GROUND MOVEMENT IN VENTNOR, ISLE OF WIGHT

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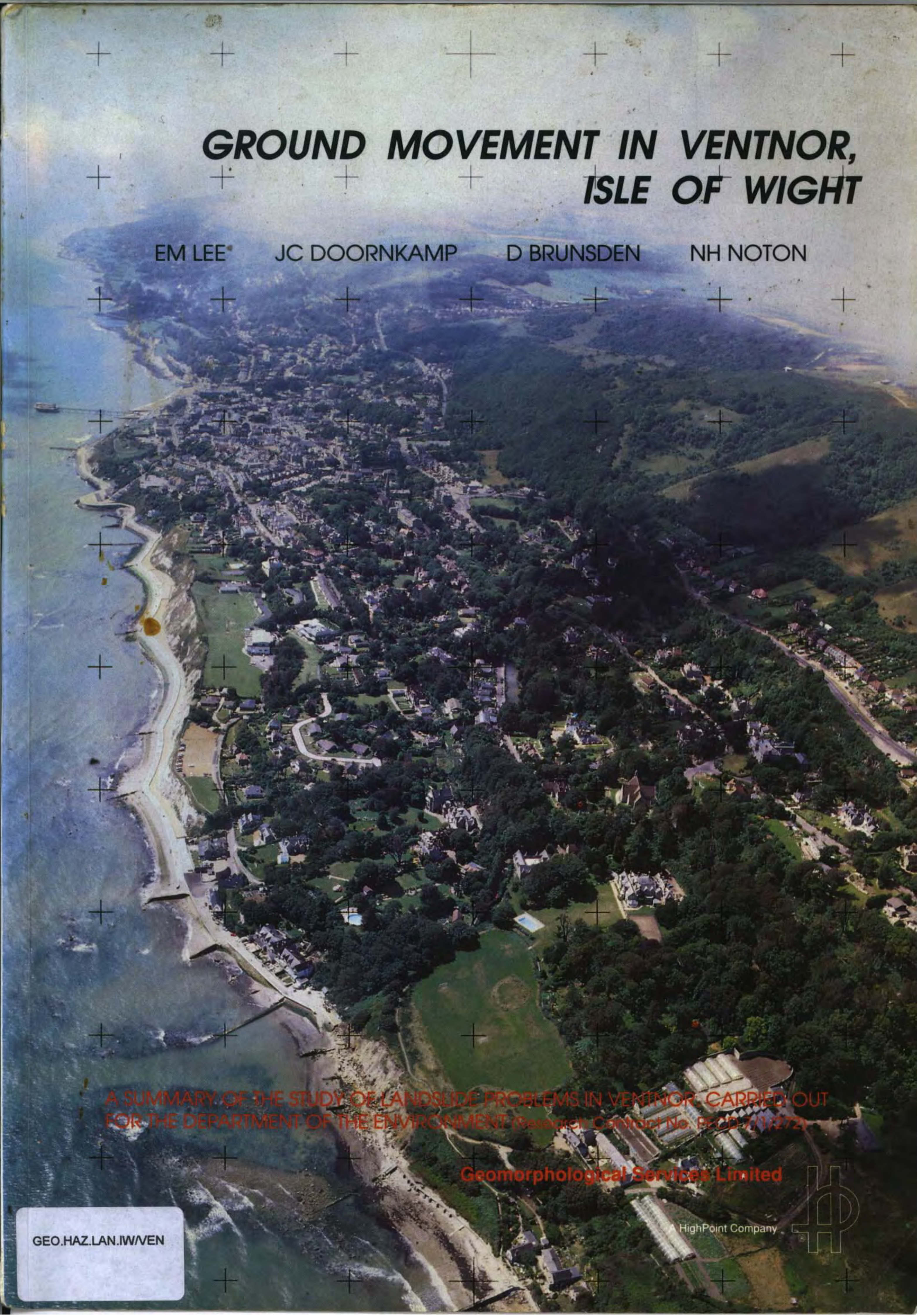

A SUMMARY OF THE STUDY OF LANDSLIDE PROBLEMS IN VENTNOR, CARRIED OUT FOR THE DEPARTMENT OF THE ENVIRONMENT (Research Contract No. PECD 7/1/272)

Geomorphological Services Limited

A HighPoint Company

[redacted]

GROUND MOVEMENT IN VENTNOR, ISLE OF WIGHT

Plate 1: The Landslip, 1810,*".....for three days successively the earth heaved and sank...."* (Adams 1856)

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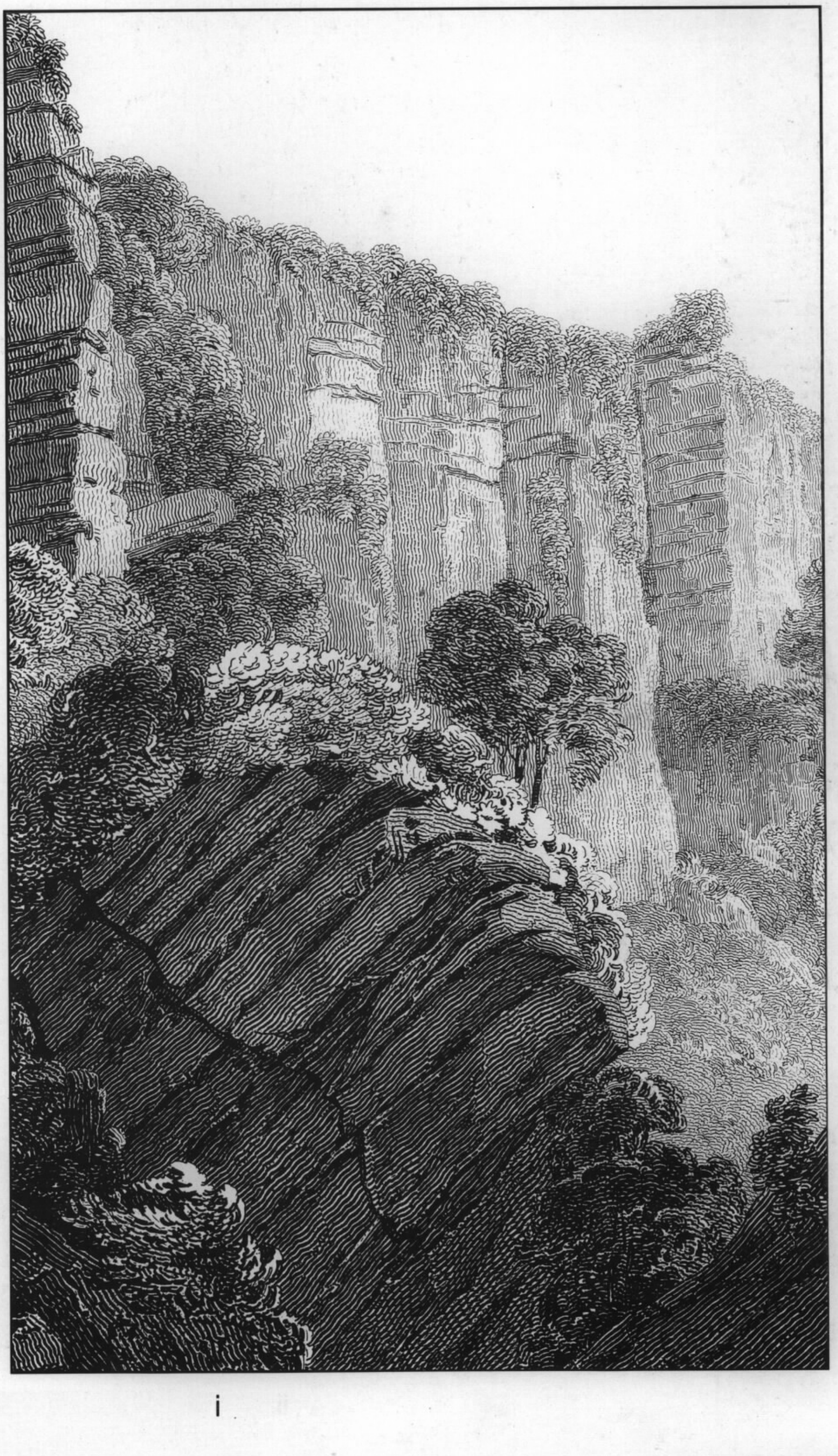

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PREFACE

The Department of the Environment (DoE) undertakes geological and related research as part of its Planning Research Programme, which includes studies of ground instability. Previous research funded by the DoE identified a general need to develop improved methods of landslide hazard and risk assessment in order that land instability can be taken into account in land use planning and development decisions[1].

The DoE therefore commissioned Geomorphological Services Ltd, in association with Building Surveys Ltd and Sir William Halcrow & Partners to carry out a study of landslide potential at Ventnor (DoE Research contract PECD 7/1/272 "Coastal Landslip Potential, Ventnor"). This work was carried out between 1988 and 1991 and involved a review of available records, reports and documents, geomorphological and geological mapping, analytical photogrammetry, a survey of damage caused by ground movement, a land use survey and a review of local building practices.

The results of this study are presented as:

- a technical report;
- a suite of 4, 1:2,500 scale, map sets (each comprising 2 sheets): Land Use, Geomorphology, Ground Behaviour and Planning Guidance

The technical report and accompanying maps can be viewed at, or purchased from South Wight Borough Council, Salisbury Gardens, Ventnor, Isle of Wight.

This publication summarises the results of the DoE study. In order to understand the significance of ground movement in Ventnor, it is necessary to have some appreciation of what is known concerning the scale and impact of past movements. This is covered in Chapter 2. The reasons behind the problem are discussed in Chapter 3, together with a description of the character of the unstable ground. In Chapter 4 the various factors which have caused ground movement in the town are described. A statement on the degree and nature of the hazard faced by the local community is presented in Chapter 5, which is based upon our present understanding of contemporary ground behaviour. Chapters 6 to 11 identify a range of approaches which could be adopted to reduce the hazard or minimise its impact on the town. In the final chapter the need for future monitoring of any further ground movement is assessed.

REFERENCE:

1. Geomorphological Services Limited 1987

CHAPTER 1
WHAT IS THE HISTORY OF GROUND MOVEMENT IN VENTNOR ?

Ground movement has been recognised as a problem in Ventnor for nearly 200 years. Indeed, in his evidence to the Royal Commission on Coast Erosion in 1906, Mr Aubrey Strahan of the Geological Survey provided a clear description of the situation at that time[1]:

> "The movement appears to be continuing ... very slowly. I do not know that in the observation of any one living man these large masses of rock can be seen to have moved, but it is the experience of the surveyor and other officials in Ventnor that flights of steps which are taken straight up and down the cliff have occasionally to be lengthened. The ground by moving downwards leaves gaps in these flights of steps, and they have to put in occasionally a few more steps to complete the staircase."

This study traces the history of ground movement in Ventnor and brings observations up to the present day. Although archaeological finds suggest that ground movements occurred during prehistoric times (see box A), the earliest recorded evidence for movement at Ventnor is provided by Webster in 1816[2]. He noted that in the west of Ventnor Bay a large amount of clay had "slid down, and ..... had occasioned the falling of a part of the sandstone stratum above". Around the same time two major landslides occurred to the east of Bonchurch, in the areas now known as The Landslip. The first, in 1810, may have involved up to 12ha[3] and "for three days successively the earth heaved and sank"[4] (Plate 1). A second and larger landslide occurred in the same area in December 1818, possibly affecting as much as 20ha[3,5]. The next recorded event in Ventnor took place in November 1839 when a large movement occurred, probably along Belgrave Road causing the road to sink 1.5m and a row of cottages to be destroyed[6].

Box A: Archaeological evidence of ground movements

A number of archaeological finds in and around Ventnor provide evidence for a long history of ground movement in the area:

> *along Belgrave Road a number of crushed skeletons (dating from c.300 AD) were found buried by fallen rocks[16,17];*
>
> *in Bonchurch a man's skeleton was found beneath a large rock[18];*
>
> *near the former Ventnor railway station human remains were discovered, in 1910, buried beneath debris[19];*

Plate 2: Within the "graben", roads and hardstandings require regular repair

Reported incidents appear to have increased during the 1870's, when the whole of Devonshire Terrace and a number of properties on the Hamborough Estate (in what is now the La Falaise area) were damaged beyond repair[7]. Further inland, cracking was reported along both Bath Road and Belgrave Road in 1877[8] and at Jollife's store (probably at the top of Bonchurch Shute) in 1879[9].

Although isolated records of cliff instability associated with coastal erosion problems were made throughout the first half of this century, the next serious problems inland occurred in 1954 when a series of 30m deep cavities (known locally as vents) opened up along Whitwell Road. Parts of the road collapsed, causing considerable alarm to the Urban District Council who sought specialist advice from the Geological Survey and British Railways[10,11]. In the end, the holes were filled and the road diverted around the problem area.

Perhaps the most dramatic period of movement in recent years occurred during the winter of 1960-1961. Cliff falls, collapsed walls and settlement were reported in November and December 1960, following the heaviest autumn rainfall since records began in 1839.

ADDENDUM

Chapter 1, page 2

Devonshire Terrace has since been rebuilt further inland from the site of earlier damage

Cracks appeared along Bath Road, with the road surface dropping 2cm a day for a week[12]. Damage was caused to a number of properties, including the Hills Lea Hotel, Sydney Lodge and Anglesey Flats which were temporarily evacuated by the Council with help from the Air Ministry[13]. In January and February 1961 movement was reported along Newport Road, Steephill Down Road, Ocean View Road, Gills Cliff Road and Belgrave Road[14]. Serious settlement occurred near the junction of Gills Cliff Road and Newport Road, and many houses along the former were damaged[15]. Along The Esplanade, the Continental and Monrose hotels were damaged and declared unsafe[14]. In recent years there appears to have been an increase in the number of reported incidents of ground movement. The most notable area has been between Steephill Down Road, Newport Road and

Plate 3: Damage caused by compression of two adjacent properties

[redacted]

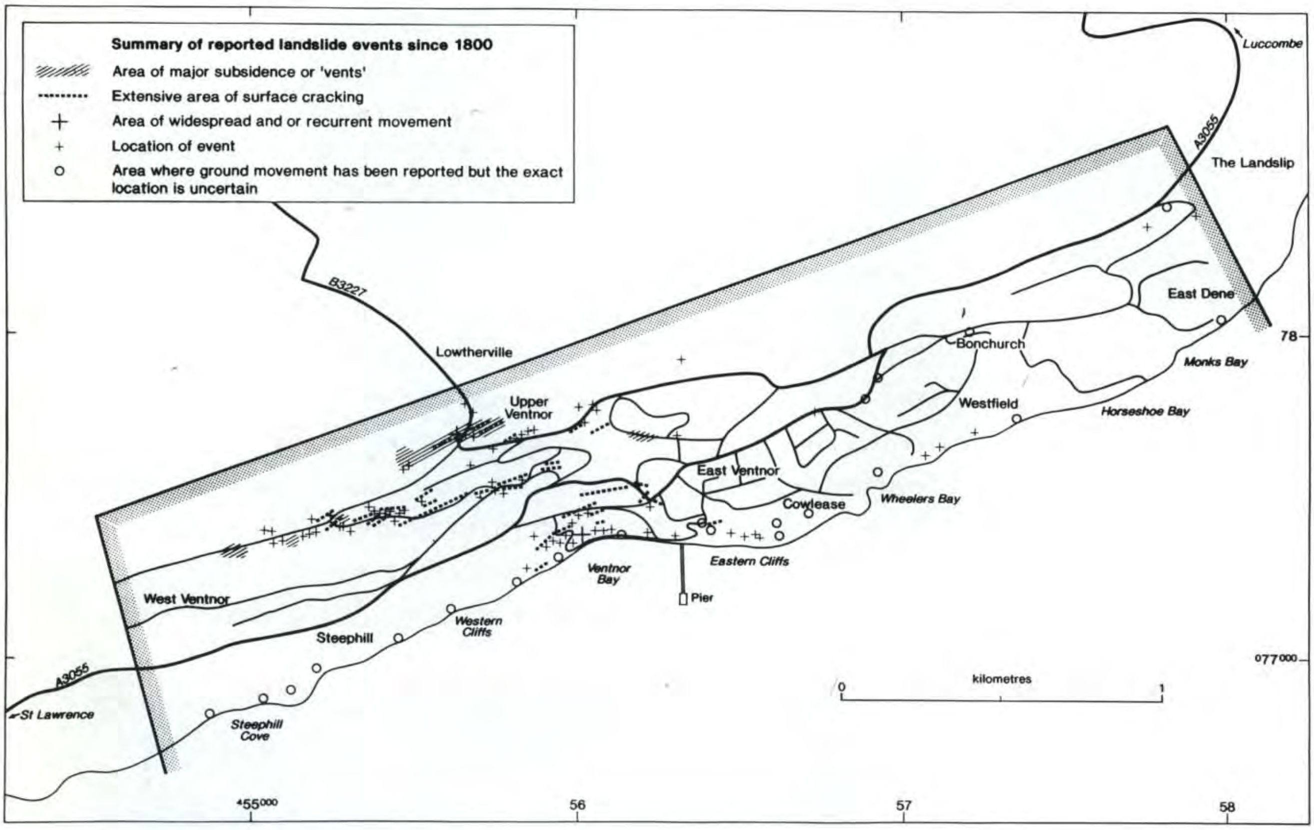


Figure 1: Summary of reported landslide events since 1800

the Havensbush play area where slow settlement seems to have been an almost continuous problem. Besides resulting in road repairs almost every year, a number of properties, including a sub-Post Office, were so badly damaged that they had to be demolished. Elsewhere, ground movement has recently resulted in further cracking along Bath Road and damage to property and services along both The Esplanade and Castle Court.

These recent movements appear to have heightened public awareness of the situation. Many householders face insurance problems. Some even fear for the safety of the local residents, although the scale and extent of ground movement over the last two centuries (Figure 1) certainly does not support this view. However, there is a clear need to assess the significance of reported movements in the context of the known ground behaviour patterns in Ventnor. This can only be achieved through a systematic analysis of any available information on both the nature and causes of the ground movement. The Department of the Environment (DoE) therefore commissioned this study to define the scale of the problem and to identify approaches which could assist in planning and development decisions.

REFERENCES:

1. Royal Commission on Coast Erosion, 1907
2. Webster, in Englefield, 1816
3. Barber, 1834
4. Adams. 1856
5. Wilkins & Brian, 1859
6. Conybeare and Dawson, 1840
7. Isle of Wight Mercury, 1934
8. Isle of Wight Mercury, 1877
9. Isle of Wight Mercury, 1879
10. Edmunds and Bisson. 1954
11. Toms, 1955
12. Hutchinson, 1965
13. Isle of Wight County Press, 1960
14. Isle of Wight County Press, 1961a
15. Isle of Wight County Press, 1961b
16. Martin, 1849
17. Basford, 1980
18. Norman, 1887
19. Whitehead, 1911
20. Dunning, 1951

Plate 4: Severe cracking, extension and settlement to the road and footpath [redacted]

CHAPTER 2
WHAT IS THE SCALE OF THE PROBLEM ?

The rate of ground movement

Although records of ground movement in Ventnor go as far back as 1816, it is very difficult to gain a clear picture as to how much movement has occurred. Only two studies report measured rates of ground displacement, though both studies, (one by M. Chandler in 1982-1983[1] and the other by M. Woodruff in 1988[2]) measured movement over short periods and in a limited number of locations. However they did highlight the fact that areas such as Upper Ventnor have been affected by movement rates of over 10mm per year and possibly as much as 125mm per year[2] (see box B).

It is almost certain that these results are not representative of the town as a whole and it is unlikely that these short-term rates are maintained over longer periods of time. Fortunately, two different lines of evidence provide information over a longer time scale. The first approach allows bench mark heights shown on the current Ordnance Survey maps of the town to be compared with the heights of those same bench marks on earlier editions of the maps (1896; 1907; 1939 and 1960). The second approach involves the use of the latest analytical photogrammetric techniques (see box C) to compare the positions of a point (e.g. the corner of a building) on an aerial photograph taken in 1988 with the position of the same point on photography taken in 1949 and 1968. The movement rates calculated by both of these methods are shown in Table 1.

[redacted]

Plate 5: Severely fractured and tilted structure in course of demolition (1988)

Box B: Measurements of short term movement rates

In 1982-1983 Martin Chandler[1] monitored short-term movement across cracks at seven sites in Upper Ventnor and one site along Bath Road. He measured the differential movement between pairs of reference studs on either side of a crack. The average annual movement rates were:

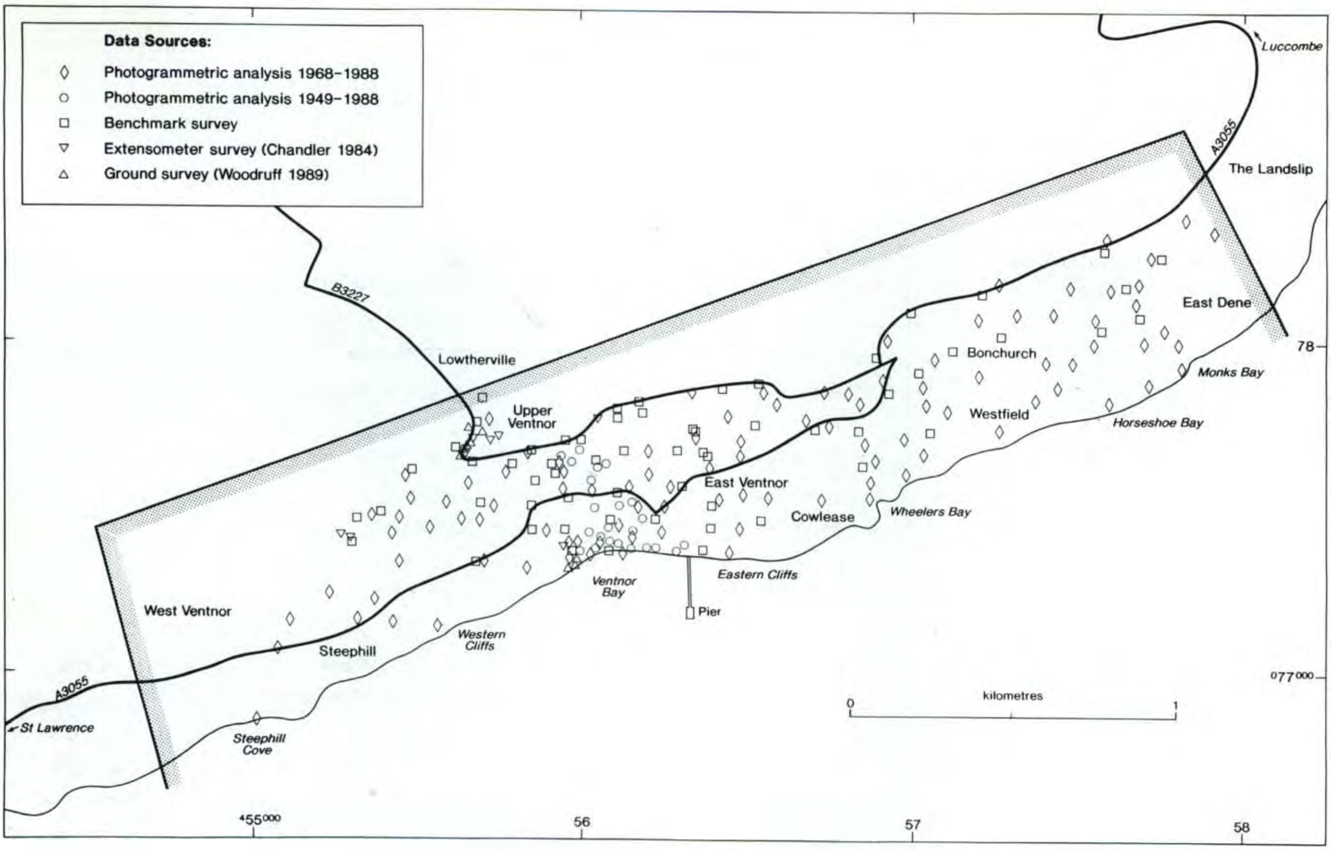
Newport Road	*39.00mm and 19.7mm*
Havensbush play area	*29.9mm and 26.9mm*
Lower Gills Cliff Road	*16.5mm and 8.0mm*
Ocean View Road	*6.0mm*
Bath Road	*0.0mm*

In 1988 South Wight Borough Council commissioned Malcolm Woodruff[2] to survey the positions of levelling points around the town. The average annual movement rates were:

Winter Gardens	*3-4mm*
Bath Road	*0-2mm*
Newport Road	*1-125mm **

*(*This rate has been extrapolated from a measurement of 21mm over 2 months and should be treated with caution).*

Plate 6: Structural damage has caused misalignment of the string course and also displacement of the arch and keystone



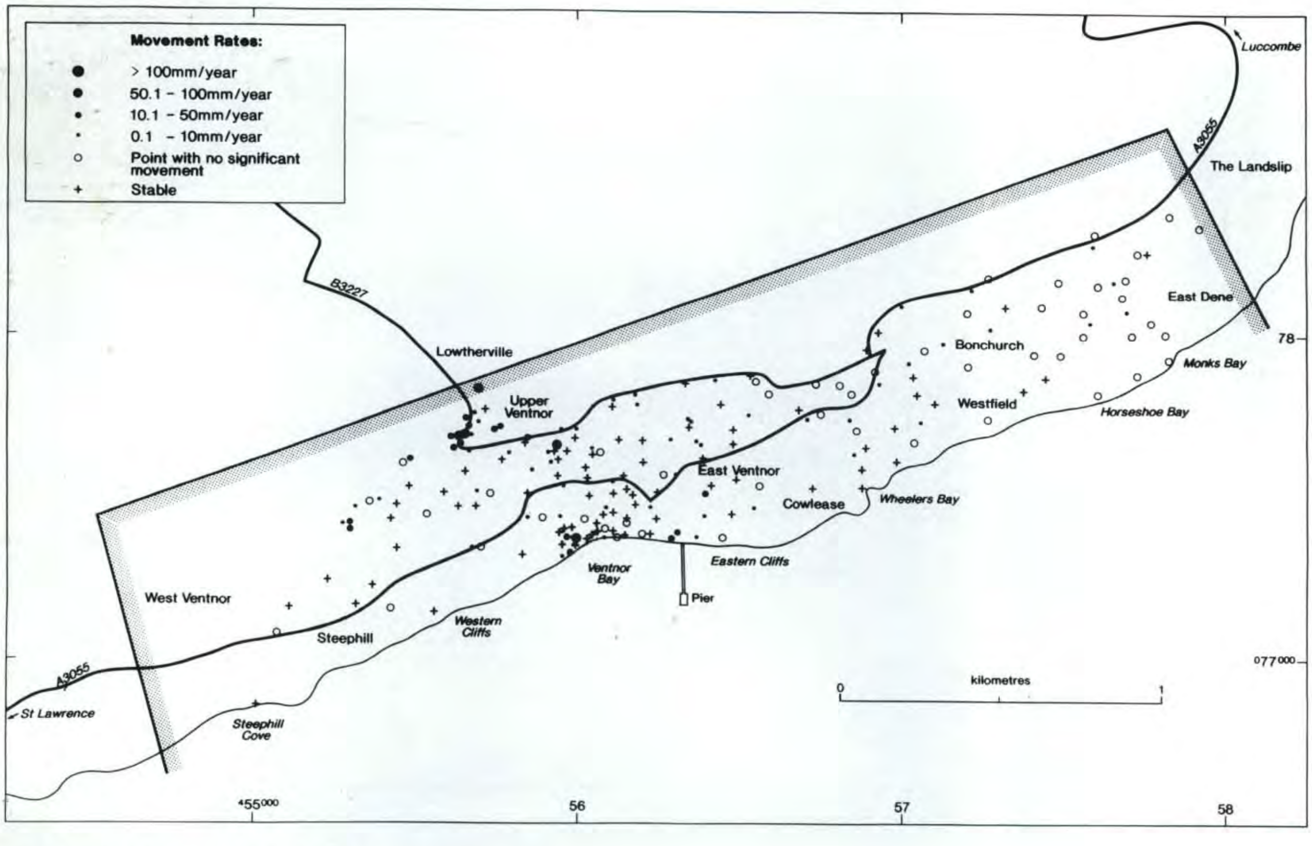


Figure 2: *Ground movement rates in Ventnor*

Box C: Analytical photogrammetry

Photogrammetry is a technique used to obtain 3-dimensional spatial measurements from photographs[3,4]. The method compares the 3D positions of the same points in photographs taken on different dates and thereby detect the magnitude of movements that may have occurred between the two dates of the photography. This provides data on both horizontal and vertical movements.

The most suitable historical photographs were sets of oblique aerial photographs taken in 1949 and vertical aerial photography taken in 1968. The 1949 photography was restricted to central Ventnor and The Esplanade while the 1968 survey covered most of the study area. These photographs were compared photogrammetrically with oblique photographs commissioned for the DoE study on the 27th July 1988.

The analysis consisted of two stages: a comparison of 1949 and 1988 photography and a comparison of 1969 and 1988 photography. A total of 129 points distributed throughout the study area were selected for measurement and the photogrammetric technique produced point co-ordinates and movement vectors for each of the points. Statistical analysis was undertaken to establish whether these movement vectors could be accepted as being `significant' and representative of a real movement rather than due to limitations of the technique. A number of points were shown to have moved, but the actual amount and direction of movement could not be calculated with confidence. Such points were termed "points with no significant movement".

Table 1: Long term movement rates, mm per year

	NO OF POINTS	PERCENTAGE OF DATA SET
STABLE POINTS	80	41.9
POINTS WITH NO SIGNIFICANT MOVEMENT (see box C)	51	26.7
0.00 - 1.00mm	27	14.1
1.01 - 2.50mm	7	3.7
2.51 - 5.00mm	7	3.7
5.01 - 10.00mm	8	4.2
10.01 - 50.00mm	8	4.2
50.01 - 100.00mm	3	1.5
	191	100.0

Three important points stand out when these results are compared with those obtained from the short-term measurements of Chandler and Woodruff (Figure 2):

- Although a number of locations appear to have had 10-125mm of movement per year, the majority of locations within the town have probably been moving at less than 1mm per year or have not moved at all.

- At many sites the short-term movement rates appear to be representative of long-term trends. Indeed, the largest overall displacement is a drop in bench mark height of 0.84m over 43 years along Gills Cliff Road (between 1939 and 1982) which gives an estimated annual movement rate of 19mm per year. This figure is comparable with the rates of 8.0mm per year and 16.5mm per year measured along Gills Cliff Road by Chandler in 1982-1983.

- At some sites, such as at the junction of Newport Road and Steephill Down Road, the short-term movement rates of

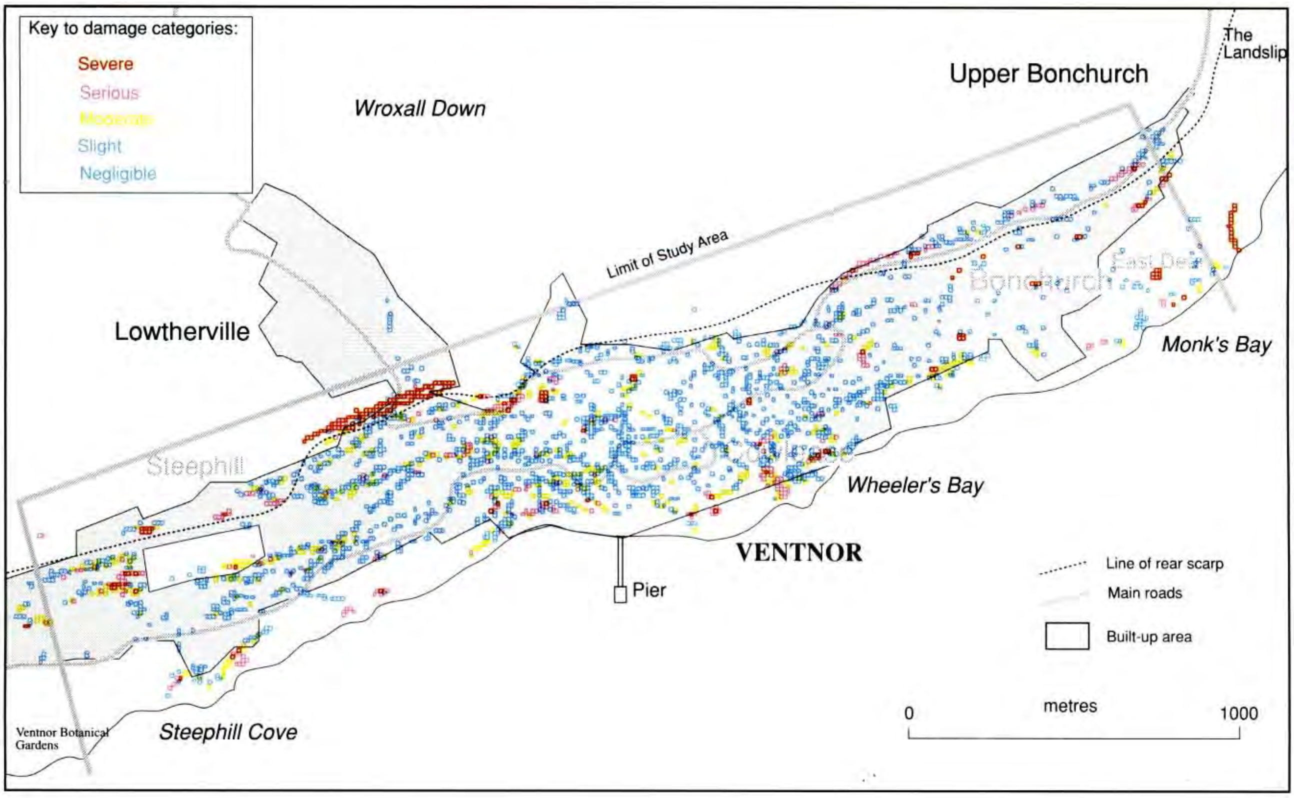


***Figure 3:** Distribution of damage caused by ground movement*

between 53 and 125mm per year (measured by Chandler in 1982-1983) are significantly higher than the longer term trend (at the same location) of 28mm per year over the last 22 years.

It is clear that measured or calculated annual movement rates can be misleading, not least because they imply uniform displacement. This, undoubtedly, is not the case in reality. Such overall rates probably hide periods of relative stability, characterised by no, or extremely slow, movement, separated by short periods of accelerated movement, as occurred in the winter of 1960-1961.

The impact of ground movement

It is clear that the occurrence of ground movement within the town has resulted in a range of problems for the community (see box D). Judging from the historical records outlined in Chapter 1 it appears that these problems may have increased over the last century or so. This is undoubtedly a reflection of the fact that urban development itself has increased the vulnerability of the community to ground movement damage by concentrating people, resources, assets and services in a limited area.

Box D: Financial costs of ground movement

Little information on the financial costs of ground movement within Ventnor are publicly available. Over the last 50 years the known losses incurred as a consequence of ground movement have included:

- *demolition of unsafe properties along Newport Road, Steephill Down Road, Ocean View Road and other sites.*
- *construction and maintenance of coastal protection schemes,*
- *road maintenance costs and disruption to traffic and services.*
- *temporary evacuation of properties in the winter of 1960-1961.*
- *compensation for damages and losses incurred in 1960-1961.*
- *insurance claims.*

Even those sites which have probably experienced very slow annual movement rates of 1mm per year could have moved 50mm over half a century. At the other end of the scale, parts of The Esplanade have risen 780mm between 1949 and 1988 and parts of Bath Road dropped 810mm between 1907 and 1982. Such displacements have caused widespread damage to property, services and structures, as was revealed by a systematic survey of building exteriors, retaining

Box E: Building damage survey

> *Examination of past records indicate that although nobody has been seriously injured there have been many cases of structural damage to property. As no systematic review of damage had been carried out in the past, a survey of damage to the outside of buildings, retaining walls and roads was undertaken during 1989. A five-fold sub-division of damage intensity was used.*
>
> ***Negligible** - hairline cracks to roads, pavements and structures with no appreciable lipping or separation.*
>
> ***Slight** - occasional cracks. Distortion, separation or relative settlement apparent. Small fragments of debris may occasionally fall onto roads and structures causing only light damage. Repair not urgent.*
>
> ***Moderate** - widespread cracks. Settlement may cause slight tilt to walls and fractures to structural members and service pipes.*
>
> ***Serious** - extensive cracking. Settlement may cause open cracks and considerable distortion to structures. Walls out of plumb and the road surface may be affected by subsidence. Parts of roads and structures may be covered with landslide debris from above. Repairs urgent to safeguard the future use of roads and structures.*
>
> ***Severe** - extensive cracking. Settlement may cause rotation or slewing of ground. Gross distortion to roads and structures. Repairs will require partial or complete rebuilding and may not be feasible. Severe movements leading to the abandonment of the site or area*

walls and roads. This survey classified the observed damage caused by ground movement (not other factors) on a simple five-fold scale from negligible to severe based on increased levels of damage and, by inference, costs of repair (see box E).

The results of the damage survey are presented in Figure 3 and Table 2, which reveal that only 18% of damage is of a **serious** or **severe** intensity. Much of the damage (32%) is only **slight** or **negligible,** not requiring urgent repair. However, the most significant class of damage (with over 1200 examples) seems to be **moderate** (i.e. widespread cracking, slightly tilted walls or fractured structural members and service pipes).

Comparing Figures 2 and 3 it is possible to recognise a number of areas in the town where significant movement rates have resulted in serious or severe damage. These are:

the Ventnor Bay area;
Central Ventnor;
Upper Ventnor;
Cowlease;
Upper Bonchurch.

Although movement and damage is concentrated in a few zones, the intervening areas have shown negligible or no movement. Thus in many areas buildings have survived for long periods, such as Bonchurch Old Church, which is believed to be over 1,000 years old. In addition, many properties were not built to modern standards. In these the foundations and building style is completely unsuited to accommodating ground movement, and the problems appear to be more serious and less manageable than they should be. It is important, therefore, that the ground movement problems faced in Ventnor are kept in perspective.

Table 2 Relative frequency of incidents of damage of different intensities (see box E for intensity definitions)

	NO OF RECORDS	PERCENTAGE OF DATA SETS
Negligible	109	4.3
Slight	710	28.3
Moderate	1238	49.4
Serious	261	10.4
Severe	191	7.6
	2509	100.0

REFERENCES:

1. Chandler, 1984
2. Woodruff, 1989
3. Chandler & Moore, 1989
4. Cooper, 1984.

CHAPTER 3
WHY IS THERE A GROUND MOVEMENT PROBLEM ?

The Undercliff landslides

Ground movements may be related to a range of factors such as slope instability, subsidence, heave or ground compression. Ground problems at Ventnor have arisen largely because the town has been built on an area of landsliding known as the Undercliff (see box F), which was present even before the town was built. Work carried out elsewhere along the Undercliff[1,2] has suggested that the main phases of landsliding took place 8,000-4,500 years ago and 2,500-1,300 years ago.

The landslides within the Undercliff are developed in Lower and Upper Cretaceous rocks (Figure 4). These consist of over 40m of Gault Clay (known locally as `Blue Slipper'), underlain by sandstones (Lower Greensand) and overlain by massive cherty sandstones (Upper Greensand) and Chalk. Of particular importance is the presence of thin clay layers within the Sandrock (Lower Greensand) which together with the Gault Clay have a very important influence on the stability of the area.

Box F: What is a landslide?

All slopes are under stress due to the force of gravity. Should the forces acting on a slope exceed the resisting strength of the materials that form the slope, then the slope will fail and a landslide occurs. A slide involves the displacement of a body of relatively coherent material, the underside and margins of which are defined by rupture surfaces or zones known as shear surfaces. Thus, blocks of material move en masse over a shear surface, although displacement inevitably leads to internal stresses which result in the break-up of the moving mass.

In general the resisting strength of materials decrease as the clay content rises. Clay slopes, therefore, are particularly prone to landsliding. Slides also occur frequently on slopes developed in a combination of impermeable fissured clays overlain by massive, well jointed caprocks of limestone or sandstone[5]. Classic examples of landslides formed in these settings include the massive coastal slides at Folkestone Warren and along the east Devon coast. Similar conditions occur along the south coast of the Isle of Wight, where the Gault Clay (Blue Slipper) is overlain by massive cherty sandstones (Upper Greensand) and Chalk. The presence of the Gault Clay and thin clay layers in the underlying Lower Greensand, have been largely responsible for controlling the nature and scale of landsliding within the Undercliff (Chapter 4).

The landslide complex at Ventnor

A geomorphological map of the Ventnor area has been produced at 1:2,500 scale in order to define the surface form of the ancient landslide complex. A much simplified version of this map is presented in Figure 5 with a schematic cross-section through part of the

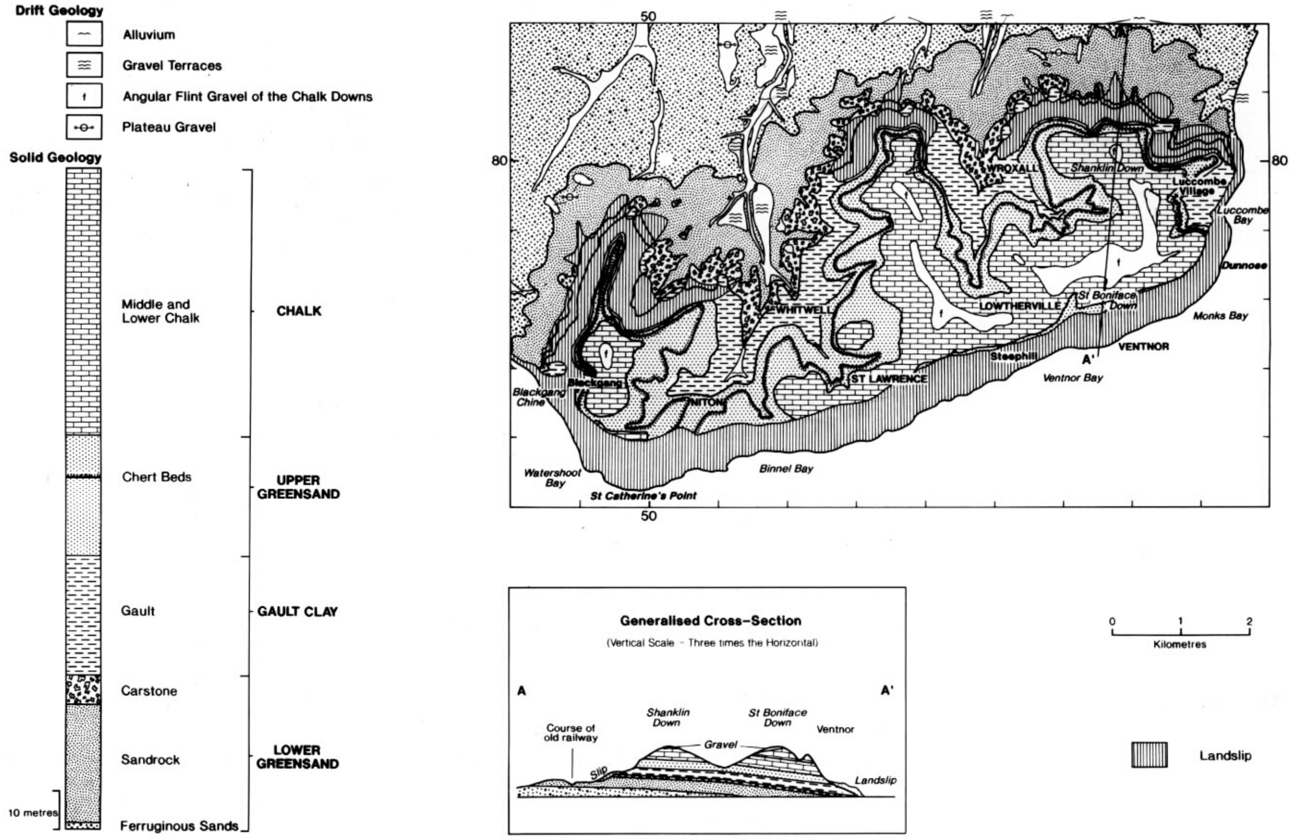


Figure 4: *The geology of the southern Isle of Wight*

Undercliff presented in Figure 10. These highlight the relationship between three main geomorphological units: the **Chalk Downs, Upper Greensand bench** and the **landslide features.** Although it is not possible to predict the actual mechanics of the original failures without extensive borehole investigations, the spatial pattern of surface features such as broad terraces, elongate ridges, back-tilted blocks, low-lying depressions and steep scarp slopes give vital clues about the nature of landsliding.

The **Chalk Downs**, as the name suggests, have been developed in chalk rock. The upper sections of the south-facing slopes are unaffected by deep landsliding, although shallow slides in weathered chalk, soil erosion and soil creep may occur.

The **Upper Greensand bench** lies immediately below the Chalk Downs. This is a narrow (60-180m wide), gently seaward-sloping bench. It is not a continuous feature, being absent from the central part of the area. Where present, the bench varies in elevation along its length, indicating that it is partly displaced by sliding. Over a long period of time the movement of the landslide features downslope has led to the removal of lateral support for the bench. This has resulted

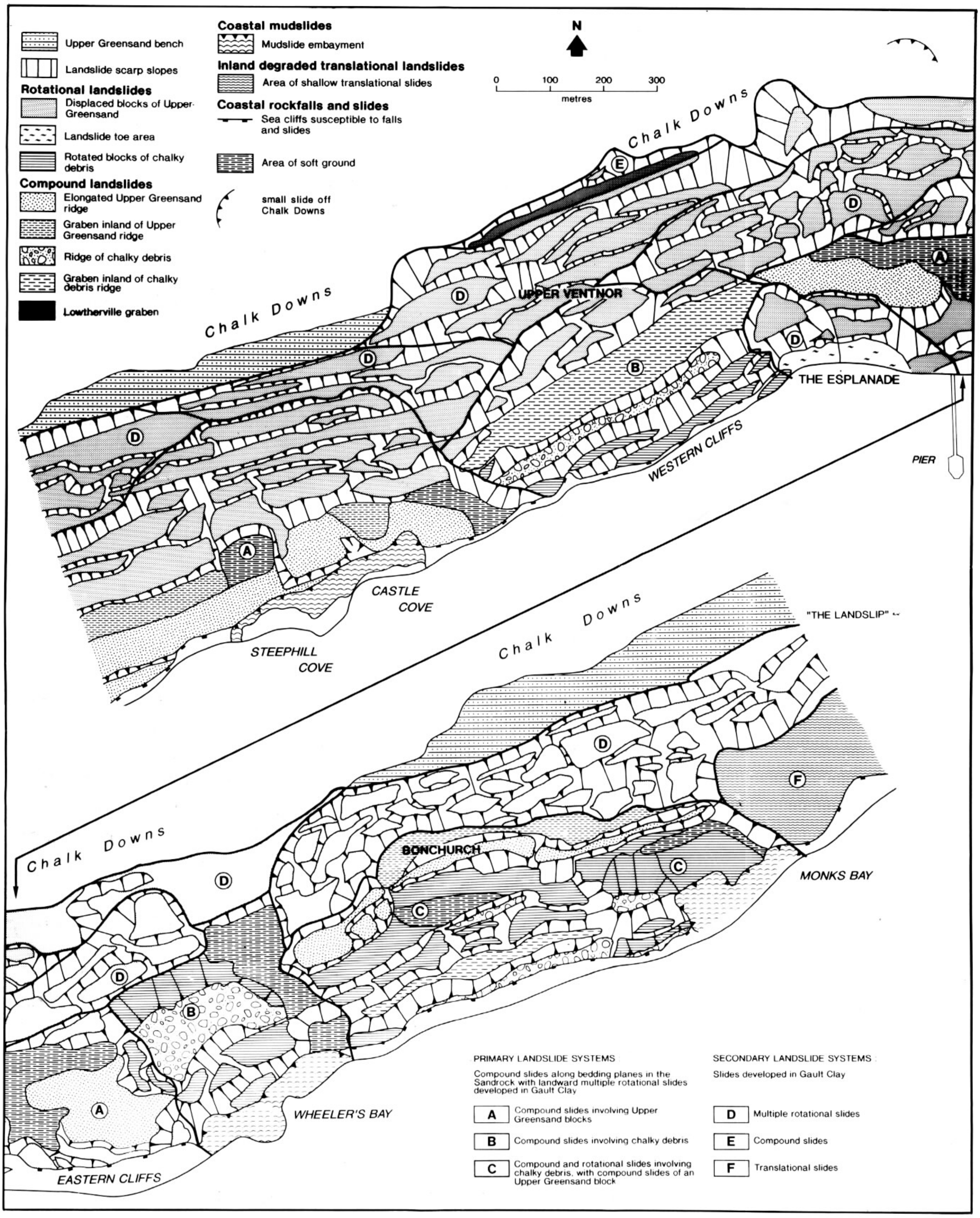


Figure 5: *Summary geomorphological map of the Undercliff at Ventnor*

in the formation of open joints ('vents') and slight subsidence (increasing seaward) of the intervening blocks.

The main Undercliff landslide complex lies immediately below these two geomorphological units. From surface evidence and borehole investigations elsewhere in the Undercliff[2], a range of separate landslide types (see box G overleaf) can be distinguished.

Multiple rotational slides occupy a broad zone in the upper parts of the Undercliff, giving rise to linear benches separated by intermediate scarps. These units comprise chiefly back-tilted blocks of Upper Greensand and Chalk. Rotated blocks of Upper Greensand are also exposed along the coast, especially in the Eastern Cliffs, generally mantled by fine chalky debris.

A sequence of **compound slides** generally occupy a zone of similar breadth in the lower part of the Undercliff, immediately beneath the zone of multiple rotational slides. In Bonchurch, this seaward zone is dominated by a near continuous ridge, 800m long, 10-15m high and parallel with the coastline, apparently composed chiefly of displaced Upper Greensand, with a depression (graben) on the landward side. In the western part of the study area there is a single continuous ridge apparently involving chalky debris, about 500m long and 15-20m high, backed by a broad graben. A similar feature is exposed along the coast at the Westfield Cliffs, Bonchurch. The grabens landward of these ridges are likely to be infilled with peat or other soft materials.

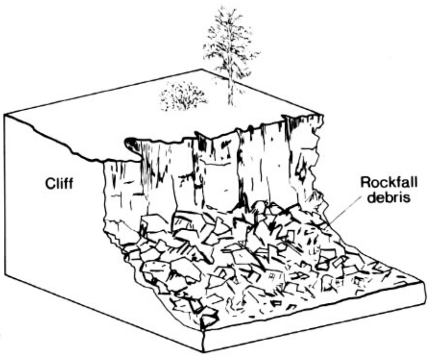
In Upper Ventnor, a graben-like feature (the **Lowtherville Graben**) occurs just landward of the zone of multiple rotational slides. This feature runs from the Havensbush play area, across Newport Road and along Steephill Down Road. It consists of a 20m wide subsiding block of material bounded by parallel fissures. The most serious ground movements recently experienced in the town have occurred in this area (Chapter 2).

Mudslides have developed on the coast where displaced Gault Clay is exposed, as at Castle Cove and Wheelers Bay. In places, these mudslides were thickly vegetated, indicating that they were relatively inactive, at the time of the survey (1990).

Degraded mudslide systems also occur inland of Monk's Bay, where they are developed in Gault Clay above the *in situ* Lower Greensand sea cliffs.

Box G: Types of landslides

The term landslide is merely a convenient name for a wide range of gravity-controlled processes (mass movement) that transport relatively dry material downslope. Three principal mechanisms are widely recognised: falling, sliding and flowing[5]*. In reality it is common for an area of instability to be affected by many different types of landsliding. Such an area is known as a* ***landslide complex.*** *Within the Undercliff two principal landslide mechanisms are dominant: falling and sliding.*

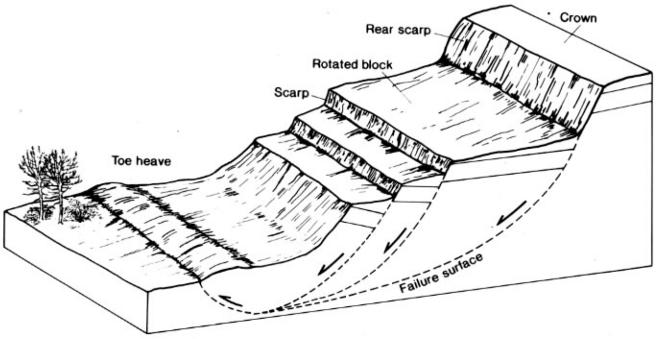


Falls *occur when material becomes detached from cliff faces (left) and occurs wherever the coast is retreating, but often leaves no lasting trace. Falls also occur from inland cliffs within the Undercliff itself, the most impressive recorded example having taken place at Gore Cliff in July 1928 (below). All falls, both coastal or inland, display a well-developed magnitude-frequency distribution with common small events at one extreme and rare large collapses at the other.*

Plate 7: Rockfall at Gore Cliff, 1928

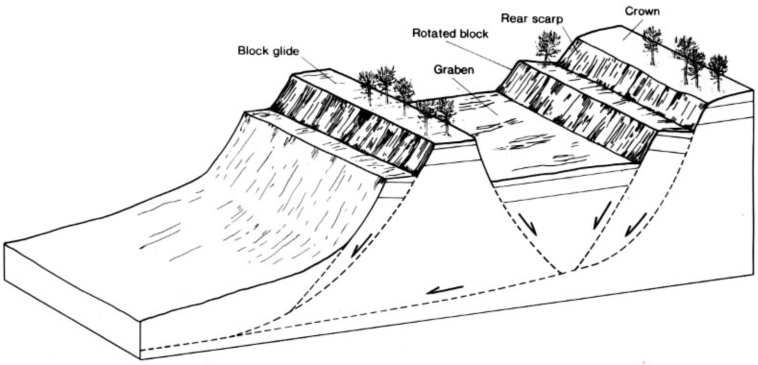
The form of a ***slide*** *is generally dependent upon the shape of the basal shear surface. Three main groups can be recognised.* ***Translational,*** *where the shear surface is parallel with the ground surface or along an inclined plane such as a bedding plane in the rock mass.* ***Rotational,*** *where sliding takes place over a curved (concave) shear surface, with the result that the displaced mass becomes tilted or rotated as it moves.* ***Compound*** *or* ***non-rotational,*** *where sliding involves elements of both translational and rotational mechanisms.*

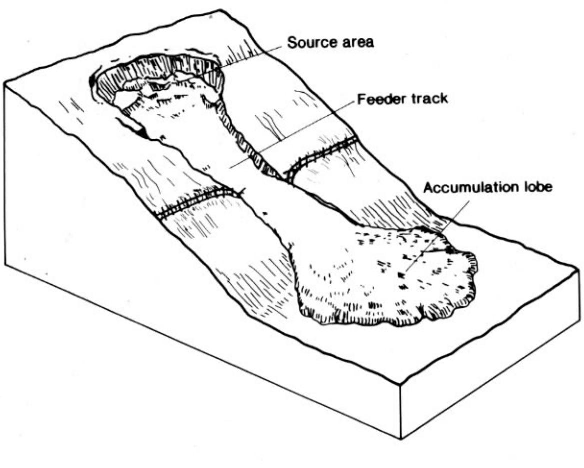
The Undercliff comprises three main types of slide :



Multiple rotational slides *(left) involving a series of slipped, back-tilted blocks each underlain by a circular failure surface that merge to form a common basal shear surface.*

Compound slides *(right) characterised by markedly non-circular shear surfaces formed by the combination of a steep curved rearward (upslope) portion and a flat sole. This type of slide involves the lateral displacement of a block forming an elongate ridge and the creation of a low-lying depression or graben immediately upslope. At the rear of the slide displacement is accompanied by some rotation.*





Mudslides *(left) are relatively slow moving, lobate masses of clay-rich debris sliding over translational shear surfaces. These slides generally comprise a steep source area from which debris is supplied, and below this a feeder track and a more gently inclined accumulation zone.*

Rockfalls and small slides occur along much of the coastline, especially where the exposed landslide debris is unprotected from marine erosion, as at the Western Cliffs. At Monk's Bay, the *in situ* Lower Greensand cliffs are affected by slides and rockfalls.

A model of landslide development

Interpretation of observations made at Ventnor rests on developing a consistent explanation which accounts for all of the features (geological, geomorphological and ground movement) in a logical, scientifically sound way. The resulting interpretation or "model" allows theories of ground behaviour patterns to be developed (Chapter 5). Possible schematic sections at four locations are shown in Figure 6. These models are based on the geomorphological evidence within the town and borehole investigations at Gore Cliff[3] and St Catherine's Point[4].

Throughout much of Ventnor the pattern of landsliding suggests a two-tier system, involving:

Zone I; compound failures along clay layers within the Sandrock in the seaward part of the Undercliff, following the St Catherine's Point model[4].

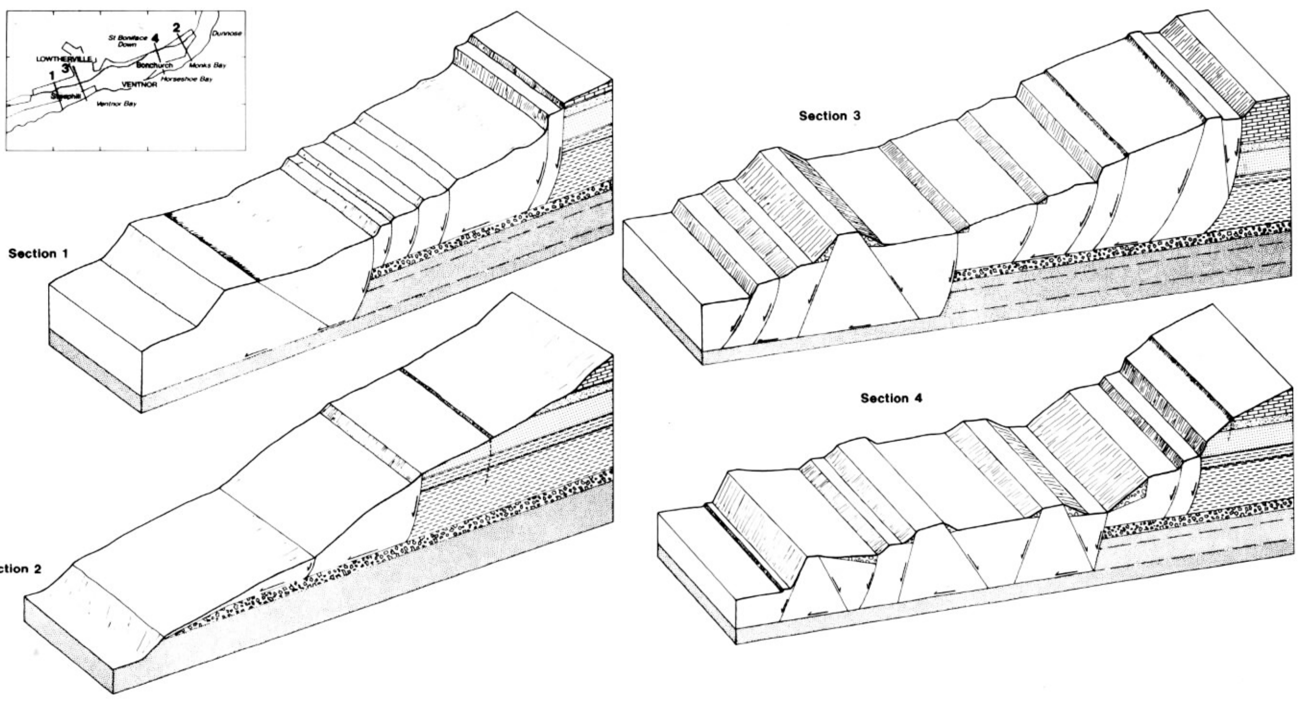


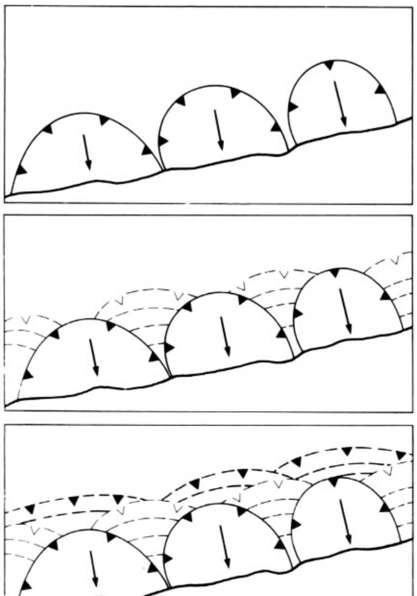
Figure 6: Schematic sections through the Undercliff

Zone II; multiple rotational or compound failures, to the landward, on slip surfaces within the Gault Clay, following the Gore Cliff model where the basal slip surface is 15-18m above the base of this unit[3].

The exception to this pattern occurs inland of Monk's Bay where the slopes comprise Zone II-type landslide features. Here, mudslides and rotational slides have developed in the Gault Clay. No Zone I-type failures appear to have developed here, with only minor rockfalls and slides occurring on the Lower Greensand cliffs.

The formation of the Undercliff is believed to be related to the interplay of climatic changes and sea level rise over the last 20,000 years or so. During periods of low sea level in the last "ice age" the coastal slopes became fronted by large aprons of landslide debris which would have acted as a natural protection to the slopes. However, the rise in sea level after the ice melted would have caused parts of the aprons and even the coastal slopes to be eroded away. As a result of this erosion, the slopes probably became partially destabilised and major deep-seated landslides developed on the lower sections (Zone I). The curved backscars of these lower slope landslide systems appear to have isolated a series of broad, triangular spurs. These spurs have subsequently failed as a result of the unloading on either side caused by movement of the earlier slides (Zone II; Figure 7). In this way a pattern of closely related landslide systems has developed (Figure 5) in response to the gradual unloading of the lower portions of the Undercliff.

***Figure 7:** The development of the Undercliff. **Top:** development of deep-seated primary slides **Middle:** unloading of spurs leading to multiple rotational failure **Bottom:** further unloading leading to retrogressive multiple rotational failure*



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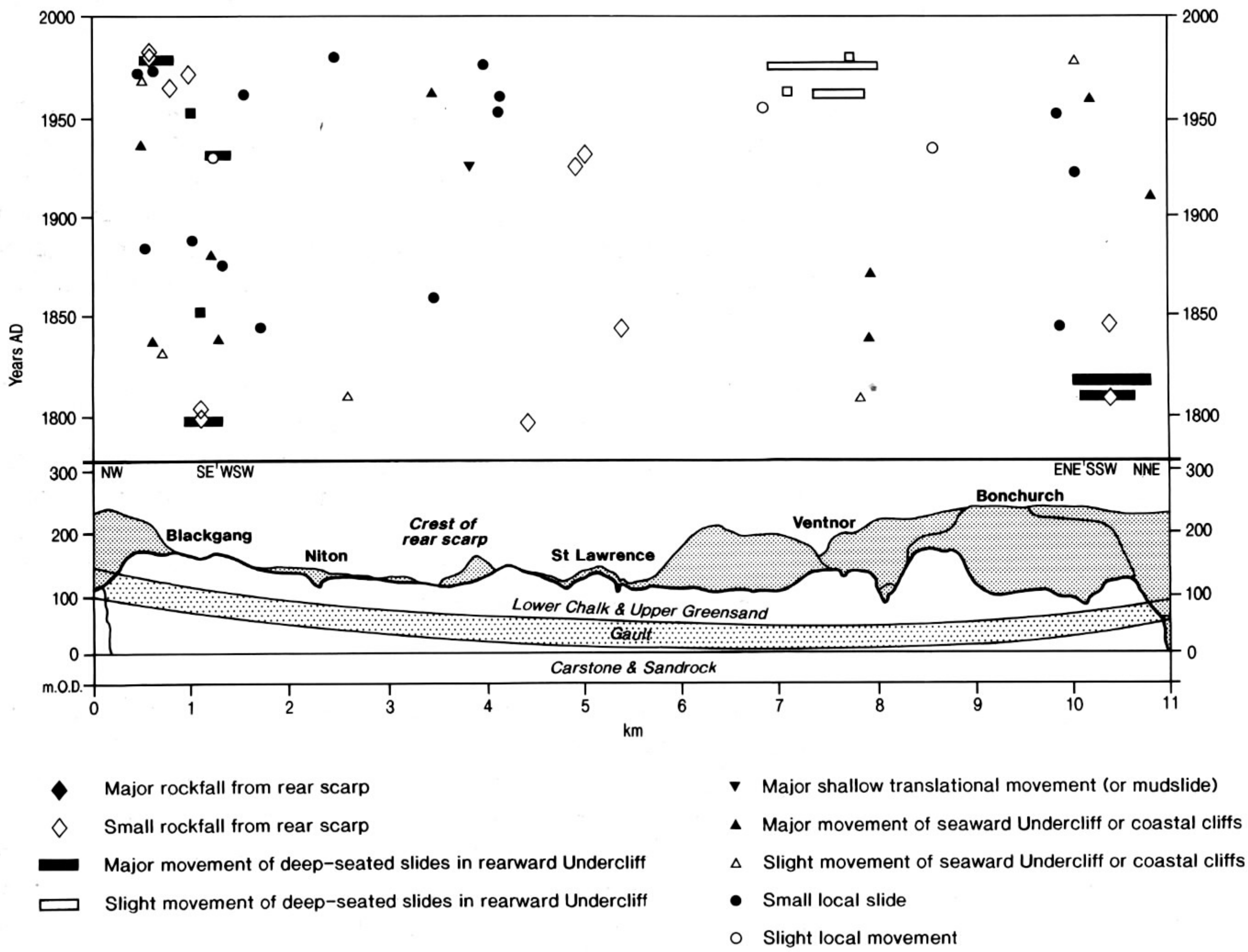
CHAPTER 4
WHAT CAUSES GROUND MOVEMENT ?

Factors influencing the pattern of movement

Landslides occur when the force of gravity acting on a slope exceeds the strength of the slope materials (see box H overleaf). In these circumstances the displaced material moves to a new position so that equilibrium can be re-established between the destabilising forces and the residual strength of the rock and/or soils along the surface of movement. A landslide, therefore, will help to change a slope from a less stable to a more stable state. No subsequent movement will occur unless changes take place which, once again, affect the balance of opposing forces.

In many inland situations landslides can remain dormant or relatively inactive for thousands of years, as is the case for many examples on the north-facing slopes of Shanklin Down (Figure 4). However, in the case of coastal landslides such as the Undercliff, past marine erosion removed material from the lower parts of the slopes, thereby remov-

Figure 8: *Landslide activity along the Undercliff (after Hutchinson 1965)*



ing passive support and allowing repeated movement. As was described in Chapter 3, over thousands of years this can lead to the area of instability extending inland, progressively affecting a larger area until the passive support provided by the earlier and lower slides in the sequence reduces the potential for further failure. That is, of course, until marine erosion at the base of the slope causes the reactivation of the landslide complex.

The fact that all parts of the Undercliff do not show similar frequencies or magnitudes of landslide activity emphasises the importance of other factors than just coastal erosion. The most active sections over the last 200 years have been the western and eastern ends (Blackgang and Dunnose, respectively), with considerably less movement in the intervening areas. This variation is influenced by the presence of a broad concave down-fold (syncline) in the rocks which controls the height of the Gault Clay relative to sea level[1]. The two most active areas occur where the clay is at its highest elevation along the coast (Figure 8).

Even within Ventnor itself the rates of ground movement are variable (Chapter 2). This, in turn, is seen to be due to the fact that the separate landslide systems which make up the Undercliff at Ventnor (Figure 5) have different margins of stability (see box H). Some systems are clearly more stable than others and, thus, are more able to resist the effects of transient factors such as periods of heavy rainfall or groundwater changes.

Causes of ground movement

Before considering those factors which cause ground movement in Ventnor, it is important to stress that the town is built on an inherently unstable slope. As the materials along the landslide shear surfaces are probably at or close to their residual strength the slopes can be made to move under conditions that they could have resisted prior to failure. Thus, events which cause ground movement in Ventnor, or along the Undercliff, will not necessarily cause problems on intact slopes of similar materials elsewhere.

Coastal erosion has long been appreciated to be an important factor in the long-term destabilisation of the Undercliff[2,3]. As a result, much of the coast has now been protected by sea defences and it is unlikely, therefore, that marine erosion remains a significant cause of movement in these areas. However, both the Western Cliffs and parts of Monk's Bay remain unprotected and uncontrolled erosion (estimated to result in cliff retreat of around 0.3m per year) may still act as a destabilising influence on the landslide slopes further inland.

Box H: Causes of landslides

The ultimate cause of all landsliding is the downward pull of gravity. The stress imposed by gravity is resisted by the ***strength*** *of the material. A* ***stable slope*** *is one where the resisting stresses are greater than the destabilising stresses and, therefore, can be considered to have a* ***margin of stability.*** *By contrast, a slope at the point of failure has no margin of stability, for the resisting and destabilising forces are approximately equal. The quantitative comparison of these opposing forces gives rise to a ratio known as the 'Factor of Safety' (F):*

$$\text{Factor of Safety} = \frac{\text{Resisting forces}}{\text{Destabilising stresses}} = \frac{\text{Shear strength}}{\text{Shear stress}}$$

The Factor of Safety of a slope at the point of failure is 1. On slopes of similar materials, progressively higher values represent more and more stable situations with greater margins of stability. In other words, the higher the value the greater the ability of the slope to accommodate change before failure occurs. These changes are usually divided, for the sake of convenience, into internal and external groups. External changes increase the stress placed on slope-forming materials, while internal changes reduce or weaken their resistance to movement. The majority of landslides are therefore the product of changing circumstances or alterations to the status quo.

The shear strength of a material depends upon both the nature of the material itself and the presence of water in fissures and pores. A slope is only as strong as its weakest horizon, often a clay. Clays such as the Gault Clay are known as ***brittle*** *materials because once they have been subject to more than the maximum stress they can withstand and have failed, further displacements are possible at lower levels of stress. In other words, the shear strength of the clay declines from a* ***peak*** *value to a lower* ***residual*** *value.*

Water contact has a major influence on reducing shear strength, not because of 'lubrication' as is often stated, but due to the fact that water in the ground exerts its own pressure which serves to reduce the amount of particle to particle contact. Within saturated horizons the pore-water therefore bears part of the load by exerting an upthrust or buoyancy effect known as ***pore-water pressure.*** *Although soil or rock particles can resist both normal and tangential (shearing) forces, fluids can support compression forces but cannot resist shearing forces. Therefore, frictional resistance to movement depends on the difference between the applied normal stress and the pore-water pressure. This difference, or that part of the normal stress which is effective in generating shear resistance, is known as the* ***effective stress.***

Two contrasting sets of conditions are often used to describe landslides:

- *first-time failures in previously unsheared ground, when the material fails at* ***peak*** *strength;*
- *reactivated failures in which movement occurs along pre-existing shear surfaces where the materials are at* ***residual*** *strength.*

The importance of this distinction is that once a slide has occurred it can be made to move under conditions that the slope, prior to failure, could have resisted. In other words, reactivations can be triggered much more readily than can first-time failures.

As slope movements are the result of changes which upset the balance between resistance and destabilisation, the stability of a slope is often described in terms of its ability to withstand potential changes:

- ***stable;*** *where the margin of stability is sufficiently high to withstand all transient forces in the short to medium term (i.e. hundreds of years), excluding excessive alteration by human activity;*
- ***marginally stable;*** *where the balance of forces is such that the slope will fail at some time in the future in response to transient forces attaining a certain level of activity; and*
- ***actively unstable slopes;*** *where transient forces produce continuous or intermittent movement.*

This perspective makes it possible to recognise that the work of destabilising influences can be apportioned between two categories of factors on the bases of their role in promoting slope failure.

Box H: Causes of landslides (continued)

These two categories are:

1. ***preparatory factors*** *which work to make the slope increasingly susceptible to failure without actu ally initiating it (i.e. cause the slope to move from a stable state to a marginally stable state), eventually resulting in a relatively low Factor of Safety;*

2. ***triggering factors*** *which actually initiate movement, i.e. shift the slope from a marginally stable state to an actively unstable state.*

When considering the actual cause of landsliding this relative simplicity gives way to complexity as there is a great diversity of causal factors. In broad terms, however, they can be sub-divided into ***external*** *causes which lead to increase shear stress and* ***internal*** *causes which lead to a reduction in shear strength:*

Factors leading to a decrease in shear resistance (internal):

1. Materials:

- *beds which decrease in shear strength if water content increases (clays, shale) (e.g. when local watertable is artificially increased in height by reservoir construction, or as a result of stress release (vertical and/or horizontal) following slope formation)*
- *low internal cohesion (e.g. consolidated clays, sands, porous organic matter)*
- *in bedrock: faults, bedding planes, joints, foliation in schists, cleavage, brecciated zones, and pre-existing shears*

2. Weathering changes

- *weathering reduces effective cohesion and to a lesser extent the angle of shearing resistance absorption of water leading to changes in the fabric of clays (e.g. loss of bonds between particles or the formation of fissures)*

3. Pore-water pressure increase

- *higher groundwater table as a result of increased precipitation or as a result of human interference*

Factors leading to an increase in shear stress (external):

1. Removal of lateral or underlying support

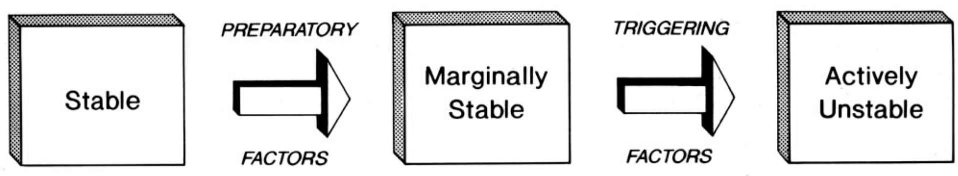
- *undercutting by water (e.g. river, waves), or glacier ice*
- *washing out of granular material by seepage erosion*
- *man-made cuts and excavations*
- *drainage of lakes or reservoirs*

2. Increased loading (external pressures)

- *natural accumulations of water, snow, talus*
- *man-made pressures (e.g. tip-heaps, rubbish dumps, or buildings)*

3. Transitory earth stresses

- *earthquakes*
- *continual passing of heavy traffic*



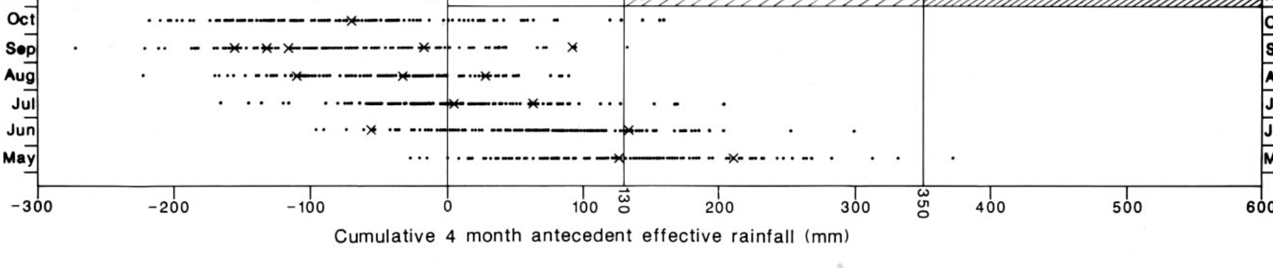
Although coastal erosion has progressively reduced the overall stability of the slopes, actual incidents of ground movement appear to be triggered by other factors, such as periods of heavy rainfall. Unfortunately, owing to the slow intermittent nature of ground movement and the lack of precise monitoring information it has not been possible to relate landslide activity with individual rainfall events. However, there appears to be a close relationship between phases of increased landslide activity and periods of heavy rainfall and inferred higher groundwater levels. A comparison of the 4-month antecedent effective rainfall (AER; the cumulative total of rainfall minus evapotranspiration occurring over a 4 month period prior to a specific date when landslide events were either reported or absent) suggests that, since 1855 (the date when newspaper records begin), the occurrence of ground movement can be defined by three broad classes (Figure 9):

Class 1 - when there has been a 1 in 50 (2%) chance of movement. This corresponds to conditions between May and October every year **and** November to April when the AER is less than 130mm;

Class 2 - when there has been a 1 in 12 (8%) chance of movement. This corresponds to conditions between February and April when the AER exceeds 130mm **and** November to January when the AER is between 130-350mm. Such conditions have occurred 1 year in 1.2;

Class 3 - when there has been a 1 in 1.7 (60%) chance of movement, corresponding to conditions between November and January when the AER exceeds 350mm. Such conditions have occurred 1 year in 22.

***Figure 9:** The relationship between antecedent effective rainfall and landslide activity in Ventnor*



Very wet conditions in the autumn are clearly a highly significant factor in explaining the frequency of landslide activity over the last 135 years, with over 80% of all recorded landslide events having occurred during periods when the 4-month AER exceeded 130mm. However, this relationship does not account for the occurrence of all periods of landsliding within Ventnor, as movements have been recorded during periods of very low antecedent rainfall conditions. Such movements may have been either of a type which is less sensitive to long-term rainfall patterns (e.g. coastal falls) or due to human activity.

It is probably no coincidence that the number of reported landslide events was found to have increased with the spread of the town over the past 100 years or so. Whilst this partly reflects better records of ground movements, it is also true that development itself has acted as a destabilising influence in parts of the town. For example, it is widely recognised that the removal of Collin's Point, in Ventnor Bay, during the construction of an artificial harbour in the 1860's caused beach depletion, rapid coastal erosion[3] and an increase in reported landslide activity in the 1870's (Chapter 1).

Throughout Ventnor, development has involved cut and fill operations to establish level plots for houses or acceptable gradients for roads. These operations have promoted local instability problems by changing the surface profile of a landslide slope to a less stable configuration.

However, potentially the most serious destabilising activity associated with development has been artificial recharge of the groundwater table. Uncontrolled discharge of surface water through soakaways and highway drains may have contributed to raising the groundwater table to a level where heavy winter storms could trigger movement. In addition, progressive deterioration and leakage of services such as foul sewers, storm sewers, water mains and service pipes are considered to have added to the problems. As an extreme example, during the winter of 1960-61, over 3million gallons of water from the flooded Ventnor railway tunnel were pumped into the back of the landslide system[4]. This, together with the exceptionally high autumn rainfall preceded the most dramatic movements in recent years (Chapter 1).

Defective construction

Unfortunately the situation in Ventnor is not a simple case of extensive damage to property in unstable areas and no damage in more stable areas. Often it is not clear whether some of the reported problems with building were a direct result of ground movement or simply due to poor construction.

Much of Ventnor was rapidly developed between 1830 and 1910, following the publication of "The influence of climate in the preservation and cure of chronic disease" by Sir James Clark in 1829 which commented on the area. A vivid description of the early years of the town is provided by the diarist Mark William Norman, who wrote:

> "there was a rush to it (Ventnor) of all sorts and conditions of men from all quarters of the compass. Among them builders without capital or credit or character. The place was infested with jerry builders who ran up houses of inferior order, mortgaged them and which generally fell into the mortgagee or lawyers hands"[5].

It is only to be expected that a rapidly built Victorian town had its fair share of defective constructions or potentially dangerous structures. However, in many cases damage appears to worsen with time, as the cumulative effects of imperceptible movement get more and more serious. The issue as to whether such damage to property is due to ground movement or poor construction is not one that is easily resolved, mainly because in most cases the two are inexorably linked. Although there can be no doubt that the town lies within a slowly moving landslide complex, many contemporary problems are probably heightened by human failings.

Plate:8 Coastal erosion at the Western Cliffs

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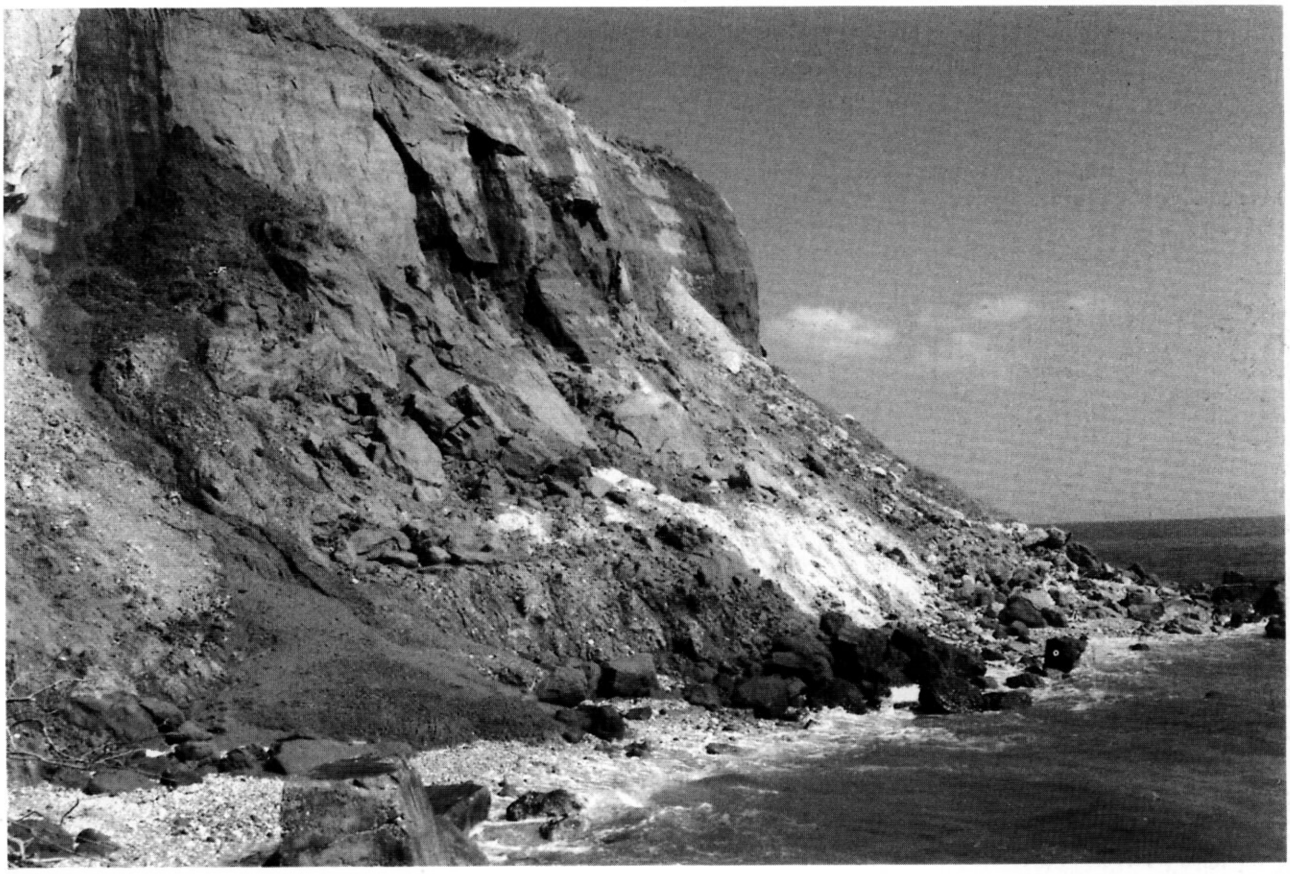
1. Hutchinson, 1965
2. Royal Commission on Coast Erosion, 1907; 1911
3. Whitehead, 1911
4. Isle of Wight County Press, 1960.
5. Norman, in Chambers, 1988.

Plate 9: Erosion of the Lower Greensand cliffs, Monk's Bay



HOW CAN WE DEFINE THE LANDSLIDE HAZARD ?

Types of contemporary movement

A search through historical documents, local newspapers from 1855-1989, local authority records and published scientific research has revealed nearly 200 individual incidents of ground movement over the last two centuries. The various forms of movement that have occurred can be summarised as 10 types. These are shown on Figure 10 and involve:

Type 1; shallow translational slides in soil and weathered chalk on the steep slopes of the Chalk Downs, e.g. above the former Seamans Mission on Mitchell Avenue in 1877[1].

Type 2; slow settlement of the Upper Greensand bench, accompanied by joint widening and the development of vents. The most widely reported example occurred along Whitwell Road in 1954[2,3] (Chapter 1).

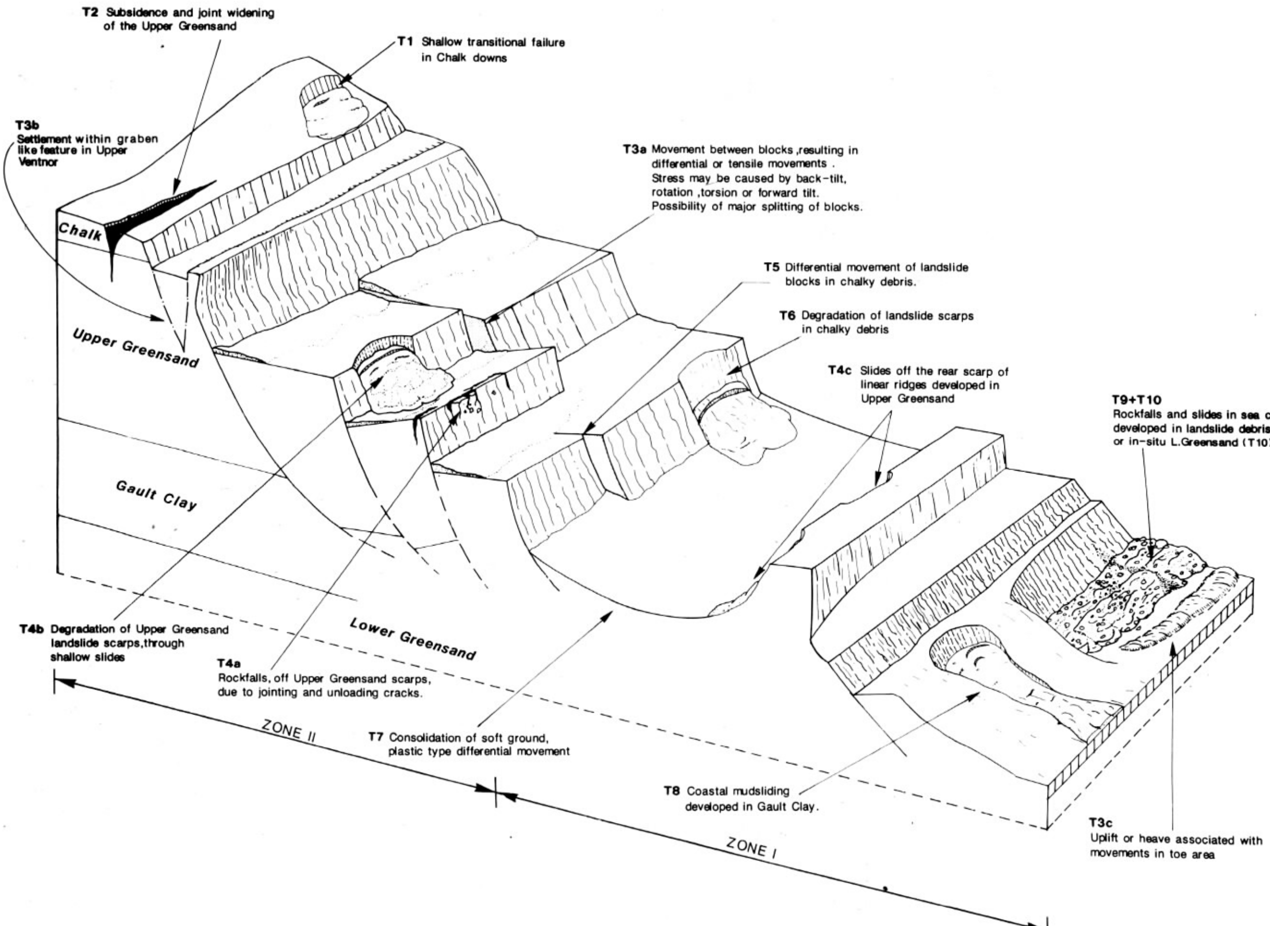


***Figure 10:** Types of contemporary ground movement in Ventnor*

Type 3; differential movement of Upper Greensand blocks, including:

Type 3a; rotation, forward tilt, torsion and differential settlement. This type of movement has taken place in many parts of the town, most notably in Upper Ventnor. Clear examples of such movements were reported along Gills Cliff Road, Ocean View Road, Castle Road and Zig Zag Road in the winter of 1960-1961[4].

Type 3b; settlement within the Lowtherville graben, where movements of up to 84mm per year (and 21mm over 2 months) have been recently recorded[5].

Type 3c; uplift and heave in the toe areas of individual landslide systems. Along the Esplanade, for example, 780mm of uplift occurred between 1949 and 1988.

Type 4; degradation of Upper Greensand landslide scarps, by means of:

Type 4a; rockfalls. Despite the large number of vertical rock faces only three minor falls have been reported since 1855.

Type 4b; slow superficial movements resulting in bulging and cracking of retaining walls. An example of this type of movement occurred behind Sea View in Grove Road during 1954[6].

Type 5; differential movement of landslide blocks in chalky debris. This type of movement has resulted in slight damage to property in parts of Bonchurch.

Type 6; degradation of landslide scarps in chalky debris. This is mainly confined to slow superficial movements which may lead to bulging and cracking of retaining walls, as was the case behind No. 13 St Catherine's Street in 1987[7].

Type 7; consolidation of soft ground within low-lying graben areas, which has caused damage to property in the centre of Ventnor.

Type 8; intermittent slow movement within the coastal mudslide systems at Steephill Cove, Castle Cove and Wheeler's Bay.

Type 9; minor rockfalls and slides off the coastal cliffs developed in landslide debris, such as occurred along the Western Cliffs in the winter of 1989-1990.

Type 10; rockfalls and slides off the *in-situ* Lower Greensand cliffs in Monk's Bay. Examples of this type of movement took place in the winter of 1989-1990.

The pattern of damage to property and structures within the town reflects a range of stress conditions related to the various forms of ground movement. There appears to be a strong relationship between the type of landslide movement and a particular geomorphological setting. This indicates that each geomorphological unit and feature has its own characteristic range of stress conditions affecting structures, producing a characteristic type of damage.

Examinations of damage to property within the small landslide system in the Ventnor Bay area (Figure 5) has revealed that many properties have been affected by a range of ground movements, including heave, subsidence, rotation and tilting. The most severely affected

Plate 10: Differential movement and extension resulting in severe fracturing to foundations

area was found to be along the seafront where many properties were tilted forward, as a result of heave of the toe of a small rotational landslide unit. The buildings at the crest of this landslide system appear to have been affected by settlement and rotational (contra-tilt) movements. However, towards the middle of the slope, outward movements of 300mm appear to have taken place, with only limited evidence of tilting.

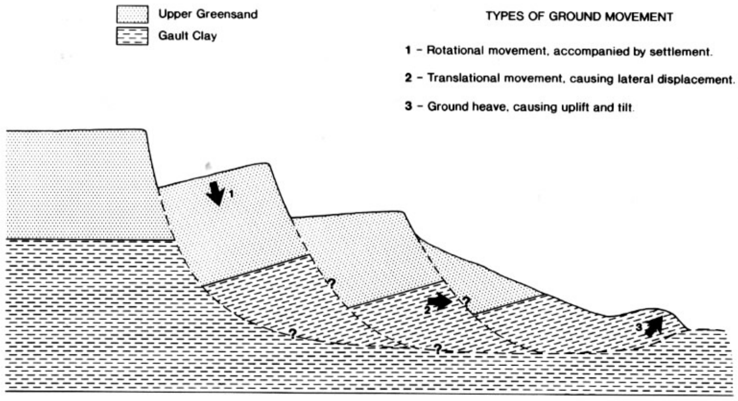
These three examples of contrasting forms of movement over a short distance (300m) indicates the range of ground movements that may occur in the town. These movements need to be interpreted in the context of the individual landslide systems and the overall mechanics of the landslide complex. In the Ventnor Bay area, for example, the pattern of movement appears to reflect the slow reactivation of a multiple rotational landslide system (Figure 11).

Ground behaviour

The nature of the landslide hazard (see box I) faced by the local community has been defined by producing a map of contemporary ground behaviour. This map is based on a thorough review of available records, documents and reports, followed by a programme of detailed field investigation comprising geomorphological and geo-

Plate 11: Vents along Whitwell Road, 1954 (courtesy of Isle of Wight County Press)

__Figure 11:__ Schematic section through a multiple rotational slide showing different types of ground movement



logical mapping, a survey of damage caused by ground movement, a land use survey, photogrammetric analysis, and a review of local building practice. Through these methods an understanding of the following components of landslide hazard and risk was achieved:

- the extent of the landslide system and the processes involved in its evolution;
- the types of contemporary ground movement;
- the magnitude of contemporary ground movement;
- the frequency of landslide events;
- the causes of landslide events and their temporal variation;
- the impact of ground movement on the town;
- the nature and extent of property at risk;
- the vulnerability of different styles of construction to ground movement.

The ground behaviour map was produced at 1:2,500 scale but has been generalised for the purposes of Figure 12 (with an accompanying legend in Table 3). The map is a synthesis of the following information:

- the nature and extent of different landslide features which form the Undercliff (e.g. multiple rotational slides, compound failures, and mudslides; Figure 5);

- the different landslide processes which have operated within the town over the last 200 years (Figure 10);

- the location of ground movement events recorded in the last 200 years (Figure 1);

- the recorded rates of ground movement (Figure 2);

Box I: The relationship between landslide hazard and risk

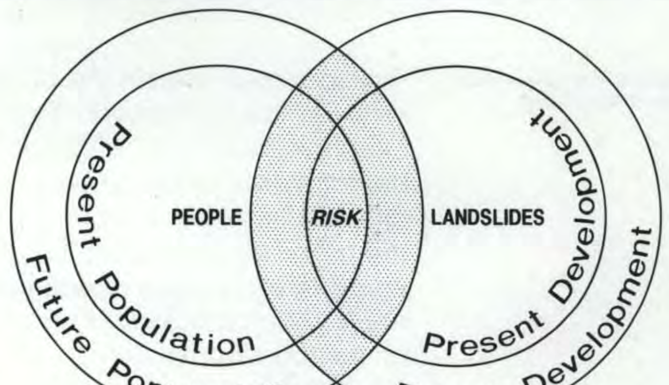
The terminology used when discussing natural events and their impact on society can be very confusing. It is not uncommon for terms like hazard, risk and vulnerability to be used to describe the same concepts. In this book the following definitions are used, following Varnes[8]:

*A **hazard** describes the chance of a potentially damaging ground movement event occurring within the area i.e. ground movement constitutes a hazard.*

***Risk** means the possible losses arising as a result of ground movement i.e. the community is at risk from ground movement.*

***Vulnerability** describes the degree of loss or damage to a particular element of the town or community (e.g. buildings, services, economic activity) i.e. different elements will face different levels of risk from the ground movement hazard.*

The concept of risk as the interaction of the human environment with the physical environment is illustrated below. Only when the two systems are in conflict does landsliding become a threat to the community. Of particular importance is the fact that as urban development increases or intensifies so the potential impact of landsliding increases.



- the intensity of damage to property caused by ground movement (Figure 3);

- the causes of damage to property as a result of ground movement (e.g. torsion, rotation and heave; Figure 11);

- the relationship between past landslide events and antecedent rainfall (Figure 9).

Plate 12: Development of a major fissure marking the side of "the graben"

The approach used in the production of the ground behaviour map involved the assessment of landslide activity within contrasting geomorphological units, i.e. ground movement problems within the multiple rotational landslide units can be expected to be fundamentally different from those experienced within a mudslide unit. In essence, the map describes both the nature, magnitude and frequency of **contemporary mass movement processes** which have operated in each geomorphological unit over the last 200 years and their **impact** on the local community. It shows clearly that the potential problems, resulting from ground movement, vary from place to place according to the geomorphological setting, and forms the basis for a **Planning Guidance Map** (Figure 13 and Table 4).

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1. The Isle of Wight Mercury, 1877
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4. South Wight Borough Council records
5. Woodruff, 1989
6. The Isle of Wight County Press, 1954
7. The Isle of Wight County Press, 1987
8. Varnes, 1984

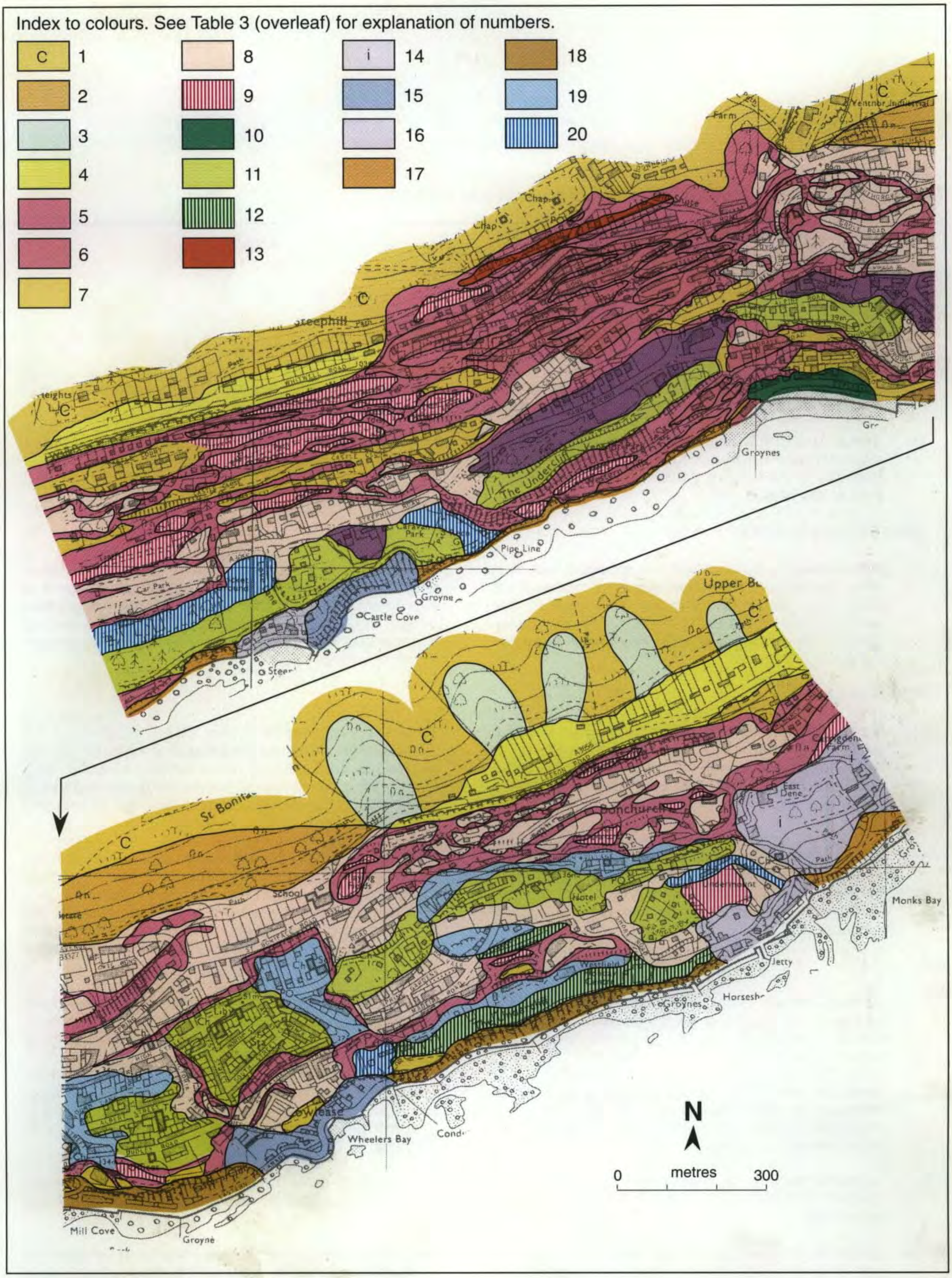


Figure 12: Summary ground behaviour map

Table 3: Ground behaviour: contemporary processes and impacts.

CONTEMPORARY PROCESS CATEGORIES	IMPACT
CHALK DOWNS	
1. Predominantly stable slopes, although soil creep and surface erosion is widespread.	Minimal.
2. Areas which could be sites of flash flooding and debris flow activity in **exceptional** storm conditions.	Property downslope may be damaged by flood water or rapidly flowing debris.
3. Areas susceptible to shallow translational slides involving soil and weathered chalk. Only one example of this type of failure has been reported in the last 200 years.	Minimal, although fast moving debris may damage property or block roads at the base of the slope.
UPPER GREENSAND BENCH	
4. Areas prone to slow settlement, probably less than 1mm per year. Gradual extension of master joints within the Upper Greensand can lead to the development of fissures or vents, up to 40m deep. Only a limited number of vents have been recorded in the last 200 years.	Properties situated within these areas have been affected by differential horizontal and vertical movements, together with forward tilt. This has resulted in light structural damage. Collapse of the ground surface into fissures or vents constitutes a significant threat to safety.
ROTATIONAL SLIDES	
5. Major scarp slopes. Degradation of scarp slopes is generally limited to slow superficial movements. In places these slopes may be susceptible to rockfall or debris slide activity, although only 3 such events have been recorded in the last 200 years.	Where scarp slopes have been supported by inadequately designed retaining structures, failure has resulted in slow bulging and cracking of walls. In a number of cases failure of the retaining wall has led to rapid ground movement, causing damage to property downslope.
6. Landslide bench; area affected by intermittent settlement of displaced blocks of material along pre-existing shear surfaces, which can lead to the formation of fissures, tension cracks and gradual subsidence.	Properties situated on these benches have been affected by differential horizontal and vertical movements, rotation, torsion, forward tilt and subsidence. Differential movement has been greatest at the back of the bench where the shear surface meets the ground surface. The cumulative effects of this movement has resulted in serious and severe damage to property.
7. Landslide bench; areas where imperceptible ground movement (< 10mm per year) has been reported in the past, although for much of the time these benches are inactive.	Most properties situated on these benches have been largely unaffected by ground movement. However, in places the cumulative effects of ground movement has resulted in moderate and light damage to property.
8. Landslide bench; no landslide events have been recorded in these areas during the last 200 years. These areas have been either inactive or subject to imperceptible movement.	Most property has been unaffected by ground movement, although in places the cumulative effects of ground movement may result in light damage to property.
9. Landslide bench; no information is available with respect to the occurrence and rate of past movement.	The effects of ground movement, if any, are unknown. Further investigations will be necessary to assess ground behaviour.
10. Landslide toe; area which has been prone to uplift and ground heave in the toe area of a landslide unit. Parts of this area have risen up to 100mm per year.	Property situated within this area has been affected by differential uplift and forward tilt. These movements have resulted in serious and severe damage to buildings, a number of which have had to be demolished or extensively repaired.

CONTEMPORARY PROCESS CATEGORIES	IMPACT
COMPOUND SLIDES	
11. Elongate ridges and scarps of Upper Greensand or Chalky debris; ground movement problems have been minimal along the ridges, although slow superficial movements have been recorded on the scarp slopes.	Most property situated on these ridges has been unaffected by ground movement. However, shallow slides on the scarp slopes may cause light damage to property downslope.
12. Elongate ridges and scarps; no information is available with respect to the occurrence and rate of past movement.	The effects of ground movement, if any, are unknown, further investigations will be necessary to assess ground behaviour.
13. Landslide bench; currently unstable area of settlement between two parallel fissures: the Lowtherville Graben. Rates of ground movement of between 50-100mm per year have been recorded in recent years.	Differential subsidence and fissuring within the graben area has resulted in severe damage to buildings (a number of which have had to be demolished) and the public highway.
DEGRADED TRANSLATIONAL LANDSLIDE	
14. Areas of currently inactive shallow mudslides and small rotational slips. Only limited information is available with respect to the occurrence and rate of past movement.	Little is known of the behaviour of these areas.
COASTAL MUDSLIDES	
15. Areas which have been affected by recurrent slow mudslide movement, although rapid movement could occur in exceptional circumstances.	Property situated within these areas has been affected by differential horizontal and vertical movement, especially footpaths which cross the mudslide units. Movements may result in property at the head of the units being undermined. At the foot of the slopes, fast moving runout may cause serious damage to structures.
16. Areas of very rare or no records of contemporary mudslide movement.	The effects of ground movement, if any, are unknown. Further investigations will be necessary to assess the impact of development in these areas.
COASTAL CLIFFS	
17. Unprotected coastal cliffs which have been prone to rock and debris falls, slides and spalling.	Falls and slides represent a threat to public safety. Property adjacent to the cliff top may be undermined by coastal erosion.
18. Coastal cliffs protected by sea walls, which have been prone to occasional rock and debris falls, slides and spalling.	Falls and slides represent a threat to public safety. Property adjacent to the cliff top may be undermined by degradation of the cliff face.
SOFT GROUND	
19. Areas which have been subject to imperceptible settlement (< 1mm/year) of soft ground.	Property situated within these areas has been affected by very gradual vertical movement and tilting. In the past this has resulted in light and negligible damage, although localised cases of moderate and severe damage have occurred.
20. No information is available with respect to the occurrence and rate of past settlement	The effects of settlement, if any, are unknown.

Index to colours. See Table 4 (overleaf) for explanation of categories.

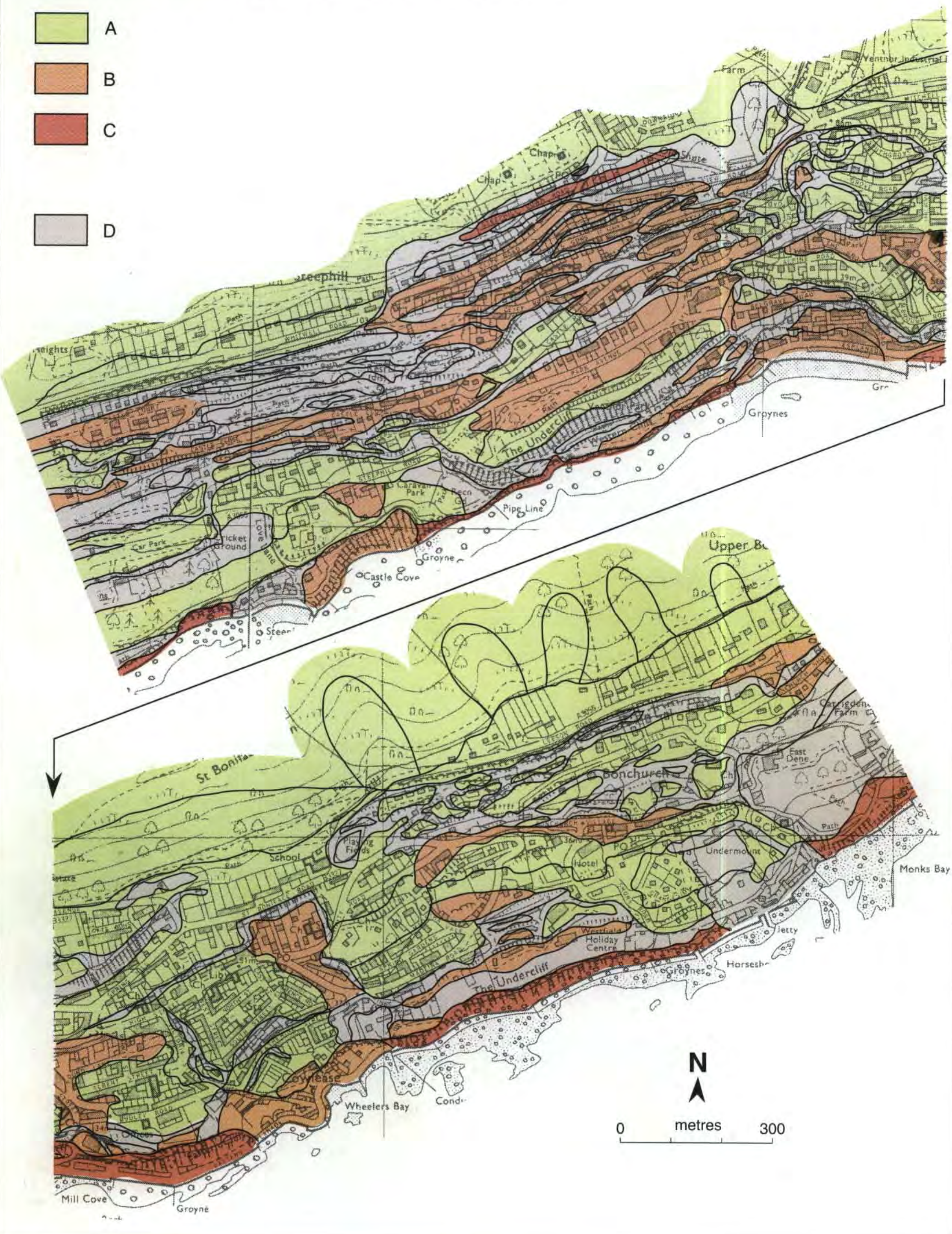


Figure 13: Summary planning guidance map

CATEGORY	DEVELOPMENT PLAN	DEVELOPMENT CONTROL
A	Areas likely to be suitable for development. Ground behaviour does not impose significant constraints on Local Plan development proposals.	Results of a desk study and contemporary walkover survey should be presented with all planning applications. Detailed site investigations may be needed prior to planning decision if recommended by the preliminary study.
B	Areas likely to be subject to significant constraints on development. Local Plan development proposals should identify and take account of the ground behaviour constraints.	A desk study and walkover survey will normally need to be followed by a site investigation or geotechnical appraisal prior to lodging a planning application.
C	Areas most unsuitable for built development. Local land development proposals subject to major constraints.	Should development be considered it will need to be preceded by a detailed site investigation, geotechnical appraisal and/or monitoring prior to any planning applications. It is likely that many planning applications in these areas may have to be refused on the basis of ground instability.
D	Areas which may or may not be suitable for development. Investigations and monitoring may be required before Local Plan proposals are made.	Areas need to be investigated and monitored to determine ground behaviour. Development should be avoided unless adequate evidence of stability is presented.

Table 4 Planning guidance categories

CHAPTER 6
HOW CAN THE LANDSLIDE PROBLEMS BEST BE MANAGED ?

Landslide management

In the past there appears to have been an ad-hoc response to specific landslide events in Ventnor, concentrating on emergency action as required; repairing buildings where possible and condemning any properties damaged beyond repair. Such 'crisis management' responses after the event are common reactions, throughout the world, to infrequent problems. However, in Ventnor, where ground movements are a recurrent problem, there is a clear need for a coherent and systematic strategy for managing the landslide hazard.

The scale and complexity of the landslide system at Ventnor dictate that conventional engineering solutions to the instability problems are unlikely to **prevent** any further movement. More realistic aims would involve **reducing** the size and frequency of future movements and minimising their impact. This may be achieved by:

- controlling the natural factors which influence landslide behaviour;

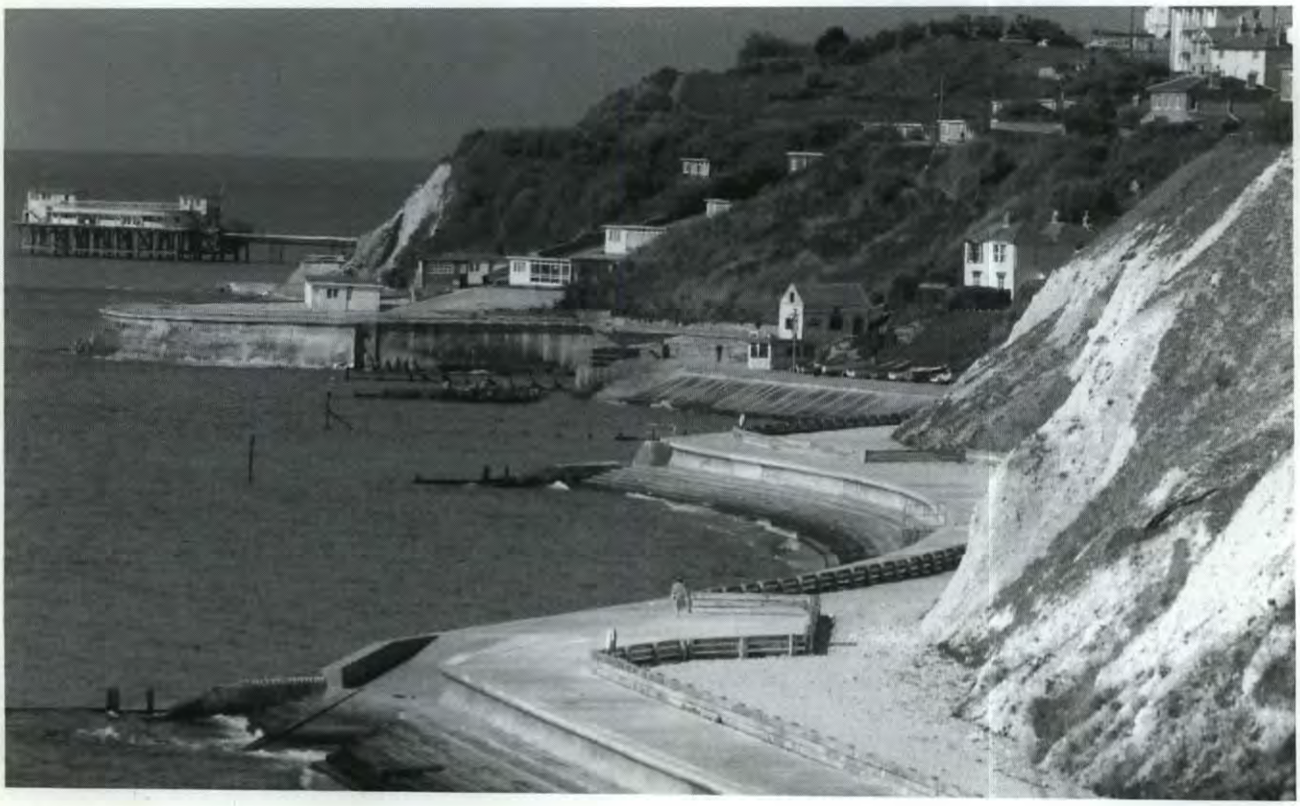


Plate 13: Coastal defences, Westfield Cliffs and Wheeler's Bay

- minimising the effects of human disturbance on the landslide behaviour;

- reducing the vulnerability of different parts of the town to ground movement.

Before describing the ways in which different sections of the community can assist in managing the landslide, it is necessary to outline those measures that could reduce the frequency of ground movement events.

Engineering works

Bearing in mind the fact that the Undercliff at Ventnor comprises a series of inter-related landslide systems rather than a single landslide, it is likely that major engineering schemes designed to improve the stability of the whole town are unrealistic. However, it is possible that appropriate areas could be targeted for less ambitious, but nevertheless important schemes.

Without more detailed information about the sub-surface conditions and the relationship between groundwater levels and rainfall, it is difficult to make judgements about what type of measures would be most appropriate. However, it is likely that two approaches could prove successful in improving stability:

- adding weight to the toe areas of individual landslide systems. However, two obvious problems need to be overcome. The exact positions of the landslide toes are, at present, unknown. It is not possible, without sub-surface investigation, to estimate what weighting would be needed and it may be that toe weighting one landslide system could end up loading the head of another;

- lowering the groundwater levels by means of horizontal drains, drainage galleries or pumping. Such measures could only be contemplated after a thorough investigation of the hydrogeology of the area.

Construction activity

Control of construction activity in the town could be an important factor in reducing the possibility of ground movement. There are a number of improvements that could be made to existing practice:

- avoiding cut and fill operations at inappropriate locations. In broad terms loading the head of a landslide system will tend to destabilise it, while loading the toe will have a stabilising effect. The corresponding unloadings will have the opposite effect. Cut and fill operations should be carried out only after due consideration has been given to the geomorphological setting of each development;

- avoiding earth moving operations during those periods when the landslide complex appears to be more prone to movement (i.e. Class 2 and 3 conditions on Figure 9);

- controlling the removal of vegetation from cliff or scarp faces, as in many cases vegetation acts to bind a slope and reduce the likelihood of superficial movement;

- controlling the planning and excavation of open trenches for maintenance of services, as they can increase rainfall infiltration or affect the stability of nearby slopes and retaining walls.

Preventing water leakage

Because it can be demonstrated that movements occur in specific groundwater and rainfall conditions and because it is known that many service lines are damaged, a major effort needs to be made to prevent water leakage.

The flow within the water supply network should be monitored to identify areas of leakage, where pipes will need to be either repaired or replaced. The use of flexible pipes is recommended. There is also a clear need to overhaul the sewerage system which, in places, has been badly damaged by ground movement.

Soakaways, French drains and other natural percolation methods of disposing of surface water must be avoided and storm water outfalls should be taken down to the sea before being discharged.

The importance of preventing water leakage into the landslide complex, either through water mains, service pipes, sewers, soakaways or highway drains cannot be over emphasised. Such actions are likely to be the most cost-effective way of reducing the occurrence of damaging ground movement events.

Protecting the coastline

It is very important to prevent marine erosion of the landslide complex. This one factor alone has probably had the greatest influence on the development and continued instability of the Undercliff (Chapters 3 and 4).

The coastline is a highly dynamic environment. Over its length it contains areas of erosion, which provide sources of sand and gravel (e.g. Chale Cliffs), which accumulates to form beaches (e.g. Ventnor Bay, Steephill Cove). These beaches can act as an excellent natural protection measure for the slopes inland. However, if the supply of beach material is reduced, either by protecting erodible cliffs or disrupting the transport and build up of sediment, then the beaches can quickly disappear. As has already been pointed out, such a situation occurred when Collin's Point was removed in the 1860's, during the construction of Ventnor harbour which led to considerable ground movement problems[1,2].

Clearly managing the coastline needs to involve a consideration of the whole system of supply, transfer and accumulation (known as a coastal process unit) and not just individual elements of the system. In this context it is important to stress that marine erosion can involve both erosion of the cliffline **and** the shore platform. Coastal protection schemes need to take both factors into account.

Where protection schemes are already present they need to be regularly inspected and their performance reviewed. Unprotected stretches of the coastline at Ventnor clearly need to be protected. At the time of writing (1991) schemes are actually being designed for both the Monk's Bay area and the Western Cliffs.

It must be realised that such schemes will not improve the Factor of Safety of the Undercliff, merely prevent it from being reduced by continued unloading. Additional approaches are needed. The most appropriate solutions will probably involve a combination of all the of approaches described in this Chapter.

REFERENCES

1. Royal Commission on Coast Erosion, 1907; 1911
2. Whitehead, 1911

CHAPTER 7
WHAT CAN THE LOCAL AUTHORITY DO ?

Most proposed developments in Great Britain require planning permission. Local planning authorities are empowered under the Town and Country Planning Act, 1990 to control most forms of development and are responsible under the Building Regulations and the Housing Acts for controlling particular aspects of development. When reviewing an application for planning permission the local planning authorities, in England and Wales, have a duty to take into account a range of material considerations, including instability problems (e.g. landsliding). The main aims of considering potential landslide problems at this stage in the planning process are to[1]:

- minimise the risks and effects of landsliding on property, infrastructure and the public;
- help ensure that various types of development should not be placed in unstable locations, without appropriate precautions;
- bring unstable land, wherever possible, back into productive use;
- assist in safeguarding public and private investment by a proper appreciation of the site conditions and necessary precautionary measures.

The Department of the Environment has recently issued Planning Policy Guidance[1] which advises local authorities, landowners and developers on the role of planning controls as a landslide management tool. The purpose of the guidance is not to prevent development (although in some cases this may be the best response), but to ensure that development is suitable and to minimise undesirable consequences such as property damage or degradation of the physical environment. However, the responsibility for determining whether land is suitable for a proposed development lies with the developer and/or the landowner.

There are considerable opportunities to prevent or reduce damage to new development by incorporating the knowledge of ground behaviour, presented in Chapter 5, within the existing planning framework. The **Isle of Wight Structure Plan**, or an interim policy statement, provides an excellent opportunity for identifying the extent of the landslide problem across the island and outlining the policies that are to be adopted in these areas. The **Local Development Plan** could be used to outline the procedures that will be used in reviewing planning applications in Ventnor and the types of planning conditions which would normally be met.

The **handling of planning applications** for development in Ventnor will need to take the possible problems into account. The procedure recommended by the Department of the Environment[1] is summarised in Figure 14 which highlights the value of prior consultation between a developer and the local planning authority before an application is submitted, and the need for the developer to provide sufficient information to enable the authority to consider the application. The authority should then determine, taking into account all material considerations of which instability is only one, whether a proposed development should proceed. If development is approved, it is then the authority's responsibility under the Building Regulations to determine whether the detailed design of the structure can be built and used safely. Even though the local authority may have granted planning permission, the responsibility and subsequent liability for safe development and secure occupancy rests with the developer and/or landowner.

Some development does not require planning permission, such as 'Permitted Development', development with deemed planning permission or activities of a *de minimis* nature (e.g. construction of swimming pools). In such cases, the local authorities might give serious consideration to making a **direction under Article 4 of the General Development Order, 1988** to remove specific development rights within an area and require planning permission to be obtained. In other cases, an advisory code of good practice may be appropriate (e.g. with regard to the construction of swimming pools).

Plate 14: Raking shores used to counter localised rotational tilt

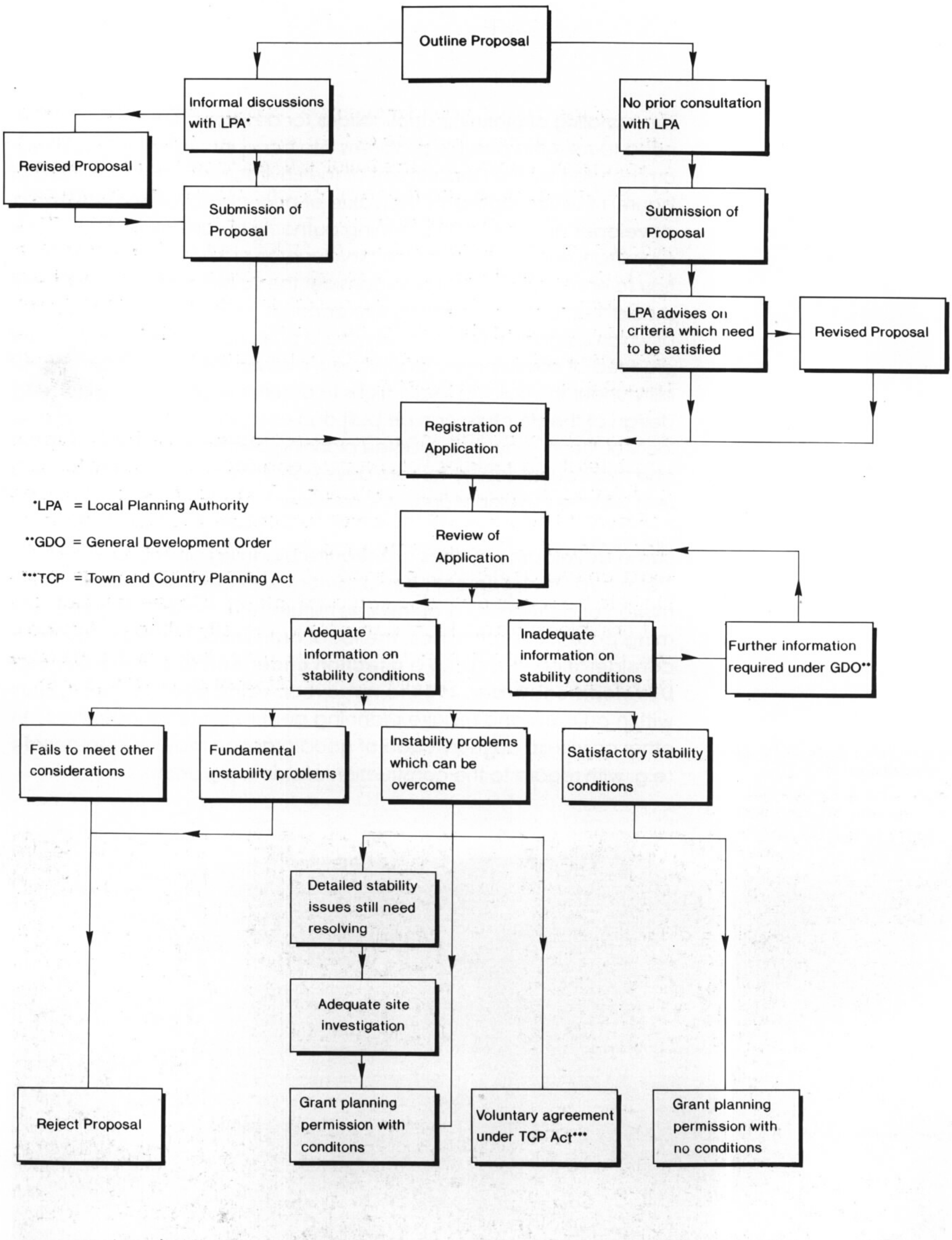


Figure 14: Suggested procedures for review of planning applications

Many of the current ground movement problems have arisen or have been made worse, because of the poor standard of some of the building and repair work. The **Building Regulations** could be used to ensure that appropriate foundations and building types are constructed in problem areas and properly checked during inspections. It is recognised that the Building Regulations cannot assist in controlling building development in areas of unstable ground, as they have no provision for dealing with the overall setting. However, improvements in building standards, administered through the Building Regulations, are considered likely to reduce the impact of future ground movement (Chapter 9).

A Planning Guidance Map has been produced at 1:2,500 scale which relates categories of ground behaviour to forward planning and development control. The Planning Guidance Map (summarised as Figure 13 and Table 4) indicates that different areas of the landslide system need to be treated in different ways for both policy formulation and development control. Areas are recognised which are likely to be suitable for development, along with areas which are either subject to significant constraints or mostly suitable. Advice is also provided on the detail of stability information which should be presented with planning applications in different areas (Chapter 8).

REFERENCE:

1. Department of the Environment, 1990

Plate 15: Differential ground movement has distorted the frame and tilted the sill

CHAPTER 8
WHAT CAN THE DEVELOPER DO ?

The responsibility for determining whether land is suitable for a proposed development lies with the developer and/or the landowner. Clearly the old adage "foreseen is forewarned" is true when considering the damage to property that has been caused by ground movement in Ventnor. Obviously it is in a developer's own interests to determine whether a site is on unstable land as any future movement will affect the value of the site and both its development costs and maintenance. If there are any reasons for suspecting instability problems the developer should instigate appropriate investigations to determine whether[1]:

- the land is capable of supporting the loads to be imposed;
- the development will be threatened by unstable slopes on, or adjacent to, the site;
- the development will initiate slope instability which may threaten its neighbours.

Plate 16: Both long-standing movement and recent fracturing are evident in this photograph

The assessment of landslide problems and the associated risk requires careful professional judgment. Developers should seek expert advice about the likely consequences of proposed developments within the town. This advice will generally involve some form of **investigation** into the nature of the problem and should provide an indication as to whether the site is suitable or a **management strategy** is needed to prevent problems affecting the site or the neighbouring land.

The developer should provide sufficient information on stability matters to enable the local authority to review the planning application (Figure 14). Indeed, the authority is entitled to require the developer to seek suitable expert advice. It is important to stress, at this point, that the developer needs to investigate not only the stability of the proposed site but also whether the development could adversely affect the surrounding land (e.g. as a result of accidental water leakage or removal of support).

If the developer's stability report indicates that ground movement can be avoided or accommodated planning permission may be granted, unless the application fails to meet other planning criteria. In some cases, planning permission may be conditional on the incorporation of any remedial measures (recommended in the stability report), in the detailed design, and that local codes of practice are observed.

Advice on the level of stability information which should be presented with applications should be sought from the local authority at an early stage. In general, three levels of investigation have been incorporated into the Planning Guidance Map (Figure 13; Table 4), based on the severity of the potential problems:

- **desk study;** developers and their consultants should review the potential instability problems in and around the proposed development site. This will involve consulting the published technical report which presents the detailed results of this study and, where relevant, reviewing the significance of any additional information on ground movement since 1990. An assessment of the implications of the proposed development on slope stability may be required;

- **walk-over survey;** involving the inspection and mapping of a site and the surrounding area to determine the geomorphological context of the proposed development and to identify any recent (post-1990) ground cracking or structural damage to property. An assessment of the implications of the proposed development on slope stability may be required;

APPROACH	TECHNIQUE	USAGE
SUB-SURFACE AND IN-SITU TESTING	TRIAL PITS TRENCHES	Sampling and logging of exposures. Most useful investigating shallow instability in soils and soft rock or locating boundaries of disturbed ground.
	BOREHOLES	Sampling and logging of disturbed or undisturbed core samples. Useful in investigating deeper instability problems. Variety of techniques eg. shell and auger, rotary drilling etc. allows use in all rock types, although core recovery can be a problem.
	ADITS	Large excavations to establish sub-surface conditions in major, deep seated landslides. Very expensive and are generally used as a drainage measure.
SURFACE MONITORING	TOPOGRAPHIC SURVEY	Measurement of displacement rates between surveyed points. Problems of vandalism.
	EXTENSOMETERS	Measurement of enlargement of tension cracks, building cracks etc. Problems of vandalism.
	ANALYTICAL PHOTOGRAMMETRY	Analysis of displacement of points on photography of different dates, usually aerial but can be hand-held. Expensive, taking considerable computing effort. Not sensitive to very small displacements.
SUB-SURFACE MONITORING	INCLINOMETERS AND SLIP RODS	Identification of zones of movement, monitoring of displacement rates.
	PIEZOMETERS	Monitoring groundwater levels and pore-water pressures.
HYDROLOGICAL MONITORING	TRACER EXPERI-MENTS, PUMP TESTS ETC.	Enables groundwater flow monitoring for design and investigation of remedial measures.

Table 5: Commonly used ground investigation techniques

- **ground investigation;** typical ground investigations are likely to involve sub-surface investigation. More extensive investigations should also include surface and hydrological monitoring (Table 5). It is important to discuss the scale of any ground investigation with the local authority. This will obviously depend on the nature of the problem at a particular site. However, it is of great importance that the objectives of any investigation are realistic, otherwise the costs of obtaining stability information might act as a restriction on development.

Should a planning application be accepted on the grounds that instability problems can be overcome and will not affect neighbouring properties, then it will be necessary to design and construct measures to reduce the potential hazard. A wide range of such remedial measures are available (Table 6), although the most appropriate methods are likely to include a combination of drainage and the construction of restraining structures. In certain circumstances modification of the slope profile by excavation or filling may be suitable although it is very important to ensure that cuts or fills actually achieve their intended purpose and do not initiate further ground movement.

REFERENCE:

1. Department of the Environment, 1990

Table 6: Principal methods of slope stabilisation

APPROACH	METHODS
EXCAVATION AND FILLING	- Remove and replace slipped material. - Excavate to unload the slope. - Fill to load the slope.
DRAINAGE	- Lead away surface water. - Prevent build-up of water in tension cracks. - Blanket the slope with free draining material. - Installation of narrow trench drains aligned directly downslope, often by shallow drains laid in a herring bone pattern. - Installation of interceptor drains above the crest of the slide or slope to intercept groundwater. - Drilling of horizontal drains into a slope, on a slightly inclined gradient. - Construction of drainage galleries or adits, from which supplementary borings can be made. - Installation of vertical drains which drain by gravity through horizontal drains and adits, by siphoning or pumping.
RESTRAINING STRUCTURES	- Retaining walls founded beneath unstable ground. - Installation of continuous or closely spaced piles, anchored sheet or bored pile walls. - Soil and rock anchors, generally pre-stressed.
EROSION CONTROL	- Control of toe erosion by crib walls, rip-rap, revetments, groynes. - Control of surface erosion. - Control of seepage erosion by placing inverted filters over the area of discharge or intercepting the seepage.
MISCELLANEOUS METHODS	- Grouting to reduce ingress of groundwater into a slide. - Chemical stabilisation by liming at the shear surface, by means of lime wells. - Blasting to disrupt the shear surface improve drainage. - Bridging to carry a road over an active slide. - Rock traps to protect against falling debris.

Unlike many areas of mining subsidence, for example, local developers are not experienced in designing or constructing buildings that are able to successfully accommodate ground movement. An advisory code could significantly improve the overall standards of design and construction, and thereby reduce the effects of further movement.

It is envisaged that the proposed code of good practice would be in the form of a series of recommendations that must be considered , covering a number of areas of design and construction practice. The scope of the code would be expected to address as a minimum the aspects outlined in Table 7, which indicates that a great deal can be done to limit the effects of ground movement. The most significant is the adoption of raft-type foundations which can `float' over the movement.

Appropriate design features are needed throughout structures. For example, the adoption of simple rectangular plan shapes, minor reinforcement in concrete and the articulation of walls. The detailed design is a question of degree. A practical balance must be struck, based on experience, between expenditure and utility.

By way of illustration, some aspects of building construction are discussed below. These details are not exhaustive and there are many other details which can be adopted or aspects considered in the design of works in this particular area. Great care must be taken to ensure that problems are not created when traditional details are modified or material specifications changed.

(a) **rafts;** structures built on a reinforced concrete raft should be able to absorb minor ground movement. The design does not need to be so strong and rigid that the raft is capable of acting like a bridge between the two extremities of the structure. But it does need to be able to span the minor voids that may form below the raft;

(b) **jacking points;** some sites may be considered particularly vulnerable to ground movement. In such situations jacking points may be included below the ring beam or the foundation slabs (both of which need special additional design). Re-levelling of the structure can then be carried out should tilt occur;

(c) **frames;** fully framed buildings are the structural form which is best suited to the problems of the area. Their advantage lies in the inbuilt structural integrity. By moving as a whole, they are capable of resisting fracturing when subsidence occurs;

(d) **structural form;** the more uniform the shape of the property in plan, the more likely it is to accommodate torsion damage from movement. Simple rectangular slabs within design parameters should be adopted. Where more complex plan forms are unavoidable, the floor slab/raft foundation should be divided up into a series of rectangular bays. Where garages cannot be incorporated as part of the main structure they should be constructed on a separate raft totally independent of the main dwelling. In any event, the separation of the garage is preferred as it minimises the slab size for the house;

(e) **height;** although tilt is rare in the area it is possible. Consequently, it is recommended that structures are kept as low as possible, certainly not exceeding three storeys and preferably only two storeys;

(f) **wall types;** the more flexible and resilient the wall type, the more able it is to resist damage from movement. A brick wall will show damage long before a plywood panel. It must be appreciated that although a reinforced concrete raft is designed to limit movement of the structure it supports, some movement is unavoidable as the raft itself flexes under load. Slight cracking of brickwork is therefore likely although generous provision of movement joints in masonry may be sufficient for movement not to show;

(g) **ceilings;** generally, the first part of a building to show damage is the ceiling, mainly due to the fragile nature of plasterboard. Slight movement of the walls causes fracturing. The damage can be minimised by setting the plasterboard back from its normal junction with the walls and completing the junction with coving. Any future cracking can then be `stopped' and the need for renewal of the ceiling avoided;

(h) **concrete;** concrete should have a minimum thickness of 100mm for footpaths and 150mm elsewhere. It should be laid in rectangular bays of as small a size as possible. The smaller the size, the less vulnerable is the concrete to cracking. Typically joints should be formed at a maximum of 2 metre centres. All concrete should contain mesh reinforcement. Dowel bars may be advisable in some instances. Movement joints should be formed with bitumen impregnated fibreboard and be topped with mastic asphalt;

(i) **gutters;** special attention needs to be paid to the design of gutters. The traditional design was based on rainfall from a 2" per hour storm. Today the standard is 75mm (3") per hour but this standard means that occasional overflows will occur during severe rain. In the Ventnor area, it is precisely this rainfall from severe storms which needs to be trapped and channelled away. Gutters should therefore be designed to a higher standard of perhaps 100 or 125mm per hour, with special arrangements for valley gutters.

It is emphasised that the proposed code would be advisory in nature and related purely to good building practice; it would not constitute a full design guide or textbook for construction on landslide areas. Compliance with the code would not guarantee the continued stability or absence from damage of a building for a particular design life. It is considered important that the responsibility for determining the suitability of a site and for the detailed design of any development should clearly remain with the developer and the developer's professional advisors notwithstanding any advice which may be given and/or enforced by the Local Authority.

Table 7: Suggested scope for code of good practice for building in Ventnor

(1) Siting:
- recommendations intended to avoid unsuitable siting of buildings within a development plot, such as adjacent to a landslide scarp, adjacent to the crest of a steep slope, close to a near vertical face from which rockfalls may occur;
- advice on the nature and sources of information and types of investigation which will assist in determining suitable siting;

(2) Earthworks:
- the importance of earthworks control in connection with general site preparation and also with landscaping;
- the avoidance of fill operations near the crest of existing slopes, and of excavation at the toe of steep slopes;
- the need for balanced earthworks over the development site;
- restrictions on the length of trenches excavated along the contours of steep slopes;

(3) Retaining walls:
- the avoidance of loading behind, or unloading in front of existing retaining walls, unless the design, construction and condition have been properly investigated and any necessary remedial or strengthening measures carried out;
- advice on the correct design of new retaining walls;
- recommendations covering the adequate consideration of ground water during design, in the detailing of drainage measures, and during construction;

(4) Groundwater control:
- provision for free drainage of groundwater;
- re-routing, repair and reconnection of existing sewers, and water supply network;

(5) Drainage:
- provision for positive drainage of surface water;
- prohibition of septic tanks and soakaways;

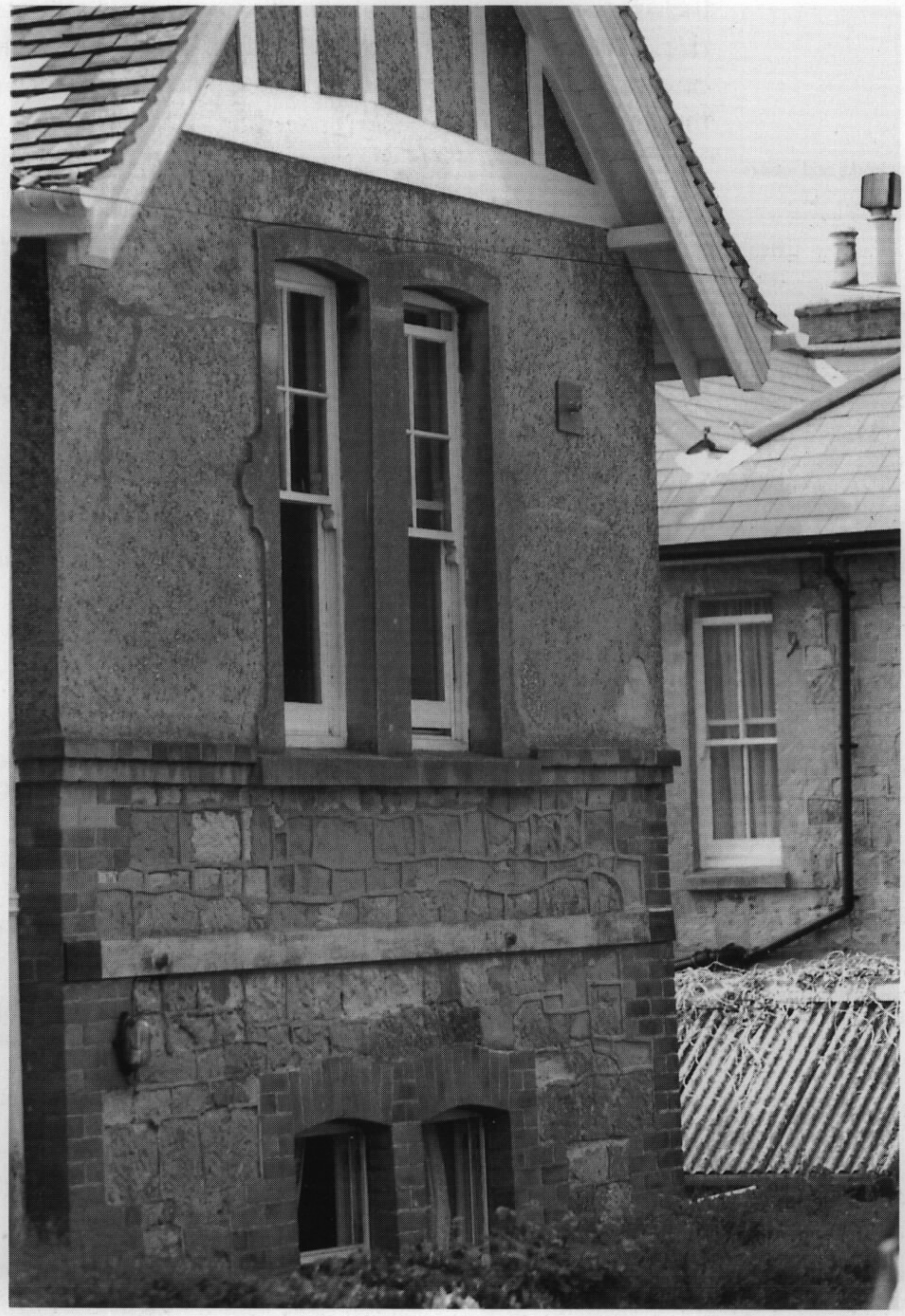
(6) Service connections:
- provision of flexible service connections from buildings;
- provision of flexible jointed pipes capable of sustaining small movements without leakage;

(7) Foundation design:
- the requirement for raft foundations, designed where appropriate for potential partial loss of support;

(8) Building form:
- identification of building forms that are unsuitable for landslide areas and advice on those forms that are more appropriate;
- restrictions on height and foundation loading;

(9) Structural form:
- advice concerning both unsuitable structural forms and those that are more appropriate.

Plate 17: Steel tie rods and beam used to hold building together



CHAPTER 10
WHAT CAN PROPERTY OWNERS DO ?

Much can be done to existing buildings to reduce the effects of ground movement. Repairs and precautionary measures can reduce maintenance costs and should also prolong the life of the property. A list of possible works is presented in Table 8. The actual extent of repairs or precautionary works needed at any property will require careful consideration and independent professional advice. Indeed, decisions on detail will vary from property to property depending on its size, location, construction and value. However, any repairs must be carried out in the knowledge that ground movement may continue.

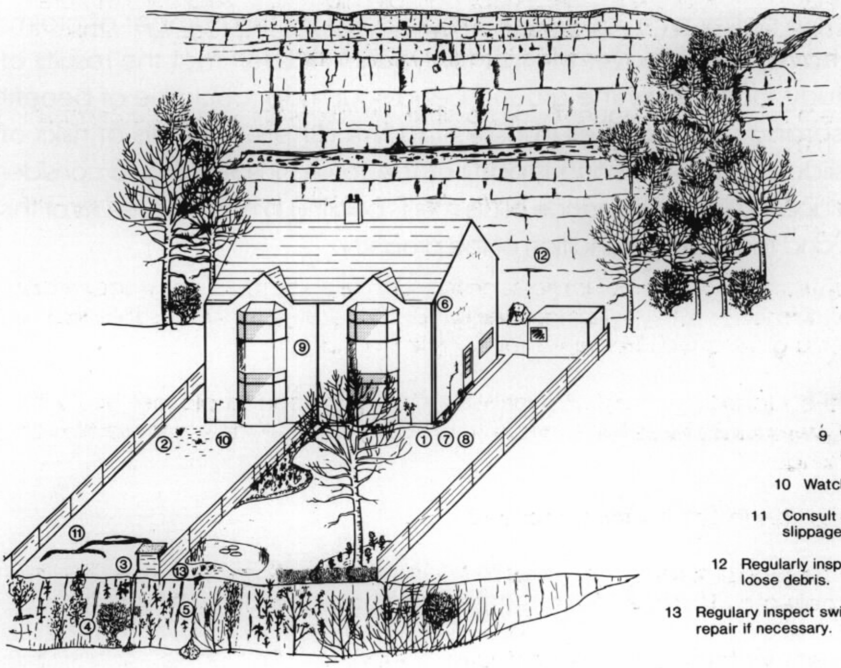
Table 8: Precautionary works and repairs

Foundations	Build on rafts to `float' over slight movement; subdivide rafts into simple rectangular shapes.
Structural form	Framed construction has better resistance to damage than masonry construction. Avoid complex plans and designs. Allow for possible slight tilt. Avoid tall structures. Allow for future repairs and movement. Allow extended bearings for supports. Consider design features which provide integral buttressing.
Property walls	Provide movement joints as frequently as possible/practicable. Subdivide complex structures with movement joints.
Freestanding walls	Provide weep holes at upper and lower levels; build in suitable designed movement joints.
Joinery	Design to provide flexibility with large rebates, dry jointed frames and loose pin hinges. Allow for future use of folding wedges. Generally use accessible screw fixings. Consider glazing with beading, soft mastic or gaskets.
Ceilings/Linings	Consider matchboarding or sheet materials. Cut gap around old ceilings with cove over. Overboard old ceilings. Avoid tight fitting of all cladding; loose fit with removable fixings.
Renderings	Incorporate expanded metal reinforcement.
Gutters	Provide gutters substantially in excess of BRE recommendations to ensure that all rain water is collected in heavy storms (suggested design standard: 125mm/hr)
Hardstandings	Provide frequent waterproof movement joints, perhaps at 2m centres. Subdivide all concrete into rectangular shapes; incorporate light steel mesh reinforcements.
Drainage	Inspect and repair existing drains. Ensure that all areas are properly drained. Landscape surfaces to provide falls towards drain inlets.
Sealants	Almost all sealant materials require periodic renewal; allow for access; choose appropriate materials.

All professional advice should warn that precautions can only mitigate damage; if serious movement occurs, structural precautions will be ineffective and failure will be inevitable.

Maintenance of individual properties is considered to be of great importance, as neglect can often lead to instability problems. A series of suggestions for good practice are presented in Figure 15. Possibly the most important of these is for property owners to refrain from discharging **any** water directly into the ground. A permanent and voluntary hose-pipe ban could only do good.

Figure 15: Suggested good maintenance practices for home owners



DON'Ts

1 Don't block or alter ditches or drains.

2 Don't allow water to collect or pond.

3 Don't shift your water or soil problems downslope to your neighbours.

4 Don't landscape the slope without notifying the Local Authority.

5 Dont clear vegetation off slopes without replanting.

DO's

6 Check roof drains, gutters and downspouts to make sure they are clear.

7 Clear drainage ditches and check them frequently during winter.

8 Make inspections during winter- this is when problems can occur.

9 Watch for water back-up inside the house at sump drains and toilets, since this indicates drain or sewer blockage.

10 Watch for wet spots on the property.

11 Consult an expert if unusual cracks, settling or land slippage occurs. Inform Local Authority of any problems.

12 Regularly inspect scarp slopes for potential rockfalls or loose debris.

13 Regulary inspect swimming pools and ponds for leaks and repair if necessary.

CHAPTER 11
WHAT CAN ESTATE AGENTS, SOLICITORS, AND INSURERS DO ?

It is important that a sensible and realistic approach is taken to property transactions and insurance in the area. Although landslide damage occurs, much is minor and substantial areas have not experienced any damage over a long period. It is not logical, therefore, to impose `blanket' measures for the whole area, when risks vary greatly within it.

Estate agents and solicitors

Professionals involved in the buying and selling of houses need to be aware of the nature and extent of the ground movement problems within the town. Where appropriate they should consult the technical report which presents the detailed results of this study in order to determine whether certain properties have been damaged by ground movement in the past or whether sites are known to have been affected by landslide events.

Insurers

Within Ventnor many householders have had great difficulty in arranging building insurance, with many companies refusing to cover properties in certain areas. One company for example, operates a selective policy with `no-go' areas decided by the number of claims they have paid out over the last ten years[1]. It is felt that the results of this study, particularly the ground behaviour map, could be of benefit to insurance companies in assessing the different levels of risks of landslide damage in various parts of the town. Insurers should consider each application for insurance on its merits bearing in mind the results of this study and the existing condition of the property.

REFERENCE:

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CHAPTER 12
WHAT DOES THE FUTURE HOLD?

Co-ordinating the community's response

When a period of landslide activity causes damage to property within the town, the community's response will be wide-ranging depending on the varied ways in which different sectors perceive the problems and solutions. Individuals may seek assistance from the government or local authority, as in the winter of 1960-1961. Differences in perception and responsibilities between the central government, local government, consultants, developers, builders, estate agents, pressure groups and individual homeowners can result in disputes.

Difficulties could arise over both the interpretation of the problem and the solutions that could be adopted. Experience from other areas where geomorphological hazards affect urban communities, such as in Los Angeles, indicate that[1]:

> "almost every proposed solution carries the seeds of conflict, and with good reason, because not only is one man's solution often to the detriment of another, but there are commonly differences of opinion about the effectiveness of proposed solutions amongst professional environmental managers."

Conflict might also arise between the adoption of short-term and long-term strategies. In general, the former may be more readily accepted than the latter, because immediate action demonstrates that something is being done about the problem.

Within Ventnor it is important that these potential conflicts are recognised and that a balance is achieved that is acceptable to the community. One obvious potential problem is that the results of this study could give rise to largely unfounded fears which may affect property values in certain areas. This may come as no surprise in areas where landslide damage has been long recognised, as in the Lowtherville Graben area. However, in undeveloped areas where instability problems are not so readily apparent, the logic of the designation will need to be clearly explained to those affected.

A positive approach to co-ordinating the community's response to the landslide problems is considered essential. Indeed, to effectively reduce the impact of ground movements in the town, planners, developers, builders, estate agents, solicitors, insurers and property owners should liaise and recognise the needs of all the parties involved.

Could the pattern of ground movement change?

Concern has been expressed in the past that the whole landslide system could be reactivated, with devastating consequences for the town. However, the behaviour pattern of the landslides over the last 200 years is well established, with detailed information available on the magnitude, frequency and impact of past movements. A massive failure has not taken place in Ventnor over this time period, although large landslides have occurred at the Landslip (1810, 1818)[2,3] and Gore Cliff (1799; 1839; 1928)[2,4,5,6]. If the past and present hold the key to the future then such an event is unlikely to occur in Ventnor, especially if the landslide management strategies outlined in this book are adopted.

It may be unwise, however, to rely on the past behaviour to continue unchanged in the future. Patterns of ground behaviour could alter significantly over the next hundred years, particularly in light of the climatic changes which are predicted to occur over the next few decades or in the event of increased development. Clearly, an ongoing programme of monitoring is required.

What are the future research needs?

Current knowledge of ground behaviour in the town is based on an understanding of past events (from around 1800 to 1990). However, the predicted effects of climatic change suggest that it may prove more and more difficult to predict future behaviour from what has happened in the past. It is considered very important that future patterns of ground movement are studied in detail, by means of:

- a co-ordinated monitoring programme, involving ground and aerial surveys, climate and groundwater measurement etc;
- maintaining detailed records of future ground movement events;
- undertaking surveys to record structural damage to property

Although the ground behaviour map represents the most complete picture so far of the landslide problems, our understanding of the mechanics and precise stability condition of the Undercliff is limited by the lack of sub-surface information. This deficiency could be overcome by:

- specially commissioned sub-surface investigations to verify the models of landslide development advanced by this study (although costs will inevitably be large);
- the collation and storage of all records of future investigations of ground conditions and evidence of ground movement. The database set up for this study forms a nucleus for such a system.

Confidence in Ventnor

There is no reason why there should not be confidence in Ventnor from a building insurance or financial development point of view. This is true so long as sensible use is made of the technical information presented in this report and obtained from future monitoring exercises, and that the proposed landslide management strategies are practiced. Of course, unstable areas must be avoided where possible. More stable areas may be successfully developed, as long as necessary stabilisation measures are adopted and the developer is willing to accept, in some locations, a higher level of risk than would be expected in normal circumstances.

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Plate 18: The eastern end of the Ventnor Undercliff (coutesy of Elaine David Studio, Shanklin)

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Much of Ventnor, Isle of Wight, lies within an ancient landslide complex, known as the Undercliff. Historical records of movement have been collected which indicate that, over the last 200 years, the town has long been subjected to slow ground movements, which have caused damage to property and services in a number of areas.

This study was commissioned by the Department of the Environment as part of its Planning Research Programme, and has involved:

- **determining the nature and extent of the landslide problems;**
- **understanding the past behaviour of separate parts of the Undercliff;**
- **formulating a range of management strategies to reduce the impact of future movement.**

The work undertaken has involved a thorough review of available records, reports and documents followed by a programme of detailed field investigation comprising geomorphological and geological mapping, photogrammetric analysis, a survey of damage caused by ground movement, a land use survey and a review of local building practice.

Detailed knowledge of the size and frequency of ground movement events over the last 200 years, and an understanding of the geomorphology of the Undercliff has allowed the production of a 1:2,500 scale map of Ground Behaviour. This summarises the nature and extent of the different landslide processes that occur in the area and their impact on the community.

It is important to note that whilst Ventnor has a reputation for landslide movement, large areas of the town have remained largely unaffected. Thus, in many areas buildings have survived for long periods, such as Bonchurch Old Church which is believed to be over 1,000 years old. In addition, many of the older properties are poorly built with foundations and buildings styles completely unsuited to accommodating ground movement. As a consequence, the landslide problems have appeared to be more serious and less manageable than they should.

This report outlines a range of approaches for managing the landslide problems which provide a basis for planning and development decisions in Ventnor, reducing the hazard or minimising the impact on the town.

There is no reason why there should not be confidence in Ventnor from a building insurance or financial development point of view. This is true so long as sensible use is made of the technical information presented in this report and obtained from future monitoring exercises, and the proposed landslide management strategies are practised. Of course, unstable areas must be avoided where possible. More stable areas may be successfully developed, as long as necessary stabilisation measures are adopted, and the developer is willing to accept, in some locations, a higher level of risk than would be expected in normal circumstances.