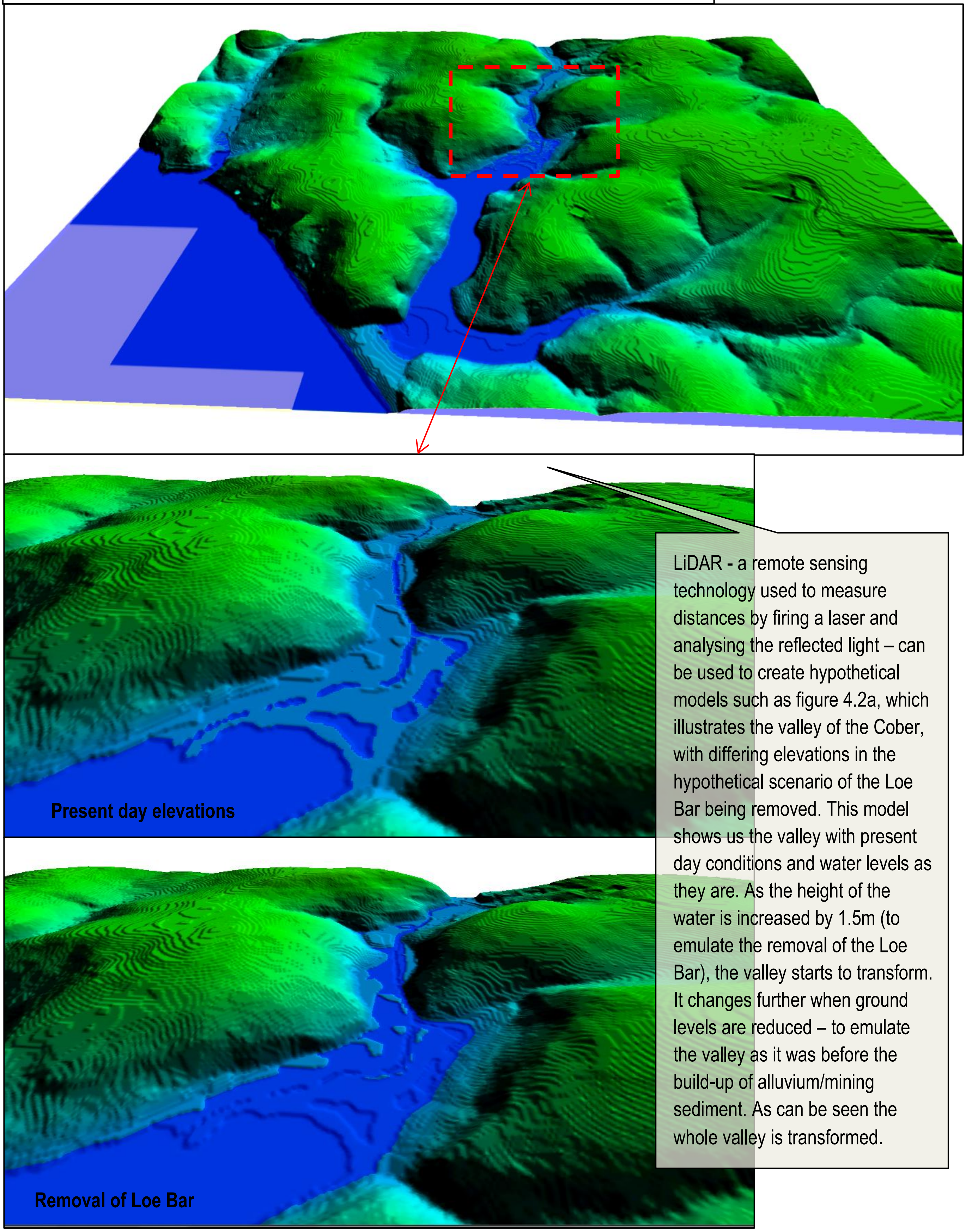
Figure 4.2b: Cross section of the Loe Bar illustrating water level elevation differences



Source: *Dataset - Landmap Kaia*
Modelled in - Global Mapper

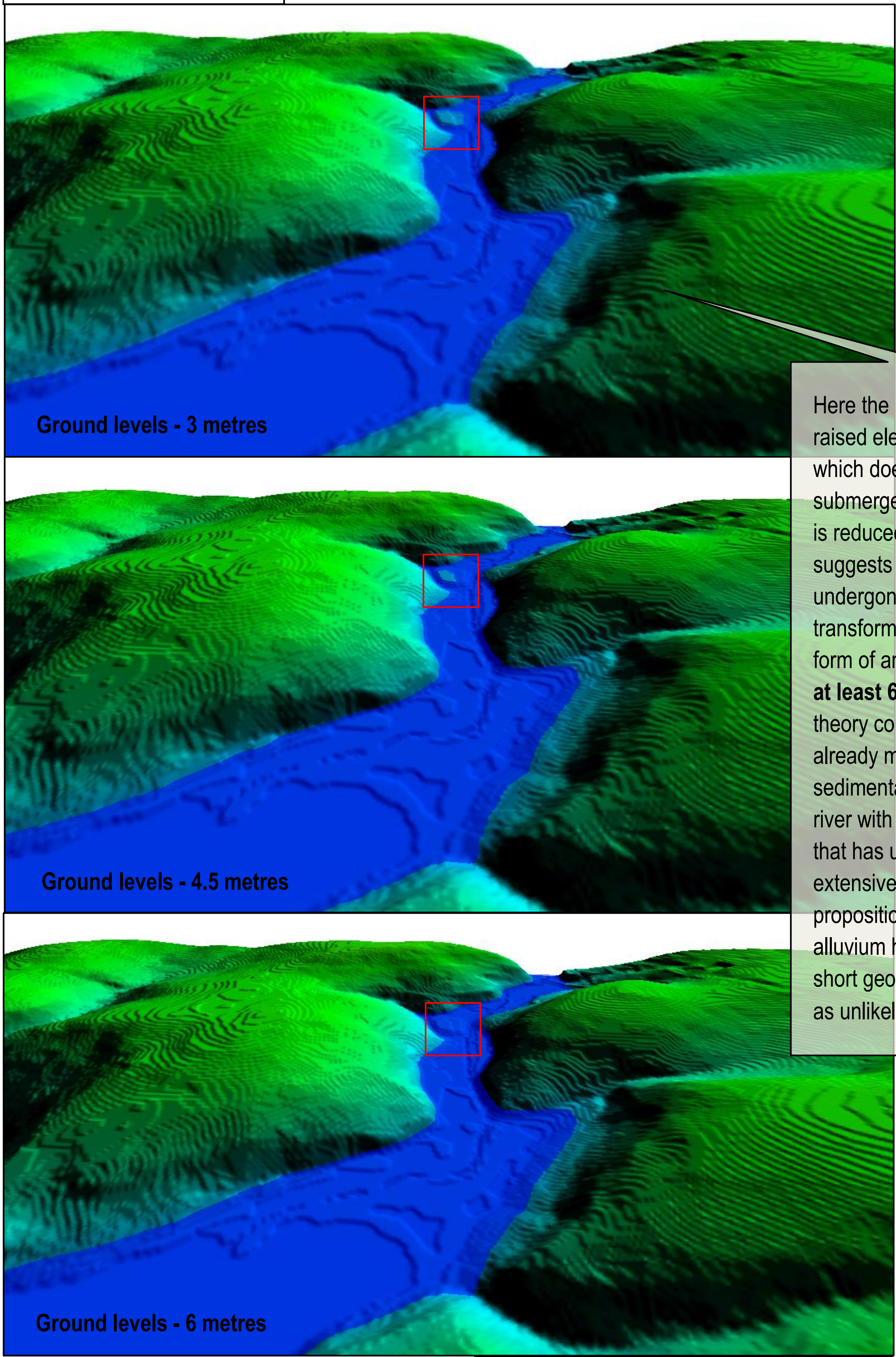
Assuming that sea water could indeed find a way into the valley (without the Bar impeding it, a possibility as already discussed), the first hypothetical question to answer is how far would the sea water reach with present day elevations of the terrain. Figure 4.2b shows that the difference in elevation between the high water mark of the sea and that of the Loe Pool is approximately 1-1.5m. Therefore, without the presence of the Bar, the sea-water would naturally fill inland increasing the height of the water within the pool by roughly 1-1.5m. Figure 4.2c aims to illustrate this further.

Figure 4.2c: 3D Digital terrain model – Using LiDAR remote sensing elevation data (5m) to interoperate the effect of differing height levels within the valley (1.5m intervals)



LiDAR - a remote sensing technology used to measure distances by firing a laser and analysing the reflected light – can be used to create hypothetical models such as figure 4.2a, which illustrates the valley of the Cober, with differing elevations in the hypothetical scenario of the Loe Bar being removed. This model shows us the valley with present day conditions and water levels as they are. As the height of the water is increased by 1.5m (to emulate the removal of the Loe Bar), the valley starts to transform. It changes further when ground levels are reduced – to emulate the valley as it was before the build-up of alluvium/mining sediment. As can be seen the whole valley is transformed.

Figure 4.2c continued



Here the LIDAR shows the area of raised elevation (highlighted red), which does not become fully submerged until the ground level is reduced by 6 metres. This suggests that if the valley floor has undergone significant transformation over time, in the form of an increased elevation of **at least 6 metres**, then the port theory could be deemed viable. As already mentioned, usual rates of sedimentation do not apply for a river with a catchment such as this that has undergone such extensive mining, thus the proposition that 6 metres of alluvium has built up in a relatively short geological time period, is not as unlikely as it sounds.

Source: *ArcMap 10 Topographic Basemap*

4.3. Final Discussion

From these models it is possible to draw the rough conclusion that for a tidal estuary creek system to have been remotely viable, an approximate level of alluvium build up no less than 6 metres would need to have taken place within the valley over time since the era when the port is purported to have been in existence. In all likelihood, the depth would probably need to have been deeper still so to account for a suitable valley depth deep enough for sea faring ships to navigate through without fear of running aground. It is apparent from analysis of these models that the current topographical state of the valley is not such that it would support a tidal creek or estuarine system forming in the hypothetical scenario of the removal of the bar.

It is important to consider whether this suggestion of a 6 metre build-up (at the very least) in the space of perhaps 2000 years is viable – allowing for liberal estimates on the earliest founding of Helston as a settlement -considering the sedimentation rate evidence. The catchment area has seen some of the most extensive mining activity within the country and the presence of sea sand at the correct corresponding heights in the strata, as well as the low depth of bedrock as discussed in previous chapters goes some way to supporting the port theory. For example as previously mentioned, Brooke (1994, p.70) references the intrusive investigations within the area made in the early twentieth century that uncovered the presence of 7 feet of sea sand underneath 25 feet of mining silt within the area; an amount that relates to the 6 metres (plus allowances for deep enough water for ships to navigate through) deemed necessary by the 3d models.

5. Conclusion

The aims of this investigation, as outlined in the first chapter, were achieved through means of fieldwork and analytical methods. The first aim, to undertake a holistic site survey has been accomplished despite significant problems encountered i.e. dense vegetation, size/scale of site. The accuracy of the LiDAR remotes sensing data has been confirmed through comparisons to the independent fieldwork data collected on site. An understanding (albeit generalised) of how far up the valley water levels would reach without the bar has been reached, and it has been confirmed that the valley in its present state does not hold the topographical formation to support a tidal creek system in the hypothetical scenario of the bar being removed. It is impossible to establish how much sediment has accumulated within the valley, however geological evidence, as well as the LiDAR remote sensing supports the claim that a historically lower elevation of the valley floor (approximately 6 metres) would have allowed sea water to reach the site of the New Cattle Market. The next section of this chapter aims to complete the final aim of this project by offering a holistic summary of the investigation.

5.1. Summary of the context

Whilst a vast amount of literature supposes that Helston could never have been a port (Hitchins, 1824; Polwhere, 1816) it would seem the main piece of evidence drawn upon by sharers of this standpoint is both the presence of the bar (and therefore the pool) as far back as historical evidence will go. Indeed, as the compelling geological evidence discussed within the literature review demonstrates (May, 2007, Bird and Schwartz, 1985), the formation of the Loe Bar could not have taken place as recently as the 13th Century, as many port theory supporters agree. The high chalk flint content of the bar is proof enough of this, and a much earlier formation date (3000-4000BC) is far more comprehendible. However, despite this standpoint on the formation of the bar, the research has concluded that a tidal creek or estuarine river system could have existed in harmony with the bar during an era when the coastal feature had a differing physical form than that of today, or was of increased susceptibility to breakages. Indeed, if the geological evidence on the bars formation and the most liberal opinions on Helstons earliest presence as a settlement are anything to go by, then 2000 years ago, the bar would have been 1/3 younger than it is today, and could have been a much different topographical feature altogether.

It is apparent from the evidence that with sea levels at their current height the removal of the bar would still not generate a navigable passage of water up into Helston. However bearing this in mind, the valley has likely undergone such a transformation (particularly in elevation caused by extensive mining sediment deposition) that this might not have been the case historically. It is impossible to calculate how much sediment has accumulated, since the usual rates of sedimentation do not apply to mining catchments (Whitley, 1881; Stapleton & Pethick, 1996). However when looking at other case studies, this 6 metres that seems the likely threshold to make the theory viable is certainly not beyond comprehension.

Barring the discovery of some irrefutable piece of archaeological evidence, the question of whether or not Helston ever did have a port will never fully be answered with 100% certainty. However in this author's opinion, based upon the collection of evidence discussed within this paper, the prerequisite conditions would have been in place, and thus the prospect and theory are a distinct possibility. This coupled with the staunch, confident claims from a large proportion of the local townsfolk who strongly believe in the town's port heritage, certainly advocates supporting the theory.

5.2. Practical use of findings and recommendations for further investigation within the area

In closing it is pragmatic to give recommendations for further study based on this investigation, as well as to highlight its practical uses for other potential investigations. This investigation has gone some way to prove that the local theories based around a ports existence in Helston at some point in history do hold some weight and could perhaps be based upon a factual foundation. However, the data this is based on, whilst of an acceptable accuracy for the purposes of this investigation, could be of improved accuracy to determine a larger degree of certainty surrounding the hypothesis. Perhaps with the use of finer resolution LiDAR data (<5m) an even more accurate and extensive digital terrain model could be formed which would offer an even better picture of how seawater would fill the valley and a more precise understanding of the alleged ports location could be gained. Camborne School of Mines Surveying department is likely to receive access to 1m resolution gridded LiDAR dataset of the area from the Tellus project in the near future. By comparing the results of this more resolute dataset to that of this project, further confidence regarding the port theory may be gained. Furthermore to this, some form of geophysical survey carried out over the entire length of the Cober valley would give a clearer understanding of the depth of bedrock along the route that ships might have taken if indeed the valley was navigable and as such might be beneficial in gaining a better understanding the likelihood of the theory.

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Appendix 1

Borehole data obtained from intrusive site investigation for New Cattle Market

Source: Moreton 2011

Borehole Number	**Ground Level (m)**	**Coordinates**	**Horizons**
Borehole 1 (BH1)	6.79 AOD	E 165555.40 N 27335.23	0 - 0.3m Tarmac 0.3 - 0.7m Angular/sub angular cobbles and gravel 0.7 – 1.5m Gravelly moist sand 1.5 – 8.2m Grey-brown, silty sand / no returns **8.2m Rock** 8.2 - 9.5m Rock, borehole called off
Borehole 2 (BH2)	6.77 AOD	E 165556.53 N 27328.50	0 - 0.4m Tarmac 0.4 – 1.5m Gravelly grey loam 1.5m – 9.0m Grey-brown, silty sand / no returns **9.0m Rock** 9.0 – 10.5m Rock, borehole called off
Borehole 3 (BH3)	6.83 AOD	E 165556.32 N 27325.13	0 – 0.2m Tarmac 0.2 – 0.7m No returns, wet/gaseous void 0.7 – 1.2m Limited returns 1.2 – 8.7m Weak / intermittent resistance, no returns, water **8.7m Rock** 8.7 – 10m Rock, borehole called off
Borehole 4 (BH4)	6.79 AOD	E 165566.67 N 27318.15	0 – 0.3m Tarmac 0.3 – 1.4m Damp, sandy, yellow/grey clay/peat 0.7 – 1.2m Limited returns 1.2 – 8.0m No resistance, no returns, water **8.0m Rock** 8.0 – 9.5m Rock, borehole called off
Borehole 5 (BH5)	6.64 AOD	E 165579.61 N 27310.79	0 – 0.4m Tarmac 0.4 – 1.8m Damp, sandy, yellow/grey clay/clinker/gravel/tailings 1.8 – 8.0m Weak/intermittent, no returns, water at 2.5m **8.0m Rock** 8.0 – 9.5m Rock, borehole called off
Borehole 6 (BH6)	6.64 AOD	E 165581.32 N 27316.75	0 – 0.3m Tarmac 0.3 – 1.2m Domestic refuse, china, clinker, glass, hydrocarbon odour 1.2m – 8.0m Very little resistance, no returns, water at 1.8m **8.0m Rock** 8.0 – 9.5m Rock, borehole called off
Borehole 7 (BH7)	6.68 AOD	E 165586.90 N 27321.61	0 – 0.3m Tarmac 0.3 – 1.4m Domestic refuse, china, clinker, glass, hydrocarbon odour 1.4m – 8.2m Very little resistance, no returns, water at 1.8m **8.2m Rock** 8.2 – 10m Rock, borehole called off
Borehole 8 (BH8)	6.68 AOD	E 165591.65 N 27312.10	0 – 0.3m Tarmac 0.3 – 1.0m Domestic refuse, china, clinker, glass, gravel 1.0m – 8.5m Very little resistance, no returns, water at 2.0m **8.5m Rock** 8.5 – 10m Rock, borehole called off