HRPP 407

Shingle beach replenishments
Some design considerations

K. Powell

Reproduced from a paper presented at:
MAFF Conference of Coastal and River Engineers
Loughborough
8 - 10 July 1991

SHINGLE BEACH REPLENISHMENTS
- SOME DESIGN CONSIDERATIONS

By

Dr K A Powell, Coastal Management Group
HR Wallingford

ABSTRACT

This paper considers the consequences with regard to the subsequent behaviour of the beach, of undertaking shingle beach replenishments with material which is either finer or of wider grading than the natural beach sediments. Preliminary results from a study set up to monitor the behaviour of a recent beach replenishment at Hastings over the 1990/91 winter are presented. The implication of these results for the design of future shingle beach replenishment schemes is discussed.

INTRODUCTION

It is common practise for the material requirements for beach replenishmnet schemes to be specified on the basis of a grading envelope obtained by sampling existing natural beaches in the area of interest. For small 'top-up' schemes suitable material can often be obtained from inland sources, however for larger schemes or those where there is no suitable inland source, the requisite material is usually dredged from offshore deposits. In recent years increasing difficulties have been encountered in obtaining suitable material for shingle beach replenishment schemes from offshore sources. As a result, clients and contractors are increasingly having to consider the use of material which is either finer, or of wider grading than that ideally required.

The Hastings Beach Replenishment

The major coast defence scheme undertaken by Hastings Borough Council in 1989/90 entailed the refurbishment of seawalls, reconstruction of groynes and the importation, in April 1990, of approximately 225,000m³ of beach fill. Initial difficulties were encountered with the specification of the replenishment material and in particular, with meeting the specification from available sources. The obvious replenishment source was the Owers Bank, however surveys by the contractors (ARC) failed to locate suitable material, with most samples containing a higher proportion of fines than that allowed by the specified grading envelope.

In August 1989 Hastings Borough Council asked HR Wallingford to undertake a study to:

1. Determine the optimum strategy for beach replenishment
2. Advise on likely losses of beach fill
3. Advise on the implications of the resultant post-replenishment size grading with respect to beach performance and stability.

The report completed in September 1989 (Ref 1) concluded that material from the Owers Bank represented the only practical replenishment option. Samples obtained from the bank were however very variable in quality, ranging from coarse shingle to fine sand. The post-replenishment performance of the beach would be significantly affected by the material grading actually achieved, consequently if this grading erred on the fine side, it was anticipated that substantial losses would occur. Given that by this stage in the project there was little scope for providing an initial overfill to compensate for potential losses, it was recommended that the beach should be built as originally designed, and that it should be intensively monitored to determine the extent of subsequent losses. These could then be accounted for on the back of a planned phase II replenishment.

<u>Hasting Beach Monitoring - Winter 1990/91</u>

Following completion of the scheme the beach monitoring study was set up under the supervision of HR in September 1990. Rather than carry out a general study of the whole frontage efforts concentrated on detailed monitoring of a typical section, comprising 4 groyne bays, near the centre of the replenishment. The site chosen for the study was just to the west of the Royal Victoria Hotel (Fig 2) where there was convenient access for plant to the beach and where the nearshore zone was relatively free of rock outcrops.

Wave conditions and water levels at the site were measured using a pressure transducer wave recorder attached to the end of groyne 42 (Fig 2). This information was supplemented by weather records provided by Hastings Borough Council which included data on air temperature, barometric pressure, windspeed and direction.

Beach profiles and sediment samples were collected at approximately fortnightly intervals by Hastings Borough Council between the 3 October 1990 and the 2 April 1991. Twelve profile lines were set up: four located down the centre lines of each groyne bay with the remaining eight lines down either side of the groynes (Fig 2). All survey data was accompanied by photographs of the beach taken from pre-set locations: these allowed general changes in beach alignment to be detected.

Sediment samples were collected from groyne bay 42-43 on each of the survey dates, in accordance with the following sampling schedule.

Sample No	General location	Depth (m)	
1	Beach crest	0	(Surface)
2	Beach crest	0.5	(mid-depth)
3	Beach crest	1.0	(full depth)
4	MHW	0	(Surface)
5	MHW	0.5	(mid-depth)
6	MHW	1.0	(full depth)
7	Lower beach	0	(Surface)
8	Lower beach	0.5	(mid-depth)
9	Lower beach	1.0	(full depth)
10	Sand foreshore	0	(Surface)

Generally samples were collected on a straight line down the beach, the location of which was moved between surveys to prevent sampling of previously disturbed areas.

Data analysis

All data collected during the study was forwarded to HR for analysis under a MAFF funded research contract. The analysis, which is still underway, concentrated on three main areas:

(i) Volumetric changes over the study period

(ii) Profile response of the beach compared to that of naturally graded beaches.

(iii) temporal changes in beach composition.

As yet, results are unavailable for the first two of these categories; the rest of this paper therefore concentrates on the temporal changes in beach composition observed during the study period.

Beach grading curves - variability and development

Figures 3 to 5 show the typical variation in beach grading curves for surface, mid-depth and full depth samples over the study period. It is noticeable, though not surprising, that the greatest variation occurs in the surface layers. The results for the full depth sample indicates that there were occasions during the study period when the beach sediments at this depth were worked by wave action. This is confirmed by recorded beach profiles which show beach displacements of up to a metre below the design profile.

It seems reasonable to assume that when a beach is exposed to wave action over a period of years it evolves a grading which is in 'tune' with the local wave climate. As such, the composition of stable beaches can be expected to change very little with time. The addition of extra material, in the form of a beach replenishment, will usually alter the natural grading and as a consequence upset the relationship which exists between the beach and the local wave conditions. In time the natural grading will be restored with the excess fines being partly winnowed out of the beach by wave action (either to form a sandy foreshore or to be lost to the system) and partly forced to migrate further into the beach structure to form a dense, low permeability core.

The extent to which fines will be lost from the surface layers of the beach will depend very much on the grading of the replenishment material, compared to that of the natural beach. If the replenishment grading is wide one might expect the sediment losses to extend to the coarse sand or even fine shingle fractions: there being less in the way of voids to accommodate finer materials in poorly sorted beaches. Conversely, a narrow shingle replenishment grading may result in a much reduced loss of fine sediment from the beach since the greater volume of voids, associated with the more uniformly sized shingle, will allow a greater proportion of the fines to be retained within the beach structure.

Figure 6 shows the average grading curve for the original beach at Hastings together with the final curve for the beach replenishment. Whilst there is a higher proportion of fines in the replenishment material the difference between the two curves is not as great as it was originally feared. If the composition of the replenishment does evolve towards that of the original beach material the trend will be slight and may well be severely masked by short term, cross shore, fluctuations in beach composition occurring in response to individual storm events.

In an attempt to account for the effect of these short term cross-shore changes all surface sediment samples for a particular survey date were combined to provide an average surface grading. Mid-depth and full depth samples were similarly treated. These average samples were then broken down into discrete sieve sizes to allow the long term trend in the percentage of material passing each sieve size to be examined. Figure 5, 7 and 8 present typical results for material sizes less than 1.18 mm and 14 mm respectively. For the smaller sieve size (Fig 7) the full depth sample shows some evidence of a slight increase in material passing. This would suggest a 'fining' of the beach at this depth. Results for the surface and mid-depth samples tend to be inconclusive but again all three sets of data still exhibit considerable short term fluctuations which may obscure the longer term trends.

Short term fluctuations are also pronounced in the results for the coarser sieve size (Fig 8), however these results are more encouraging in that by this stage there is a clear long term increase in the percentage material passing for all three sampling depths. This again suggests a general 'fining' of the beach, which is now evident throughout the top metre or so of material.

In order to further clarify the long term behaviour of the beach, regression analysis was carried out for all sample depth and sieve size combinations. The results of this analysis provide an indication of the rates of long term development of beach composition, and allow an estimate to be made of the likely extent of this development over the study period. These estimated gradings are shown, together with the initial replenishment gradings, in Figures 9, 10 and 11 for the surface, mid-depth and full depth samples respectively. Integrating these results across depth enables an overall estimated grading curve for the beach to be produced. This is shown in Figure 12.

Analysis of Figures 9 to 12 reveals a number of interesting points:

(i) The surface layers of the beach are indeed tending towards a narrower grading (Fig 9) but in doing so both coarse and fine material is being lost. A similar though less pronounced trend can also be observed for the mid-depth samples (Fig 10).

(ii) The full depth curves (Fig 11) reveal a significant 'fining' of the beach apparently due to an increase in the proportion of material between 0.3 and 0.425 mm. These additional fines have arisen as a result of migration from the surface layers into the core of the beach. There is no immediate evidence of a significant long term change in the coarser fractions of the beach at this depth.

(iii) The overall development results (Fig 12) suggest that over the beach depth considered (~1m) there has been no significant change in the volume of material below about 1.18 mm, but that there has been a nett loss from the beach at the coarser end of the grading curve.

Taking these points together leaves us with the following (tentative) conclusions:

(i) There has been no significant loss of fines from the replenishment, instead there has been a pronounced migration of the finer fractions (generally material below 1 mm) into the core of the beach.

(ii) Over the study period there has been a loss of coarse material from the surface layers of the beach. This material appears to have moved out of the system, presumably in an offshore direction. It would be interesting to see if it re-appears under calmer summer conditions or whether it represents a permanent loss to the scheme.

It appears possible that the loss of the coarser surface fraction could be linked to the migration of the fines into the core of the replenishment. It has been recognised for some time that fine material will move into the core of a beach, and the process has been observed in both laboratory (Ref 2) and field studies. If, however, in a shingle replenishment there is an unnaturally high proportion of fines, and these all move into the core of the beach, then there will be a significant increase in the permeability gradient within the beach and a corresponding increase in the internal wave energy dissipation gradient. The coarser material which resides on the beach surface will therefore be more mobile than on a naturally graded beach. As a consequence the replenished beach may, in time, become proportionately finer.

This of course is only speculation and further studies of replenished shingle beaches, particularly those incorporating a very high proportion of fines, will be required in order to provide a clearer insight into the likely long term behaviour of these schemes.

ACKNOWLEDGEMENTS

The study described in this paper was funded by MAFF under Contract CSA 1436 and Hastings Borough Council. Hastings Borough Council were responsible for the collection of beach profile and sediment data.

REFERENCES

1. HR Wallingford. Hastings Coast Protection Works: An assessment of beach replenishment strategies. HR Report EX 2007, September 1989.

2. Powell K A. The dynamic response of shingle beaches to random waves, Proc 21st Coastal Eng. Conf, Malaga, Spain. 1988.

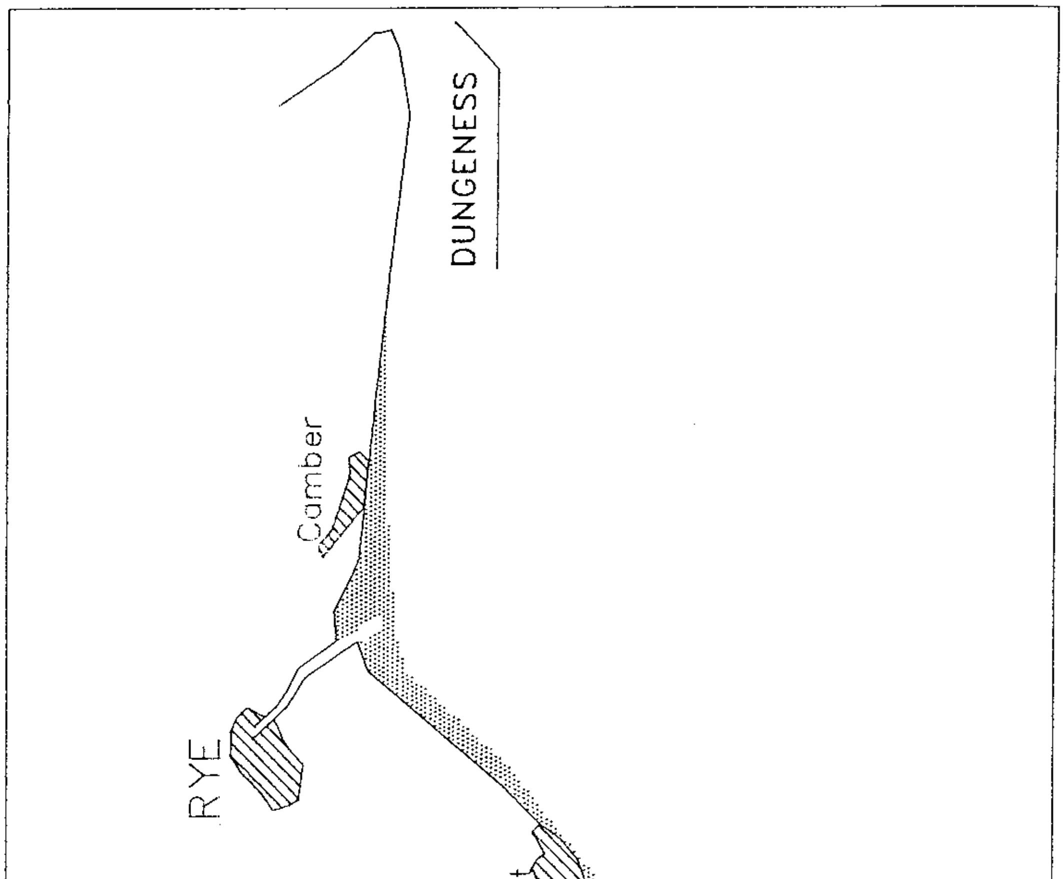

Fig 1 Location map

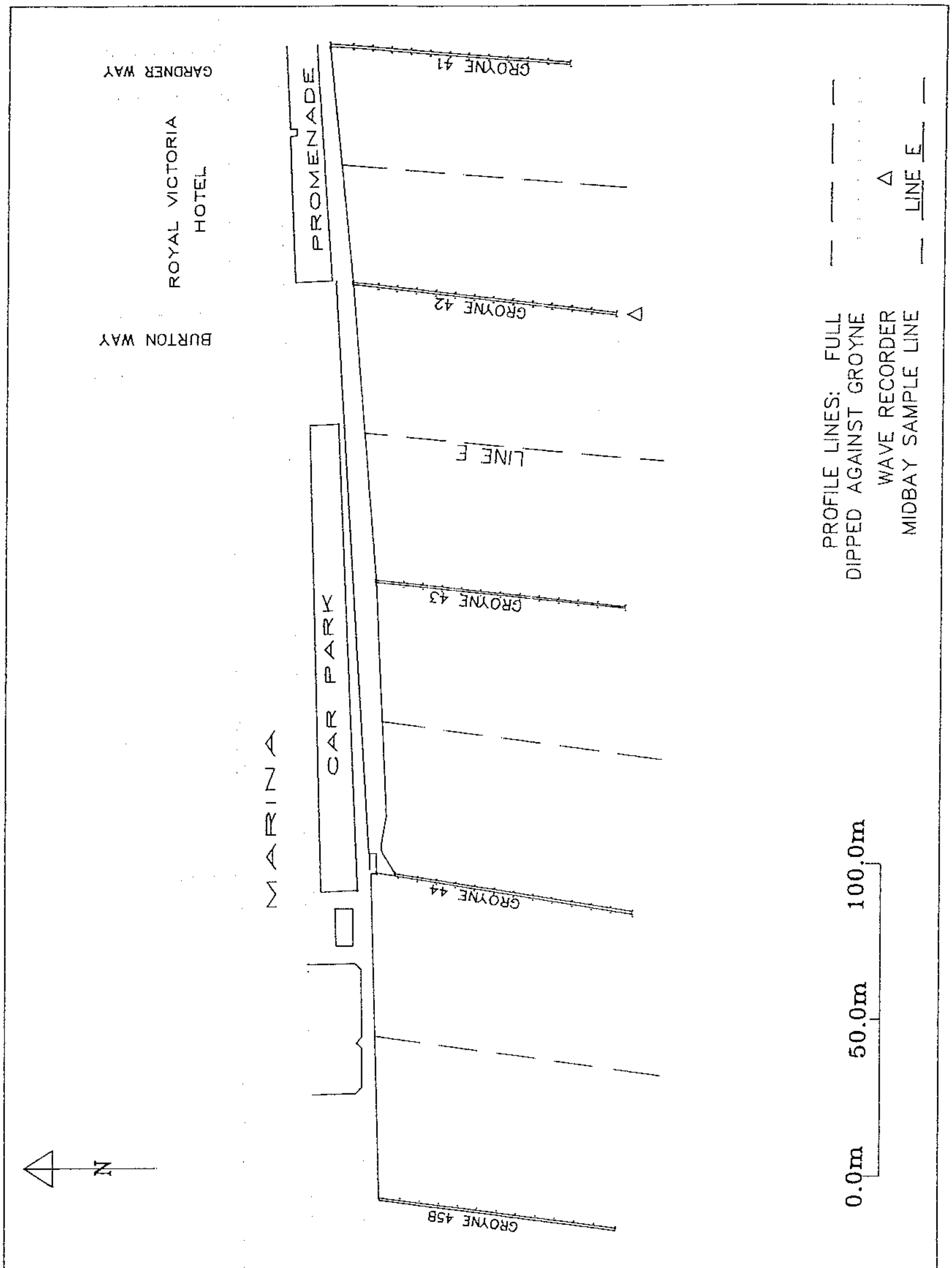

Fig 2 Details of study area

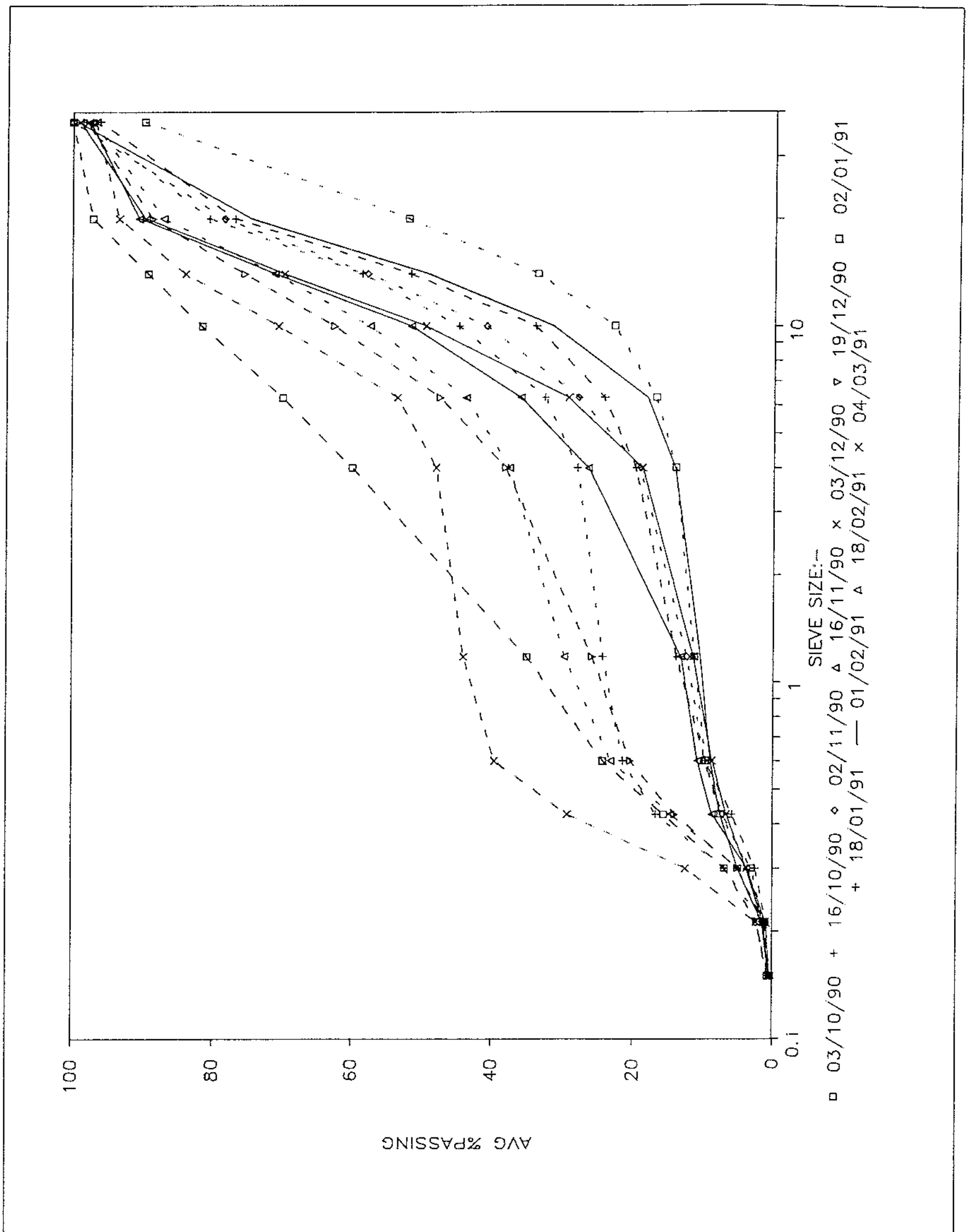

Fig 3 Typical sediment grading curve
Surface samples

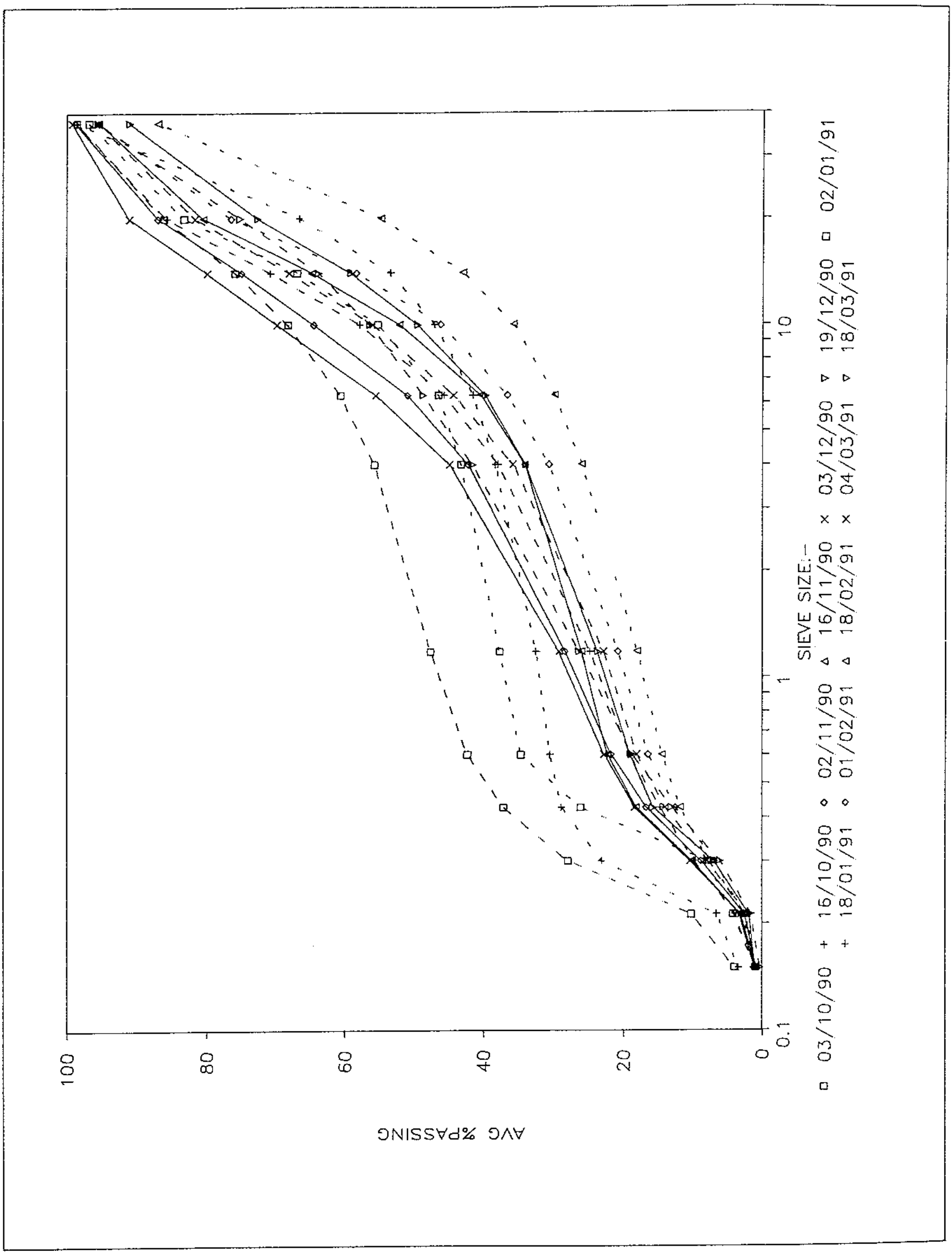

Fig 4 Typical sediment grading curve
Mid-depth samples

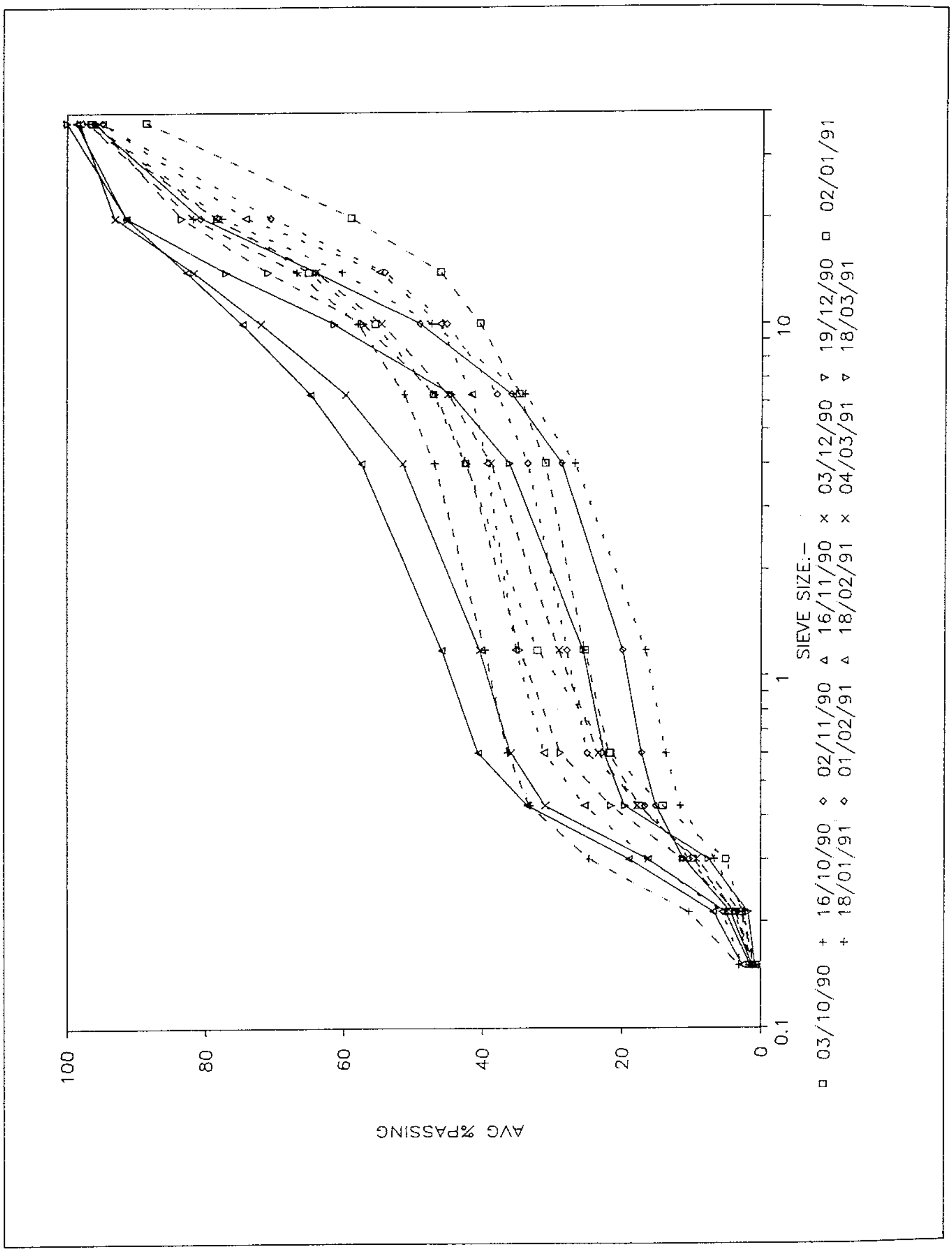

Fig 5 Typical sediment grading curve
Full depth samples

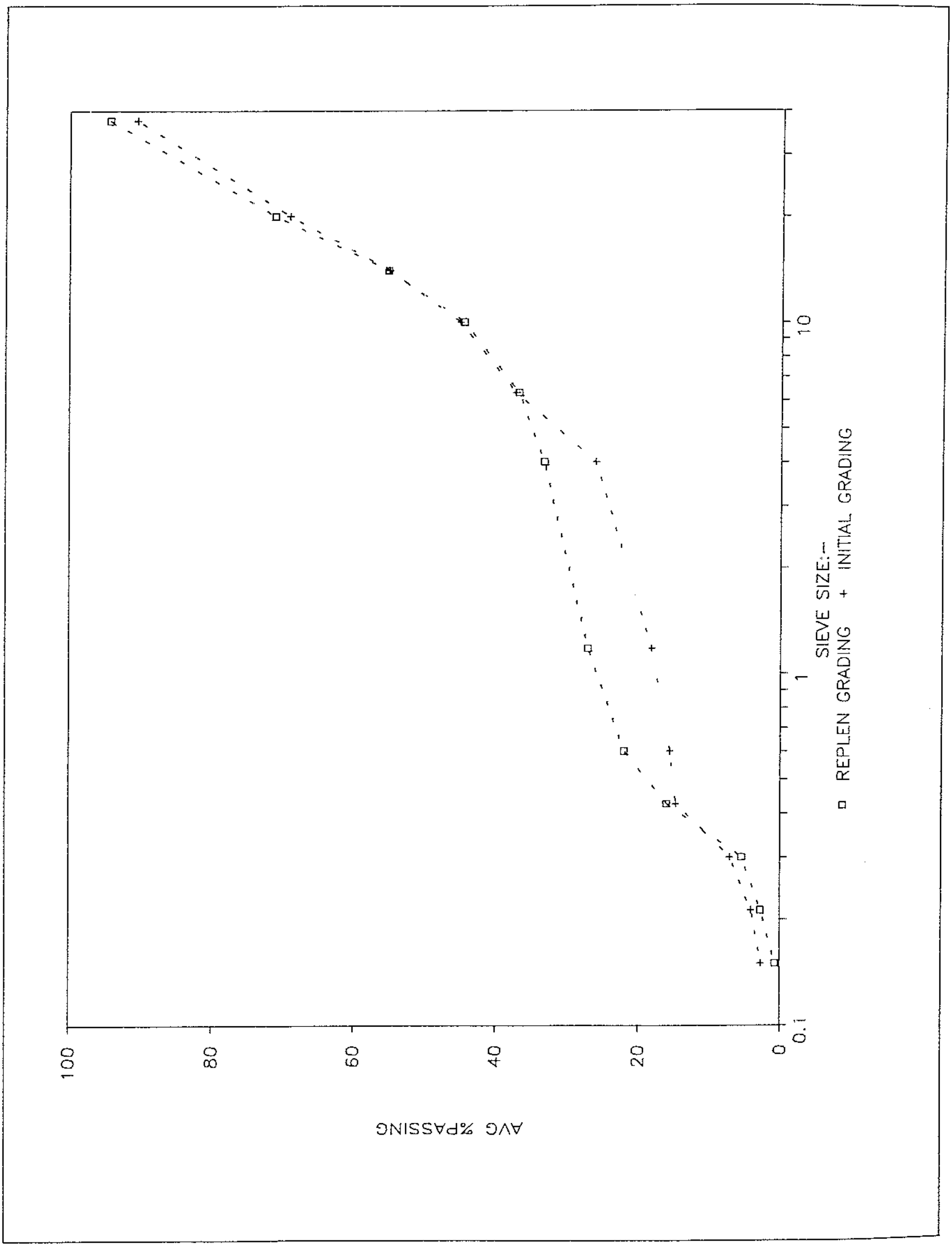

Fig 6 Comparison of initial beach grading and replenishment beach grading

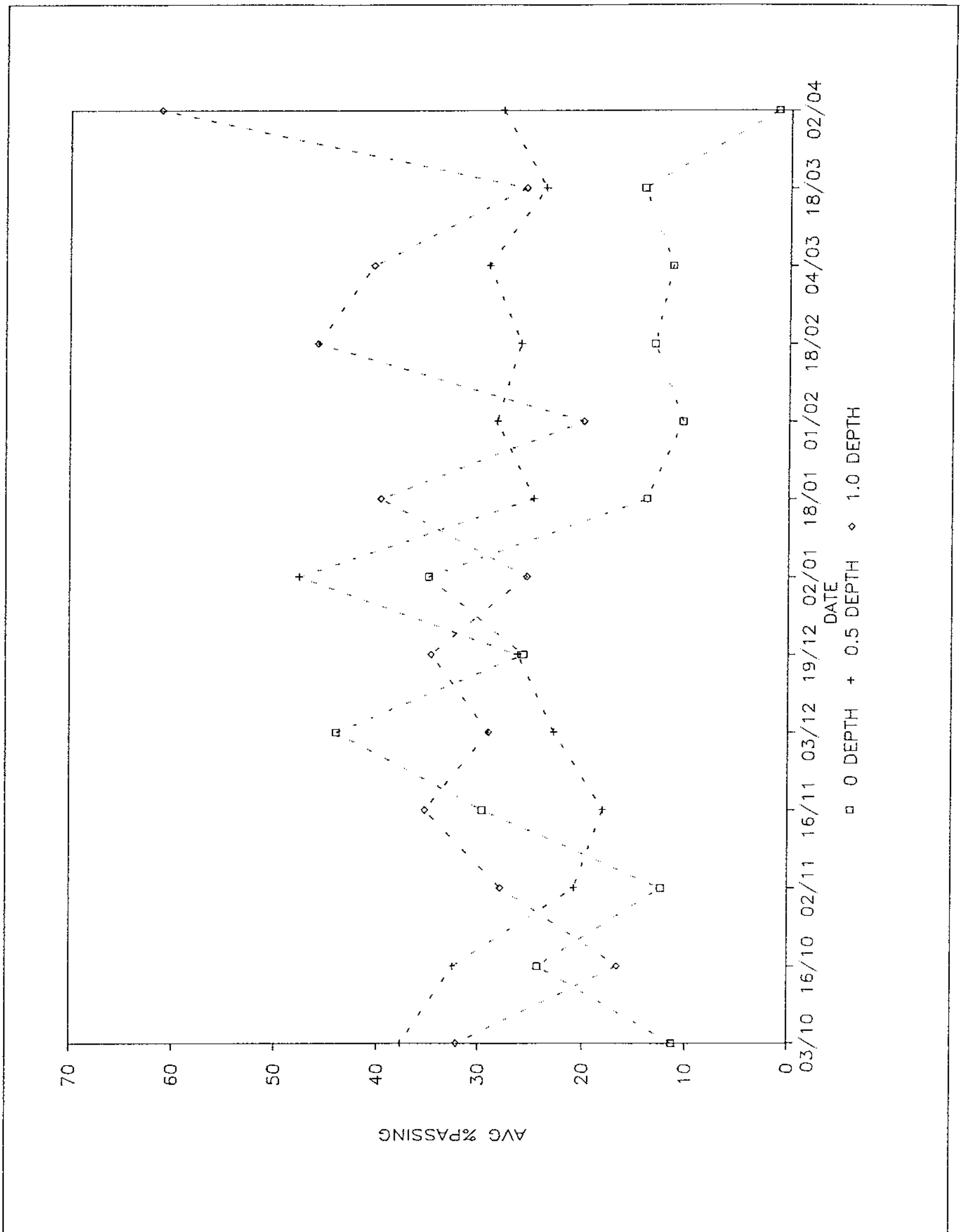

Fig 7 Time dependent grading variation
Material < 1.18mm

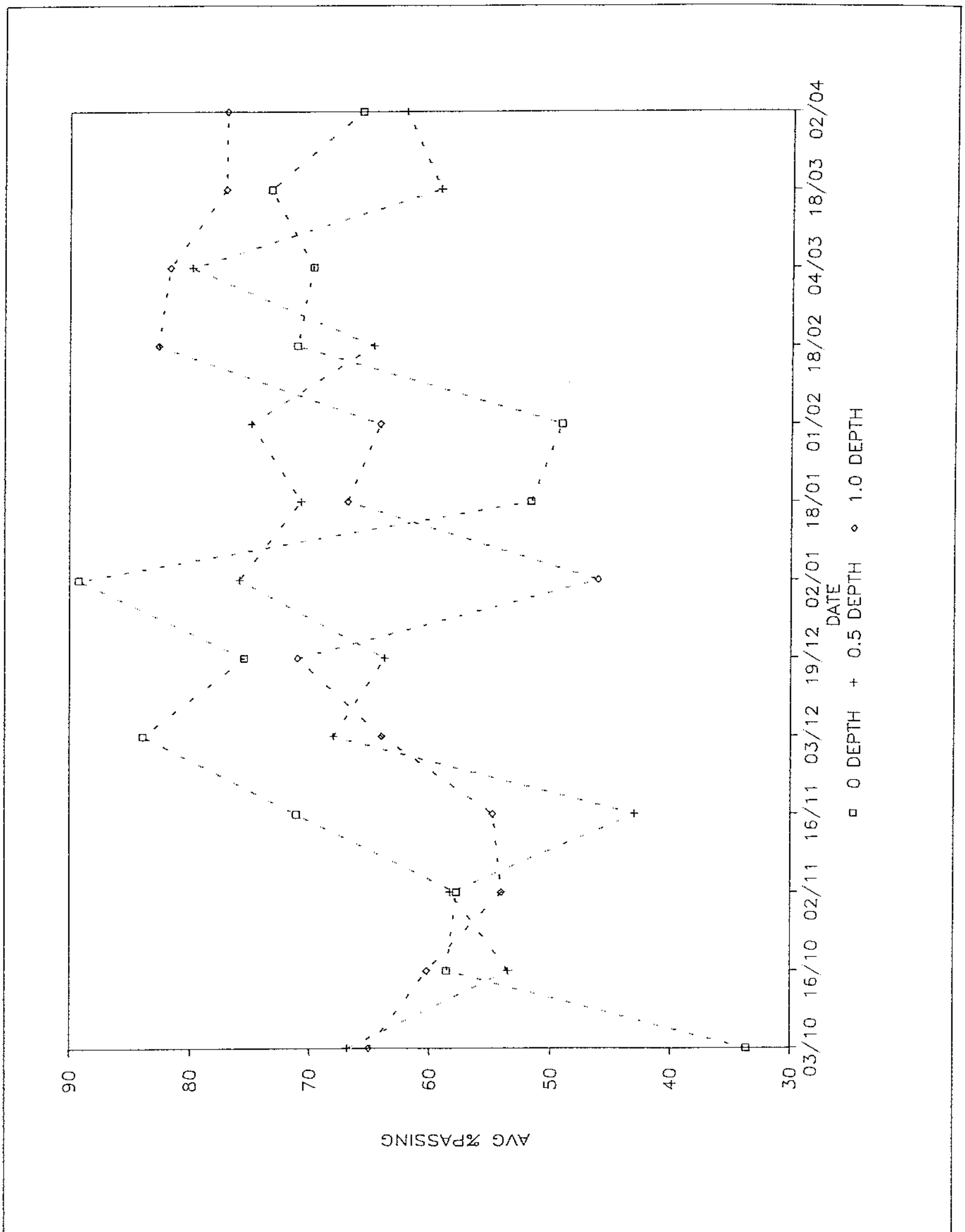

Fig 8 Time dependent grading variation
Material < 14mm

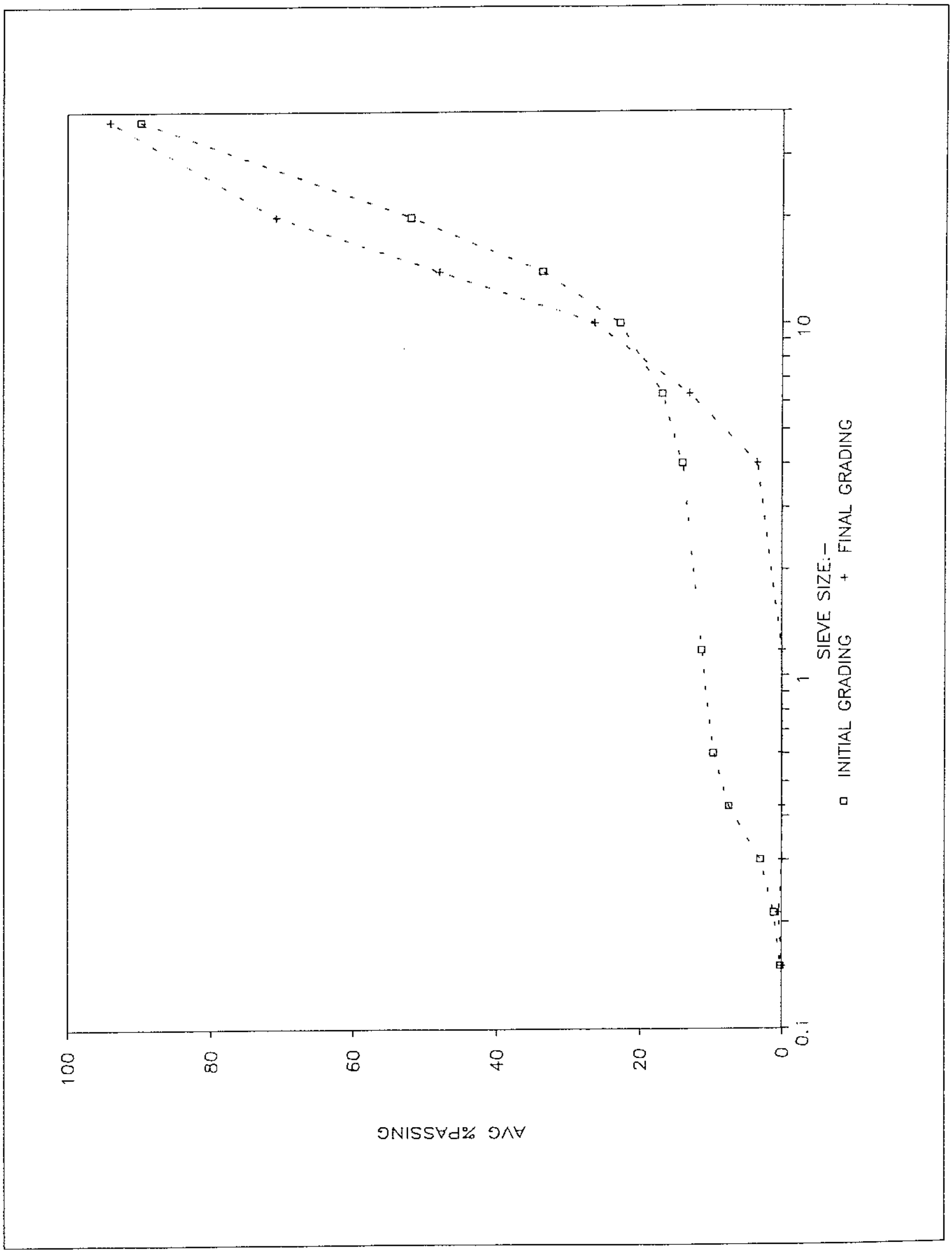

Fig 9   Development of beach grading
Surface samples

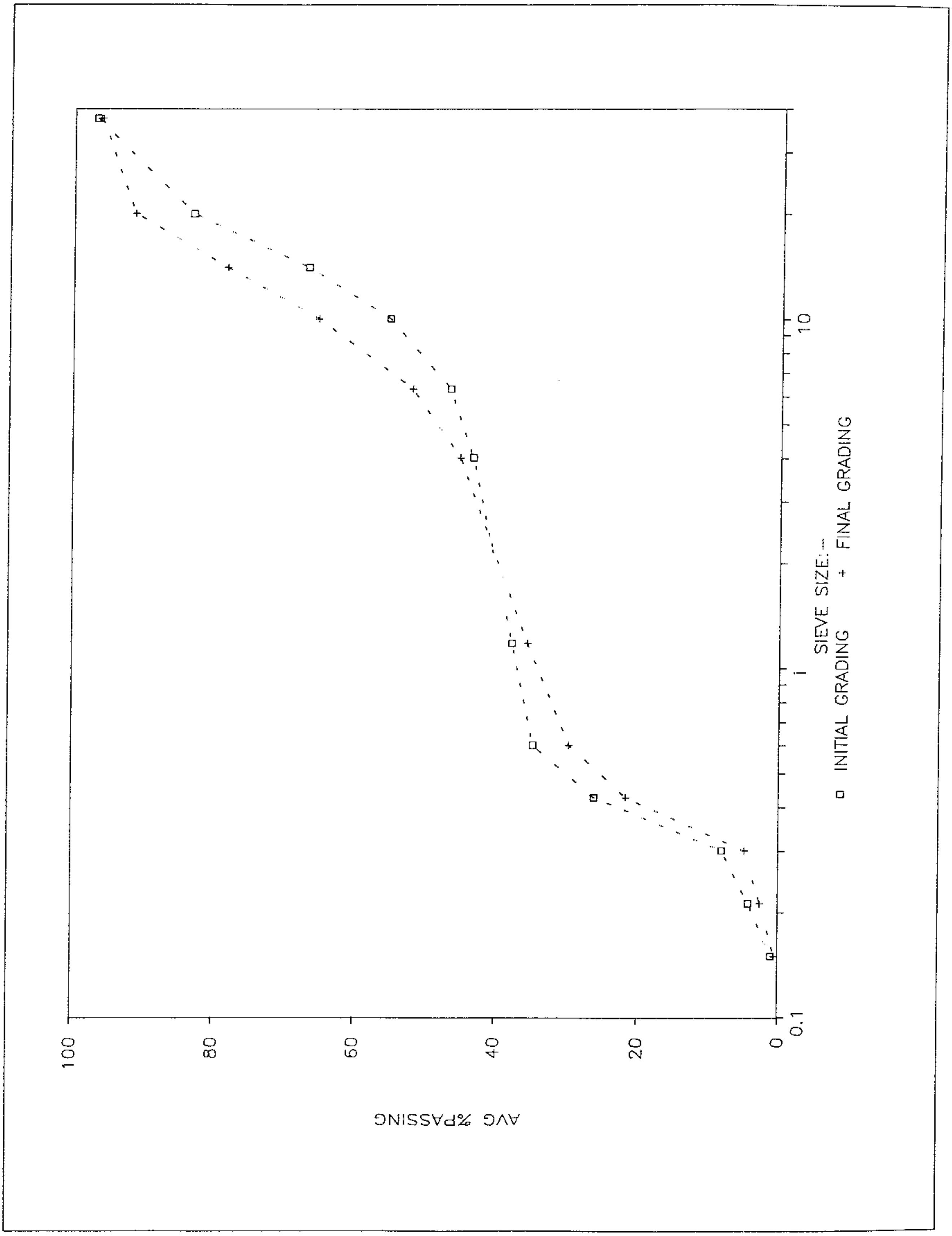

Fig 10 Development of beach grading
Mid-depth samples

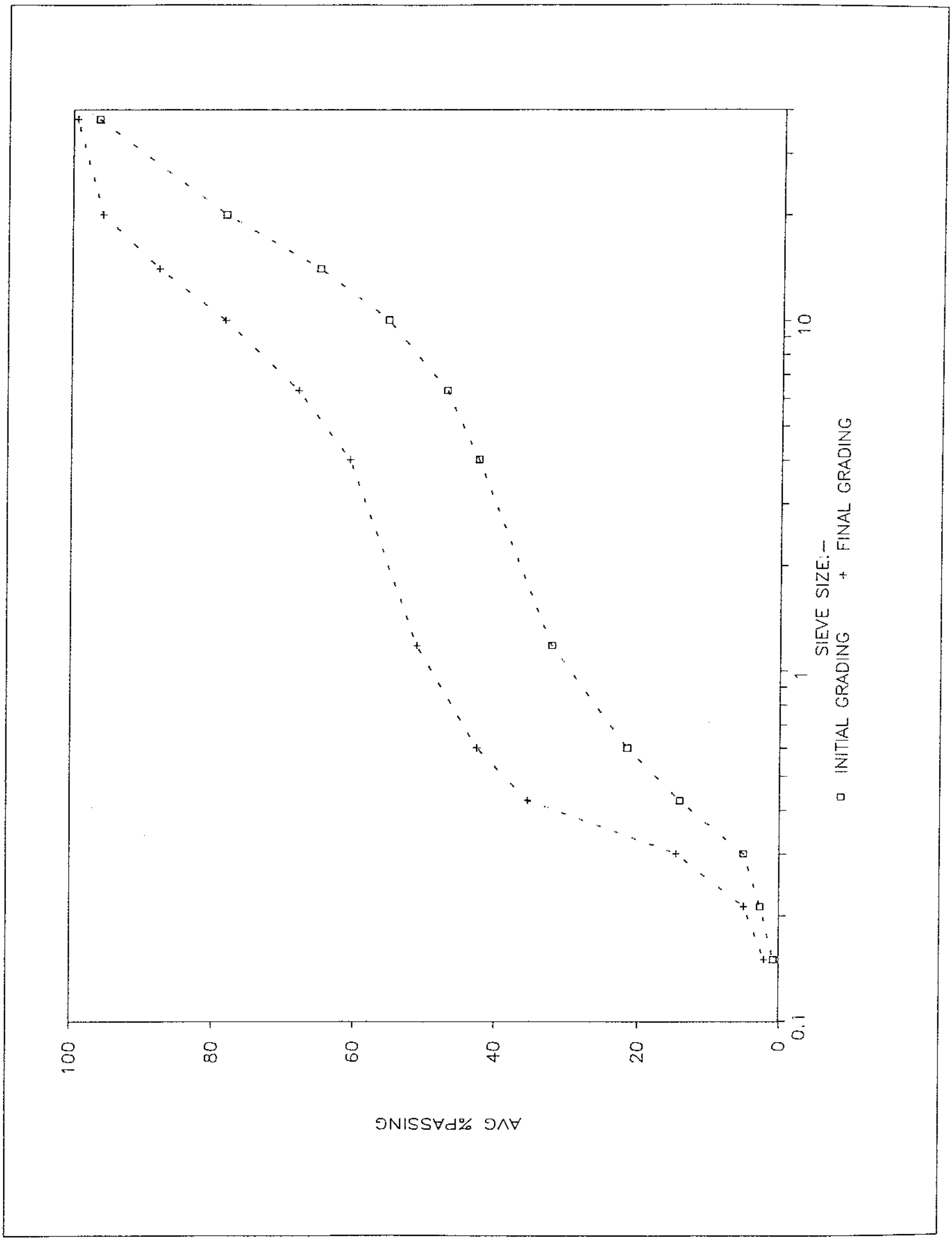

Fig 11 Development of beach grading
Full depth samples

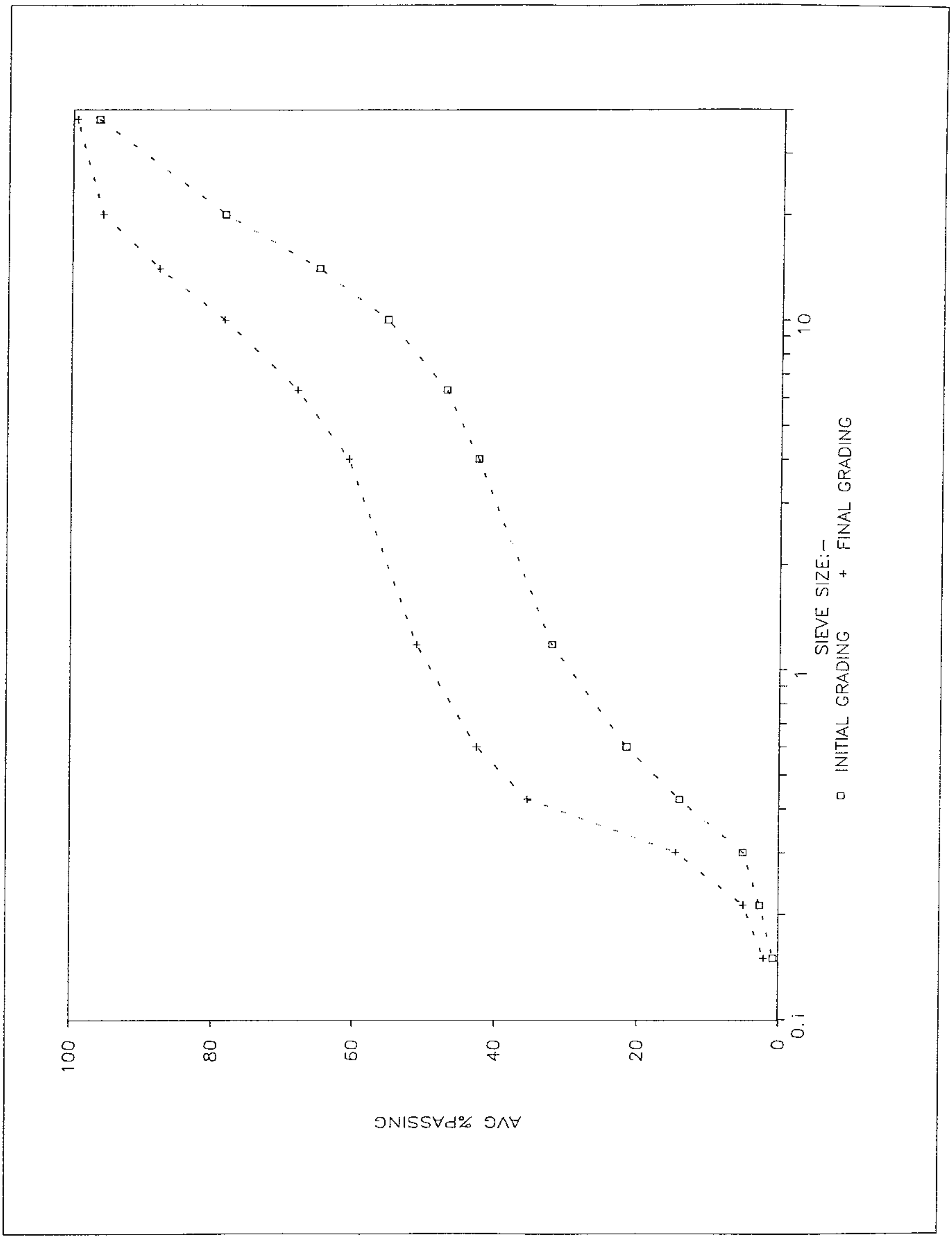

Fig 12 Overall development of beach grading

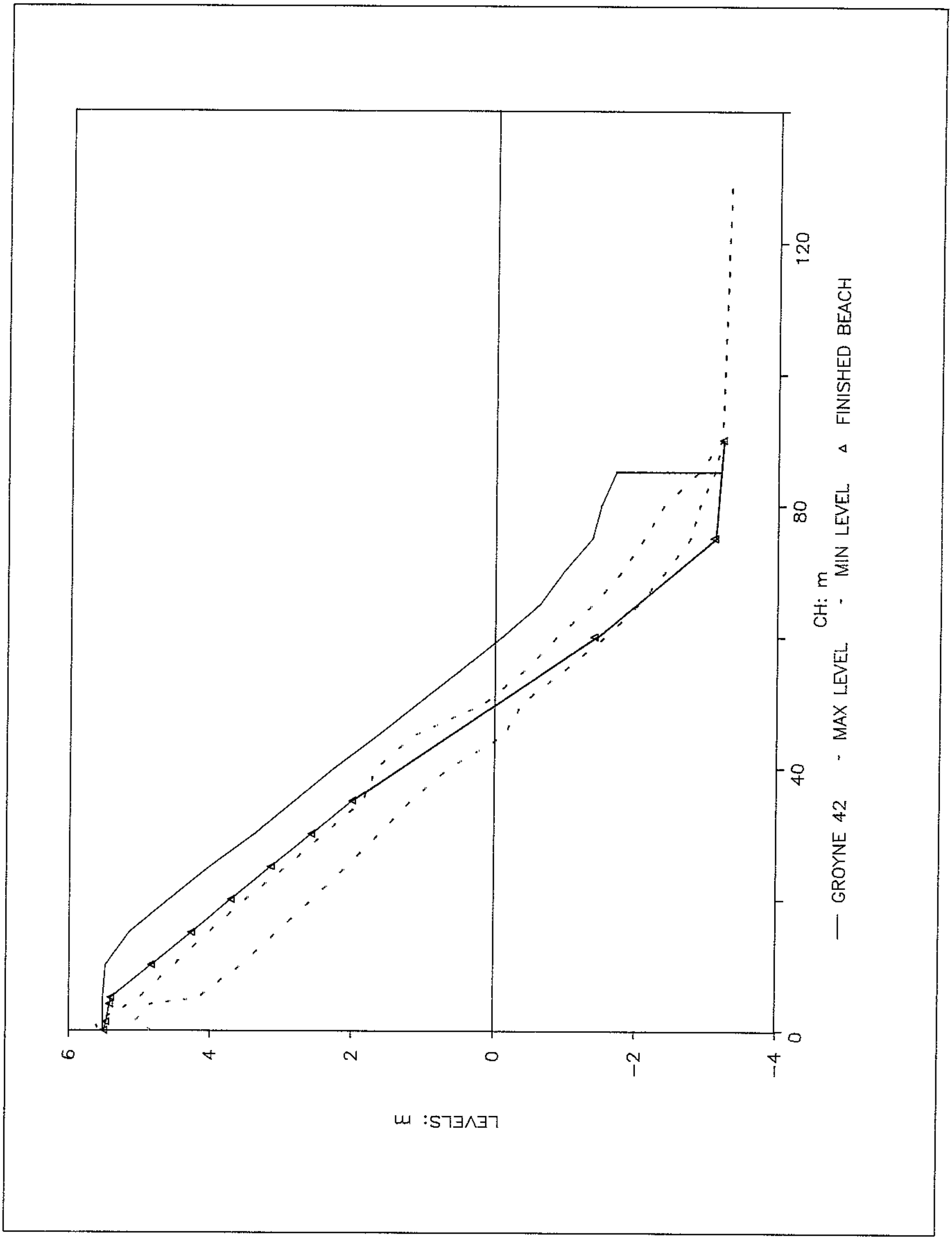

Fig 13 BEACH PROFILE ENVELOPE

Fluid thinking...smart solutions

HR Wallingford provides world-leading analysis, advice and support in engineering and environmental hydraulics, and in the management of water and the water environment. Created as the Hydraulics Research Station of the UK Government in 1947, the Company became a private entity in 1982, and has since operated as a independent, non profit distributing firm committed to building knowledge and solving problems, expertly and appropriately.

Today, HR Wallingford has a 50 year track record of achievement in applied research and consultancy, and a unique mix of know-how, assets and facilities, including state of the art physical modelling laboratories, a full range of computational modelling tools, and above all, expert staff with world-renowned skills and experience.

The Company has a pedigree of excellence and a tradition of innovation, which it sustains by re-investing profits from operations into programmes of strategic research and development designed to keep it – and its clients and partners – at the leading edge.

Headquartered in the UK, HR Wallingford reaches clients and partners globally through a network of offices, agents and alliances around the world.

HR Wallingford
Working with water

HR Wallingford Ltd
Howbery Park
Wallingford
Oxfordshire OX10 8BA
UK

tel +44 (0)1491 835381
fax +44 (0)1491 832233
email info@hrwallingford.co.uk

www.hrwallingford.co.uk