CHAPTER 113

IMPORTANCE OF HANDLING LOSSES TO BEACH FILL DESIGN

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ABSTRACT

Beach nourishment models commonly employed by the U.S. Army Corps of Engineers compare textural properties of native beach and dissimilar borrow sediments to determine overfill and renourishment requirements for beach fill projects. It is assumed for these comparisons that the texture of borrow sediments is unchanged by dredging and handling operations but investigations have shown that significant handling losses do, in fact, occur.

This paper presents results from four field studies that document textural changes caused by dredging and sediment handling at Rockaway Beach, NY, and at New River Inlet, NC. Errors associated with calculating volumes of sediment dredged and lost using standard surveying and production methods are discussed and an alternate method is presented as a handling-loss model that compares bottom and dredged sediment texture to determine volumes lost.

The results of the studies presented are that handling operations do create significant changes in bottom sediment texture which, in turn, do affect beach fill model calculations by generally improving the predicted performance of these sediments as fill. The proposed handling-loss model predicts volumetric losses that greatly exceed losses generally anticipated during project construction. Discrepancies between loss estimates are discussed in terms of possible inadequacies of the model and of mechanisms that might consistently minimize losses using the standard methods for determining dredged sediment volumes.

INTRODUCTION

Beach nourishment is a commonly selected method of shore protection in the United States. Nourishment projects often receive substantial federal government support and they not only protect against loss and damage caused by storms and ongoing erosion, but also provide recreational benefits to an area while maintaining its natural aesthetics. Sand for beach fills is typically won offshore and may be pumped directly from the dredge to the beach when the borrow site is nearby. When the site is too far away for direct pumping, the sand is loaded into hoppers or barges, rehandled and pumped onto the beach from a location closer to the project.

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Studies of longshore transport, erosion rates, wave climate and storm history provide the kinds of data needed by the engineer to design a fill section that will withstand anticipated waves and water levels during storms as well as contain a sufficient volume of sand to meet expected erosion losses (U.S. Army Coastal Engineering Research Center, 1977). Renourishment needs are also considered in the design since most eroded beaches will continue to erode after nourishment and the fill section must also provide sufficient sand to meet these losses. Since beach fill design elements are determined using data from process-response studies of waves and currents interracting with native beach sediments, it is important to appreciate that the resulting fill volume requirements are for sediments similar to those found on the native beach. Dissimilarities between native beach and potential borrow sediments require adjustments to the designed volume which are commonly accomplished by applying beach fill models to calculate initial overfill and adjusted renourishment estimates (James, 1975). For these models, native beach sand serves as a standard for comparison with potential borrow sediments. The comparisons are between represen-tative samples called composites (Hobson, 1977a) of the native beach and potential borrow sediments. Grain size distributions (gsd's) of these composites are expressed as phi sizes (Krumbein, 1938) and their phi means (M_{ϕ}) and phi sorting (S_{ϕ}) values commonly serve as input for the models.

HANDLING LOSS STUDIES

When applying the beach fill models, it is assumed that the volume and texture of sediment dredged from a borrow site is unchanged during project construction. However, sediment losses are commonly observed in the form of turbid water surrounding a dredge or as plumes extending seaward of a beach during nourishment. The term "handling loss" is used here to describe these project-related sediment losses. If significant, handling losses might modify the texture of borrow sediments enough to affect their performance as predicted by the beach fill models.

Handling losses are commonly caused by removal of sediment in suspension (elutriation) from the water-sediment slurry. These slurrys commonly contain 10 to 25 percent solids and elutriation losses can occur during dredging on the bottom, during the overflow process used to fill hoppers with sediment, during recharge of sediment with water to allow hoppers to be pumped out, and during hydraulic placement of sediments on the beach. Documentation of this kind of loss has been minimal. Taney (1965) suggests losses in excess of 80 percent caused by prolonged overwashing of a dredge's hoppers and Mauriello (1968) reports that handling losses resulted in a fill sediment that was 0.2 mm coarser than the borrow sediment dredged. Neither of these studies was directly designed to examine handling losses and clearly there is a need for studies that both document these losses and assess their possible effects upon beach fill design.

Four handling loss examples are discussed below where suitable sedimentary data sets are available. Three of these sets were collected during field studies designed to investigate handling losses and these studies were conducted at New River, North Carolina, in the summers of 1976 and 1978, and at Rockaway Beach, New York, in 1977 (Figure 1). The fourth data set was also collected at Rockaway Beach but in 1975 during one phase of that project's construction, and by personnel from the New York Army Corps District office. For simplicity, these four examples are henceforth referred to as Rockaway (1975), Rockaway (1977), New River (1976) and New River (1978). Each example is briefly described below. Detailed descriptions of the Rockaway project are provided by Nersesian (1977) and Hobson (1977b), and the New River experiments by Hobson (1977b)and 1977c).



FIGURE 1. Location map - Rockaway Beach and New River Handlingloss studies.

<u>Description and Sampling</u>: Rockaway Beach is a barrier island with a morphology that has evolved over the past century in response to multiple episodes of artificial nourishment. The latest episode was accomplished in three phases during the summer months of 1975, 1976, and 1977. The beach was nourished along its 16 kilometer length with approximately 5,500,000 m³ of sand obtained from local offshore borrow sites. During the first phase (Rockaway 1975), borrow sediments were dredged and loaded into scow barges offshore, transported 13 km to the leeward side of the barrier where they were recharged, and pumped hydraulically onto the beach. For phases two and three (Rockaway 1976, 1977), a suction dredging barge was used to load the sand, transport it to an offshore discharge point, recharge the load with water, and pump the slurry onto the beach. Sampling for Rockaway (1975) was conducted by the U.S. Army Corps of Engineers and consisted of coring bottom sediments at the borrow site using vibratory-type equipment, and collecting surface or grab samples from 26 of the scow barge loads and, of fill sediments at the 26 beach locations where the barged sediment loads were discharged. A three meter long, suction-assisted coring device was used to collect cores of bottom and barged sediments during the Rockaway (1977) study. Native beach sediments were sampled during preconstruction investigations of the area.

New River Inlet is periodically dredged to maintain a shallow access channel for small boats. A side-casting suction dredge and a split-hull barge have been employed by the Wilmington Corps of Engineers District office to accomplish this work. Studies were conducted by the Coastal Engineering Research Center (CERC) in 1976 and 1978 to evaluate sediment losses incurred during dredging. In 1976, the side-caster was used to fill the split-hull barge which then carried the dredged sediments to a nearshore dump site located downdrift of the By 1978, the split-hull barge had been equipped with suction inlet. drag heads and was able to perform all loading and dumping operations by itself. Sampling during both studies consisted of using divers to collect surface sediment samples from the bottom prior to a pass of the dredge, and using the suction corer to sample the entire thickness of the barged loads where sediments located near the bottom were subjected to less elutriation effects than upper layers. Three cores were taken from the hopper loads sampled and at least 10 surface samples were obtained to characterize each load. In addition, samples of sediments overwashed from the hoppers were collected as were samples of native beach sediments (e.g. 45 beach samples in 1976 and 22 in 1978). In both cases the beach was sampled at the downdrift dump area along profile lines that extended offshore from the storm berm to water depths of approximately 4.5 meters below MSL.

<u>Discussion</u>: Figures 2 and 3 are presented as typical plots of grain size distributions sampled during the Rockaway and New River studies, respectively. Table I is a summary of textural changes and beach fill model predictions for the four cases studied and it is evident from inspection of this table that in all cases, dredging and handling operations have coarsened dredged sediments (decrease in M_{ϕ} , Table I). The degree of coarsening varies but it is the kind of textural change anticipated where considerable overwashing is required to fill a scow or hopper. The smallest change in grain size occurred at Rockaway (1975) during the recharging and placement phase of handling where less overwashing was required to recharge the scow loads and where losses to the offshore were low during placement because the "fill" sampled included all sand placed on the beach within elevation limits of +3 to -5.5 m, sea level datum.

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	TEXTURAL PAR	BEACH FILL MODEL PREDICTIONS		
	Native Sediments	Borrow Sediments	Overfill Factor	Renour. Factor
	M _o S _o	M _o S _o	R _A	Rj
ROCKAWAY 1975	1.69 0.72			
Native vs. Bottom		1.85 0.86	1.24	1.00
Native vs. Barged		1.31 0.66	1.00	0.64
Native vs. Placed		1.24 0.64	1.00	0.56
ROCKAWAY 1977	1.63 0.70			
Native vs. Bottom		2.23 1.02	1.20	0.58
Native vs. Barged		1.33 0.73	1.00	0.25
NEW RIVER 1976	2.39 0.80			
Native vs. Bottom		1.51 0.91	1.00	0.29
Native vs. Barged		1.04 1.02	1.00	0.13
NEW RIVER 1978	2.24 0.82			
Native vs. Bottom		1.20 1.25	1.01	0.14
Native vs. Barged		0.26 1.46	1.00	0.10

TABLE I Textural parameters describing native beach and handlingaltered sediment gsd's, and beach fill model predictions for Rockaway Beach and New River handling loss studies. The symbols M_{φ} and S_{φ} are the phi mean and phi sorting values, respectively.

The observed coarsening should reflect selective removal, by washing, of finer sized sediments. The gsd's of elutriated sediments sampled during the New River experiments support this interpretation with mean sizes of 0.11 mm finer than bottom sediment means in 1976 and and 0.21 mm finer in 1978. Losses of fine sediments should also improve the sorting of barged or placed sediments. Sorting does decrease with each handling episode for the Rockaway studies (Table I). However, at New River, sorting values were observed to increase with handling even though the mean grain sizes of barged sediments were significantly coarser than for bottom sediments, and sediments overwashed were fairly fine grained. These curious changes in sorting at New River may reflect inadequate sampling of bottom sediments but they cannot be explained here using the data available from the experiments.

In all cases, the textural changes produced by handling do lower the overfill and renourishment estimates provided by the beach fill models (Table I) which suggests that handling improves a sediment's performance as fill. These changes are more striking for the Rockaway examples where borrow sediments were finer grained and more poorly sorted than native beach sediments than for the New River cases where borrow sediments were dredged from a high energy shoal complex and were significantly coarser than native beach sediments. At Rockaway, changes to the overfill ratios (R_A 's, Table I) of 0.20 (1977) and 0.24 (1975) indicate that losses of fines from the borrow material during construction will produce a fill sediment that will match the performance of native beach sand. Thus no overfill is predicted and project volumes are reduced by 17 and 20 percent, respectively. It is also predicted from the renourishment values (R_J 's) that the same winnowing losses will generally double the time span required between renourishment operations.



Rockaway Beach, NY (1977)

FIGURE 2 Grain size distributions (gsd's) showing textural differences between dredged (barged) and bottom sediments, Rockaway Beach (1977).



FIGURE 3 Grain size distributions (gsd's) showing textural differences between dredged (barged), bottom, and sediments overwashed during hopper filling (elutriate) at New River, NC (1978).

VOLUMETRIC CALCULATIONS

The experiments described provide some documentation of textural modifications to dredged sediments caused by handling operations. Sediments placed as fill contain a smaller fine-grained fraction than the same sediments contained prior to dredging, and thus initial fill volumes may be reduced and slower erosion rates may be expected. The effects of these potential changes upon project design and performance can be further evaluated by determining actual volumes lost during construction.

Handling loss volumes can be determined using estimates of the volumes of sediments dredged from the borrow site, volumes loaded into hoppers or rehandling sites, and volumes placed as fill on the beach. These volumetric estimates are typically calculated using data obtained by surveying, from plant production specifications, or from hopper load measurements. A general evaluation of these data sources reveals

potential problems with each and demonstrates the need for improved calculation procedures.

Surveying: Volumes of sediment placed on a beach or dredged from a borrow site are commonly calculated by multiplying differences in elevations surveyed along profile lines by some spacing factor between the profiles. Both land and hydrosurvey techniques are often used and errors in the volumes calculated are usually the result of inaccurately measured elevations or locations, and by inadequate profile spacing. Improvements in equipment are gradually reducing the measurement errors and are providing for quicker data collection as Nevertheless, considerations of time and costs often result in well. surveys with fewer profiles than needed for areas of irregular topography. For example, the self-loading suction barge used at Rockaway (1977) changed the fairly smooth bottom topography of the offshore borrow site into a surface irregularly dotted with cone-shaped depressions of varying diameter and depth (up to 6 meters deep). Obtaining an adequate estimate of the volume of sediment dredged in this case would have required that more profiles be surveyed than would have been possible during the time available to the crews assigned to the project.

<u>Plant Production</u>: Although slurry concentration and slurry flow meters are available for dredging plants, this equipment is seldom installed on American dredges. Determining production values therefore requires estimates of these factors which are usually provided as a slurry density constant for particular types of sediment (sand, silt, etc) and rating values for pump performance in clear water. No general factors are applied to account for density changes caused by variations in texture, bottom firmness, topography, and the like, nor for factors that affect the pump such as water depth or the degree of impeller wear. The result is that a competent leverman knows how to maintain a dredge's efficiency by watching his suction and engine performance gages but it is extremely difficult translating this kind of efficiency into actual volumes of sediment dredged, or lost, during a filling operation.

<u>Hopper Loads</u>: These kinds of data are fairly accurate with volumes determined from the number of containers filled (hoppers, scows, etc) or from the mass of sediment loaded into a container as metered by displacement-types of equipment. Although bulking and density changes can often be determined, these volume estimates still give no method for determining the total volume of solids lost overboard during the filling process. Clearly, alternate methods to surveying, plant production and load metering are desirable for calculating more accurate estimates of the volumes of sediment dredged and lost during handling.

HANDLING-LOSS MODEL

Comparing the properties of grain size distributions provides another method for estimating handling loss volumes. Losses are mostly from the finer grain sizes of a sediment and occur because the fines are carried away with the fluid phase of a dredged slurry to leave a coarser sediment in the hopper or on the beach. Only sizes small enough to be transported by fluids at the velocities present are removed. The result

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should be that the smallest sizes are most affected and that losses should progressively decrease with increasing grain size until a critical size is reached that is too large to be transported. All grains larger than the critical size should therefore be retained and their relative proportion increased in the resulting gsd as compared to their proportion in the gsd of the pre-dredged sediments. These relationships lead to the following handling-loss model.

During dredging it is assumed that all sediments encountered on the bottom are picked up by the dredge head so that the volume dredged from the bottom (V_B) equals the sum of the volumes placed (V_P) and lost (V_L) during handling. A simple mass-balance equation provides the relation

$$V_{B}F_{B}(\phi) = V_{p}F_{p}(\phi) + V_{L}F_{L}(\phi)$$
(1)

where ϕ is a measure of grain size (Krumbein, 1938) and F (ϕ) is the proportion of material coarser than ϕ in each gsd. It is assumed that all losses are due to elutriation, that abrasion is negligible, and that losses are restricted to particle sizes finer than some critical size (ϕ *). The result is that handling losses will effectively increase the proportion of sediments coarser than ϕ * in the gsd and that for these coarse sizes F_L (ϕ) is zero value so that equation (1) leads to the relation

$$\frac{V_{\rm B}}{V_{\rm p}} = \frac{F_{\rm p}(\phi)}{F_{\rm p}(\phi)} = K , \qquad (2)$$

where K is a constant reflecting the proportion of material lost. Therefore, inspection of the ratios of cumulative frequencies for all sizes coarser than ϕ * should be fairly constant (Figure 4) and the percentage volume lost is given by

$$V_{\rm L} = (1 - \frac{1}{K}) \times 100.$$
 (3)

Evaluation of the Model: The textural data describing sediments collected during the handling-loss experiments were used to evaluate the model. The results of this evaluation are summarized as Table II. Figure 5 is presented as a typical plot of gsd ratios and is for the cumulative size distributions of barged and bottom sediments (Figure 3) collected at New River (1978). In general, the ratios of gsd's for each pair of composites plotted like those in Figure 5 and showed the kind of pattern predicted by the model (Figure 4) of fairly constant frequency ratios for an initial range of coarse sizes followed by a gradual decrease of the ratios to unity as grain size became finer. The only real variation to this pattern is that on some plots, the gsd ratios were quite variable (of both low and high value) for the very coarsest grain size fractions. These "irregularities" are interpreted to mainly reflect sampling errors as they usually occurred when cumulative weight percentages were less than five percent which is in that portion of a gsd where a very few grains constitute each size fraction and where grain number is easily affected by splitting and sieving operations. Nevertheless, the presence of these fluctuations had little effect upon the calculated K-values (loss constants, Table II).



FIGURE 4 Relationship of K and ϕ^* for schematized plot of ratios of gsd's for bottom, F_B() and pumped, F_P(), sediments as predicted by the proposed handling-loss model (for case of K=1.3 representing a 23 percent volume loss).

New River Inlet, NC (1978)



FIGURE 5 Observed ratios between gsd's for barged and bottom sediments, New River, 1978.

	¢* Critical Size (mm)	K Constant of Loss	V _L Estimate of Loss	Increase in Mean (mm)
BOTTOM VS PLACED				0.74
Rockaway 1975	0.39	2.10	52%	0.14
BOTTOM VS BARGED				
Rockaway 1975	0.33	1.71	42%	0.12
Rockaway 1977	0.55	2.96	66%	0.19
New River 1976	0.92	2.70	63%	0.47
New River 1978	0.46	2.33	58%	0.39
BARGED VS PLACED Rockaway 1975	0.46	1.23	19%	0.02
AVERAGED VALUES	0.52	2.17	50%	0.22

TABLE II Critical Size (ϕ^*), Loss Constants (K's) and Volume Loss estimates (V_L's) predicted by the proposed handling-loss model for Rockaway Beach and New River studies (Mean grain size increases also shown).

The data presented in Table II Suggest that handling losses for the cases studied: (a) tend to increase the average size of sediments handled by about 0.2 millimeters; (b) are from grain sizes finer than about half of a millimeter; (c) and average about 50 percent. The first suggestion simply reports those changes observed during the field studies. The second suggestion comes from estimates of the critical grain size (ϕ^*) determined from plotted gsd ratios and this suggestion is generally supported by inspection of the grain size distributions for three overwash samples collected during the studies. In these cases, 95 percent of the samples overwashed were finer than 0.64 mm (vs $\phi^* = 0.92$ mm) at New River (1976), finer than 0.50 mm (vs $\phi^* = 0.46$ mm) at New River (1978). The third suggestion of fifty percent handling losses is

at least twice that expected and claimed during dredging operations at Rockaway (Nersesian, personal communication, 1977).

The discrepancy between handling loss volumes predicted by the proposed model versus losses estimated during construction may reflect inadequacies in the model, problems associated with sampling and analytical procedures,or possibly, greater losses do occur during project construction than have been generally recognized. A few different models have been examined which, using these same textural data, have not significantly narrowed the gap between predicted and estimated losses. New field studies are generally needed to collect adequate data for evaluating most other models.

The textural properties of nearshore zone sediments are typically quite variable over short distances and thus sampling procedures should be considered as possibly contributing to the textural differences found between bottom and dredge-modified sediments. Sampling procedures that might affect textural properties include the number and spacing of sample locations, the type of samples collected (e.g., surface vs. cored samples) to characterize sediment sources (bottom, barged, or placed), and the kind of equipment used to collect the samples. Evaluation of these procedures used in the studies reveals a need to investigate potential losses of fine sizes during core sampling operations and the desirability of increasing the bottom sampling density in future studies where suction, drag head plants are used to dredge over fairly large areas. Still it is tentatively concluded here that elements of sampling have not significantly affected the results of these dredgeloss studies since results from each study are similar in type and magnitude even though the sampling procedures varied from study to study.

Perhaps handling losses are greater than generally recognized. Potential errors in calculating sediment volumes using survey, production and hopper load data have been noted but no reasonable explanation is apparent for why these kinds of errors would consistently minimize losses. Other explanations are needed.

One possible explanation for the discrepancies in loss estimates is that handling operations not only cause sediment losses but that they also change the internal arrangement of dredged sediments in a way that creates a false impression of dredged volumes. For example, Turnbull and Mansur (1974) have shown that dredging tends to decrease the bulk density of sandy sediments in cases where the material is not well drained (as in hoppers below the water line?) whereas Poulos and Hed (1973), and Youd (1973), showed that the volume of solids in clean sands decreased with improvements in sorting and decreases in angularity, respectively. These relationships were applied using the Rockaway (1977) samples and the results are summarized in Table III.

Relative densities of the sediment sources at Rockaway (1977) were not measured in the field and thus estimates of their values are required for the following calculations. A relative density of 50 percent is assigned to the barged sand which is the average for hydraulically-

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placed fills as measured by Paulos and Hed (1973), and a 78 percent value is calculated for the bottom sediments in-place that have been assigned a void ratio of 0.40. The percent of solids per unit volume of sediment determined using these relative densities is 64 percent for the barged sediment versus 71.4 percent for the sediment in-place. Volume differences like the 7.4 percent shown in this example would not be apparent during the construction phase of a beach fill but could become quite important at a later time when this uncompacted material was under attack by storm waves.

	Roundness (Powers, 1953)	Uniformity Index	Maximum Void Ratio (Youd,1973)	Minimum Void Ratio (Youd,1973)
Bottom Sand	0.37	3.00	0.62	0.34
Barged Sand	0.33	1.91	0.77	0.38

TABLE III Textural and Bulk properties of bottom and dredged (barged) sand collected at Rockaway Beach, NY, 1977.

Increased handling losses of 5 to 10 percent don't equalize volume losses estimated during construction with those predicted by the model. For Rockaway (1977) the predicted losses (model) are at least double those claimed during construction. Nevertheless, it is clear that many factors affect the volume of handling losses such as changes in textural and bulk properties and that interrelationships among these factors are not well understood even though they affect both the design and the economics of a beach fill project.

CONCLUSIONS

The following remarks summarize results, to date, of investigations of handling effects upon sediment properties and beach fill design. These investigations are part of an effort that will continue and that will hopefully explain those problems that remain unsolved.

1. Significant changes in sediment texture are caused by dredging and handling operations. For all cases studied, the winnowing (elutriation) of finer sizes produced a dredged sediment that was coarser (0.22 mm average increase) than bottom sediments. Sorting values decreased in some cases (Rockaway) and increased in others (New River).

2. Textural changes produced through handling can effect the estimates of overfill and renourishment elements of beach fill design. In all cases studied, the changes improved the predicted performance of sediments as beach fill. 3. Traditional methods of measuring beach fill volumes (surveys, plant production records, and hopper load measurements) often provide unreliable results and therefore, a need exists for improved or alternate methods.

4. A handling-loss model that compares textural differences between dredged and bottom sediments provides handling-loss estimates that are approximately double the losses estimated using the methods listed in item 3 above. These discrepancies are being evaluated by testing alternate handling-loss models, by evaluating different sampling procedures, and by considering mechanisms that explain handling losses of the magnitudes shown with the model.

5. Changes in the bulk properties of sediments caused by dredging can affect sediment volume calculations. These changes warrant further investigation as they may well affect the sediment's performance as beach fill.

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