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TECHNICAL COMMUNICATION

Bypassing and Backpassing at Harbors, Navigation Channels, and Tidal Entrances: Use of Shallow-Water Draft Hopper Dredgers with Pump-Out Capabilities

Per Bruun† and Gerard Willekes‡

†Hilton Head Island, SC 29928, U.S.A.

‡Bos Kalis Westminster & Stuyvesant Dredging Company Metairie, LA 70002, U.S.A.

ABSTRACT

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A port's success often depends upon maintenance of depths they provide. Major ports are located in rivers, estuaries, bays or lagoons, but a fair, and still increasing number of ports or terminals, have been established on open, often exposed, shores where the requirement for natural depths are more easily met. The increasing size and drafts of vessels raises questions of maintenance depths.

On the open sea coast, entrances to harbors and tidal inlets on littoral drift shores present major obstacles to natural longshore drift of sand causing extensive accumulations updrift and in navigation channels and heavy erosion downdrift. This paper first briefly reviews existing methods of maintenance and then concentrates on new procedures for bypassing of materials, combinations of bypassing and backpassing, and the associated economics.

ADDITIONAL INDEX WORDS: *Backpassing, bleach nourishment, bypassing, fluidization, jet-pumps, maintenance of navigation channels, shallow water hopper dredge.*

MAINTENANCE OF NAVIGATION CHANNELS

Maintenance or increase of depths to ports started with the development of dredging equipment. It was not until the 19th century that steam engines made it possible to use larger equipment including grab, bucket and hydraulic pipeline dredgers that were suited for hard, silt and sand bottoms, respectively. These techniques were improved gradually. Hydraulic dredging developed along two different pathways: (a) pipeline dredging where powerful pumps discharged material often several kilometers from the site of dredging and (b) hopper dredging where the material dredged was first stored in the hull of the vessel and then dumped through bottom doors in a disposal site (usually offshore). The latter method, of course, was particularly suitable for exposed navigation channels. Both fields have developed still more effective equipment and procedures.

Environmental concerns, however, raised important questions regarding disposal sites. For pipeline dredgers, the practical method of disposal was on land or elevated shoals. Both areas might be classified as "wetlands". As the biologically active wetlands are becoming endangered by sea level rise, such disposals have been met with increasing opposition. It is still practiced in countries which have an abundance of undeveloped coastal areas, like Argentina and Ecuador, or where the object is to gain land as practiced until very recently in many coastal states in the United States and in The Netherlands. With respect to ocean disposal, the original practice of just dumping where it was convenient has been replaced by a practice based on "selected sites"

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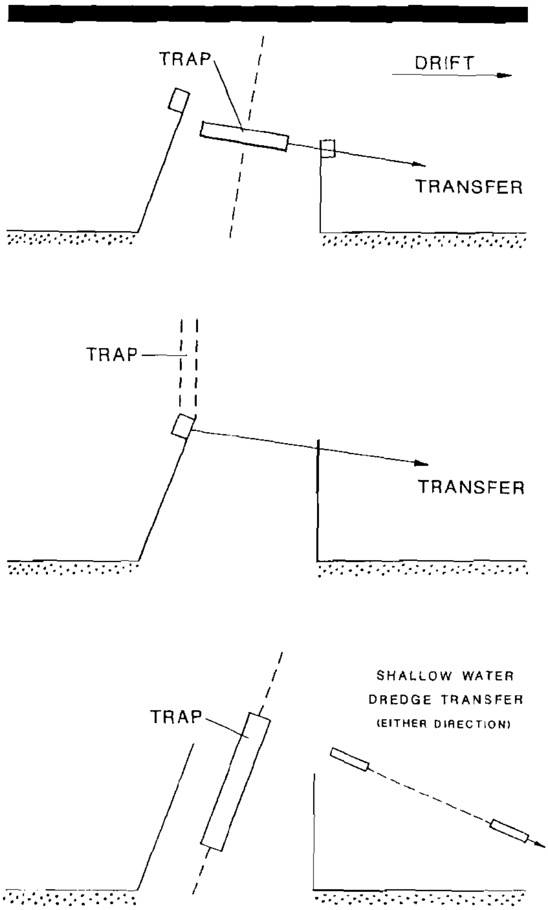

Figure 1. Schemes for bypassing using fluidization systems. (Note: Dashed lines represent fluidization pipes.)

dumping, i.e. in areas where the adverse effects on biological life is minimal. A number of international conventions on disposals exist (*e.g.* BRUUN, 1990b, Vol. 2, Chapter 10). In many cases the transfer of materials that are suitable for nourishment of beaches was established. In some states or countries, viz. Florida and Spain, it is now prohibited by law to dump offshore materials that are dredged in navigation channels. If the material is suitable for beach maintenance, it should be dumped on beaches adjacent to the navigation channel or inlet entrance (BRUUN, 1990b, Vol. 2, Chapter 10). This procedure has, however, raised a number of technical questions, some of which focus on existing bypassing procedures which are generally inadequate. Also, conventional backpassing methods using sand from the inlet channel for dumping on the beach and/or in the shallow waters need improvements.

The existing bypassing methods are based on conventional pumps operating with rather short boom intakes and/or floating conventional dredging equipment which, however, often lacks efficiency. BRUUN (1978, 1990a) gives a thorough review of bypassing plants and arrangements world-wide. Most of them operate at less than 50% efficiency, and some are down to 20–30%. The remaining material is then carried or jettied by tidal currents out of the entrance and left in bay or ocean shoals or on the bay or offshore bottom. The limited capacity of conventional procedures presents a practical engineering problem because the equipment presently available can't produce and maintain trap(s) of sufficiently large size that they will not be overpowered by extreme littoral drift events.

One recent solution to this problem featured jet-pumps that were placed in an array along a trestle built updrift of the Nerang River entrance in Queensland, Australia. The system now operates successfully when clogged intakes are kept clear of wood and steel debris. A lift and fluidization system seems to have added advantages. This modern bypassing is described by BRUUN (1990, Vol. 2, Chapter 9) who indicates how fluidization pumps may be applied to the establishment of large traps at the tip of an updrift jetty carrying the material to a central pump for transfer. Additional details are summarized in BRUUN and ADAMS (1988). This system may also be applied in navigation channels as 2–4 rows of pipes fluidizing material to a central trap for intermittent dredging and transfer. In this way a constant depth may be preserved in important transportation arteries eliminating shoaling problems and the associated nuisance to navigation.

Figure 1 shows various schemes of bypassing, including a double fluidization system with transfer from a trap placed crosswise in the navigation channel. The middle diagram in Figure 1 illustrates transfer from a large oblong trap placed in the extension of the updrift jetty and operated by jet pumps or fluidization pumps including transfer to downdrift beaches. The bottom diagram in Figure 1 shows the transfer from a major trap placed in the navigation channel and fed by fluidization pipes. The trap is emptied on an "as needed" basis by a shallow water hopper dredger with pump-out capability to downdrift beaches. The cost of transfers of quantities of the order of some hundred thousands of cubic yards per year range from \$3 to \$4/yard (\$4 to \$5/m^3). Prices by conventional methods are almost twice as high (Bruun, 1991). Used at tidal entrances, the shallow-water hopper dredgers are able to transfer material to either side, as no "downdrift side" exists in their operation. In a sense both sides are "downdrift"!

Operation is always based on sands, not on silts or clays which are useless for beach maintenance. These materials may still be fluidized to traps arranged in the channel. Because unconsolidated silts and muds are very liquid, traps may be spaced at greater intervals which, of course, is an advantage. Such traps may be emptied on an "as needed" basis by dredgers that can dispose the material at selected sites that are environmentally acceptable.

DUMPING PROCEDURES FOR BEACH AND NEARSHORE NOURISHMENTS

Figure 2 shows various dumping procedures as applied in the United States, Denmark and Australia. The problem with the U.S. procedure is that the steep deposit slope is extremely vulnerable to erosion. Because longshore and cross shore material transport increases with steeper slope angles, a single storm may therefore cause considerable erosion. As mentioned by Quick (1991), the situation is such that "although the beach slope changes can be quite moderate, it should be borne in mind that a small slope decrease represents a quite significant offshore movement of sediment that means a loss from the beach". The Danish method of "profile nourishment" of the beach and the very nearshore bottom leaves a more stable profile that is not as prone to rapid failure. The equipment used to produce such a cross section is described in the following.

The Australian method involves beach, nearshore dumping, and dumping by bottom doors or split-hulls in the offshore. The material subsequently spreads out on the bottom. This is the least expensive procedure. Prices vary from \$1.7–\$1.8 per cubic yard (\$2.3–\$2.5/m^3) for nearshore dumping to \$2.4–\$2.8 per cubic yard (\$3.1–\$3.6/m^3) for beach dumping, with the lower number referring to Australia and the higher to Denmark.

ECONOMIC ADVANTAGES OF COMBINING BYPASSING AT ENTRANCES WITH BACKPASSING TO SHORES

The economic advantages of the schemes shown in Figure 1 are three-fold: (1) For navigation there is always a stable channel. Deposits are cleared

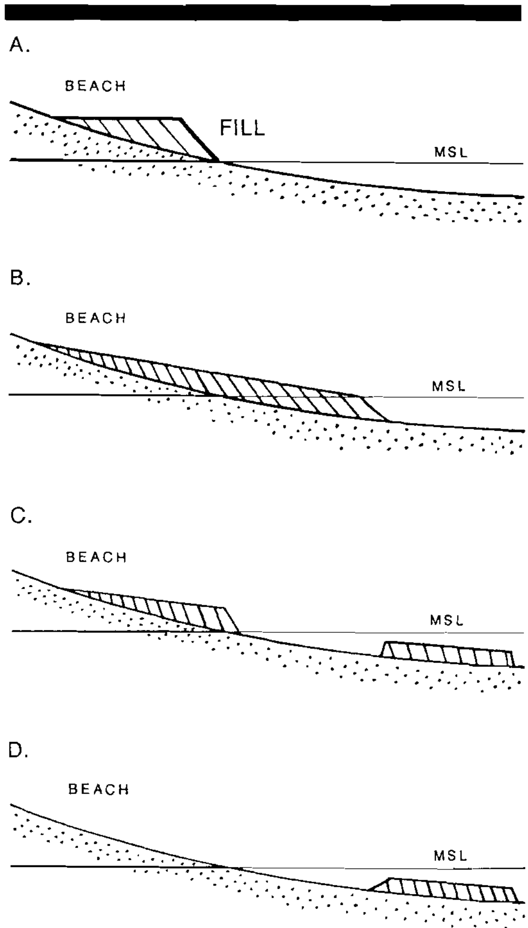

Figure 2. Procedures for placing materials in the nourishment profile. (A) Conservative American, (B) Danish "profile" (Netherlands, United Kingdom), (C) Australian "profile" (Queensland, New South Wales), and (D) U.S. Army Corps of Engineers.

from the channel by just pushing a button and the fluidization process starts immediately. (2) The material that accumulates in the traps is transferred directly to the downdrift beaches. Nothing is lost from the shore. (3) These maintenance procedures are less expensive than conventional methods.

The equipment needed for fluidization is *new by application,* but most recently it has been tested in the field by the U.S. Army Corps of Engineers at Oceanside, California. Dredging from traps certainly is not new, but the combination of bypass/backpass as described using a shallow-water hopper dredger is new. The U.S. dredging industry has demonstrated interest. The international dredging company Bos Kalis Westmin-

Figure 3. Nourishment by over-the-bow pumping as shown for a Danish beach, North Sea coast, 1989.

ster of The Netherlands through its American subsidiary (Stuyvesant Dredging Company of Metairie, Louisiana) in cooperation with the Florida Shore and Beach Preservation Association, the Florida Bureau of Shores and Beaches and P. Bruun developed prices for a number of alternatives ranging from 10 ft (24″ pipe), 12 ft (28″ pipe) to 14 ft (32″ pipe) drafts in load with annual capacities (45 weeks year) of 1 to 3 million cubic yards. These dredgers are able to dump over the bow or via a jet-pontoon (to bridge shallow nearshore areas, reefs or bars) (Figures 2 and 3). These dredgers have very powerful pumps and are highly maneuverable. The analyses undertaken to obtain prices have been comprehensive, involving beach and bottom profiles from a number of locations in Florida and the corresponding tides, wave action and inlet conditions.

Table 1. *Comparison of prices for large and smaller operations for beach and profile nourishments. Basic criteria: a = mobilization costs for equipment; b = unit price (as experienced); s = annual quantity needed; i = interest rate; T = period between operations; PV = present value cost of operation over planning period with determinisitic erosion.*

Large dredge	Smaller dredge
a = \$1 × 10⁶	a = \$0.1 × 10⁶
b = \$4/c.y.	b = \$2.45/c.y.
s = 150,000 c.y./year	s = 150,000 c.y./year
i = 12%	i = 12%
Using these figures one arrives at:	
T = 4.9 years	T = 28.4 years
PV = \$9.3 × 10⁶	PV = \$3.91 × 10⁶
Annualized to	
\$1.05 × 10⁶/year	\$0.475 × 10⁶/year

Source: From Bruun (1991)

RESULTS OF THE BOS KALIS WESTMINSTER STUYVESANT ANALYSES

Figure 4 (A,B,C) shows schematics of prices for 35, 40 and 45 week/year operations by 10 ft, 12 ft and 14 ft loaded draft vessels, indicating contract unit costs. Procedures are "over the bow" and "jet-pontoons" by short discharge pipes jetting directly onto the beach. The capacity of the 10 ft draft vessel is too low to give a low price. The 12 ft dredger can deliver 2×10^6 m^3 per year by direct pump-out and the 14 ft dredger can deliver 3×10^6 m^3 per year by direct pump-out; the 12 ft dredger can deliver 1.5×10^6 m^3 per year by a jet-pontoon whereas the 14 ft dredger can deliver 2.5×10^6 m^3 per year by a jet-pontoon. The unit prices for American (Florida) conditions of 3–4 km steaming distances are as follows: for 12 ft the operation unit cost is \$1.95/cubic yard by direct pump-out (on contract \$2.45); for 12 ft operation the unit cost is \$2.60/cubic yard by jet-pontoon (on contract \$3.25); for 14 ft operation the unit cost is \$1.50/cubic yard by direct pump-out (on contract \$1.85); for 14 ft operation the unit cost is \$2.00/cubic yard by jet-pontoon (on contract \$2.45). Without a jet-pontoon part of the sand must be dumped offshore. A (small) mobilization-demobilization cost may be added increasing prices by 5–15%. Australian or European prices are 20–30% less.

Comparing prices for 35, 40 and 45 weeks of operation and assuming 3–4 km steaming distance, based on Figure 4 (Stuyvesant Dredging Co.), shows the following contract prices for a 14 ft draft 32″ discharge pipe dredger with jet-pontoon: 35 weeks [\$2.8/c.y. (\$3.6/m^3)], 40 weeks [\$2.6/c.y. (\$3.4/m^3)], 45 weeks [\$2.45/c.y. (\$3.2/m^3)].

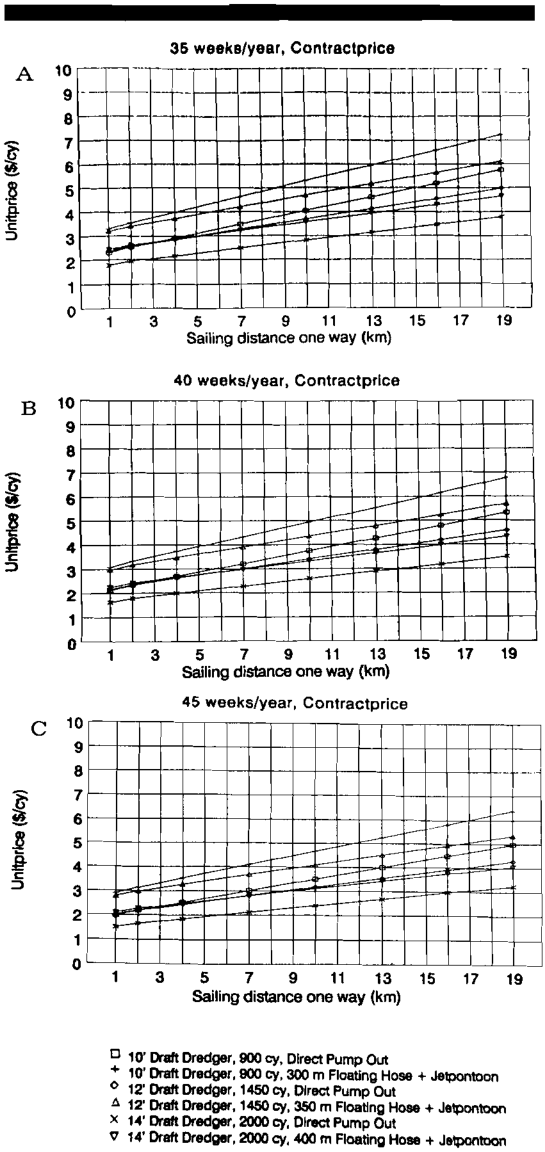

Figure 4. Contract prices for backpassing by 10 ft, 12 ft, and 14 ft draft dredgers by over-the-bow pumping and by jet pontoon procedures for operation terms of (A) 35 weeks per year, (B) 40 weeks per year, and (C) 45 weeks per year. (Data from Bos Kalis Westminster & Stuyvesant Dredging Company.)

For the American (Florida, South Carolina, etc.) market, these procedures mean a reduction to nearly half of present prices. The difference in prices is caused partly by outdated, less efficient equipment in the United States and partly by a relatively low employment ratio in the American dredging industry (currently only about 50% on an annual basis). The advantages of using smaller more efficient equipment for more frequent operations include (1) a more stable beach, (2) increased recreational use, (3) better dune and storm tide protection, and (4) decreased costs.

LUND (1990) describes procedures for optimization of dredging projects. Table 1 gives results for optimization of similar procedures for beach nourishment with special reference to prices in Australia and in Denmark compared to American prices.

The difference in price, large dredge versus small dredge, is surprising. Both assume that sand suitable for nourishment, *e.g.* from inlet maintenance, is available at a distance of 2–4 km (1.5–3 miles) from the shore. The shallow-water hopper equipment may change nourishment procedures drastically and will, in many practical cases, replace the present equipment for combined inlet and beach maintenance operations.

CONCLUSION

Maintenance of navigation channels and tidal inlet entrances on littoral drift shores can be improved greatly when considering environmental concerns, by combining bypassing and backpassing to the benefit of neighboring shores as well as to the economy.

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□ RÉSUMÉ □

Le succès d'un port dépend souvent du maintien de la profondeur de ses chenaux d'accès. La plupart des installations portuaires sont localisées dans les rivières, les estuaires, les baies ou les lagunes, mais un nombre croissant de ports et de terminaux sont installées sur des littoraux ouverts, souvent exposés, où les conditions de profondeur sont plus facilement rencontrées.

Les entrées de ports en mer ouverte, les goulets tidaux sur les côtes d'accumulation, font obstacle à la dérive littorale naturelle des sables et provoquent des accumulations en aval du courant. On énumère brièvement les méthodes de maintien portuaire pour se concentrer ensuite sur les nouveaux moyens visant à favoriser la transit des matériaux dans les deux sens et les mesures économiques afférents.—*Catherine Bousquet-Bressolier, Géomorphologie E.P.H.E., Montrouge, France.*

□ ZUSAMMENFASSUNG □

Der wirtschaftliche Erfolg eines Hafens hängt oft von der Garantie einer sicheren Zufahrtstiefe ab. Viele Häfen liegen an Flüssen, Ästuaren, Buchten oder Lagunen, aber eine zunehmende Zahl von Häfen oder Terminals werden an der offenen und exponierten Küste errichtet, wo die benötigte Tiefe leichter garantiert werden kann. Dabei entstehen allerdings Schwierigkeiten durch zunehmende Größe und Tiefgang der Schiffe.

An der offenen Meeresküste bilden Gezeiteneinlässe und Hafeneinfahrten Haupthindernisse für den küstenparalelen Materialtransport, was zu ausgedehnten Akkumulationen an den Luvseiten und in Fahrrinnen und zu starker Lee-Erosion führen kann. Diese Arbeit beschreibt zunächst die üblichen Methoden und konzentriert sich dann auf neue Verfahren für die Steuerung des Materialtransportes und ihre ökonomischen Konsequenzen.—*Dieter Kelletat, Essen, Germany.*

□ RESUMEN □

La operatividad de un puerto suele depender del mantenimiento de las profundidades. Los puertos importantes están localizados en los ríos, en los estuarios, en las bahías o en las lagunas costeras; aun cuando un gran número de ellos o terminales portuarias has sido establecidos en mar abierto sobre costas expuestas, donde los requerimientos para mantener las profundidades naturales son faciles de cumplimentar. A pesar de ello, los problemas de mantener las profundidades se han acrecentado con el incremento de las dimensiones y calados de las embarcaciones.

En las costas abierta al mar, en las entradas a los puertos, y en los canales con influencia de marea y sobre las costas con deriva litoral, se presentan los principales obstáculos a la deriva de la arena a lo largo de la costa, dando lugar en los canales navegables a fuertes acumulaciones de sedimentos aguas arriba y notable erosión aguas abajo.

Este trabajo presenta una revisión de los métodos de mantenimiento existentes y luego se concentra en nuevos procedimientos para el bypassing de los materiales, combinaciones de bypassing y backpassing, y la economía relacionada.—*Néstor W. Lanfredi, CIC-UNLP, La Plata, Argentina.*