The Erosion Dynamics of the Peacehaven Shore Platform.

University of Sussex
BSc Geography Third Year Project

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Abstract

Peacehaven, East Sussex is home to an extensive shore platform at the base of its chalk cliffs and up to 200m of which can be exposed at low tide. This investigation is an insight to the erosion dynamics of this chalk shore platform. In 1977 work commenced on a major sea defence scheme covering the length of Peacehaven, the foundations of which are set into the shore platform.

Through the use of a Micro-Erosion Meter (MEM), Scanning Electron Microscope (SEM) and a Schmidt Hammer; micro erosion, rock porosity, and rock hardness were all measured to determine causes for varying erosion rates across the width of the shore platform.

Erosion results showed a ‘bell’ shaped distribution with higher rates at the sea wall base, mainly caused by increased localised abrasion; and at the seaward edge, primarily cause by increased porosity and softer rock. Porosity and rock hardness grew and reduced respectively the further away from the sample was taken from the sea wall.

Erosion results were also monitored around one of the groynes constructed in 1977. Through the use of the MEM and pinnacle measurements, erosion rates were found to be greater in runnel formations that their adjacent ridges, and on the eastern side of the groyne in comparison to the west. Average erosion rates around the groyne were calculated at 0.7mm per month. Pinnacle calculations stood at a comparable 0.86mm per month, calculated from 25 years of denudation. The difference

Errors of the investigation methods and techniques are discussed, and a possible use of the data in a future management plan for the Peacehaven sea defences is explored.

1 – Introduction

1:1 Shore Platforms

Rocky coasts form 62% of the British coast *(May 2001)*, and with the ever-increasing demand for homes, the need for research into the dynamics and behaviour of the coastline has never been so imperative. However the majority of documented coastal studies concentrate on the recession of cliff lines, leaving the cliffs natural breakwater or shore platform very much neglected *(Trenhaile 1980).*

A shore platform is a gently sloping bed of rock extending seaward from the base of a cliff. It is a well documented fact that platforms widen as the cliff retreats, but it is the vertical erosion of the platform surface that provides much controversy.

The major factors that are said to have an erosive effect on shore platforms include salt weathering, alternate wetting and drying, water level weathering, quarrying, hydraulic action, pneumatic action, abrasion, and bio-erosion. Although all of these processes contribute to the shaping of the shore platform, there is a need to fully understand the impact each has in shore platform development.

Even though a large body of literature concerned with shore platforms exists, there is no clear explanation of how they develop *(Stephenson 2000)*. *Trenhail (1980)* described shore platforms as ‘a neglected coastal feature’. And despite providing intriguing research problems, shore platforms have been the subject of accurate study by relatively few coastal scientists. This is in part due to the obvious need to understand other coastal landforms for the purposes of management and hazard mitigation. However, with increasing human demand for coastal resources and increasing interest in changing sea level, rocky coasts are now being subject to ever increasing pressure and scrutiny. Future coastal management may be as equally concerned with rocky shores as it is with beaches today. Many believe in the wider coastal research community that important questions regarding shore platform development, prevalent in the middle of the twentieth century, have been sufficiently answered. However these features have not been researched enough to rely on dated conclusions *(Stephenson 2000)*.

Before 1970 attempts to calculate rates of surface lowering on platforms relied on techniques such as, weathering of dated inscriptions *(Emery 1941)*, chemical analysis of pool water *(Revelle and Emery 1957)* and the use of scour pins *(Hodgkin 1964)*. These techniques lacked the precision to measure rates of erosion that proceeded at millimetres per year. In 1970 the micro-erosion meter (MEM) was introduced by *High and Hanna (1970)* as a technique for measuring small rates of erosion on bedrock. The MEM was then drafted into the erosion studies of shore platforms. The MEM was later modified by *Trudgill (1981)* to allow a greater number of measurements to be made and became known as the traversing micro-erosion meter (TMEM). However there are only a few published accounts of erosion measured on shore platforms with this instrument *(Stephenson 2000)*.

1:2 Shore Platform Erosion

Although the contributory factors to shore platform erosion are known, their extent remains an area of contradiction and controversy among available reports.
Wave action would seem the obvious causation of platform erosion. It is known as a contributory factor, but many researchers have branded wave action as being of little importance. Bartrums 'Old Hat' theory relegates wave erosion to a very minor role, but others infer that mechanical wave erosion assumes an important role in the development of shore platforms *(Trenhaile 1987)*.
Stephenson and *Kirk (2000a)* also argued that storm waves were not capable of causing erosion because the largest waves broke in deeper water further from the shore and were required to shoal greater distances before reaching the cliff edge. *Trenhaile (2000)* also shared this theory when he stated there was no consistent relationship between simulated platform width and wave height,

Wetting and drying seems to be a popular and a major factor in the wearing and erosion of shore platforms. *Robinson (1977)* measured different erosion rates on platforms and ramps, and proposed wetting and drying together with corrosion were both primarily responsible.
According to *Stephenson and Kirk (2000b)*, on the Kaikoura Peninsula New Zealand the maximum number of wetting and drying cycles occurred between the peaks of spring and neap tides. The zone of most cycles was estimated to occur between 0.6

and 0.9m above the mean sea level. It was at these elevations that the highest rates of erosion occurred. This is a direct contradiction of the findings in *Kirks (1977)* investigation which observed the lowest erosion rates of the platform in this middle section.

In high latitudes, frost and ice may play a similar role to chemical weathering and wetting and drying in low latitudes *(Trenhaile 1987)*
In western Scotland, shore platforms may have developed in sheltered areas because of frost action in the Younger Dryas, Loch Lomond. However it's latitude would have resulted in a greater influence by wave action *(Trenhaile 1997)*. Even in the milder climate of southern England, chalk shore platforms have been damaged by frost during severe winters *(Robinson* and *Williams 1994)* ;*(Robinson* and *Jerwood 1987a)*. Studies by *Trenhaile (1987)* indicate that rocks that are saturated by solutions with 2-6% of their weight in salts are more susceptible to frost damage than those, which contain fresh water. He also stated that more freeze-thaw cycles and more rapid changes in temperature can occur in the inter-tidal zone than above the high tidal level. *Dionne* and *Brodeur (1988)* in their review of ice processes on rocky coasts identified two processes, frost weathering and ice action as major developmental processes on shore platforms. During their investigation they noted that there was not a clear relationship between latitude and the importance of ice processes, and that it was more significant than had been previously thought.

Biological activity is another factor that has received little attention when considering the development of shore platforms *(Little and Kitching 1996)*. According to *Stephenson (2000)* it has two effects. 1) It causes erosion that can be separated into biomechanical and biochemical components; and 2) it prevents or protects the platform from other erosional processes. The role of bio-erosion did not receive attention prior to *Trenhaile (1980)*. *Hills (1949)* reported that the 'growth of marine plants and animals is so profuse as to form an almost uninterrupted cover to rock surfaces below a certain level. The level concerned is usually about the mean sea level, although it may vary according to local conditions' *(Stephenson 2000).* Together with *Gomez-Pujol et al* (2001), he considered that the growth of marine organisms in such dense mats prevented abrasion and wave quarrying. Another effect of present marine biology is the prevention of surfaces drying out and thus limiting

the erosive effect of wetting and drying cycles. *Stephenson and Kirk (2000b)* have also stated that seasonal algae growth reduces the number of wetting and drying cycles during winter months.
However, relating to *Stephenson's (2000)* first effect, some of this present marine biology may have the opposite effect. *Andrews* and *Williams (2000)* and *Andrews (2001)* stated that limpets (*Patella vulgata)* living on the platforms contribute significantly to platform erosion in southeast England, by ingesting chalk as they graze and by excavating hollows to which they return after feeding. The implication is that limpets are responsible for an estimated 12% of platform down wearing. This figure rises to 35% in areas of maximal population density.

The factor of salt weathering is also to be considered. *Mottershed (1989)* calculated a mean lowering rate on supratidal gren schist on the Spart-Prawle Peninsula off the south Devon coast and identified salt spray weathering as a principle agent of erosion.

Stephenson and Kirk (1998), using both the MEM and the TMEM, found seasonal variations in erosion rates on Kaikoura Peninsula. During summer months erosion was greater by as much as an order of magnitude in some cases compared with winter. They argued that this was evidence for sub-aerial weathering because summer provided better conditions for salt weathering, and the wetting / drying process. This is one particular area that has received little research.

Rates of erosion across platforms are also highly debated, and were once though to be equal. However *Kirk (1977)* and *Foote et al (2001)* found a variation in erosion rates across platform profiles, with higher rates on the landward and seaward margins. A contradiction to this comes from *Stephenson (2000)*, who recently reported that the middle section of the platform experienced greater levels of erosion than both the landward and seaward sides. To add to this confusion, *Stephenson and Kirk (1998)* found that rates were generally higher on the landward margins and decreased in a seaward direction. The variance in erosion rates across the platform width found by *Kirk* and *Stephenson* were primarily obtained on mudstone and limestone in New Zealand. There is a evident lack of literature regarding the existence of this phenomenon on chalk based shore platforms.

Variations in rock strength across shore platforms could play an important role in controlling spatial variations in erosion. Differences in rock strength over short distances may be caused by differences in rock composition, degree of cementing, differential weathering and different shrink swell behaviour *(Moses and Marques 2001).*

It is difficult to compare studies from one environment with another, and there are few hard data sets with which to rigorously test different hypotheses of shore platform development *(Stephenson 2000a)*. Every case is suspect to varying influences and seasonal factors. Thus making every platform a unique study.

1.3 Peacehaven Shore Platform

Peacehaven is a small cliff-top town situated between the Sussex towns of Brighton and Eastbourne (fig 1 and 2)

Fig 1:
Map illustrating location of Peacehaven (Digimap 2001)

Fig 2:
Map illustrating Peacehaven and proposed experiment region (Digimap 01).

The shore platform at Peacehaven extends seawards from the base of the cliffs for up to 200m, to below the low water mark *(Robinson and Williams 1983).* It is subject to semi-diurnal tides with a range of 3 - 6m *(Ellis 1986)* and the average tide reaches approximately 4.7m *(ESPED 2000).*

The climate is generally milder than adjacent inland areas in winter but cooler in the summer. Average mid-winter temperatures are 5-6^{0}C whilst mid-summer temperatures average at 16-17^{0}C *(Ellis 1986).*

The chalk found in Sussex is formed of fine calcium carbonate deposits including the external skeletons of coccoliths. These were deposited while much of England and Wales was submerged from early the Cenomanian and onwards during the late Cretaceous marine transgression *(Jones 1981)*. Upper Cretaceous chalk dominates the solid geology along this stretch of the coast *(Barne et al 1998)* and at Old Nore Point; the Brighton Marl in the *Marsupites testundinarius* Zone is exposed in the shore platform *(Mortimore 1997)*

1:4 Peacehaven Sea Defences

With the first infrastructure erected in 1921, Peacehaven is a relatively new development. The town has now become a large settlement primarily being inhabited by the elderly and retired, and is described by *Dickens (1975)* to be "a disgusting blot on the landscape". Despite this graphic description it was felt necessary by Richard Stammers (Chief technical officer) to construct a large-scale sea defence to prevent this "important place" *(Stammers 1982a)*, from eventual destruction by the retreating cliff line.
The Peacehaven coastline is now an ideal example of the effect artificial protective infrastructures, can have on natural geomorphological processes.
Work commenced in 1976 and took the form of a substantial reinforced concrete sea wall, topped with an under-cliff walk with 19 adjacent concrete groynes extending at right angles across the shore platform (see fig 3). Work was undertaken in 4 stages, the last being completed in 1997. In the attempt to prevent future cliff recession, the cliff face was trimmed from it's original near vertical angle to a more stable 70-80^0.

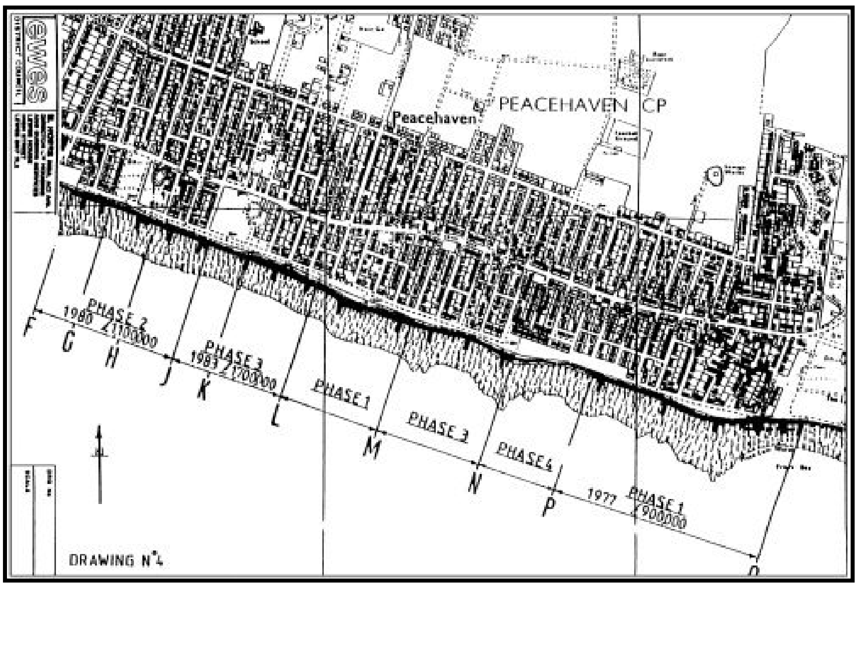


Fig 3: Map illustrating sea defence phases and location of concrete groynes.
(Stammers 1982a)

The groynes impede the eastward movement of beach material by longshore drift and help to build up the level of the beach in front of the sea wall. However the groynes are rather widely spaced in relation to their height and the beach tends to disappear on their eastern sides and pile up excessively on their western sides *(Cleeve and Williams 1987)*. This inconsistent spread of beach material will have direct 'knock on' effects in either protection the underlying shore platform, or enhancing abrasion.

The platform surface is often dissected by systems of runnels that act as drainage channels during the rise and fall of tides. These runnel formations are distinctly noticeable in the abrasion zone at the base of the sea wall *(Robinson and Williams 1983)* (fig 4).

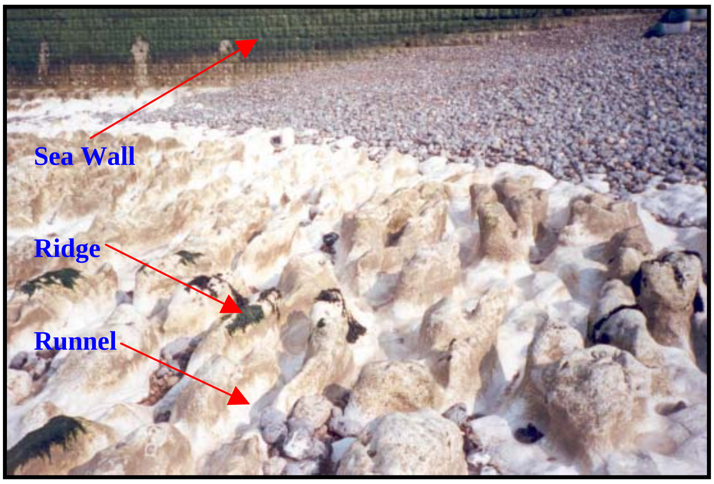


Fig 4: Photograph of Ridge and Runnel formations at Peacehaven.

The runnels vary in concentration, depth and width. They form as sea and rainwater flow up and down to a much greater extent than the adjacent ridges, increasing solution as well as localised abrasion.

The prevailing south-westerly winds cause waves to hit the western sides of the groynes with a greater force than the eastern sides. This would create a localised channelling effect, which would in turn increase erosion rates, and increase the runnel formation and depth. In contrast the eastern side of the groynes act as a wave shadow and as a result this reduced energy would cause less erosion.

However, these groyne structures were constructed to assist in beach material retention. Beach material consisting of sand and shingle generally travels eastwards along the platform, tending to build up in greater volumes on the western sides of the groynes. Here the sediment forms a protective "high permeable storm ridge" and therefore could protect the western sides of the groynes rather than contribute to increased erosion *(Wallingford 1999)*.

From observation the eastern groyne sides normally have more but less concentrated larger sediment located on the platform. This is because the wave energy transferred into this section is shadowed by the groyne and insufficient to wash it away. Therefore preferential movement to the west will be with smaller sediments and sand.

With the foundations of the defences being constructed on the shore platform, the erosion dynamics of the chalk will unquestionably affect the life span of these defences by exposing and undermining their foundations.

March 2002 witnessed the failing of one of the phase 1groynes (see fig 5), emphasising the importance to understand the behaviour of the shores natural breakwater.

Fig 5: The collapse of a phase 1 groyne due to foundation undercutting (02/04/02.

With the reduced level of rock debris from the cliffs being restricted from entering the platform due to the cliff walkway, the base of the sea wall is receiving no natural protection against the erosive, and hydraulic power of the present natural elements. It is therefore essential to obtain a clear idea of the erosion dynamics across the shore platform, in order to implement maintenance strategies for the existing defences, in the absence of dynamic equilibrium. Factors such as the rock hardness of the platform, makes full understanding an impossible task. The platform chalk varies considerably in hardness within short distances, both horizontally and vertically, and no correlation of a standard pattern has so far been determined *(Stammers 1982b).*

This is an area that has little documentation, but *Tsujimoto (1985)* successfully correlated compressive strength with erosion rates during his study of shore platforms on the Pacific Chiba coast of Japan.

2 – Instigation Aims

The aims of this investigation represent a need to understand, not how the platform has been created, but how it behaves and reacts to current geomorphological, marine and climatic conditions (see table 1).

Number	Investigation Aims
1	To determine the rate of downward erosion on the Peacehaven shore platform.
2	To investigate differences in erosion rates across the width of the platform. This will be done with the intention of determining the fundamental factors that lead to these variations
3	To observe and continue the studies of *Charman (2001)* and determine if the present concrete groynes in Peacehaven have an effect on shore platform dynamics and runnel formations.
4	To measure the erosion of the shore platform in relation to artificial pinnacles, with the intention of determining total erosion since their construction.
5	To investigate if the platform displays various levels of rock ‘hardness’, in order to relate this variable to erosion variations.
6	To investigate porosity variations of the chalk across the platform, and to determine if there is a distinct correlation between localised porosity and erosion rates.
7	To observe the presence of seasonal variations in erosion rates.
8	To observe and to monitor the compaction and removal rates of sediment ‘inputs’ to the shore platform.

Table 1: Investigation Aims

3 - Hypotheses

It is expected that at the completion of this experiment, the following trends will have been observed:

- **1,2)** The erosion rates across the width of the platform will not be constant. The erosion levels will be greater at the top and the base in comparison to the middle of the platform. This will be due to factors such as scouring and abrasion (landward side) and comparative rock strength (seaward side).

- **3)** It is expected that the continuation of the MEM sites of *Charman (2001)* will have a similar outcome to his investigation. The presence of the groynes is significant, and the average erosion rates experienced on the western side will be less rapid than the east due to the protective nature of the beach sediment. However there will be a greater difference between the erosion rates of ridges and runnels on the west, but a higher overall average is expected on the eastern side.

- **4)** The hardness of the rock will not remain at a constant across the width of the platform. Through wetting and drying, the more exposure the area of the platform has to the sea, the softer the rock will be. Therefore the lower region of the platform will be composed of softer rock than that at the top.

- **5)** It is expected that the total denudation of the platform adjacent to artificial pinnacles, will provide accurate information regarding average erosion rates dating from the construction of the groyne.

- **6)** The porosity of the chalk will increase towards the bottom (seaward side) of the platform, thus being a primary reason for decreased rock strength and enhanced erosion rates.

- **7)** Although *Stephenson and Kirk (1998)* found micro erosion to be greater during the summer months, *Robinson and Jerwood (1987)* found the winter months to be responsible for destructive freezing and frost weathering.

Therefore it is predicted that micro-erosion will be faster during the winter months.

- **8)** The removal of sediment from rock falls on to the platform will initially be rapid, but as the finer sediment washes away, larger chalk blocks will remain and erode / be transported more gradually.

4 -Project Location

After careful consideration of the entire Peacehaven shore platform, a focal research site was chosen on the grounds of accessibility for safety reasons, and high exposure of the chalk at low tide.

The section of platform chosen lies in the phase 1 area to the far east of the Peacehaven defence works. According to the platform classification in *Sunamara (1992)*, the particular area of the platform selected for this investigation is a 'Type B', thus having a seaward vertical drop. *Trenhaile (1987)* suggested type A platforms are most common in macro-tidal environments, and type B in meso-tidal regions. From observation, the majority of the platform stretch at Peacehaven is under the classification of 'Type A'. One explanation for this 'Type B' section of the platform is a harder base rock than surrounding areas. They are often well developed on headlands where, with 'Type A' being more common in intervening embayments.

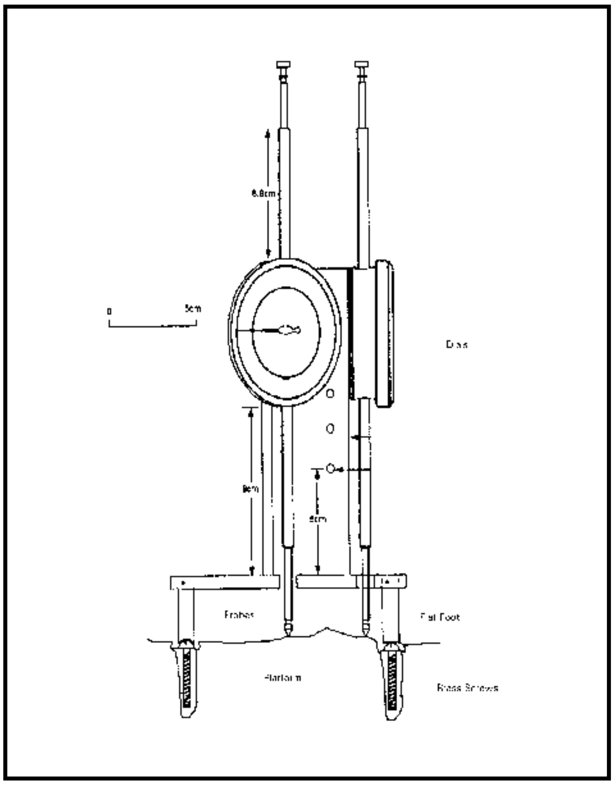
- Appendix 1: Project Location and Type B confirmation.

5 - Methods

5:1 Micro Erosion

In order to obtain the erosion rates of the Peacehaven platform, a Micro Erosion Meter (MEM) will be used. The height of the rock surface is measured on successive occasions from an arbitrarily established datum level, based on 3 fixed studs / screws in the rock surface *(High and Hanna 1970)*. The particular Micro Erosion Meter to be used in this investigation incorporates two engineers dial gauges, which record the extension of 2 spring-loaded probes. These dials are mounted on a firm metal base plate with three equal legs, but with varying feet shapes (i.e. flat, wedge and cone.)

(See Fig 6 and 7). This enables the MEM to be located with minimal error on the three datum studs / screws.



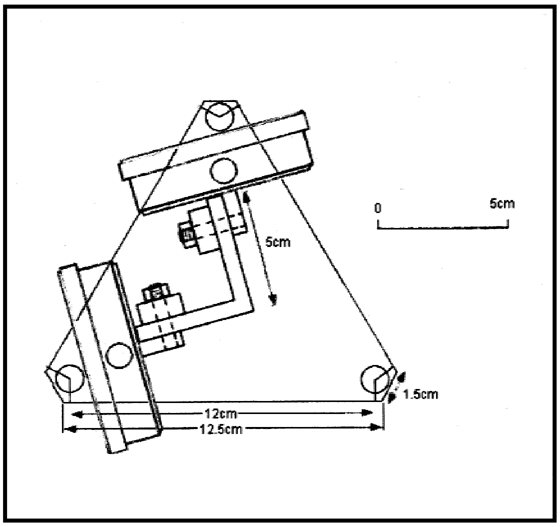


Fig 6: Side view of MEM. (*High and Hanna 1970* – Modifications by *Charman* and *Doyle 2001).*

Fig 7: Top view of MEM (source as Fig 6)

To measure the variability of erosion across the width of the platform, 12 MEM (P) sites were drilled 15 meters apart covering an area of approximately 180 meters (see fig 8). MARFIX, a strong waterproof resin, was used to ensure the $2^{1/2}$ inch; size 12 brass screws of the MEM site did not travel in the experiment duration.

Firstly a 6mm drill bit was used to create a 7cm deep screw hole, followed by a 20mm drill bit to create a 1.5cm deep foot hole for the MEM.

The hardness of the chalk varied considerably between the seaward and the landward sides of the platform. Together with added locational difficulties, this made some of the lower sites very difficult to drill due to softness of the rock. Because the location of the (P) MEM sites is open platform, losses of sites due to flooding and covering of beach material as described by *Williams et al (2000)*, was not expected. Therefore to compensate for this fact, only 12 sites were drilled. And because of the nature of this particular investigation in accessing very low areas of the platform, particular care was placed on the time in which these sites could be measured safely between tide retreat and tide advance.

Fig 8: Photograph displaying the distribution of MEM sites P 1-12

Measurement of erosion has been proven to be overestimated when the MEM is at an angle other than parallel to the surface of the platform *(Ellis 1986).* Therefore all new MEM sites were drilled on areas where the chalk surface was relatively parallel to the MEM base.

To enhance the findings of this investigation, the research of *Charman (2001)* will be continued. MEM Sites were located either side of a phase 1 groyne, and located in both ridges and runnels. The aim of this investigation was to have transects following one particular runnel and it's adjacent ridge across the length of the groyne. 4 sites covered each ridge, and 4 sites covered each runnel, with approximately 7m between each of the four sites. With these existing 16 MEM sites (R) set by *Charman (2001)*, 28 MEM sites will be monitored between October 2001 and April 2002. With the use of a Dictaphone for data collection, the (P) sites will be measured every 2 weeks to gain sufficient data and evidence to prove the project hypotheses, and the (R) MEM sites will be measured every 4 weeks to obtain consistency with the results of *Charman (2001)*.

- Appendix 2: Location of P and R MEM sites and accessibility difficulties.
- Appendix 3: MEM in action.

5:1:2 MEM Precautions

- Calibration of MEM will be undertaken once a month on the supplied brass calibration plate.
- WD40 will be applied frequently as exposure to rain and salt water has the reputation of ceasing movement in the MEM after use. This will reduce the risk of mechanical shift in the equipment.
- The MEM will be thoroughly wiped after grease application to prevent leakage on to the platform, as this is documented to reduce erosion *(Mottershed 1989)*
- To ensure the screws in the shore platform are protected. After measurement each foot hole is to be capped with watertight grease and blue tack, as partly suggested by *High and Hanna (1970)*. This not only protects the foot screws, but prolongs the life of the MEM site, as well as preventing the filling of the foot holes with beach sediment or marine wildlife.
- Each site will be measured twice to determine evident variations due to microscopic particles beneath the probe, on the screws or on the legs, flexibility of the MEM, and possible probe damage.

5:2 Pinnacle Denudation

When constructed, the foundations of the groynes were countersunk between 60 and 90cm below the platform surface. The gap was then filled with concrete infill, level to that of the shore platform *(Stammers 1982a)*. These concrete groynes have blocked the denudation beneath the foundations, creating pinnacles. The chalk has eroded, slowly exposing the foundations. The distance between the top of the concrete plinth and the surface of the shore platform represents the amount of denudation that has occurred since the groynes were first constructed. However the groynes themselves are likely to cause increased turbulence in the surrounding water, and therefore the surrounding platform may experience abnormal levels of erosion. In an attempt to compensate for this fact, both the runnel at the base of the groyne and the adjacent ridge will be measured and an average of the two will be taken (see fig 9). This should provide the investigation with slightly more reliable and realistic results.

With the use of 2 ranging poles and a spirit level, measurements will be taken at 2m intervals along the length of the groyne, resulting in 15 data points either side.

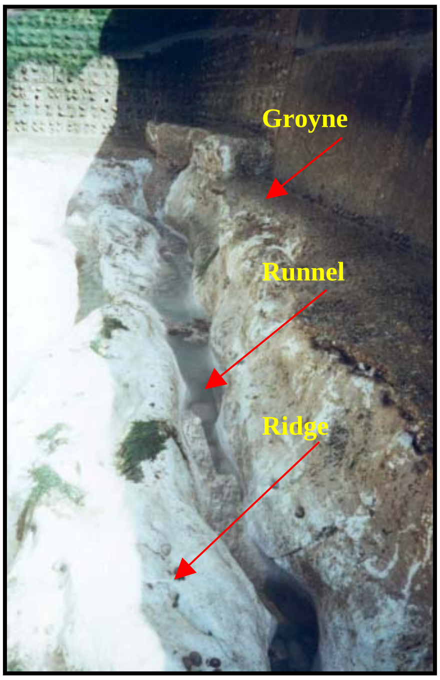


Fig 9: Photograph displaying chalk denudation caused by the concrete groyne, together with adjacent ridge and runnel.

- Appendix 4: Cross section of groyne construction and photograph of evident erosion.

5:3 Rock Hardness

The 'hardness' of the surface rock on the shore platform will also be measured, with the use of a Schmidt hammer. A Schmitt hammer consists of a spring contained in a handle with a steel rod, and when triggered gives an impact to the material under test *(Goudie 1994b).* This is then recorded on a meter and compared to other areas.

The Schmidt hammer has been used in a number of geomorphological applications, in particular rock-weathering rates in comparison to rock hardness *(Goudie 1994b).*

Adjacent to each of the (P) MEM sites, 3 Schmitt hammer measurements will be taken every 4 weeks. This will be of major importance in measuring the hardness variability across the platform as well as possible seasonal variations (i.e. winter freezing).

Minimal surface preparation will be undertaken before each measurement in order to prevent unnecessary compaction of the surface material. However external matter such as seaweed, snails and beach sediment will be removed by hand prior to testing.

5:4 Porosity

Porosity is the ratio of the aggregate volume of voids to the total volume of rock *(Goudie 1994a).* The porosity of the shore platform rock will be measured to determine it's possible relationship to the rate of erosion across the platform. Porosity is said to be of geomorphological significance to the shear strength of materials *(Goudie 1994b),* and therefore should have a significant effect on varying erosion rates.

To measure the porosity of the platform rock, a small section of chalk (5x5cm approx) will be taken within a 2-meter radius of every second (P) MEM site. R MEM sites will not be measured, as they cover the same area of the platform as sites P1 and P2. Through the use of a Scanning Electron Microscope (SEM), which is ideal for viewing the sub-microscopic detail of chalk *(Walker 1978),* images of 500x, 1000x, 2000x, 4000x and 8000x will be taken of each sub-samples fractured surface, from approximately 2cm below the platform surface. The sample surface will not be scanned for porosity due to the possible influence of Polydore worms and other surface obstructions. The fractured surface will not be ground, due to the possibility of the pores in the chalk being filled with the debris.

These images will then be scanned into Imagine (Geographical Information System classification software), where the images will be simplified into two phases, pores and particles, and the specific surface of the solid phase will be calculated. From this the porosity can also be determined and estimated (modified from *Solymar and Fabricius 1999).*

5:5 Shore Platform Input / Sediment Removal

On the 10/11/01 a large section of the cliff collapsed on to the existing shore platform in Friars Bay (see fig 2 for location). It is the intention of this particular investigation to map the compaction and sediment removal rate of this fall, and thus study the inputs to platform dynamics as well as the outputs through erosion.

Little literature is available regarding sediment removal from rock falls, but *May and Heeps (1985)* describe the mapping of a fall that occurred at Ballard Down in 1969. The debris accumulation measured 500m^3, but marine processes removed an average of $50m^3$ pa. By 1977 only $90m^3$ remained, and by 1984 no chalk blocks were evident and a notch had appeared in the base of the cliff.

To achieve results of sediment removal rates from the platform at Peacehaven, 3 static points have been created covering 180^o from the cliff, where photographs will be taken every 4 weeks until April. The outlines of these photographs will then be traced at 600x magnification, digitised, and placed into Arc Info (GIS analytical software). Each layer will then be geo-referenced off the right angle of the cliff and the flat chalk plane overhanging to the fall. An accurate visual representation of the compaction and sediment removal will be produced.

Fig 10: Photograph of the rock fall at Friars Bay, Peacehaven, on the 26/11/01.

6 - Fieldwork and Data Collection

Table 2: Fieldwork Diary.

Date	Activity
02/07/2001	• Accompanied Richard Charman to Peacehaven to be familiarised with location of existing MEM sites. • Advise received on the use of the MEM.
02/08/2001	• Individual familiarisation of existing MEM sites, and the Peacehaven shore platform as a whole.
29/09/2001	• Investigation of the shore platform at low tide to determine potential research sites.
02/10/2001	• Research site chosen. • Drilling of (P) MEM sites commenced.
05/10/2001	• Continuation of site drilling.
08/10/2001	• Continuation of site drilling.
12/10/2001	• Continuation of site drilling.
15/10/2001	• Collection of MEM. • Due to the different base size to that of template used, each site currently drilled, had to be re-drilled to new size specification.
18/10/2001	• Re-drilling to new size specification.
22/10/2001	• Re-drilling to new size specification. • Initial setting of brass screws.
24/10/2001	• MEM taken to platform for initial measurements, however the screws had failed to set.
25/10/2001	• All screws re-set with MAFIX
29/10/2001	• Initial MEM measurements taken
12/11/2001	• MEM measurements taken
26/11/2001	• MEM measurements taken. • Schmidt Hammer tests taken • Initial photography and mapping of rock fall, Friars Bay.
09/12/2001	• MEM measurements taken.
23/12/2001	• MEM measurements taken.

	• Schmidt Hammer tests taken. • Continued mapping of rock fall, Friars Bay
07/01/2002	• MEM measurements taken. • Denudation / erosion measured in ridge and runnels adjacent to groyne.
22/01/2002	• MEM measurements taken • Schmidt Hammer tests taken • Continued mapping of rock fall, Friars Bay.
31/01/2002	• Scanning Electron Microscope (SEM) used on chalk samples collected from the platform on 30/01/2002.
05/02/2002	• MEM measurements taken.
19/02/2002	• MEM measurements taken. • Schmidt Hammer tests taken. • Continued mapping of rock fall, Friars Bay.
05/03/2002	• MEM measurements taken.
19/03/2002	• MEM measurements taken. • Schmidt Hammer tests taken.
02/04/2002	• MEM measurements taken. • Continued mapping of rock fall, Friars Bay.

7 – Results

7:1 Micro Erosion

1440 / P MEM data sets have been recorded in the six-month period, with the addition of 1152 / R from *Charman (2001).* Due to the vast quantity of data, averages have been taken for each MEM site. The averages of the P MEM sites can be seen in tables 3 and 4, and R MEM sites in table 5 and appendix 11.

Although there were few missing values, to make the results more meaningful, missing values have been predicted using the Expectation Likelihood Maximisation logarithm (part of multivariate analysis).

(P) MEM Site	Total Erosion (mm)	Average Erosion	Standard Deviation
1	2.615	0.238	0.32
2	1.875	0.17	0.433
3	1.28	0.116	0.411
4	0.956	0.087	0.43
5	1.204	0.109	0.203
6	1.687	0.154	0.289
7	0.4	0.036	0.294
8	2.86	0.224	0.404
9	3.38	0.307	0.241
10	3.84	0.349	0.193
11	3.78	0.343	0.224
12	3,85	0.35	0.293
Average	2.27		

Table 3: Showing total erosion over 6 months, average fortnightly results and standard deviations of sites P 1-12

Month	Average Erosion (mm)
November /01	0.529
	0.46
December / 01	0.12
	0.767
January / 02	-0.653
	0.436
February / 02	0.204
	0.178
March / 02	0.245
	0.194
April / 02	0.21

Table 4: Showing average fortnightly results of sites P 1-12 combined.

Month	Average Erosion 2000/01 (mm)	Average Erosion 2001/02 (mm)
September	1.19	0.58
October	1.08	1.16
November	1.26	1.49
December	1.66	1.21
January	0.72	0.52
February	0.69	1.14
March	0.73	0.97
April	0.28	
May	-0.14	
June	0.28	
July	0.39	
August	0.32	

Table 5: Represents the average monthly erosion rates for the R MEM sites. Column one represents the rates gained by Charman 2001, and the column 2 rates, in this investigation.

7:2 Pinnacle Denudation

The mean denudation has been calculated as 25.71cm for both sides of the groyne. Because phase 1 reached completion in 1977, it must be assumed that the concrete infill was created last, so therefore the groyne will be assumed to be 25 years old. Taking this into consideration, the average erosion rate around this particular groyne stands between 9.89mm and 10.28mm pa (with a twelve month buffer to limit error).

7:3 Schmidt Hammer

216 Schmidt hammer readings have been taken in this six-month investigation. The local and monthly averages of these results can be seen in tables 6 and 7.

Data Site	Site Average N/mm^2 SD
1	23.8
2	23.2
3	17.6
4	23.2
5	21.6
6	18
7	17.6
8	16.6
9	13.8
10	10.2
11	7.4
12	0

Table 6: Schmidt Hammer averages for each experiment site.

Month	Average N/mm^2 SD
November	18.42
December	17.5
January	12.5
February	15.25
March	16.75

Table 7: Schmidt Hammer monthly averages for combined sites 1-12.

7:4 Porosity

The porosity was measured twice for each sample at both 500x and 8000x magnification to ensure accuracy. The estimated % porosity for each sample is given in table 8.

Table 8: Porosity estimations for every second research site, at 500x and 8000x magnification.

Site	Porosity at 500x %	Porosity at 8000x %
1	7.24	12.62
3	8.53	14.59
5	8.38	16.44
7	12.85	16.39
9	14.33	24.84
11	22.74	35.98

7:5 Rock Fall Sediment Removal

- **Appendix 6: Final visual representation of rock fall retreat and sediment removal.**

From appendix 6 and table 9 the retreat and sediment removal over time can be seen. 72.1% of its volume is lost in just over 4 months.

Date	Volume (m^3)	% original fall
26/11/01	2194.5	100
23/12/01	1527.4	69
19/02/02	1053.4	48
02/04/02	611.5	27.9

Table 9: Calculated volume of the rock fall for dates shown and % lost from previous recording.

7:6 Statistical Analysis

Firstly, to determine the relationship each variable has to the other, Pearson's product-moment correlation coefficient will be used. This will indicate to what extent each variable is related to another *(Burt and Barber 1996)*.

Erosion (P MEM) and Distance from Sea Wall	= 0.658	(sig 0.02)
Erosion (P MEM) and Porosity	=-0.722	(sig 0.08)
Erosion (P MEM and Rock Harness	= 0.776	(sig 0.03)
Distance and Porosity	= -0.905	(sig 0.00)
Distance and Rock Hardness	= 0.918	(sig 0.00)
Porosity and Rock Hardness	=-0.9.73	(sig 0.00)

From these figures it is evident that distance from the sea wall, porosity, and rock hardness are all very strongly correlated with each other. Erosion is correlated to these three variables, but not to the same extent.

To determine how predictable erosion rates will be by knowing the other three variables, Multivariate linear regression analysis will be used *(Williams 1986)*.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.798	.638	.502	.8713

SPSS Calculations

a Predictors: (Constant), Distance, Porosity, Rock Hardness

The entry R signifies that 0.798 (80%) of the observed variability in erosion rates across the platform can be explained by the three independent variables of distance from the sea wall, porosity, and rock hardness.

R is the correlation coefficient between the observed value of the dependant variable and the predicted value based on the regression model. A value of 1 (100%) signifies the dependant variable can be perfectly predicted from the independent variables. Therefore 0.798 (80%) indicates a strong relationship between the four data sets, but signifies 20% unaccredited to the variables in the regression analysis *(Norusis 1998)* This difference can largely be attributed to the abrasion zone (discussed in analysis).

- Appendix 5: Statistical Tables and Graphs showing statistical relationships between variables of P and R sites (NB: 2 Pages)

8 - Analyses

8:1 Micro Erosion

8:1:1 P MEM Sites

- Appendix 7: Graph to display the total erosion measured at each P MEM site between 29/10/2001 and 02/04/2002.
- Appendix 8: Graph to display the observed monthly erosion variations from the combined P MEM readings.

From the range of 0.4mm to 3.85mm, it has been calculated that the average total micro-erosion rate across the platform between 29/10/01 and 02/04/02 was approximately 2.27mm. However this figure is not representative of the overall erosion distribution. Appendix 7 illustrates the erosion levels were observed to be higher at the seaward and landward sides, as stated in the hypotheses. Reasons for this observed 2.615mm of erosion at the sea wall seem obvious. Waves striking the sea wall tend to rise higher than usual, and plunge down at the base of the wall with greater force *(Cleeve and Williams 1987)*, scouring away at the platform at increased rates.
Therefore processes of mechanical wave erosion include breaking wave shock, water hammer, air compression in the joints, hydrostatic pressure, cavitation, and abrasion *(Sanders 1968)*, will be the fundamental factors responsible for increased erosion rates at the base of the sea wall. Evidence of this abrasion can be seen in fig 11.

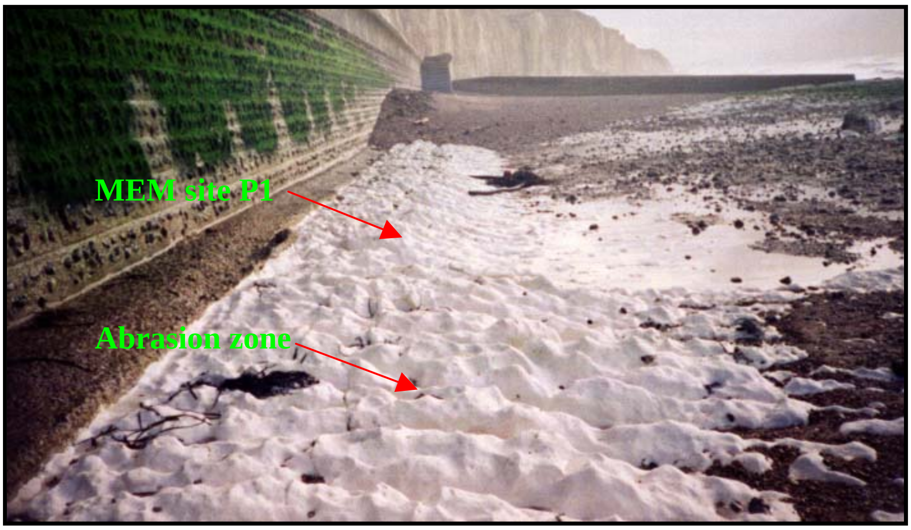


Fig 11: Photograph of evident abrasion zone at the base of the sea wall. The chalk surface is very clean representing high levels of abrasion

Andrews (2001) also experienced this increased erosion at the base of sea defences. Maximum rates at the sea wall reached 37.31mm over a two-year period.

A dramatic increase in erosion is apparent between sites 7 and 8 and increases further, be it at a slower rate to site 12. In the absence of localised trapped sediment and plunging waves, abrasion is not thought to be major factor in this high erosion rate. High levels of biological activity are evident on lower levels of the platform, but in this particular case study, do not seem to be protecting the platform surface. Together with saturation caused by long submersion, they may in some way reduce the strength of the chalk, thus leaving it more susceptible to erosion through limited abrasion or hydraulic action. This reduced strength of the rock can be confirmed and correlated by the findings of the Schmidt hammer tests and porosity investigation, described in more detail in the latter part of this section. The middle region of the platform, as predicted in the hypotheses received less erosion than the seaward and landward sides. This is due to the absence of localised abrasion, absence of crashing waves, and intermediate rock hardness. This middle section is however highly prone to wetting and drying as stated by *Stephenson (2000)*. Ideal conditions for this particular type of weathering occurs in the summer months, not included in this investigation. Therefore no accurate conclusion can be created, as it may be misleading. The other main weathering option is that of frost weathering.
Frost weathering tends to remove surface irregularities and wear back platform steps *(Robinson and Jerwood 1987b). Robinson and Jerwood (1987b)* also found spalling to decrease across the platform width from 36.4% at the top, 3.5% on the lower parts of the platform, and less than 1% near the low tide line, where the surface is largely protected by a covering of seaweed. It was also noticed that small projections of the chalk standing above the general level of the platform, the top edges of risers, and the upper edges and corners of drainage runnels were more frequently damaged than were the flatter masses of the platform. Although shore platforms are very susceptible to high frequencies of freeze thaw cycles, frost occurrences were very few in the study duration, and therefore it is believed not to be a major factor in the data distribution

If manipulated to create an annual erosion rate, the results from this investigation would stand at approximately 4.54mm. In 1981-82 *Ellis (1986)* measured the lowering of the platforms between Brighton and Newhaven at 44 sites and found that rates varied from 1mm to 10mm per year, with an average of 3mm per year. These results are relatively comparable to those of this investigation. *Ellis* also described that most of the lowering occurred in the winter in comparison to summer months. Due to the lack of summer data for the P MEM sites, the two studies cannot be compared. However monthly variations were also apparent in this investigation. Appendix 8 illustrates the monthly variations across sites 1-12, showing greater erosion levels in November, late December and late January in comparison to February, March, and April. A possible reason for this increased erosion could be more extreme weather conditions in these months. The prevailing winds throughout the year are from the southwest and west *(Robinson and Williams 1983),* with the strongest winds occurring in winter, with speeds up to 80 knots being recorded in the region *(Barne et al 1998).* Thus in theory should increase wave energy, which in turn enhances the physical influences the waves have on platform down wearing.

From the (P) MEM data (table 4) and appendix 8, it can be seen on one occasion there was an apparent 'rise' in the shore platform level. Initially this growth was thought to be a technical error with the MEM. However as documented by *Goudie (1994b),* problems may be encountered because of the result of the expansion and contraction of the rock surface caused by temperature and moisture changes, salt and frost heave. This occurrence has been outlined in detail by *Mottershed (1989)* where she describes it as 'episodic occurrence of elevations of the surface and later as a swelling', and has also recently been noticed by *Stephenson et al (2001)*. From day to day swelling was noticed with rates above instrument error with a maximum gain of 2mm. Apparent swelling was also found to be an important precursor to some erosion events and an integral part of weathering and ultimately shore platform development *(Stephenson et al 2001).*

- Appendix 9: Graph to display the average MEM data on the 07/01/02, for each P MEM site.

Appendix 9 to some extent proves this theory. It illustrates the individual site averages for 07/01/02, and only shows an apparent rise in (P) MEM sites 2-8. Sites 1, 9, 10, 11, and 12, all experienced erosion. Along with the results from 22/01/02 where erosion was witnessed across the platform, to some extent, this proves there was no mechanical fault with the MEM.

This apparent regional swelling could have occurred for two reasons. Firstly, this expansion in the middle and upper section of the platform could be due to sub-aerial wetting through increased exposure times. This wetting would be the result of increased precipitation or high levels of moisture in the atmosphere. Sites 8-12 would not be affected due to existing high saturation, and limited exposure time in comparison. However as stated previously, sites 1 and 8-12 have been found to erode at faster rates than the central sites. Therefore it is possible that for some reason the whole platform was subject to growth, but the erosion experienced at these sites was greater than that of the rising distance. It is possible that this swelling could be due to freeze expansion, however the climatic conditions at the time do not warrant this theory.

There also remains the question regarding the brass MEM screws. If the platform grew, then surely the screws that were fixed to the chalk would rise simultaneously and cancel out the apparent rise. Therefore it is likely that if growth occurred, the swelling only affected the top 1cm of the platform surface.

8:1:2 Ridges, Runnels and the Groyne

- Appendix 10: Graph to illustrate the varying erosion rates of ridges and runnels along the length of the groyne using the R MEM sites.
- Appendix 11: Corresponding table to accompany appendix 10.
- Appendix 12: Graph and illustration showing measured erosion since the groyne construction, from the concrete groyne infill.
- Appendix 13: Graph to illustrate monthly variations for combined R MEM sites.

The average monthly erosion rate for ridges was calculated at 0.59mm and 0.81mm for the runnels. Although the ridges are in theory more exposed to the forces of waves and sub-aerial weathering, the runnels appear to erode quicker due to increased localised abrasion and solution processes. The question remains as to why aren’t these runnel formations deeper. This can be explained by levelling or macro erosion of the ridges (see fig 12). Normally this zone would be continually covered by sediment from the adjacent cliff, and therefore the runnels would not be given a chance to produce. It can therefore be concluded, that the localised runnel formations in the vicinity of the sea wall and groynes, have only appeared since the construction of the defence scheme.

Fig 12: Photograph to show the macro erosion and the fracture of a ridge on the western side of the groyne.

Variations were also apparent on the west and eastern side of the groyne, monthly erosion rates being 0.63mm and 0.77mm respectively.

The western side should in theory experience more channelling due to increased wave energy, and therefore assist in transporting existing beach material along existing runnels, and thus increasing abrasion in these concentrated areas.

This would in turn account for observed less prominent ridge and runnel formations on the eastern side of the groyne. However in this investigation this does not seem to be the case. An explanation can be found in large relict sediment on the eastern sides of the groyne. In high-energy conditions, the apparent wave shadow (see fig 13) created by the groyne becomes less significant and large volumes of sediment can be washed against the eastern side of the groyne. Future preferential movement lies with smaller beach sediments to the western side of the adjacent groyne. The larger sediments of the beach load then remain to the eastern side of the groyne cell, as sufficient energy is not present to provide longshore movement. Because these rocks (observed to be up to 19cm across) are large and heavy, any movement that does exist will result in higher abrasion than the western smaller sediment. This explains not only why erosion was found to be faster on the east side, but also why there are less prominent ridge and runnel formations. With larger sediment, the directional rolling required is not as likely. Together with the wave shadow, energy is restricted from implementing this process.

Varying rates of erosion were also evident along the length of the groyne (appendix 10). Results were not consistent for either side of the groyne, and the ridges and runnels displayed faster erosion rates at the sea wall and groyne tip ends. This would primarily be due to wave plunging at the wall, and the water turbulence created by the channelling of waves at the toe of the groyne. This has been outlined by *Ellis (1986)* that erosion is greater on lower parts of the platform were wave quarrying is dominant and deep runnels form. It is also known that concrete sea defences cause the waves hitting them to 'rise higher than usual, and plunge down at the base of the walls with greater force' *(Cleeve and Williams 1987)*. This would increase scouring at the sea wall and the base foundations of the groyne.

Fig 13: Photograph to illustrate the evident wave shadow created by the concrete groyne. The waves can be seen approaching from a south-westerly direction, and thus energy is slightly reduced in the immediate region to the east of the groyne.

This trend can be confirmed by the findings of the pinnacle measurements (appendix 12). From the graph it is evident that for the ridges, runnels, east and west sides, erosion has been greatest at the seawall end of the groyne.

Monthly variations were also observed in erosion rates of the R MEM sites (appendix 13). From 18 months of data two distinguished peaks can be seen in November and December of both 2000 and 2001. The graph also illustrates a fall in erosion rates in the summer months, with an apparent rise in May *(Charman 2001)*. The fundamental reason for this would lie in the reduction of wave energy during the summer months. Combined with the absence of freeze thaw cycles in the current climate, little erosion occurs in the summer months *(Robinson 1977)*.

8:2 Rock Hardness

- **Appendix 14: Graph to display the average Schmidt hammer results for each site, on each day recorded.**
- Appendix 15: Graph to display the average Schmidt hammer results for each site across the study duration, with standard deviations for each data set.
- Appendix 16: Graph to display the observed average monthly variation in the hardness of the platform chalk.

As predicted and as shown in appendix 13 and 14, the apparent 'hardness' of the rock decreases with distance from the sea wall. The key explanation to this is purely the time the rock is submerged by the sea. The lower the rock is on the platform, the greater the time spent submerged. This then reduces the time spent exposed, and thus decreases the gap between wetting and drying cycles. This theory does however make the assumption that chalk is primarily softer due to saturation and ignores the possibility of the rock at the base of the platform being from a softer bed. However without detailed geological maps of the shore platform, this theory cannot be proved. Appendix 15 illustrates the observed monthly variations found in the Schmidt Hammer measurements. A reduction in average rock hardness can be seen in January, with the highest measurements being obtained in November. This particular distribution could to some extent be related to climatic conditions at the time. January was very wet in comparison and received higher levels of precipitation than the previous November. Therefore it can be suggested that this drop in chalk hardness could be related to higher precipitation levels, and the peak in November due to frost hardening. No climatic data was collected at the time and therefore cannot be used to prove this theory.

8:3 Porosity

- Appendix 17: SEM images of each chalk sample at 500x magnification.
- Appendix 18: SEM images of each chalk sample at 8000x magnification.
- Appendix 19: Graph to display the porosity readings of both 500x and 8000x magnification.

Appendix 16 and 17 show the images used to calculate the porosity for sites 1,3,5,7,9,and 11. Samples were only taken from these sites due to the time scale required to analyse the results, and uncertainty regarding how successful the method would be. To limit the error involved in classifying the porosity, both 500x and 8000x images were analysed. The 500x images were classified in order to provide data for a larger surface area, and thus eliminate chances of 'freak' or obscure results from the 8000x images. The results which be seen in appendix 18, display an evident variation between the porosity measurements of 500x and 8000x magnification. The 8000x image of every sample produced slightly higher rates of porosity than the 500x images. This was to be expected because micro pores not evident on the 500x image would have become visible when the 8000x image was analysed. The average of this variation was calculated to be 7.79% of the total porosity with a range of 3.54% to 13.24%.

This variation aside, the distribution shows a strong trend of higher porosity levels the further the sample was from the sea wall. This in turn would have a direct effect on the reduction in rock strength, and possibly contribute to the observed high erosion rates at the seaward end of the shore platform.

Due to the experimental nature of this technique, the porosity percentages may not accurately represent the true porosity levels of each of the samples. This method does however supply an accurate percentage of porosity in relation to the other samples.

Therefore this technique has proved to be successful, to the extent of confirming an increase in the rock porosity across the platform width.

8:4 Rock fall and Sediment Removal

- Appendix 20: Visual representation of how the mass of the original rock fall was calculated.
- Appendix 21: Graph displaying the predicted rate of sediment removal between 26/11/01 to 02/04/02.

Cliff retreat is episodic with large volumes being lost in one fall, which can then protect the cliff base from attack for a time. Further falls are unlikely until the sea removes the debris and wave attack can erode the cliff again to the point of failure (see fig 14). This process has been documented to take between 8 and 9 years *(Robinson and Williams 1983)*. This input to the platform is of major importance, not only in protecting the cliff base, but also protecting the shore platform from further erosion. In the absence of defences, this dynamic equilibrium is evident. It could therefore also have an important role to play in the prediction of cliff retreat, as the fall would act as a natural obstruction to wave attack.

Fig 14: Photograph to show the formation a notch at the cliff base in Friars Bay. (02/04/02)

The removal of sediment from the Friars Bay rock fall can be seen on appendix 6 and appendix 20. A 72.1% reduction in the volume was the calculated sum removed over a 6-month period. Appendix 20 displays a relative predicted uniform rate of removal, with sediment removal being slightly quicker in the initial month after the fall.
It is thought the finer sediment and loess in the fall load would have been transported from the rock fall at a rapid rate due to their size and mass. However the rapid and evident removal of large-scale boulders (2m diameter in measured example) is slightly more puzzling. *May (2001)* suggested that the large boulders that dominate the toe of the landslide are washed to sea. These have been reported several km offshore of the west Dorset coast, and substantial boulder fields lie seawards of previous landslides.
To gain these results a number of assumptions have been made. Monitoring the fall from 3 positional perspectives failed due to equipment error, and as a result, volume loss was assumed to be occurring at the same rate 180^0 around the fall. There may also be errors in the calculation of the original volume of the material. This was however measured with relative accuracy in the field and calculated accordingly (see appendix 19). Even if the volume calculation has an element of error, the percentage reduction calculated is accurate, as this was obtained by pixel reduction in the digitised images.

- See Appendix 6

9 - Criticisms and improvements

Marine platforms are lowered at such gross rates; the likelihood that error sources may be overlooked or neglected is rather high. However, due to the long duration of this investigation, many of these foreseeable problems were identified and rectified at an early stage.
Tables 10 – 17 identify possible errors that may have affected the results in this investigation.

Error Source	Errors and Improvements
Micro Erosion Meter (MEM)	• Probe erosion is of a major concern as stated by *Spate et al (1985)*. It is essential that the probe of the dial gauge should be lowered slowly to prevent damage to the surface being measured. Although linen pegs were used to prevent probe scraping, the MEM lacked the recommended finger operated probe lowering mechanism suggested by *High and Hanna (1970).* • It is documented by *Spate et al (1985)* that lowering of the probes takes on a decaying exponential character, which could be due to compaction of the rock surface by the MEM probes. • Physical wear of the MEM. *High and Hanna (1970)* and *Trudgill (1981)* refer to this aspect of the technique, which can be detected by repeated use of a test plate. *High and Hanna (1970)* state the non-traversing MEM error arising from this cause was less than 0.001mm over a two year period *(Spate et al 1985)*. Although a relatively small figure, it demonstrates the potential of falsifying results. And because all MEM’s are made to individual specification, different materials could be used in its production, thus resulting in varying wearing rates • **Temperature changes in the instrument, temperature changes of the studs and the rock, are all error sources pointed out by *Spate et al (1985)*.** • It should be remembered, an MEM reading is a point reading. Therefore major assumptions are necessary when creating averages for an area *(Goudie 1994b).* • MEM investigations focus on a single process or a group of processes without being able to identify the precise role or contribution each makes to platform erosion. • *Kirk (1977)* stated that the MEM does not provide data on mass wasting when large blocks are quarried by waves. Macro erosion not taken into account.

	• Obstruction of the MEM sites proved to a major factor in consistent data collection. Impediments such as Limpets (fig 15), shingle (fig 16) and algae / seaweed (fig 17) were all found to be major factors. In particular, the common Limpet *(Patella vulgata)* proved to be very difficult as it has a remarkable tenacity of up to 0.23MNm^{-2} *(Little and Kitchling 1996).* • There was the tendency to place sites on flat areas, which may be untypical of the shore platform, and therefore creates the potential for bias results *(Goudie 1994b)*. • The movement of foot screws required some of the MEM sites to be re-drilled causing possible error in the final results (fig 18). • Short time scale of the investigation. It would have been beneficial to monitor the P MEM sites over the summer months to compare full seasonal variations in erosion rates. • With many of the mid platform sites having little distinguished topography to identify their exact location, more time than necessary was spent measuring and relocating these sites. Time could have been saved by using a metal detector to determine their exact location quickly and effectively *(Williams et al 2000)*.

Table 10: Possible errors from the use an MEM.

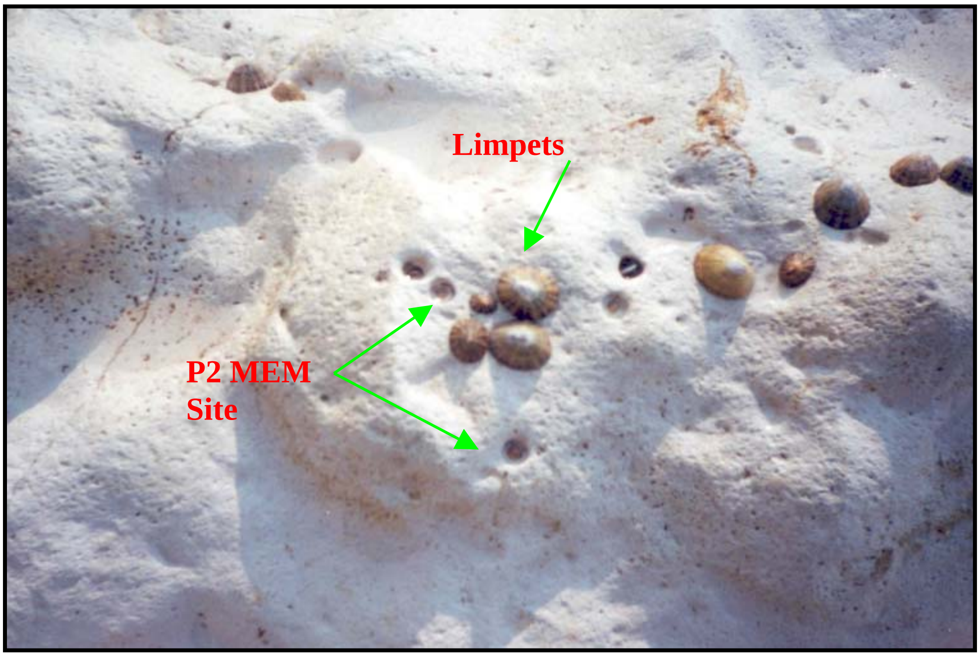


Fig 15: Photograph displaying P MEM site 2 with a family of limpets obstructing measurement, but also increasing erosion on the site simultaneously.

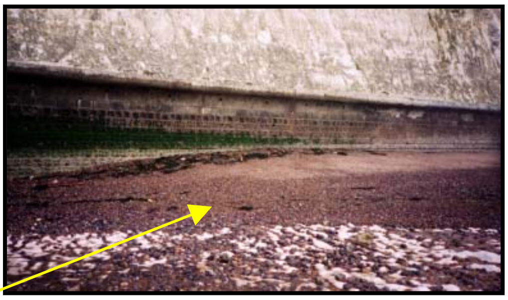


Fig 16: Photograph to show site P1 covered by beach sediment.

Fig 17: Photograph to show coverage of algae / seaweed, obstructing MEM reading.

Fig 18: Photograph to show screw shift, and thus the need to drill a new MEM site

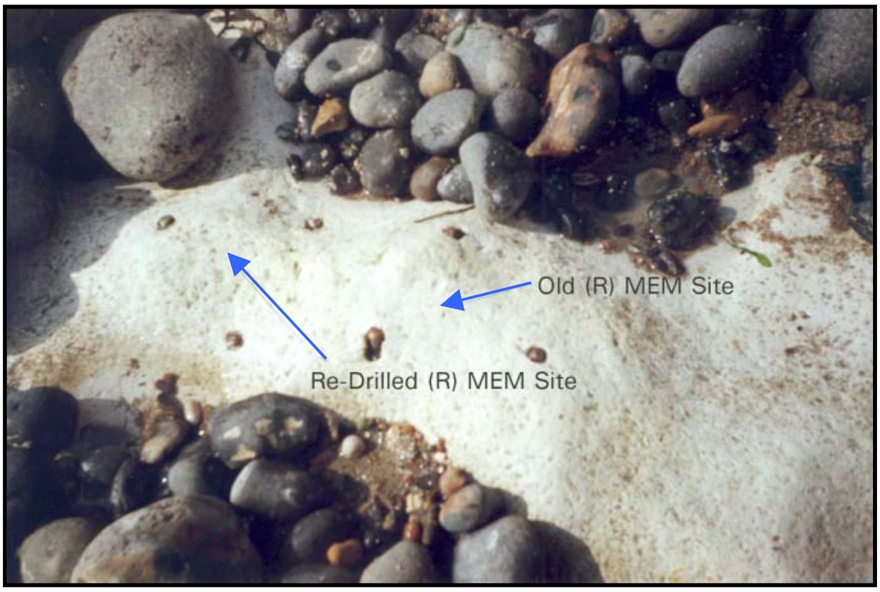


Table 11:
Possible errors from pinnacle measurements

Error Source	Errors and Improvements
Pinnacle Measurements	• There is the large assumption that the concrete in-fills in the groyne foundations were exactly the same height as the surrounding platform at the time. • Measurements were only based around one groyne from one phase. If repeated groynes from all 4 phases would have been measured in order to obtain more accurate results regarding platform erosion over time. • In measuring the adjacent ridges to the groyne with a ranging pole and spirit level, slight inaccuracies may have been made. A Tachometer could have been used, although difficult to use and understand.

Table 12: Possible errors Schmidt Hammer m

Error Source	Errors and Improvements
Schmidt Hammer Measurements	• While the Schmidt hammer gives an evaluation of surface hardness and has been found to correlate well with compressive strength *(Hucka 1965)*, the testing of rock strength provides many difficulties. • Evident variation in results, even from the same point. This could have been calibrated with the dropping of playing darts from a controlled height. • Errors could have occurred due to inconsistent surface preparation.

Table 13: Possible errors from porosity readings.

Error Source	Error and Improvements
Porosity Calculations and SEM scanning	• **Because the fractured samples were not ground to create a flat surface for scanning, the possibility of shadowing was relatively high. Due to the nature of the GIS analytical software IMAGINE, percentages were determined through pixel colour in a supervised classification. Although this has proved to be a relatively accurate technique in satellite remote sensing, dark shadows due to undulations in the surface could have been mistaken for pores in the chalk (see fig 19).** • **Pore filling could have been prevented somewhat if an ultra-sonic bath had been used after grinding, but this was not available at the time.** • **If more time was permitted, the saturation capacity of all 12 samples would be tested to correlate with the results obtained from the SEM scans**

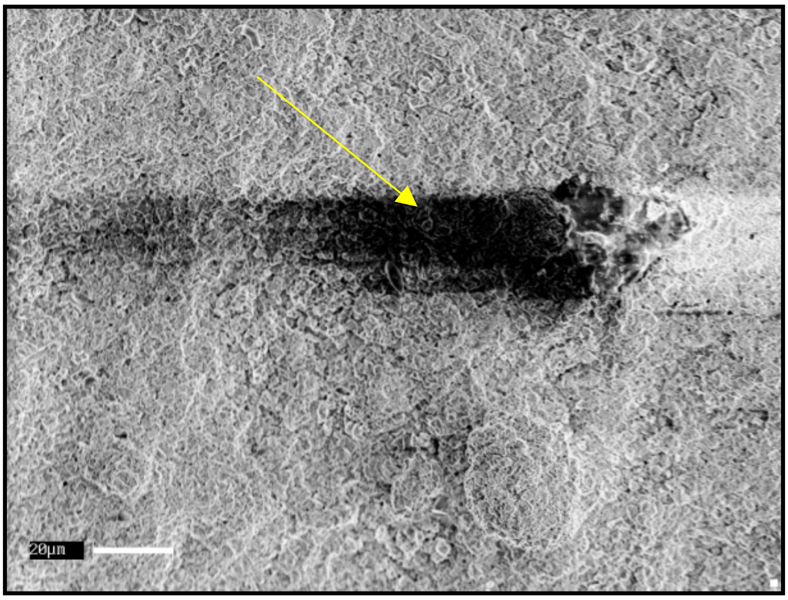


Fig 19: An SEM image displaying an evident surface shadow, which under an unsupervised classification, would be mistaken for porosity. This image together with any other that displayed obvious surface shadowing was not used for analysis.

Table 14: Errors related to rock fall and sediment removal analysis.

Error Source	Errors and Improvements
Rock fall and sediment removal analysis.	• **A number of the photographs did not develop, and therefore valuable data was lost.** • **There was the assumption that the sediment removal was equal from all dimensions of the fall.** • **A Total Station could have been used to survey the rock fall accurately. Recently, *Pan and Morgan (2001)* have used a Metric Survey Camera from two stationary points to determine cliff retreat rates and rock fall density. Together with advanced GIS techniques, 3D animations of cliff topography can be created.** • **The rock fall volume and removal figures are merely estimations and did not take into account gaps between the chalk boulders and rock debris. These figures are also subject to line and human error in the digitising and geo-referencing process.** • **It would be interesting to observe the retreat and sediment removal over a 12-month rather than a 6-month period.**

Table 15: Data Errors

Error Source	Errors and Improvements
Data Errors	• **Predictive statistics were used when MEM sites were covered or obscured beyond retrieval. Therefore visual representations / graphs may be slightly inaccurate as a result.** • **Due to the extent and nature of data, averages were made throughout the investigation. This may have obscured abnormal results.**

Table 16: Errors and flaws in the investigation.

Error Source	Errors and Improvements
Investigation flaws and errors	• **Although successful, the location of the R MEM sites could have been improved for more accurate results. The original MEM sites were placed in and on the same ridge and runnel either side of the groyne, thus biasing the results to the individual dynamics of these features. An array of ridges and runnels could have been investigated in the same way to obtain a more reliable average for the lower platform region.** • **It was the original intention of this investigation to create 2 more complete transects of the shore platform. One in the same location as *Charmans (2001)* western groyne, and one in Friars Bay, where there is no artificial defence. *Charman (2001)* noticed a 0.19mm per month difference between two groynes approximately 2km apart. This factor was highlighted by *Stammers (1982b),* in that inconsistency was noticed in the hardness of the chalk across the platform. A transect in Friars Bay would also have been useful to determine the dynamics of a platform that is subject to constant input from the cliffs, and is not impeded by artificial defence works. However due to the time required to drill and set the first transect of MEM sites, and the time required to obtain results, the initial plan of three transects was neither viable or feasible.** • **Some of the P MEM sites where almost in-accessible at times and dangerous to access.**
	• Due to type B nature of platform it would be an interesting factor to investigate the erosion of the vertical seaward edge. *Stephenson (2001)* attempted to correlate cliff retreat with the seawards edge erosion in Kaikoura, but found no relationship between the two. However turbulence created by passing waves as they enter the platform may have a more noticeable effect on the soft chalk of the Peacehaven platform. • It must be noted that this investigation has concentrated on the 'micro' erosion of the shore platform. Therefore large blocks lost through macro erosion (see fig 20) were not

	accounted for. • Particularly noticeable in lower regions of the shore platform, large proportions of the erosion occurring may be due to localised abrasion in the form of pot-holes or rock basins. These are created by small gatherings of beach sediment, trapped in a small undulation in the rock surface. Over time this sediment is frequently disturbed and moved by the actions of the tides and waves, and thus localised abrasion is the result *(Goudie 1994a)* (see fig 21). If allowed a longer research duration, the erosion of these features could be measured. • Climatic conditions should have been closely observed and correlated with varying seasonal erosion rates. • The platform could have been surveyed to determine any angle changes in relation to observed varying erosion rates. • Although valuable results have been obtained, the experiment was not long enough to determine accurate patterns or trends. • Other methods such as using a Laser scanner (*Williams et al 2000); (Swantesson and Henaff 2001)*, and aerial photography could have been used to enhance results.

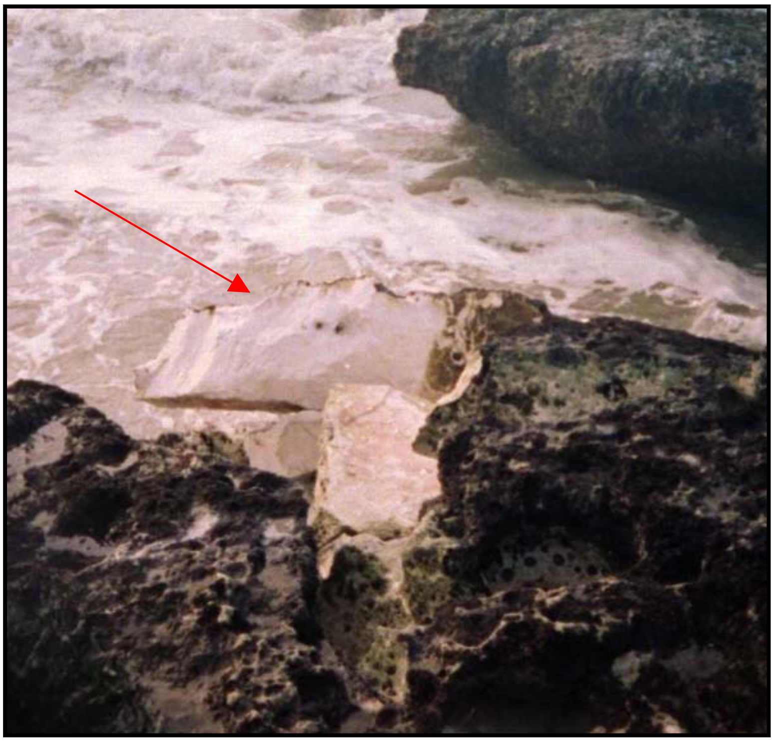


Fig 20: Photograph to represent platform loss through macro erosion.

Fig 21: Photograph showing the forming of a rock basin through localised abrasion, and one of the deeper drainage runnels adjacent to P MEM site 10.

10 – Conclusion

10:1 Hypotheses: Proven or disproved?

- ✓ **1,2)** The erosion rates did not stay constant across the width of the platform. Higher levels of erosion were experienced at the base and the top of the platform, with reduced rates in the centre.

- ✓ 3) Higher erosion rates were experienced on the eastern side of the groyne, but a greater difference was obtained on the western side between the ridges and runnels.

- ✓ 4) The rock hardness did not stay at a constant across the shore platform. Rock hardness decreases with distance from the sea wall.

- ✓ 5) The artificial pinnacle measurements proved to be very useful in determining erosion rates around the groyne structure, and correlated well with the MEM results showing increased erosion rates at the back of the groyne.

- ✓ 6) The porosity of the chalk increased with distance away from the sea wall.

- ✓ 7) Although summer data is absent for the P MEM sites, the R MEM sites prove seasonal variations in erosion, with higher erosion rates being witnessed in the winter months

- ✓ 8) The removal of sediment from the Friars Bay rock fall proved to be slightly more rapid in the initial month after collapse, but after which the removal rate was relatively uniform.

10:2 What has been achieved

From the results presented in this investigation, it is evident that erosion rates across the platform are substantially related to the hardness and the porosity of the rock. The results have also proved that the erosion rates across the platform are not uniform. They follow a bell shaped distribution with higher erosion levels at the top and bottom ends, with reduced rates being recorded in the middle. This does however raise the question as to why the shore platform is not shaped like a bell? It must be assumed that the platform reaches a dynamic equilibrium through macro erosion or increased frost flaking in the middle region of the platform, in order to maintain its level appearance.

Porosity has been proved in this investigation to decrease with distance from the sea wall, thus being more porous on the seaward side. Using the SEM to determine the chalks porosity is not the standard method used, due to shadowing and pore blockage. It does however give the opportunity to explore surface pores that are not permeable by water, but that still contribute to strength variations. This increase in porosity is thought to have a direct relationship with rock strength and therefore would be a major fundamental in increased erosion rates in areas of high porosity. Enhanced effects from freeze expansion, solution, and abrasion due to reduced strength, are all major factors thought to contribute to higher erosion rates observed at the seaward edge. However high erosion levels together with the increased 'softness' of the rock at the base of the platform could purely be blamed on probe erosion. Application of methods such as laser scanning that does not rely of mechanical measuring of the platform surface could eliminate areas of uncertainty such as this.

Abrasion and wave quarrying are thought to be the dominant forces in the high erosion rates at the sea wall. The presence of large quantities of beach sediment help to scour and abrade in this area, and facilitates in the further development of ridge and runnel formations.

The average denudation measured from the base of the groyne to the adjacent runnel bottom and ridge peak, coincided with erosion data obtained in ridge and runnel erosion from the last 18 months. An average difference of between 0.124mm and 0.16mm per month has been calculated between the pinnacle denudation over a 25-

year period, and recent MEM measurements. This small but significant figure could either represent measurement error, or macro erosion of the ridges and runnels, that cannot be observed were not observed by the MEM over this relatively short period.

Although informative and intriguing, the results from this study cannot be conclusive of the erosion dynamics of shore platforms. Variability exists between rock strength and rock types. *Stephenson and Kirk (1996)* observed erosion at 1.43mm pa recorded on mudstone and limestone on the Kaikoura Peninsula, New Zealand. The relative importance of each erosion factor in beach and platform development depends entirely on the individual location and geomorphological circumstances (*Pidwirny 2000); (Trenhaile 1997)*

The findings of this report do however present an area of future application and benefit. *Beckett (2000)* has suggested that the sea defences will be in need of reconstruction work within the next 5-10 years. However figure 5 illustrates the need for more immediate action. By determining primary causes for erosion and calculating erosion rates, across the platform and around artificial structures, accurate management plans and objectives for the re-engineering of the coastal defence infrastructure at Peacehaven, can be produced and applied accordingly.

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Appendix 1

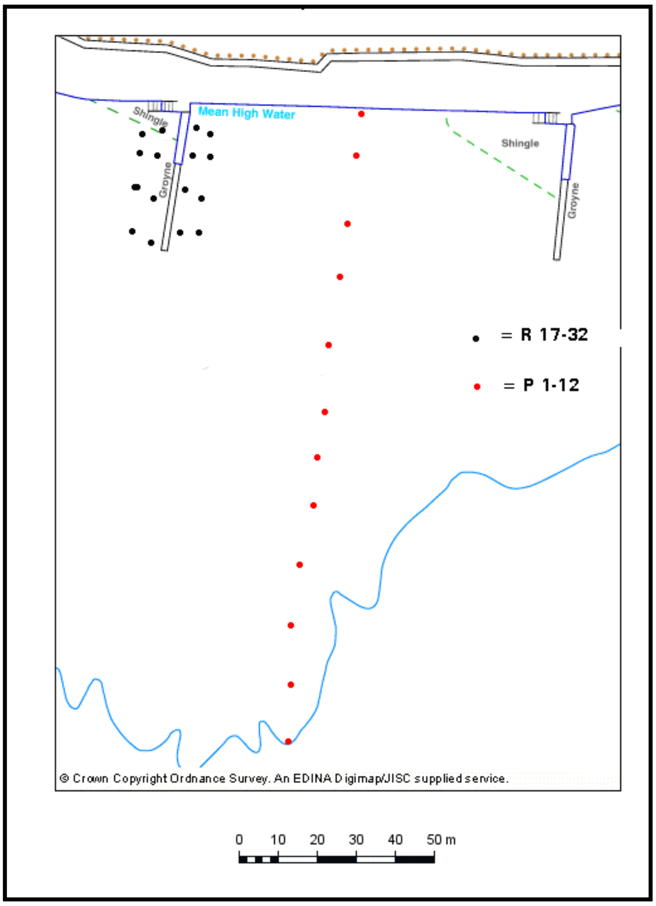
Project Location and Platform Type

Aerial photograph of erosion study site.

Photograph illustrating the seaward drop, and thus confirming the classification of 'Type B'.

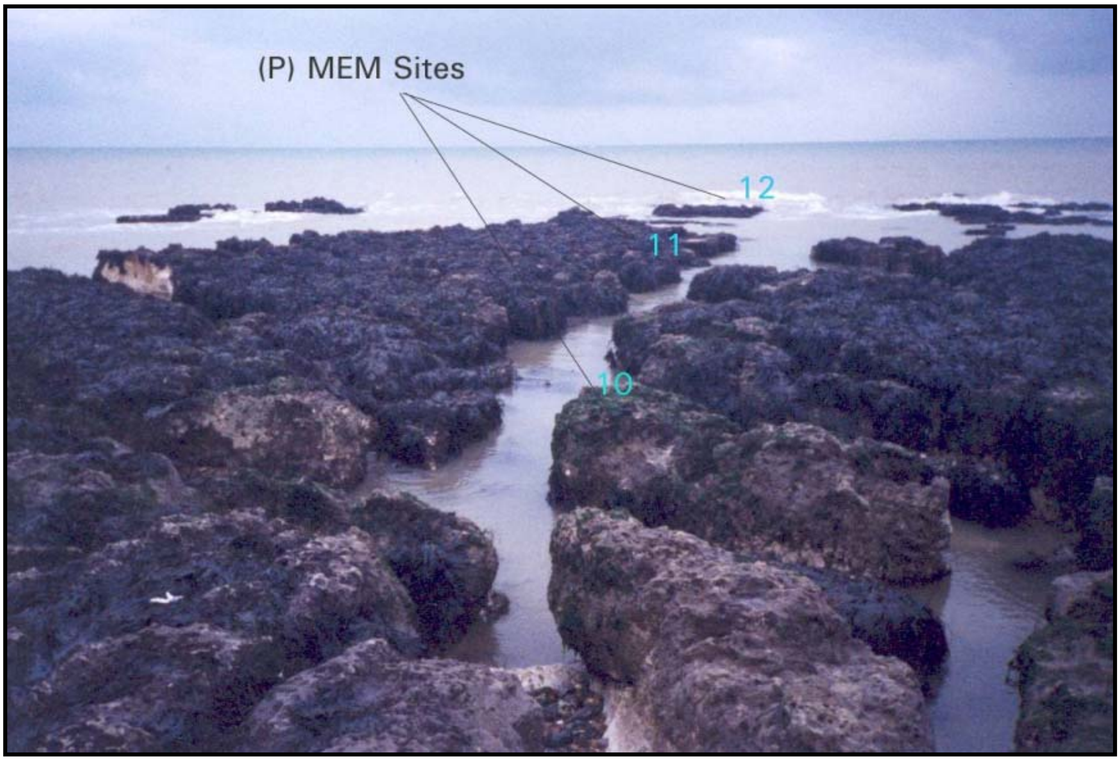
Appendix 2

Location of P and R MEM Sites and Accessibility Difficulties



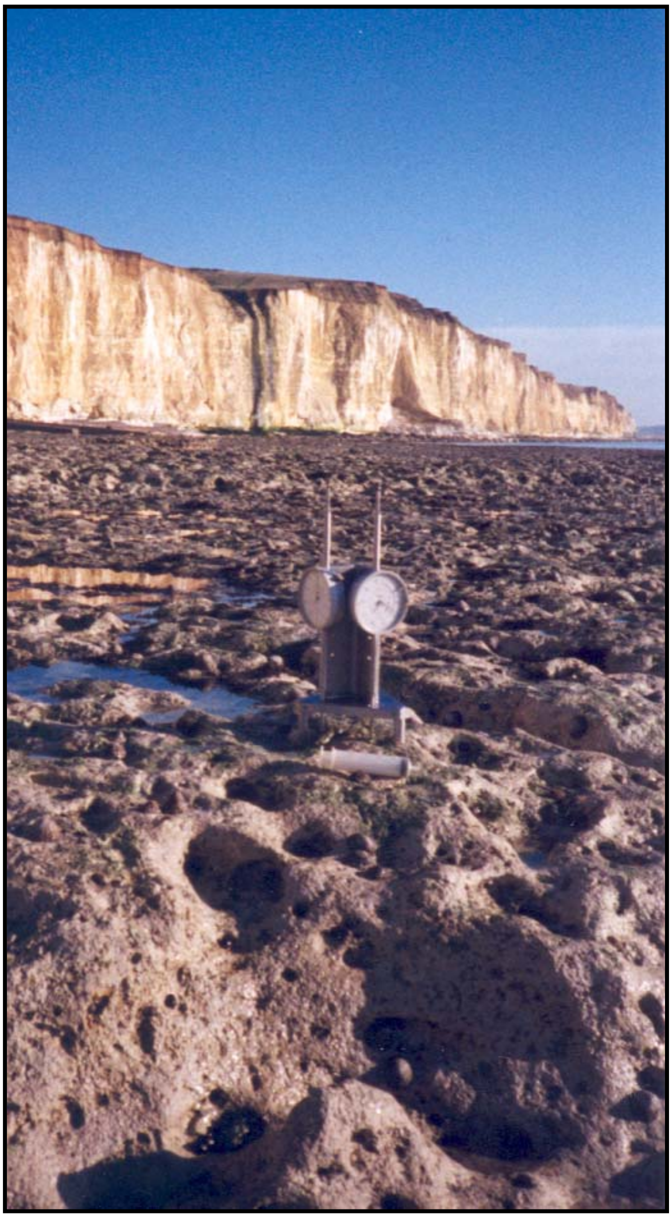
Location of P and R MEM sites in relation to the shore platform. (Digimap 2001)

P MEM sites 10-12 – Illustrating accessibility difficulties at low tide.



Appendix 3

MEM in action

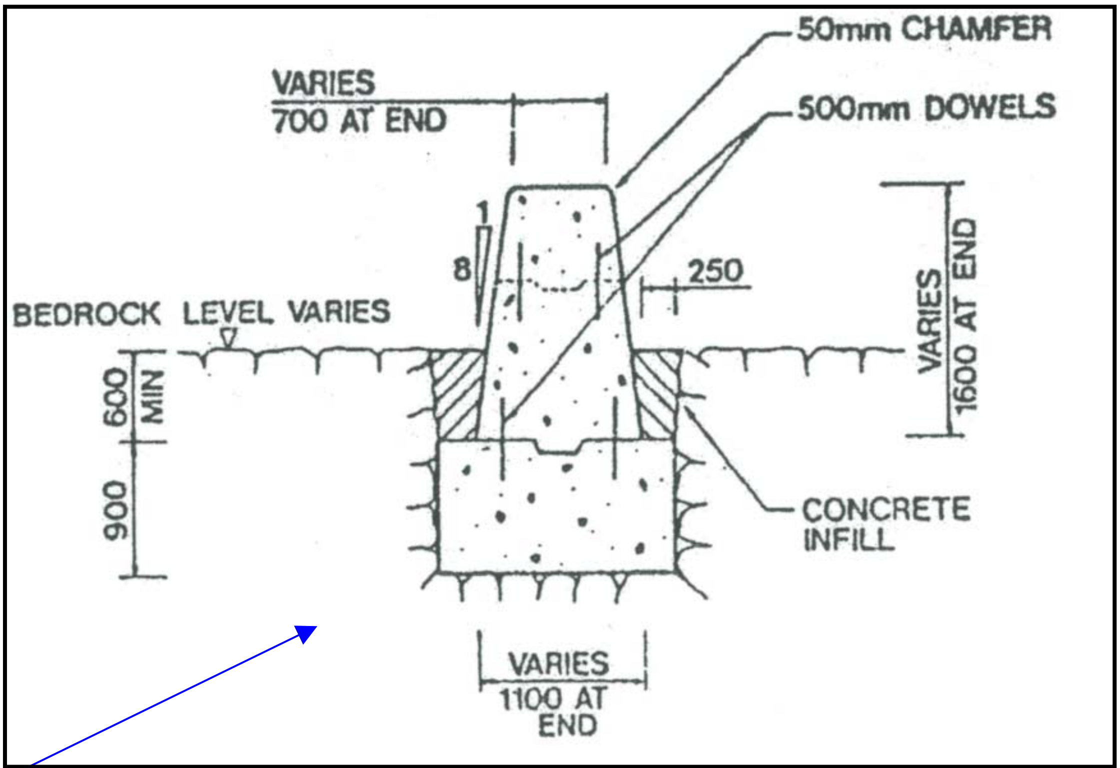


MEM on site P 7

MEM on site P 4

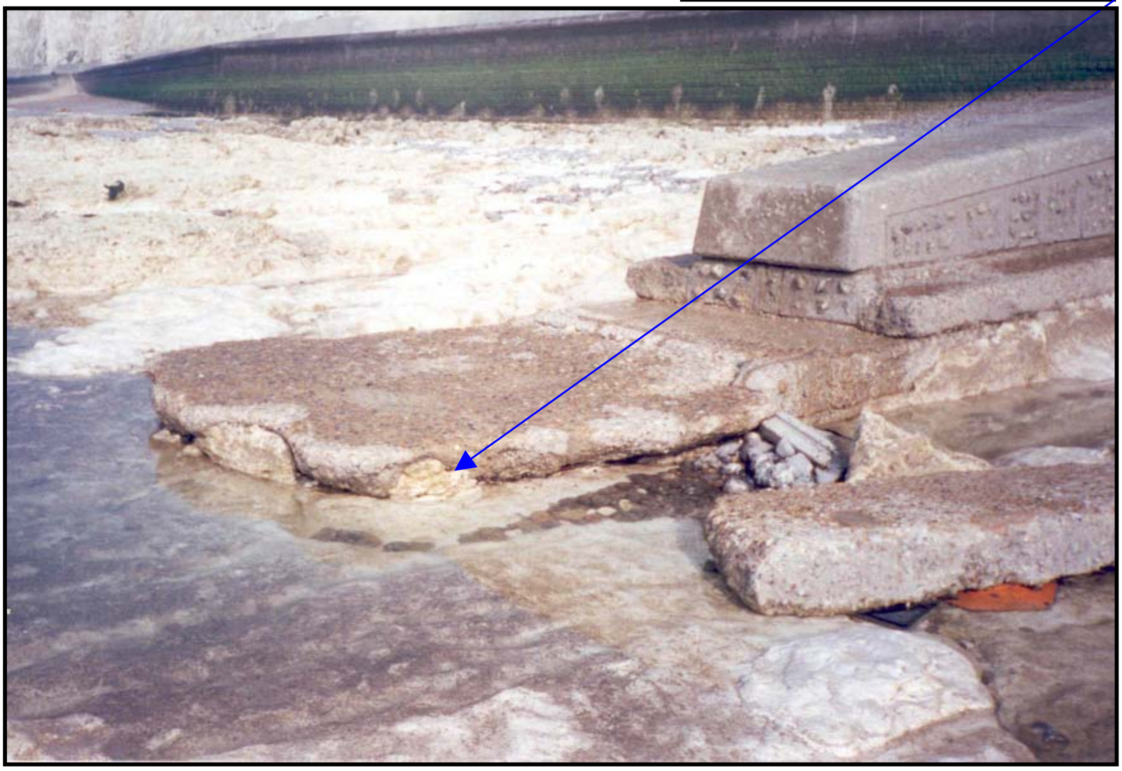
Appendix 4

Cross section of groyne construction and photograph of evident erosion



Cross section of groyne construction illustrating concrete infill at the same height as adjacent platform (Stammers 1982b)

Photograph illustrating the evident erosion of the platform since construction of the groyne.



Appendix 5

Statistical Analyses (continued)

P MEM Sites

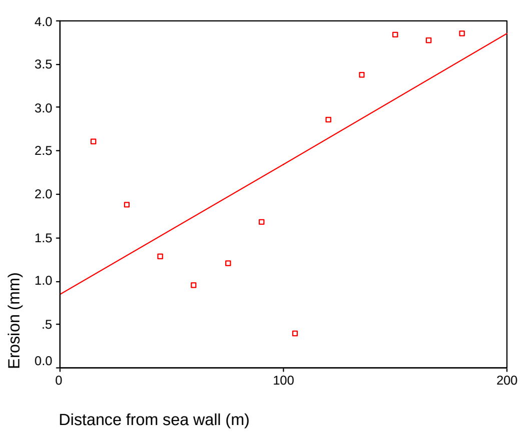
Coefficients

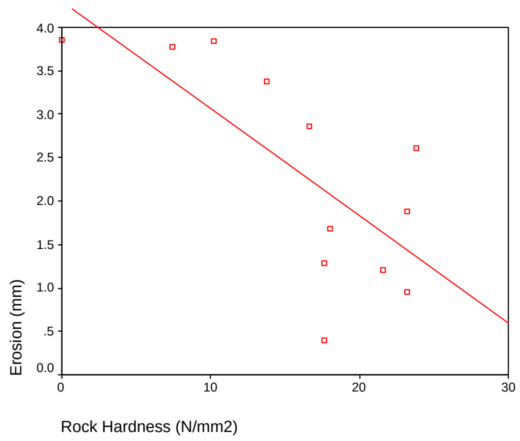
Transect (P) Sites		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	-2.812	5.004		-.562	.590
	Rock Hardness	9.339E-02	.158	.546	.591	.571
	Porosity	.247	.154	1.591	1.597	.149
	Distance from Sea Wall	-7.047E-03	.012	-.309	-.570	.584

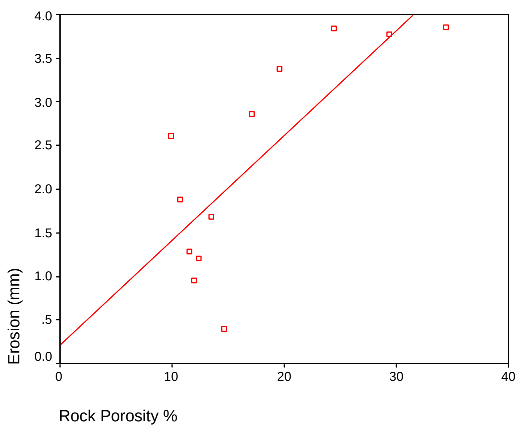
a Dependent Variable: Erosion

Table of Regression Analysis showing intercept values (B), correlations (Beta) and significance levels (sig) for the three independent variables (distance, porosity, and rock hardness), against the dependant variable (erosion rate).

SPSS Graphs showing linear regression lines of independent variables.







R MEM Sites.

To test if the erosion rates are significantly different to suggest that they are from different populations, an ANOVA or analysis of variance is required.

Source	Significance Value	Significance Level
Ridges / Runnells	0.02	0.5%
West / East	0.39	0.5%

Ridges against runnels produced a significance value of 0.02. Against a significance level of 0.5. This illustrates that the data sets are from separate populations, and therefore can be analysed accordingly.

Likewise, the western side of the groyne against the eastern side provided a significance value of 0.39 against a significance level of 0.5. Again this represents significant variance between the two populations to classify them as being separate.

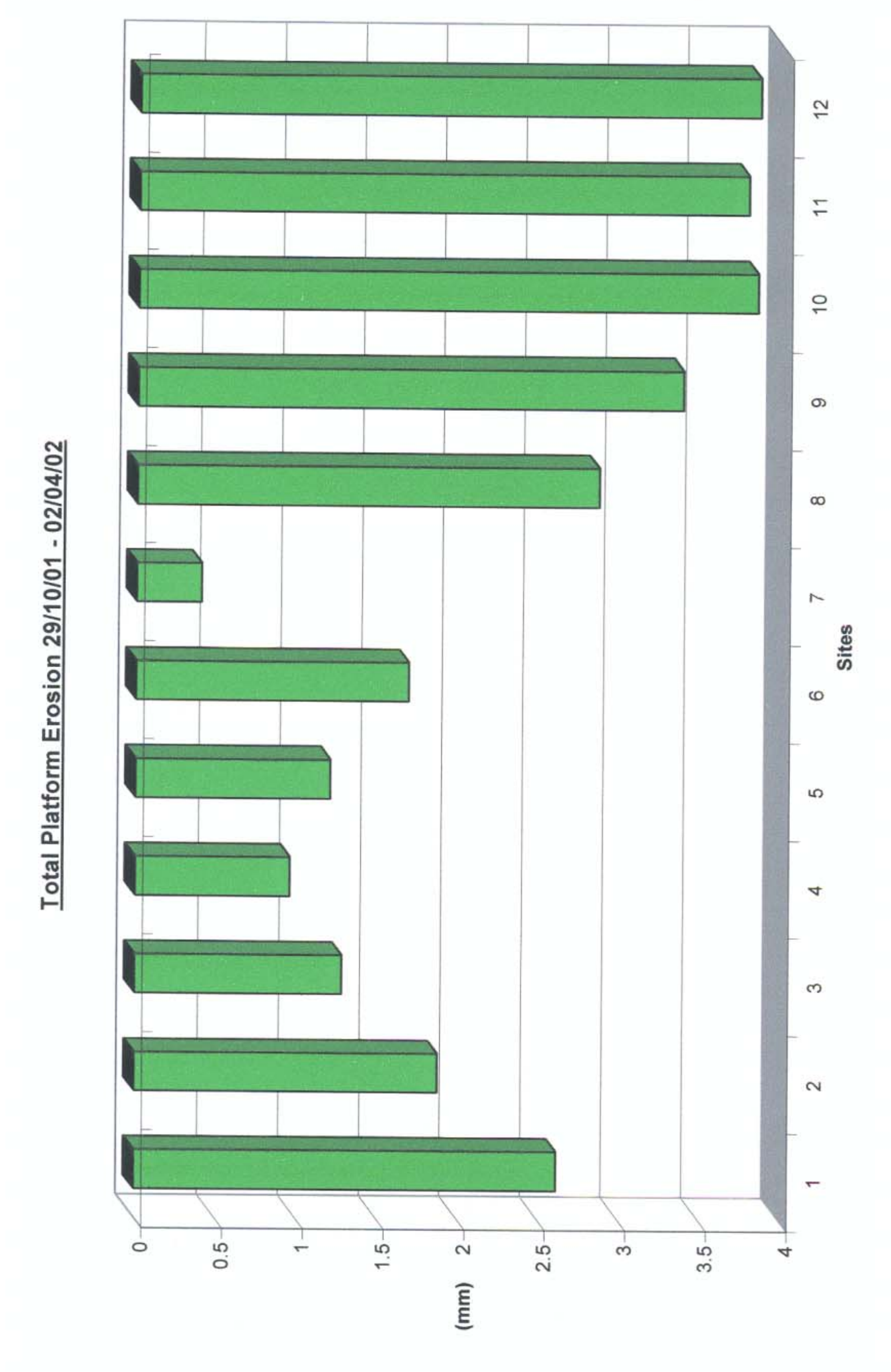
(NB – SPSS was used for all Statistical Analyses)

Appendix 6

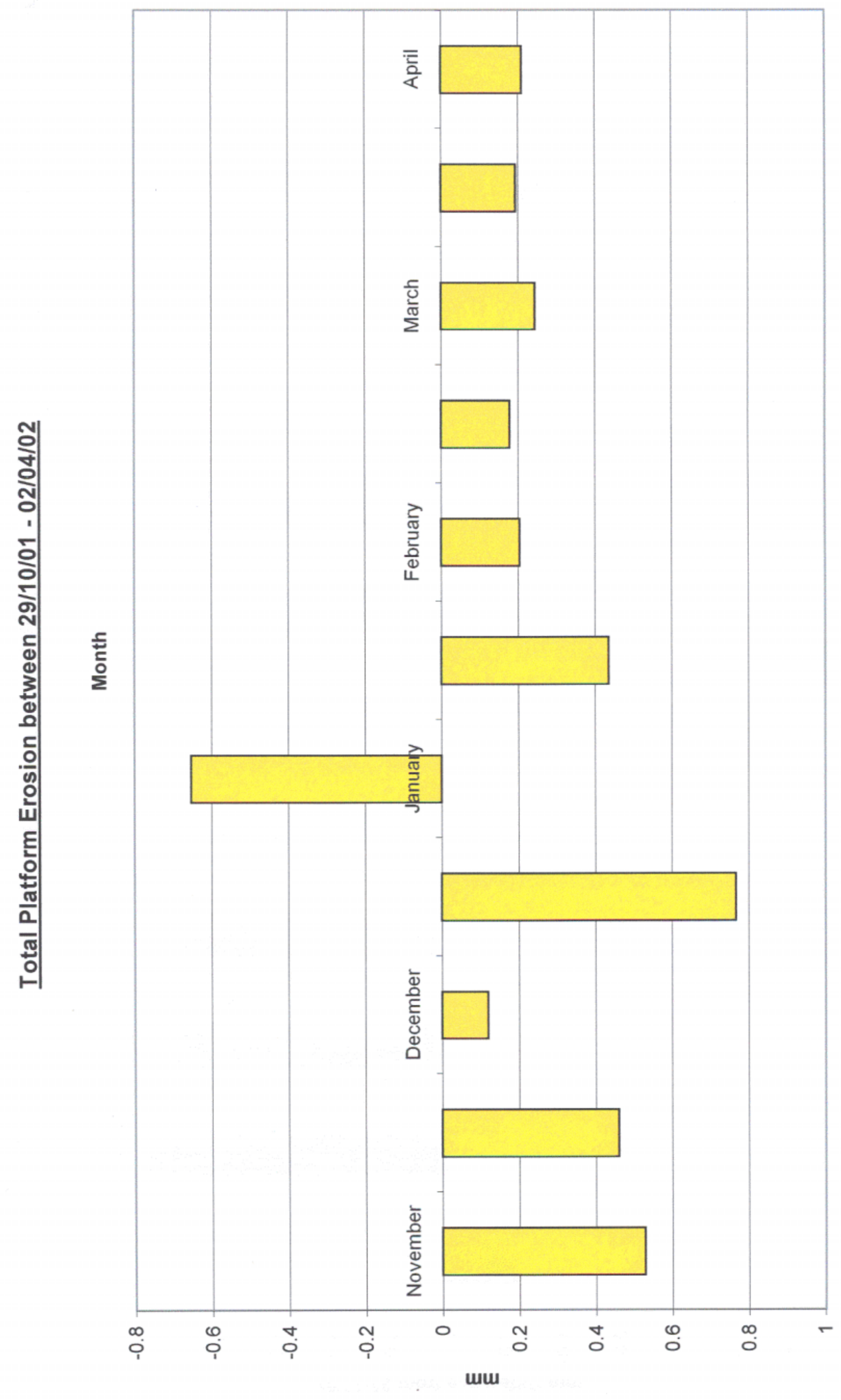
Sediment Removal 26/11/01 – 02/04/02

26-11-01	
23-12-01	
19-02-02	
02-04-02	

Appendix 7

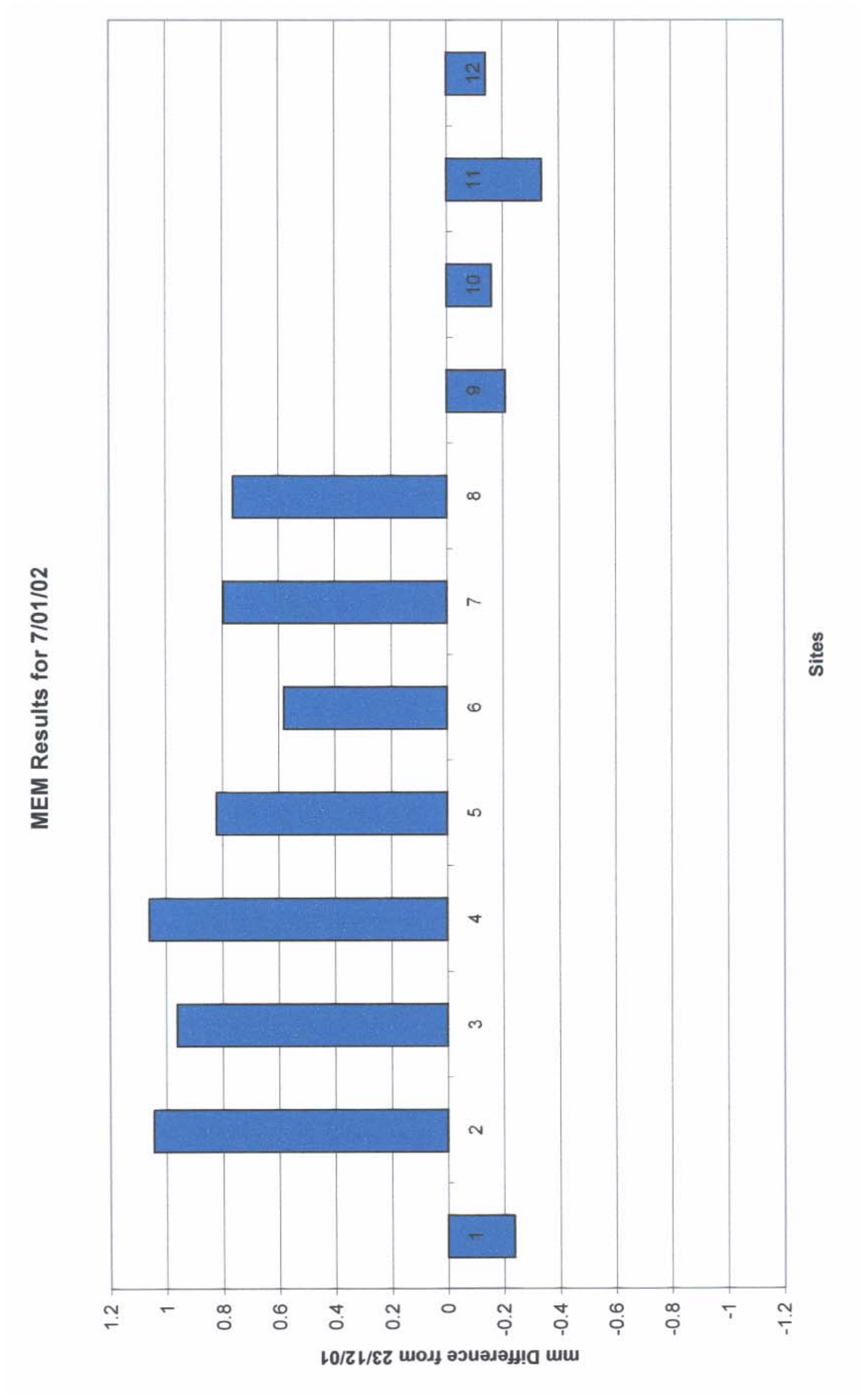

Total Platform Erosion 29/10/01 - 02/04/02
(mm)
0
0.5
1
1.5
2
2.5
3
3.5
4
Sites
1
2
3
4
5
6
7
8
9
10
11
12

Appendix 8



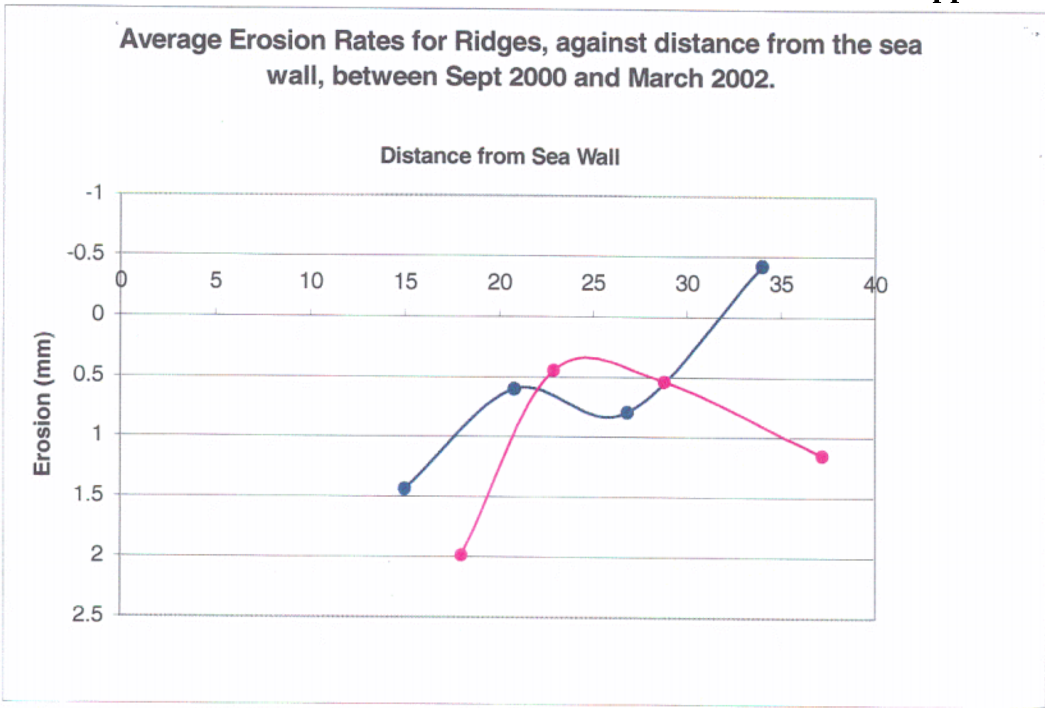
Total Platform Erosion between 29/10/01 - 02/04/02
Month
mm
November
December
January
February
March
April
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

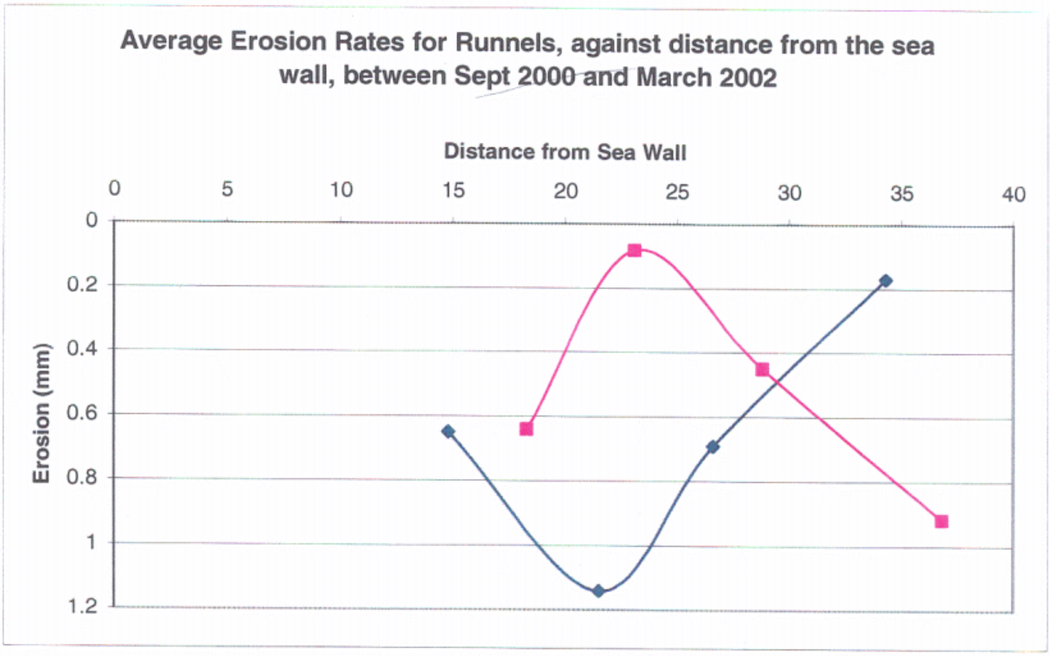
Appendix 9



MEM Results for 7/01/02
mm Difference from 23/12/01
Sites
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
1
2
3
4
5
6
7
8
9
10
11
12

Appendix 10





Key
Western Side
Eastern Side

Appendix 11

Tables Displaying Average Monthly Results for R MEM Sites 1-16

R MEM Site Western Side	Distance from the sea wall	Average from Sept 00 to Sept 01 (Charman 2001)	Average from Oct 01 to Apr 02.	Monthly Average
1	15	1.09	2.12	1.43
2	14.8	0.49	0.96	0.65
3	20.8	0.41	0.98	0.6
4	21.5	1.48	0.46	1.14
5	26.8	0.68	1.02	0.79
6	26.6	0.72	0.65	0.69
7	34	-1.06	0.87	-0.42
8	34.3	-0.2	0.92	0.17

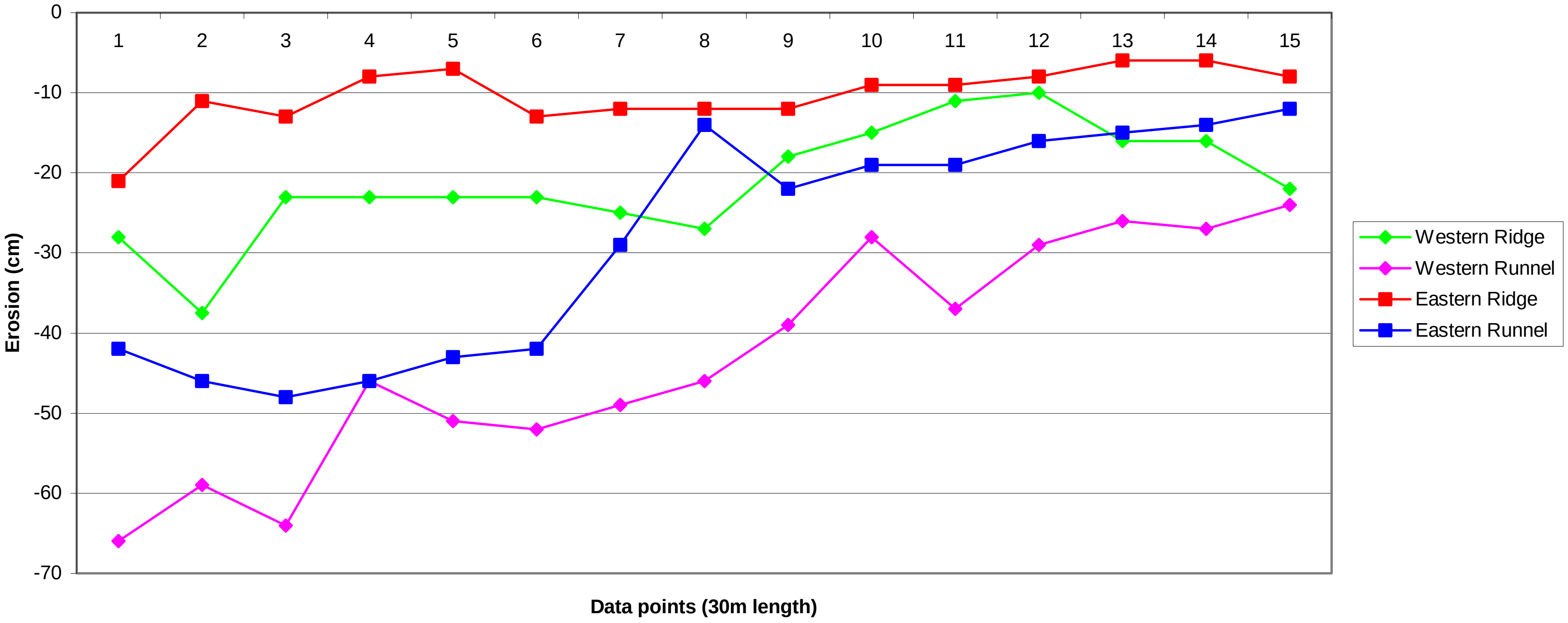
R MEM Site Eastern Side	Distance from the sea wall	Average from Sept 00 to Sept 01 (Charman 2001)	Average from Oct 01 to Apr 02.	Monthly Average
9	18	1.58	2.77	1.98
10	18.3	0.25	1.41	0.64
11	22.9	0.6	0.13	0.44
12	23.1	0.09	0.07	0.083
13	28.8	0.62	0.36	0.53
14	28.8	0.54	0.28	0.45
15	37.2	0.77	1.87	1.14
16	26.8	0.91	0.93	0.916

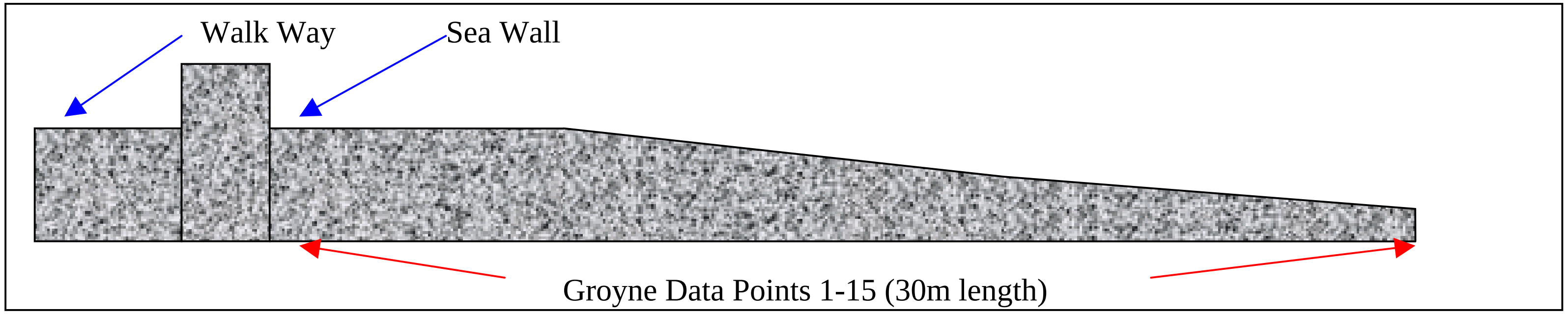
Key

Runnels	(grey)
Ridges	(white)

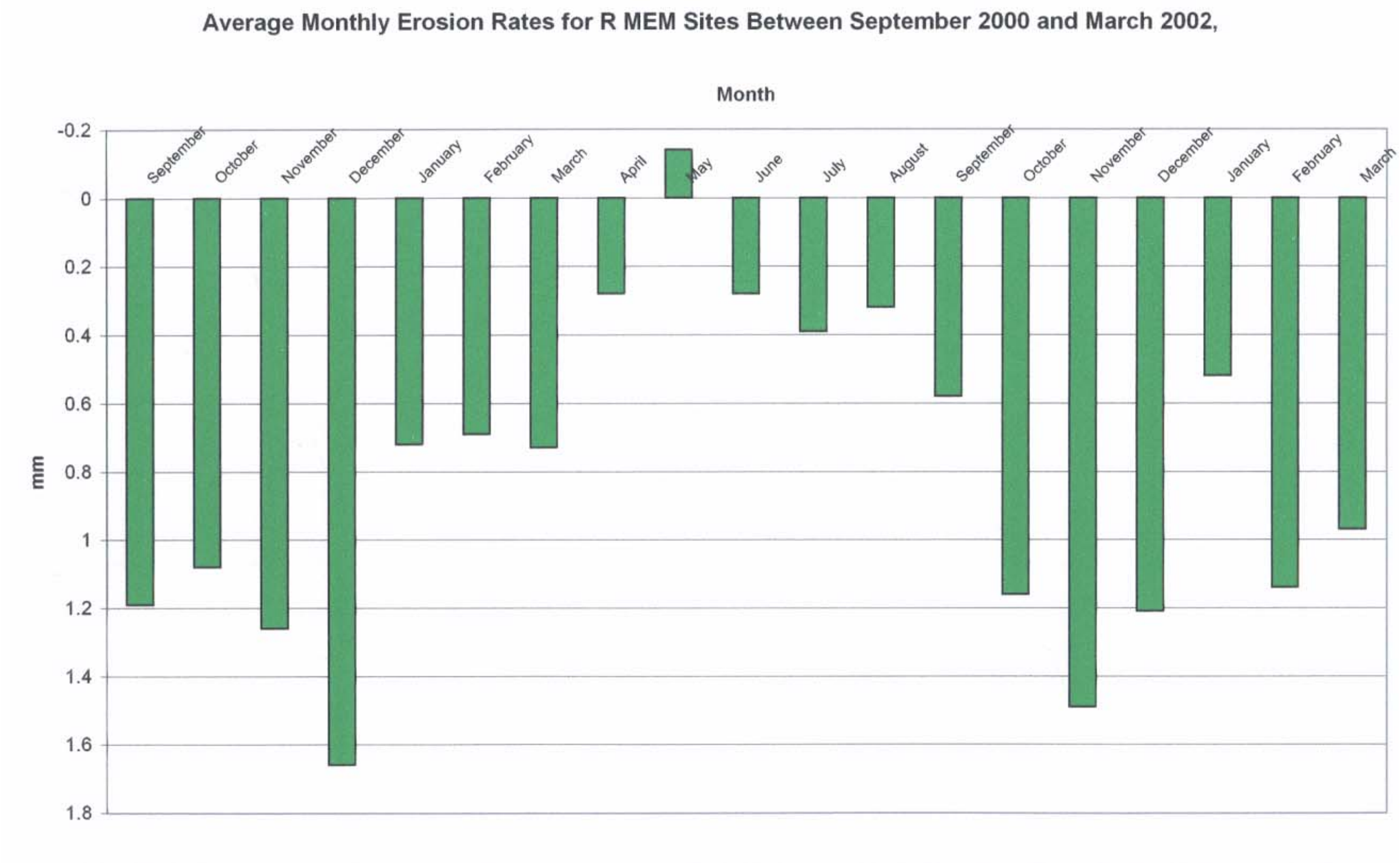
Appendix 12

Denudation of the Shore Platform from an artificial pinnacle constructed in 1977.

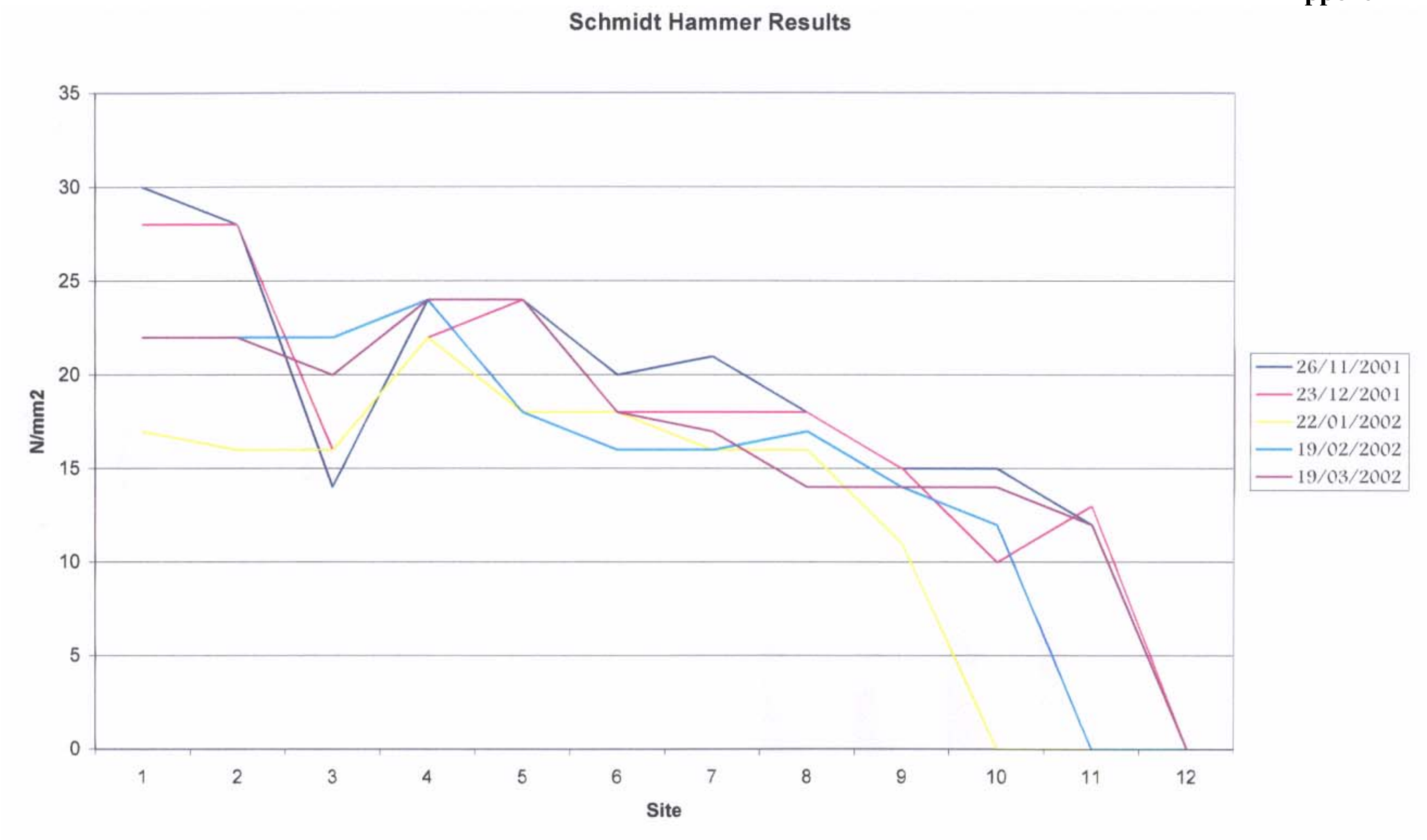


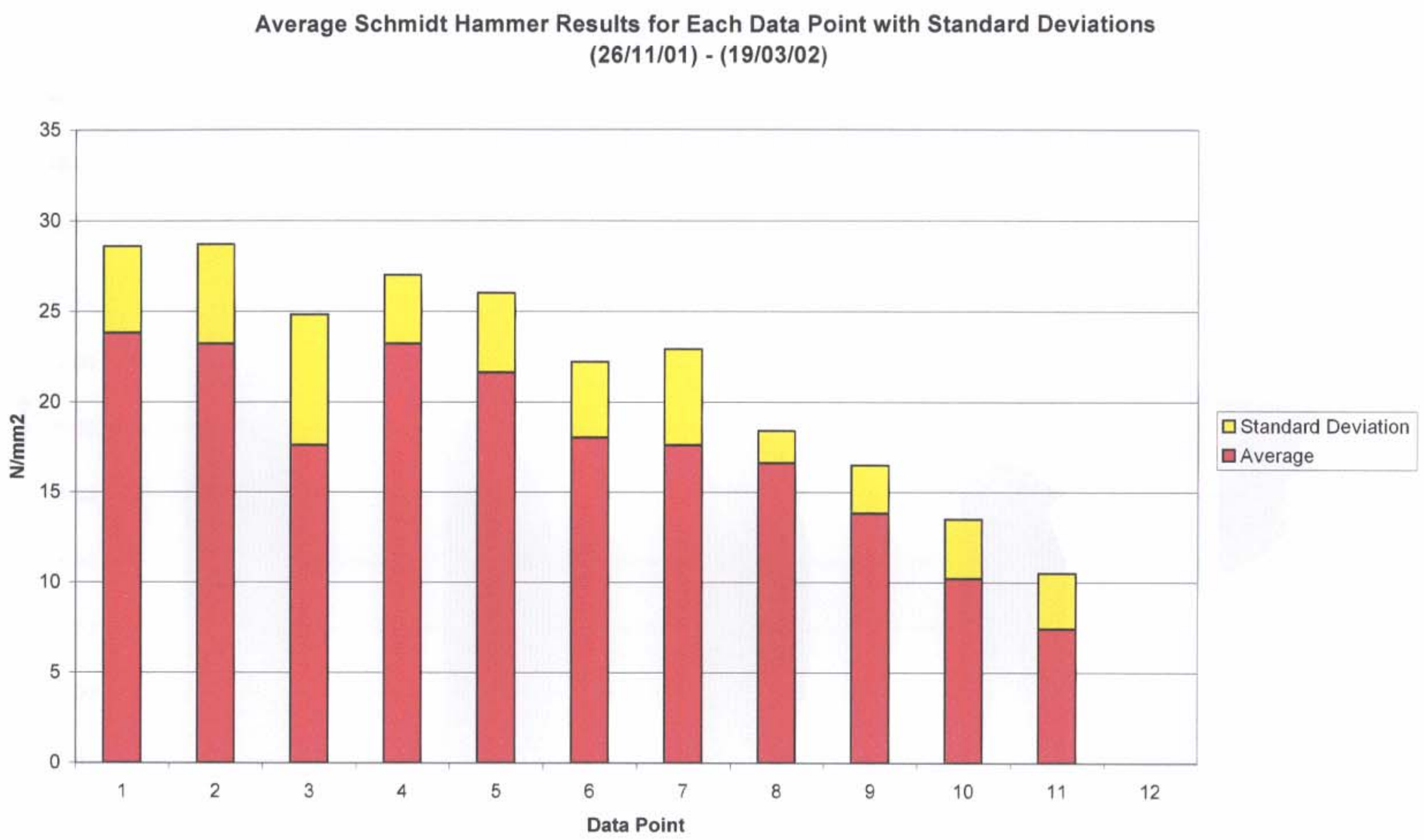


Appendix 13


Average Monthly Erosion Rates for R MEM Sites Between September 2000 and March 2002,
Month
mm
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
September
October
November
December
January
February
March
April
May
June
July
August
September
October
November
December
January
February
March

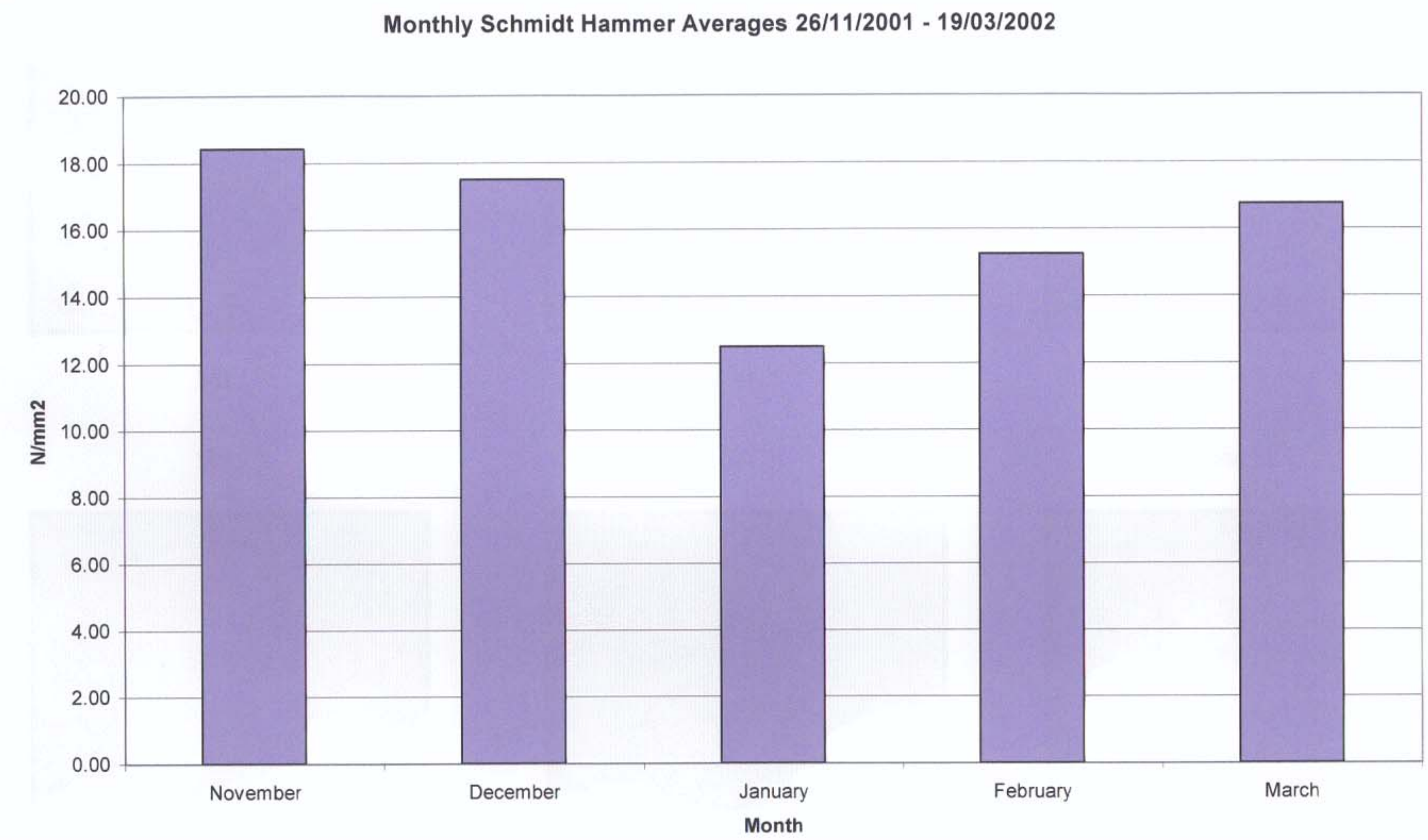
Appendix 14


Schmidt Hammer Results
35
30
25
20
15
10
5
0
N/mm2
1
2
3
4
5
6
7
8
9
10
11
12
Site
26/11/2001
23/12/2001
22/01/2002
19/02/2002
19/03/2002


Average Schmidt Hammer Results for Each Data Point with Standard Deviations
(26/11/01) - (19/03/02)
N/mm2
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
Data Point
Standard Deviation
Average

Appendix 15

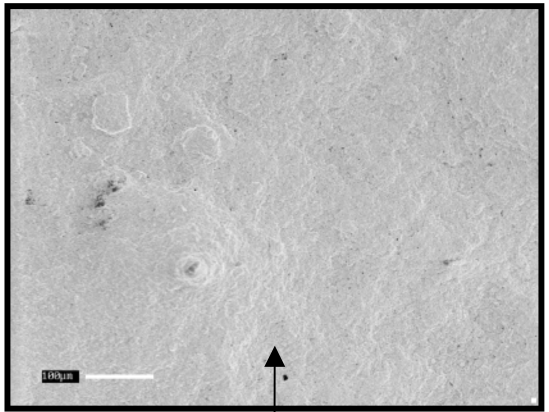
Appendix 16



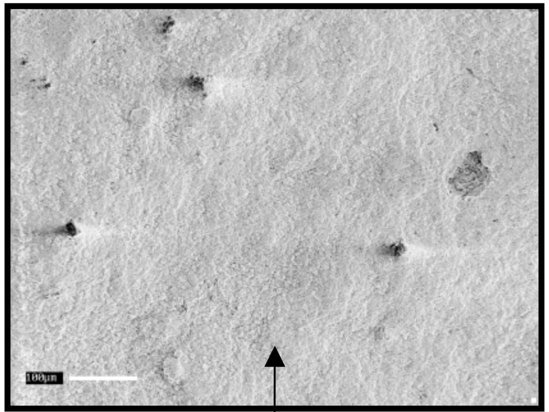
Appendix 16

Scanning Electron Microscope Images of sites 1,3,5,7,9,11 at 500x

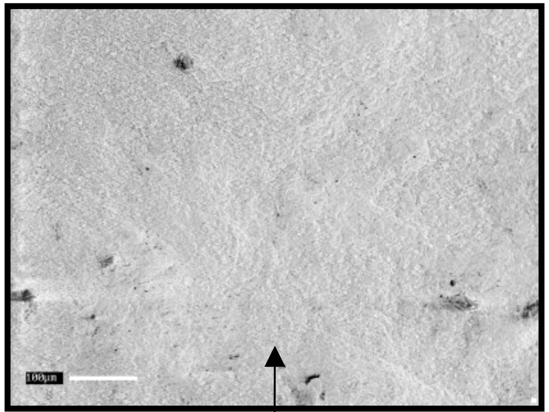
Appendix 17



Site 1

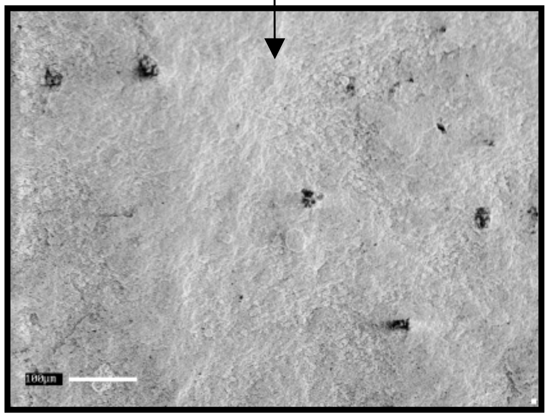


Site 3

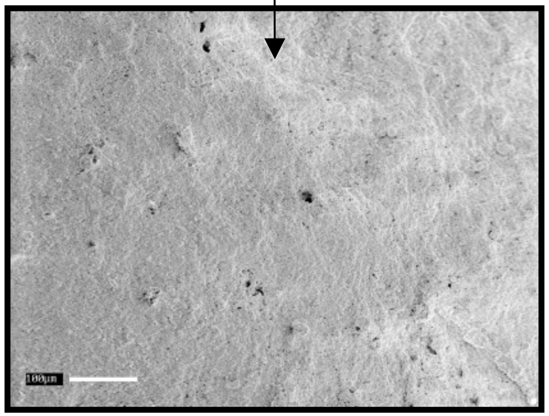


Site 5

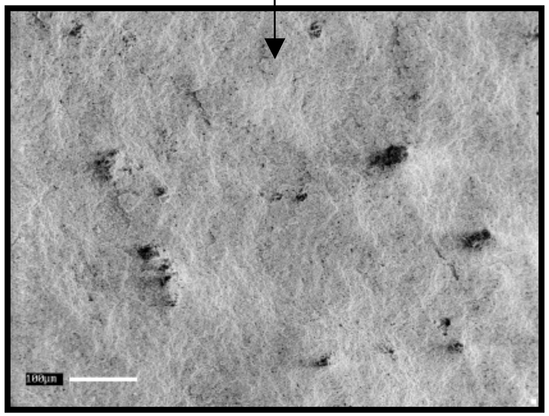
Site 7



Site 9

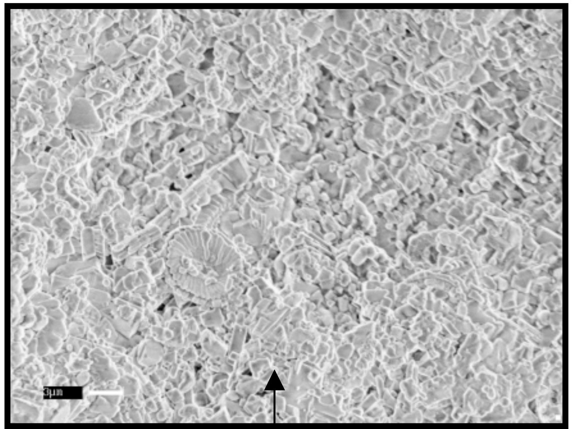


Site 11

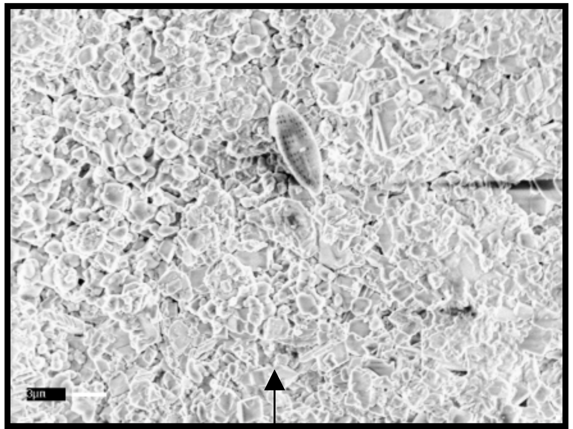


Appendix 18

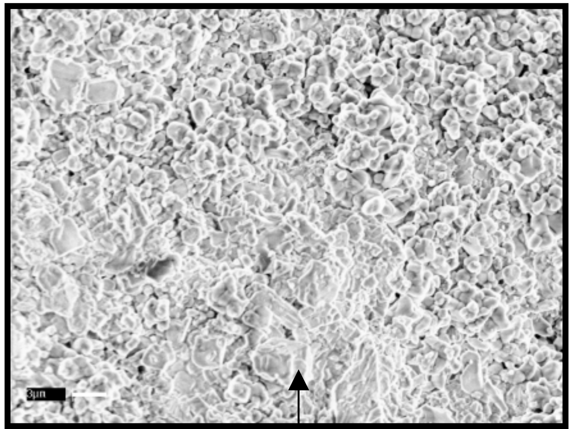
Scanning Electron Microscope Images of Sites 1,3,5,7,9,11 at 8000x



Site 1

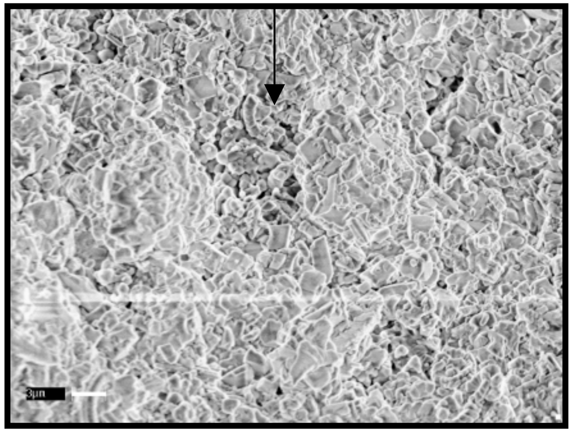


Site 3

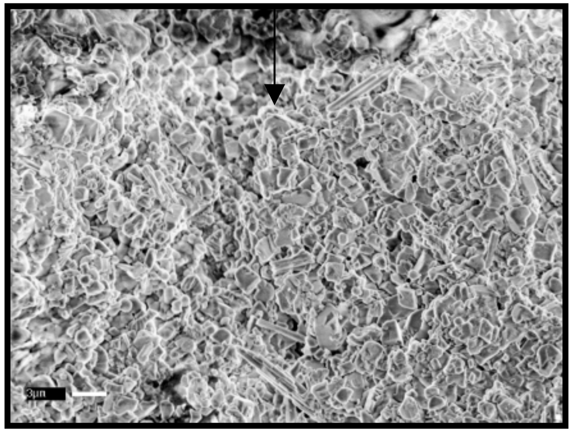


Site5

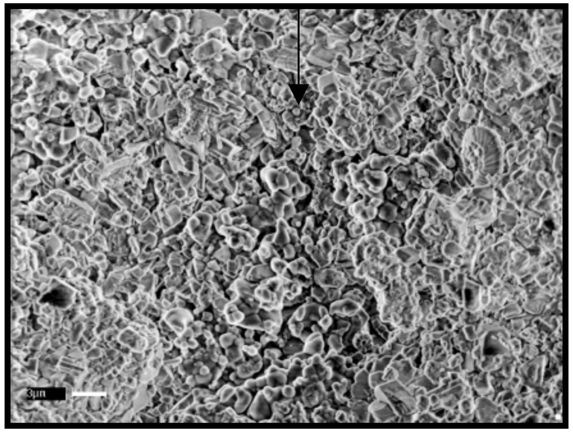
Site 7

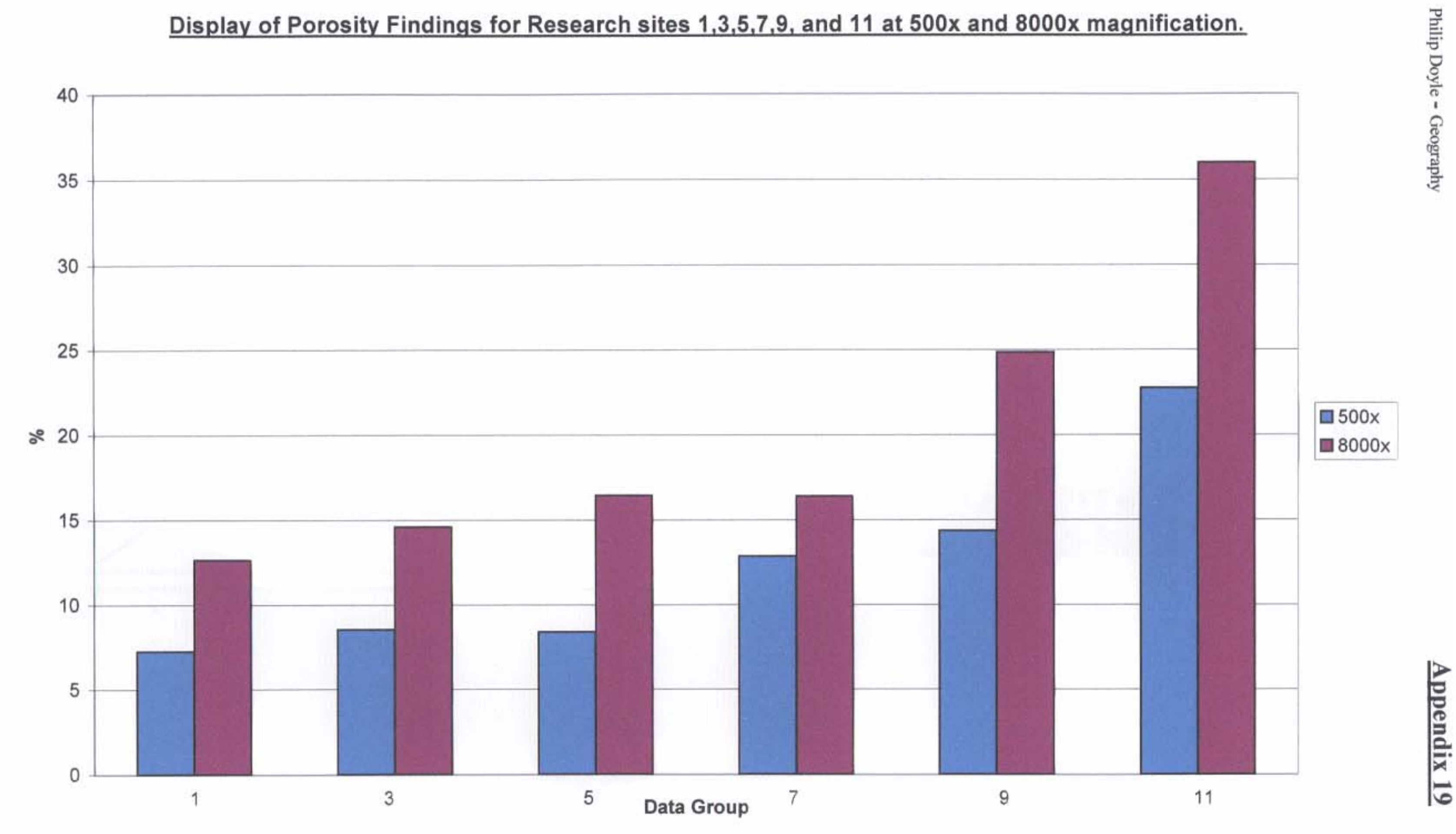


Site 9



Site 11




Display of Porosity Findings for Research sites 1,3,5,7,9, and 11 at 500x and 8000x magnification.
%
40
35
30
25
20
15
10
5
0
1
3
5
7
9
11
Data Group
500x
8000x

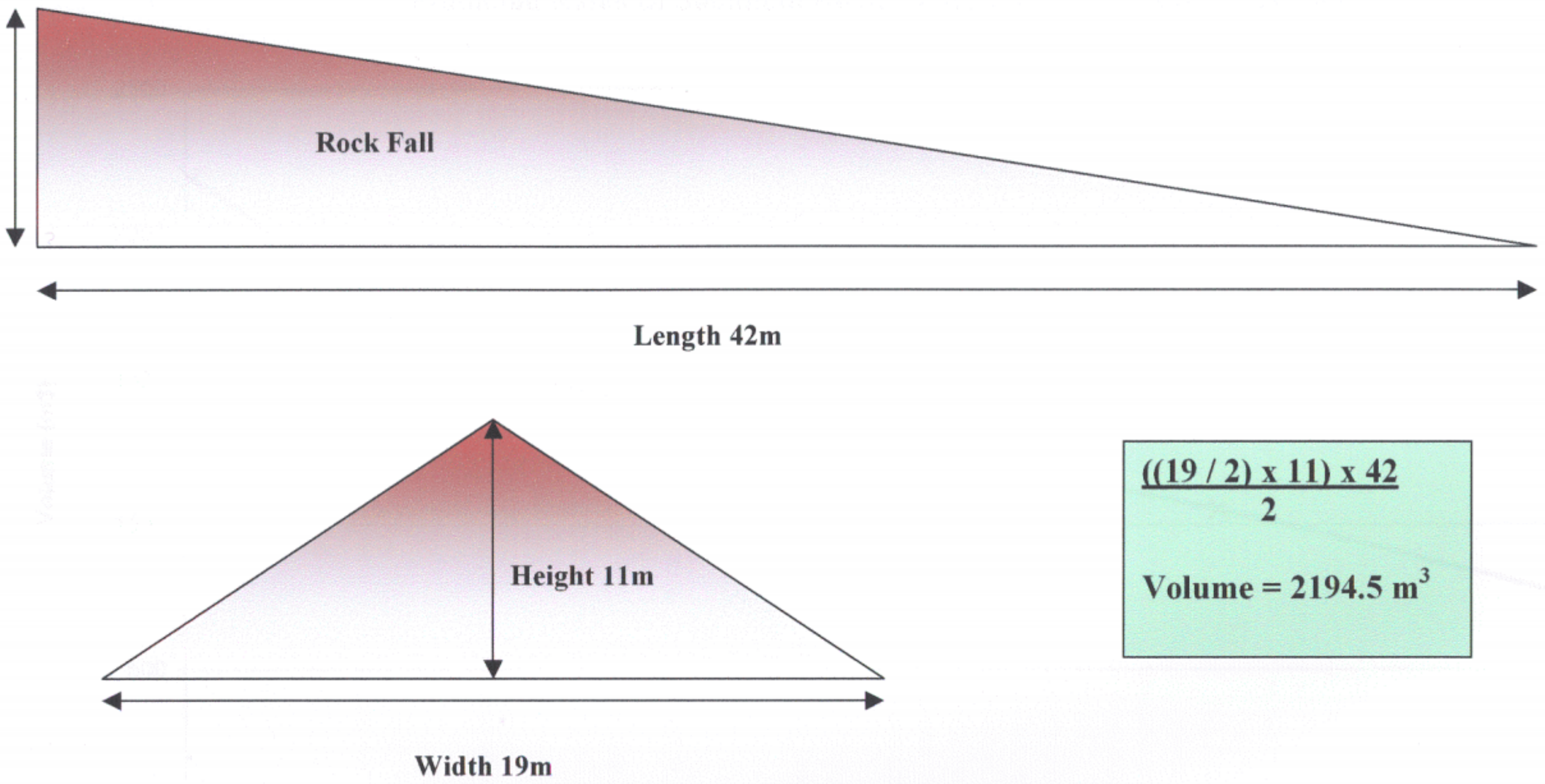
Appendix 19

Appendix 20

Approximate Calculation of Friars Bay Rock Fall

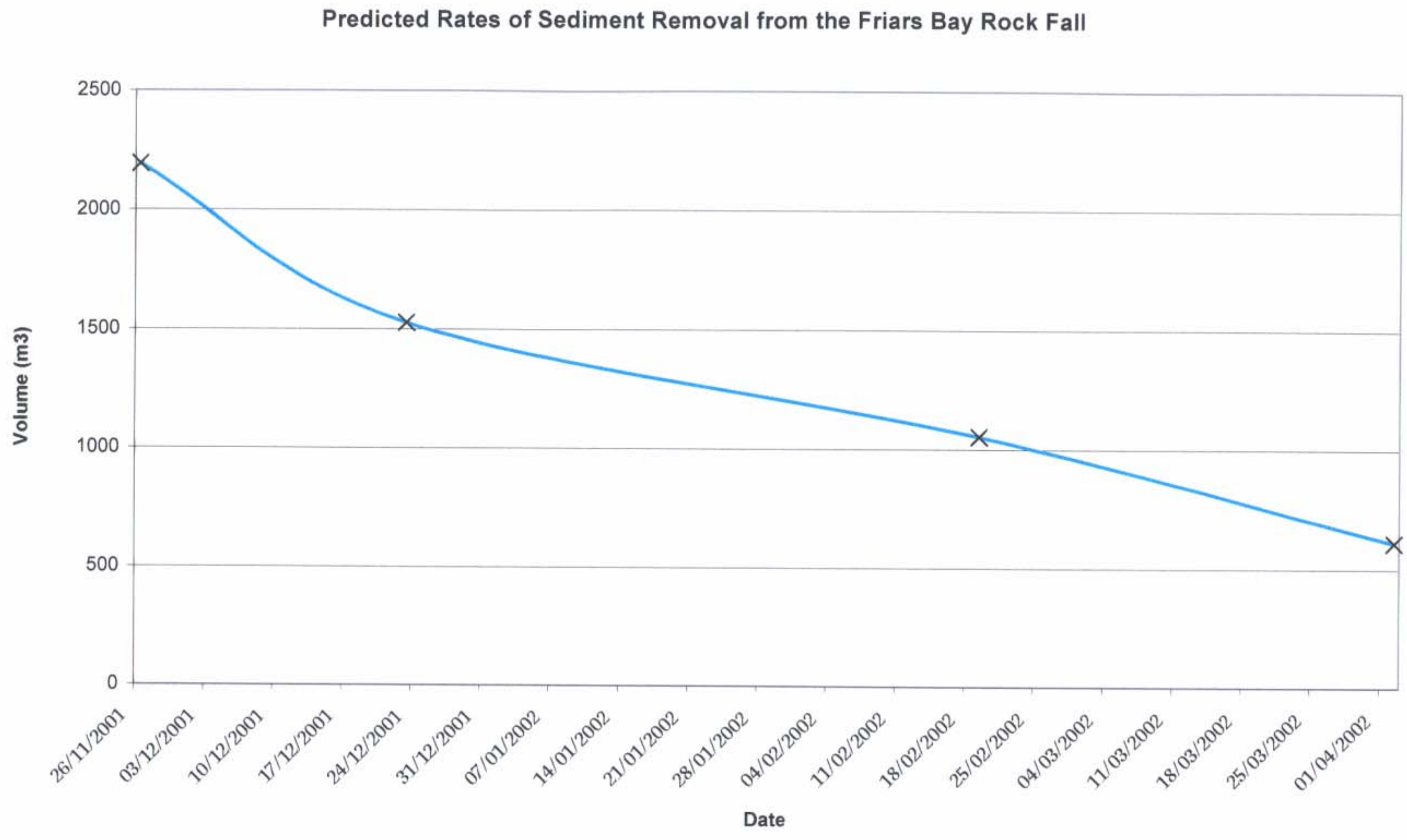
26/11/01

Philip Doyle - Geography



Appendix 20

Appendix 21



Appendix 21