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Prévention des risques d'érosion et de submersion littoraux: la connaissance du risque, les études d'impact en vue des travaux de protection

Prevention of coastal erosion and submersion risks: knowledge of the risk, impact studies with a view to protection works

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Organisé par le Centre Européen sur les Risques Géomorphologiques
Organised by the European Centre on Geomorphological Hazards

Sous la Direction de
Directed by

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Avec le Concours de
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THE COAST OF PAYS D'AUGE MONITORING OF THE VILLERVILLE LANDSLIDE

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For 12 km between Trouville-sur-Mer and Honfleur, the Pays d'Auge plateau ends in high cliffs which rise to a maximum altitude of 140 m and are composite in their topography and geological structure. The variable profile from one end to the other is related to the thickness of the sedimentary strata, which dip slightly towards the East.

Several points along the coast are unstable and disturbances have occured in previous centuries, particularly in the Cirque des Graves near Villerville and in the Fosses du Macre near Cricqueboeuf, which had always been considered unstable.

On the night of 13-14 January 1992, after some precursory movements, a sudden acceleration of the displacement caused extensive damage (subside compartmentalised by sub-vertical scarps, appearance of a marly ridge at the foot of the cliff, etc.).

A hazard mitigation programme was drawn up to answer the questions raised regarding possible dangers in the Villerville-Cricqueboeuf area.
The monitoring of displacements and piezometry continued for about three and a half years between 1985 and 1988.

DISPLACEMENTS

The monitoring network consists of :

- 87 concrete markers fixed in the ground, whose spatial co-ordinates were regularly calculated by means of triangulation using a Wild T2 theodolite equipped with a DI4L electro-optical distance meter ;
- Three core drillings with inclinometric tubes and 21 wells and piezometers, including one equipped with a liquid-level could be constantly monitored.
- Climatic data were supplied by the Saint-Gatien-des-Bois weather station situated on the plateau less than 2 km from the slope.

MEASUREMENT OF SURFACE DISPLACEMENTS

200 sightings were made (Fig. 1). It should also be noted that stations E1 to E4 are located on the rock bench and are therefore only accessible at low tide.Over a period of slightly more than three years, cumulative movements varied very considerably from 4 cm to 5,20 m. The average speed gives a better idea of the spatial distribution of these movements (Fig. 2).

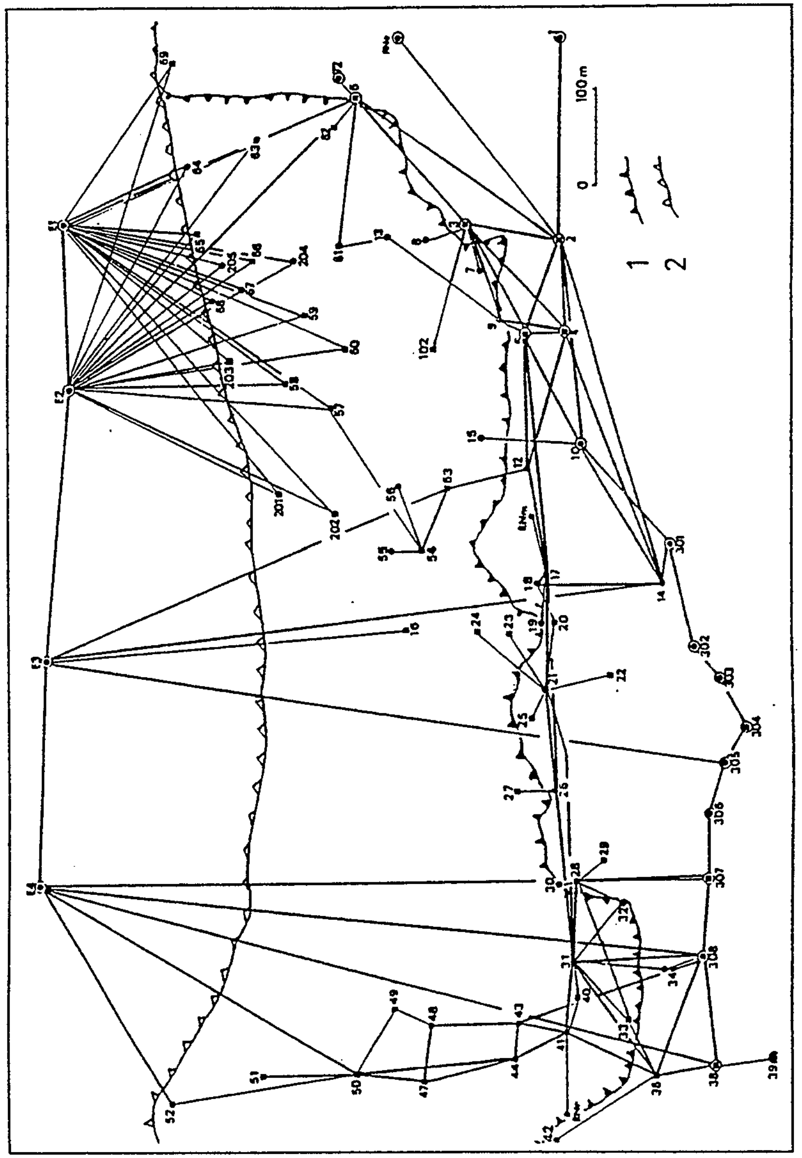


Fig. 1 Diagram of recorded views during a topometric survey at Villerville
(1: main scarp ; 2: toe of the cliff)

The cumulative displacement curves show a trend towards an acceleration of movement both in planar terms and in terms of altitude (Fig. 3).

They also reflect the acceleration of movement in February 1988 which led to a major landslide on the night of 12-13.

THE RELATIONSHIP BETWEEN PIEZOMETRY AND CLIMATIC CONDITIONS

Observations of pressure curves (Fig. 4) shows that recharge or drainage phenomena occur virtually simultaneously at all points on the slope, but that the altimetric variations differ considerably from one point to another. Groundwater which is close to the surface, or deeper groundwater circulating in a fissured environment, for exemple, undergoes large altimetric fluctuations of short duration.
A comparison of pressure curves and cumulative daily rainfall (Fig. 5) shows altimetric variations with sudden recharges following periods of heavy rain. On the other hand, drainage commences and continues even for short periods with little or no rain. Another phenomenon which has been observed id the brevity of the periods of high water. The response time berween the rise in the water level and the beginning of the effective rainfall is four to five days (Fig. 5).

For each rise, the quantity of rain responsible and its value were calculated. The results obtained are very scattered if only gross rainfall is taken

into account. The correlation is better with effective rainfall.

RELATIONSHIP BETWEEN PIEZOMETRY : SEASONAL VARIABILITY

This variability may be seen on the graphs plotted from spirit-level readings or on the cumulative displacement curves, but it is particularly apparent on the graphs of average speed (Fig. 8).
Nearly all the markers have average speeds which increase from one year to the next. The winter peaks are increasingly high, and the same trend is found in the speeds recorded during the summer.

The regular increase in movement and the increasingly hugh speeds from one year to the next can be related to the multi-annual increase in piezometric levels.

ALARM SYSTEM AND LONG-TERM FORECASTING

The steadily increasing pace of nearly all displacement curves in relation to time led them to be adjusted to a curve of the exponential type (Fig. 9).
Long-terme forecasting of displacements over a period of several

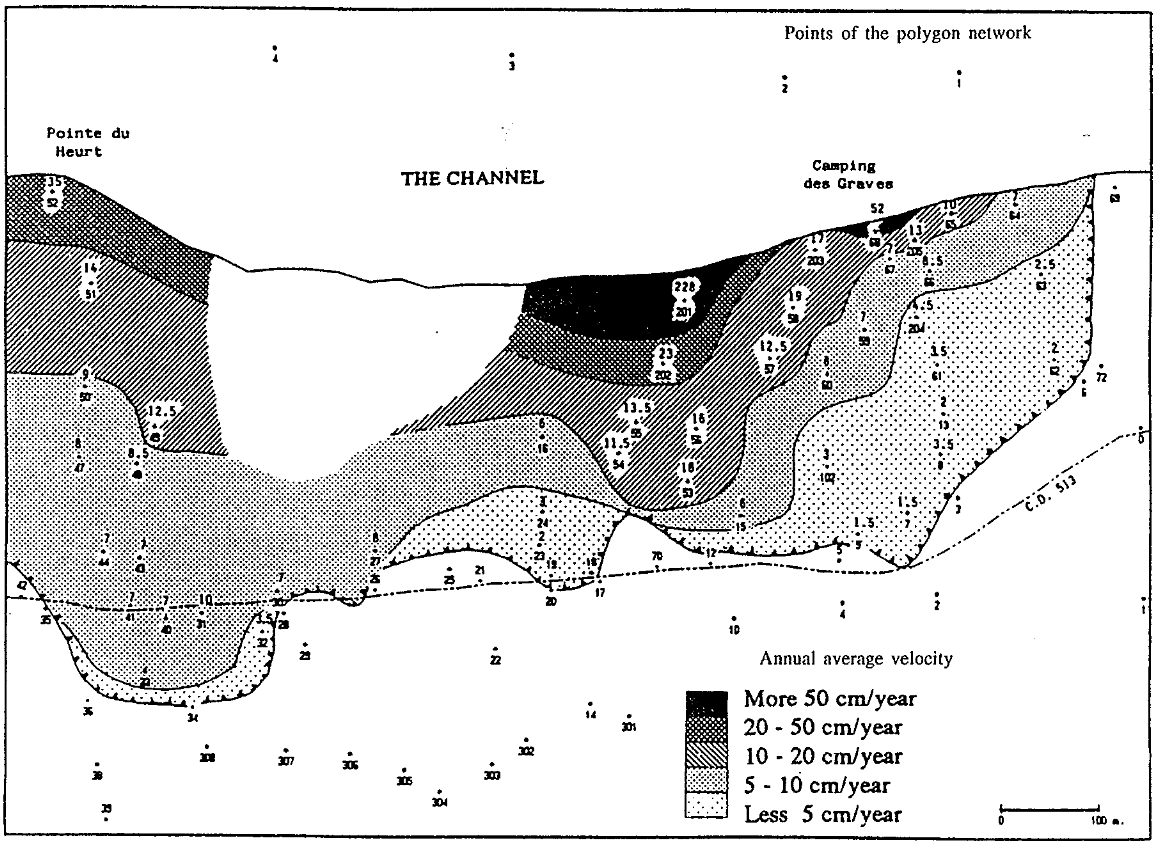


Fig. 2 Average annual speed in planimetry between January 1985 and February 1988

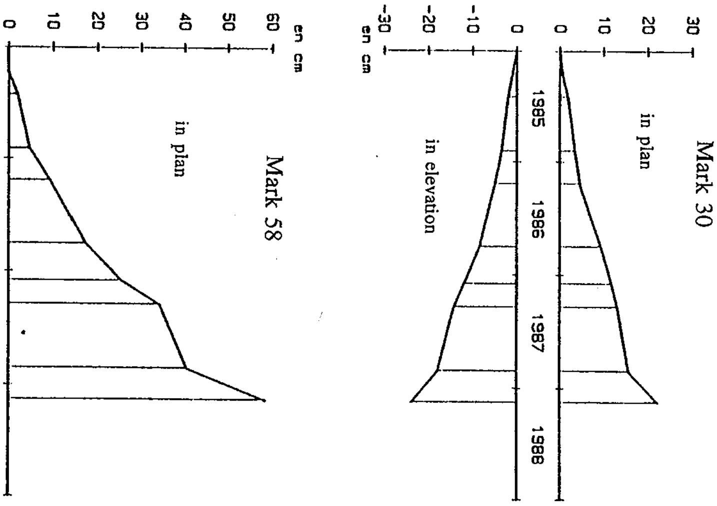


Fig. 3 Cumulative movements in plan and in altitude of marks 30 and 58

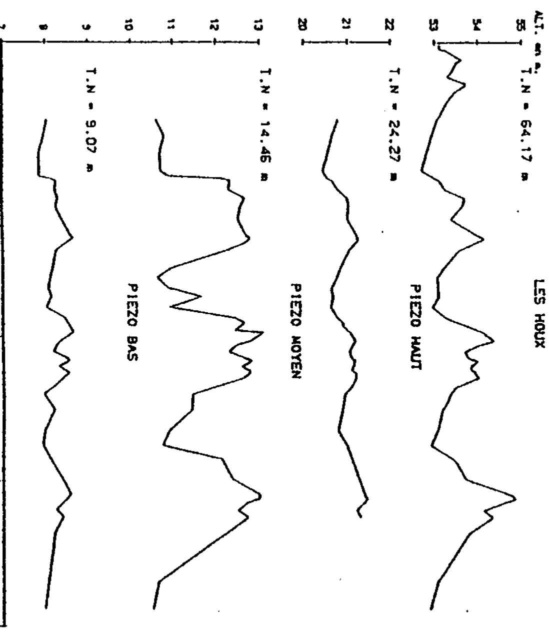


Fig. 4 Evolution of piezometry between 1985 and 1988

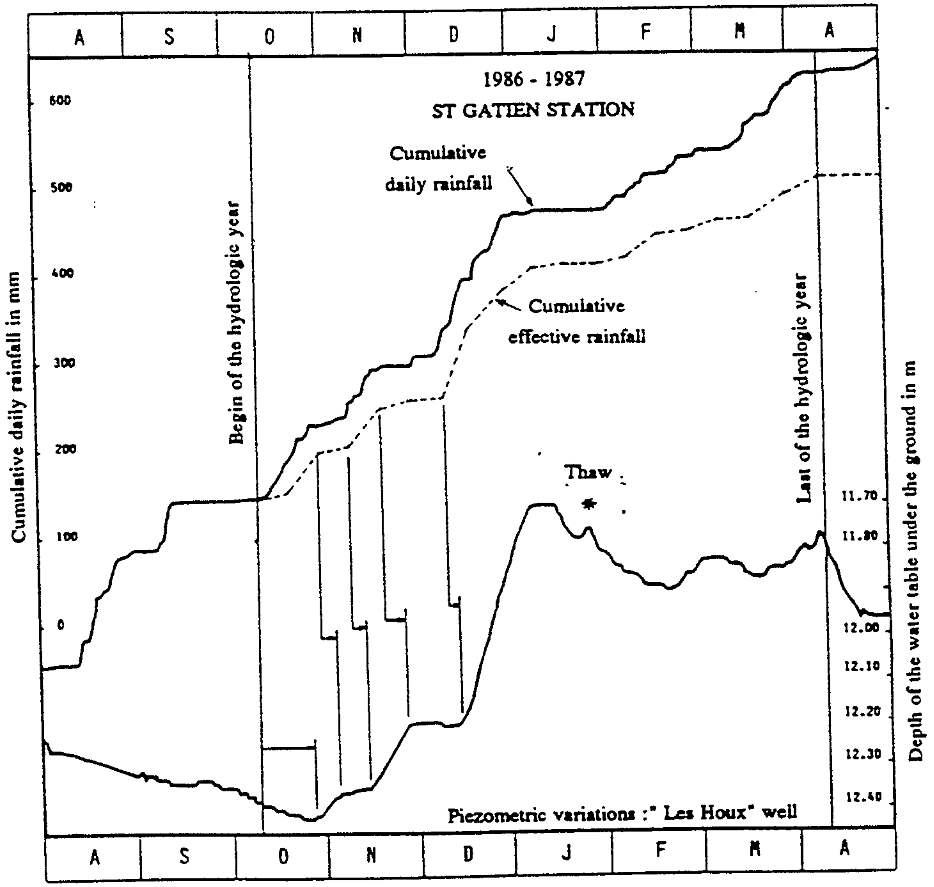


Fig. 5 Cumulative daily rainfall of the Saint-Gatien-des-Bois station and piezometric variations of the "Les Houx" well from August 1986 to April 1987

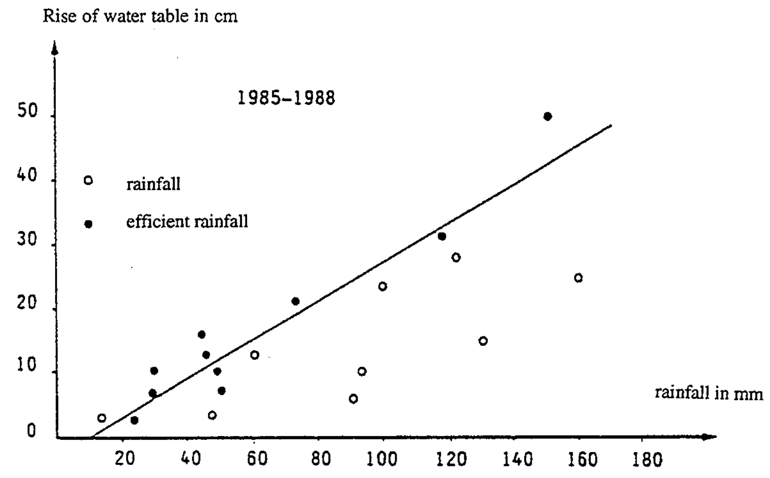
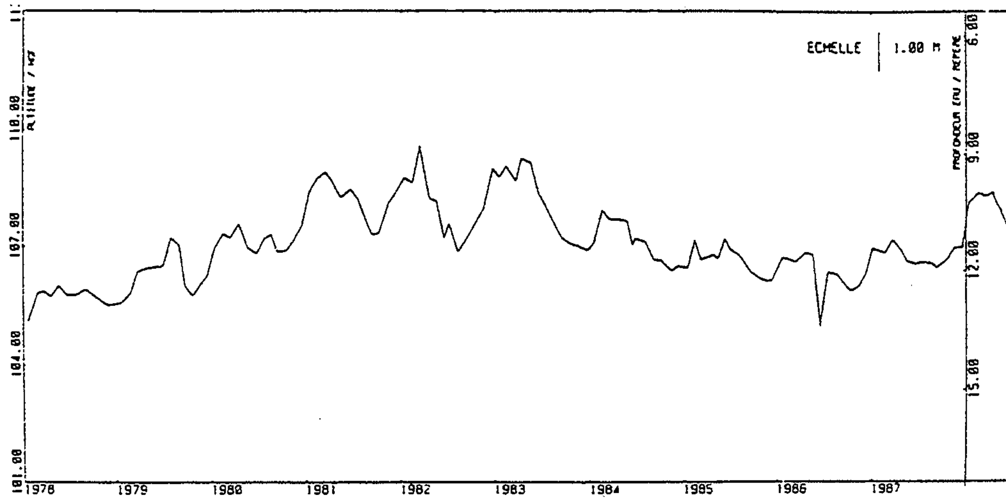


Fig. 6 Relation between rainfall and rise of water table



NAPPE AUG/02....../+0L NAPPE DU CENOMANIEN
RESEAU PROFONDEUR OUVRAGE 17.10 M.
COTE DU REPERE PIEZOMETRIQUE 118.37 M.
COTE DU SOL 118.07 M.

Fig. 7 Piezometric variation between 1978 and 1988 at Danestal (Pays d'Auge)

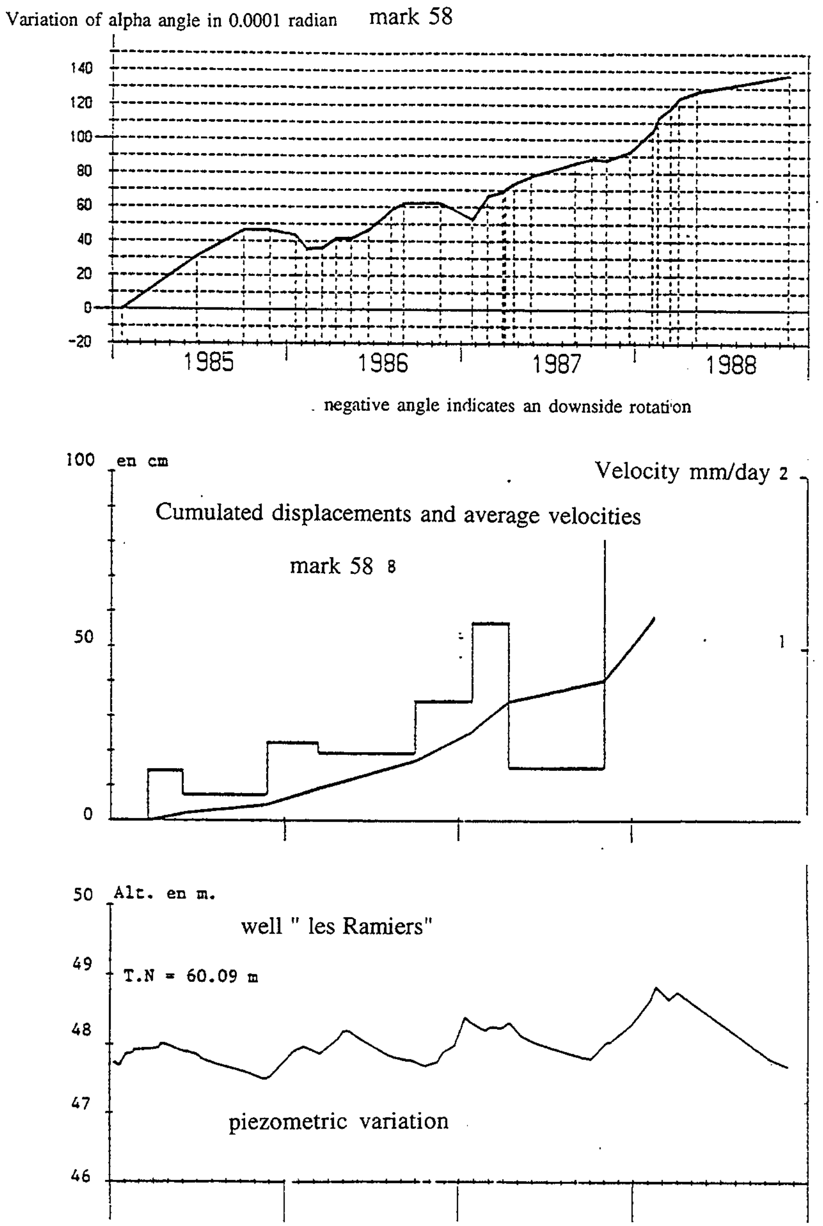


Fig. 9 Seasonal variability of mark 58 and variation in piezometric level

years is a delicate matter. Some considerable uncertainties remain.
The forecasting model is directly dependent on the piezometric fluctuations in relation to climatic trends and the sequence of pluviometric events.
Thus, the uncertainty which remains clearly underlines the need to have measurements, preferably on a continuous basis, over a very long period in order to be able to make reliable forecasts.

DEVELOPMENT OF MODELS: STABILITY CALCULATIONS

The models developed from topographical profiles, the geomechanical characteristics of the materials and the form and position of the failure areas indicated by the inclinometric data provided a quantative assessment of the respective roles played by the different instability factors.

According to several working hypotheses (Fig. 10), a raising or lowering of the level of the water table in the slope by one metre may be

shown to alter the value of the overall safety co-efficient by approximately 5% to 6 %. A tenmeter recession of the foot of the slope accounts for only 1 % to 2 %.

For the record, the average recession calculated by comparison of cadastral maps opposite the Cirque des Graves is in the region of 60 to 70 m between

1829 and 1987, ie a average annual recession of 40 cm.

n addition to the weakness of the mechanical characteristics (zero cohesion and an average internal friction angle of 13 °), the decisive role played by water as a triggering factor is proved yet again. Although the removal of support seems to have little impact on the overall safety co-efficient, its role is nevertheless essential in maintaining instability since the probability of a landslide starting at the foot of the slope is increased substantially.

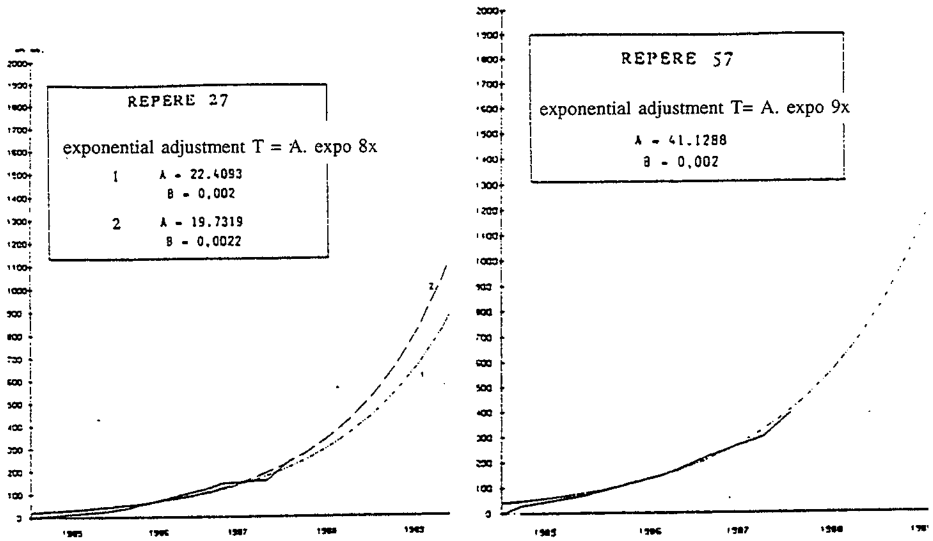


Fig. 9 Adjustment of an exponential curve to the cumulated displacement curve of the marks 57 and 27

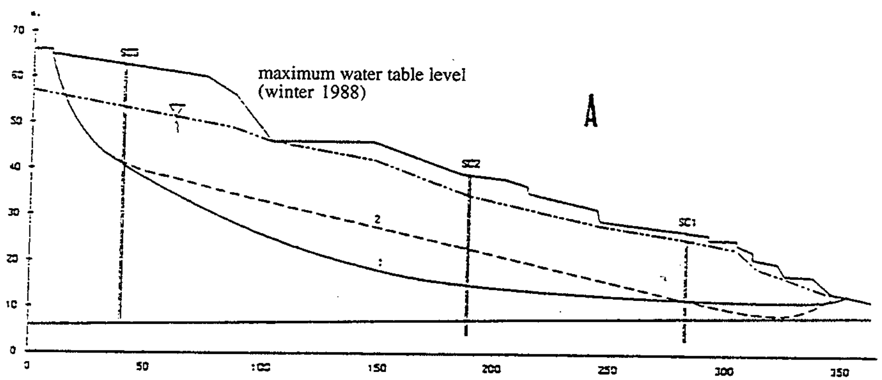


Fig. 10 Stability calculation: tested shear surfaces