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BEACH FILL CONSTRUCTION USING SEABED REHANDLING AREAS

Kevin R. Bodge, Ph.D., P.E.[1]

Abstract: Use and design of nearshore sand rehandling areas is described for two beach nourishment projects in Florida. The method allows hopper dredges to dump sand from a distant borrow area into a designated seabed area, from which a cutterhead dredge transfers the sand to the beach fill site. A 0.6-m deposit of dredged sand is maintained and left atop the seabed to buffer ambient non-compatible sand from the fill sand. This optional construction method represented the least-cost bid in the two projects for which it was offered. The construction process is contrasted with a design-build hopper dredge pump-out project that was built simultaneously, using the same borrow area, as one of the rehandling projects. In this case, overall fill productivity was higher and costs were cheaper for the rehandling option; and turbidity and grain size changes were similar. Applicability and benefit of the rehandling option will vary by project.

INTRODUCTION

This paper summarizes the design and performance of a sand rehandling method for beach fill construction. The method is an alternative to hopper dredge pumpout for projects where the borrow source is far from the fill area. It entails *double*-handling the material using a seabed staging (rehandling) area. Specifically, sand is dredged from an offshore borrow area and bottom-dumped to a designated stockpile area on the nearshore seabed by hopper dredge. From there, it is rehandled and pumped onto the beach by conventional cutterhead pipeline dredge. Contrary to intuition, this rehandling approach can yield more efficient, and less costly, construction in certain circumstances relative to conventional, direct hopper dredge pump-out.

The rehandling concept endeavors to make maximum efficiency of the dredging equipment and fleet. Specifically, hopper dredges are efficient at picking up sand and dumping it. Cutterhead dredges are efficient at continuous transfer and placement of sand. Their *combined* use can potentially improve (speed) production. Further, the demand for hopper vs. cutterhead dredges changes throughout the year;

[1] Vice-President, Olsen Associates, Inc., 4438 Herschel Street, Jacksonville, FL 32210 USA
kbodge@olsen-associates.com

and the opportunity to employ various pieces of otherwise idle dredge plant allows the contractor to optimize the fleet's schedules. In one case described below, for example, it allowed the contractor to begin dredging (and seabed stockpile) of the fill prior to the start date allowed by environmental regulations for placement of fill onto the beach. This enabled the contractor to utilize hopper dredges that were otherwise idle prior to the beginning of the environmental window for beach construction.

The paper describes the use of a rehandling area for two federal beach fill projects. Use of the rehandling area was at the contractors' option. In both cases, its use represented the least cost bid – and was ultimately employed for construction. Both projects were located along Florida's central Atlantic Ocean shoreline, just south of the U.S. Space Launch Facilities at Cape Canaveral, in Brevard County, Florida (Figure 1).

PROTOTYPE EXPERIENCE

The two projects utilizing seabed sand rehandling areas for construction included the North Reach and South Reach segments of the Brevard County Federal Shore Protection Project. The projects were built in 2000/01 & 2002, respectively, under separate contracts. A third beach fill project was also built along Patrick Air Force Base (PAFB) in 2000/01 immediately adjacent to, and concurrent with, the North Reach project. The PAFB project used the same offshore sand borrow area as the North Reach, but employed direct hopper dredge pumpout instead of the rehandling option. As such, it provides a useful comparison to the rehandling operation.

North Reach and Patrick AFB Projects (2000/01)

The 2.1 million cubic meter (mcm), 15-km long North Reach beach fill was managed by the U.S. Army Corps of Engineers, for which Brevard County, FL was the local sponsor. The 0.4 mcm, 5-km long Patrick AFB beach fill was a separate U.S. Air Force project built under private contract. (The author was the coastal engineering consultant for Brevard County and the Engineer of Record for the PAFB project.) Both projects utilized the Canaveral Shoals II sand borrow area, in federal waters, located amidst the extensive sand shoals offshore of Cape Canaveral. This borrow area was over 10 to 25 km from the boundaries of the two fill areas. (At the time of construction, the Space Coast Shoals II borrow area shown in Figure 1, offshore off Patrick AFB, had not yet been fully developed. Its use was intended for the South Reach project in 2002/03.)

The construction contractor for both projects was Great Lakes Dredge and Dock Company (GLDD). The contractor elected to utilize the rehandling area for construction of the North Reach. The Patrick AFB fill, however, would have required between 7.5 and 12 km of pipeline from the permitted rehandling area to the fill area, and therefore would have required a second booster pump for the cutterhead dredge. The contractor instead elected to construct the PAFB fill by hopper dredge pumpout.

Ultimately, GLDD utilized 2100 m^3 (Island Class) hopper dredges for both projects, often operating two at a time. The 81 cm (32") cutterhead pipeline dredge *Alaska* was used to rehandle the sand to the North Reach fill area. The hopper dredges commenced loading the rehandling area at 2 a.m. on the first day of the Notice to Proceed for the North Reach project, about 45 days prior to the arrival of the *Alaska*.

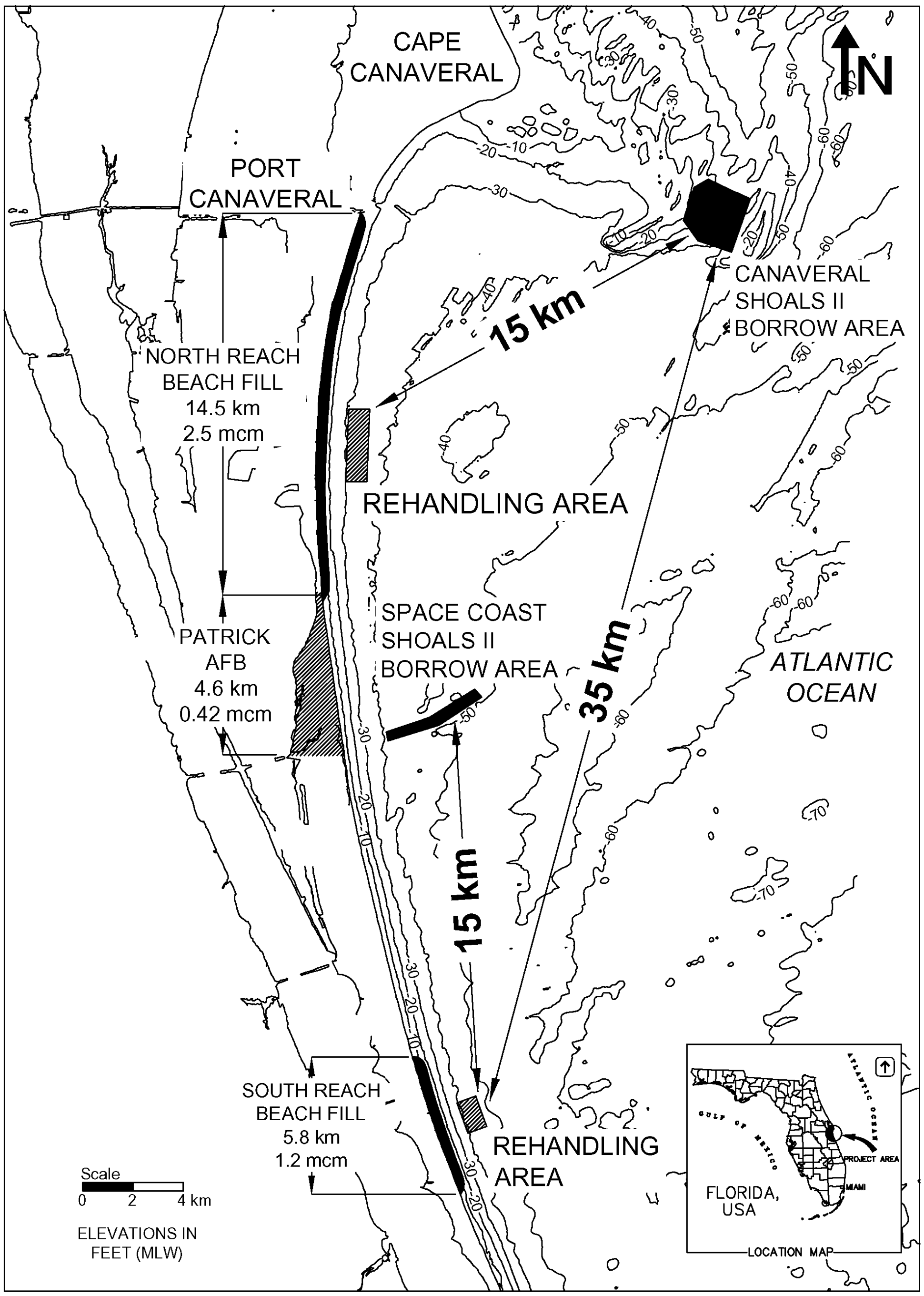


Figure 1. Location Map.

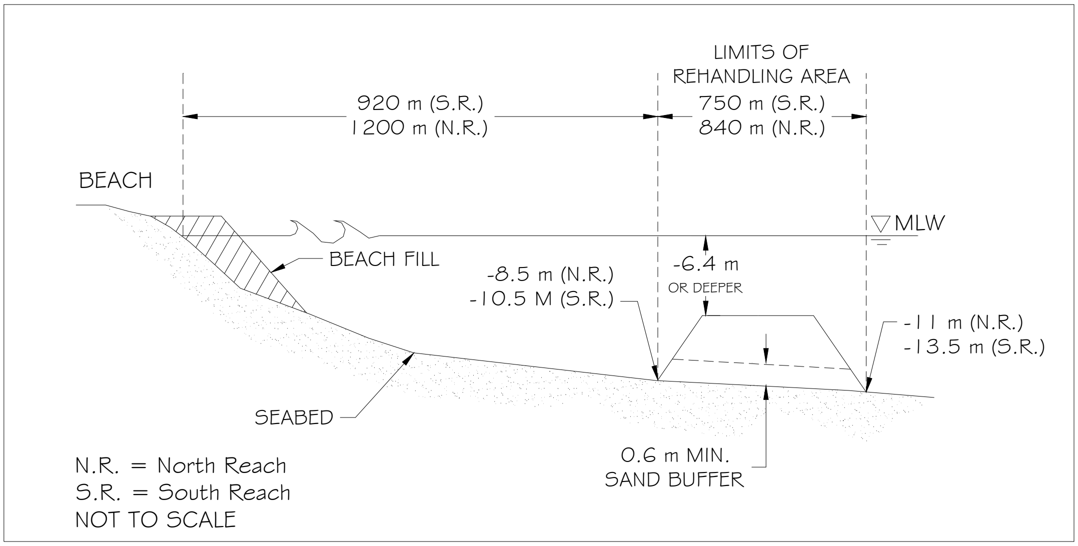


Figure 2: Profile depiction of the nearshore rehandling areas for the North and South Reach beach fill projects.

The permitted limits of the North Reach rehandling area were 840 x 2900 m, in mean low water depths of 8.5 to 11 m, about 1200 m from shore (Fig. 2). On center, the borrow area was about 17 km from the rehandling area. The maximum specified stockpile elevation was -6.4 m or deeper. Tides are 1.2 m mean range.

Because the ambient seabed consisted of non-beach compatible silty sand, use of the rehandling area required the contractor to build and maintain a 0.6 m (2-ft) buffer atop the seabed of clean sand dredged from the borrow area. This was a condition of the environmental permits and subsequently the job specifications. No payment was made for this buffer, or for any material placed in the rehandling area. Payment was solely made for sand placed within the construction template, on the beach.

Figure 3 depicts a typical seabed profile at the rehandling area prior to, during, and after construction. The contractor surveyed the area continuously to monitor and direct the loading, and unloading, of the disposal area and to ensure compliance with the seabed buffer requirement. The environmental permit (and ultimately the specifications) formally required the contractor to survey and submit profiles at 75-m line spacing and 45-day (max.) intervals during construction, for compliance review. From Figure 3, the sand stockpile in the rehandling area reached about 3.8 m height above the seabed (December 2000). The figure also illustrates the requisite 0.6 m buffer of sand left in the rehandling area after construction (April

2001). Neither the periodic surveys nor the contractor's observations indicated any significant migration or losses of the material associated with the rehandling area.

In planform, the contractor used two sub-areas, each measuring about 43 Ha (106 acres), out of the total 244 Ha (600 acres) disposal area, in order to conduct the rehandling operations. One area served the southern third of the fill, and the other served the remainder. Use of the two areas, separated by about 600 m, also helped to minimize potential conflict during simultaneous hopper and cutterhead dredge activity.

Post- versus pre-construction surveys for the North Reach indicated that approximately 3.25 mcm were dredged from the borrow area, 661,000 m^3 remained in the rehandling area, and 2.45 mcm were placed on the beach. That leaves 142,000 m^3 unaccounted for, neglecting survey error, and suggests handling losses of 4.4% (vs. dredged) to 5.8% (vs. fill). These values, which are consistent with the contractors' estimates, reflect very low loss rates. This is presumably due, in part, to the fairly coarse nature of the material (see below); but it also indicates that the rehandling operation did not result in atypically high handling losses.

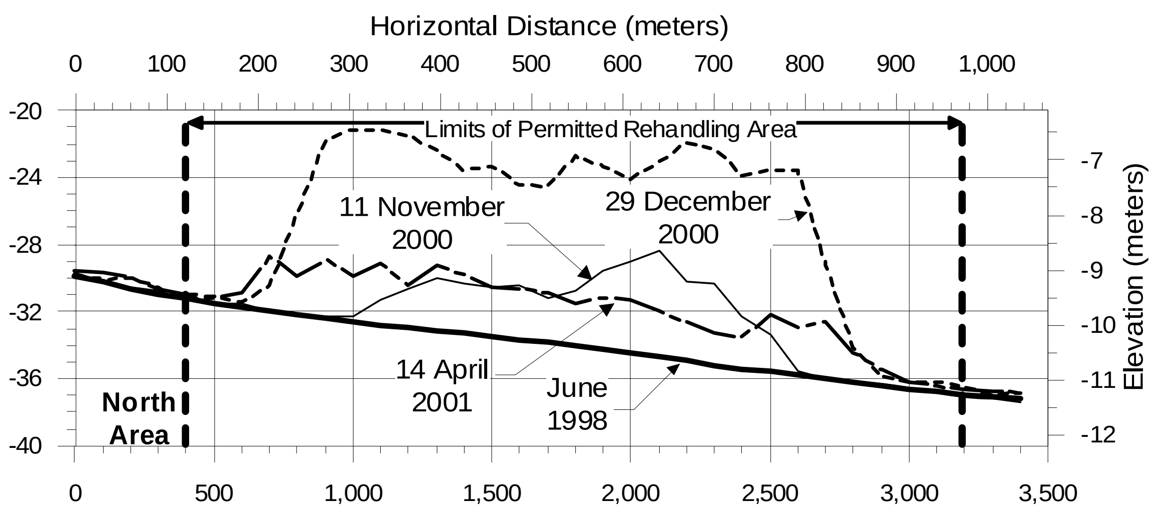


Figure 3: Typical cross-shore profile surveys across the North Reach rehandling area, prior to, during, and after construction (June 1998 through April 2001, respectively).

Implementation of the Patrick AFB beach fill project was by a private-sector firm, Amec Earth & Environmental, Inc. The Air Force tasked the firm to design, permit and construct a USD$5M beach fill along the Base shoreline beginning south of the North Reach project. The Notice to Proceed was issued one day after the hopper dredges began dredging for initial construction of the North Reach beach fill. Using a modified design-build approach, and by making maximum advantage of the ongoing North Reach work and through modification of prior environmental permits, Amec and GLDD brought the Patrick AFB beach fill project to construction within *57 days* after the Air Force's NTP.

Upon commencement of the PAFB project, dredging for the North Reach fill was mostly segregated from that for PAFB within the single borrow area. Core borings showed no significant difference in sediments across the borrow area. Pre- and post-construction surveys for the PAFB fill indicate that between 430,000 and 450,000 m^3 were dredged from the borrow area, and 413,000 m^3 of fill were measured in-place on the beach. This suggests loss rates of 3% to 9%, which are very similar to those for the North Reach project constructed using the same material via the rehandling area.

<u>Productivity.</u> The North Reach project was principally constructed between October 1, 2000 and April 9, 2001, with transfer of sand from the rehandling area to the beach commencing November 13, 2000. A fixed booster was used, and the initial submerged pipeline landing was moved twice during construction. Pipeline lengths ranged from 1,800 m to a maximum of 7,900 m. A second booster was added (borrowed from the PAFB job) when the pipe exceeded about 6,600 m. At short pipe lengths, maximum daily rehandling production reached 38,000 m^3/day nearest the rehandling area. The overall, average job productivity of beach fill placement was 19,600 m^3/day. This included down days for weather and equipment delays. The average rate at which sand was loaded to the rehandling area was about 11,000 m^3/day.

Because of its large size (2.14 mcm) and distance from the borrow area (over 15 km), the North Reach project was contracted for a two-year construction schedule. Beach fill placement in Brevard County is suspended from May 1 to November 1 to protect marine turtle nesting activity. The project, however, was constructed in a single season. Both the Corps and contractor attribute this to the high productivity achieved through use of the rehandling area. Ultimately, this resulted in further significant cost savings, beyond those described below, by elimination of second season mobilization payments. This also enabled the second phase (South Reach) of the project to be accelerated by one year, improved project performance by constructing a contiguous 14.5-km fill, and greatly improved the satisfaction of the project's Local Sponsor and general public.

The Patrick AFB project was constructed between Dec. 8, 2000 and April 12, 2001, with no work in the months of March and April, 2001. The borrow area was about 23 km from the fill area. Using hopper-dredge pumpout with floating booster, the average productivity of beach fill placement was about 7,600 m^3/day

Seas were typical to slightly higher than normal during the 7 months of construction. By offshore buoy measure, seas exceeded 2 m for about 980 hours (41 days equivalent) during construction -- compared to an average, 13-yr historical occurrence over the same months of 795 hours. Seas exceeded 1m for about 3,500 hours during construction versus the average historical occurrence of about 3,370 hours. In seas near and greater than 2 m, when neither cutterhead dredge nor hopper dredge pumpout operations were possible, the hopper dredges were able to continue peforming useful work by loading the rehandling area.

Sediment. The offshore borrow area consisted of a fairly homogeneous coarse sand, with median diameter of about 0.36 mm and negligible fines. By burn, the mineralogy is about 40% carbonate and 60% silica. A total of about 60 samples collected from along the constructed berm showed negligible differences in the fill material's in-place grain size between the two projects -- despite the difference in their construction techniques. Both projects showed the same slight coarsening of fill relative to the (vibracore) samples of the borrow area. Limited samples of the material from within the hopper dredge, in transit from the borrow area, also showed the same slight coarsening and closely matched the in-place berm samples.

Figures 4 and 5 contrast the average measured grain size distributions of the material. The comparison suggests that there was a minor loss of fine sand fraction in the 0.1 to 0.2 mm range, but the loss was consistent between the rehandling and direct pump-out construction methods. This loss appears to be associated with the initial dredging at the borrow area. As noted above, the computed handling losses for both projects were similar and fairly minor.

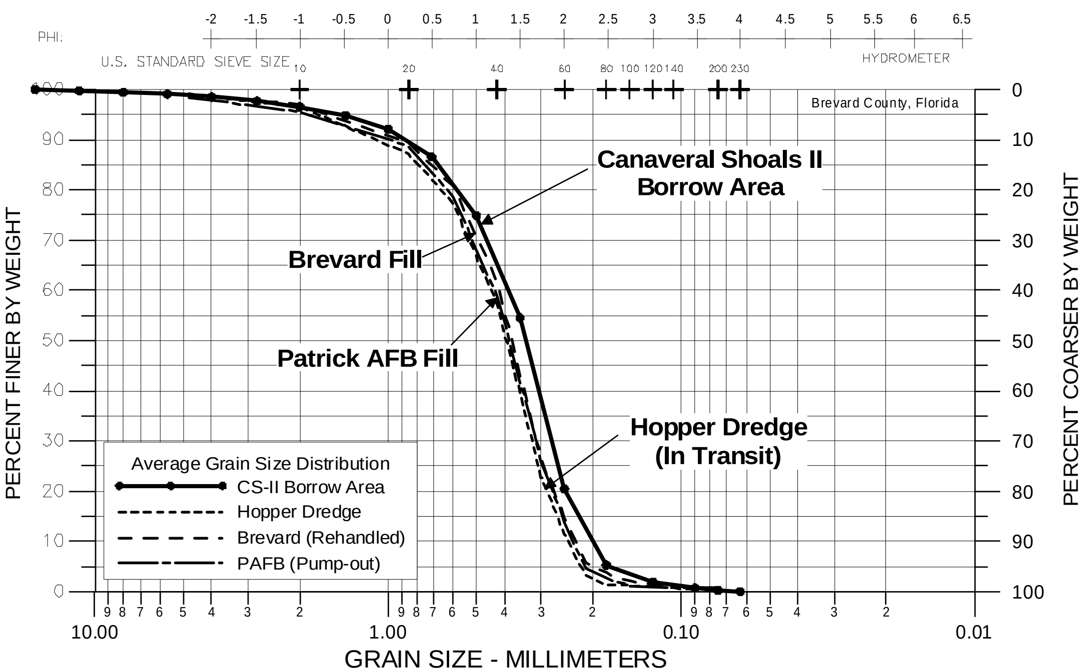


Figure 4: Composite, cumulative grain size distribution of the beach fill material measured at the borrow area, in the hopper dredge, and as placed along the beach.

Turbidity. There were no statistically significant differences in turbidity between the two construction techniques, nor as measured from one point to another in the construction sequences. Background turbidity levels in the area typically average about 5 nansen turbidity units (ntu), with about 4 ntu standard deviation. On average, construction-related turbidity above background was as follows:

Borrow Area -- Dredging:	2.7 ntu
Rehandling Area -- Disposal:	2.2 ntu
Rehandling Area -- Dredging:	1.9 ntu
Beach Fill -- Rehandled:	2.9 ntu
Beach Fill – Hopper Pump-out:	3.9 ntu

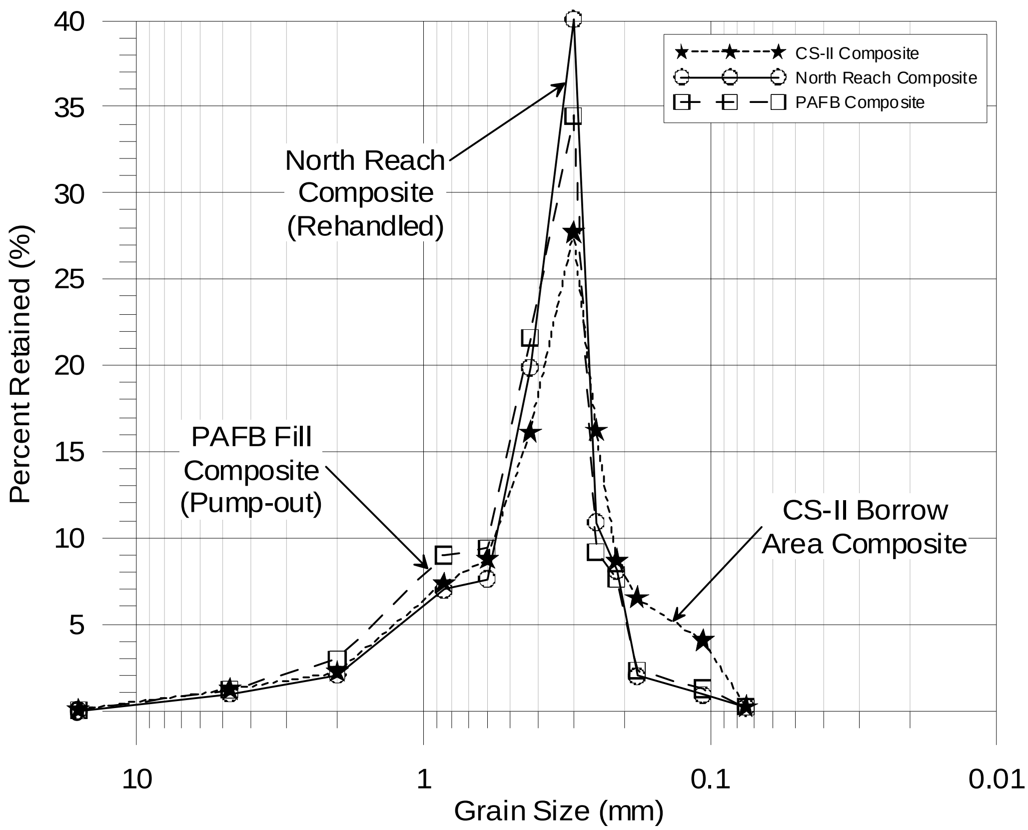


Figure 5: Composite grain size distribution for the fill material as sampled at the borrow area and along the constructed beach nourishment projects.

<u>Construction Costs.</u> Three proposals were received for the North Reach project. The least-cost, by GLDD, was the only one to propose use of the optional rehandling area. Mobilization costs were USD$2.16M plus $\$8.92/m^3$ unit cost, for an equivalent cost of $\$9.95/ m^3$. This was about $\$0.57/m^3$ less than the competing bids; amounting to about $1.2M in total.

The negotiated cost for the hopper dredge pumpout fill at Patrick AFB was USD$0.65M mobilization plus $\$10.68/m^3$ unit cost, for an equivalent total cost of $\$12.27/ m^3$. This value is about 23% greater than the North Reach project; however, direct comparison is not necessarily valid because the volume of the PAFB fill was only 1/5th that of the North Reach fill.

South Reach (2002)

Satisfied with the performance of the rehandling area for the North Reach phase of the Brevard County Shore Protection Project, an optional rehandling area was then developed and permitted for the South Reach phase. The South Reach fill consisted of a 6 km long, 1.2 mcm beach fill located about 36 km from the Canaveral Shoals II borrow area used for the North Reach, and 16 km from an additional, small borrow area (Space Coast Shoals II) developed specifically for the South Reach. See Figure 1.

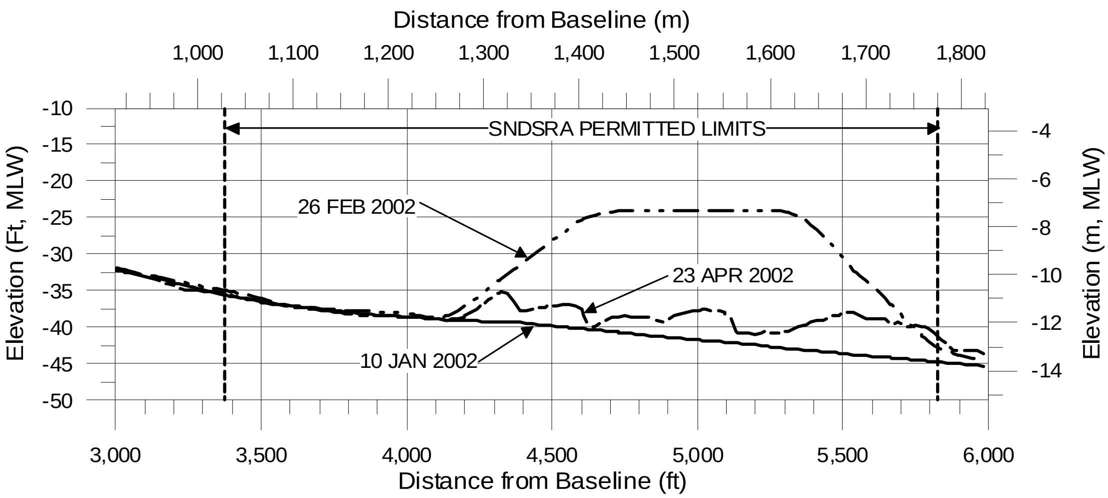
The rehandling area for the South Reach was about 1370 m alongshore by 750 m cross-shore, about 900 m offshore, and located at the project midpoint. See Figure 2. This resulted in maximum pipeline lengths of about 4600 m (15,000 ft) or less, with the intent of eliminating the need for a booster. A minimum 0.6-m buffer of clean dredged sand was again required to be placed and maintained above the ambient silty seabed.

Relative to the North Reach, the steeper nearshore depth contours allowed the South Reach rehandling area to be nearer to shore but in greater water depths: -10.5 to -13.5 m mlw. The maximum sand stockpile elevation was again specified as -6.4 m or deeper. This potentially allowed the contractor to construct a higher stockpile berm (with greater bank cut and lesser sand buffer volume) or to maintain greater working depths for the hopper and cutterhead dredges. This choice was left to the contractor.

GLDD submitted the lowest cost of the three bids received for this 1.26 mcm fill project, and was awarded the contract by the Corps. The GLDD bid proposed use of the rehandling option, while the other two bids proposed hopper dredge pump-out. The GLDD bid was USD$1.22M for mobilization plus $9.47/m^3 for an equivalent cost of $10.47/m^3. The second bid was $1.05M for mobilization plus $10.80/m^3 unit cost for an equivalent cost of $11.66 /m^3. The third bid equated to $13.07/m^3.

The GLDD bid using the rehandling area was thus about $1.20/m^3 less than the next lowest bid, which proposed conventional pump-out; or, about USD$1.5M less overall. Of course, competitive bid values are based upon many complex factors, and like the North Reach, it is not accurate to say that this cost savings was solely due to the use of the rehandling area. It is noted, however, that the least cost bid in both the North and South Reach projects was via use of the rehandling option – thus demonstrating that the method can be less costly than hopper pumpout, at least in certain circumstances.

Figure 6 depicts a typical profile through the South Reach rehandling area prior to, during, and after construction. The profile from Feb 2002, after loading of sand and prior to cutterhead transfer to the beach, depicts actual actual highresolution bathymetric survey data of the sand stockpile. This profile shows the precision to which the contractor was able to construct and maintain a coherent berm of 5 to 6 m typical height in preparation for the rehandling operation. The profile



after rehandling (April 2002) depicts the 0.6 m minimum buffer left upon the seabed. In planform, the contractor used about 28 hectares (69 Ac) of the 103 Ha (253 Ac) permitted rehandling area.

Figure 6. Typical seabed profile across the South Reach rehandling area prior to, during, and after construction (Jan 2002 to April 2002, respectively).

Work on the beach was suspended from May through October to protect the area's intensive marine turtle nesting activity (>300 nests/km). The contractor is expected to return after November 2002 to complete the remaining 25% of the beach fill. The permits presently allow loading of the rehandling area to commence in October.

REHANDLING AREA DESIGN

In laying-out a rehandling area, principal design considerations include:

- Sufficient area for the requisite fill volume and potential simultaneous operation of the hopper & cutterhead dredges;
- Maximum specified berm elevation to ensure stockpile stability and ample underkeel depth for hopper dumping and adequate declination angle of the cutterhead ladder;
- Seabed depth that provides an ample stockpile height for a productive bank cut above the buffer (if any), yet still as close to shore as possible to minimize pipeline head loss;
- Lack, or minimization, of impact to sensitive environmental resources.

Toward ensuring that the stockpiled sand berm would be stable during construction, the empirical technique of Hands & Allison (1991) was used to predict the maximum height of the berm crest. In this technique, one calculates the percent occurrence of the nearbed horizontal wave orbital velocity, from hindcast wave data, for a given water depth. The exceedence probability of the computed velocities are plotted and compared to an empirical curve prepared by Hands & Allison. Shallower depths, or higher velocities, will yield a curve falling further into their range ascribed to “active” berms (meaning that that the placed sand may tend to migrate or disperse during typical hindcast wave activity). Greater depths, or lower velocities, will yield a curve falling further into their range ascribed to “stable” berms.

For both the North and South Reach projects, the interim point between “active” and “stable” berm was computed to be about 6.5 m depth. This was then specified as the shallowest elevation (mean low water) to which the stockpiled sand could be constructed. This approach had been previously applied in the North Reach area in 1992 to identify seabed depths at which to create an *active* nearshore “feeder” berm for beneficial disposal of maintenance dredged material from the Canaveral Harbor Federal Navigation Project. Monitoring of the subsequent disposal in 1992/93 showed the Hands & Allison technique to yield accurate results (Bodge, 1994).

To ensure a productive bank cut for the cutterhead, the seabed depth should be at least 3 to 4 m below the specified maximum berm height. A *minimum* total work area of about 100 Ac (40 ha) is recommended, although a total permitted area that exceeds this by 2 or 3 times should be developed. For the medium and coarse sand used in the projects described above, the natural side slopes of the stockpile mound were about 1:22. Finally, at least in the 70 to 81 cm (30 to 32 inch) dredge class and for medium/coarse sand, an ideal goal is to site the rehandling area such that the total maximum pipeline length is less than about 4900 m (16,000 feet) to avoid requisite use of a booster pump.

CONCLUSIONS

For the two prototype projects described above, use of an optional nearshore rehandling area represented the least-cost bid relative to conventional hopper-dredge alternatives, and contributed to cost savings of well over USD$2M in total. The method cut a year off the construction schedule of the largest of the two projects.

The grain size characteristics of in-place fill constructed by rehandling and by direct hopper dredge pump-out, both dredged from the same borrow area, were essentially identical. Handling losses and turbidity measurements for both construction methods were similar and low (about 5%). The predictive method of Hands and Allison (1991) provided an accurate means by which to compute and specify the maximum berm elevation of the sand stockpile within the rehandling area. Overall, there were no adverse physical effects observed from the rehandling operation, and the dredging contractor and the client were both pleased with the progress and ultimate performance of this construction approach.

The degree to which a sand rehandling area may benefit beach fill construction in those cases where the borrow area is distant from the fill area will depend upon many factors. It is the experience of the projects described above, however, that presentation of this construction option to the dredging industry – where practicable – can potentially result in more economically and physically efficient beach fill construction in certain circumstances.

ACKNOWLEDGEMENTS

The concept, permits and physical parameters of the rehandling areas described above were developed under contract to Brevard County, Florida, Natural Resources Management Office under the supervision of Ms. Virginia Barker, and with support of the Canaveral Port Authority and the Florida Department of Environmental Protection (FDEP). The U. S. Army Corps of Engineers, Jacksonville District is gratefully acknowledged for its willingness to include elective use of the rehandling area in the projects' NEPA, bid and construction documents. Funding for construction of these projects was provided by the U. S. Army Corps of Engineers, Brevard County Tourist Development Council, FDEP, and the U. S. Air Force through contract with the Air National Guard. The support of the U. S. Dept. of Interior, Minerals Management Service, is acknowledged for the projects' use of the Canaveral Shoals sand borrow area.

REFERENCES

Bodge, K. R., 1994. Performance of Nearshore Berm Disposal at Port Canaveral, Florida. *Proceedings, Dredging '94*. ASCE.

Hands, E.B. and Allison, M.C., 1991. Mound Migration in Deeper Water and Methods of Categorizing Active and Stable Depths. *Proceedings, Coastal Sediments '91*. ASCE, 1985-99.