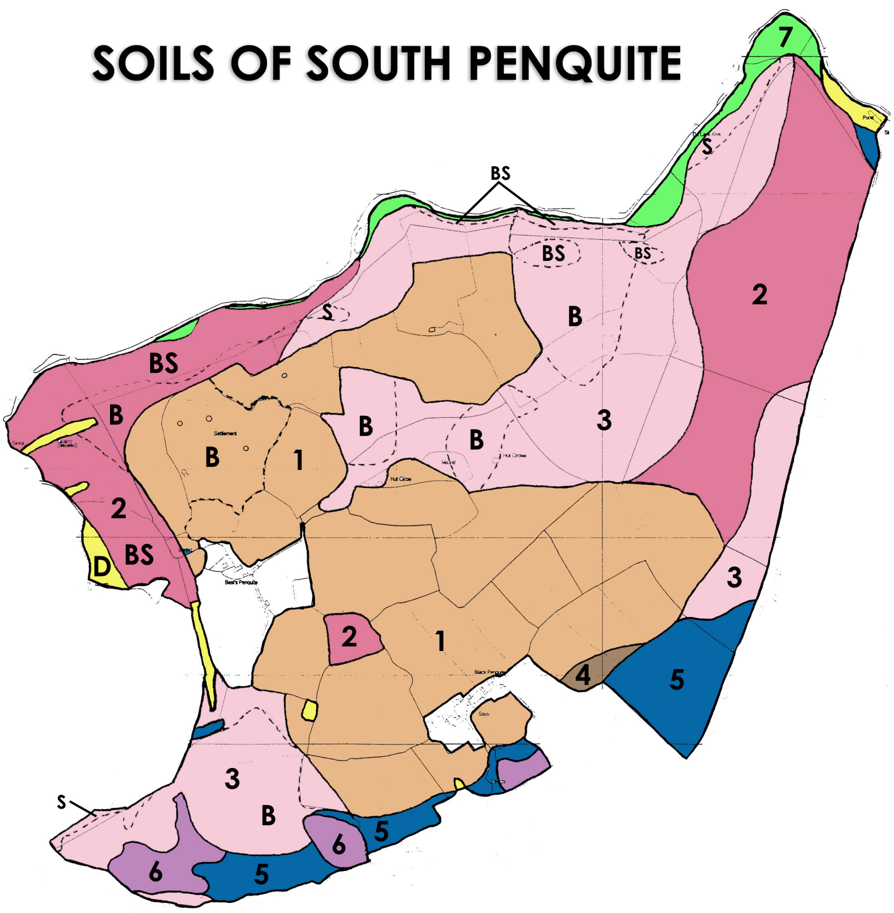
Soil Survey of South Penquite Farm
Blisland, Cornwall



Moretonhampstead series	1
Moor Gate series	2
Hexworthy / Rough Tor series	3
Lustleigh series	4
Laployd series	5
Crowdy series	6
Mixed soils in alluvium	7
Steep [> 11^{O}]	S
Bouldery	B
Disturbed ground	D

Soil Survey of South Penquite Farm Blisland, Cornwall

A component of the Biodiversity and Soil Survey for South Penquite Farm & De Lank Quarry

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Dominic Fairman is thanked for his encouragement and unflagging interest, as are fellow workers, Sally Foster [who also coordinated the projects], Keith Alexander, Peter Floyd-Spong and Colin French.

An unseen influence in the inclusion of a soil study among these projects must be acknowledged. At times Richard Smith of the Environment Agency must have felt himself to be a lone voice in advocating the role of soils and their management as a key part of the wider environment. Clearly there are those who have listened.

John Macadam provided helpful comments on the geology, while I am grateful to Peter Dudley and Peter Herring for discussion on links between the farm's soils and archaeology.

Access to National Soil Map survey field sheets was kindly provided by the National Soil Resources Institute at Cranfield University's Silsoe campus. My thanks go to Bob Palmer of the NSRI's York Office for discussing his methodology for assessment of soil structural degradation.

Sonia Thurley and James Burke [Environment Agency] are thanked for making available stereoscopic vertical aerial photography of the farm.

Mike Saul provided the quotation [abridged below] from the16th Century husbandry guide.

The small discrepancy at the western extremity of the Coombe represents the author's surveying of the fence line under tree cover where it is not apparent from aerial photography.

"We know more about the movement of celestial bodies than the soil underfoot". LEONARDO DA VINCI. [ATTRIBUTED BY THE 1996 ROYAL COMMISSION REPORT ON "THE SUSTAINABLE USE OF SOIL"]. Nothing changes.

"Go upon the lande….and if it synge or crye or make any noyse under thy fete then it is too wet…." 16th CENTURY HUSBANDRY GUIDE. Still sound advice to farmers, whether of livestock or arable.

"This we know, the Earth does not belong to man, man belongs to the Earth. This we know. All things are connected like the blood which unites one family. All things are connected." CHIEF SEATTLE'S TREATY ORATION TO THE US PRESIDENT IN 1854. [HOLLYWOOD'S VERSION AND NOT IN THE ORIGINAL]. Nevertheless a valid and eloquent view of life.

"Dig we must! Dig a hole or cause a hole to be dug". ADVICE IN MID 20th CENTURY NOTES ON HOW TO START STUDYING SOIL. This too remains true, despite technology's wonders, whether satellite images, ground-penetrating radar or scanning electron microscopes.

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1 SUMMARY

This soil survey contributes, with other studies on biodiversity, geodiversity and archaeology, to the educational and scientific background of South Penquite Farm. This report explains and interprets the accompanying soil map.

Background information is provided on methodologies and the physical characteristics of South Penquite. Seven natural soil map units are shown and described, along with small areas of disturbed ground. The soils of the Cornish hedges and banks are also described.

The farm has a widespread mantle of sandy silt loam soil material. In places surface accumulation of organic matter has formed humose sandy silt loam or peaty topsoils and some thicker peat.

Although the altitudinal range of the farm is limited, most of the soils found across Bodmin Moor are present. Most extensive are the freely draining Moretonhampstead and Moor Gate soils. Moretonhampstead soils, occupying the longer enclosed land, including the Bronze Age field system, have only small amounts of organic matter in their topsoils. By contrast the other soils have black, humose or peaty surface horizons. At the southern end of the farm are a few hectares affected by groundwater. In places, where groundwater reaches the surface throughout the year, there is thick peat.

Figures are provided demonstrating how climatic wetness restricts the periods when the soils are sufficiently firm to avoid damage by stock or traffic. This contrasts strongly with both drier, lower parts of the county and all of lowland England.

Soils and their use and abuse play numerous parts in the wider environment, and contribute to diversity. They have very strong effects on hydrology and hydrological properties of the farm's soils are reviewed.

The local soils are all inherently acid. On the agricultural land topsoils are moderately acid to neutral in reaction; under semi-natural vegetation surface pH is strongly or moderately acid.

Semi-natural vegetation forms on some part of each soil map unit, although affected by varying amounts of agricultural pressure. Wetland vegetation is associated with groundwater-affected soils. Most striking is the heathy bog in the south east of the Coombe, contrasting with rushy pasture on the farmed equivalents. Old downland on the highest part of the farm has patchy wetland linked with surface soil wetness and acidity. On the farmed land some of the ryegrass / crested dog's tail pastures contain plants indicative of the underlying soil conditions.

There are some links between fauna and soils. Earthworms are most active on the freely draining soils, particularly on farmed ground. On wetter soils their

activity is reduced. Alexander's (2006) survey of terrestrial invertebrates identifies the hedgebanks as their most extensive habitat, contrasting with the minimal diversity on the pastures. He notes the groundwater-affected wetlands as key habitats, with some wetland invertebrates are also found on peaty topped old downland soils.

Agriculturally climate and soils encourage grass growth, but with the risk of damage to soil and sward during its utilisation. The freely draining soils are the most favourable, while on the wetter land that risk is almost always present.

There is an association between the soils and landscape history. Moretonhampstead soils occupy the old enclosures, both those of Bronze Age and medieval origin. Boundaries to former moorland soils outside the enclosures are often sharp and follow the hedge banks. Additionally peaty topsoil development on the highest old downland seems to have benefited from protected landuse over many centuries. Was it that the enclosers astutely followed soil differences or has farming and moorland management since enclosure brought about much of the soil differences seen today?

Recommendations, and comments on dilemmas for management, are made concerning the use of the soils at South Penquite for educational, agricultural and scientific purposes.

For education some emphasis should be given to soils' place in the countryside's physical, biological and cultural make up, both in their own right and as links between other components. This report provides a fund to be drawn on in achieving that. There will be a need for good illustrations of soils at South Penquite, which has not been met as yet.

There are dilemmas regarding soil management, notably over the use of wet ground and out-wintering of stock. Both damage the sward and soil. While there is shorter-term justification for the practices, in the longer term productivity is likely to be reduced, a particular concern with organic farming, since the silver bullet of bagged nitrogen is not available. At the same time some damage to the soil surface is desirable from some ecological standpoints.

It is suggested that at some time in the future there should be archaeological and soil study of the evolution of soils inside and outside old enclosures. This would provide important insights into landscape evolution here and more widely in the upland fringes. This survey has also highlighted the need for research to establish what constitutes undamaged soil structure.

2 INTRODUCTION

2.1 Background

This soil survey was undertaken to provide information on the soils of South Penquite for use by schools, colleges and visitors.

It parallels, and contributes understanding to, other surveys of South Penquite. Several of these, which address biodiversity on the farm, have been carried out concurrently. They include one of the National Vegetation Classification (French, 2006), a survey of terrestrial invertebrates (Alexander 2006), surveys of water beetles and butterflies (Foster 2006 a] and b]), and of Odonata and birds (Floyd-Spong 2006 a] and b]). An archaeological assessment has already been made (Dudley 2005), as has a survey of geodiversity of the farm and the adjacent De Lank and Hantergantick quarries (Macadam 2005).

Together these study the bio- and geo-diversity of the farm, along with its archaeological and historic features. At the same time South Penquite is a commercial, organic farm with a long agricultural history. This, as elsewhere, has influenced and will influence, the way the land and nature on it evolve. In furthering conservation on a working farm there will be choices, opportunities and dilemmas.

2.2 Introduction to the Soil Survey

The purpose of a soil survey is to describe and define kinds of soil and to map their distribution. This survey of South Penquite was carried out with field work in August and September 2005 when the soils were reasonably dry. That was followed by further surveying in November and December, when the soils had thoroughly rewetted. This provided the opportunity to see the land in contrasting conditions.

Soil is the basic growth medium, supporting both crops [grass included] and natural or semi-natural vegetation. Variations in soil properties can strongly influence the development of vegetation and, particularly through their reactions to weather and climate, the responses of farmed land to cultivation, stocking and traffic. Soil conditions also affect the assemblages of soil fauna, from microscopic species, through invertebrates, such as earthworms, to the presence or absence of large burrowing mammals, for example badgers and rabbits.

It should not be overlooked that plants and animals in the soil can have roles in soil development. The most important example locally is the interaction of heathy vegetation and podzolisation of moorland soils following Bronze Age climatic deterioration. Both plants and animals can have parts in cycling nutrients and enriching surface horizons. At other times bioturbation may result in the mixing of soil horizons.

The soils' key role in the rural landscape is self-evident. Sympathetically managed they can be a readily sustainable natural resource. The character of the countryside is moulded through soils' links with geology and relief, reactions to climate and the influence of each of these on landuse and vegetation. Perhaps less obviously soils also fulfil other environmental roles, such as the storage of water and modulation of runoff, in short buffering the aquatic environment. Awareness of the importance to that of interactions between soil management and weather, particularly rainfall, has grown apace in recent years.

It is for such reasons that this soil survey was conducted. The basic mapping and description of the soils establishes the broad character of this pivotal element of the farm's natural environment. Within that context the study of soil structure in the surface and upper soil horizons shows the impact of soil management. This of course can affect other aspects of the environment and the farm's productivity.

2.3 Unit of Study

The basic unit of study is the *soil profile* as displayed in vertical sections. Distinctive soil *horizons,* layers roughly parallel to the surface, are recognised. The sequence of horizons constitutes the soil profile, while the material in which it has formed is termed *parent material.*

Soils are diverse. The soil surveyor looks for important differences in permanent soil properties in profiles; full descriptions of methods of this are given in Hodgson (1997). Among these are *texture* [whether the soil is a clay, a loamy sand, a silty clay loam, etc], organic matter content, colour, stoniness, *hydrology* [whether for example it is naturally freely draining or seasonally waterlogged, etc], *structure* [aggregation], pH, as well as the configuration of soil horizons, evidence of various soil-forming processes and parent material or geology.

N.B. As an important part of this survey is concerned with the assessment and interpretation of soil structure in the surface and upper horizons of the soil; attention is drawn to the relevant section of the Soil Survey Field Handbook (Hodgson, 1997), pages 37-57 and to A Guide To Better Soil Structure (National Soil Resources Institute, 2001). The latter has excellent illustrations of soil structure and is available free from NSRI, Silsoe, MK45 4DT or electronically at www.cranfield.ac.uk/soil

Soils with similar assemblages of horizons and developed in the same parent material, as defined by Clayden and Hollis (1984), are grouped in the same *soil series.* Soil series are conventionally named after the place where they were first recognised or where they are well developed, much after the manner of naming breeds of domesticated animals.

Soil series can be classified systematically, depending on the configuration of their horizons, following the categories of Avery (1980). The relevant terms in Avery's classification for South Penquite's soils are given, in italic, after the series name in the left-hand column of the soil map's key.

2.4 Methods

The soil surveyor proceeds by observing soil profiles in pits, auger borings and casual exposures, attempting to map the distribution of different soil series. Once an initial reconnaissance has established the broad pattern of soils, closer observations are made to provide greater detail. As well as profiles observed with the auger and spade [at the rate of about 4 per hectare in this survey], use is continually made of supporting insights, particularly the "lie of the ground" and the kind of semi-natural vegetation, indicator plant species and agricultural weeds. Aerial photography, principally well-timed, vertical, stereoscopic pairs, can be revealing.

Where nature cooperates, discrete separation of individual soil series may be possible. At times, however, this proves difficult. Within the mapped separations, the *soil map units*, although dominated by the named soils series, contain variable amounts of subsidiary soils, reflecting geomorphological, hydrological and pedological changes at scales too small to be represented by mapping. As part of the natural landscape, a soil map unit's composition is more analogous to features such as natural vegetation associations [e.g. an oak wood with scattered inclusions of ash, birch, holly etc], rather than to pure stands, as with agricultural crops, like wheat or potatoes.

At times it is appropriate to delineate *phases* of soil map units, where properties of the soil or land change. At South Penquite both steep [slopes more than 11º] and bouldery phases are identified.

In nature boundaries between soils are often gradual, despite being represented on maps by narrow lines. However abrupt boundaries can occur, for example on the edge of river alluvium and at South Penquite across the boundary of several medieval enclosures. In places boundaries drawn during soil mapping represent a compromise. A gradational change between contrasting soils may include a narrow zone of profiles of intermediate character, too small to delineate with confidence.

The map units on the accompanying soil map are described below. However, before that, it is useful to review the landform, climate and soil parent materials, each important components of the environment, which have great influence on the soils make up and behaviour.

2.5 Landform

The land at South Penquite at its lowest point in the foot of the Coombe stands at about 100 m O.D., rising close to 225 m O.D. at the highest point near the hut circle in enclosure 11. It forms an asymmetrical spur, with, in the most part, gentle slopes up to about 4^{O}, steepening on the northern and western sides towards the De Lank River. The river valley is broad and shallow in the north, being incised only about 15 m at Delford Bridge, where its downstream fall is less than 1:100. Downstream it sharpens and at the lowest part of the farm is incised around 70 m, with the river descending at about 1:20 between the north east of Stepfield and the southern end of De Lank quarry. In the Coombe and facing Hantergantick and De Lank quarries the slope steepens to above 20^{O}, in a strip 100 m or so wide up from the valley floor.

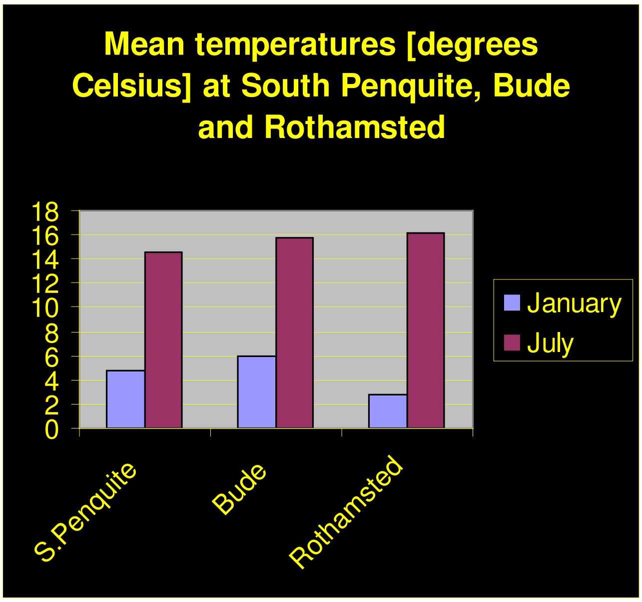
Most of the ground has even, linear slopes, broken by minor undulations, with convex changes as the gradient steepens progressively downslope. Concave changes of slope are found at the edge of the De Lank floodplain and in the head of the shallow basin occupying the southern and south eastern edge of the farm.

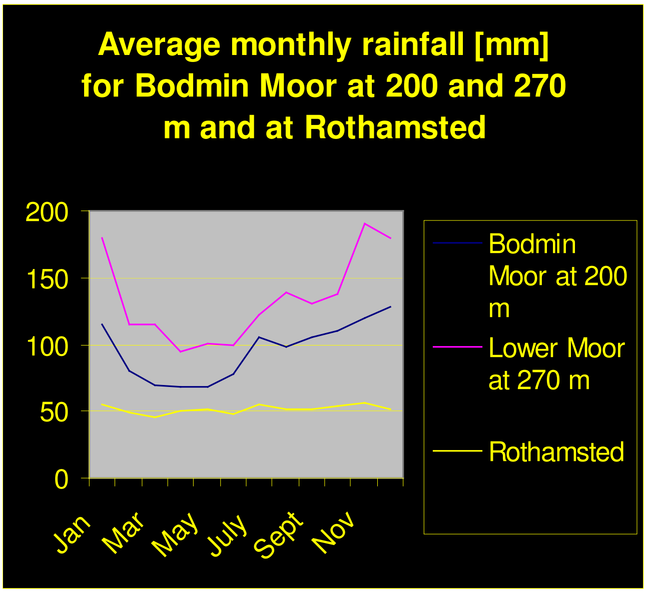
Bouldery areas are shown on the soil map. On and near the steepest ground there are numerous large boulders, plus tor-like crags and granite outcrops.

2.6 Climate

The climate at South Penquite is mild, wet and exposed, in short typical of western, oceanic Britain. Rainfall, exposure and susceptibility to mist and hill fog increase with altitude, while temperatures fall. Average annual rainfall is about 1,400 mm, although the year to year values vary widely from this. Distribution through the year is strongly cyclical, autumn and winter being the wettest, with spring and summer months, on average being drier. Staines (1976) [p 3] shows that mean annual temperature at sites at about 200 m O.D. near Bodmin Moor are about 4.7^{o}C in January and 14.5^{o} in July.

Comparison of these climatic statistics with other places helps set the context. Average annual rainfall at Bude is around 1,000 mm and mean temperatures are about 1.2^{o}C greater than at South Penquite, in both winter and summer. At Rothamsted, in eastern England, annual rainfall averages 700 mm and is not cyclical, summer amounts there being broadly similar to those in the west. Temperatures at Rothamsted average 3.2^{o}C in January and 16.2^{o}C in July. Cornwall's oceanic climate has less temperature contrast between winter and summer and the growing season is longer, but less intense, than in the more continental regime of eastern counties.





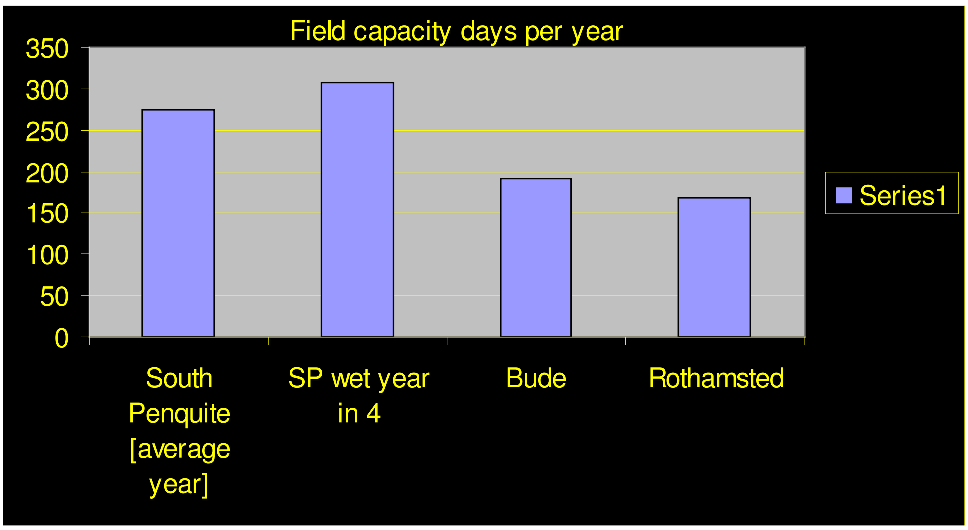
Exposure is an obvious, although less readily measured, feature of the climate at South Penquite, as in most of Atlantic Britain away from sheltered valleys. Wind pruning of trees and shrubs is perhaps its most striking expression.

In their “Bioclimatic Classification” of England and Wales Hartnup and Bendelow (Soil Survey 1980) mapped the 3 categories of thermal region, moisture class and exposure class. Across the country they made 5 subdivisions of each of these categories. The west side of Bodmin Moor around South Penquite is in their second warmest class in terms of thermal regime, defined by accumulated temperature. The area falls in their median class of moisture conditions [defined using summer moisture deficit values]. In mapping climatic exposure it is in their second highest [very exposed] category, as is most of the county apart from the coastal areas and the higher uplands, which are classed as the extremely exposed highest class.

In comparison Bude is in the highest thermal category, their second driest moisture category, but shares the same exposure rating. Rothamsted is in their second highest thermal class and the second driest moisture class and second least exposed category.

An understanding of **c**limatic conditions is essential for a proper appreciation of the environmental and economic performances of soils. Conventionally these have been summarised by reference to long–term [usually 30 years] averages of rainfall, temperature etc., whether these be monthly or annual statistics. While these are useful for broad comparisons between relatively widely spaced locations, there are several limitations to such an approach, from both environmental and agricultural standpoints, when it comes to quantifying conditions for critical times or activities. Among these limitations are: the absence in rainfall and temperature averages of any sensitivity to the *reactions of soils to climate*; the wide day to day, month to month and year to year *variability in the weather* that is summarised as climatic statistics; the implication of any long-term *change in climate*.

The contrast between the dryness, which typifies summer, and the wetness, which sets in most autumns and persists into spring, is the obvious expression of responses of soils to the seasons. Agricultural meteorologists (Smith and Trafford, 1976, and Smith 1976) use *soil moisture deficit* and *field capacity* as meteorological measures of those contrasting conditions. Soil moisture deficits form when *evapotranspiration* by plants exceeds incoming rainfall. The latter expresses fully moist soil conditions. In the average year at South Penquite soil moisture deficits start to form in mid May, giving way to meteorological field capacity in mid August. In the field capacity period, which averages about 275 days, mean *hydrologically effective rainfall* is 920 mm. By contrast field capacity at Bude lasts for 191 days and at Rothamsted 168 days. [A fuller discussion of how climate acts upon soils is in section 5].



Both for the water environment and agriculture the large amount of variation in weather and climate are critical. For example, in considering the likelihood of environmental damage or agricultural consequences following autumn harvesting of maize, September or October rainfall [or related] data for the wet year in 4 or 5 may be more meaningful than those for the average one.

An obvious problem with the use of long-term statistics is the effect of climatic change. While there is evidence of a rise in mean annual temperatures over recent years, what form change is taking with regards to interactions of temperature and moisture regimes have yet to be established. Only once questions such as that have been resolved, will full confidence be restored in long-term climatic statistics.

2.7 Parent Materials

2.7.1 Granite and its weathering products

Along with the other south western granite masses, the Bodmin Moor granite originated about 290 million years ago. Then repeated melting of parts of the roots of the Armorican mountain range formed granitic magma during the course of 25-30 million years. The magma then rose as discrete bodies to within a few kilometres of the ground surface of that time. Subsequent erosion has revealed the separate granite masses we see across the south west of England today.

The Bodmin Moor granite consists predominantly of quartz, mica and feldspar [both orthoclase and plagioclase]. The granite ranges in types from forms with very large crystals of orthoclase [referred to as *megacrysts* and up to 10 cm long] in a finer matrix, to types in which the majority of the crystals are about the same size. Much of the granite at De Lank is notable in that the larger orthoclase crystals, though only a couple of centimetres in length, show a preferred orientation a texture more commonly associated with lavas and with metamorphic rocks.

As the newly emplaced granite cooled, vertical and horizontal cracks [joints] formed. The predominant north north-west to south south-east and west south-west to east north-east grain of valleys and hills on the granite outcrops reflects major vertical joint patterns. In the final stages of cooling hot, [pneumatolytic and hydrothermal] fluids escaped via the more open joint systems. As well as emplacing tin and other metal lodes, plus boron-rich tourmaline, these fluids altered the plagioclase feldspars in their path into kaolinite or china clay.

Over many millions of years the mountain range was gradually denuded and the granite exposed. It is likely that there were then millions of years of tropical “deep” weathering during the Tertiary, [the last 65 million years], a process known to break down granite to considerable depths. Both hydrothermal / pneumatolytic and deep weathering processes exploited any joint planes in the granite, leaving “onion” weathered corestones, separated by softer residues of “rotten” granite.

The intense cold of the Pleistocene ice ages provided the next step. With the ice sheets reaching the North Devon coast, Bodmin Moor endured an arctic, tundra-like climate for much of the last 2 million years, although interspersed with milder interludes. During these interglacials, some of which were warmer than the present day, slow weathering of the rocks proceeded through wetting and drying, freezing and thawing, the action of acidulated rainwater and by biological processes. In the glacial episodes permafrost penetrated deep into the ground, with only the surface metre or two thawing in the summer. Then the freshly thawed ”soil” material, being a semi-liquid slurry, flowed downslope on all but the flattest sites, by the *periglacial* process of *solifluction*. Solifluction was able to move not only the sand and smaller particles of *“fine earth”,* but also the largest detatched granite blocks and boulders. Each autumn this slurry refroze from the top down, with the trapped liquid suffering further churning before refreezing. The granitic detritus, previously broken down by hydrothermal and tropical deep weathering, was redistributed as a soliflucted, crudely stratified, weathered mantle, locally known as “*growan”, “rab”* or *“granite gravel*”, [and shown on geological maps as “*head”*], which in places can be several metres thick. In contrast still-unweathered corestones remain and when above the ground surface stand out as boulders, *clitter*, crags and tors.

With the end of the Pleistocene, about 10,000 years ago, solifluction ceased and the present soils began to develop. Over much of the farm, as with most of Bodmin Moor, they have formed in growan, rather than being weathered directly from the solid granite itself. However, the soundness of the granite in and around De Lank and Hantergantick quarries and the very rocky nature of the north west corner of South Penquite, shows that the effects of hydrothermal alteration and deep weathering there were minimal. By contrast the presence of marshy ground along the southern edge of the farm may signify the presence of rotten granite or china clay below. Many of the scattered surface boulders, along with those in the more concentrated groups, known as *clitter,* are a relict periglacial landscape element, fossilised once Pleistocene solifluction stopped.

2.7.2 Loess

At South Penquite most soil profiles are less gritty in the upper horizons than those in other parts of Bodmin Moor, or on other granite outcrops in south west England. A possible explanation is that wind-blown loess has been deposited and incorporated in the growan. This is known to have happened sporadically on Dartmoor and on the granite of West Penwith, as well as loess being deposited across southern England, including the Lizard peninsula, during the late Pleistocene. Staines (1976) noted occasional silt-rich soil profiles on the granite in the Camelford area, 5 to 10 km to the north and north east. However detailed mineralogical studies of the silt and very fine sand fractions [2-100 µm diameter] of soils from South Penquite would be needed to confirm this explanation.

2.7.3 Alluvium

The floodplain of the De Lank River is widest at the farm's northern end, just north west of Delford Bridge. Downstream it is often only a few metres wide and in places absent. The alluvium on it comprises variable thicknesses of more or less sandy fine earth, in places stone free, over gravel and boulders.

Immediately north of Long Down plantation, where the alluvium widens, the ground nearer to the river stands noticeably higher than that closer to the rising ground behind the floodplain. This is classic "levee" and "backland" terrain often found on floodplains. The topographic contrasts are mirrored by soil differences, including those brought about by the hydrological contrasts, while the drier, higher levee soils carry bracken, which is absent from the rushy backland.

Although there is a relatively wide [up to 60 m] swathe of floodplain nearer to Delford Bridge, the levee and backland pattern is less clearly expressed. Part of this ground was, of course, tin streamed in the past. This, and a long history of soil disturbance higher in the catchment, may explain the preponderance of humose, sandy textured soils on the De Lank floodplain on South Penquite. Disturbance, such as tinning, turbary, over-grazing, soil erosion etc., will have destabilised peat and mineral soil. During floods loose material will have been then carried down stream as suspension load in the floodwater, a portion of it being redeposited on the floodplain.

2.7.4 Peat

Peat soils, defined as having at least 40 cm of peat, are inextensive at South Penquite. However, peaty or *humose* [mixed organic and mineral] topsoils not reaching that thickness are widespread in the Hexworthy / Rough Tor, Moor Gate and Laployd soil map units described below and outlined on the accompanying soil map.

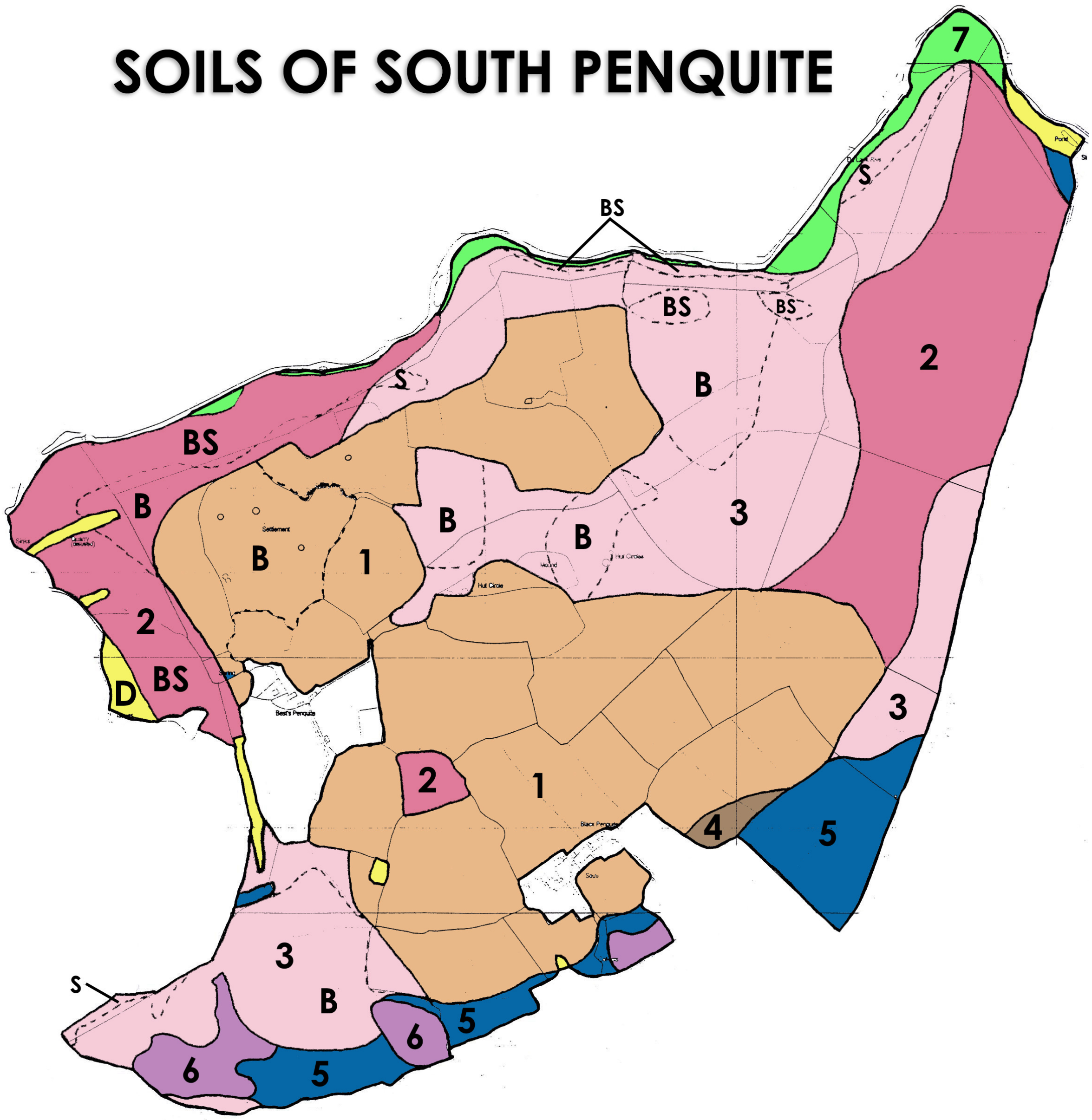
Peat, the decomposed residue of plants, accumulates both under conditions of permanent waterlogging, brought about by high water-tables, springs and flushes, or under very acid conditions which retard the biological activity involved in full decomposition, breakdown and oxidation, or with a combination of wetness and acidity. In some peat humification has left only a black, amorphous residue, in other circumstances plant remains can still be identified.

Degradation of peat can come about through agricultural activities. Cultivation aerates the soil allowing oxidative losses from the peat. Also where the ploughing penetrates into the mineral soil below, the peat is diluted into a thicker, mixed mineral and organic [humose] plough layer. Drainage of wet soils also removes the hydrological reason for peat development and preservation, as well as encouraging cultivation and further degradation following from that.

Addition of lime to acid soils is a necessary part of good soil husbandry to sustain any form of agriculture, but removes the acidity helping preserve peat. Historically there are numerous accounts from south west England of a practice variously termed “beat burning”, “paring and burning” and “densuring”, which was carried out until the 19th century. It comprised paring or ploughing off the turf and part of the topsoil, drying it in windrows, then burning it, followed by spreading of the ashes as a fertiliser. Clearly this practice was a very effective way of removing peat and organic matter from the soil.

There has also been a long history of turbary, the cutting of peat for fuel, even on soils with only limited thicknesses of peat. On moorland cut-over ground is recognisable by the linear steps the working front has left.

It is likely that any long-term increase in temperature, as is envisaged in some climatic change scenarios, would encourage oxidation of organic matter and peat. There is evidence nationally from Soil Survey sources that this has happened since the early 80s, a period when mean annual temperatures experienced a small but significant rise. Other forces, however, may counter this; for example wetter winters, or the de-intensification of farming and reduced use of lime.



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Soil survey by T.R. Harrod, 2005

Boundaries shown on this soil map often represent gradual changes, however abrupt boundaries can occur, for example between the medieval enclosures and Rye Down and on the edge of the river alluvium. Within the mapped areas the soil units, although dominated by the named soils described in this legend, contain variable amounts of subsidiary soils, reflecting geomorphological, hydrological and pedological changes at scales too small to be represented by mapping. As part of the natural landscape, a soil map unit's composition is more analogous to features such as natural vegetation associations, rather than to pure stands, as with agricultural crops.

Key to the soil map

SOIL		TEXTURE & MORPHOLOGY	NATURAL DRAINAGE	SUBSIDIARY SOILS	LANDSCAPE POSITION
Moretonhampstead series *[typical brown podzolic soils]*	1	Dark brown sandy silt loam topsoil over orange or brown sandy silt loam subsoil	Freely draining, seldom waterlogged		Gentle slopes in the medieval enclosures and around the Bronze Age settlements
Moor Gate series *[humic brown podzolic soils]*	2	Black, humose sandy silt loam topsoil over orange or brown sandy silt loam subsoil	Freely draining, seldom waterlogged	Hexworthy and Rough Tor; in steep sites, as in enclosures 4 & 12, some *ferric podzols* of the Bodafon series [black, humose sandy silt loam or peaty topsoil over grey, unmottled subsurface over orange, sandy silt loam subsoil]	Gently rolling ground on Rye Down; steep slopes above the river gorge in Watt's Coombe
Hexworthy & Rough Tor series *[Ironpan stagnopodzols and ferric stagnopodzols]*	3	Black, humose sandy silt loam or peaty topsoil over grey, mottled subsurface horizon over orange or brown sandy silt loam subsoil. In Hexworthy series thin ironpan at base of grey subsurface horizon	Seasonally waterlogged in surface and subsurface; freely draining, seldom waterlogged in subsoil	Moor Gate series; Princetown series *[stagnohumic gley soils]*, black, humose sandy silt loam or peaty topsoil over grey, mottled subsoil, becoming less mottled with depth	Rolling ground outside old enclosures
Lustleigh series *[gleyic brown earths]*	4	Dark brown sandy silt loam topsoil over orange or brown sandy silt loam subsurface over greyish mottled sandy silt loam subsoil	Seasonally waterlogged in the subsoil		Concave footslope in Clapp's Park
Laployd series *[typical humic gley soils]*	5	Black humose sandy silt loam or peaty topsoil, over grey mottled subsoil	Seasonally waterlogged to the surface; many springs		Some concavities and receiving sites
Crowdy series *[raw oligo-amorphous peat soils]*	6	Peat, at least 40 cm thick	Perennially waterlogged	Winter Hill series *[raw oligo-fibrous peat soils]*	Around intense springs and flushes
Mixed soils in alluvium	7	Mostly sandy soils with variable organic matter contents and colours	Variable: subject to flooding		De Lank floodplain
Steep	S				Slopes steeper than 11°
Bouldery	B				Scattered boulders, with crags and rock outcrops in the Coombe and Watt's Coombe, etc.
Disturbed ground	D				Made ground, quarries, tin streaming, etc.

3 SOIL MAP UNIT DESCRIPTIONS

The soil map's key provides a useful tabular summary of all of the soil map units. They are now described below in detail. In the opening paragraph of each map unit description the soil's overall properties are outlined, accompanied by description of its location on South Penquite, then more widely on the granite.

A more detailed profile description of the map unit's principal soil[s] follows, covering typical horizons, their colour, texture and stoniness in particular.

Soil structure, the form and development of aggregates, is then treated separately, because of its importance as a measure of any physical degradation likely to have environmental consequences. Methodologies are those of Hodgson (1997) pp37-57 and Palmer (2005).

The descriptions are then completed with a statement of subsidiary soils found within the map units.

Throughout this text field names are those on the 1840 Tithe Map of Blisland parish. Where a field name occurs more than once, as with "Bovetown" or "Potato Plot", the appropriate 1840 holding name is included. In large fields or enclosures, notably Rye Down, a directional notation [north, south, etc] is used. In tables these notations are abbreviated as single or double letters.

3.1 Moretonhampstead Map Unit

Moretonhampstead series is a naturally well-drained soil, associated with the older enclosures of the in-bye at South Penquite. It is also the soil found around the hut circles north of Best's Penquite in Watt's Coombe Park. This is the most extensive map unit on the farm, occupying about 32 ha. It is the main soil of the older enclosed land around the moorland fringes of Bodmin Moor and the other granite uplands of Cornwall and Devon.

Soil profile:

Its horizons comprise a dark brown, gritty, sandy silt loam surface layer [Ap horizon], usually about 30 cm thick, overlying an ochreous [orange brown] subsoil [Bs horizon] of similar texture to about 60 cm depth. A number of profiles were observed with thicker Ap horizons [up to 50 cm]. Some, but by no means all of these thicker topsoils were at the down-slope ends of fields. In places variably sized pockets and "pipes" of dark brown topsoil have been incorporated into the subsoil along former root channels and animal burrows. Earthworms, and their vertical burrows, up to 10 mm diameter, are commonplace. Below about 60 cm the ochreous subsoil passes to increasingly stony, paler brown sandy loam or sandy silt loam [BC horizon]. This gives way downward into weakly stratified growan of similar texture, but with increasing stone and boulder content. Long agricultural use, particularly dressings of lime, is likely to have modified the natural moderate acidity of these soils. However, the relatively coarse texture and wet climate will ensure that, at least for the surface horizons, the agriculturally beneficial effects of liming will decline within a few years.

Soil structure:

In the Ap [topsoil] horizon under permanent pasture at South Penquite this is usually moderately or strongly developed fine subangular blocky. Poaching and traffic damage, as in gateways and at feeding sites or by any excessive or ill-timed stocking, would bring about deterioration to angular blocky or massive structure. In the examination of soil structure carried out in the late autumn of 2005 the topmost 1-3 cm in places showed some mild signs of smearing and compaction, following stocking during wet weather. There did not appear to be any surface ponding as a consequence. It is likely that any structural degradation of the A horizons of Moretonhampstead soils under grass will recover relatively quickly, once the degrading conditions are removed. This is explained by the high earthworm population and the vigour of grass growth.

In the Bs moderate or strong fine crumb or fine subangular blocky structure is commonplace, although this readily deteriorates under intensive use, particularly when soils are moist. On land under semi-natural vegetation, which has not been cultivated or stocked, such subsoils can be very friable and often are described as “fluffy”. Microscopic examination of such fluffy aggregates reveals that they comprise faecal pellets of small soil fauna, such as springtails and earthworms. Below about 60-70 cm the structure is less well developed. In places on the Camelford survey (Staines 1976) platy structures were reported at these depths. These “fragipan” like structures are interpreted as fossil ground ice features from the Pleistocene glacial episodes.

Subsidiary soils of the map unit:

In a minority of profiles subsoils have drabber brown colours, giving soils of the Gunnislake series. Inclusions of darker-topped profiles of the Moor Gate series are present in the map unit, as east of the hut circle at SX1071 7540 in Harper’s Down. Several of the medieval fields appear to have lynchet-like accumulations of soil above their downslope boundaries. These give differences in ground height across the hedge-bank of 0.5-1.0 m, although possible degraded track ways or hollow ways along the lower side of the hedge bank, [as at SX1087 7500 and 1091 7581] may exaggerate the apparent effect Any build-up of colluvium might be attributable to prolonged cultivation, and possibly to erosional movement of the soil occasioned by cultivation. Examples are in Black’s Long Park, Down Park, Little and Great Abovetown, South Park and South Penquite’s Bounda Park. Profiles with subsoil horizons appropriate to Hexworthy and Rough Tor series, but with non-humose, [and therefore long-cultivated] topsoils, form sporadically in parts of South Park and the north east corner of Well Park.

Boundaries to the Moretonhampstead map unit are commonly abrupt and coincide with long established, often medieval field boundaries. Exceptions include the ground in Harper's Down around SX1071 7540, in the northern end of Watt's Undertown and Watt's Long Park, in Watt's Coombe west of the Bronze Age settlement, in the north east corner of Well Park and the west end of Lower Ground. Also the boundary with Lustleigh soils is transitional in nature.

3.2 Moor Gate Map Unit

These naturally acid, freely draining soils cover about 17 ha at South Penquite They occupy the steep and bouldery slopes and adjacent valley top shoulders in the north west of the farm flanking the river gorge in Watt's Coombe and the Coombe, much of Rye Down, plus the small former field of Watt's Potato Plot. More widely in granite country in the south west of England, Moor Gate soils are found on steep valley sides, but also on gentler slopes between the medieval enclosures and the higher moors and on some steep slopes on the higher ground.

Soil profile:

Moor Gate series differs from Moretonhampstead series principally by having a black peaty or humose topsoil. Where there has been cultivation this Ahp horizon can be 20–30 cm thick, although in undisturbed, semi-natural vegetation the Ah horizon is usually thinner, often overlain by a litter layer of a few cm of plant debris and a fermentation horizon of similar thickness. Between 30-60 cm an ochreous subsoil [Bs horizon] of gritty, sandy silt loam overlies stony and gritty, pale brown sandy loam or sandy silt loam, the BC horizon. As in the Moretonhampstead series, piping and pocketing of topsoil material penetrate the subsoil, marking former burrows and root lines. On farmed land earthworms appear plentiful. Unless lime has been applied the upper horizons of Moor Gate soils are normally moderately [pH 4.5-5.5] or strongly acid [pH <4.5], rising only slightly in the subsoil BC horizons.

Soil structure:

Soil structural development in Ap horizons on enclosed grassland is moderately or strongly developed fine subangular blocky. This may become degraded by stocking or traffic under wet conditions. Some profiles in dense bracken develop coarse angular blocky structure, this contrast in structure with pasture may reflect the differences in density and pattern of rhizome development compared with that of grass roots. Under woodland and shrubby semi-natural vegetation structure in the Ah can be strongly developed fine crumb or granular. "Fluffy" strongly developed fine crumb structures are usual in subsoil Bs horizons under semi-natural vegetation and very low stocking / traffic rates. However these do degrade easily if used more intensively when moist or wet, leaving less well developed blocky structure. Deeper in the subsoil in the BC horizon, structure is less well expressed.

Again instances of fragipan development are known from elsewhere on Bodmin Moor.

Subsidiary soils of the map unit:

In addition to the dominant Moor Gate series, this map unit includes occasional profiles of the Hexworthy and Rough Tor series, as on Rye Downs. A few soils, very similar to the Moor Gate series as described above, but with drab brown subsoils, were observed in and around the corner of the current RPA map enclosure 3, in Watt's Coombe, west of the Bronze Age settlement. Freely draining podzolic soils [i.e. without subsurface mottling] of the Bodafon and Trink series occur occasionally in the map unit on the steep slopes in the north west and west. In bouldery areas very shallow soils [rankers] were noted, with a few cm of humose sandy silt loam over rock or large boulders.

3.3 Lustleigh Map Unit

Lustleigh soils are of very limited extent at South Penquite [about half a hectare], situated in Clapp's Park and Middle Park between the freely draining Moretonhampstead soils and the groundwater gley soils of the Laployd unit. They experience some seasonal waterlogging of the subsoil. Elsewhere on the south western granite, Lustleigh soils are inextensive.

Soil profile:

Lustleigh series has similar upper horizons to the Moretonhampstead series, with a dark brown gritty sandy silt loam topsoil, changing at about 30 cm to a brown or orange brown [ochreous], upper subsoil of gritty sandy silt loam or sandy loam texture. At about 50 cm greyish mottles are present in the subsoil and persist to depth. Below about 60cm the matrix colours become drabber and prominent ochreous mottles are evident. The subsoil mottling [gleying] is indicative of seasonal waterlogging of these lower horizons. The location of Lustleigh soils between the Moretonhampstead and Laployd map units supports this interpretation. However, in some profiles there may be the complication of weathering from undisturbed [i.e. not soliflucted] rotten granite.

Subsidiary soils of the map unit:

The Lustleigh map unit contains limited inclusions of profiles of both the Laployd [wetter] and Moretonhampstead [drier] series.

3.4 Hexworthy / Rough Tor Map Unit

This map unit of wettish, very acid podzolic soils [stagnopodzols] occupies much of Great, Little and Long Downs,, northwest facing parts of Rye Down near the river, New Coombe Park, Well Park and Broad Lane, as well as well as the ridge crest in Harper's Down between South Penquite and Watt's Penquite and the western part of Rye Down, totalling about 24 hectares. Most of the land is gently or moderately sloping, although there are steep slopes close to the De Lank River and its floodplain. The ground has surface boulders in places, as in much of Great and Little Down and New Coombe Park. The narrow, steep bluffs, just above the floodplain in Great Down Plantation, are particularly bouldery. Hexworthy / Rough Tor soils are the most extensive soil type of Bodmin Moor. At South Penquite they are close to their lower altitudinal limit.

Soil profiles:

The Hexworthy and Rough Tor series have black, humose sandy silt loam [Ah] or peaty [Oh] surface horizons, usually 15-20 cm thick. At South Penquite peaty Oh horizons are limited in development, being largely confined to small patches on the ridge crest between SX1060 7534 and SX1075 7545 [in Harper's Down] and SX1090 7553 [the south western end of Little Down], plus ground about SX1116 7582 above the river in Rye Down, facing West Rose. Earthworms appear to be fewer in these soils than on the better drained Moretonhampstead and Moor Gate soils. The surface horizons merges downwards into a black or dark greyish brown, variably mottled, gritty sandy silt loam or sandy loam, the Eg horizon. Mottling is mostly subdued and greyish brown, although ochreous and reddish mottles are present in some profiles. Often stones, which are common in this horizon, are soft and strongly weathered. Bleached sand grains can be present. Cultivation, as on Rye Down has mixed the Oh horizon with all or part of the Eg. A thin ironpan [Bf horizon] underlying the Eg horizon, and fluctuating between 20-45 cm depth, is diagnostic of the Hexworthy series; where that is absent the Rough Tor series is recognised. Fragments of ironpan can also become incorporated in the plough layer. In the Hexworthy series there can be a concentration of roots immediately above the ironpan. Below this is an ochreous Bs horizon of gritty sandy silt loan or sandy loam, becoming browner and paler and usually stonier below about 45 cm depth. Below 60-70 cm this passes to pale brown material of the BC horizon. Typically, where unlimed, pH in most of the profile is around 4.0 [strongly acid], rising to around 5.0 [moderately acid] in the BC horizon.

The hydrology of these soils is unusual. Surface wetness above the Bs horizon is marked in some profiles, less so in others, but is not evident lower in the soil. The most obviously wet areas [in parts of fields 1, 7 and 11, as listed above], in the sense of "walking wet" and poaching risk after wet weather, are those with peaty rather than humose topsoil textures. The combination of the surface organic matter, ironpan [when present] and rainfall amounts mean that for much the year infiltration from the surface is slow enough to show as gleying in the subsurface Eb horizon. Below that soil colours confirm that there they are well aerated and freely draining.

Hexworthy / Rough Tor soils on the south western granites, as well as related stagnopodzols on slate uplands such as Exmoor and St Breock Downs, have varying thicknesses and amounts of surface organic matter. This primarily tends to build up with climatic severity and increasing altitude. At their lower junction with Moor Gate and similar soils, the peaty, or humose surface horizons are often least well developed. As altitude increases and the true [thicker than 40 cm] peat soils are approached, the peaty tops of Hexworthy series etc. start to approach that thickness.

The effects of human activity, however, can add complications. On the inherently thinner peaty tops at lower levels, agricultural reclamation by cultivation, inducing mixing with underlying mineral horizons and spontaneous oxidation, plus any paring and burning, have exaggerated the natural differences. In places peat has been removed by cutting or turbary.

Soil structure:

Soil structural aggregation in the surface layers of Hexworthy / Rough Tor soils in farmed grassland is usually a reflection of timeliness of use, since it is readily damaged by stocking or traffic in moist and wet conditions. The peaty-topped profiles are particularly vulnerable. Subsequent recovery without cultivation is likely to be slow and dependent on avoidance of further damage. Where undamaged moderate or strongly developed subangular blocky structure forms, but will be replaced by less well developed, angular blocky aggregates if poached. Subsequent recovery is much slower than in the freely draining soils because of soil wetness and reduced earthworm populations. Below the plough layer moderately or weakly developed, medium or fine subangular aggregates are usual in the Eg; in the Bs moderately or weakly developed crumb or fine subangular blocky. Commonly the BC is structureless or has very weakly developed aggregates, although sporadic development of platy structure was reported in the Camelford area, (Staines, 1976).

Subsidiary soils of the map unit:

Within the map unit sporadic profiles of soils described elsewhere in this section were recognised. These include Moor Gate, Laployd and Lustleigh series. Inclusions of Moor Gate series have been noted in New Coombe Park and Well Park and the north of Long Park at Watt's Penquite. Examples of Laployd series were apparent in the lower parts of the map unit in Best's Coombe Park, while sporadic Lustleigh series profiles occur in the Reclaimed Common and the south east of Rye Down.

In Little Down a few profiles of Princetown series, a stagnohumic gley soil, are included. These have similar Ah or Oh surface horizons to Hexworthy and Rough Tor series, as well as mottled subsurface Eg horizons. Textures too are similar. However podzolic horizons are absent and the mottling penetrates deeper into the subsoil. In some profiles, intermediate between Princetown and Rough Tor, the upper subsoil is suffused with very fine rusty and ochreous mottles. Princetown soils, although permeable in the mineral soil, are waterlogged for long periods in winter due to the water retentive surface soil. Elsewhere on Bodmin Moor and Dartmoor Princetown soils are an important element in the hydrological sequence, or catena, of soils on granite. In that, as altitude increases and climate becomes more severe, Princetown soils often gradually replace the stagnopodzols of the Hexworthy and Rough Tor series, before themselves passing into blanket peat.

In bouldery areas, including the very narrow, steep bluff immediately above the river in Great Down Plantation, shallow humic rankers, comprised of a thin layer of peat, humus or humose sandy silt loam form over granite boulders or rock.

Hexworthy and Rough Tor series are waterlogged in the upper horizons for part of the winter, but are rarely so deeper in the subsoil. In the Hexworthy series this wetness can be partly explained by the presence of the ironpan, an effective barrier to deeper infiltration. In the Rough Tor series, which lacks an ironpan, explanation has to be solely in terms of the effect of the acid peaty or humose surface. This, in conjunction with the high rainfall and limited biological activity, forms an anaerobic sponge on top of the soil profile.

Considered in terms of their overall distribution on the granite outcrops, Hexworthy / Rough Tor soils at South Penquite are close to the lower altitudinal limit of their range. With increasing altitude the thickness of surface peat and organic horizons increases steadily. In places this reaches the 40 cm minimal thickness limit for peat soils. In places on Dartmoor, where a greater altitudinal range exists, podzolic features, such as Eg horizons and ironpans, are present beneath the Crowdy soils in the blanket peat. Conversely in some lower lying locations, which are obviously more favourable for agricultural reclamation, the already weakly developed organic horizon will have been quickly degraded by repeated cultivation or beat burning.

3.5 Laployd Map Unit

Laployd soils, although mostly intrinsically permeable, are severely waterlogged and strongly affected by groundwater. They are largely confined to the gently sloping footslope along the southern boundary of the farm, with small, additional outlying patches near Delford Bridge and Best's Penquite in Well Park and Well Garden. Overall the map unit covers about 3 hectares. Similar soils are widespread in flushed basins on the granite outcrops of Cornwall and Devon.

Soil profile:

In the Laployd series the surface horizon comprises 10-20 cm of amorphous peat [Oh horizon] or humose sandy silt loam [Ah], which is usually stoneless or only slightly stony. Rusty mottles are commonplace, particularly on root channels and structure faces. The topsoil overlies a grey or strongly mottled subsoil [Bg horizon] of gritty sandy silt loam, sandy loam or loamy sand texture. Matrix and mottle colours interchange between grey, yellow and ochreous hues. Locally reddish mottles are evident. Mottling persists to depth into the growan [BCg horizon]. Surface peat development and gleying, expressed by mottling, in all horizons of the Laployd profiles, reflect the exclusion of air brought about by nearly continual waterlogging. Subsoil textures in this map unit are more variable than in the other soils of South Penquite, and occasional heavier, clay loam or silty clay loam bands are present. The subsoil becomes increasingly stony with depth. Laployd profiles are naturally moderately or strongly acid.

In the Reclaimed Common peaty topsoils are mostly in the rushy, southern part of the map unit separation, profiles in its northern half tending to be humose. This may be an inherent soil difference or it may be an artifact of cultivation of ground that has had effective pipe drainage.

Soil structure:

Because of the prolonged wetness affecting these soils surface structure is easily damaged in the event of mistimed stocking or traffic. The wetness also increases the risk of such mistiming. In the lightly stocked land in South's Baker's Park, used for camping, the loamy peat topsoil has strongly developed fine subangular structure. The subsoil Bg horizon can be structureless and massive or have some weakly developed prismatic aggregates, which break into fine angular blocks.

Subsidiary soils of the map unit:

Within the Laployd map unit are inclusions of peat thicker than 40 cm [Crowdy series], also occasional profiles of mineral soils with non-humose surface horizons. Where heavier subsoil horizons occur, these may be sufficiently impermeable to impede movement of groundwater and cause some additional surface wetness. In one or two places [South's Baker's Park, Moor Meadow and the Reclaimed Common] drainage is likely to have been attempted in the past. Where there is sufficient outfall and area of land to warrant the effort, the permeable Laployd soils should be responsive to pipe drainage.

3.6 Crowdy Map Unit

Strongly acid peat soils, developed in small, spring-fed pockets along the southern edge of the farm, make up the Crowdy map unit, which covers about 2 hectares. On Bodmin Moor it is most commonly developed in valley bogs and flushes, whereas on Dartmoor it forms blanket bog at higher altitude.

The Crowdy series is an amorphous peat soil at least 40 cm thick and, at times, up to 1 m deep over mineral substrates. The peaty soil horizons are usually black or dark brown, and may include thin, semi-fibrous bands. pH in the peat is often less than 4.0, rising only slightly above that in any mineral subsoil. A few profiles of fibrous peat soils [Winter Hill series] were recognised during the survey. In Moor Meadow some artificial drainage may have been carried out.

3.7 Mixed Soils in Alluvium

The De Lank alluvium involves about 2 hectares of the farm. It largely comprises a more or less sandy, relatively stone-free upper layer, over gravel and boulders at variable depths below about 40 cm. The soils vary in their expression of wetness, since the depth to the permanent groundwater table varies from place to place. At the widest point on the floodplain, at the northernmost part of the farm, the floodplain has a fairly uniform surface. South westward, immediately north of Long Down, there is more diversity, with a raised levee and sunken backland. These features are reflected in the soils, hydrology and vegetation, with groundwater being nearest the surface in the backlands, indeed forming a persistent pool in the winter, but considerably deeper on the levee. The more or less freely draining levee soils support bracken, whereas the backland has rushes and other wet-tolerant vegetation. Further downstream, apart from 2 minor widenings at SX1070 7478 and SX1038 7459, the floodplain is rarely more than 6 m wide, often less than 2 m and in several places absent.

Soil profiles:

Many of the soils have humose, sandy loam topsoil Ah horizons. In some profiles this rests on brown sandy loam or loamy sand of a subsurface Bw horizon, with mottling developing below about 50 cm depth, before passing downward to gravel. In others, the humose sandy loam persists to depth. This may reflect the widespread disturbance higher in the catchment due to tinning, turbury, etc over the centuries. In the backland area north of Long Down plantation, gleying [mottling and grey subsoil matrix colour] affects all the profile, reflecting the relatively high groundwater-table and lower lying position. Also soil textures are heavier [sandy silt loam or clay loam]. This is explicable as floodwater remains there longer, allowing time for finer sediment to be deposited. In contrast the levee receives floodwater only in the height of a flood and no more than the coarser part of the suspension and saltation loads can be deposited there.

3.8 Disturbed Ground

This comprises quarries at SX1020 7544, SX1024 7536 and SX1035 7523, quarry spoil around SX1027 7525, all on the valley side in Watt's Coombe and the Coombe facing De Lank quarry, recent mounds of soil in the north east corner of Well Park and on the south side of South's Baker's Park, ground dug over during tin stream working near Delford Bridge and the incline and dressing area and associated structures around SX1042 7513. In total the disturbed ground covers about 2 hectares. Where earthy materials are involved in the disturbed ground, they are considered as forms of *man-made soils.*

Insufficient time has elapsed for significant soil development, even on the rare, gentler slopes in the quarried areas, although pioneering vegetation development is evident in places. Some overburden appears to have been mounded on the edges of the gullet quarries at SX1020 7544 and SX1024 7536. The spoil around SX1027 7525, an area of man-made clitter, is made up of very coarse, angular granite blocks, among which some shrubs and trees have managed to establish.

The mounds in fields South's Baker's and Well Parks are thoroughly mixed Moretonhampstead soils, growan and builders' rubble, including concrete and slate [shillot] stones, excavated during recent building work at the farmstead. Elsewhere there are several heaps of boulders, many near field boundaries, resulting from 20th century stone clearance.

The streamworks near Delford Bridge involved progressive excavation of the earthy upper layers and underlying gravels of the De Lank alluvium in the search for tin, followed by backfilling of homogenised spoil. This has left a series of linear channels and gravely heaps, as well as areas of more or less flat ground. Although there has been insufficient time for soil formation since working ceased, the disturbance has created a range of hydrological contrasts in these man-made soils.

The incline / dressing area appears to have been constructed by excavation of the soil and underlying growan from the east side, with filling or dumping 3-5 m to the west. Again there has been insufficient time for significant soil formation in the filled material, although vegetation has established well in the area as a whole.

3.9 Soils of the Field Boundaries

There are around 15 km of field boundaries on South Penquite. Dudley (2005) notes that the most extensive are stone-faced, earth-cored walls [Cornish hedges] and stone-faced earth banks, many of which still form field boundaries. In addition there are stony banks [in places incorporating boulders placed vertically] and scarps within the Bronze Age field system, dry-stone walls, plus modern post and wire fences bounding recent enclosures.

Dudley (2005) describes the Cornish hedges as stone-faced, earth walls having vertical faces up to 1.6 m high and 2 m at the base, with shallow ditches extending 1 m or so out from the base. Accepting variability in height, width and cross section, they are likely to have an overall surface area of a few hectares. For that alone their properties as soils deserve examination.

Added to that, the hedge banks are distinctive in their structure, shape and management and provide a range of ecological niches that are not present in the fields they enclose. Constructed of soil dug from the shallow, flanking ditches, with their sides commonly stone faced, they are elevated above the field soil level, giving an extra freeboard of good natural drainage. They represent a special form of *man-made soils.* As field boundaries in places they carry some shrubs and trees and so have had a different vegetation cover and history; they have been less subjected to compaction by stock and machinery or disturbance by cultivation or fertiliser and lime applications.

Examination of the soils of the hedges and banks was carried out, largely by augering [to avoid damage], as part of this survey at 22 representative points in the farmed area. The Hedge Importance Test [HIT] assessment [www.cornishhedges.co.uk] was also carried out over 30 m lengths at these sites. The hedge banks appear to have been constructed with soil dug from the shallow trenches, a metre or so wide, which often flank them. In many instances the bulk of the soil used appears to have been topsoil. No doubt from time to time the same source has served during repair. At sites of relatively modern reinstatement soil may have been brought short distances.

Soil profiles:

Colour of the banks surface soil reflects that of the nearby *in situ* soil, although locally a few cm of slightly darker surface material occurs. In most cases soil texture is sandy silt loam throughout, much as is most of the undisturbed, natural soil mantle. Where the surrounding soils are humose or organic, this is reflected in the hedge bank's composition. Stone content within the banks is not dissimilar to that of the natural soil, although of course many have continuous external stone facings.

In some cases lighter coloured, subsoil material is encountered towards the centre or base of the hedges and banks, but only occasionally, as in the relatively modern one along the road at Kerrow Down, does subsoil appear to comprise a large part of the structure. Pre-existing soil beneath the hedge bank was identified at a number of places, most often away from Moretonhampstead soils of the medieval and Bronze Age fields. The soil in the hedge banks is moderately or strongly acid, somewhat more acid than that of the fields. Further information on this is in the section and appendix on soil acidity below.

Soil structure:

A striking feature of the soil in the hedge banks is the strong development of fine to medium granular structure in the upper 40-50 cm and also behind the stone and turf facings. Consistence of this soil is either loose or of weak soil strength. Deeper into the banks aggregation is usually less clearly developed and consistence firmer. Substantial voids, some of which are clearly rabbit burrows, are commonplace.

Stones facing the hedges' and banks' sides penetrate variable distances into them. Usually nearer the base, where boulders and larger stones have been used, this penetration is greatest. Higher up it is often a distance of 20-30 cm.

To ensure stability the stonework is battered, usually at 60-80°, while the higher courses are pitched vertically to encourage interlocking.

Collapses of the stone facings and bank sides are not unusual, partly caused by burrowing and by stock walking on the bank tops. This produces a gentler, scree-like slope of fallen stone and soil at the foot of the hedge bank, which, with time, becomes grassed over. Some of the scars left by stone and soil falls remain bare, as stock use them as “sheep scrapes” or routes across the banks.

On most of the hedge banks the vegetation cover is grassy, often grazed as closely as the adjacent pasture, although in places the growth is sufficiently rank to conceal the stone facing. It is worth noting that, with exceptions, there is no continuous cover of woody shrubs, bushes and small trees that would form a stock-proof barrier, as would be usually understood as the description of a hedge, and is widely found on the hedge banks on the slate [shillot] lowlands nearby. On about a quarter of them there is significant growth [in terms of the HIT classification this amounts to more than 25%] of shrubs, bushes or small trees, mostly gorse or hawthorn. Tall trees [greater than about 5 m] were present at 3 of the 22 sites where HIT assessments were made. In a few places small trees and bushes have grown alongside the hedge banks.

	Height [cm]	**Height difference across the bank [cm]**	**Top width [cm]**	**Base width [cm]**	**Batter angle°**
Number of observations	45	22	16	14	41
Range	50 - 200	0 - 55	50 - 250	150 - 280	40° - 85°
Median	120	20	100	192	65°
Mean	119	23	104	205	63°
Commonest	130 *[13 cases]*	10 *[6 cases] N.B. No difference in 3 cases*	Not appropriate	Not appropriate	80°, 70°, 65°, 45° *[7 cases each]*

Table 1: Summary of the form of hedge banks measured at South Penquite

Dudley (2005) distinguishes the Cornish hedges from asymmetrical stone-faced earth banks. These have vertical, stoned faces external to the enclosure facing out to the common land, with a ramped slope within it. Where the stock-proof function of either type continues, they are usually topped with galvanised sheep netting supported by wooden posts. Elsewhere breaches and degraded sections are not uncommon and are often lengthy. Dudley also notes drystone walls, which, with exceptions, function as repairs or blockages to established hedge banks. In the Bronze Age field systems the degraded and breached banks vary in height up to about 70 cm and are marked by occasional large, upright stones. In places they have been worn down to low ridges, with the pasture passing over, with little or no change in its character.

Tithe apportionment details quoted by Dudley (2005, Appendix 9) show a total of 5.46 acres of hedges in 227 acres [92 ha] of land. It can be assumed that this area is in plan [i.e. the tithe surveyor will have conventionally measured their extent *horizontally* on the drawing]. However, further allowances need to be made for the near vertical faces of the Cornish hedges and banks.

Applying the mean values of batter angle, base width, top width and vertical height in Table 1, the area needs multiplying by 1.77. This takes the total surface area of tithe survey hedges to 9.64 acres or 3.90 hectares [about 4.25% of the farm]. There has been a slight reduction in the farm size since 1840, now it is around 81 ha; [with the loss of Penquite Marsh and 2 fields at Best's Penquite amounting to 8.5 ha and a gain of about 2.5 ha in the Reclaimed Common, south of Stone Park]. Together these figures suggest that the surface area of hedgebanks at South Penquite is around 3.4 hectares.

3.10 Identification Key for Soil Series Formed over Granite:

The key is intended to help the non-specialist differentiate between soil series. On the left are listed successive choices, with, on the right, either numbered steps to then follow, or the soil series name obtained by the elimination procedure. Important terms are marked by an asterisk and are explained in the glossary below.

Mineral soils	**1**
Peat* soils [i.e. peat thicker than 40 cm]	**10**
I soils with dark brown topsoil	**2**
soils with black, humose* or peaty topsoils	**3**
2 soils with brightly coloured subsoil immediately beneath the topsoil, unmottled to depth	MORETONHAMPSTEAD
with greyish mottles below 40 cm	LUSTLEIGH
3 soils with podzolic features*	**4**
soils without podzolic features*	**7**
4 podzolic soils with mottled* subsurface	**5**
podzolic soils without mottled* subsurface	**6**
5 with thin ironpan*	HEXWORTHY
without ironpan*	ROUGH TOR
6 with humus enriched subsoil*	Trink
without humus enriched subsoil	Bodafon
7 with greyish mottles above 40 cm	**9**
unmottled and with orange subsoil	MOOR GATE
9 in basins and flushes	LAPLOYD
on hill crests and gentle slopes	Princetown
10 Amorphous peat*	CROWDY
Fibrous peat*	Winter Hill

Glossary of terms used in the identification key

Bleached subsurface horizon: Light grey mineral horizon which may be mottled. The paleness is due to loss of organic matter and iron.

brightly coloured subsoil: Comprising the strong brown [orange] reddish yellow and yellowish brown of the Munsell Soil Color charts.

Humose: Dark soil with a smooth or silky feel, the organic matter content being intermediate between that of peat and mineral soil material.

Humus enriched subsoil: Dark subsoil horizon containing redeposited organic matter

Ironpan: A reddish brown band a few millimetres thick, enriched with iron and carbon and forming a barrier to roots and water. It occurs in podzolic soils beneath a bleached subsurface layer.

Mottled: With spots or blotches of colour of varying intensity, commonly the result of periodic waterlogging. Most commonly such mottles are greyish, reddish or yellowish.

Peat: Dark, organic soil material derived from plant remains formed or deposited under water or under very acid conditions. *Amorphous* peat is usually black and decomposed without recognisable plant remains. *Fibrous* peat has less decomposed material and is usually browner or lighter in colour.

Podzolic features: Combination of bleached subsurface with brightly coloured subsoil, or thin ironpan, or humus-enriched subsoil.

3.11 Soils of South Penquite and their Wider Distribution on Bodmin Moor and Other Granite Outcrops

The pattern of soils on the granite uplands forms a topographic sequence, or *catena*. This is brought about by differences in altitude, related rainfall and severity of climate, with slope in places playing a part. The granite soils from the Isles of Scilly to Dartmoor are mapped on the National Soil Map and described in detail in Findlay *et al*. (1984). Soils on granite have been mapped in detail on 28 km^2 of northern Bodmin Moor (Staines, 1976), a similar sized area around Moretonhampstead (Clayden, 1971), and about 15 km^2 in both the Hayle district (Staines, 1979) and on southern Dartmoor (Harrod *et al.,* (1976).

Over most of the altitudinal range gritty sandy loam or sandy silt loam soils are weathered directly in granite residues, such as growan. However, increasing altitude is matched by the gradual development of peat. At first it is only a few cm thick and may be partly mixed with mineral soil, but forms blanket bog on the highest land.

In relatively dry, lower districts, usually in medieval enclosures, on both steep and more gently sloping land, freely draining *brown podzolic* Moretonhampstead soils predominate. They cover relatively extensive tracts on the Land's End granite and on eastern Dartmoor, rarely extending much above the 1400 mm annual rainfall isohyet. Around the moorland margins Moor Gate soils, with their humose topsoils, mark the first stage in organic matter accumulation, but remain essentially freely drained. Moor Gate soils also cover some steeper slopes higher on the moorland.

On the moors *ironpan stagnopodzols,* the Hexworthy soils, have ironpans in the subsoil and show subsurface wetness, which increases with altitude, along with a thickening of surface peat. Rough Tor soils are similar but lack the ironpan. On the lower ground the peat on Hexworthy / Rough Tor soils is often thin and may have been degraded by cultivation mixing it with the mineral subsoil. Higher up the peat can be up to 35 cm thick. On the gentler ridges Hexworthy / Rough Tor soils give way to Princetown *stagnohumic gley* soils at 300-400 m O.D. on Bodmin Moor and Dartmoor. Princetown soils have peaty surface horizons over strongly gleyed subsurface horizons. The catena is completed only on Dartmoor. There blanket peat [40+ cm] forms above about 450 m O.D. and 2,000 mm annual rainfall. The amorphous peat, Crowdy soils are most widespread, although where the peat is still growing and is fibrous, Winter Hill soils are shown on the soil map.

In basin sites and along the valley bottoms flushes of groundwater produce wet mineral *[humic gley]* Laployd soils, with Crowdy and Winter Hill peat soils in the deeper valley bogs.

4 SOILS' RESPONSES TO CLIMATE

Leading up to the 1970s agricultural meteorologists developed a number of concepts derived from basic meteorological data that permit quantification of the way crops, soils, the management, [or abuse], of both and the environment, all interact in their responses to weather and climate. Among these were ideas such as *potential transpiration, soil moisture deficit, meteorological field capacity* and *hydrologically significant rainfall*. At the same time at the Soil Survey Arthur Thomasson and Bob Jones were developing ways of rating different soils' reactions to seasonal changes of moisture conditions, culminating in the concepts of *good machinery work days, crop-adjusted soil available water, soil droughtiness classes* and *crop-adjusted soil moisture deficits.* More extended discussion can be found in Findlay *et al.* (1984) p20-7 and 59-66.

Potential transpiration is defined as the amount of water transpired by an actively growing green crop, completely shading the ground and having adequate moisture supply. It is derived by the Penman formula using data on temperature, humidity and wind speed.

Soil moisture deficit is a measure of the amount of water lost from the soil by transpiration by plants and evaporation, offset by moisture provided by the soil and by rainfall during the period being considered. As temperatures rise in the spring, potential transpiration exceeds rainfall in April or May in the average year and the soil moisture deficit develops. It accumulates through the summer, peaking before rainfall increases and temperatures fall in the autumn. Thereafter rainfall normally exceeds transpiration and soil moisture reserves are replenished. Once that is complete the soil is at *field capacity.*

Thereafter, until spring brings the next season's moisture deficit, any rain will fall on soil already at field capacity during the *field capacity period*. It will be *hydrologically significant rainfall*, exceeding storage capability and will run off the surface, flow laterally through the soil or rapidly percolate to the groundwater-table, as well as being available to leach nutrients and cations from the soil.

For many purposes meteorological models of these concepts, assuming a single standard soil, are adequate. In detail, soil moisture deficit and field capacity are modified by the soil, with deeper soils storing more water than shallow ones. Different crops have different growth and transpirational patterns; grass contrasting with spring-sown crops, as an example.

The south west often sees a rapid change in late summer and autumn from moisture deficit to a return of field capacity and wetter as the rains break. The field capacity period at South Penquite starts about 20th August on average and lasts for about 275 days, with hydrologically significant rainfall of the order of 920 mm. In the average year the soil moisture deficit starts its development around 22nd May. In the wet year in 4 late summer return to field capacity will have happened here by early August, while in the wet spring in 4 the formation of a soil moisture deficit is delayed well into June. At South Penquite it is not unusual for summer rain to be sufficient to bring temporary returns to field capacity.

Of the criteria developed by Jones and Thomasson, the idea of *good machinery work days* is useful in the context of the present report. The concept applies weightings [in days], which are added or subtracted to the baseline dates of the mean start in autumn of the field capacity period and at its end in spring. The weightings depend on the soils' texture and profile hydrology. Wet, difficult soils have negative weightings and as well as being vulnerable throughout the field capacity season, their unsuitability extends some way beyond it. By contrast, freely draining soils can be worked in rain-free interludes during the field capacity period; they receive positive weightings accordingly.

Good machinery work days assessment was originally conceived for the evaluation of ease of cultivation of different soils on arable land and in different districts. It does, in addition, give a measure of how much soils are susceptible to structural damage, not just by ill-timed cultivation, but also by stocking, as well as by traffic, as in applications of manure.

However, for grassland in an area with high rainfall, a modification of the approach seems appropriate. By applying Jones and Thomasson's weightings to meteorological field capacity dates, the summer *safe grazing period*, with minimal risk of structural damage by stock or traffic, can be quantified.

Table 2 does this, along with good machinery workdays. It illustrates the vulnerability of all the soils at South Penquite, where even the freely draining Moretonhampstead and Moor Gate soils are at risk of damage for two thirds of the year, while the other soils have very limited periods when not open to structural degradation. Crowdy soils are perennially vulnerable, with the Laployd series little better. It should be born in mind that poaching damage on such land will be a feature of almost any rural land system involving grazing, whether that be agriculture, or with semi-natural or even primeval vegetation cover. Consequently poaching may not only have to be accepted, but valued as a necessary part of the system, as it adds ecological niches.

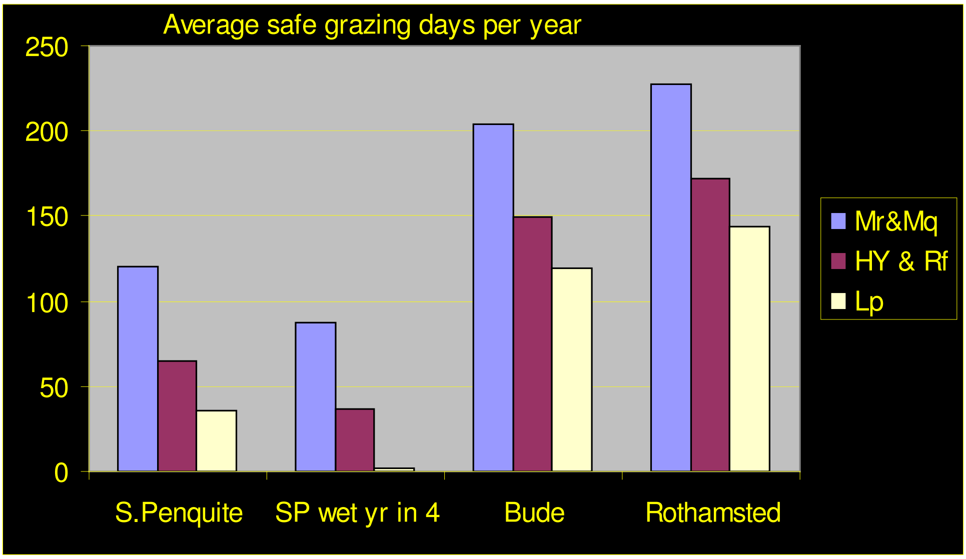
On grassland the consequences of stocking and trafficking other than in the safe grazing period are soil compaction and poaching. From this there comes a resultant reduction in infiltration of rain and commensurate increases in overland flow, which is more likely to be sediment charged. By turn surface wetness is increased, adding to the risk of further degradation. Depression of grass yield and quality and increased opportunities for colonisation by weed species are additional penalties. Compaction is known to have a detrimental effect on beneficial, near-surface living earthworms, and it is likely to have similar consequences for other soil invertebrates by drastically reducing the number of coarse pores. It will also produce a wetter and less well aerated microclimate within the soil. By contrast under semi-natural vegetation some poaching of naturally wet soils may be acceptable, if not desirable.

The figuresin Table 2 for good machinery work days demonstrate the limited opportunities for arable work, being largely confined to autumn or summer cultivation of the Moretonhampstead and Moor Gate soils. Comparisons with figures for Bude and Rothamsted reiterate the consequences of South Penquite's severe climate, particularly the rainfall regime, and its impact on the soils.

	Moretonhampstead & Moor Gate series	**Hexworthy and Rough Tor series**	**Laployd series**	**Crowdy series**
Safe Grazing Days				
South Penquite [FC days = 275]	120 [87]*	65 [32]*	35 [2]*	0
Bude [FC days = 191]	204	149	119	-
Rothamsted [FC days =168]	227	172	144	-
Autumn good machinery work days				
South Penquite	20	0	0	0
Bude	58	33	0	-
Rothamsted	80	56	21	-
Spring good machinery work days				
South Penquite	0	0	0	0
Bude	13	0	0	-
Rothamsted	22	7	0	-

* Bracketed figures are for the wet year in 4.

Table 2: Safe grazing days and good machinery work days at South Penquite, Bude and Rothamsted



Mr = Moretonhampstead series; Mq = Moor gate series; Hy = Hexworthy series; Rf = Rough Tor series; Lp = Laployd series

5 SOME ENVIRONMENTAL ASPECTS OF SOILS

The part played by soils in the water environment was alluded to in the introduction, together with mention of the importance of interactions between soils and land management and their responses to seasonal weather patterns, along with perturbations of these.

5.1 Soil Structure and Hydrological Degradation

There has been concern nationally that changes in late 20th century methods in both grassland and arable farming were having deleterious environmental effects, not least an increase in rapid runoff responses to rainfall. Consequently the Environment Agency commissioned a survey of soil structural conditions across the Camel catchment, including the De Lank basin, (Palmer 2005). Observations were at an overall density of about 1.5 / km^2, but with 6 on this farm. Palmer's work indicated that overstocking of much of the moorland had resulted in soil structural degradation sufficient to seriously reduce infiltration of rainwater and increase surface run-off. Depending on the site, degradation affected between 50 and 100% of the land inspected. On enclosed land nearly 40% of the soils examined were similarly damaged.

As part of the current soil survey of South Penquite a more detailed investigation of soil structural condition was carried out, using Palmer's methodology. This involves excavation of small pits approximately 40 x 40 x 40 cm at sites chosen to sample the diversity of soil and management conditions across the field. In recording soil properties from the pits particular reference is made to pertinent permanent soil properties as well as more transient conditions, using the criteria and terminology of Hodgson (1997). Included are: soil surface form and condition; topsoil depth; soil texture, colour, stoniness, moisture status, structure; anomalous vertical moisture gradients. Together these are indicators of the severity, or otherwise of any structural degradation of the soil and land. Attribution to classes of soil degradation follows the defining features for grassland in Table 3, which is derived from Palmer's (2005) Table 3.

Since the inherent composition of the soil, summarised in the soil series and map unit descriptions set out above, determine the overall morphological and hydrological context, the soil series at each observation pit was confirmed by augering in its base to below 40 cm.

Degradation class	Hydrological implications	Soil degradation features
Severe [S]	Soil degradation generates sufficient enhanced runoff [overland flow] to cause widespread erosion that is not confined to wheelings.	Extensive rill erosion on slopes, depositional fans on footslopes and level ground. Plus most characteristics of the High degradation class.
High [H]	Soil degradation generates enhanced runoff [overland flow] across whole fields where slopes allow.	Extensively poached surface or wheelings 5 cm or deeper; damage to topsoil or immediate subsurface structure *[apedal* or *weak coarse angular blocky structure];* change in vertical wetness gradient.
Moderate [M]	Soil degradation generates localised areas of enhanced runoff [overland flow] where slopes allow.	Slightly poached [locally severe]; weak subsurface structure / compaction
Low [L]	Insignificant enhanced runoff generation	Few signs of enhanced runoff mechanisms present, but can show signs of localised poaching and standing water as long as whole profile maintains a good soil structure.

Table 3: Soil degradation classes and their defining features under grassland [after Palmer (2005), Table 3].

Easting	Northing	Field	Soil	Degradation	Topsoil structure	Subsoil structure	Wetness gradient	Vegetation / crop	Comment
1095	7542	Rye Down [w]	Hy / rF	moderate	wfsab	massive	man ind'c'd	p grass	
1100	7542	Rye Down [w]	Hy / rF	moderate	wfsab	massive	ac'nt'ted	p grass	Massive 0-3cm
1104	7553	Rye Down [w]	Princetown	mod-low	wfsab	massive	typical	p grass	
1101	7571	Great Down	Hy / rF	moderate	**m**mab	massive	typical	bracken	
1095	7562	Great Down	rF	moderate	**m**fsab	wsab	ac'nt'ted	p grass	wet to 2cm
1095	7758	Little Down	rF or mQ	moderate	**m**fsab	massive	ac'nt'ted	p grass	wet in top
1106	7562	Long Down	Hy	moderate	**m**fsab	wfsab	typical	p grass	wet in top cm
1107	7581	Floodplain	dry alluvium	moderate	wcsab	single grain	ac'nt'ted?	bracken	
1057	7542	Higher Abovetown	Mr	low	sfsab	wfsab	typical	p grass	
1047	7546	Watt's Coombe Pk	Mr or mQ	low-mod	sfsab	wfab	ac'nt'ted?	bracken	
1034	7549	Watt's Coombe Pk	Mr	low-mod	**m**fab	wfab	ac'nt'ted?	bracken	
1058	7559	Crooked Park	Mr	low	**m**fsab	wfsab	typical	grass+br'k'n	
1063	7549	Broad Lane	rF	high	wfsab	wab	typical	p grass	poached
1077	7557	Watt's Bovetown	Mr	low	sfsab	**m**fg	typical	p grass	
1085	7569	Watt's Long Park	Gunnislake	low	sfsab	**m**fsab	typical	p grass	
1042	7553	Watt's Coombe	Mr or mQ	low - mod	**m**fsab*	sfsab	typical	grass+br'k'n	*weak in top 3cm
1062	7568	Stepfield	mQ	moderate	sfsab	**m**mab	ac'nt'ted?	oak wood	steep;top = 5cm
1039	7560	Watt's Coombe	Bodafon?	moderate	c&vcab	massive	ac'nt'ted?	bracken	steep
1031	7553	Watt's Coombe	Bodafon?	moderate	smab	massive	ac'nt'ted?	br'k;n+mol	
1069	7489	Lower Ground	Laployd	low	sfsab	wmab	typical	p grass	camping
1118	7591	Rye Down [nw]	Hy	low	**m**fsab	wsab	typical	mol+br'k'n	
1110	7532	Down Park	Mr	low	sfsab	wfg	typical	p grass	
1098	7533	Borough Park	Mr	low	sfsab	**m**fg	typical	p grass	
1121	7534	Rye Down [s]	mQ	low	sfsab	**m**fsab	typical	p grass	
1114	7542	Rye Down [s]	mQ	low	sfsab	indeterm'	typical	p grass	stony
1112	7551	Rye Down [s]	Hy	low-mod*	**m**-sfsab	wfsab	typical	p grass	*weak in top 2cm
1118	7550	Rye Down [s]	mQ-Hy	low	sfsab	wfsab	typical	p grass	
1114	7559	Rye Down [c]	Mq or rF	low	**m**fsab	wfsab	typical	p grass	
1129	7560	Rye Down [c]	mQ	low	sfsab	wfsab	typical	p grass	
1130	7570	Rye Down [c]	mQ	low	**m**-sfsab	wfsab	typical	p grass	

1123	7576	Rye Down [n]	rF	low	sfsab	wfsab	typical	p grass	
1125	7589	Rye Down [n]	?	low	sfsab	Indeterm'	typical	p grass	stony
1133	7585	Rye Down [n]	Hy	low	sfsab	wfsab	typical	p grass	
1088	7533	Best's Long Park	Mr	low	sfsab	**m**fg	typical	p grass	
1078	7526	Best's Long Park	Mr	low	**m**fsab	indeterm'	typical	p grass	stony
1069	7536	Harper's Down	Mr	low-mod*	**m**fsab	wfab	typical	p grass	*0-2cm weak
1072	7541	Harper's Down	Hy	high	wfsab	wfab	man ind'c'd	rushy grass	poached
1088	7541	Harper's Down	Hy,rF,Pc	high	wfab	vwfab	man ind'c'd	p grass	poached
1030	7541	Watt's Coombe	mQ	low-mod	**m**fsab	wfsab	ac'nt'ted?	mol+br'k'n	10cm top
1055	7513	Rounda Park	Mr	low-mod	wfsab	wfsab	man ind'c'd	p grass	0-1cm apedal
1067	7527	Great-a-Park	Mr	low-mod	**m**fsab	wfsab	typical	p grass	0-1cm apedal
1118	7521	Recl'd Common	Hy or rF	low	**m**fsab	wab	typical	p grass	
1090	7525	Great Abovetown	Mr	low-mod	**m**fsab	wab	man ind'c'd	p grass	slight poaching
1101	7508	Middle Park	Mr	low	**m**-sfsab	wfab	typical	p grass	slight poaching
1109	7512	Recl'd Common	Laployd	moderate	**m**fsab	wfab	man ind'c'd	p grass	water on surface
1113	7508	Recl'd Common	Laployd	moderate	**m**fg	massive	man ind'c'd	rushy grass	water on surface
1069	7506	South Park	Mr	low	**m**fsab	wfsab	typical	p grass	
1079	7514	South's Long Park	Mr	low	**m**fsab	wfab	typical	p grass	
1050	7491	Best's Coombe Pk	rF	low-mod	sfsab*	wmsab	typical	rushy grass	*0-2cm weak
1038	7492	Coombe [se]	? Rocky	moderate	**m**mab	indeterm'	ac'nt'ted?	bracken	rock at 20cm

Table 4: Soil degradation assessments at South Penquite

Abbreviations used in Table 4
Fields or parts of fields [column 3]: Recl'd = Reclaimed; n = north; c = central; s = south; w = west; se = south east; nw = north west.
Soil series [column 4]: Mr = Moretonhampstead; mQ = Moor Gate; Hy = Hexworthy; rF = Rough Tor; Pc = Princetown
Structure [columns 6 & 7]: [a] development: s = strongly; **m** = moderately; w = weakly. *[b] size:* f = fine; m = medium; c = coarse. *[c] shape:* ab =angular blocky; sab = subangular blocky; g = granular. **N.B. *** indicates reference across to column 10.
Wetness gradient [column 8]: man ind'c'd = management induced; ac'nt'ted = accentuated
Vegetation / crop [column 9]: p = permanent [grass]; mol = *Molinia;* br'k'n = bracken.

The soil structural assessments, summarised in Table 4, show at the time they were made [November and December 2005] that, with exceptions, on much of South Penquite the level of soil structural degradation was low. This is partly attributable to the freely draining nature of the extensive Moretonhampstead and Moor Gate soils and their resilience in restructuring after poaching and other damage. The extent of these soils also means that it should be possible to keep stock and traffic away from the more susceptible soils at wet times and through the winter. Nevertheless out-wintering of stock is likely to bring some structural deterioration, particularly around feeding sites, even on the freely draining land. It must also be kept in mind that the assessments, although carried out after the soils had returned to field capacity, followed the relatively dry winter of 2004-5.

The most severe degradation is on the wet, peaty topped soil of the Hexworthy /Rough Tor map unit on the highest part of Harper's Down. Much of the damage is residual from poaching at an earlier time, with the sward having recolonised the hummocks and poach holes. However, if stock continue to be allowed access to this ground this winter, further degradation will ensue. Immediately north of this Hexworthy /Rough Tor soils in Broad Lane have similar damage, along with rutting.

To the east in Little Down, again on Hexworthy /Rough Tor soils, there is moderate degradation. This is expressed as weakly developed or massive structure in the surface and subsurface, along with either management induced or accentuated wetness gradients.

The vulnerable, groundwater-affected Laployd soils in the Reclaimed Common show moderate degradation, mainly as surface waterlogging and poaching by sheep. By contrast soil of the same series in the camping site [Lower Ground] shows little sign of damage. As Laployd soils abut watercourses any serious poaching has implications for stream water quality.

A number of sites under bracken are listed in Table 4 as moderately or low to moderately degraded. They are on the floodplain north of Long Down plantation, in the Watt's Coombe Park, Stepfield, Watt's Coombe and the south east of the Coombe. There is some uncertainty concerning the interpretation of soil structure and its relationship with management induced soil degradation. Conditions at these sites may be residual from heavy stocking in the past, or may be a reflection of the soil structure that is most likely to develop under bracken, particularly where grass growth has been suppressed or eliminated. Whereas grass roots are commonly very fine [<1 mm} and abundant [> 20 / cm ^{2}] in grassland topsoils, bracken rhizomes are usually very coarse [>10 mm] and much further apart. On the basis of size and distribution it seems likely that grass roots will encourage the development of very fine grades of structure, whereas coarser, more angular aggregates might be expected around bracken rhizomes.

Much of the land in the freely draining Moretonhampstead and Moor Gate map units is undegraded. However, some slight damage occurs in Fern Park, in parts of South's Long Park, in Great-a-Park and in Great Abovetown. This mainly has the form of weakly developed structure in the surface 1-3 cm or widespread slight poaching. Such mild damage is the consequence of winter stocking of these soils, which are the most robust on the farm. At the time of the structural assessments field feeding of out-wintering cattle was only beginning. More severe, albeit localised, damage is likely to occur at feeding sites used during wet spells. Moretonhampstead and Moor Gate soils can be expected to show some resilience under grass, with structural damage recovering relatively rapidly, once the grazing pressure is removed, probably as a consequence of their high earthworm activity and free drainage. Where excessive demands are made of the soil, its structural degradation is inevitable. Coupled with the morphology and hydrology of the soil, meteorological conditions define the circumstances in which the land is used. How climate and weather interact with the soils at South Penquite is discussed above in section 4 and set out in Table 2. This graphically illustrates the background of risk of structural damage, not only between the soils of the farm, but in regional and national senses too.

5.2 Hydrology And Soils

The Institute of Hydrology's report No. 126 (Boorman *et al.* 1995) states that "*it is difficult to overstate the importance of soils in influencing hydrological phenomena at both the site and catchment scale………… most of this [soil information] needs interpretation before it can be readily used by hydrologists."* That report produced a classification *"The hydrology of soil types"* [HOST], which forms a framework for understanding the place of soils in hydrology.

HOST uses 3 physical contexts for soils, and where apt, their substrates:

- soil on a permeable substrate with a deep aquifer or groundwater at >2 m depth,
- soil on a permeable substrate in which there is normally a shallow water table at <2 m,
- a soil [or soil and substrate] which contains an impermeable or semi permeable layer within 1 m of the surface.

Different soil properties [e.g. a peaty top] and wetness regimes [as indicated by gleying] are applied to these 3 physical contexts, giving 11 HOST *models.* Other properties, such as substrate geology, subdivide the 11 models into 29 HOST *classes.* The classification applied to the soils at South Penquite is given in Table 5.

Applying the classification nationally to gauged catchment data on *base flow* index and *standard percentage run-off,* Boorman *et al.* (1995) produced average data of these core parameters for all HOST classes. Table 5 contains the relevant values for South Penquite's soils.

The classes occurring here are defined as follows:

- 4: *no impermeable or gleyed layer within 100 cm over substrate that is strongly consolidated, non or slightly porous, by-pass flow common*
- 10: *gleyed within 40cm over substrate with groundwater or aquifer at < 2 m*
- 11: *drained peat soils with groundwater normally present < 2 m*
- 12: *undrained peat soils with groundwater present < 2 m*
- 13: g*leyed layer at 40-100 cm over substrate that is strongly consolidated, non or slightly porous, by-pass flow common*
- 14: *gleyed within 40 cm with groundwater or aquifer present at > 2m*
- 15: *peat soils with groundwater or aquifer present at > 2m*

The Hexworthy / Rough Tor map unit is classified as HOST 14 or 15 because of the range of its surface textures from humose sandy silt loam [class 14] to peat [class 15]. The Crowdy peat soils are placed in classes 11 and 12 to cover drained and undrained soils respectively.

Soil Map Unit	HOST class	Base flow index	Standard percentage run-off
Moretonhampstead	**4**	0.790	2.0
Moor Gate	**4**	0.790	2.0
Lustleigh	**13**	1.005	2.0
Hexworthy / Rough Tor	**14** or **15**	0.219 or 0.387	25.3 or 48.4
Laployd	**10**	0.437	25.3
Crowdy	**11** or **12**	0.838 or 0.092	2.0 or 60.0
Soils in alluvium	**10**	0.437	25.3

Table 5: The HOST classification of soils at South Penquite

Base flow indeces close to 1.0 indicate that all water movement goes to groundwater, only feeding river flow after substantial delay. Lower index amounts are measures of partition of water between movement to groundwater and more rapid, shallow or surface flow. Conversely the standard run-off percentages illustrate nationally measured and modelled proportions of movement as overland flow or shallow, lateral flow during storms.

The base flow values of class 4 are probably reduced by being nationally derived, and so including freely draining arable soils, which often suffer surface damage in cultivation. This will cause some overland flow, depressing the national base flow index in such soils. Such distortion will only pertain in severely poached grassland soils and base flow indeces for Moretonhampstead and Moor Gate soils at South Penquite are likely to approach closely to the value of 1.0.

5.3 Groundwater Vulnerability

Physical and chemical properties of soils, along with the characteristics of the underlying rocks in the unsaturated zone above the groundwater in an aquifer, influence the vulnerability of that groundwater to contamination from diffuse and point source pollutants discharged into or onto the land. The variably permeable Bodmin Moor granite functions as an aquifer.

A national Groundwater Vulnerability classification has been applied in east Cornwall by the Environment Agency (1997). This assesses soil properties which affect the downward passage of water and pollutants. These include texture and organic matter content, structure, soil wetness [water regime] and depth. The soil classification is then overlain on a geological classification. For this purpose variability in fissuring and fracturing in the granite mean that it is classified as a *minor aquifer*.

Moretonhampstead soils are classified as being of *High Leaching Potential,[class H3],* that is with little ability to attenuate diffusely sourced pollutants. Any non-adsorbed pollutants and liquid discharges are likely to move rapidly into the underlying rock or shallow groundwater. This is attributable to the soil's coarse texture. Limited clay and organic matter content provide just a modest ability to attenuate adsorbed contaminants.

In view of their more organic surface layers Moor Gate soils have a somewhat larger [moderate] capacity for attenuation of readily adsorbed pollutants, although less easily adsorbed materials may penetrate the soil layer. Consequently Moor Gate soils are classified as *Intermediate Leaching Potential [class I2].*

Included in soils of *Low Leaching Potential [class L]* are the Hexworthy, Rough Tor, Laployd and Crowdy series. High organic matter mean that adsorption potential is high, while, particularly in the wetter soils, water movement is largely lateral. It should, however, be recognised that any lateral flow from such soils will enter watercourses or contribute to groundwater elsewhere.

5.4 Soil Acidity

All of the soils here are naturally acid, thanks to parent material with little clay and low base status and high rainfall. During this survey topsoil pH was measured at about 5cm depth at around 50 points, along with 18 hedge bank sites. The results are presented as Appendix 1 and are summarised in Table 6 below.

	Permanent grass	**Semi-natural**
n	27	16
Range	4.8 – 6.9	3.9 – 5.2
Median	5.4	4.3
Mean	5.4	4.4

Table 6: summary of pH values

The values for semi-natural sites show that naturally the soils are moderately [5 out of 16 are between pH 4.6 and 5.5] or strongly acid [11 out of 16 have pH between 3.6 and 4.5]. Similar reactions are likely to have prevailed over the farmed areas before human intervention in the form of liming or spreading of ash following paring and burning.

The most acidic sites are on the Moor Gate and Moretonhampstead soils. Reactions of pH 3.9 and 4.1 were obtained on the steep ground in Stepfield and Watt's Coombe, partly under oak trees [a few with evidence of coppicing] with bracken, *Molinia* and *Vaccinium* beneath. In the Bronze Age field system, where there is vigorous bracken growth, pH was similarly strongly acid [4.0 and 4.2], as was the topsoil in enclosure 7 [pH 4.1] under *Molinia* and bracken and on the bracken-dominated, alluvial levee in north of Long Down [pH 4.3].

In current enclosure 20,[Best's Coombe Park, New Coombe Park, Well Park and the south eastern part of the Coombe, in the south west of the farm, reaction was mostly moderately acid. pH of 4.6 and 4.7 in the peat of the Crowdy map unit may be slightly modified by the powerful influence of ground water there. The slightly lower value [4.4] on a tussock there is of interest. Parts of this enclosure may have had agricultural "improvement" in the past, as the pH of 5.2 suggests.

By contrast the farmed soils are generally about a pH unit higher, most are moderately acid [19 out of 27], with a minority slightly acid [5] or neutral [2]. Although South Penquite has not received lime or inorganic fertilisers for many years, there is clearly a residual effect of them on much of the permanent pasture. The last fertiliser dressing likely to have had any residual effect on pH was of calcified seaweed to much of the northern part of Rye Down in about 1995, although calcareous north coast sea sand is used as a substrate beneath straw bedding for winter-housed stock. Its subsequent spreading is likely to raise pH on the treated land. Low pH values for 2 sites in parts of Harper's Down and the Reclaimed Common, where wetness is likely to have restricted access by spreaders, were excluded from the summary as anomalous outliers. Both had pH values of 4.8. Similarly excluded was the value for a mound top, possibly a degraded anthill, with pH 4.3, in Long Down. The "normal" soil near to this was pH 5.1.

From the figures in the appendix, Great Park clearly stands out, having the 2 neutral values [pH 6.7 and 6.9]. In the north facing Great and Long Downs and the northern Coombe Park pH is generally lower than on the fields nearer to the farmstead. Aerial photographs from 1946 and 1988 suggest that at these times this relatively remote land, with the exception of that immediately next to Watt's Penquite, was less intensively farmed.

Historically the agricultural performance of granite soils was transformed by the application of lime, to bring soil pH close to the neutral values optimal for most grass and crop growth. Earlier the practice of paring and burning may have had an effect through the scattering of ash [alkaline in reaction]. Lime was first provided as calcareous sea sand and is known to have been used on and around Bodmin Moor in the 19th century [P. Herring, personal communication]. Later, with mechanised transport, burnt and later ground limestone was also used. In the decades of subsidised farming, from the Second World War until the 1970s, substantial payments towards lime dressings were available to farmers. With the removal of the subsidy and the decline in the profitability of farming, lime spreading has largely ceased in upland areas. South Penquite has not been limed for many years. This alone will have reduced agricultural production as soil pH will have declined. This might eventually turn out to be a matter of some environmental concern if it contributes to depression of pH in stream and groundwaters.

The strongly acid pH in the Bronze Age field system suggests that it has been treated quite separately in the past; that no attempt has been made to bring this area of Moretonhampstead soils into productive agricultural use. This is understandable from the modern view points of mechanised farming and the institutionalised recognition of the heritage value of such sites. For the modern farmer the combination of numerous man-made scarps, stone lines and circles with natural boulderiness, would seriously inhibit access for spreading. However before mechanisation in the mid 20th century lime and fertilisers were widely spread “by hand”, when boulders would have been less inhibiting. One explanation for the “neglect” of the area may be long-term cultural memory or respect for such sites.

18 pH measurements were made on hedge banks. They ranged between 4.1 and 5.4, with median and mean values of 4.7.

5.5 Soils And Ecology; Some Examples

The broad physical and chemical properties of the soils are given above in the map unit descriptions and are summarised in the map’s key. The soils, along with climate and land management, provide both opportunities and limitations for plant and animal life. This framework is helpful in not only understanding the present landscape, its ecology, biodiversity and landuse, but in reconstruction of past patterns and in considering future directions for sustainable management. The following comments are by no means comprehensive, but summarise observations made during the survey.

Several examples of the influences of soil conditions on flora and fauna at South Penquite are discussed below. Some will have relevance at a wider scale on the granite and other upland landscapes. Others, no doubt, would emerge, at various scales, were further investigations undertaken. For example recent work at University College, Dublin has shown distinctive microbial assemblages on each of the different minerals, [quartz, mica and feldspar], making up an outcrop of granite. At the national scale the NSRI’s soilscapes map matches the distribution of hoverflies across England and Wales more closely than land-cover [vegetation and cropping] data at the equivalent scale.

5.5.1 Soils and semi-natural vegetation

Agricultural grassland dominates much of the farm. However parts of all the main soil map units have areas with semi-natural vegetation, although most of these have experienced some forms of pressure from agriculture. That has varied in intensity and form, involving particularly grazing, poaching, cutting and burning, with liming, fertilising and cultivation affecting parts of the peripheries of the semi-natural sites. Agriculture has favoured the freely draining soils, at least where slope and boulders have not restricted use. Where these, along with soil wetness, are present, forms of semi-natural vegetation survive.

The heathy bog community on the Crowdy soils in the south east of the Coombe and in the eastern end of the southern Coombe Park is distinctive, and contrast with the rushy grassland on the same soil in Moor Meadow. Similarly there are contrasts on the Laployd soils, between sites with semi-natural vegetation and the farmed land. There some of the ground is obviously wet, with thick rush growth, in other parts, thanks either to slight hydrological differences, artificial drainage or other agricultural management, the inherent wetness is less obvious, at least at dry times. The Crowdy and Laployd soils, with the wet backlands on the river alluvium, form the main areas of wetland on the farm. Prior to the advent of agricultural enclosure these soils would have formed a strip of basin peat and bog, as still exist along many of the valley floors and lower slopes across Bodmin Moor.

As noted early in section 2.4, indicator plant species and agricultural “weeds” can prove useful in soil mapping. Although most useful on farmland they are by no means universally present there, indeed traditionally their suppression has been an important objective for many farmers. Prominent plants indicating wetness are more numerous than those suggesting free drainage. Various rush species often betray wet soils, as does marsh thistle, willow and silverweed. Less prominent, but still favouring wet sites, are plants such as sedges, cuckoo flower and marsh cudweed. Creeping thistle particularly, and bracken, are the most obvious indicators of good soil drainage. Bracken can be the less robust as an indicator, but it is only where drainage is at its most free that it grows to its greatest height and density. Others such as purple moor grass, ling and the heathers indicate acidity.

Links between indicator species and soils can help explain some of the diversity, particularly on the farmed land, within vegetation classes, such as those described in the NVC study by French (2006). As French notes, only with exceptions are there close correlations between the *communities* that the NVC defines and the soils at South Penquite. In most cases these exceptions are communities, such as the mires and rush pastures, associated with the wet Laployd and Crowdy soils in the south of the farm. Additionally the peaty topped Hexworthy / Rough Tor soils on the higher parts of Harper’s Down and Little Down [French’s NVC compartments 15, 15a, 16a and 32b] are grasslands, containing many wetland plants, fitting either NVC communities U4 or U5 or not matching any NVC type, as in compartment 15.

The main grassland community mapped by French at South Penquite, MG6 and including subcommunity MG6b, occur on Moretonhampstead, Moor Gate, Hexworthy / Rough Tor and Laployd soils. The most extensive soil, the Moretonhampstead series, is freely draining and so pastures on it are least likely to be poached and deteriorate agriculturally. Their floristic condition is no doubt helped by the closeness of many of the fields with these soils to the farmstead, so that they have attracted greater returns of nutrients in farmyard manure etc. Creeping thistle is often evident on these fields. The Moor Gate soils on Rye Down have similar characteristics in their profile drainage. Where the community overlies Laployd soils in the Reclaimed Common and parts of Baker's Park [NVC community 30] French's records of bird's-foot-trefoil, oval sedge and marsh thistle reflect the soil's wetness. Similarly wetness indicators are present in the [marginal] MG6b pastures in Long Down and the western "panhandle" of Rye Down [French's compartments 33 and 34].

The groundwater affected soils, the Laployd and Crowdy map units, plus parts of the alluvial soils and the leats or trenches in the tin streamed areas, in places contain ponds and ditches. Some of these are perennial, others are seasonal.

Vegetation growth patterns show some contrasts between pastures on the freely draining soils and the wetter ground. Early spring growth is more forward on the drier land, which however is more prone to checking in dry spells in summer. The later start on the wet soils is probably attributable to denitrification, following the stimulation of microbial activity in still waterlogged soil by rising temperatures.

Across the moors of south west England stagnopodzols, including the Hexworthy /Rough Tor soils, more than any other soil, carry heather moorland. At South Penquite semi-natural vegetation on the soil map unit, just above the river in the north of Rye Down, facing West Rose, and in Coombe Park, New Coombe Park and the adjoining land in the south east of the Coombe, comprises mosaics of grasses [some introduced by agriculture], gorse, bracken, *Molinia* and bramble. On the farmed grassland the limited, wetter areas on this soil map unit are marked by poaching, spear thistle and sporadic rush. The 1946 aerial photography shows these soils having only lightly grazed vegetation with numerous gorse bushes on Little and Great Down,Broad Lane and Crooked Park, most of Rye Down, plus Well Park, Coombe Park, New Coombe Park and the contiguous part of the south east of the Coombe. More widely on Bodmin Moor these soils support grassland, in places with heather and gorse, in others where grazing or burning has suppressed the heather, dominated by *Molinia,* The link between Hexworthy /Rough Tor soils and the long-term evolution of moorland boundaries is discussed in section 5.6 below.

The freely draining Moor Gate and Moretonhampstead soils, particularly where steep or bouldery, have substantial areas with semi-natural vegetation in the north and west of the farm, much of it dominated by bracken. As well as grassy ground flora, particularly found in the Bronze Age enclosures, gorse, bramble and *Molinia* are present widely. Bracken also picks out the better draining ground on the limited areas of floodplain levee. Patches of bracken have invaded some of the grazed fields of the farm on Moretonhampstead soils, where creeping thistle is a common weed. The latter is in line with the widespread westcountry adage that good land has "*dashals"* and [formerly] elm trees. The small area of open oak woodland on the steep ground in Stepfield has a few old coppiced trees and an under-storey with bracken,wood rush and *Vaccinium.* Accentuated acidification of the soil beneath old coppiced oakwood is widespread in western Britain, where coppicing was an essential part of the rural economy both for oak bark [for tannin] and for timbers, for centuries, only ceasing in the 20th century. Interestingly rentals for gorse-covered ground matched those for coppices, gorse faggots being used domestically, including in bread ovens. Beyond the farm boundaries on Bodmin Moor these better drained Moretonhampstead and Moor Gate soils have bent-fescue grassland, which, as on South Penquite, can be invaded by bracken.

5.5.2 Soils and fauna

Links between fauna and soils are, with exceptions, indirect. Where they can be demonstrated, as in the following examples, soil hydrology plays an important part. The only open ground well suited for deeply burrowing mammals is in the Moretonhampstead and Moor Gate map units, where there is minimal risk of flooding. There is an obvious attraction in the hedge banks for rabbits and badgers, enabling them to establish burrows and setts in areas of otherwise ill-suited locations. The Moretonhampstead and Moor Gate soils, particularly on the farmed land, contain numerous deeply burrowing earthworms. While present on the other, wetter soils, either on farmed land or in fields reverting to semi-natural vegetation, earthworm numbers are smaller and their penetration into the soil shallower.

Other than earthworms, occasional unidentified larvae and ants [at one point on Rye Down] were the only invertebrates encountered in this soil survey. Soil-living fauna has not been studied in this group of investigations at South Penquite. It may form a worthwhile future project, as would other studies of soil biology.

Alexander's (2006) survey of terrestrial invertebrates at South Penquite notes the Cornish hedges and banks as the most extensive important habitat throughout the farm. This contrasts with the more intensively farmed fields, where there is least diversity of invertebrates. He earmarks the wetlands on Crowdy soils in the south east of the Coombe and the rushy pasture on Laployd soils at the south end of the Reclaimed Common as key habitats, noting some correlations with the soils. Both contain invertebrate assemblages of mire and rush pasture type. Some of these wetland invertebrates are also found in the wet higher part of Harper's Down on peaty topped Hexworthy / Rough Tor soils. The wet soils, similar to many traditional west country "snipe moors" are likely to attract waders, although compaction of these soils by ill-timed grazing is likely to make the soil less attractive, as well as affecting invertebrates in the soil. Wet ground, such as that on these soils, provides a habitat for molluscs carrying fluke.

The low mounds in Long Down around 1105 7563 are of interest, with perhaps the appearance of degraded anthills. They are mostly roughly circular, 30-40 cm across, 15-25 cm high and 1-1.5 m apart.

5.5.3 Soils and economic use

The land at South Penquite although acidic and of moderate depth, has a moist climate, encouraging substantial growth of grass or other biomass. Only Moretonhampstead and Moor Gate soils have the potential for utilisation of the growth without serious damage to the soil and sward. Even so substantial areas are restricted by boulders and steep slopes, along with the archaeological importance of the Bronze Age field system in Watt's Coombe Park. Where practicable the potential of these soils can be enhanced if pH is maintained near to neutral. Their utilisation with stock or machinery is easier on these soils than any others on the farm due to the good natural drainage, although figures in Table 4 show that for two thirds of the year even these soils can be damaged. This relative resilience almost inevitably leads to their preferential use during winter, with the risk of poaching and compaction damaging both the soil and sward.

The agricultural potential of the rest of the farm is, to various degrees, limited by the wetness of the ground, which restrict the grazing or harvesting of grass or other crops.

Although light textured and easily worked, the arable potential of even the freely draining soils is very limited, due to climatic conditions. However, there might be potential on them for small-scale, specialist organic enterprises benefiting from geographical isolation, such as seed potato growing.

5.6 Evolution of the Soils within and around the Medieval Fields at South Penquite

South Penquite, with average annual rainfall around 1400 mm, appears to be close to a regional threshold, where the change from mineral surface horizons to humose topsoils takes place. Moretonhampstead soils here are distinct from the rest of the farm by having non-humose surface [Ap] horizons. With the exception of an area around the Bronze Age hut circles, north of Best's Penquite, they fall largely within the medieval, or possibly older, field systems. Frequently abrupt soil boundaries with adjoining humose-topped soils follow the hedge bank at the edge of the fields.

Dudley (2005,Figs. 8 and 9) shows the distribution of The Bronze Age and medieval field systems. Several areas, such as Watt's Abovetown and South Park and Rounda Park west of South Penquite farmstead, have no attribution, although Dudley notes that the field systems at South and Best's Penquite may have incorporated and fossilised a more extensive older system.

This raises the question of whether the land was enclosed by picking out already more favourable, non-humose and possibly less acid soils, or whether subsequent farming practices have removed the humose topsoils. If the former, then the boundary was unusually abrupt and the enclosers' eyes for it very astute. If the latter, then residual organic topsoils beneath the hedgebanks might be expected. Also there is the possibility that subsequent vegetation cover and landuse practices outside the enclosures have encouraged build up of soil organic matter and podzolisation there.

There are numerous historical accounts of medieval and pre 20th century agriculture, which refer to the practice variously termed “beat burning”, “denshuring” or “paring and burning”. The latter best describes what happened, with upper soil layers pared or ploughed off, left to dry, put into windrows and then burned. The ashes were spread on the land, both providing nutrients and an alkaline dressing, which would raise soil pH, further increasing the availability of nutrients. How long this would have been effective for is uncertain, but, bearing in mind the area’s high rainfall and the soil’s limited buffering capacity, probably shorter rather than longer. Although it might be imagined that denshuring would be most effective with organic topsoils, its repeated use would eventually deplete organic matter, while, in terms of nutrient availability, becoming progressively less effective. It could however create Moretonhampstead soils from Moor Gate profiles.

Archaeological and pedological excavation of the hedge banks, and perhaps the weak lynchets at the lower end of some fields, would provide some answers on these aspects of farming practices and soil evolution. These would apply, not only at South Penquite, but more widely, since similarly abrupt soil boundaries mark the junction of moors and medieval enclosures elsewhere on Bodmin Moor, Dartmoor and Exmoor.

The conventional view of post-glacial soil evolution on the south west’s granite uplands, supported by pollen studies, is that the original soils developed under deciduous woodland as freely draining brown earths, similar to Gunnislake series and not so different from Moretonhampstead series. Topsoils, no doubt, had typical woodland features of thin litter, fermentation and humified layers in the upper 10-20 cm. Being poorly buffered and developed on a nutrient-poor parent material, Neolithic and Bronze Age farmers, who cleared the forest, must have found that they quickly declined in fertility. This would have made them ripe for acidification and the invasion by heathy vegetation, which led to podzolization and surface peat formation. Contemporaneous climatic deterioration also played a part.

It might be argued that this suggests fundamental differences between Neolithic and Bronze Age farming practices and those of medieval times. The former seem to have been unable to retain sufficient cations and nutrients in the system, whereas the latter could. Medieval farmers also had the advantage of doing it in relatively low, dry situations.

Interestingly the process has not degraded the bouldery phase of Moretonhampstead soils in the irregular Bronze Age field system north of Best’s Penquite. Perhaps the lower altitude meant that humus accumulation, acidification and podzolization did not occur and agricultural use persisted. However pH there is now strongly acid, close to 4.0. Persistence of, or reversion to deciduous woodland rather than heath could have been another explanation.

The medieval system [Dudley, 2005 pp 25-6] was mixed livestock and arable farming, cultivating strips for 2 or 3 years followed by longer intervals under grass. The, albeit limited, colluvial or lynchet development above the lower hedge banks suggest that cultivation may have taken place over long periods, since the slopes involved are rarely steeper than 3 or 4^{o}. It seems unlikely that on Moretonhampstead soils, with their limited inherent fertility, that this could have continued for long period without adding nutrients. Then, and for most of the period since, there would have been no question of importing these from far outside of the farm.

So how was it done? Cutting of moorland vegetation, such as bracken, for bedding livestock, with subsequent spreading of the spent bedding and faeces on the land is one possible answer. This would amount to “mining” of nutrients from the moorland soils and subsoils. Collection of vegetation from the moor and its burning on the fields, in a modification of beat burning, is perhaps another means. Grazing stock on the moorland and bringing them into the enclosures each night, yet another. The latter, perhaps with the elaboration of housing stock on bracken bedding, may have been necessary, either to conform with the ancient laws of *levancy* and *couchancy,* or simply for protection against predation or theft.

The bringing in of vegetation from the moorland may have helped sustain nutrients on the enclosed land, but at the cost of their loss from the moorland. This may have accelerated acidification and podzolisation there.

Whatever the explanation, medieval farmers and their successors before the ready availability of fertilisers, appear to have found a sustainable farming system on soils that, although freely drained and easy working, have little inherent long-term fertility.

The converse of the close association of the Moretonhampstead soils with the medieval enclosures and the abruptness of boundaries at South Penquite and Watt’s Penquite, is the presence of peaty topped Hexworthy / Rough Tor soils on the ridge crest in Harper’s Down and Little Down, separating the medieval holdings. This must be presumed to have been moorland into the medieval period. Peat development and podzolisation is conventionally taken to have been a post Bronze Age process, i.e. over the last 3,000 years. The medieval fields must have been enclosed within the last 1,600 years, although they may have been superimposed on older fields. The formation of the Hexworthy / Rough Tor stagnopodzols right up to the limits of the old enclosures could be taken as evidence that at least part of their development has occurred after enclosure, possibly in the medieval or later eras. The survival of peat in the stagnopodzol’s topsoils on Harper’s and Little Down suggest that this ridge crest has maintained a distinctive land use history since enclosure. Whether that was purely as a buffer or common between the adjacent farms, or whether there were other cultural reasons, has to be a matter of speculation.

6 RECOMMENDATIONS

South Penquite, is a commercial organic farm with substantial diversity in its soils, ecology and archaeology. Inevitably from time to time there are tensions between land use and environmental concerns. From the standpoints of agriculture, land management, education, the environment and science, it presents both opportunities and dilemmas.

6.1 Educational

- In developing South Penquite's facilities for education and the public understanding of science and rural issues, the role of soils as cultural, scientific and economic resources should be included. That should take in both soil features in their own right, plus their place linking the diversity of the biological, cultural and physical environments. Some examples are:

    - *Soils and parent materials.* There are several points of geomorphological interest. These include the weathering of the granite, by both deep weathering and hydrothermal processes, to form growan, its periglacial redistribution, plus the strong possibility of loessial additions; the numerous boulders on parts of the farm represent "fossilised" periglacial landforms, including emerging tors in Watt's Coombe. On the floodplain levee and backland landforms have developed north of the Long Down plantation, while a nickpoint in the river's thalweg has reached up the valley as far as the small islands in Stepfield.

    - *Soil hydrology.* For much of the year there is self evident wetness in the groundwater affected strip in the south, along with surface wetness due to peat development and climate on Harper's Down / Litttledown. This all contrasts sharply with the near perennial firmness of the freely draining soils. On the floodplain north of Long Down plantation backland wetness contrasts with the drier conditions on the levee.

    - *Ecological responses to soils* are most obvious in the wetland areas in the south, but again the surface wetness on the highest part of the farm in Harper's Down has ecological expression. On the "improved" agricultural ryegrass / crested dog's-tail pastures there are wet tolerant plants on the wet soils. The association of agricultural "neglect", soil acidity and the bracken domination of dry soils in the north west of the farm should not be overlooked.

    - *The association of non-organic topsoils and old enclosures,* which contrasts with the prevalence of organic tops on old moorland, provides a useful demonstration of links between soils and landscape development, however it came about.

   - *Future management of the long farmed, freely draining soils*, as in the medieval enclosures, should agriculture in the upland margins collapse, [see 6.2 below], could be a useful topic for students to consider.

- While this report provides a source of information for education, the diversity of levels likely to be encompassed means there may be a need for a range of interpretations or information packages. These could cover the spectrum from primary schools through to undergraduate level and perhaps CPD for land use professionals, such as ecologists and archaeologists. Dealing with all this will need contributions from teachers, etc.

- An essential first step in this is good illustration of soils; [an undertaking that is beyond the scope of this report]. This could be done using photographs, monoliths or permanent pits / exposures. Each illustrative method has advantages and drawbacks, with time and materials being needed for their preparation, collection and conservation. [Monoliths are permanently preserved soil profile columns about 1 m high, ideally stored under glass].

- It is important that students and the wider public appreciate that the need for farmers to earn livings from the land and the soil inevitably presents tensions and dilemmas when there are also environmental or scientific concerns on their land. Balances need to be struck.

- The farm is a microcosm, not just of much of Bodmin Moor and its margins, but of large parts of the other uplands of south west England, lessons learned here can often be extended more widely there.

6.2 Agricultural and land management

- There will be advantages to animal health, to sustainable agriculture through the quality of the pastures, to the aquatic environment and to soil structure by keeping stock off wet sites. This will help to avoid fluke infestation of livestock, plus the degradation of pasture by poaching and compaction. On an organic farm any reduction of the productivity of pasture is a serious loss, since there is no option of redressing matters by using more fertiliser. However, the floristic and faunal value of the wet pastures depending on a measure of poaching and trampling, presents a dilemma between ecological and agricultural needs.

- Out-wintering of livestock, particularly using ring-feeders, is a widespread and convenient practice. But it damages swards and soils, even on the freely draining Moor Gate and Moretonhampstead soils. Wheel ruts are also widely formed in the process. Convergence of

stock close to the feeders is likely to mean that concentration of urine and faeces takes place there, just where severe poaching has destroyed the sward. Consequently there will be no efficient uptake of the nutrients later; something that is particularly undesirable on an organic farm. Solutions are either:
  - *spot reseeding of ring feeder sites in the spring*
  - *corralling of out wintered stock with adequately absorbent bedding to retain nutrients for later composting and spreading*
  - *or further housing of the livestock [a non-starter?]*

- Links between grazing and the evolution of wetland ecology are widely appreciated and form part of wetland management prescriptions. The avoidance of poaching and compaction is desirable both agriculturally and from the standpoint of stream water quality. Yet this presents a dilemma, as the opposite is true for some ecological considerations.

6.3 Scientific

- Archaeological and soil investigations into the evolution of soils in and out of long established enclosures would be of real interest in understanding more fully the cultural and natural landscapes of both South Penquite and much wider areas of upland margins throughout south west England.

- This survey revealed particular soil structural conditions under bracken, which conventionally would be interpreted as degraded, with apparently obvious implications for run-off and the aquatic environment. This seems anomalous. However it does highlight the need for soundly based values of what bench marks for absence or presence of structural / hydrological degradation can be expected under semi-natural vegetation. [Ultimately reference to what is "natural" has to be part of the reasoning in considering agriculturally induced soil degradation. The Environment Agency has a particular interest in this and it is recommended that it should conduct a review of the issue, if necessary followed by appropriate research.

- As mentioned in 6.2, wet pastures are widely reckoned to be the habitats of the snail hosting liver fluke. However in the parallel study of invertebrates none were identified, yet fluke is present on the farm. A fuller study of the distribution of this mollusc at South Penquite is warranted.
- With the future of agriculture in the upland margins entering a new and very uncertain era, its virtual withdrawal is at least one possibility. Future management of vegetation and landscape on the long farmed, freely draining soils of areas such as the medieval enclosures, should that happen, deserves to be addressed, not just wetland habitats. Is reversion to bracken and gorse the only option?

- This group of scientific projects at South Penquite is unusual for the inclusion of a comprehensive soil study along with others on archaeology, biodiversity and geodiversity. While most aspects of the cultural, physical and biological environments benefit from some form of institutional scientific recognition and consideration, soil seems to have largely slipped through the net. Yet, as this report illustrates, it forms a significant part of the context of all of them, and for the farming that still has to use the land. Further it provides links between disciplines and explanations for what otherwise may seem as anomalies, if not conundrums. For the scientific establishment, plus proposers and funders of projects, robust soil investigations should, in future, form a core part of environmental evaluation.

- Following from this, the nation's lamentable failure over the last 20 years to train a generation of field soil scientists [as noted in appendix 2] cannot pass without comment. There is an urgent need for funding bodies [such as Defra, NERC and the Environment Agency] to put this right before the current generation becomes unable to pass on its hard earned skills and insights.

7 REFERENCES

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8 APPENDICES

8.1 Appendix 1: pH at South Penquite

1] field soils

Easting	Northing	pH	Field name	Soil map unit & *land use* [*unless stated otherwise permanent grass*]
1095	7758	4.8	Little Down	Hexworthy/Rough Tor
1106	7562	5.1	Long Down	Hexworthy/Rough Tor
1105	7563	4.3	Long Down	Hexworthy/Rough Tor; *?anthill?*
1095	7542	5.4	Rye Down [w]	Hexworthy/Rough Tor
1107	7581	4.3	Flood plain	Alluvium; *bracken*
1077	7557	5.4	Bovetown [n]	Moretonhampstead
1085	7569	5.0	Long Park [n]	Moretonhampstead
1063	7549	5.6	Broad Lane	Hexworthy/Rough Tor
1042	7533	5.6	Fern Park	Moretonhampstead
1047	7546	4.0	Co'mbe Park [n]	Moretonhampstead; *bracken*
1039	7549	4.2	Co'mbe Park [n]	Moretonhampstead; *bracken*
1039	7560	4.1	Watt's Coombe	Moor Gate; *bracken*
1031	7553	4.0	Watt's Coombe	Moor Gate; *bracken & Molinia*
1081	7578	4.9	Undertown [n]	Hexworthy/Rough Tor; *bracken*
1043	7533	3.9	Stepfield	Moor Gate; *bracken & Molinia*
1062	7568	4.1	Stepfield	Moor Gate; *oak wood*
1040	7532	3.9	Stepfield	Moor Gate; *oak wood*
1069	7489	5.2	Lower Ground	Laployd
1118	7591	4.1	Rye Down [nw]	Hexworthy/RoughTor; *bracken & Molinia*
1114	7559	5.1	Rye Down [s]	Hexworthy/RoughTor
1114	7542	5.2	Rye Down [s]	Moor Gate
1112	7551	5.4	Rye Down [s]	Hexworthy/RoughTor
1118	7550	5.3	Rye Down [s]	Moor Gate
1129	7560	5.2	Rye Down [c]	Moor Gate
1130	7570	5.4	Rye Down [c]	Moor Gate
1123	7576	5.5	Rye Down [c]	Moor Gate
1125	7589	5.1	Rye Down [n]	Hexworthy/RoughTor
1133	7585	5.0	Rye Down [n]	Moor Gate
1088	7503	5.4	Long Park [c]	Moretonhampstead
1078	7526	5.5	Long Park [c]	Moretonhampstead
1069	7536	5.6	Harper's Down	Moretonhampstead
1072	7541	4.8	Harper's Down	Hexworthy/Rough Tor; *rushes*
1088	7541	5.7	Harper's Down	Hexworthy/Rough Tor
1030	7541	4.5	Watt's Coombe	Moor Gate; *bracken & Molinia*
1055	7513	6.9	Great-a-Park	Moretonhampstead
1067	7527	6.7 (ave of 3 [6.5-7.1])	Great-a-Park	Moretonhampstead
1118	7521	5.2	Recl'd Common	Hexworthy/Rough Tor
1101	7508	5.5	Recl'd Common	Moretonhampstead
1109	7512	5.6	Recl'd Common	Laployd
1113	7508	4.8	Recl'd Common	Laployd; *rushes*
1069	7506	4.9	South Park	Moretonhampstead
1078	7914	5.4	Long Park [s]	Moretonhampstead
1037	7480	4.6	Coombe Park [s]	Crowdy; *Bog*
1043	7484	4.7	Coombe Park [s]	Crowdy; *Bog*
1043	7484	4.4	Coombe Park [s]	Crowdy;*15cm Molinia tussock*
1050	7491	5.2	Potato Plot [s]	Hexworthy/Rough Tor; *rushes*
1038	7492	4.6	New Coombe Pk	Hexworthy/Rough Tor; *bracken*

2] Hedge banks

Easting	Northing	pH
1070	7500	4.1
1084	7517	4.7
1091	7518	4.3
1088	7529	5.0
1069	7532	4.7
1070	7562	4.4
1072	7554	5.1
1066	7488	4.5
1047	7493	5.0
1113	7507	4.5
1115	7534	4.5
1091	7543	5.3
1115	7526	4.7
1121	7520	4.4
1052	7544	5.4
1135	7570	5.1
1138	7580	4.7
1110	7562	4.4

8.2 Appendix 2: History of Soil Science and Soil Surveys

During the Napoleonic Wars the Board of Agriculture conducted surveys of the agriculture of England, county by county. Some of these contained the earliest attempts to map out soils, albeit in very generalised forms and at times using somewhat arcane terminology, such as “tender loams”. An important upshot of the Agrarian and Industrial Revolutions of 200 years ago was the recognition that systematic and scientific approaches to agricultural chemistry could transform crop production. Laws and Gilbert at Rothamsted were leading lights in this in Victorian times. The scientific study of soil profiles [or *pedology*] developed in Russia and the United States in the early 20th century, with the realisation that soil profiles reveal much about the soil’s chemical, physical, biological and environmental development and behaviour. Soil surveying and mapping were obvious extensions of this.

Early soil surveys in the UK concentrated on the chemistry of major nutrients in broad, geologically-defined swathes in several counties, particularly in the south east of England. Overemphasis on geology and chemistry risks obscuring some of the soil contrasts that can occur within one parent material thanks to hydrological differences between sites. In the 1930s mapping of soil series, which began in a few areas, such as the Vale of Evesham, the strawberry growing district near Southampton and north Wales, started to redress this shortcoming. The Soil Survey of England and Wales was established in 1939. It became a department of Rothamsted Experimental Station, for a time funded from the Privy Purse, and later through the Agricultural Research Council.

By the late 1940s soil surveying was taking place in several parts of the country, mainly for a publication scale of 1 inch to the mile. Production of maps at this scale covering several hundred square miles, each by one or two individual surveyors, was time consuming and published maps and memoirs were few and far between until the early 60s. Also the maps tended to be of areas of special interest or around university towns or major NAAS [later ADAS] centres. More systematic distribution of detailed mapping and complete national coverage, were no more than hopeful objectives for the future.

In 1968 soil surveying in England and Wales switched to mapping at the 1:25,000 [2½ inch to the mile] scale, on base maps showing field boundaries. These maps covered 10 x10 km blocks, sited to represent major soil landscapes or land uses county by county. Each of these 10,000 hectares blocks took about 18 months to survey. Writing up and preparation for publication involved similar amounts of time.

In Cornwall the first 2½ inch survey by S.J. Staines was of the Ordnance Survey Camelford map sheet SX18, a few km north of South Penquite. This was chosen to reveal soil patterns on the Bodmin Moor granite and on slates at relatively high altitude and in high rainfall country. The Rough Tor and Crowdy soil series names used in this survey hail from the Camelford survey. Subsequently the horticulturally important Hayle sheet [SW 53] and Lizard peninsula, with its unusual geology, were soil surveyed by Staines. Small portions of 2½ inch soil maps at Tavistock [SX47, -over Palaeozoic slates and the Tavistock Volcanic Group] and Holsworthy [SS30, -on Culm Measures], impinged on east Cornwall.

By this stage ideas about the practical significance of soil information were developing, firstly addressing soil suitability for agriculture, but subsequently for grading for a range of non-agricultural uses. A few examples follow: grading for risk of soil erosion; assessment of corrosion and fracture risk of buried pipes; soil suitability for badger setts [which in Devon explained their distribution better than any other parameter]; appropriateness for septic tank irrigation fields; suitability grading for a wide range of tree species.

Along with the earlier 1 inch scale mapping, the 2½ inch maps gave some understanding of the broad patterns of soil across the landscapes that those maps exemplified. Although the 2½ inch map programme was incomplete, in 1979 the switch was made to a 5 year programme of national mapping for publication at ¼ million [about 1 inch to 4 miles] scale. This proceeded by infilling the gaps [about 75% of the country remained without detailed soil maps] using rapid, reconnaissance methods, surveyors covering 10,000 hectares in 10 days. Mapping in Cornwall by Steve Staines, assisted by David Hogan, David Cope, Graham Colborne and the author, was completed early and Staines transferred to Dorset. By 1984 the 6 regional maps of England and Wales and their explanatory bulletins were published.

The National Soil Map project brought to a head the need to rationalise soil series naming. Traditionally people in the UK have thought of soils in terms of the underlying geology, probably because geological maps were available in this country long before soil mapping started. Differentiation of soil series on the basis of stratigraphic age as well as lithology of parent material was commonplace. There was the realisation that, within definable limits, the lithology of parent material, not its age, was the issue for soils. For example granite is granite, whether of Palaeozoic age [about 290 million years old] on Bodmin Moor or of Tertiary age [roughly 53 million years old] on Lundy. Within a logical framework encompassing all parent materials in the country, rationalisation of the names of soil series on the National Map was a necessity for its coherent description, and, as importantly, for its interpretation for practical uses. Part of that framework was, in the event of several names being candidates, the retention of the series name established earliest; a form of primogeniture.

While soil series rationalisation has minimal effect at South Penquite, at the worst introducing some names from Devon, its impact is evident in Cornwall's shillot country. Welsh series names such as Denbigh, Powys and Manod prevail there. However there is a swing to that particular roundabout, with Crowdy series mapped in the blanket peat of Wales.

The quality of the achievement of a robust National Soil Map was acknowledged internationally. Representatives of sister organisations from Canada, France, New Zealand and Spain were particularly flattering. On the technical side the maps received a national award for their cartographic excellence. The wide use that they are put to in digitised form by scientific modellers etc is further measure of the accomplishment.

The scale of these maps, plus the reconnaissance nature of their production, does mean that they need careful interpretation, with their accompanying bulletins requiring thorough reading. Useful as they are in setting the context of soil patterns, they are not substitutes for detailed soil maps, as in the 2½ inch surveys or in the current work. For example, it has to be appreciated that their map units [*Soil Associations*] are of geographically associated soils, inevitably making their pedological content more diverse than in map units from more detailed surveys. Scale alone also means that proportionally larger inclusions of different soil associations may be concealed within a mapped separation. It is not difficult for the over-enthusiastic user to stretch the ¼ million scale National Soil Map beyond its capabilities.

In 1984 attention returned to completion of detailed mapping, but it was soon clear that previous rates of progress [about 100 surveys at 2½ inch scale had been completed by 1979] were unacceptable. Some 2½ inch mapping continued, but the emphasis changed to semi-detailed surveying of the OS 1:50,000 sheets, with planned completion within 10 years. In east Cornwall the Plymouth and Launceston sheet [Landranger 201] was started, with parts of Bodmin Moor, as far west as Hawk's Tor, mapped. However, sheet 201 was then left, as the author was directed onto 2½ inch mapping in east Devon.

In 1985 the Minister of Agriculture announced the planned closure of the Soil Survey of England and Wales and the end of soil mapping. Lobbying modified this decision to a 3 year taper to the end of funding. There followed the privatisation and transfer in 1987 of the Survey to Cranfield Institute of Technology as the Soil Survey and Land Research Centre. The survival of the organisation can be seen as a victory, yet at the price of redundancy for half the scientific staff, the commensurate dispersal and loss of hard earned skills and experience, but most seriously the effective end of systematic soil surveying in this country.

Remaining staff of the SSLRC had to move quickly into scientific research and consultancy, with much time given over to seeking and winning work; not always the best use of scientists' skills and talents! However, the soil surveyor's unique perspective and insight into land and soils proved to have many practical applications. These came to the fore in seeing land as a component of the wider environment, not just as a medium for agricultural and forestry production. Examples are numerous; a few will suffice. The importance of soil variation in the attenuation of pollutants leaching down to groundwater is one example. The realisation of how much modern farming methods are degrading surface hydrology comes largely from SSLRC work and thinking. The place of soils in the deterioration of buried infrastructure, particularly pipes, has been a field of commercial achievement.

However, because there has been no serious soil surveying for 20 years, and no recruitment of soil surveyors for more than 30, the skills and insights have not been handed down. SSLRC now survives as the National Soil Resources Institute, but young scientist spend too much of their time in the office, at the keyboard. The days of practical year round contact with the land have gone. No more seeing the spectrum of soils, Moretonhampstead series at one end, Crowdy at the other. No more walking them, digging them and augering in them in drought, in flood, and through all the in-betweens; sometimes seeing sympathetic, well-timed farming, at others gross abuse. Soil surveyors and, for that matter, soil scientists, with real field experience, are a dying breed. Coming at a time when increasing stress is placed on environmental and ecological aspects of land use, when informed, lateral thinking becomes at a premium, this failure to pass on the skills is all the more galling.

Still, look on the bright side, this is just a drop in the ocean of infrastructure that's been thrown down the drain. More of us than need it can afford to guzzle gas and burn rubber down to Tesco's in our 4x4s, whether it be a Datsun "*Insult*", Toyota "*Talibanvan*", Seat "*Sin Necesidad*" or Land Rover "*Chelsea Tractor*". Then there's the once a week trip off-roading across the local "Rec", to flog off another boot-full at the "*Loot Launderers 'Я' Us*" car boot sale, followed by the obligatory visit to the car wash and valeting centre.

As many, Bob Dylan included, have said, "*Eden is burning!*"