CHAPTER ONE HUNDRED

AN ASSESSMENT OF BEACH NOURISHMENT SEDIMENT CHARACTERISTICS

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ABSTRACT

An important component of beach nourishment design is to assess the compatibility of the borrow material with the native beach sediment. One avenue to judge the "success" of a project is the amount of fill retained over a specific period of time after fill placement. Presumably, if the fill material placed on the eroded beach is compatible with the energy of the coastal processes, it will be resorted along the profile but be retained within acceptable limits in the vicinity of the project area.

At present the selection of suitable borrow material is based only on theoretical criterion. Specifically, the Fill Factor and Renourishment Factor are based on models developed by Krumbein (1956), Krumbein and James (1965), James (1974), Dean (1974), James (1975) and Hobson (1977). These methods of judging borrow area suitability have not been fully tested in the field and the Shore Protection Manual (U.S. Army, 1977) warns that they should only be used as a general indication of possible fill behavior.

A review of monitoring reports on selected recent beach restoration and sand by-pass projects revealed a lack of standardization on data collection and analysis. Little evaluation of the actual behavior of fill material on the nourished beach had been carried out. To assess the suitability of the fill material, projects with adequate data were investigated and the short (one year) and long term (two to three years) behavior of actual fill data was described. Detailed collection of native sediment before nourishment, representative borrow material at time of placement and samples at specific times after fill placement were used to determine the redistribution of fill grain size characteristics and determine the accuracy of the present beach fill models.

It was found that present models do not take into account non-normal grain size distributions found at the projects studied or $CaCO_3$ shell material. A safety factor assuming loss of fine material from the borrow should be used with the Adjusted Shore Protection Manual Fill Factor Method to give more accurate results. The delta variable in the Renourishment Factor was found to vary between projects and should be calculated for each project. At the present time use of the entire grain size distribution is necessary to understand the sediment redistribution after fill placement.

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INTRODUCTION

Beach Nourishment as a technique for shoreline stabilization and storm protection has become increasingly popular over the past decade. Beaches widened by artificial fill placement act to dissipate erosive wave energy, provide upland property storm protection and supply additional sediment to a usually sediment starved sand budget area. Aesthetically, renourished beaches are also of recreational value to an important coastal tourist industry.

The rapidly rising cost of beach restoration and inlet sand by-passing projects have led opponents to question the long term value of such a "soft" coastal structure. In the past, many projects have been poorly monitored and inadequately documented. This has resulted in a dearth of scientific and engineering data for design and permitting officials to assess project success; and has contributed to costly project delay and redesign.

The high cost of beach restoration projects requires that we be able to predict how the sediment placed on the beach is going to respond to the physical forces acting upon it. The present theoretical beach-fill models have only been tested on a limited basis. Therefore, a more accurate understanding of beach-fill redistribution using actual field data from past projects would be a major contribution to our knowledge of beach erosion control.

Engineering monitoring reports and field collection from several recent beach nourishment projects provided the sediment data used in this study. It was difficult to find projects that had enough usable sediment data to make a comparison study possible. At present, there is no standardization in project monitoring and it was sometimes difficult to compare projects directly since the data provided were obtained in various ways and presented in different formats. The projects selected for this study had minimal similarity in data and were from locations that provided variation in both sediment characteristics and wave climate. The locations used to evaluate monitoring techniques, accuracy of the current beach fill models and to develop monitoring and analysis guidelines for future projects, included beach nourishment projects at Indialantic/Melbourne Beach, Delray Beach, and Hollywood/Hallandale located on the moderate to high wave energy (Tanner,1960) East Coast of Florida. The Captiva Island project was located on the low to moderate Gulf Coast of Florida and the Ocean City project was located on the high wave energy Atlantic Coast of Southern New Jersey (Figure 1).

SEDIMENT SAMPLING AND ANALYSIS CONSIDERATIONS

To evaluate a beach for nourishment, one must be able to obtain representative native beach and borrow sediment samples. The question of what is a representative sample arises. There are noticeable differences in the grain size distribution as one proceeds from the dune base, across the beach and continues offshore as described by Bascom (1959). The largest grains are usually found in an area just seaward of the backwash/surf interaction zone, an area of much turbulence. The summer berm crest area also contains significant coarse material due to runup sediment transport dynamics. Finer material is found in the dune area owing predominantly to wind transport processes. Seaward of the mean low water area sediments become finer with increasing distance seaward of the breaker zone. When determining the grain size

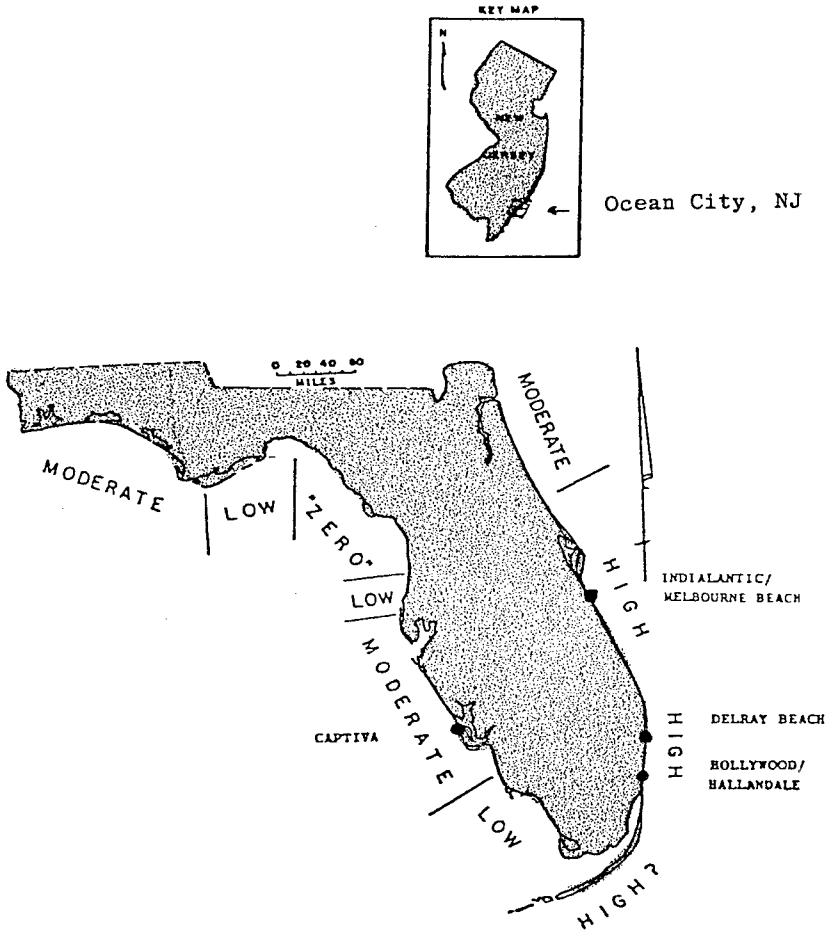

Figure 1. Locations of beach nourishment projects used in this study. Wave energy zones after Tanner (1960).

distribution of the native beach, it has been found that by combining samples from across the beach and nearby offshore areas, the variability in grain-size is reduced (Hobson, 1977). The grain size distribution of these composite samples will vary depending on the location of the included samples.

Analysis of some of this unique field data indicates that location of sediment sampling is critical to give a true picture of the native beach sediment characteristics and post-nourishment fill redistribution. A variety of sampling designs were used in the projects with little standardization (Table 1). A minimal requirement for inclusion in this study was data on the native beach, borrow area and a reasonable interval of post-nourishment monitoring sediment samples. Most monitoring reports used fixed distances from a benchmark, or fixed elevations about NGVD for collection of samples independent of the dynamic coastal processes. It was found that choosing sampling sites along the profile based on hydrodynamic zonation on the beach (ie. area of maximum runup, mid-tide area and mean low tide area) gives the best representative picture of grain size distribution. These zones change over the coarse of any study depending on tide, wave and profile shape parameters.

Location of sediment sampling is critical to give a picture of the true fill redistribution. A wide variety of sampling designs were used with differences in location, number and frequency of sampling. To reduce variability between the various sampling intervals, a mathematical composite was constructed from data generated after the individual samples have been analyzed either from graphic representation in project monitoring reports or actual field collection. The samples were all seived at either 1/2 or 1/4 phi intervals. The percentage of sediment in each size class of the different samples was then combined and an average grain size distribution was calculated. This method preserved information on individual samples for later use and allowed for various combinations of composites.

Several types of composite samples, as described by Hobson (1977), were examined to determine which of these samples eliminated the variability and provided the best comparison of behavior over time. Two basic types of composites were chosen after an examination of various combinations of samples available from each project, the intertidal composite and the profile composite:

1) The intertidal composites consist of samples from within the intertidal zone, (Figure 2) between mean hightide to mean lowtide, collected around the time of lowtide. This composite gave a good picture of the behavior of the beach-fill since this is the area of fill placement and most of the subsequent reworking.

2) The profile composites consist of intertidal samples plus samples collected seaward of the swash zone to approximately a 12 foot depth (Figure 2). This is a common type of composite used on most past projects.

The borrow area sediment sampling and analysis also varied from project to project (Table 1). Some of the projects reported composite samples of cores taken from the borrow area, summarizing vertical and horizontal distributions while others used composites or individual samples from the area of fill placement. The borrow material was obtained from various environments. Indialantic/Melbourne Beach had borrow material with a similar mean grain-size but was more poorly sorted and was sediment dredged from a barrier island to

SEDIMENT SAMPLE TYPES

PROJECTS	NATIVE	BORROW	3 MO.	6 MO.	9 MO.	1 YR.	18 MO.	LONG TERM
INDIATLANTIC/ MELBOURNE BEACH	(HT,MT,LT) 200,300,400	FROM DUMP TRUCK 3 LOCATIONS	X	X	X	X	X	X
CAPTIVA	ENTIRE PROJECT COMPOSITE ONLY	FROM CORES COMPOSITE	(+6, +3, 0) -3,-6,-9,-12	-	X	X	X	X
DELRAY	+15, +12 (+9, +6, 0) -3	FROM CORES COMPOSITE		-	-	-	-	X
HOLLYWOOD/ HALLENDALE	(+7, +4, 0) -3, -6, -9, -12 FT.	NO BORROW	-	X	X	X	-	-
OCEAN CITY, N.J.	(HT, MT, LT) NO OFFSHORE	FROM PIPE	X	X	X	X	X	X

Table 1. Variation in sediment sampling location on beach and time interval between sample collection. Sample locations within parentheses were collected in the intertidal area, others below NGVD. HT = high tide, MT = mid tide and LT = low tide area.

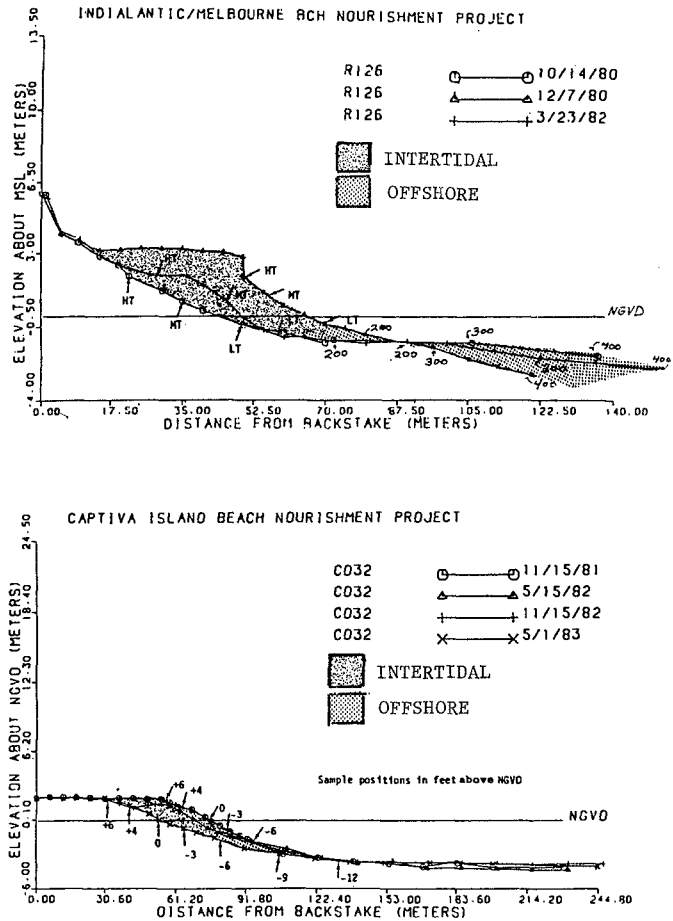

Figure 2. Sediment sampling locations on two of the projects thru time showing the change in intertidal and offshore samples with change in profile shape.

produce a harbour area. Delray Beach had much finer borrow material whose sorting was slightly poorer than the native beach and was from an offshore source area. Hollywood/Hallendale had a borrow that was slightly better sorted and contained finer material owing to its offshore origin. The borrow at Captiva Island was almost identical to the native beach and was obtained from an ebb tidal shoal. At Ocean City, NJ, the borrow was slightly finer and better sorted than the native beach and was dredged from a flood tidal bay source. When comparing native and borrow materials, there was more variation in the sorting values than there was in the mean grain-size. Table 2 summarizes the characteristics of each project.

Ideally, borrow material should have a grain size distribution congruent only with the intertidal samples where the fill is to be placed (Figure 3). The inclusion of offshore samples, however, results in a skewness to the finer grain-sizes and may not provide a true representative picture of the hydrodynamic effects on the native beach in the area of fill placement. A comparison of the borrow to native frequency curve of figure 3b) shows the standard practice of using the profile composite of the native sediment (including both intertidal and nearshore samples) vs. borrow sample, showing a reasonable match in distribution at all grain sizes. Figure 3a) shows a composite of only the intertidal samples, which gives a better picture of a borrow sediment that is deficient in the medium to coarse sand range, with an excess of fine material.

An examination of the various project data shows a distinct difference in grain size distributions landward and seaward of the low tide area. Sediment collected from the intertidal area (where most fill was placed on the projects examined) was found to be most representative of native beach material and gave a better picture of fill redistribution after placement (Stauble, et. al., 1983). Samples collected seaward of the low tide zone exhibited a distinctly different grain size distribution, tending to be composed of finer, better sorted material. This offshore area post-fill sediment grain size redistribution behaved differently from the intertidal area (Figure 4) in that the offshore sediments remained fined grained with little change in the mean and sorting. The intertidal composites, however, changed their mean and sorting as the coastal processes resorted the sediment and changed the profile shape.

At the present time, the difference between the native and borrow grain size distributions is one of the major determining factors for the project's success. From the data analyzed in this study, it was found that excess fine-grained material in the borrow was quickly winnowed away and transported offshore and/or downdrift of the nourished area. The standard practice of including the finer grained nearshore sediment samples into native beach composites appears to give a false picture on which to compute suitability of borrow material.

FILL MATERIAL COMPATIBILITY

Once sediment data is obtained for the native beach and the prospective borrow material, a method is needed to determine how suitable the material will be for placement on the beach. Several beach-fill models have been established to calculate an "overfill ratio" or fill factor which is defined as the volume

PROJECT	VOLUME OF FILL PLACED	LENGTH OF PROJECT	SOURCE AND METHOD OF PLACEMENT	SAMPLING INTERVAL	PROFILES WITH SEDIMENT SAMPLES	SAMPLES ALONG PROFILES	COMMENTS
Indialantic/ Melbourne Beach, FL	195,060m^3	3.38km	upland source dumped from truck onto beach	1 per week for 2 months, then gradually reduced to every 3 months	3 within project profiles, plus 2 control profiles	dune base, HT, MT, Swash, + 3 offshore samples at 200, 300, 400 feet seaward of hightide line	project completed Jan. 1981
Hollywood/ Hallandale, FL	1,514,432m^3	8.46km	offshore source 1500 - 3050m. 7 borrow sites dredge.	Pre-Construction every 3 months thereafter to 1 year	6 profiles	+7, +4, 0, -3, -6, -9, -12ft.	project completed Nov. 1979
Delray Beach FL	1,249,749m^3 (1973) 536,188m^3 (1978) (two areas)	4.93km	offshore source dredged/trucked from stockpile source	Pre (6-73) Borrow (6-73) Post (7-81)	3 profiles	+15 to -3ft (3ft intervals)	project completed July 1978
Captiva Island, FL	501,195m^3	3.05km	source: ebb tidal delta dredge	Pre, post, 6, 12, 18 months	4 within, 1 outside	+6 to -12ft (3ft intervals)	project completed Oct. 1981
Ocean City, NJ	917,520m^3	3.6km	source: flood tidal delta/ bay area dredge	Pre, post, 2 weeks, each 3 months until 15 months	3 profiles	HT, MT, LT	project completed Aug. 1982

Table 2. Project characteristics showing design variations and lack of standardization in data collection.

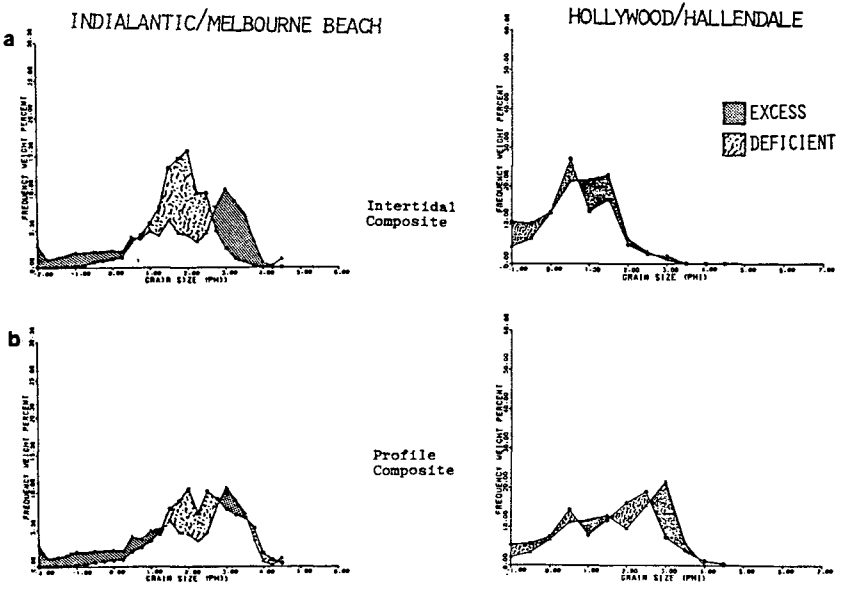

Figure 3. Comparison of grain size distribution frequency curves of borrow vs. native sediment using a) composite of just the intertidal samples and b) composite of the entire profile including the offshore samples. Intertidal composites give truer picture of size variation.

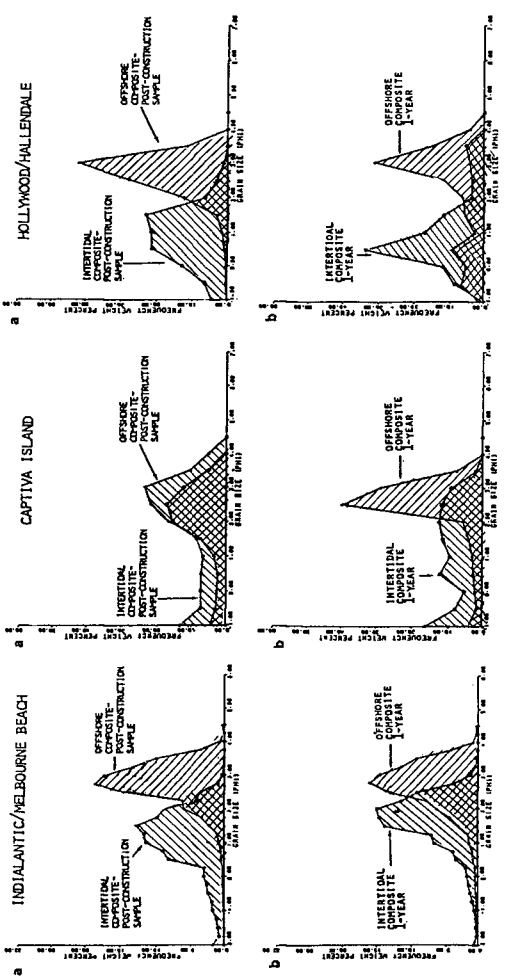

Figure 4. Comparison of intertidal vs. offshore composite grain size distribution frequency curves from three projects a) immediately after fill placement and b) one year after construction. Intertidal sample composites show the largest resorting.

of borrow material required to produce a unit volume of usable fill material with the same grain size distribution as the native material (James, 1975, Hobson, 1977). These beach-fill models require two parameters for calculations: the mean grain-size which is a measure of the central tendency and the sorting which is a measure of the spread of the grain sizes about the mean.

Currently there are three beach-fill models described by the Shore Protection Manual (U.S. Army, 1984): (1) The Shore Protection Manual (SPM) Method proposed by Krumbein and James (1965), (2) The Dean Method (Dean, 1974) and (3) The Adjusted Shore Protection Manual (Adjusted SPM) Method developed by James (1975).

The SPM method, developed by Krumbein and James (1965), compares the ratios of weight percentages of the native-to-borrow composites across the range of observed grain-sizes to determine the grain-size at which the ratio is a maximum (critical grain-size). One major problem with this method is the assumption that the coarse, more stable fraction will be winnowed away to create the compatible grain size distribution.

To overcome problems with the SPM method, Dean (1974) proposed a second method to calculate a fill factor. His approach assumes that selective sorting will winnow fine materials from the fill until the mean of the modified fill equals the native mean. A major problem is that the model predicts stability for all grain-sizes when the borrow materials are coarser and more poorly sorted than native sediments, even though the finer grain-sizes will be removed by winnowing. The SPM method implies that selective sorting will occur in both coarse and fine size fractions, whereas Dean's method implies only removal of material in the finer size classes.

James (1975) created a third fill factor model to correct the basic problems of the first two. This model, known as the Adjusted SPM method (Adjusted SPM), assumes the fill factor to be equal to the "critical ratio" of the SPM method, except when the borrow is coarser than the native sediments. This results in a modified grain size distribution which is as close as possible to the proportions of the native distribution in the finer size classes, but retains the borrow characteristics of the coarser size classes. Typically, the Adjusted SPM method produces fill factors less than the SPM method but greater than Dean's method (Hobson,1977).

Each of fill factor approaches use many of the same assumptions:

(1) Sediments native to the beach are considered to be the most stable for the environment.
(2) Local sorting processes act upon the entire volume of fill to achieve a GSD similar to the native sediments sometime after fill placement.
(3) Sorting processes change the fill material into native-like sediments by winnowing out a minimum amount of the original fill.
(4) GSD's of the native and borrow sediments are assumed to be normally distributed for the purposes of simplifying calculations.(Hobson, 1977).

There is some question as to the validity of these assumptions. The native and borrow sediment distribution was not found to be normally distributed in the projects studied. A typical borrow vs. native frequency

curve shows that there was usually excess material in the coarse fraction consisting mostly of carbonate shell and in the fine fraction due to the lower energy environment of the borrow area. Most of the fill was deficient in the medium sand sizes typically found on the native beach (Hansen,1982).

A post-nourishment fill estimate provides a technique to determine the accuracy of the various beach fill models. The fill factor is the volume of borrow material required to produce a unit volume of stable fill material. A fill factor of 2 would mean that 1/2 of the borrow material was unstable, so twice the design volume of sediment would have to be placed on the beach to result in the design beach. The post-nourishment fill estimate is the reverse of this calculation. If 50% of the fill is lost from a project after one year, then a post-nourishment fill estimate of 2 is calculated. By comparing what actually happened to the fill with what the models predict, one can get a better idea of each model's accuracy.

With these values of actual fill behavior estimates, a comparison of the three fill factor models was undertaken to see which one estimates fill behavior the best. Hobson (1977) suggested using a safety factor with the Adjusted Shore Protection Manual Method to account for the proportions of material finer than sand (>4 phi), since these sizes are considered unstable on the beach and are lost soon after fill placement. The safety factor, G, can be calculated to account for these unstable sizes, using:

$$G = \frac{100\%}{\text{ß phi}} \times R(a) \qquad (1)$$

where: ß = % of sediment expected to remain (in phi units)
Hobson, 1977 suggests <4 phi or % sand size contained in sample, this study suggests <3 phi or % > very fine sand.

The use of G has the effect of increasing the Adjusted fill factor when there are percentages of sediment finer than sand (>4 phi) or as found in this study material finer than fine sand. These values still fall between the Dean and SPM fill factors as predicted.

It was found in all of the study projects that the borrow material contained a maximum of only 3% mud-size particles and the cut off point of 4 phi was insignificant when using the safety factor G. After analyzing the post nourishment fill behavior it was discovered that most of the material finer than 3 phi was winnowed from the fill on most of the projects. A calculated safety factor using the 3 phi cut off was used and gave results close to the post-nourishment fill estimates. Table 2 summarizes the fill factor calculations and compares them to the post fill loss estimate.

James (1974) established a technique to predict how often renourishment will be needed and to evaluate the long-term performance of different fill materials. This technique involves the use of a mass-balance equation which compares material going into and out of the nourishment area. This equation is:

$$R_J = e^{\Delta \left[\frac{\mu_b - \mu_n}{\sigma_n} \right] - \frac{\Delta^2}{2} \left[\frac{\sigma_b^2}{\sigma_n^2} - 1 \right]} \qquad (2)$$

Site	Post-Nour. Fill Est.	R(s) SPM F.F.	R(d) Dean F.F.	R(a) Adj. F.F.	R(a) with G 4 phi	R(a) with G 3 phi
I/MB profile	2.17	1.65	1.00	1.10	1.11	1.40
inter-tidal	2.17	2.20	1.00	1.38	1.40	2.10
Delray Beach	1.7	>10	15	>10	----	----
Hol/Hal	1.09	----	----	1.09	----	----
Captiva Island	1.22	1.02	1.00	1.01	1.01	1.20
Ocean City N.J.	No Volume Lost Estimates Available	unstable	----	1.75	1.75	2.3

Table 3. Comparison of post nourishment fill estimates with the Shore Protection Manual (R_a), Dean (R_d), Adjusted Shore Protection Manual (R_a) fill factor models and the Adjusted Shore Protection Manual model with the safety factor G using the 4 phi and 3 phi size cut off for each project. The G of 3 phi gave "overfill" ratios closest to post nourishment estimates.

where: R_J=relative retreat rate (renourishment factor)
μ and σ=phi mean and phi sorting parameters
b and n=subscripts referring to borrow and native sediments
Δ=dimensionless parameter related to selective sorting (winnowing) in the environment.

James suggests that the range of delta values may be from 0.5 to 1.5. He recommends that calculations nf the renourishment factnr use a value of 1.0 for the delta parameter and that the calculated values should be regarded as only approximate (James, 1975). The "delta" value can be computed from the following equation:

$$\Delta = \frac{\mu_n - \mu_n'}{\sigma_n} \qquad (3)$$

where: μ_n = the native mean before an ernsional event.
μ_n' = the native mean after an erosional event.
σ_n = the sorting of the native material, where
$\sigma_n = \sigma_n'$ is assumed true (James, 1974).

The delta value was computed for the projects from data obtained before and after erosional events as best that can be determined for projects where data was available. This value gave a better estimate of fill behavior than an assumed value of 1.0. It is recommended that a delta value should be calculated for each nourishment project to accurately apply this model. Usually, a beach requiring nourishment is undergoing an erosional period, so by taking sediment samples several times prior to nourishment, the delta value can be determined using equation (2).

LONG TERM GRAIN SIZE REDISTRIBUTION

An examination of long term grain size characteristics of the fill material has lead to a complex picture nf project grain size redistribution. The projects used in this study exhibited a wide range of native-to-borrow grain size distributions and coastal wave energy distributions. A method was developed, using a "post-nourishment fill estimate", based on volume of fill stabilized over a year or longer and the changes in grain size distribution over time, to graph fill behavior.

The inclusion of the safety factor, G, seems to predict more accurate fill factors than the Adjusted fill factors alone. Our findings indicate that safety factor calculations should be shifted to the fine limit of native sediment, not the 4 phi limit suggested by Hobson (1977). Figure 5a-d depicts the grain-size excesses and deficiencies in the borrow material as compared to the native beach at the top half of each figure and actual gains and losses one year later (8 years later for Delray Beach) at the bottom of each figure. If there was excess fine material in the borrow, the intersecting grain-size is shown by the dashed line. In the lower half of each figure, the solid line indicates the 3 phi grain-size at which the G values were calculated. The grain-size at which actual losses of fines occurred (if any) are shown with the crossed line. The 3 phi cut off point was used for the ease of obtaining percent sand at that point. Use of the 3 phi cut off point for calculating G

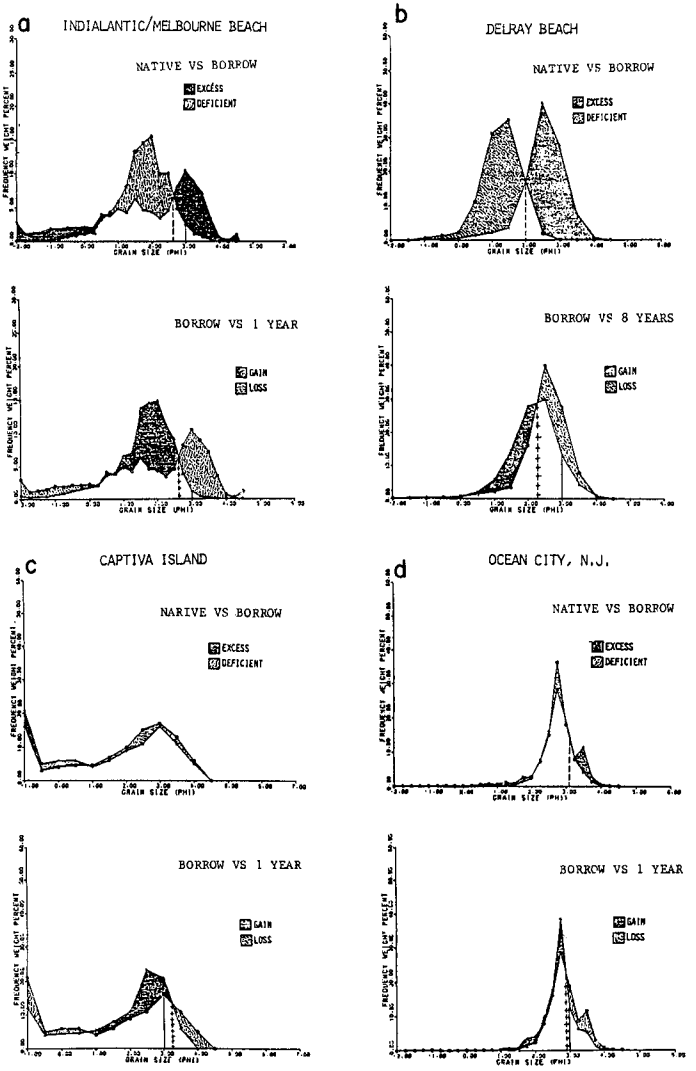

Figure 5. Grain size frequency curves from the four projects comparing 1) the borrow with the native showing the 3 phi cut off and the actual excess fine grain material and 2) the borrow with the one year (8 year for Delray Beach) showing the calculated 3 phi cut off with the actual loss of fine material.

and actual losses correlate well at Indialantic/Melbourne Beach (Fig. 5a), Captiva Island (Fig. 5c) and Ocean City (Fig. 5d). For the projects that had a reasonably good match between borrow and native or borrow that was for the most part slightly finer than native in areas of moderate to high wave energy the 3 phi adjustment gave a reasonable prediction of fill behavior. The correlation was not as good at Delray Beach (Fig. 5b) which had such a large grain-size difference between the borrow and native and resulted in a significant long term change in the grain size distribution. No borrow information was available for Hollywood/Hallandale, but analysis using sediment collected three months after fill placement showed that the native material contained coarser material than the borrow that replaced it even though the borrow was composed of medium sand. From three months to one year later, the beach gained a significant amount of fine material not found in either the native or borrow sediment.

CONCLUSION

From this study it can be concluded that:

1. Composite samples are needed to remove the variability in sediment distribution across a beach and in a borrow area. Intertidal composite samples are more suitable for use in the models. Offshore sediments include fine sizes and changed little in their grain size distribution over the project life. Fill was placed in the intertidal area in all projects studied and this area had the greatest redistribution of sediment grain sizes.

2. The Adjusted Shore Protection Manual method (recommended in the majority of cases by U.S. Army, 1984), gave the best calculation of actual fill behavior, provided a safety factor (G) was used. A safety factor of 3.0 Phi has been found to give the best results for the projects studied.

3. Fill factor models commonly use only the sediment mean and standard deviation values. The sample mean and sorting alone are not sufficient to describe the variability of the native, borrow and post-fill sediment behavior because natural sediment distributions are not normally distributed as assumed in the models. Frequency distribution plots provide the best means of showing the differences between the native and borrow grain sizes over the entire sediment distribution.

4. Renourishment Factor calculations using computed Δ values gave the best match to actual fill behavior.

5. Standardization of collection, analysis and presentation of beach nourishment sediment data is needed for better understanding of project behavior.

It must be noted that grain size information alone is not sufficient to predict success of a project. Compatibility of the borrow material is but on of the factors to be considered in project planning, along with fill placement techniques, knowledge of coastal processes and interaction with other coastal structures (Dean 1983). New guidelines are in the process of being developed (Stauble and Nelson, 1984) for monitoring all aspects of a nourishment project. More projects with adequate data need to be examined and a standard data collection and reporting system established. We will then have a better basis

for understanding fill behavior and development of new predictive methods for project success.

ACKNOWLEDGMENTS

Portions of this research have been supported by the U.S. Army Corps of Engineers, Jacksonville District; Florida Sea Grant; and the Florida Department of Natural Resources, Division of Beaches and Shores.

REFERENCES

Bascom, W.N., 1959. The relationship between sand size and beach-face slope: American Geophysical Union Transactions, V.32(6), pp. 886-874.

Dean, R.G., 1974, Compatibility of Borrow Material for Beach Fills. Proc. 14th International Conf. on Coastal Eng., ASCE, Vol. II, pp. 1319-1330.

Dean, R.G., 1983, Principles of Beach Nourishment. in: CRC Handbook of Coastal Processes and Erosion, P.D. Komar, ed., CRC Press, Boca Raton, Fl., pp. 217-231.

Hansen, M.E., 1982. Evaluation of Beach Fill models and the effect of carbonate material on beach fill. Unpublished Masters Thesis, Florida Institute of Technology, Melbourne, FL., 107P.

Hobson, R.D., 1977, Review of Design Elements for Beach Fill Evaluation. TP 77-6, U.S. Army Corps of Engineers, Coastal Eng. Res. Center, 42 p.

Krumbein, W.C., 1957, A Method for Specification on Sand for Beach Fill Evaluation. TM 102, U.S. Army Corps of Engineers, Beach Erosion Board.

Krumbein, W.C., and W.R. James, 1965, A Lognormal Size Distribution Model for Estimating Stability for Beach Fill Material TM-16, U.S. Army Corps of Engineers, Coastal Eng. Res. Center, 17 p.

James, W.R., 1974, Beach Fill Stability and Borrow Material Texture. Proc. 14th International Conf. on Coastal Eng., ASCE, Vol. II, pp. 1334-1344.

James, W.R., 1975, Techniques in Evaluating Suitability of Borrow Material for Beach Nourishment. TM-60, U.S. Army Corps of Engineers, Coastal Eng. Res. Center, 81 p.

Stauble, D.K., M. Hansen, R. Hushla and L. Parsons, 1983, Beach Nourishment Monitoring, Florida East Coast: Physical Engineering Aspects and Management Implications. Proc. Third Symposium on Coastal and Ocean Management, ASCE, pp. 2512-2526.

Stauble, D.K. and W.G. Nelson, 1984, Beach Restoration Guidelines: Prescription for Project Success. In: The New Threat to Beach Preservation, L. Tate, ed., Fl. Shore and Beach Pres. Soc., Tall., Fl., pp. 137-155.

Tanner, W.F., 1960, Florida Coastal Classification. Trans. Gulf Coast Assoc. of Geol. Soc., Vol. X, pp. 259-266.

U.S. Army, 1984, Shore Protection Manual, 4th. ed., Coastal Eng. Res. Center.