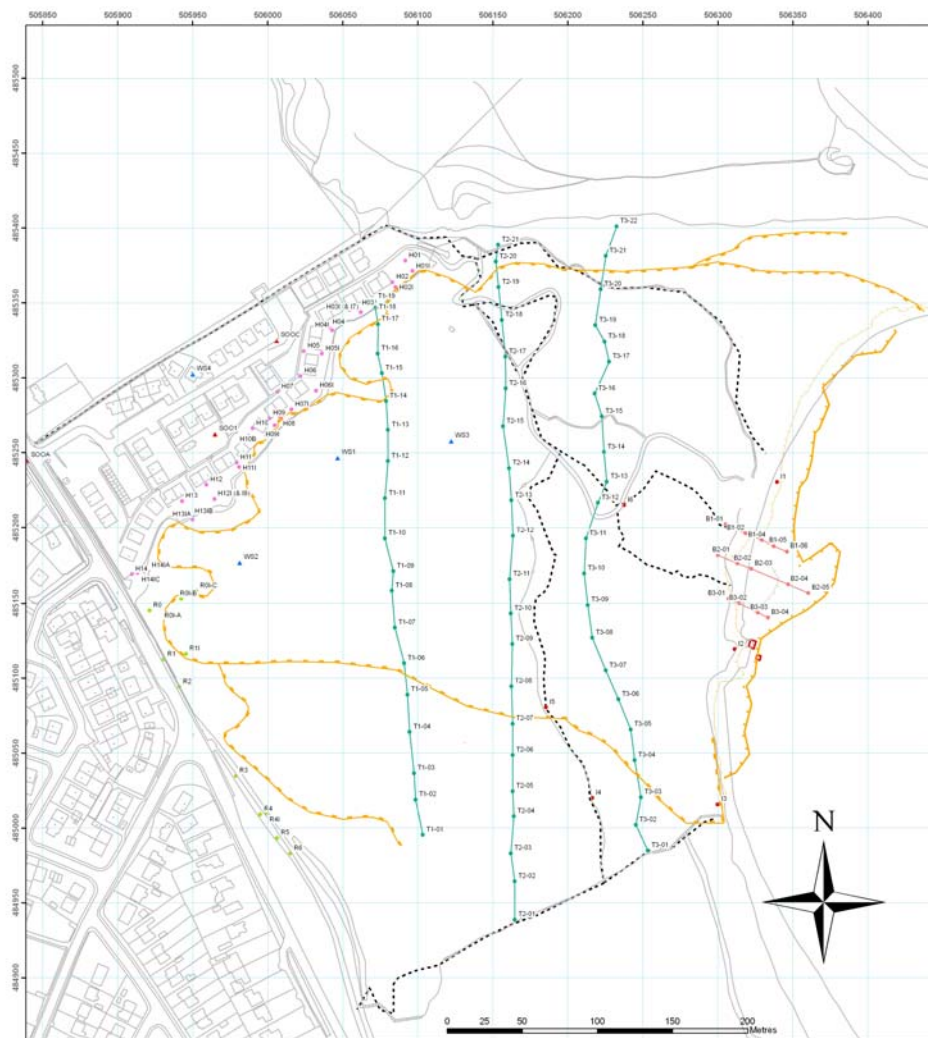


# Cayton Cliff & Cornelian Bay, North Yorkshire Monitoring Report

Report No.: 009 Issue Date: 10.9.09

## Monitoring data and analysis:

1. Ground Marker Network: April 2009- August 2009 (31.3.09- 27.8.09)
2. Groundwater: 5.12.08- 27.8.09
3. Rainfall: Scarborough (1995- August 2009)  
Knipe Point (11.12.08- 26.8.09)



### Legend

Active Landslide (2 May)

### Survey Points (23-24 April)

- Kinpe Point Headscarp Pin
- A165 Headscarp Pin
- Transect Pin (Landslide Body)
- Transect Pin (Landslide Toe/ Beach)
- Fixed Inspection Point
- Water Sampling Point
- Local Survey Control Network Point

### Survey Lines (23-24 April)

- ..... Path
- Pillbox
- Transect (Landslide Toe/ Beach)
- Transect (Landslide Body)
- Remnant Boulder Arc
- Cliff Toe
- Landslide Toe Platform

### Monitoring Layout Cayton Cliff, North Yorkshire (Version 6.5.08)

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The National Trust

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## Knipe Point Headscarp Recession

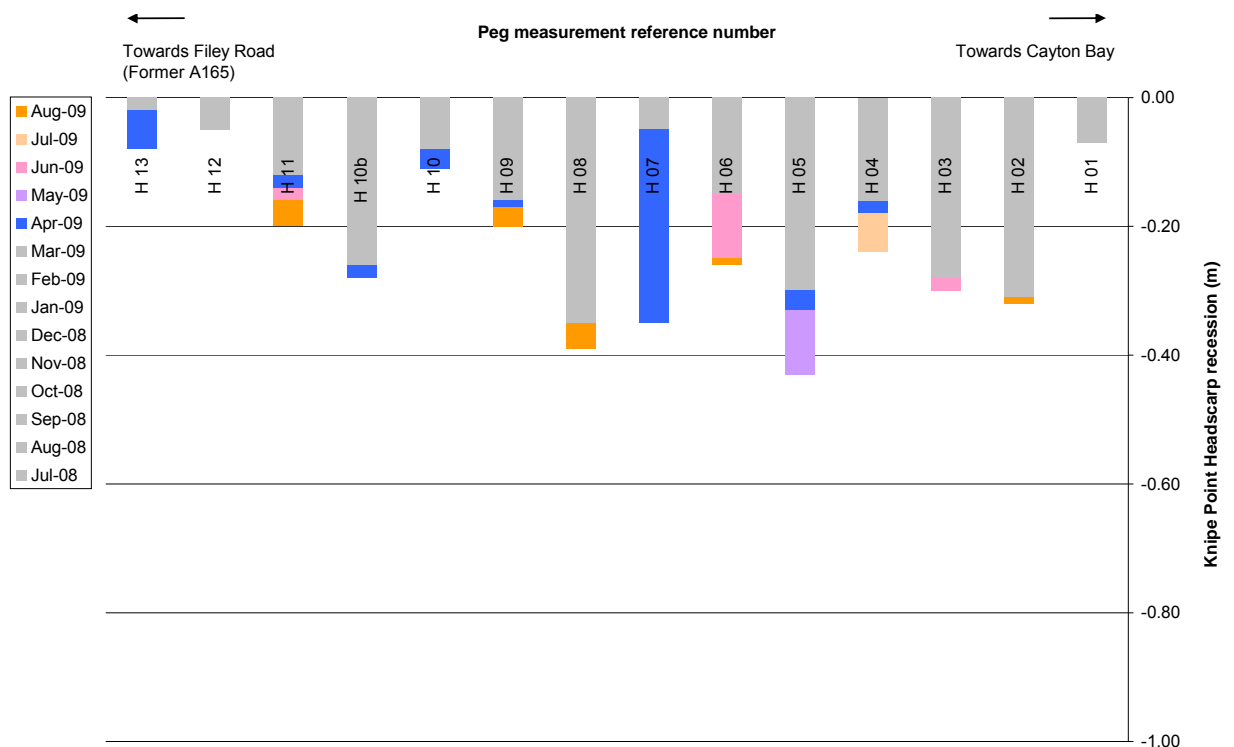


### KEY RESULTS

- Recession measured in April was  $\leq 0.06$  m except for H07 which recorded 0.3 m
- Recession measured in May to July was  $\leq 0.1$  m per month
- Recession measured in August was  $\leq 0.04$  m
- New tension cracks (length up to 11m, depth  $\geq 1.4$  m) and uneven ground in the vicinity of H07I. These are 3-4 m landward of the current headscarp. First recorded observation on 9.7.09, with crack width and frequency increasing since (Photo 1 C & D).

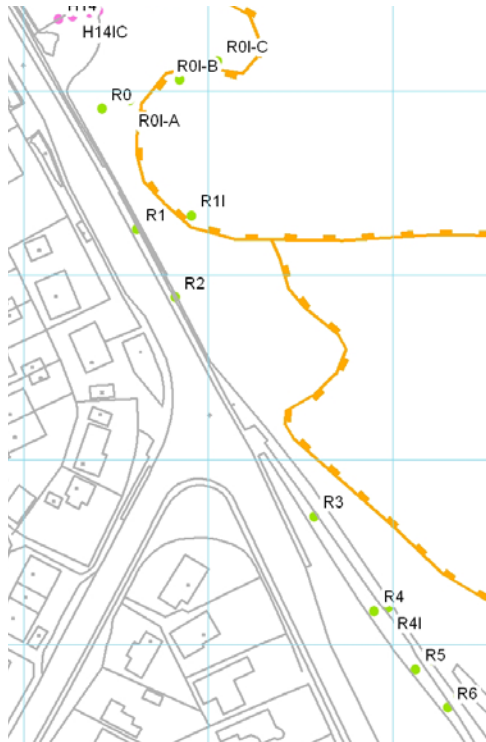
### RECOMMENDATIONS

- As we approach the autumn/ winter, groundwater levels will rise, increasing the likelihood of ground movement and headscarp recession. It is recommended that weekly observation and monitoring is continued
- Carefully observe and monitor the incipient headscarp recession fronting 18 Knipe Point Drive (east of H07I).



**Note:** bars in the graph show total monthly recession measured since 1.7.08. Refer to user notes at the end of this report. Average monthly error of  $\pm 0.04$  m (error compounded in graph).

## Former A165, Filey Road, Headscarp Recession

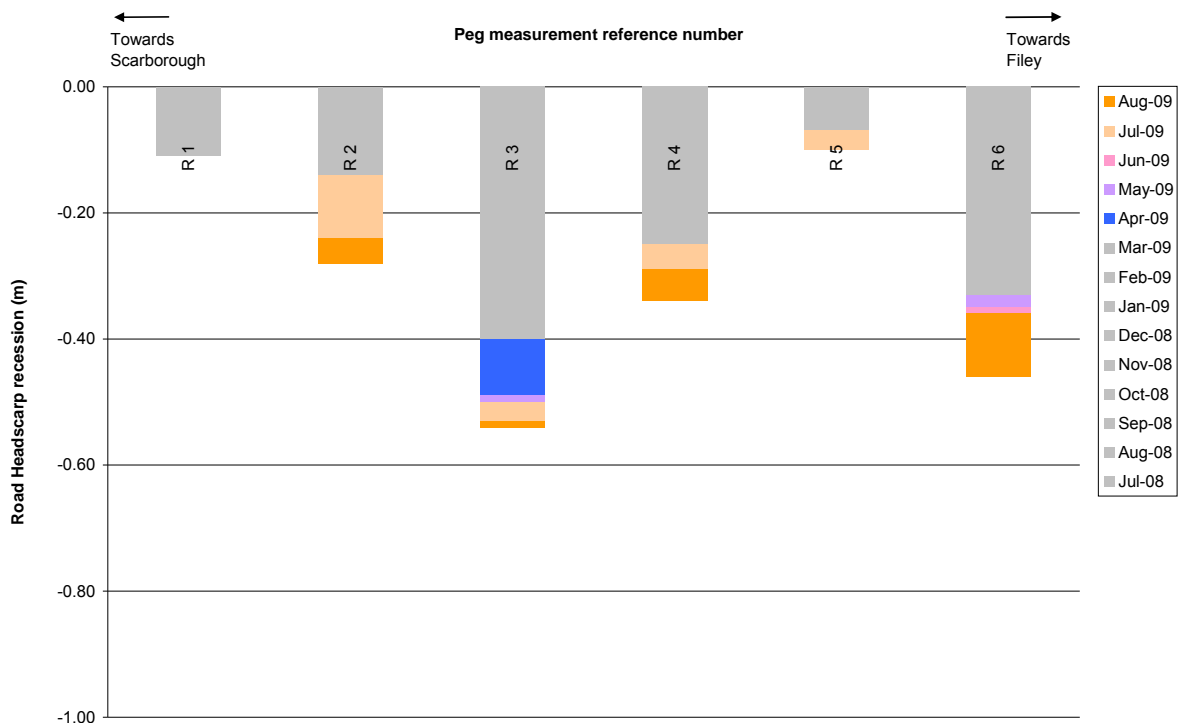


### KEY RESULTS

- No significant recession of the headscarp observed; the changes indicated by the graph are very likely to reflect measurement error
- A surface crack and shallow depression along the road between R0 and R1 was reported 1.8.08. No change has been observed.

### RECOMMENDATIONS

- As we approach the autumn/ winter, groundwater levels will rise, increasing the likelihood of ground movement and headscarp recession. It is recommended that weekly observation and monitoring is continued.

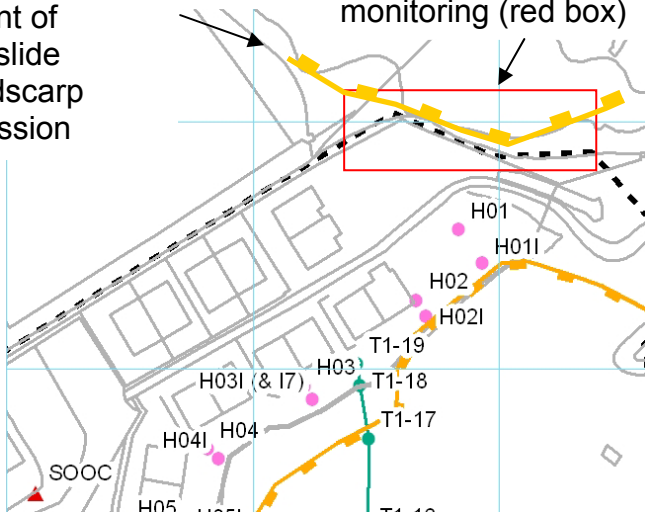


**Note:** bars in the graph show total monthly recession measured since 1.7.08. Refer to user notes at the end of this report. Average monthly error of  $\pm 0.05$  m (error compounded in graph).

## Cornelian Bay Headscarp Recession

Approximate extent of landslide headscarp recession

Zone of pin monitoring (red box)

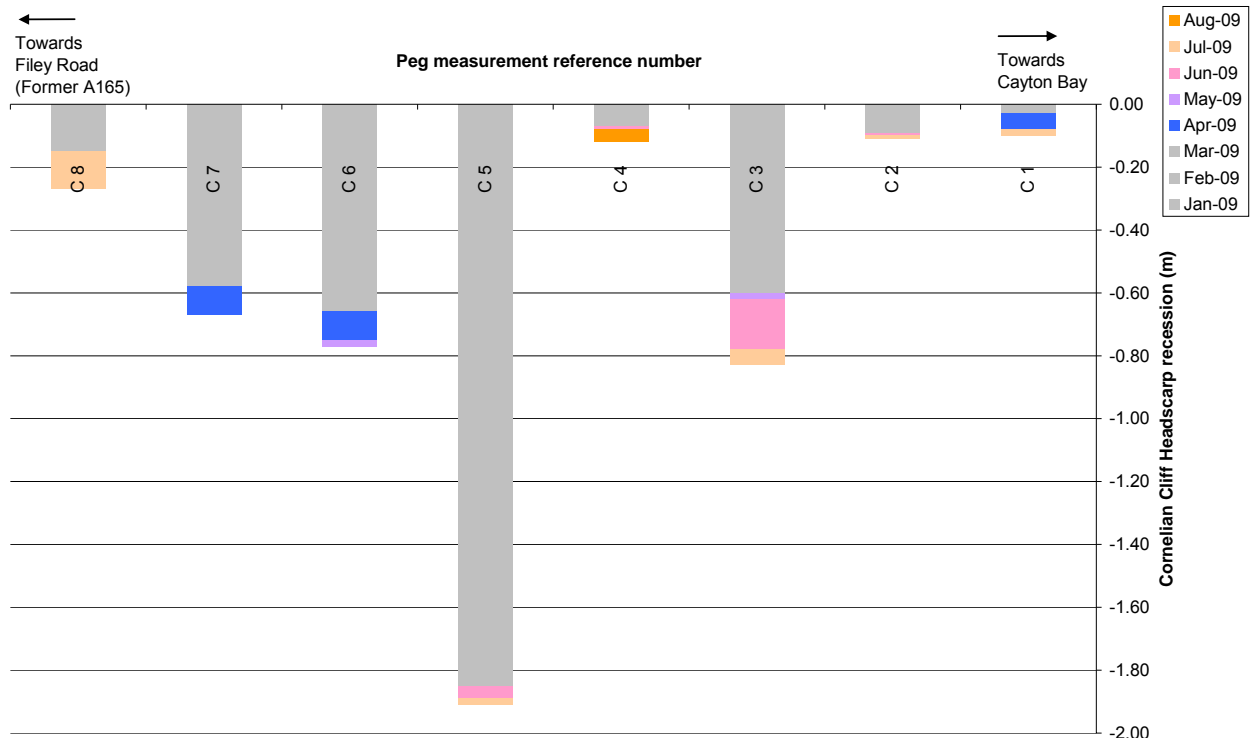


### KEY RESULTS

- The scarp face is active albeit much less than observed prior to March 2009. Localised evidence of ground movement comprises fresh tension cracks and exposure/ failure of made ground. The fence line is now closer to the headscarp between pins C5-C7 (not shown on map), and as a consequence is starting to dip seaward
- Recession ranges between 0.02 to 0.16 m per month.

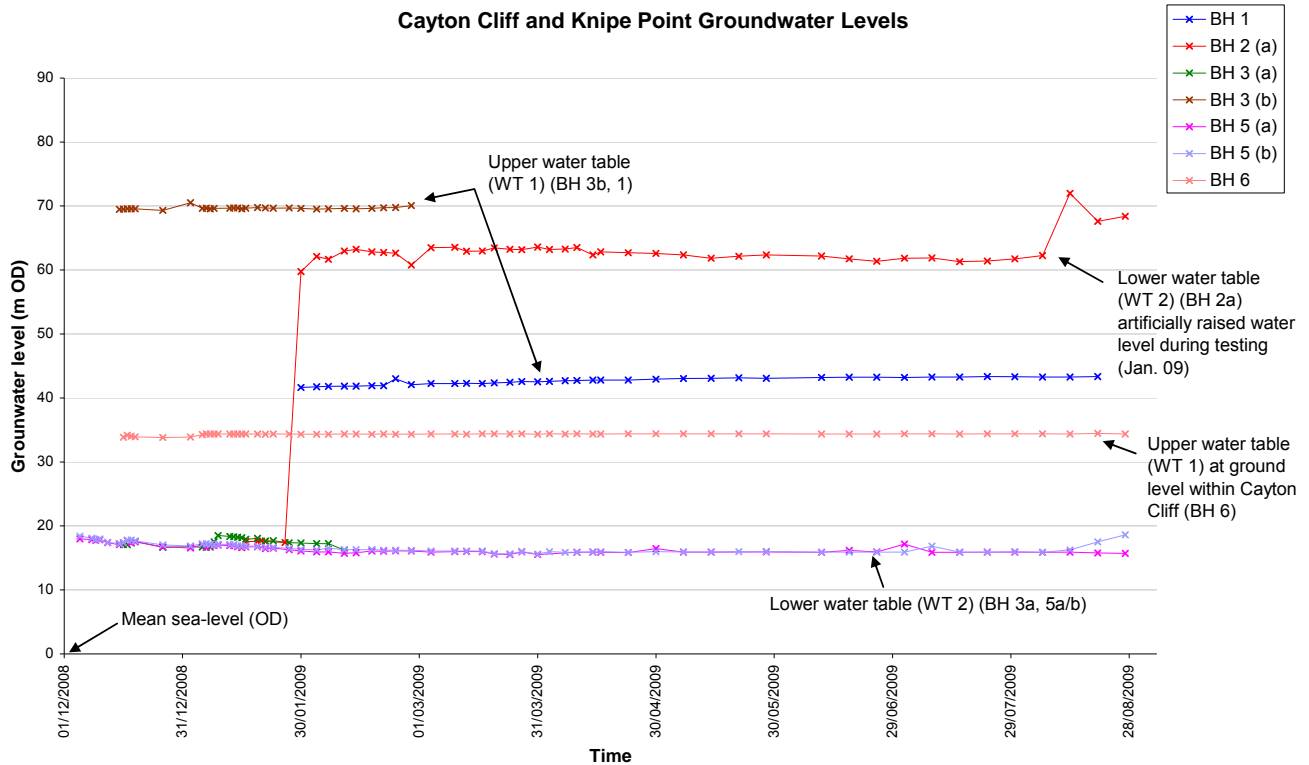
### RECOMMENDATIONS

- As we approach the autumn/ winter, groundwater levels will rise, increasing the likelihood of ground movement and headscarp recession. It is recommended that weekly observation and monitoring is continued
- Replace and obtain new baseline measurements for missing pins.



**Note:** bars in the graph show total monthly recession measured since 12.1.09. Refer to user notes at the end of this report. Average monthly error of  $\pm 0.05$  m (error compounded in graph).

## Groundwater Conditions



### KEY RESULTS

- BH 2 (b) and BH 4 are not shown as no water strikes have been recorded
- No data for BH 3 have been recorded since the end of February 2009
- BH 2 (a) has a response zone for the lower water table. The current water levels are c. 50 m higher than anticipated, most likely due to defective operation. The data displayed are therefore considered unreliable
- The upper water table (WT 1) rose gradually between April (42.6 m OD) and August (43.4 m OD) at BH 1; and was coincident with the ground surface level at BH 6 indicating fully saturated groundwater conditions at this location
- The lower water table (WT 2) at BH 5 has ranged between 15.8 to 16.0 m O.D, with a series of sharp rises above this level (ranging +0.6 to +2.7 m).

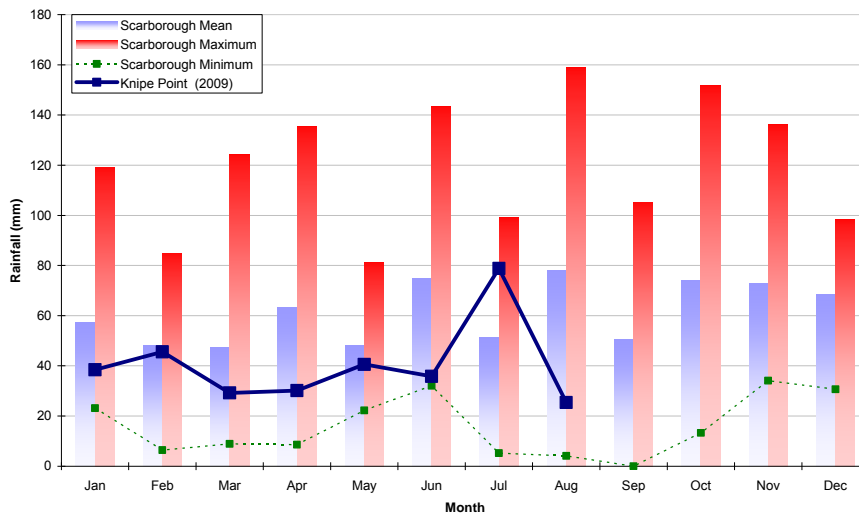
### RECOMMENDATIONS

- Continue groundwater monitoring of operational boreholes (as currently specified, once a week)
- Perform maintenance of boreholes (BH 2, BH 3) to full working order.

## Rainfall Conditions

### A. Monthly

Monthly rainfall at Scarborough (1995-2006), & Knipe Point (2009)

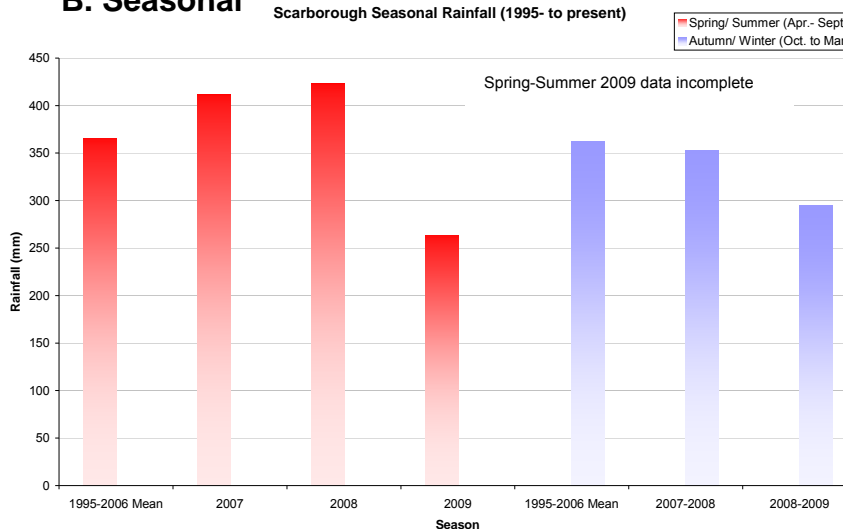


Month	Scarborough average (1995-2006) mm	Scarborough (SN: 2291)		Knipe Point	
		mm	% of average	mm	% of average
Mar. 2009	47.5	23.3	-51%	29.2	-39 %
Apr. 2009	63.3	36	-43 %	30.2	-52 %
May 2009	48.2	45.8	-5 %	40.6	-16 %
Jun. 2009	75.1	41.9	-44 %	35.8	-52 %
Jul. 2009	51.2	109.2	+113 %	78.8	+54 %
Aug. 2009	78.3	30.9	-61 %	25.4*	-68 %*

\* Incomplete dataset

### B. Seasonal

Scarborough Seasonal Rainfall (1995- to present)



Season(s)	Scarborough Spring/ Summer (April- September)		Scarborough Autumn/ Winter (October- March)	
	mm	% of average	mm	% of average
1995-2006 (Average)	365.8	N/A	363.0	N/A
2007	412.0	+13 %	-	-
2007-2008	-	-	353.1	-3 %
2008	423.4	+16 %	-	-
2008-2009	-	-	294.8	-19 %
2009	263.8 *	-28 %*	-	-

#### KEY RESULTS (MONTHLY)

- Rainfall at Knipe Point and Scarborough are broadly similar March to June 2009. A notable difference in the monthly rainfall total occurred in July 2009
- March 2009 rainfall total was 29.2 mm which was drier than average (-39 %)
- April to June 2009 were drier than average (range: -5 to -52 %)
- July 2009 was considerably wetter than the norm (+54 & +113 %)
- August was drier than average in Scarborough (-61%).

#### KEY RESULTS (SEASONAL)

- The summer of 2009 has so far been drier than average. Up to the end of August 264 mm had been recorded against a mean of 366 mm
- Analyses of prior seasonal trends are given in report 008.

#### RECOMMENDATIONS

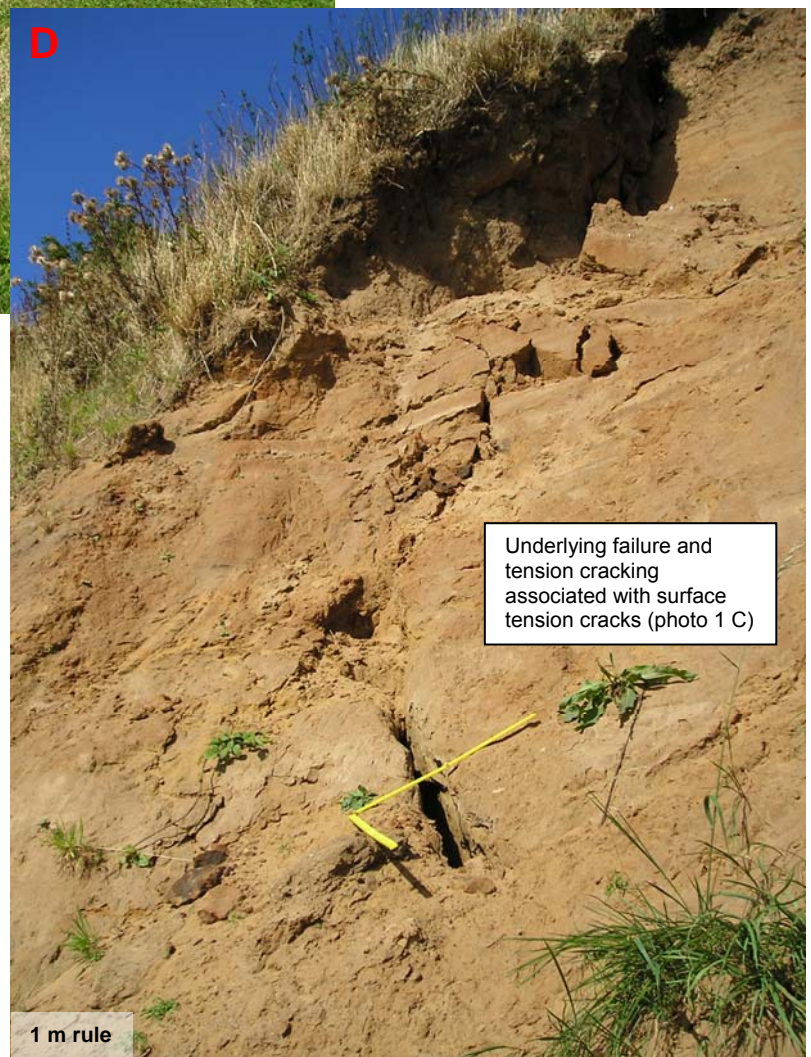
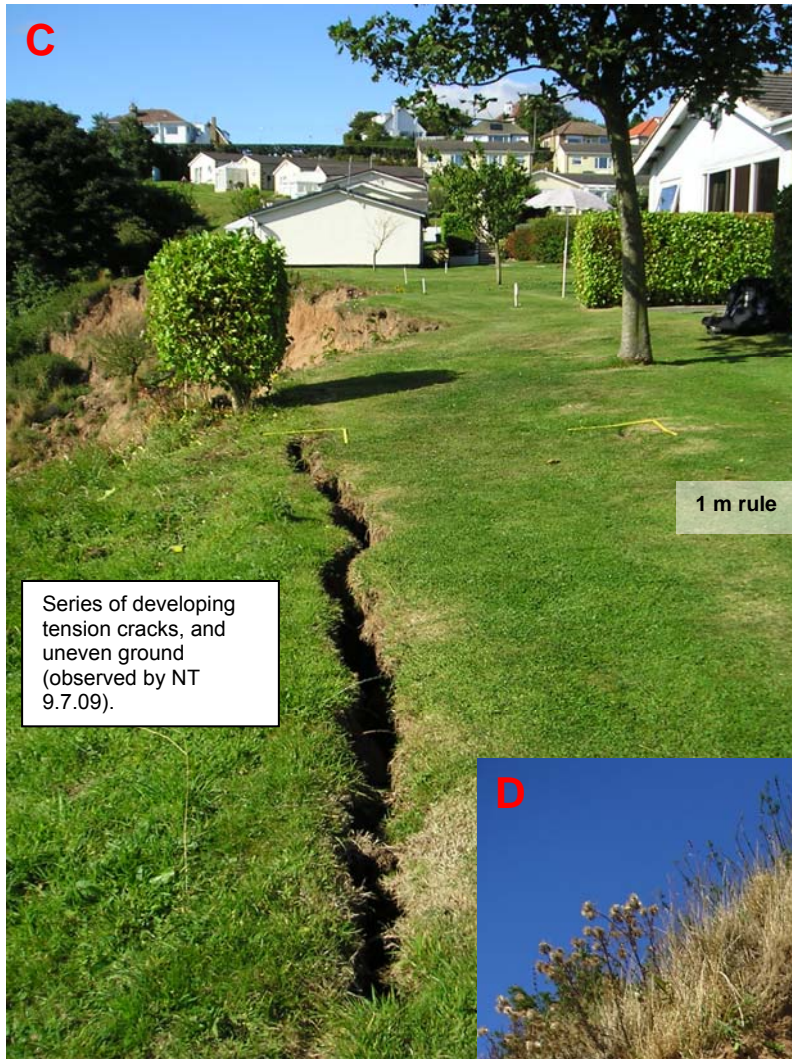
- Continue monthly maintenance and data recovery of the Knipe Point weather station.



Photo 1: Ongoing failure and recession of the Knipe Point headscarp (A: 27.3.09; B, C, & D: 27.8.09)









**Photo 2:** Shallow slide development in the Cornelian Bay landslide  
(Immediately north of Knipe Point) (A: 27.3.09; B & C: 27.8.09)

**A**



**B**



**C**



## USER GUIDE

### 1. Background to the report:

A major reactivation of the Cayton Cliff landslide complex occurred on 1<sup>st</sup> April 2008. The landslide has led to recession of the headscarp and the loss of three bungalows at Knipe Point in April and May 2008. Further cliff top property, major services, and Filey Road (former A165) are at risk from landslide activity and headscarp recession in the future. More recent (post October 2008) headscarp recession at Cornelian Bay is also ongoing, adjacent to the Knipe Point residential area.

An observation and monitoring strategy has been developed for the site. This now comprises:

- Regular survey of a fixed ground marker network**, which permits an assessment as to whether these landslides are active or not. *Operational since April 2008;*
- Regular survey of sub-surface groundwater levels**, within the boreholes installed during the ground investigation in late 2008. This provides a record of the changing levels of groundwater that triggers ground movement. *Operational since December 2008-January 2009;*
- Continuous automatic recording of weather conditions** (rainfall, air and ground temperature) at Knipe Point, which influence groundwater conditions. *Operational since December 2008.*

These monitoring reports provide a technical summary of the observation and monitoring results to inform stakeholders of present and future forecast landslide activity, and potential consequences at Cayton Cliff and part of the Cornelian Bay landslide.

### 2. Monitoring methodology:

#### a) Slope observation and monitoring (surface)

This comprises a ground marker network installed in specific landslide areas (See Table 1). Observations and taped measurements of the landslides are made from these markers. For example, at the headscarp, regular measurements are made from a fixed marker to features of interest (e.g. the edge of headscarp) (Figure 1). All measurements are recorded on a monitoring record sheet.

Tension cracks are also noted, as these extension fractures are commonly associated with landslide induced ground movement (Figure 2).

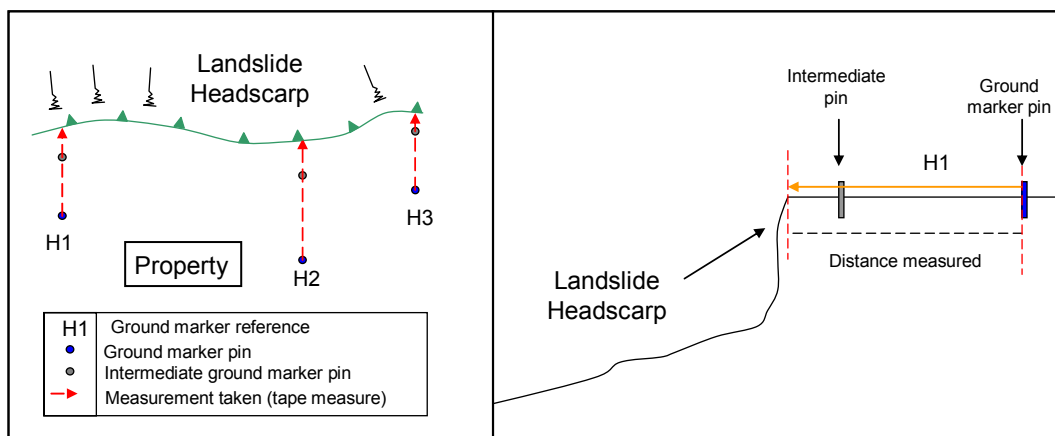


Figure 1. Schematic of ground marker measurement at the Headscarp

Landslide area	Monitoring components	No.	Purpose
Knipe Point Headscarp	Measurement pins	15	Measure headscarp recession and evidence of tension cracks
	Field observation points	3	Visual observations of change
A165 Headscarp	Measurement pins	7	Measure headscarp recession and evidence of tension cracks
Cornelian Bay (Jan. 2009)	Measurement pins	8	Measure headscarp recession and evidence of tension cracks

Table 1. Summary of the ground marker network

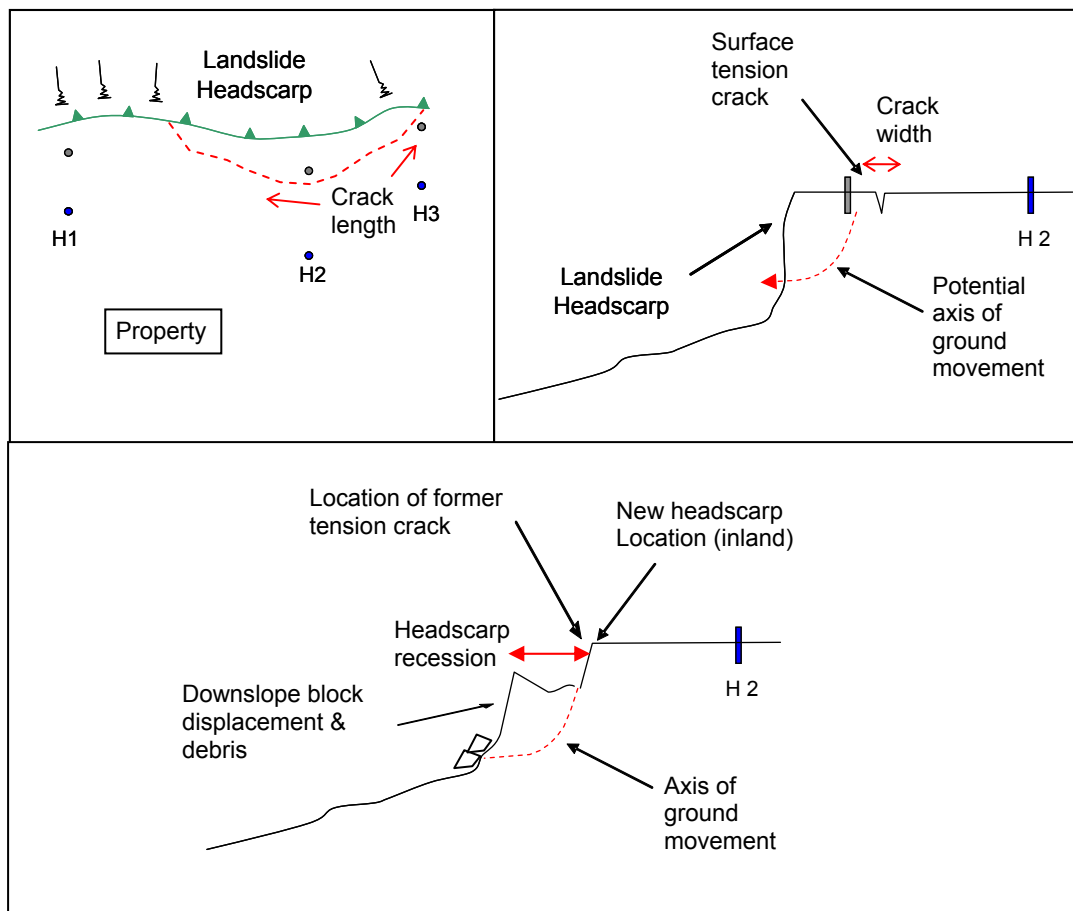
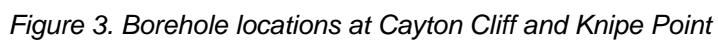


Figure 2. Schematic of tension cracking, and subsequent block displacement (ground movement) at the headscarp, and their measurement axes

## b) Groundwater (sub-surface)

Six boreholes of variable depth (56 to 110 m below ground level) were drilled between October 2008 and January 2009 (Figure 3 shows their locations); these have either one or two piezometer standpipe tubes installed within. These tubes permit the measurement of sub-surface groundwater levels across selected rock and soil layers. Water levels are detected by lowering a water sensor (a dip meter) from the ground surface (Figure 4), and the presence/absence and depth of water are recorded on a monitoring record sheet. Table 2 summarises the key characteristics of these installations.





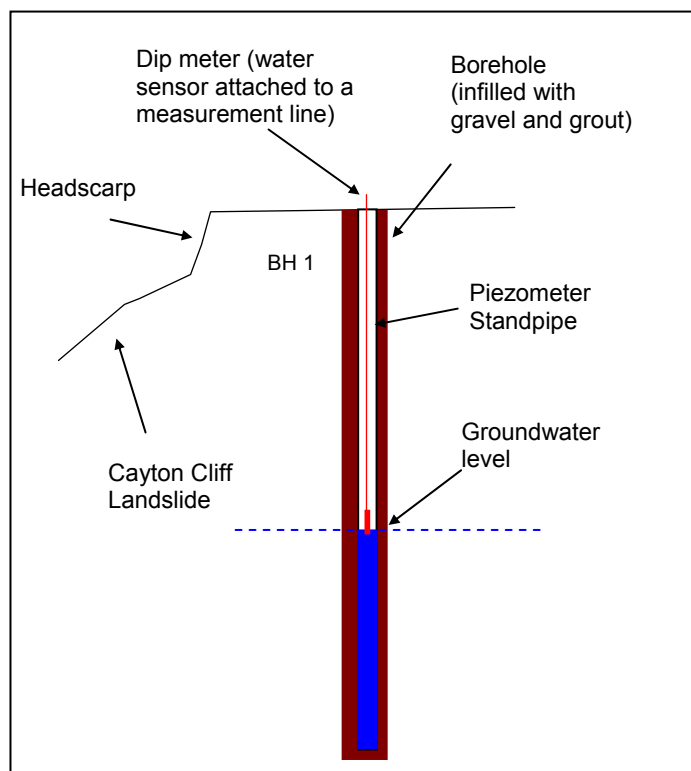


Figure 4. Schematic of ground water level measurement

Borehole Number	Location	Number of Installations	Installation ground level (m O.D.)	Drilled depth (below ground level, m)	Piezometer basal depth (below ground level, m)
1	Next to former A165	1	86.1	110.0	45
2	Knipe Point car park, near garages	2	86.6	97.4	a) 97 b) 25
3	Knipe Point, next to no. 20	2	79.1	95.8	a) 75 b) 38
4	Knipe Point, next to no. 7	2	70.0	90.2	b) 90 a) 63
5	Cayton Cliff woodland (access closed)	2	30.1	75.7	a) 75 b) 32
6	Cayton Cliff woodland (access closed)	1	34.4	56.3	30

Table 2. Summary of the borehole monitoring network

### c) Weather conditions

An automatic weather station, installed at Knipe Point in mid-December 2008 at 80m OD, has since recorded air and ground temperature conditions and rainfall amounts every 10 minutes. These records are stored electronically by an in-built data logger (small computer), which are downloaded regularly, when the weather station is also maintained.

## 3. Analysis of monitoring results

### a) Ground marker network:

Field measurements are entered into a master database, validated, and measurement errors are calculated (average standard deviation). The data are plotted on a graph to show the amount of recession recorded by month, since 1<sup>st</sup> July 2008 (Figure 5); these reflect the location specific combination of change including measurement errors that are not entirely possible to filter out. The graphs reveal that headscarp recession is sporadic over time with some locations and time points recording no recession (i.e. no change is shown on the graph). Other locations show a variable amount of recession from one time to another confirming the unpredictable nature of headscarp recession due to variable weather and ground conditions.

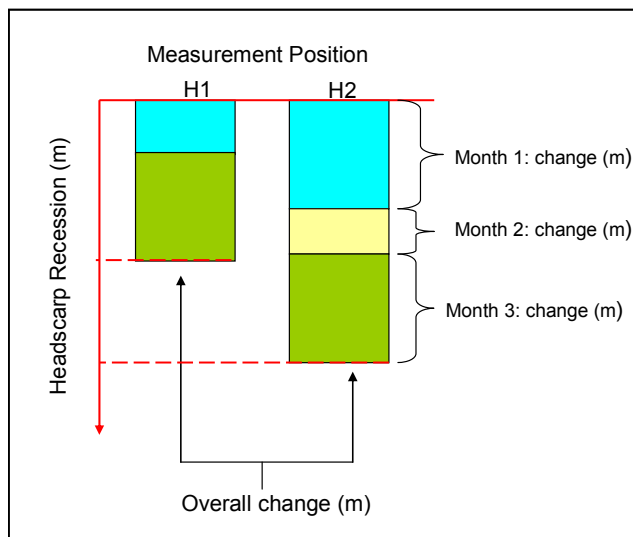


Figure 5. Explanation of cumulative change

### b) Groundwater & Rainfall

These data are entered into a master database, where they are analysed and plotted onto graphs to reveal trends over time. Analyses of their inter-relationships are also undertaken.



#### 4. Where is your property at Knipe Point?

Figure 6 provides a plan of the properties at Knipe Point. This will help locate a property relative to the preceding maps of the observation and slope monitoring network.

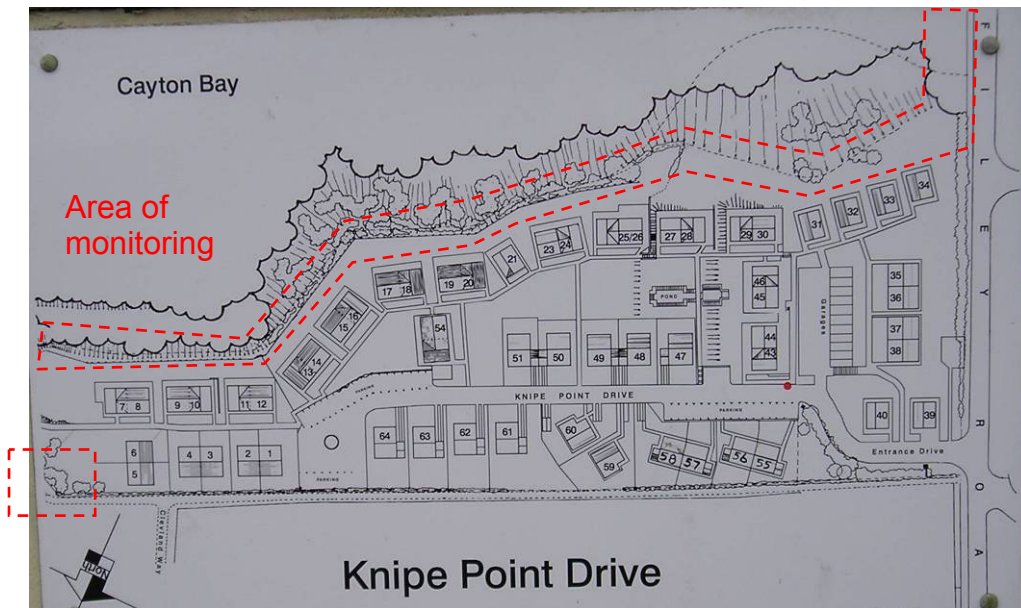


Figure 6. Map of the Knipe Point Development