CHAPTER 212

# THE EXTENT OF INLET IMPACTS UPON ADJACENT SHORELINES

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**Abstract**

*The erosional impacts of improved inlets upon adjacent shorelines may be best estimated by first computing the volume of material removed from the littoral system and then examining the adjacent shorelines to identify the length along which this volumetric impact has been manifest. This contrasts with the traditional approach whereby erosion is identified along a finite reach of shoreline and attempts are then made to link the erosion to a plausible cause. The length and volume of inlet-related erosion at two inlets considered herein are significantly greater than that traditionally ascribed to the inlets. Both feature near-field and far-field downdrift erosion signatures separated by stable shoreline.*

## INTRODUCTION

Improved ocean inlets are becoming increasingly recognized for their role in effecting beach erosion along adjacent shorelines. Such inlets include those which have been created or stabilized by dredging and/or by structures for purposes of navigation, water quality, flood control, etc. The total extent of these projects' influence upon the adjacent shorelines is not presently certain and is the subject of considerable debate. In the United States, perhaps the first examination of the topic was prepared for the U. S. Army Chief of Engineers in 1938 (Blackman, 1938). More recent discussions include those of Dean and O'Brien (1987), Fields *et al.* (1989), Work and Dean (1990), Bodge (1993), Bruun (1994), among others.

This paper considers the proposition that the littoral impact of inlets (and similar coastal perturbations) may be much greater than previously suspected. The reasons for this could be that (1) the littoral impacts are more closely related to interruptions of the gross transport rates (rather than the net transport rates), and (2) that the traditional identification of downdrift shoreline change may be a poor indicator of an inlets' total volumetric impact. Because the paper examines the degree to which man-made coastal projects impact the shoreline's littoral drift regime, its applicability need not be limited to ocean inlets. That is, the principles considered herein should be appicable to coastal perturbations in general which act as a sediment sink; e.g., marinas, breakwaters, long groins, nearshore dredging, etc.

## GENERAL CONSIDERATIONS OF INLET IMPACTS

**The Influence of Gross vs. Net Transport.** An inlet's littoral impact is often expressed in term of its "interruption of the *net* littoral drift." While this is a useful

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concept to help explain inlet impacts to laymen, it is a significant simplification of littoral processes -- and risks marked underestimation of an inlet's actual impacts.

For example, it is known that a perturbation (such as a groin) placed along a beach with large gross transport but negligible net transport will, indeed, induce changes to the adjacent shorelines. The degree to which the beach will be erosional or accretional on each side may depend upon the state of the transport regime or the overall supply of sediment at the time the pertubation is introduced. Thus it is recognized that the *gross* components of transport may be central in characterizing the response of shorelines to perturbations. This idea is not new (Galvin, 1990, among others), but perhaps is increasingly overlooked.

An improved inlet represents such a shoreline perturbation, and in particular, is often a sediment sink in response to gross transport processes (e.g., Bruun and Battjes, 1963; Dean and Walton, 1975; Walton and Adams, 1976). Consider, for example, a shoreline with component drift rates of +100 and -20 units, yielding a net drift rate of +80 units, along which is constructed a stabilized inlet (Figure 1). If all or part of the transport directed toward the inlet on its downdrift side leaks into the entrance channel, then the net downdrift erosion stress could be as much as 100 units instead of 80. Similarly, if all or part of the transport directed toward the updrift side is sunk to the channel or permanently impounded, there will be up to 20 units of localized erosion well updrift of the inlet. The total potential erosional impact would thus be 120 units (the gross transport rate), not 80 units (the net transport rate).

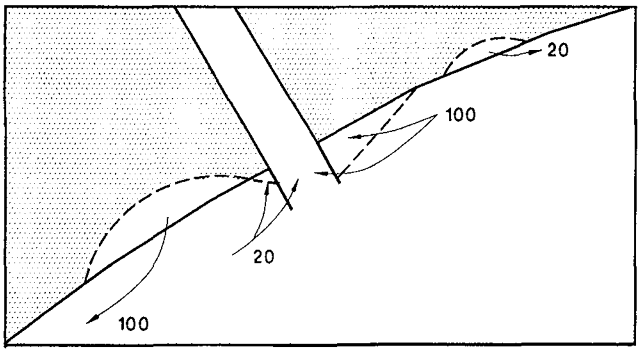


**Figure 1:** *Potential effect of an inlet upon a shoreline with gross transport rate components of 100 and 20 units. By introducing the inlet, the potential downdrift and updrift erosional impacts are 100 units and 20 units, respectively. Consideration of only the net drift rate leads to the erroneous conclusion that erosional impacts are limited to 80 units on the downdrift side.*

**Mechanisms of Inlet Impacts.** The general mechanisms by which inlets impact the adjacent shorelines are known: Material is removed from the littoral system by impoundment against the inlet's terminal structures and by transport through, over and around leaky terminal structures (i.e., jetties which are too short, porous, or low). That material which is transported past the structures is then deposited into tidal shoals or along the channel seabed. Dredging and subsequent offshore disposal further removes some of this material from the system. Even recent efforts to restore the suitable dredged material to the system are not 100% effective because the beach material which deposits in the channel often mixes with ambient silts and clays -- making the material unsuitable for nearshore recovery (i.e., beach or nearshore berm disposal).

The volumetric sum of these components (impoundment, shoal formation, and dredge disposal out of the system), measured relative to natural conditions, represents the inlet's littoral impact. Through consideration of the conservation of mass, this must also represent the total erosional impact of the inlet upon the adjacent beaches.

**Approach.** A reasonable approach to estimate an inlet's littoral impacts may therefore be to *first* identify the volume of sand removed from the system by the inlet, and *then* examine the adjacent shorelines to identify the extent of the shoreline along which this volume has been realized. This approach contrasts with that conventionally employed to determine inlet impacts; i.e., where one first estimates volumetric erosion along a finite length of beach and then attempts to link the erosion to a plausible cause.

## APPLICATION: PORT CANAVERAL, FLORIDA

As an example of the approach outlined above, the case of Port Canaveral, Florida, will be considered. Port Canaveral is located on the Atlantic coastline of the southeastern United States in the state of Florida (Figure 2). The port's inlet is presently

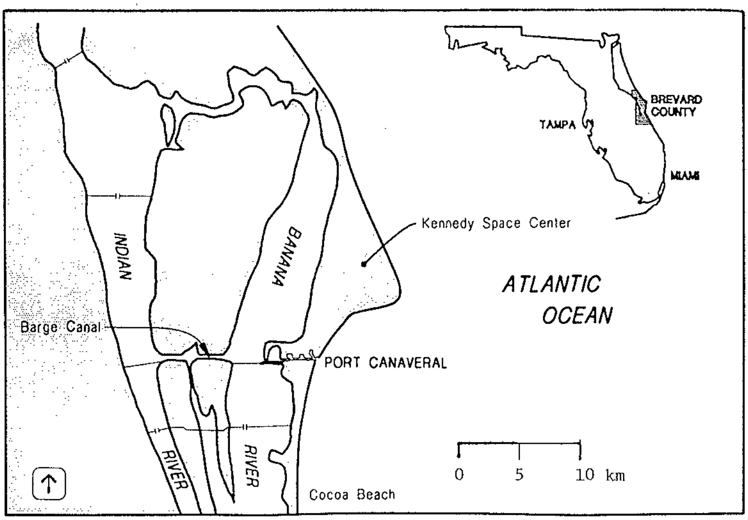


**Figure 2:** *Location map of Port Canaveral, Florida.*

maintained to a depth of -14 m MLW. Dual rock jetties which extend about 275 m and 70 m seaward of the pre-inlet MHWL bound the channel entrance to the north and south, respectively. There are no tidal shoals associated with the inlet because the port has always been hydraulically isolated from inland waters by a navigation lock or berm, and the inlet's tidal currents are weak. The dominant drift direction is southerly.

The inlet was artificially established by dredging through a sandy barrier island in 1950-52. The pre-inlet shoreline was regular, though arcuate, and accretive. Subsequent to the inlet construction, the shorelines north and south of the new inlet rapidly advanced and eroded, respectively. Despite the placement of almost 1.8 MCM of beach fill in the mid-1970's, the present shorelines north and south of the inlet are offset by over 280 m.

**Updrift Impoundment.** The volume of sand impounded by the inlet's north jetty was estimated by comparing historical shoreline records prior to and after construction. The shoreline changes were converted to volumetric changes through an approximate, fixed multiplier of 8.23 $m^3$ per m of change per m of shorefront. (This is a conservative value; i.e., it may underestimate the volume change. Comparison of the limited profile data historically collected along this beach suggested a value 20% greater than 8.23 $m^3/m/m$.) The computed volume changes were then expressed as *cumulative* volume change updrift of the inlet -- annualized over the years between shoreline surveys (Figure 3a).

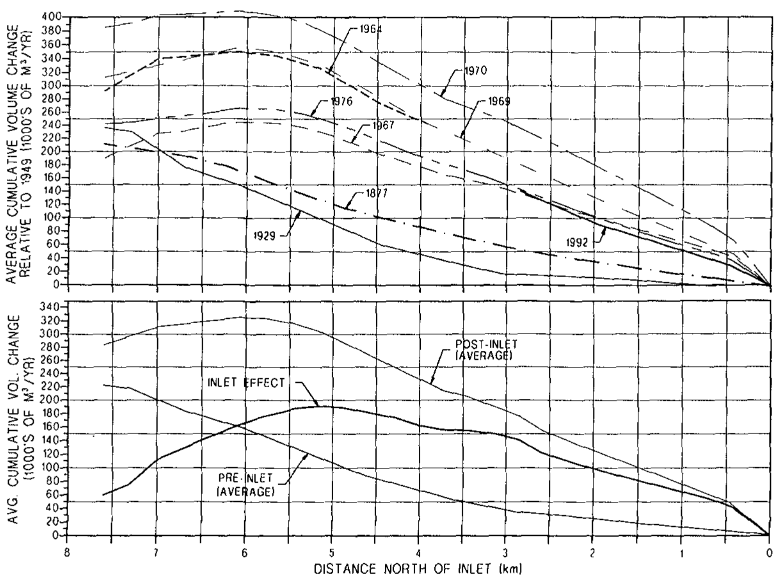


**Figure 3:** *Cumulative annualized volume changes updrift of Port Canaveral developed from (a) discrete shoreline change records and (b) the average signals of the pre- and post-inlet shoreline change records. The difference between the pre- and post-inlet signals is the inlet effect.*

The volume change data expressed in this way clearly fell into two groups corresponding to pre- and post-inlet conditions, respectively. The average of the cumulative curves in each of the two groups was computed to yield the approximate pre- and post-inlet rates of updrift volume change as a function of distance from the inlet. The difference between these two averages represents the net updrift effect of the inlet (Figure **3b**). The updrift extent of the impoundment signal -- suggested by the maxima in the curve -- is noted about 3.3 to 5.0 km updrift of the inlet. The magnitude of the impoundment signal over this distance is about 152,500 $m^3$/yr ($\pm$37,500 $m^3$/yr). Over the first 40 years since the inlet was constructed, this represents about 6.1 ($\pm$ 1.5) million cubic meters (MCM) of impoundment.

**Dredging.** Only a portion of the sand which is transported toward the north jetty is impounded. The jetty is low and porous, and is now too short relative to the accreted shoreline. The south jetty is likewise low and porous. Sand which is transported over, through and around the jetties deposits in four well-defined, consistent shoals at the landward and seaward ends of the structures. Diving, core-boring, and dredging inspection reveals that these shoals are composed of sand from the adjacent beaches. From "condition" surveys of the inlet entrance collected quarterly over the past few years, these shoals re-appear after dredging at a combined, average annual rate of about 150,000 $m^3$/yr. Over a 40 year period, this amounts to 6.0 MCM. The latter value agrees well with independent estimates of the sand volume thought to have been dredged from the inlet. Specifically, dredging records and geotechnical data (which reveal a consistent lower depth to the local surficial sand lens) suggest that about 6.0 MCM of the 38 MCM of material dredged from the inlet over its first 40 years was beach-quality sand which was removed for purposes of maintenance and placed in deep water, offshore.

Over the inlet's first 40 years since construction, then, about 6.1 ($\pm$ 1.5) MCM of sand have been impounded by the north jetty beyond pre-inlet trends, and about 6.0 MCM have been dredged and disposed of out of the littoral system. The total, about 12.1 ($\pm$1.5) MCM, represents the inlet's littoral impact to the beaches over 40 years.

**Impact to Shorelines.** It has been historically assumed that the inlet's effects extended only about 3 km downdrift -- an area over which the post-inlet shoreline has been severely erosive (Figure **4**). South of this distance (for a length of about 4 km), the shoreline has been stable to accretional. It is important to note, however, that the rate of accretion along this reach has been less than in pre-inlet conditions, and the beach south of this area has exhibited erosion.

Erosion along the downdrift 3 km of shoreline was estimated in a similar manner as for the impoundment signal on the updrift side of the inlet. Historical shoreline change data were converted to volumetric equivalents (using a multiplier of about 5.8 $m^3$/m/m based upon typical profile comparisons), and expressed as average annual, cumulative volume change downdrift of the inlet. The effects of two beach fills during 1972-1975 were approximately removed by subtracting the placed volume from the post-fill data along the placement area. Like the updrift volume changes, the results fall into two groups corresponding to pre- and post-inlet timeframes (Figure **5a**). The difference between the average of the two groups yields the inlet's effect (Figure **5b**).

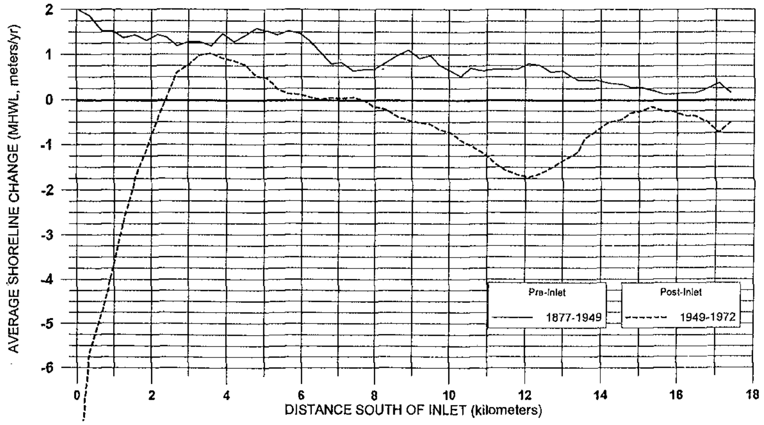


**Figure 4:** *Historical shoreline changes south (downdrift) of Port Canaveral Entrance for pre- and post inlet conditions.*

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The inlet's primary erosive effect is evident within about 3.3 km south of the inlet (i.e., the point at which the cumulative volume change curve "levels out" in Figure 5b). Over this reach, the inlet's effect has been equivalent to about 75,000 $m^3/yr$ of erosion, on average. Over the first 40 years since the inlet's construction, this represents about 3.0 MCM of erosion. The inlet's total littoral impact, however, is computed as about 12.1 (±1.5) MCM -- which leaves another 9.1 (±1.5) MCM of impact unaccounted for. It is possible, but not certain, that 1.3 MCM of inlet-related impact may be associated with erosion north of the inlet's impoundment fillet. Such updrift erosion is predicted by the sediment budget (see below). Impacts further updrift are improbable; therefore, by deduction, the inlet's remaining 7.8 (±1.5) MCM of erosional impacts are likely associated with the beaches beyond 3.3 km south of the inlet. The inlet's total downdrift impact is thus estimated as about 10.8 (±1.5) MCM (Figure 6).

Cumulative volume changes along the beach downdrift of the inlet were computed beginning at the inlet for pre- and post-inlet conditions (Figure 7). An erosional volume of 10.8 MCM, accounting for pre-inlet processes is noted between 31 and 42 km south of the inlet. The ±1.5 MCM uncertainty in the volume impact increases this range to between 22 and 53 km. Recent independent estimates of beach nourishment requirements within 42 km south of the inlet total 5.6 to 8.8 MCY (USACE 1992; Coastal Tech. Corp. 1992). Another 2.8 MCM of beach fill have already been placed herealong during the period of study. When this 2.8 MCM is added to the existing requirements, the total restoration requirement is 8.4 to 11.6 MCM. These values corroborate the author's findings; i.e., that the inlet's total downdrift impact, based upon a sediment budget, is 10.8 (±1.5) MCM.

**Sediment Budget.** The sediment budget developed for the inlet in pre- and post-project (existing) conditions is illustrated in Figure 8. The results are based solely

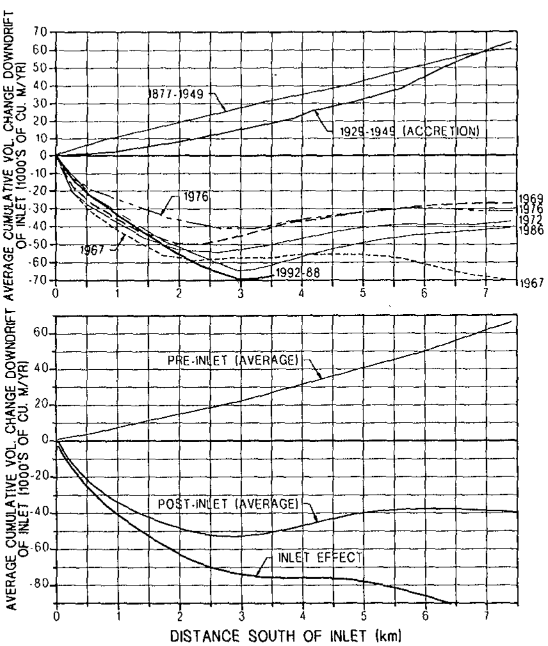


**Figure 5:** *Cumulative annualized volume changes downdrift of Port Canaveral developed from (a) discrete shoreline change records and (b) the average signals of the pre- and post-inlet shoreline change records. The difference between the pre- and post-inlet signals is the inlet effect.*

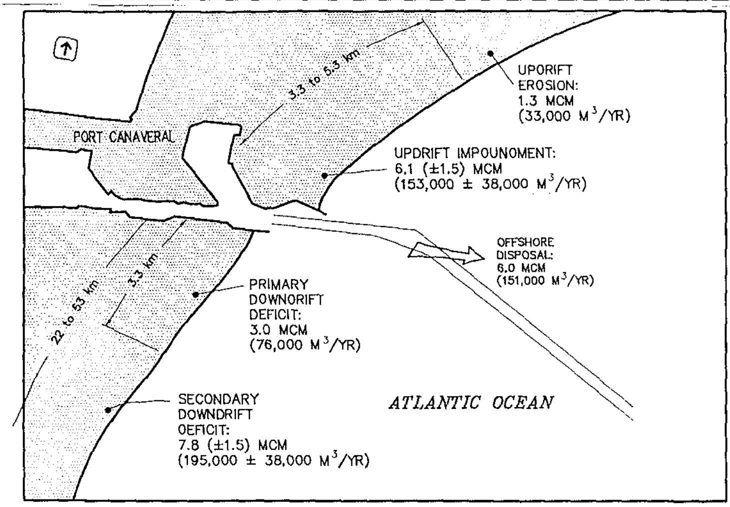


**Figure 6:** *Overview of volumetric impacts attributed to Port Canaveral over the 40 years since the inlet's construction.*

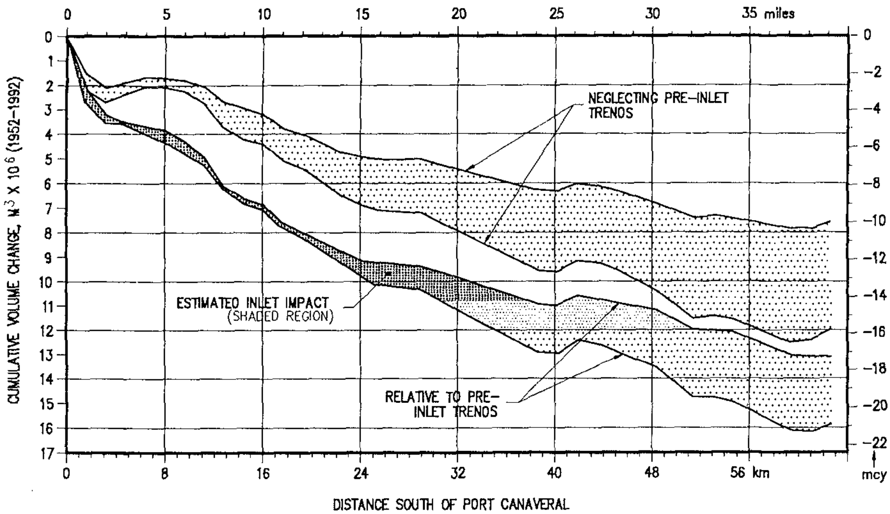


**Figure 7:** *Cumulative change in beach volume estimated as a function of downdrift distance from Port Canaveral Entrance. The upper pair of curves refers to "observed" changes since the inlet's construction. The lower pair refers to changes since the inlet's construction -- relative to the local pre-inlet accretional trend. The range between the curves in each pair reflects error bars associated with transforming shoreline change data to volumetric estimates.*

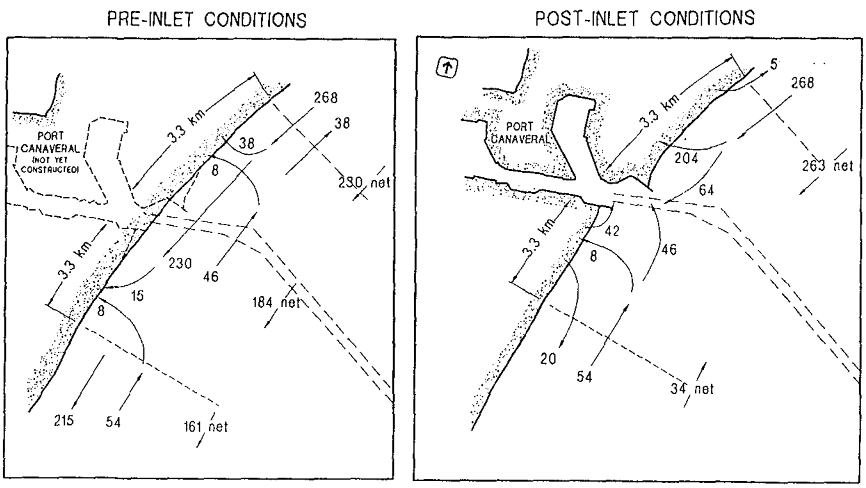


**Figure 8:** *Gross sediment budget computed for Port Canaveral Entrance. The arrows and values represent longshore sediment transport rate in thousands of cubic meters per year.*

upon interpretation of (i) measured shoreline changes north and south of the inlet, (ii) maintenance dredging records, and (iii) assumed values of the gross southerly and northerly transport rates incident to the inlet. The selection of the latter values was guided by refraction and GENESIS modelling results, and early studies of shoaling at the newly cut inlet (USACE 1961, 1992).

The pre-project, net littoral drift rate across the inlet entrance is estimated to have been 184,000 $m^3$/yr to the south. From the sediment budget, however, the inlet's net impact is estimated to be 302,500 $m^3$/yr. The 64% differencein these values is attributable to the sink effect of the inlet. Along the south beach in particular, the sand which chronically leaks through the south jetty (about 88,000 $m^3$/yr) is lost from the beach and is no longer available for southerly transport during the predominant wave climate. At Port Canaveral, the result is an apparent *reversal* in the net transport direction downdrift of the inlet. This example illustrates the potential underestimates of inlet impact when *net* transport rates are considered in lieu of *gross* transport rates.

## APPLICATION: SOUTH LAKE WORTH INLET, FLORIDA

South Lake Worth Inlet, Florida, is another example of a case where traditional examination of the downdrift erosion signature fails to reveal the extent of the inlet's littoral impacts. The inlet is located along the Atlantic coastline of Florida, about 150 km south of Port Canaveral, in Palm Beach County. The inlet was artificially cut through a sandy barrier island in 1927 for the purposes of improving water quality within the southern half of Lake Worth. Dual jetties stabilize the entrance channel, which reduces to 41 m width and 3 meters depth at its smallest point. The net littoral drift is southerly-directed. Despite the operation of a sand bypassing plant at the inlet's north jetty (which discharges sand to the downdrift shoreline south of the inlet), the beach to the south of the inlet has exhibited chronic erosion. The shoreline within about 2 km south of the inlet has been authorized as the site of a Federal shore protection (beach restoration) project.

**Sediment Budget.** The major sediment transport paths at the the inlet were identified as shown in Figure 9. The net volume of sand reaching the inlet's north shoreline ($Q_1$) is impounded at the north beach ($Q_2$), lost to the ebb shoal or offshore ($Q_3$), lost to the inlet interior ($Q_4$), naturally bypassed via the inlet's bar ($Q_5$), and/or mechanically bypassed ($Q_6$). The net volume of sand which is transported away from the inlet's south shoreline ($Q_9$) includes sand which is naturally and artificially bypassed ($Q_5$ and $Q_6$), placed upon the south beach from interior dredging ($Q_7$), and/or eroded from the south shoreline within about 2 km of the inlet ($Q_8$). That is,

$$Q_1=Q_2+Q_3+Q_4+Q_5+Q_6 \quad (1)$$

$$Q_9=Q_5+Q_6+Q_7+Q_8 \quad (2)$$

Estimates of six of the nine components in Eqs. 1 and 2 were developed for a number of time intervals using available data, including shoreline change records,

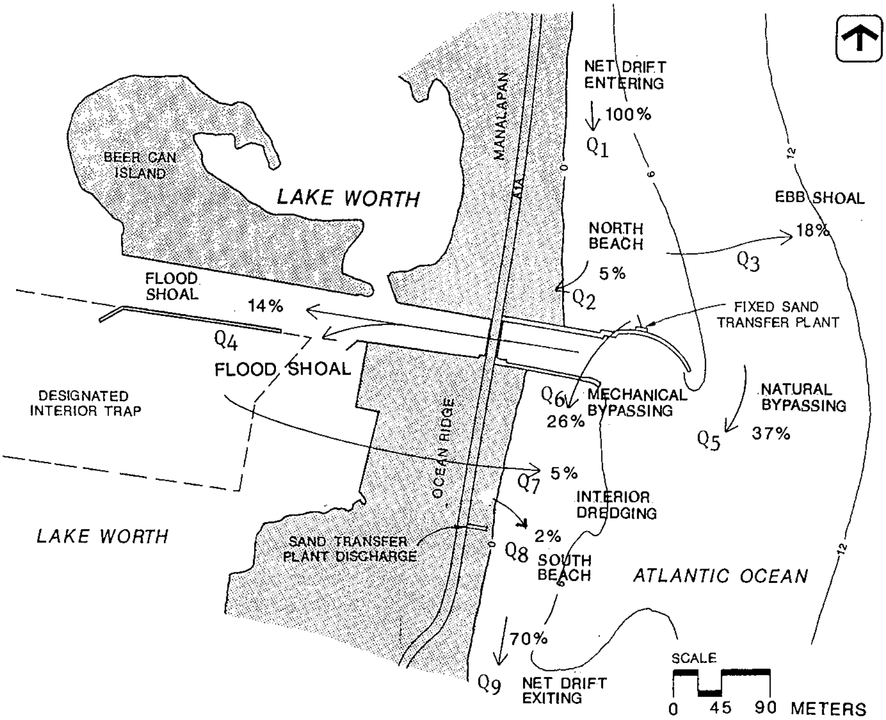


**Figure 9:** *Net sediment transport components identified for South Lake Worth Inlet.*

surveys of the ebb and flood tidal shoals, aerial photography, sand bypassing and dredging records. Using the values for these components, estimates of the natural bar bypassing rate ($Q_5$) and the net drift rate leaving the inlet area ($Q_9$) were computed from Eqs. 1 and 2 for net littoral drift rates incident to the inlet ($Q_1$) ranging from 135,000 to 173,000 $m^3$/yr. In this way, it was estimated that over the period 1927-90 (the first 63 years since the inlet's construction), about 28% to 36% of the incident net drift was bypassed mechanically ($Q_6$ and $Q_7$) while about 37% of the incident net drift was bypassed naturally ($Q_5$). (See Figure 9.) Thus, only about 65% to 73% of the net drift incident to the inlet's north beach has been transported across the inlet to the beaches south of the inlet -- implying that the inlet has removed a volume of sand from the area's littoral system equal to about 27% to 35% of the incident net drift rate. This material has been diverted to interior shoals (much of which was dredged and used for upland fill along Lake Worth's shoreline), and the formation of an ebb shoal/bypassing bar platform and updrift impoundment fillit.

Considering the incident net drift rate to be on the order of 154,000 $m^3$/yr (Watts, 1953; Bruun et al., 1966), the inlet is therefore estimated to have diverted as much as 2.6 to 3.4 MCM of sand from the littoral system over its first 63 years. On the other hand, shoreline change records (including those which were incorporated to the sediment budget analysis) suggest that the shoreline within about 2 km south of the inlet has eroded by only about 2% of the net drift rate incident to the inlet's north side -- or about 0.2 MCM over the inlet's first 63 years.

**Obfuscation of Downdrift Impact.** In the case of South Lake Worth Inlet, the downdrift erosion signature along the 2-km (+/-) reach of coastline thought to be most severely impacted by the inlet potentially underestimates the inlet's littoral impact by a factor of *16*. The reason may be related to the significant degree to which the downdrift shoreline has been artificially manipulated through armoring (seawalls), the construction of groins, and the placement of sand (sand bypassing). In such cases, the shoreline's response to erosional stress may be extraordinarily obscured.

By simple inspection of the nautical charts and historical aerial photography, there can be no doubt that the construction of South Lake Worth Inlet has removed from the littoral system far more than the 0.2 MCM of sand indicated by the immediate downdrift shoreline. The erosional stress that the inlet placed upon the shorelines (coupled with imprudent development in some cases) resulted in significant shoreline armoring adjacent to the inlet. This armoring limits the erosional signal of the beach, and/or precludes its identification from shoreline change data (which describe shoreline positions, not beach volumes). Reliance only upon the "near-field" downdrift shoreline history to deduce inlet-related impacts can result in significant underestimation of the inlet's impacts in those cases where the shoreline has been artificially manipulated. Additionally, in those cases where the adjacent shoreline(s) has (have) been stabilized against erosion, the inlet's erosional impacts must -- by deduction -- extend particularly far afield.

## DOWNDRIFT EXTENT OF INLET-RELATED EROSION

**Theoretical Considerations.** In the two example applications presented above, it was noted that the inlets' littoral impacts may extend far from the inlets, despite their young age. In both cases, however, the apparent *limit* of the erosion was traditionally thought to be about 2 km or less downdrift of the inlets; i.e., on the order of about 10 jetty lengths downdrift. Pelnard-Considére (1956) presented now-classical solutions for shoreline change adjacent to a sediment-trapping structure. At the time at which the structure becomes filled to capacity and begins to bypass sand, according to his solution, the shoreline recession (y) at a distance (x) downdrift of the structure is

$$\frac{y}{Y} = [\exp(-u^2) - \sqrt{\pi}\, u \; erfc(u)] \tag{3}$$

where

$$u = \frac{x}{Y} \frac{1}{\sqrt{\pi}} \tan(\alpha_b) \tag{4}$$

where Y is the structure length, and $\alpha_b$ is the wave breaking angle (assumed to be quasi-steady). Both y and Y are measured relative to the no-structure shoreline. Figure **10** presents solutions to Eq. 3 for various values of the wave breaking angle. For typical angles on the order of 4 to 8 degrees, shoreline recession on the order of 5% of the structure's length might be anticipated between 15 and 30 jetty lengths downdrift.

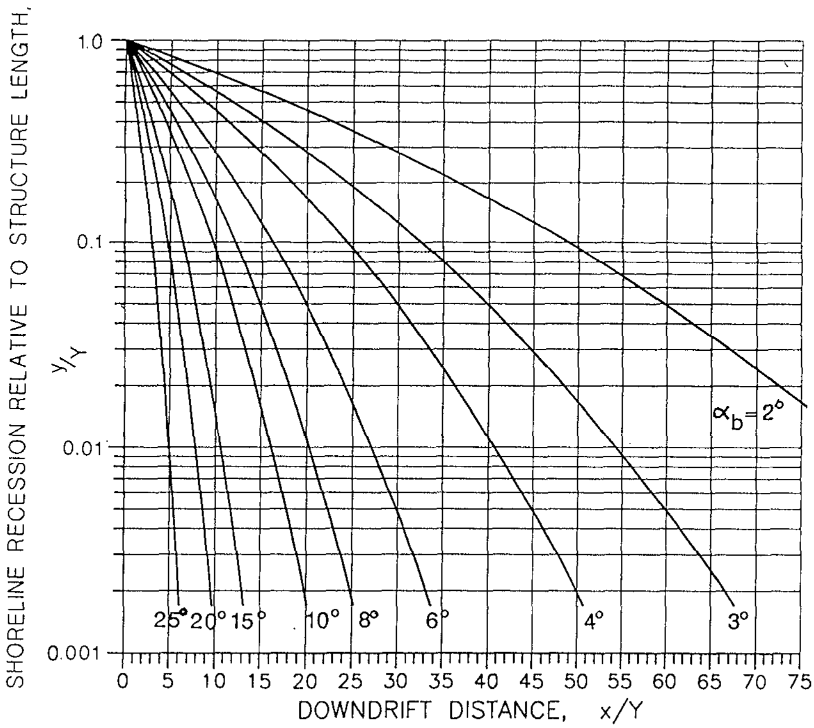


**Figure 10:** *Shoreline recession predicted from Eq. 3 as a function of structure length and distance downdrift of the structure. The condition corresponds to the time at which sand begins to bypass the structure.*

In the case of Port Canaveral, the average-annual breaking wave angle south of the inlet (as computed from hindcast data refracted to shore) is about 4 degrees. Taking Y = 275 m (the length of the north jetty measured from the pre-inlet shoreline), downdrift recession on the order of 5 m over the inlet's history is predicted to occur about 37 jetty lengths downdrift, or about 10 km. (Recession less than about 5 m over 40 years is generally perceived as negligible in this locality.) When one considers that the updrift impoundment represents only half of the inlet's estimated impacts (the other half is dredging related), then the appropriately predicted distance may be twice as great -- or about 20 km. This length agrees in general magnitude with that estimated by the method presented in this paper. In any case, it is considerably greater than the 3 km shoreline reach along which the inlet's erosion is traditionally attributed.

In the case of South Lake Worth Inlet, the lineal extent of the inlet's impacts to the adjacent shorelines is not entirely clear. Considering that the estimated volumetric impact is 2.6 to 3.4 MCM over 63 years, and that typical observed erosion rates in the area are on the order of 0.5 m/yr or less (or about 2.75 $m^3/m/m/yr$), the length of effected shoreline may be on the order of 15 to 20 km. The actual length is probably much greater -- and/or perhaps the volume of sand removed by the inlet has never been fully mitigated by erosion of the adjacent beaches -- because long reaches of the adjacent shorelines are armored by seawalls which significantly reduce observed shoreline and volumetric erosion of the beach.

**"Near-field" and "Far-field" Impacts.** The primary reason that the inlet impact associated with Port Canaveral was considered as only 3 km was that the shoreline south thereof (for a distance of a few km) appears stable to accretional. Indeed, this shoreline remained accretional after inlet construction -- but the rate of accretion was about two-thirds less than pre-inlet rates. Bodge (1994) demonstrates through a large-scale sediment budget that it is possible to have net shoreline accretion in the midst of an otherwise erosive regime downdrift of the Port Canaveral inlet. In any case, the overall picture is one of a severe "near-field" erosion wave within a few km of the inlet and a less dramatic "far-field" erosion wave separated from the former by a relatively short reach of stability or accretion. Bruun (1994) discusses numerous examples of this phenomenon and examines possible migration rates of these two erosion features downdrift of inlets. Bruun concludes that the "downdrift shoreline development at a littoral drift barrier may in general, but not always, be described by a short (local) as well as a long distance effect which both move downdrift at various rates, the long distance movement being 2-3 times faster than the short distance, or about 0.5 km/yr versus 1 to 1.5 km/yr.... The short distance effect is a coastal geomorphological feature, the long distance a materials deficit feature."

The appearance of the stable area between the near- and far-field erosion areas may be due to localized shoreline stability (rock outcrops, etc.), local refraction effects (such as those related to the ebb shoal across the inlet mouth), or far-field refraction effects. Local refraction effects and the shoreline attachment of the inlet's bypassing bar are responsible for a short reach of stability/accretion at South Lake Worth Inlet (Bodge, Olsen and Savage, 1990). Far-field refraction effects -- induced by Bull Shoals south of Cape Canaveral -- are apparently responsible for the reach of stability south of Port Canaveral Entrance (Bodge, 1994).

## CONCLUSION

The erosional effects of improved inlets upon adjacent shorelines may be best estimated by first computing the volume of material removed from the littoral system (beyond that which would have been removed naturally in the absence of the improvements) via consideration of the inlet-related (1) impoundment fillets, (2) flood and ebb shoal development, and (3) disposal of maintenance dredged, beach-type material outside of the littoral system. One next examines cumulative beach volume changes along the adjacent shorelines -- beginning at the inlet -- to determine the up- and downdrift-extent along which the inlet's volumetric impacts may be manifest. This fundamental approach contrasts with that conventionally employed to determine inlet impacts; i.e., where one first estimates volumetric erosion along a finite length of beach and then attempts to link the erosion to a plausible cause. The latter approach is shown to be potentially deficient because (1) the length of the downdrift shoreline classically selected for examination may be much shorter than the actual length which has been affected by the inlet, and (2) downdrift shoreline changes may obfuscate erosion impacts via the effects of coastal armoring, beach reclamation, and other works which have been undertaken in defense against erosion.

The mechanisms by which the inlet's littoral impacts occur illustrate the behavior of many improved inlets as a sediment sink – and the importance of adequate terminal structures to limit sink behavior. It is likewise illustrated that an inlet's impacts are not necessarily limited to interruption of the *net* littoral drift rate, but can extend to the area's *gross* drift rate.

The methodology presented above for deducing inlet-related impacts should also be important to the development of regional sediment budgets. In such regional budgets, the volume of sand removed from the littoral system by an inlet must be accounted for as a deficit within the system as a whole. Barring changes in the wave climate or the natural expansion or appearance of an external sand source, this effect must be manifest as (1) a volumetric erosion of the adjacent beaches, and/or (2) a decrease in the littoral drift rate which reaches the adjacent, downdrift inlets.

For the two example cases presented, the extent of the inlet's littoral impacts is considerably greater (by a factor of 15 to 20) than has been traditionally thought. For the first 40 years after construction of Port Canaveral entrance, the downdrift impact of the inlet is estimated to be 12.1 (± 1.5) MCM -- affecting between 31 and 42 km (±10 km) of shoreline south of the inlet. Traditionally, the effect has been thought to be limited to about 3 km of shoreline, along which only 4 MCM of erosion is detectable. Likewise, for the first 63 years after construction of South Lake Worth Inlet, the inlet's impact is estimated as 2.6 to 3.4 MCM as compared to only 0.2 MCM of impact which is detected from shoreline changes observed along the first 2 km (approx.) south of the inlet. Both inlets feature "near-field" and "far-field" erosion signatures -- separated by a relatively short reach of stable to accretional shoreline. For the two cases examined, the appearance of the latter is related to local and offshore wave refraction effects respectively induced by inlet-related and non-inlet related bathymetries.

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