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An Evaluation of the Economic Performance of the U.S. Army Corps of Engineers Shore Protection Program

T. M. Hillyer, E. Z. Stakhiv, and R. A. Sudar*

ABSTRACT

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This study of the U.S. Army Corps of Engineers' (USACE) shore protection program was undertaken as a result of a request from the Office of Management and Budget (OMB). The investigation disclosed that the USACE shoreline protection program covers 8 percent of the nation's 2,700 miles of critically eroding shoreline and consists of 82 specifically authorized projects. Total actual expenditures, including periodic nourishment, for these 82 projects from 1950 to 1995 have been $731 million. When updated to 1995 dollars this expenditure becomes $1,662 million. Over the period of time covered by this study (1950-current) the program has shifted from primarily "hard" structures (groins, seawalls, breakwaters, etc.) to primarily "soft" beach restoration and nourishment through placement of sand. Beach restoration and nourishment is also the most environmentally compatible shore protection measure. The projects receive intense preconstruction coordination with environmental agencies to assure no long term adverse environmental impacts result from the projects. Over this same time period, as a result of Administration policy and law, the program has shifted from primarily recreation oriented to one of protection for storm damage reduction.

From the standpoint of program cost and volumes of sand emplacements the evaluation of the long-term performance of the program shows that it is a well-managed and cost-effective program. Overall, costs were slightly less than estimated, and overall quantities of sand were slightly higher than estimated. Whether or not the projects are performing as expected from a benefit standpoint, however, is very difficult to determine. Because of the high variable and largely unpredictable nature of coastal storms, the "actual" storm damage reduction benefits of shore protection projects can differ greatly from those forecasted during planning and design. The key to the benefit-cost analysis is that the benefits are estimated based on a probabalistic assumption that, over the period of analysis (generally 50 years), a comparable sequence of events will occur as in the past, causing a comparable level of property damages. Hence, the longer the period of record, the more likely that the "estimated" benefits will converge on the "actual" or measured benefits (and costs).

One item of specific concern to OMB was that of induced development, *i.e.*, do shore protection projects' lead to more growth and development in protected areas, and hence, ultimately to increases in storm damages rather than a reduction in damages. Three specific economic analyses were applied during the course of the study to determine whether USACE shore protection projects induce development in the areas they protect. These three complementary studies were: (1) a survey of beachfront community residents; (2) an econometric model of beachfront development; and (3) an econometric analysis of beachfront housing prices. None of these approaches could verify that there is a measurable induced development link. The analyses demonstrated that the primary determinant of development of beachfront communities is growth in beachfront demand based on rising income and employment in noncoastal areas, rather than the presence or absence of a shore protection project. In fact, there is limited public awareness of the Federal shore protection program, where Federal projects currently exist, and of the involvement of the USACE in reducing risks through project construction.

ADDITIONAL INDEX WORDS: Coastal erosion, beach replenishment, restoration, benefit-cost analysis, beachfront development, coastal environments.

INTRODUCTION

The future of the Federally-sponsored shoreline protection program of the U.S. Army Corps of Engineers (Corps) is currently being debated within the Administration and Congress as to its future scope, and whether it should remain principally as a Federal responsibility. There are proposals to terminate the program completely and others to increase the non-Federal share of costs. Some contend that shore protection projects should not be constructed, but that "let nature takes its course." Still others think it should be left up to local communities to protect their own shores.

Shore protection is as much a part of infrastructure development as storm sewers, wastewater treatment plants or highways, yet few of the nation's infrastructure investments undergo as detailed an economic analysis as do Federal shore protection projects; not to mention extensive environmental impact analysis. The decision to maintain a beach is no different from a decision to maintain a navigable harbor or port for commerce. Beaches generate income, tax revenue and jobs. It's an investment with economic benefits and costs to the economy of the nation, region, and local community.

With these questions and criticisms of Federal shore protection activities as a background, the U.S. Office of Man-

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* *Policy and Special Studies Division, U.S. Army Institute for Water Resources, 7701 Telegraph Road, Alexandria, VA 22315.*

Table 1. *Total expenditures adjusted to 1995 prices shore protection program (1950–1995).*

Item	1950–1993 $ million	1993 $ million	Δ 94[1] $ million	Δ 95[1] $ million	Total 1995 $ million
82 projects	674.8	1,507.1	45.2	46.6	1,598.9
Future costs of the 82 projects[2]	0	0	30.9	31.8	62.7
Total	674.8	1,507.1	76.1	78.4	1,661.6

[1]Assumes a 3 percent inflation factor per year for 1994 and 1995
[2]Future cost of program determined to be $30 million per year based on 1993 conditions and prices

agement and Budget (OMB) requested that the Corps undertake a study of the economic performance of the Corps' shore protection program. This entailed an investigation and accounting of costs, benefits, impacts on development, and environmental effects. Phase I results of this Shore Protection Study (CORPS, 1994) were reported earlier (SUDAR ET AL., 1995). This article will summarize the major findings of the final report (CORPS, 1996) in the areas of future project costs, project benefits, impact on development, and environmental considerations. While efforts have been made to update costs for this article to reflect 1995 costs, the Corps' 1996 report is based on a survey of Corps districts performed in July 1993 and, except as noted, is based on data obtained at that time. The primary purpose of the Corps shore protection program is to reduce the economic and physical impacts of coastal storm damage from waves, inundation and beach erosion. In most cases today, this means restoring and maintaining the beaches with periodic nourishment. Artificial dune and/or beach protection measures are simply replications of the comparable natural features and rely on the high wave-energy dissipation characteristics of such features as the means of protecting coastal developments. In addition, restored beaches and dunes have the added advantage of possessing essentially the same aesthetic and environmental qualities as their natural counterparts.

TOTAL EXPENDITURES OF CONSTRUCTED PROJECTS

Since 1950, the Federal government, through the Corps, has constructed 82 specifically authorized shore protection projects protecting 226 miles of shoreline. The cumulative actual funds expended between 1950 and 1995 on these projects have been $731 million, with the Federal share of about 60 percent, or $440 million. When adjusted to 1995 price levels, these Federal and total costs are, respectively, about $1,000 million and $1,662 million. The procedure used for adjusting these expenditures to 1993 price levels involved the volumes of sand placed and the current cost in each area for obtaining, transporting, and placing the sand at the respective project sites. Structural costs were adjusted by means of the *Engineering News Record* Construction Cost Index. These 1993 costs were then adjusted by an inflation factor of 3 percent per year for 1994 and 1995 to arrive at 1995 price levels. Periodic nourishment costs for these two years were also increased to account for a average annual cost of about $31 million. This adjustment is summarized in Table 1.

Table 2. *Expected future federal expenditures of already-constructed projects (assuming no extensions).*

Type of Measure	Remaining Federal Expenditure ($ million 1995)
Initial restoration	13
Periodic nourishment	563
Sand bypassing system	17
Total	593

FUTURE COSTS OF THE SHORE PROTECTION PROGRAM

The second phase of the OMB requested study examined two scenarios of possible future Federal costs of the shore protection program over the next 50 years: 1) the Federal cost associated with the projects which are already constructed; and 2) the Federal cost associated with projects which are currently under construction and design.

(1) *Federal Cost of Constructed Projects.* This first scenario assumes that for the 82 constructed projects, all planned and currently authorized nourishments are carried out, but that no projects are extended beyond their current authorized period. As expected, these yearly expenditures gradually decline over the next 50 years as project authorizations expire. Total Federal expenditures over this period, are estimated to be $593 million ($1995). The expected distribution of Federal funds among the types of shoreline measures is shown in Table 2. These projections assume that there will be no additional Congressional authorizations to extend Federal involvement in these projects.

If the Federal involvement in these projects is extended, the annual Federal expenditure for these constructed projects is expected to approximate $20 million ($1995) for the foreseeable future.

2) *Federal Costs if all Currently Planned Projects are Constructed.* At the time of the 1993 survey, there were 26 projects that were either under construction or in the advanced planning stage. The data reflecting this survey is contained in the final report of the Corps (Corps, 1996). Subsequent to completion of that report in June 1995, certain of the data were updated to reflect costs and status of studies as of October 1995. This updating produced a dramatic change in this category of projects and studies, particularly in the category of "Under Construction." While in 1993, only one project was

Table 3. *Estimated costs of planned projects based on 1995 conditions (1995 dollars).*

Status	Number of Projects	Estimated Federal Cost ($ million)	Estimated Total Cost ($ million)
Under construction	12	1,168.8	1,695.0
Authorized/awaiting initiation of construction	6	65.1	131.6
Preconstruction engineering & design	13	961.6	1,489.5
Total	31	2,195.5	3,316.1

Table 4. *Average annual benefits by project (in thousands).*

Project Name	Price Level	Interest Rate	Storm Damage Reduction: Upland Dev.	Storm Damage Reduction: Land Loss	Recreation	Other	Total Average Annual Benefits	Average Annual Costs	B/C Ratio
Galveston Seawall, TX	1947	3.000	360.0	0.0	0.0	195.0	555.0	358.0	1.6
Winthrop Beach, MA	1947	3.000	17.4	0.0	22.8	4.4	44.6	43.0	1.0
Harrison Co., MS (1)	1948	3.000				454.0	454.0		
Presque Isle, PA	1948	3.000	0.0	30.0	250.0	50.0	330.0	274.9	1.2
Quincy Shore Beach, MA	1950	3.000	20.9	0.0	56.9	15.3	93.1	43.7	2.1
Hampton Beach, NH	1953	2.500	5.8	0.0	22.0	36.1	63.9	38.1	1.7
Prospect Beach, CT	1953	3.000	3.2	0.0	20.0	0.7	23.9	8.3	2.8
Seaside Park, CT	1953	3.000	8.1	0.0	96.0	0.0	104.1	18.7	5.6
Channel Islands Harbor, CA	1957	2.500	276.0	0.0	50.0	68.0	394.0	328.0	1.2
Long Island, Fire Is. to Montauk Pnt, Southampton to Beach Hampton, NY	1958	2.500	1,075.5	161.1	139.1	0.0	1,375.7	543.6	2.5
Carolina Beach & Vicinity, NC	1960	2.625	213.5	0.0	133.9	28.3	375.7	123.1	3.1
Oceanside, CA	1960	2.625	0.0	55.1	35.9	0.0	91.0	42.2	2.2
Wallis Sands State Beach, NH	1960	2.500	0.0	0.0	18.0	0.0	18.0	18.4	0.9
Wrightsville Beach, NC	1960	2.625	95.4	38.6	45.9	16.6	196.5	45.4	4.3
Fort Macon, NC	1961	2.625	242.6	40.9	86.7	0.0	370.2	148.9	2.5
Ventura-Pierpont, CA	1962	5.000	125.3	0.0	60.0	0.0	185.3	82.8	2.2
Surfside/Sunset, CA	1962	5.000	1,896.0	0.0	280.0	45.0	2,221.0	613.0	3.6
Fort Pierce Beach, FL	1962	3.000	3.4	53.7	62.7	0.0	119.8	89.4	1.3
Raritan and Sandy Hook Bay, Madison and Matawan Townships, NJ	1963	3.000	14.5	3.6	92.8	2.5	113.4	58.9	1.9
Long Island, Fire Island to Montauk Pt., Moriches to Shinnecock Reach, NY	1963	3.000	745.0	581.0	650.0	0.0	1,976.0	1,184.4	1.7
Raritan and Sandy Hook Bay, Keansburg and E. Keansburg, NJ	1964	2.625	430.9	4.5	187.5	3.8	626.7	359.5	1.7
Coast of CA, Point Mugu to San Pedro	1966	3.125	20.0	0.0	441.0	0.0	461.0	107.0	4.3
Pinellas Co, Treasure Is., FL	1968	3.250	60.2	0.0	0.0	73.4	133.6	96.0	1.4
Hamlin Beach State Park, NY	1969	3.250	0.0	0.0	220.9	0.0	220.9	116.3	1.9
Cliff Walk, RI	1969	3.250	16.9	0.0	97.2	6.3	120.4	62.5	1.9
Long Island, Fire Is. to Jones Inlet, NY	1970	3.250	0.0	2,242.0	0.0	1,949.0	4,191.0	2,788.1	1.5
Tybee Island, GA	1970	4.875	0.0	0.0	322.8	22.3	345.1	111.3	3.1
Brevard Co, Cape Canaveral, FL	1972	3.250	0.0	0.0	206.0	10.0	216.0	84.3	2.6
Palm Beach Co, Delray Beach, FL	1973	3.250	112.2	0.0	482.2	0.0	594.4	199.3	3.0
Sherwood Island State Park, CT	1974	5.875	1.0	0.0	1,299.0	11.3	1,311.3	286.7	4.6
Rockaway, NYC	1974	6.625	70.0	0.0	4,611.6	338.8	5,020.4	1,860.6	2.7
Duval Co, FL	1974	3.250	340.2	11.4	1,948.0	92.0	2,392.0	1,581.0	1.5
Dade Co, FL	1974	3.250	1,448.0	0.0	14,375.0	285.0	16,108.0	2,708.0	5.9
Pinellas Co, Treasure Is. FL	1974	3.250	151.0	0.0	0.0	196.0	347.0	181.0	1.9
Corpus Christi Beach, TX	1975	5.875	2.0	0.0	1,002.0	0.0	1,004.0	323.0	3.1
Lakeview Park Coop, OH	1975	3.250	0.0	0.0	406.0	0.0	406.0	140.0	2.9
Broward Co., FL, Segment 3	1978	6.625	136.4	30.9	2,382.3	9.8	2,559.4	673.2	3.8
Point Place, OH	1978	6.625	556.7	0.0	21.1	68.2	646.0	538.3	1.2
Brevard Co, Indialantic/Melbourne, FL	1978	6.625	11.5	0.0	1,154.0	0.0	1,165.5	597.1	2.0
Grand Isle and Vicinity, LA	1978	6.875	659.0	429.0	605.0	195.0	1,888.0	1,249.0	1.5
Pinellas Co, Long Key, FL	1978	6.625	22.0	0.0	302.0	0.0	324.0	116.0	2.8
Broward Co, Segment 2, FL	1980	7.375	1,532.0	0.0	565.0	67.0	2,164.0	1,412.0	1.5
Sherwood Island State Park, CT	1981	7.375	0.0	21.6	713.2	0.0	734.8	94.9	7.8
Wrightsville Beach, NC	1981	7.375	414.1	225.7	270.5	0.0	910.3	668.0	1.4
Fort Pierce Beach, FL	1982	7.625	0.0	63.0	973.0	2.0	1,038.0	226.0	4.6
DE Coast Sand Bypass	1984	8.375	0.0	412.5	0.0	8,789.8	9,202.3	383.0	24.0
Pinellas Co, Long Key, FL	1984	8.125	278.0	0.0	154.0	52.0	484.0	392.0	1.2
Pinellas Co, Sand Key, FL	1984	8.125	4,912.0	0.0	4,481.0	282.0	9,675.0	2,684.0	3.6
Dade Co., FL, Sunny Isles (N. Dade Co.)	1984	8.125	419.0	0.0	2,185.0	10.0	2,614.0	1,850.0	1.4
Pinellas Co, Treasure Is., FL	1984	8.125	401.0	0.0	0.0	213.0	614.0	337.0	1.8
Revere Beach, MA	1985	8.375	868.0	0.0	65.0	0.0	933.0	724.6	1.3
Reno Beach, OH	1986	3.250	603.1	0.0	0.0	441.4	1,044.5	338.0	3.1
Palm Beach Co, Boca Raton, FL	1986	8.875	1,130.0	14.0	389.0	0.0	1,533.0	745.0	2.0
Palm Beach Co, Lake Worth Inlet to South Lake Worth Inlet, FL	1986	8.875	4,845.0	633.0	0.0	0.0	5,478.0	3,485.0	1.6
Presque Isle, PA	1986	8.625	0.0	21.0	0.0	2,912.0	2,933.0	2,560.0	1.2
Cape May Inlet to Lower Twp., NJ	1987	8.625	2,977.0	0.0	856.0	160.0	3,993.0	2,389.7	1.7
Virginia Beach, VA	1987	8.625	6,611.0	0.0	6,120.0	0.0	12,731.0	2,511.0	5.1
Maumee Bay, OH	1988	8.625	0.0	6.7	2,540.6	0.0	2,547.3	1,061.4	2.4

Table 4. *Continued.*

Project Name	Price Level	Interest Rate	Storm Damage Reduction: Upland Dev.	Storm Damage Reduction: Land Loss	Recreation	Other	Total Average Annual Benefits	Average Annual Costs	B/C Ratio
Great Egg Harbor and Peck Beach, NJ	1988	8.875	25,903.4	0.0	5,699.3	232.0	31,834.7	7,051.2	4.5
Revere Beach, MA	1988	8.625	0.0	0.0	65.0	1,308.6	1,373.6	778.0	1.8
Lee Co, Captiva Island, FL	1988	8.625	783.3	93.8	540.0	0.0	1,417.1	902.5	1.6
Prospect Beach, CT	1989	8.875	279.0	0.0	100.0	0.0	379.0	346.3	1.1
Ocean City, MD	1989	8.875	13,453.1	0.0	534.0	0.0	13,987.1	9,510.0	1.5
Folly Beach, SC	1990	8.250	1,865.0	0.0	1,403.0	0.0	3,268.0	2,007.0	1.6
Duval Co, FL	1990	8.875	2,188.0	377.3	2,108.5	1,207.2	5,881.0	3,434.0	1.7
Broward Co, Seg. 3, FL	1990	8.875	2,013.0	434.0	1,082.0	0.0	3,529.0	2,886.0	1.2
Manatee County, FL	1991	8.875	3,765.7	91.6	321.0	0.0	4,178.3	1,856.5	2.3
Palm Beach Co, Delray Beach, FL	1991	8.875	1,816.0	71.0	497.0	0.0	2,384.0	981.0	2.4
Broward Co, Segment 2, FL	1992	8.250	8,591.0	1,193.0	632.0	0.0	10,416.0	2,152.0	4.8
Brevard Co, Indialantic/Melbourne, FL	1992	8.500	850.0	112.0	0.0	0.0	962.0	694.0	1.4
Carolina Beach & Vicinity, NC	1992	8.250	4,094.3	989.3	228.3	0.0	5,311.9	2,686.8	2.0
Brevard Co, Cape Canaveral, FL	1992	8.500	739.0	631.0	0.0	0.0	1,370.0	1,856.0	0.7
Fort Pierce Beach, FL	1993	8.125	1,694.0	40.0	20.0	0.0	1,754.0	1,148.0	1.5
Rockaway, NYC	1993	8.750	3,400.0	0.0	6,370.0	0.0	9,770.0	5,136.9	1.9
Tybee Island, GA	1994	8.000	569.0	0.0	7,567.0	0.0	8,136.0	975.0	8.3

[1]Complete information was not available for this project

under construction, in 1995 there were 12 projects listed in this category and the Federal share of costs had increased from $10 million ($1993) to $1,169 ($1995). Those projects in the "Authorized/Awaiting Initiation of Construction" stage reduced from 10 to six with an accompanying decrease in Federal costs of $426 million, and the projects in the "Preconstruction Engineering & Design" stage decreased by two, but the Federal cost increased by $204 million. The estimated costs of the planned projects as of October 1995 are shown in Table 3. Of these costs, approximately 21 percent is for initial restoration, 71 percent is for periodic nourishment and 8 percent is for structures. A list of these projects and the associated cost by construction feature is provided in the final Corps report (CORPS, 1996).

Annual Federal expenditures on the shore protection program has historically been a small portion of the annual USACE Civil Works Budget, varying from less than 1 percent to about 2 percent. While the appropriation has varied considerably from year to year it has been on a upward trend as more projects have been constructed. Overall, Federal shore protection program costs have increased from $5 million in 1950 to $63 million in 1990 ($1995). In the Fiscal Year 1996 budget there was $88 million allotted to the program. The recent increase in shore protection costs is attributed to the unusual start of construction of four large Atlantic Coast projects. Based on current Administration policy, it is expected that yearly Federal expenditures for shore protection projects will decrease in the future.

BENEFITS OF SHORE PROTECTION PROJECTS

Expected Benefits

The benefits of shore protection projects are much more difficult to measure than the costs. This difficulty was highlighted by the National Research Council in their recent report (NRC, 1995). The basic approach for determining benefits and costs is to develop two future scenarios of forecasted development and use of the proposed project area: 1)"with" the project; and 2) "without" the project. The difference between these two projected streams of development is considered to represent the measure of the economic, social and environmental benefits and costs of whatever project alternative is selected. This procedure is a fundamental requirement of water resources' project planning as prescribed by U.S. Water Resources Council's "Principles and Guidelines" (WRC, 1983). The major categories of allowed benefits for shore protection projects are storm damage reduction and erosion protection. Other benefit categories include recreation, reduced maintenance of existing structures, and enhancement of property values.

It should be noted that because of the great variability of storm, wind and wave activity in the coastal zone, potential damages are estimated by assuming that the past history of storm damage will repeat itself, in a statistical sense. Over a very long period of time (disregarding climate change and sea level rise) this assumption is sound and the statistical distributions for storm and wave events should be very similar. For any specific time period of 10, 20 or 50 years, however, this assumption may not hold. Hence, projects planned and designed today, on the basis of the previous 50 years of storm, wave and erosion data, may not be subject to the expected frequency of events over the next 10 or 15 years period of performance. Storms may be more or less frequent than expected, creating discrepancies between the anticipated and realized benefits (storm damage reduction) and costs (beach nourishment maintenance). Thus, while the extension of an absolute measure of benefits and costs may be problematic for a specific time period, the relative difference between the "with" and "without" project case is on firmer footing, because the same storm and wave frequency data are used for both. One redeeming aspect of this hypothetical forecasting exercise is that information is constantly updated. While a shore

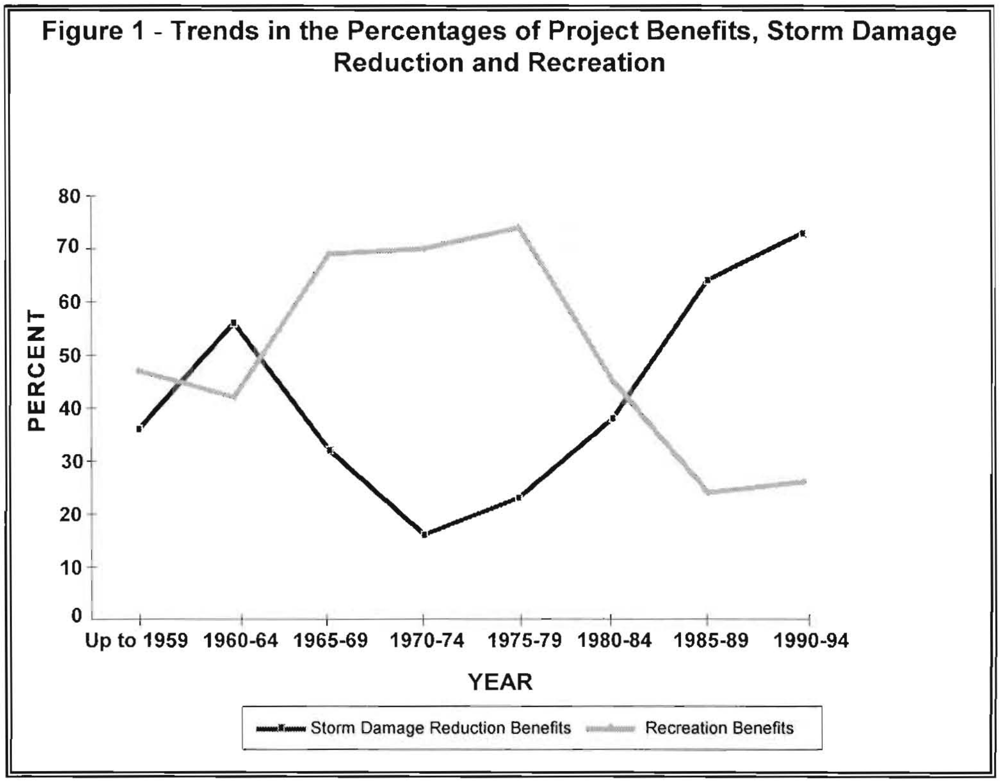

Figure 1. Trends in the percentages of project benefits, storm damage reduction and recreation.

protection project may be planned and designed for one set of statistics, if it is a periodic beach nourishment project, each replenishment takes into account updated wave and storm information. Unlike a hard structure, such as a groin, seawall or breakwater, beach nourishment, by its nature, allows new information to be factored into the decision for the next nourishment period of 3-10 years.

As discussed earlier, there were 82 large constructed projects identified in the 1993 survey. Of these projects, 26 were authorized in the 1950s and 1960s and were deleted from detailed comparison because they were small in scope and cost, would have been included in the Corps' Continuing Authorities (Small Projects) Program had it been in effect at that time, or, there was insufficient data available. The analysis focused on the remaining 56 large projects. These projects protect a shoreline distance of about 210 miles compared to the 82 projects which protect a shoreline of about 226 miles.

The expected average annual benefits of the 56 shore protection projects are listed by category in Table 4. The discount rates used in deriving the present worth of projects, are specified by law, and vary according to the year that the project was authorized. These figures are not adjusted to a common price level and, therefore, cumulative benefits are not presented. The project benefits have been arranged in chronological order based on the price level. Several projects appear more than once in the table, because they were evaluated more than once. Most of these reevaluations were required by the Water Resources Development Act of 1986 (WRDA '86), resulting in significant changes in policy and consequent evaluation procedures.

When the storm damage reduction and recreation benefits in Table 4 are calculated as percentages of the total project benefits, and grouped by five-year periods, a pattern emerges, as illustrated in Figure 1. This figure shows that projects designed and evaluated prior to 1964 contained significant proportions of both storm damage reduction and recreation benefits. From 1965 to 1979, projects were justified primarily on the basis of recreation benefits, while storm damage benefits assumed a minor role. During the 1980's a reversal of this trend occurred, which has continued on into the 1990's. This change was caused primarily by successive and consistent Administration policy changes, and then consolidated in law by WRDA '86. The economic justification of a typical 1990's shore protection project derives about 73 percent of its benefits from storm damage reduction and about 27 percent from recreation. Principally, since 1975, each Administration considered that Federal investments in recreation should not be the basis of project justification—even though it was recognized that recreation comprised a large portion of the economic benefits of a shore protection project.

Measuring "Actual" Benefits

"Actual" benefits are those potential damages that are avoided because of the presence of the project. In contrast to the actual costs of a project (Corps, 1994 and 1996), "actual" benefits are not measured, but are somewhat of an estimate based on very detailed storm damage rating curves. The "actual" benefits of a project are defined as the difference between: 1) what happened since the project's construction in terms of storm damages, recreation, or any other type of benefit claimed for the project; and 2) what would have happened during that time period if the project had not been constructed. Again, it is the difference between the estimated stream of benefits since the time that the Federal project has been operating versus the assumption that there was no Federal project during that period of time; i.e., the "with" versus "without" condition. The benefits that are realized "with" a project could, in principle, be measured directly, although such measurements are not routinely conducted by USACE district offices. Although there are periodic post storm damage surveys conducted to ensure that the estimates were reasonable, there are no routine daily measurements of events which are somewhat less than the large damaging storms, but which also cause damage, primarily erosion. Benefit estimation "without" the project, however, is a hypothetical exercise. The "without" analysis attempts to determine what physical and economic conditions would have happened "without" the project and hence, can only be estimated through modeling. This hypothetical situation is similar to the type of analysis that is done as part of planning and design prior to the construction of a project, except in the case of trying to determine "actual" benefits, one is looking backward over the life of a constructed project rather than forward into the future of a proposed project. Because one is hindcasting, the storm events are known, so that these actual values can be inserted into storm damage models. The models are then run under "with" and "without" project conditions, and the difference in damages is the "actual" damage prevented by the project (SKAGGS and MCDONALD, 1991).

Eleven shore protection projects had sufficient data and models available to generate estimates of "actual" storm damage reduction benefits. A list of these projects are listed in Table 5. In most cases, these are older projects which do have some history, but which have also been recently reevaluated as a consequence of the requirements of WRDA '86 and have employed some of the more recently developed and presumably more accurate storm damage models.

Recognizing that estimating the actual economic performance of a project is largely a comparison of estimated benefits—one of hindcasted "actual" benefits with forecasted benefits, and that both estimates represent differences between the "with" and "without" project scenarios, one must interpret this information cautiously. Even though the methodology is conceptually sound, the available information does not warrant a firm conclusion because of the estimation uncertainties and the relatively short period of record upon which the statistics are based. Percentage differences between "actual" annual storm damage benefits (averaged over the life of the project), and predicted average annual storm damage benefits are presented also in Table 5. Of the 11 projects, six had "actual" storm damage benefits higher than projected and five had "actual" storm damage benefits lower than projected. As mentioned previously, the number and severity of storms play a significant role here. Some projects have simply not been in operation long enough to demonstrate their damage prevention capabilities because they have not been subjected to the "normal" distribution of expected storms. Others have had a larger number of storms than anticipated according to the expected frequency distribution of those events for the given area.

Table 5. *Storm damage reduction (SDR) benefits comparison for selected projects.*

Project	Years Project has Been in Place	"Actual" SDR Benefits (average annual million $)	Predicted[1] SDR Benefits (average annual million $)	Percent Difference Between Actual and Predicted SDR
Rockaway, NYC	19	6.4	3.4	88
Ocean City, MD	4	23.3	13.5	73
Virginia Beach, VA	30	6.9	6.6	5
Carolina Beach, NC	29	1.9	5.1[2]	(−) 63
Duval Co., FL	16	2.0	2.6[2]	(−) 23
Palm Beach Co., FL—Delray	21	0.4	1.9[2]	(−) 79
Broward Co., FL—Segment II	24	6.0	9.8[2]	(−) 39
Broward Co., FL—Segment III	14	0.8	2.4[2]	(−) 67
Manatee Co., FL	2	6.0	3.9[2]	54
Pinellas Co., FL—Sand Key	9	8.7	4.9	78
Grand Isle, LA	9	3.9	1.1[2]	254

[1]Predicted Storm Damage Benefits are from the most recent project evaluation

[2]Includes the sum of upland development and land loss, for other projects there were no land loss benefits claimed

"Actual" recreation benefits were measured for only two projects. Virginia Beach, VA reported $496,000 in actual annual recreation benefits compared to $115,000 in predicted annual recreation benefits. Carolina Beach, NC calculated the total cumulative recreation benefits to be $3,616,700, significantly higher than the predicted cumulative recreation benefits of $2,705,000. So, although Carolina Beach had fewer storm damage benefits than expected, the recreation benefits were higher than expected. This is to be anticipated, as recreation attendance is inversely proportional to the number of stormy days.

Do Shore Protection Projects Induce Development?

Background

Concerns have been raised (KAUFMAN and PILKEY, 1983 and PILKEY and NEAL, 1992) that shore protection projects might, in the long run, lead to increases in storm damages rather than reductions in storm damages. The rationale behind this stems from the fact that no storm protection project can guarantee complete protection from all storms. There is always some degree of what are termed "residual damages" which would occur if the project were subjected to extreme events beyond its derived, economically efficient designed level of protection. The second component of this argument is that because the shore protection project is there, it will stimulate private investment (and the accompanying public infrastructure) and the economic damage associated with any given event might even increase (NRC, 1995). This line of reasoning further contends that the increase in "residual damages" due to the increased development may be larger than the damages which are prevented by the project. Finally, as more growth is attracted, the economic basis for justifying more extensive projects also increases, thereby leading to a perpetual spiral of reinforcing, self-justifying rationale.

Economic Investigations

Empirical evidence was not available to support or refute the contention that Federal shore protection projects induced growth and development. Therefore, a separate research effort was undertaken and a report (CORDES and YEZER, 1995) was produced on this issue. Under this study, three empirical economic investigations were conducted to ascertain whether USACE projects increased the rate and extent of development in protected areas, *i.e.,* whether they induced development. The three complimentary studies were: 1) a survey of Beachfront Community Residents; (2) an Econometric Model of Beachfront Development; and (3) an Econometric Analysis of Beachfront Housing Prices.

(1) *Survey of Beachfront Community Residents.* From an economic evaluation perspective, the methodology used by the Corps is based on the principal that shore protection projects are designed to lower the risk of storm damages primarily for the development that is already in place, and are justified primarily on that basis. In order for a shore protection project to attract additional development, developers and potential home buyers must first be aware of the project, and second, perceive that the project lowers expectations of future storm damage problems.

The survey was administered in three beachfront areas to compare public perception and knowledge about shore protection in areas "with" and "without" a project. One area included southern Duval County, Florida (Jacksonville, Atlantic, and Neptune Beaches) that had ("with") protection projects and adjacent northern St. Johns County (Ponte Vedra), where there was no ("without") Corps project. The survey was also administered in an area near Wilmington, North Carolina where two neighboring beaches have active Corps beach nourishment projects (Carolina Beach and Wrightsville Beach). The third area surveyed was in the Manasquan area of New Jersey where the Corps does not have projects, but there are proposals for projects. All areas had a history of erosion and storm damage problems. The specific zones selected for the survey were the first and second rows of beachfront residential single family housing. The details of the questionnaire and survey techniques are reported by CORDES and YEZER (1995). Some of the statical results of interest are contained in the following paragraphs.

Beach erosion is a significant problem in these areas. Thirty-nine percent of the respondents had observed erosion damage to either their own property or nearby property. Furthermore, more than 25 percent of the respondents felt that this erosion had a moderate or large effect on the sale price of their homes. More than 70 percent of households responding to the survey participated in the National Flood Insurance program. These results suggest high levels of concern with erosion and storm damage.

Awareness of USACE activity and specifically, knowledge of discrete shore protection measures, among beachfront property owners, however, was remarkably low. In response to a question designed to reveal the general role of the Federal, state or local governments in relation to local storm damage or erosion problems, the Corps was mentioned by less than 10 percent of the respondents. When responses regarding the specific role of the Corps were elicited, 20 percent of the respondents mentioned the Corps. However, in a third question which was designed to determine any indirect role of the Corps, only 10 percent of the respondents mentioned the Corps. This level of recognition of Corps activity is quite low, considering the fact that the Corps has longstanding and active projects in three of the six beach areas. However, longtime residents tended to be more aware of Corps projects than newer residents. These survey results suggest that the Corps has little effect on residential real estate development decisions in beachfront communities.

At the same time that the household survey described above was being conducted, an informal attempt was made to determine the perceptions of local real estate agents in the Duval and Wrightsville areas, where Corps activity has been significant. Local real estate offices in these beachfront communities were visited and agents were asked about the effects of Corps activity on local real estate markets. These interactions with real estate professionals revealed the following: 1) there was a general inability to recognize which areas were protected by Corps projects; and 2) Corps protection was not regarded as an important factor influencing the pattern of real estate development.

In conclusion, most shoreline property owners surveyed are not aware if there is, or is not, a shore protection project protecting their property. Yet, they are the beneficiaries of storm damage prevention projects and provide the basis for the economic justification of such projects. The extremely low level of awareness among this group suggests that USACE shore protection projects do indeed have a low profile and is even more remarkable for the fact that about 40 percent of project costs are shared by the local (community and state) sponsors. This evidence alone is inconsistent with the induced development concept. *How can Corps projects attract development when they are nearly invisible to those who live right next to them?*

A survey conducted by NRC (1995) of largely secondary governmental individuals indicated a slightly better understanding. This small sample survey indicated that the interested and affected publics were generally well informed about many aspects of beach nourishment projects with respect to technical and policy issues. However, lack of public understanding was reported to have the potential to stimulate controversy over project performance. The NRC believed that the surveyed governmental employees could provide reasonable, if not complete, indications of public understanding.

(2) *Econometric Model of Beachfront Development.* Another line of reasoning which was pursed in the economic assessment was that if induced development is significant, it should be possible to detect its effects on the economy of beachfront

Table 6. *Induced development study selected communities.*

Community	Corps Project	Project Status
Anna Maria, FL (Manatee County)	Manatee Co, FL	Constructed
Holmes Beach, FL (Manatee County)	Manatee Co, FL	Constructed
Bradenton, FL (Manatee County)	No project	
Longboat Key, FL (Manatee County)	No project	
Atlantic Beach, FL (Duval County)	Duval Co., FL	Constructed
Jacksonville Beach, FL (Duval Co)	Duval Co., FL	Constructed
Neptune Beach, FL (Duval County)	Duval Co, FL	Constructed
Bal Harbor, FL (Dade County)	Dade Co, FL	Constructed
Miami Beach, FL (Dade County)	Dade Co, FL	Constructed
North Miami Beach, FL (Dade Co)	Dade Co, FL	Constructed
Boca Raton, FL (Palm Beach Co)	Palm Beach Co, Boca Raton, FL	Constructed
Delray Beach, FL (Palm Beach Co)	Palm Beach Co, Delray Beach, FL	Constructed
Boynton Beach, FL (Palm Beach Co)	Palm Beach Co, FL—All segments from south Lake Worth Inlet to Boca Raton Inlet	PED[1]
Riviera Beach, FL (Palm Beach Co)	Palm Beach, Co, FL—all segments from south Lake Worth Inlet to Boca Raton Inlet	PED
West Palm Beach, FL (Palm Beach Co)	No Project	
Clearwater, FL (Pinellas Co)	Pinella Co, FL—Clearwater Beach Island Segment	AF[2]
Naples, FL (Collier County)	No Project	
Daytona Beach, FL (Volusia County)	No Project	
Treasure Island, FL (Pinellas Co)	Pinellas Co, FL—Treasure Island Segment	Constructed
St. Petersburg, FL (Pinellas Co)	Pinellas Co, FL—Long Key Segment	Constructed
Indian Rocks Beach, FL (Pinellas Co)	Pinellas Co, FL—Sand Key Segment	Constructed
Cocoa Beach, FL (Brevard Co)	No project	
Melbourne Beach, FL (Brevard Co)	Brevard Co, FL—Indialantic/Melbourne segment	Constructed
Fernandina Beach, FL (Nassau Co)	Nassau Co, FL	PED
Vero Beach, FL (Indian River Co)	Indian River Co, FL—Vero Beach Segment	PED
Venice Beach, FL (Sarasota Co)	Sarasota Co, FL—Longboat Key and Venice Beach segments	PED
Ormond Beach, FL (Volusia Co)	Daytona Beach Shores, FL	Reconnaissance Study
New Smyrna Beach, FL (Volusia Co)	No project	
Panama City, FL	Panama City Beaches, FL	PED
Ocean City, MD	Ocean City, MD	Constructed
Long Beach Twp, NJ (Ocean Co)	No project	
Long Branch, NJ (Monmouth Co)	Atlantic Coast of NJ, Sandy Hook to Barnegat Inlet, Section 1—Seabright to Ocean Township	AF
Union Beach, NJ (Monmouth Co)	No project	
Ocean City, NJ (Cape May Co)	Great Egg Harbor Inlet and Peck Beach, NJ	Constructed
Sea Isle City, NJ (Cape May Co)	No project	
Long Beach, NY (Nassau Co)	Atlantic Coast of Long Island, Jones Inlet to East Rockaway Inlet, Long Beach Island, NY	Feasibility study
Southampton, NY (Suffolk Co)	No project	
Carolina Beach, NC (New Hanover Co)	Carolina Beach, NC	Constructed
Wrightsville Beach, NC (New Hanover Co)	Wrightsville Beach, NC	Constructed
Isle of Palms, SC (Charleston Co)	No project	
Myrtle Beach, SC (Horry Co)	Myrtle Beach, SC	PED
Virginia Beach, VA	Virginia Beach, VA	Constructed

[1]PED—preconstruction engineering and design
[2]AF—Authorized awaiting funding

communities using standard local area econometric models. Application of standard techniques allows direct testing for the statistical significance of Corps projects, ranging from approval of a project, to initial construction and periodic nourishment measured in tons of sand and in dollars, on the economy of a beachfront community. Thus, it is possible to estimate the size and significance of any induced development effects. The statistical test implicitly holds constant the stimulus to local development provided by general growth of income and employment in the national economy. It is important to differentiate between beachfront development that occurs after a shore protection project is built, but which is due to general economic growth of income and employment, and would have occurred "without" the project anyway, and any induced development which took place because of the project. The results of such tests are reported in this section.

The 42 beachfront communities which constituted the sample were selected based on data availability, and are listed in Table 6 with the status of the associated Corps project. Of the 42 communities, 19 have a constructed project, 11 have a project that is in some stage of planning, and in 12 areas there are no Corps projects. The time period covered is 1960 to 1992, yielding 33 annual observations for each area. The sample includes communities where the Corps was active for the entire period, areas where the Corps had no authorization to act, and communities in which the Corps gained authorization during the 1960 to 1992 period. Within the sample of communities, it is possible to observe cases of development

Table 7. *Variables used in the econometric model of beachfront communities.*

Variable	Definition
TSAND	Tons of sand used annually in beach nourishment
TCOST	Annual cost of nourishment ($1993)
YRAUTH	Dummy variable designating year of authorization
YRMOD	Dummy variable designating year of modification
ACTIVE	Dummy variable designating year when project was active (beginning with YRAUTH)
NFI	Dummy variable designating years when the community participated in the National Flood Insurance Program
FEMAP	Dummy variable designating years when a completed *flood insurance map* was available.
DINCOME	Links beachfront development to inland economic growth through a proximity-weighted index of change in income in eastern metropolitan areas
DEMPLOY	Links beachfront development to inland economic growth through a proximity-weighted index of change in employment in eastern metropolitan areas
STORM1	An index of the strength of storm which reached a landfall in the county in which the beachfront community is located
STORM2	An index of storm damage to the beachfront area for areas with authorized Corps projects

both "before" and "after" Corps projects as well as "with" and "without Corps activity.

In this model, new beachfront development is measured by the number of new housing units authorized by building permits granted by the county or community during a given year. The building permit data includes units in both single family and multi-family structures. These are annual data and are not subject to problems of seasonal peaks that render use of other indicators of beachfront community development questionable.

In order to detect any possible influence of Corps activity on beachfront communities, a variety of indicators of the Corps' presence were selected. These variables are summarized in Table 7.

The estimated equations also include a time trend and a series of zero-one dummy variables for the various states in which the communities are located. State location dummy variables should be associated with differences in local economic activity, infrastructure development, taxes and subsidies, zoning and land development policy, etc. The constant term reflects the reference state, Virginia. The results of the model in the double-log form are presented in Table 8A with demand driven by growth in *employment* and in Table 8B with demand driven by growth in *income*.

The separate research study undertaken on the effects of induced development (CORDES and YEZER, 1995) also presented a series of steps beginning with a very simple model that includes only variables reflecting Corps activity through the final double log model given in Tables 8A and 8B. This paper provides only the final model as it is the most appropriate because it includes the influence of growing income and employment in inland areas on the demand for beachfront housing. The original simple model which included only Federal government policy variables were presented so that the interaction between the estimated coefficients of these models and variables reflecting economic growth may be observed. Two functional forms, linear and double-logarithmetic, were then tested. In the linear model, estimated coefficients reflected the relation between changes in the level of independent variables and change in the level of new residential construction. In the log-linear model, estimated coefficients reflect the relation between percentage changes in the independent variables and the percentage change in new residential construction. The addition of an "L" as a prefix to the name of a variable indicates that it is the logarithm of the variable. The significant findings of the double log model are as follows:

(a) In areas where periodic nourishment is relatively inexpensive, more development takes place than in areas where nourishment is relatively costly.

(b) Initial approval of a community for the National Flood Insurance program had a significant positive effect on residential development, but that publication of the first flood maps had no effect.

(c) Storm damages depressed development in the short run.

(d) Residential development of beachfront communities along the east coast is driven by a large economic growth effect from metropolitan areas east of the Mississippi River.

(e) A 10 percent rise in weighted real income in metropolitan areas in the east generates a 1.7 percent rise in new construction in beachfront communities and a 10 percent rise in employment in these same metropolitan areas generates a 2.0 percent rise in new construction in the beachfront communities. *This increase in construction occurs independent of Corps activity in the communities.*

In conclusion, the econometric results presented here imply that general economic growth of inland communities is sufficient by itself to drive residential development of beachfront areas at a rapid pace. Many beachfront communities have experienced substantial residential development following approval and construction of USACE shore protection projects. *However, this statistical analysis shows that such development is generated by growth of income and employment in inland areas and would have taken place without USACE projects. Indeed, high levels of development have occurred in areas where the USACE has never been active.*

(3) *Econometric Analysis of Beachfront Housing Prices.* The econometric model of beachfront community development presented above allows a direct test of whether or not shore protection projects generate induced development. It is very informative, but its ability to show the effects of shore protection are reduced if coastal development regulations severely restrict beachfront construction. A more sensitive means of assessing the existence of shore protection effects is through the use of spacial housing price indices. (*i.e.* how house prices vary by location) These are used in an indirect test that looks for neighborhood effects of public projects. There are two benefits of this test over the previous estimations. First, it is possible to estimate price changes out to the limit of development in the "first row" of residences. Second, price changes are more flexible and immediate than changes in new construction. Therefore, they may show induced development effects that do not appear in the direct test.

There are two parts to the indirect test. First, indices that

Table 8A. *Determinants of new residential building permits in beachfront communities—demand driven by employment growth.*

Double Log Model with Demand Driven by Employment Growth					
Variable	Coefficient	Std. Error	t	Prob > |t|	Mean
Newhouse					4.842448
LTSAND	0.1317549*	0.0626096	2.104	0.036	0.5101688
LTCOST	−0.1662381*	0.0459951	−3.614	0.000	0.8241782
YRAUTH	−0.3499372	0.2719229	−1.287	0.198	0.21645
YRMOD	−0.8012403*	0.4320752	−1.854	0.064	0.008658
ACTIVE	−0.0706443	0.0958217	−0.737	0.461	0.466811
NFI	0.313942*	0.1835137	1.711	0.087	0.6507937
FEMAP	−0.1625444	0.1644793	−0.988	0.323	0.5829726
LSTORM1	0.0670711	0.0654757	1.024	0.306	0.1544012
LSTORM2	−6.119795*	0.2790012	−2.193	0.028	0.0247323
LDEMPLOY	0.1951873*	0.0396918	4.918	0.000	4.487639
LTIME	−0.0656433	0.084936	−0.773	0.440	2.577408
WEST FLA	−3.234556*	0.3015899	−10.516	0.000	0.2380952
EAST FLA	−3.171374*	0.3015899	−10.516	0.000	0.2142857
SOUTH FLA	−2.576936*	0.2933138	−8.786	0.000	0.2380952
NY	−2.64167*	0.3574655	−7.390	0.000	0.047619
NJ	−3.6496*	0.3122149	−11.689	0.000	0.1190476
MD	−2.837016*	0.3698573	−7.671	0.000	0.0238095
NC	−3.933733*	0.3355893	−11.752	0.000	0.047619
SC	−3.406025*	0.3421078	−9.956	0.000	0.047619
CONSTANT	7.188815*	0.3953833	18.182	0.000	1
Number of obs = 1,386		F (19, 1,366) = 19.45		Prob > F = 0.0000	
R-square = 0.2129		Adj R-square = 0.2020		Root MSE = 1.4393	

*Indicates that the estimated coefficient is statistically significant at the 90% level.

estimate the relationship between distance from the shoreline, and changes in house prices over time are developed. To generate the indices, the repeat sale method is employed. This method produces an index by following changes in prices of homes that sell more than once during the interval being studied. Three Florida counties in which the Corps has been active are involved in the study (Dade, Duval, and Pinellas). Within each county, the price index is estimated at three distances from the coast. The index for properties on the coast is labeled "coast-line". For properties one mile off the coast,

Table 8B. *Determinants of new residential building permits in beachfront communities—demand driven by income growth.*

Double Log Model with Demand Driven by Income Growth					
Variable	Coefficient	Std. Error	t	Prob > |t|	Mean
Newhouse					4.842448
LTSAND	0.136205*	0.0628502	2.167	0.030	0.5101688
LTCOST	−0.1685439*	0.0462128	−3.647	0.000	0.8241782
YRAUTH	−0.3520084	0.27299	−1.289	0.197	0.21645
YRMOD	−0.7784236*	0.4337647	−1.795	0.073	0.008658
ACTIVE	−0.0680478	0.0964501	−0.706	0.481	0.466811
NFI	0.3200446*	0.1842608	1.737	0.083	0.6507937
FEMAP	−0.222441	0.1660494	−1.340	0.181	0.5829726
LSTORM1	0.0885788	0.0852358	1.039	0.299	0.120004
LSTORM2	−0.6221634*	0.2801718	−2.221	0.027	0.0247323
LDINCOME	0.1687254*	0.0464011	3.636	0.000	3.150971
LTIME	−0.0959131	0.0872685	−1.099	0.272	2.577408
WEST FLA	−3.33039*	0.3127567	−10.649	0.000	0.2380952
EAST FLA	−3.25483*	0.3077755	−10.575	0.000	0.2142857
SOUTH FLA	−2.660056*	0.2979054	−8.929	0.000	0.2380952
NY	−2.884983*	0.3519592	−8.197	0.000	0.047619
NJ	−3.677426*	0.3233194	−11.374	0.000	0.1190476
MD	−2.778978*	0.3709214	−7.492	0.000	0.0238095
NC	−4.165021*	0.3297802	−12.630	0.000	0.047619
SC	−3.60674*	0.3379658	−10.672	0.000	0.047619
CONSTANT	7.734884*	0.3601105	21.479	0.000	1
Number of obs = 1,386		F (19, 1,366) = 19.45		Prob > F = 0.0000	
R-square = 0.2068		Adj R-square = 0.1975		Root MSE = 1.4449	

*Indicates that the estimated coefficient is statistically significant at the 90% level

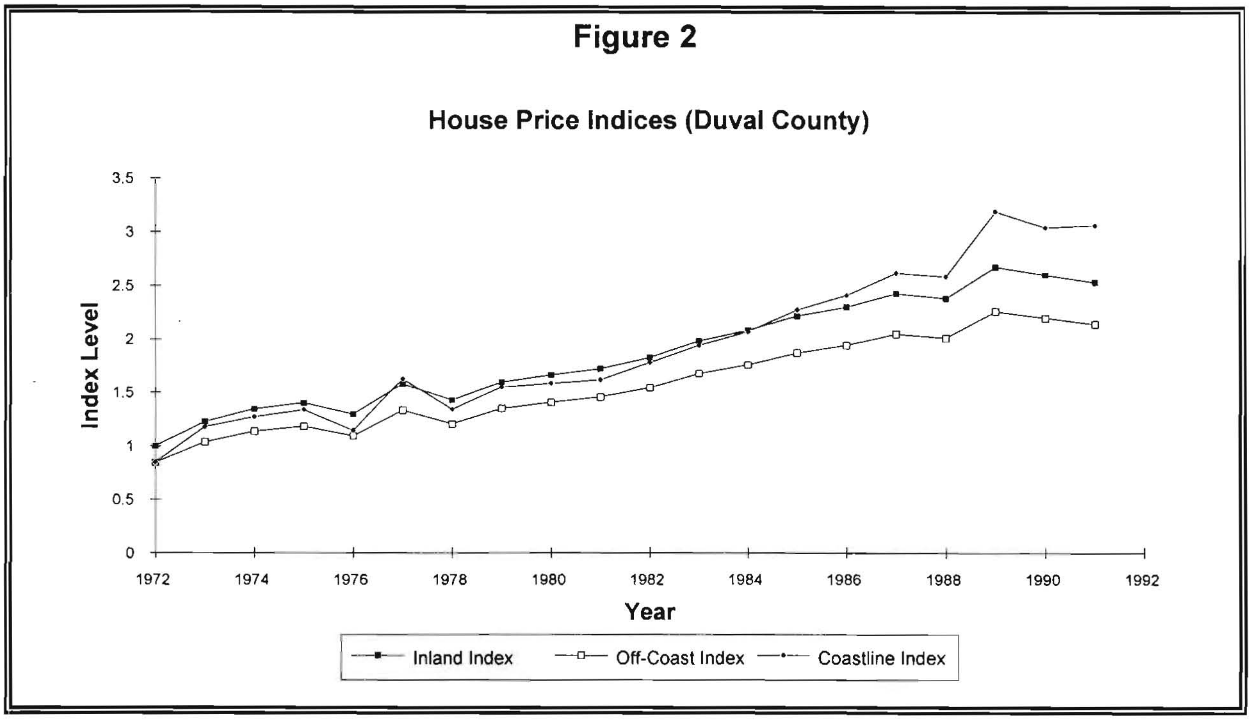

Figure 2. House price indices (Duval County).

the index is called "off-coast". Finally, for houses located at a distance of five miles from the coast, the index is known as "inland". If individuals value proximity to the shore, then this should be captured by the relative levels of the indices. The "coastline" index should be higher than the others. Different rates of appreciation for the indices will alter their relative levels over time.

To check specifically for effects caused by the existence of Corps shoreline protection projects that mitigate future losses, statistical testing is done on the "coastline" index. If the protection offered by Corps projects is recognized by homeowners, housing prices on Corps protected beaches should be higher than those on unprotected beaches. The empirical test allows changes in housing prices to be explained by inland development, and the incidence of storms, as well as Corps activity. A detailed description of the methodology for estimating the spatial house price change indexes and the impact of Corps activity on housing prices is given by Cordes and Yezer (1995).

(a) *Housing Price Indices.* Figure 2 shows the pattern of house prices indexes for Duval County over the 1972 to 1991 period. Indexes have been normalized so that the inland price index in 1972 equals 1.0. While only one of the three counties has been shown in this report, in all cases, the computed price indexes follow a similar pattern. The 1972 value of the index at the inland location is highest and the index for the beachfront is the lowest, but *the rate of price appreciation for the beachfront area is higher, so that the beachfront price index is highest by 1991.*

(b) *House Price Appreciation.* Figure 3 displays changes in the house price index at Duval County over the 1972 to 1990 period. This county is representative of the three counties in that the rate of appreciation in the price index for beachfront areas often differs significantly from that of either the off coast or inland areas. There is a high variation in the rate of change in house prices over the period, including periods of very rapid price appreciation and even some periods when prices fell slightly. It appears that the beachfront real estate market is subject to some influences that do not characterize either off-coast or inland areas. This raises the possibility that *differences in rates of appreciation could be due to shore protection efforts.*

Given that, by the 1990's, the housing price index in all three counties is higher on the beachfront than inland, it is not surprising that these areas have significant rates of investment in beachfront real estate. *Market prices are clearly directing development to beachfront areas of all three counties.* The estimates reported here are an attempt to determine the extent to which more rapid rates of beachfront price appreciation are determined by USACE shore protection activities.

(c) *Statistical Analysis.* The average annual beachfront appreciation rate was 12 percent, with a substantial standard deviation of 22 percent, including some years in which the rate of change in housing prices was as low as minus 19 percent. The data was analyzed in a series of equations in which COAST (the annual percentage change in estimated house prices at the shoreline) is the dependent variable. The first equation showed that beachfront appreciation is largely a

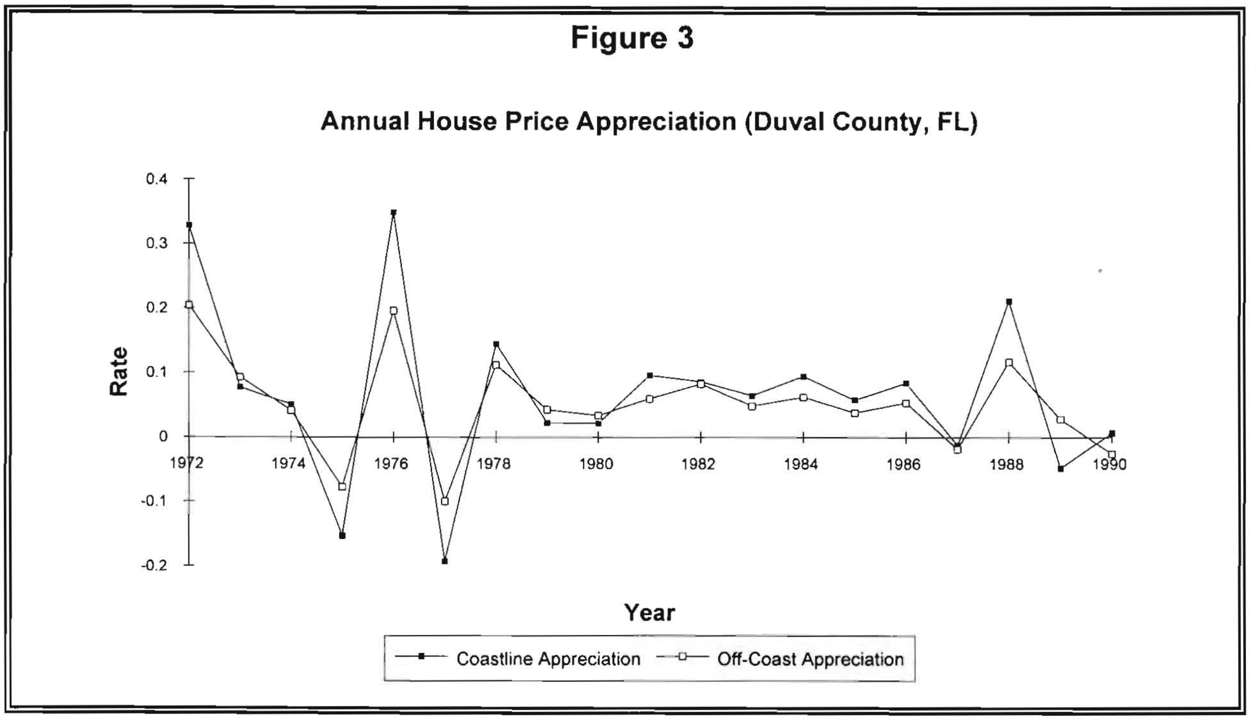

Figure 3. Annual House Price Appreciation (Duval County, FL).

function of inland appreciation. That is, changes on the coast reflect inland economic growth.

Adding the two variables reflecting the presence and level of Corps activity, ACTIVE and TCOST, and the STORM variable indicating significant storms, adds essentially nothing to the predictive power of the model. These variables are added sequentially in a series of steps. The model containing all of the variables is presented in Table 9. While the estimated coefficients of ACTIVE and TCOST generally have a positive sign, they are always non-significant. The estimated coefficient of STORM is negative and non-significant.

Table 9. *Determinants of beachfront housing price change.*

Estimates Using Inland Price, County, Storm, Corps Activity and Corps Cost Variables					
Variable	Coefficient	Std. Error	t	Prob > |t|	Mean
Coast					11.97733
Dade	−0.4603655	1.557026	−0.296	0.769	0.3333333
Duval	−0.4009376	1.440037	−0.278	0.782	0.3333333
Inland	1.010759*	0.283721	35.625	0.000	9.853667
Active	0.5306881	2.057417	0.258	0.797	0.2666667
Tcost	0.0000903	0.0001324	0.682	0.498	3146.767
Storm	−2.341485	2.569889	−0.911	0.366	0.0333333
Constant	1.957012*	1.058918	1.848	0.070	1

Number of obs = 60 F (6, 53) = 242.43 Prob > F = 0.0000
R-square = 0.9468 Adj. R-square = 0.9609 Root MSE = 4.402

*Indicates that the estimated coefficient is statistically significant at the 90% confidence level.

In conclusion, even if the estimated coefficients of all three variables were statistically significant, their combined effect on the rate of beachfront housing price appreciation would be modest compared to the average rate of appreciation of beachfront real estate.

Findings

The overall findings of these three empirical investigations are remarkably consistent and can be presented as a single set of conclusions.

- The primary determinant of development in beachfront communities is growth in demand based on rising income and employment in inland areas.
- The statistical evidence indicates that the effect of the Corps on induced development is, at most, small compared to the general forces of economic growth which are stimulating development in those areas.
- It appears that Corps activity has little effect on the decisions of developers, homeowners, and housing investors.

There are many possible reasons for this lack of effect found in the formal empirical tests and informal surveys. It may be that recent buyers of real estate in beachfront communities are not aware of the hazards of living along the shorelines or discount the economic impacts. Or they may simply take for granted an array of Federal programs and liability insurance to compensate them for any damages. The attraction of living and recreating along the coastline simply outweighs the disadvantages and there appears to be little need to account for a myriad of state, local and Federal programs, including tax incentives, which comprise the decision of an individual homeowner.

ENVIRONMENTAL CONSIDERATIONS ASSOCIATED WITH SHORE PROTECTION PROJECTS

Environmental Resource Categories

There are five environmental resource categories that should be considered in evaluating the environmental impacts of shore protection projects: physical, water quality, biological, aesthetic, and cultural. These requirements apply equally to "borrow" areas as well as the "project" site (CORPS, 1989).

The *physical modifications* of the environment from coastal shore protection projects can result in both desirable and undesirable impacts. Many adverse impacts can be avoided by formulating a number of alternatives for siting and design. Structural and, to a lesser extent, nonstructural measures have the potential of altering the hydrodynamic regime (erosion, deposition, and longshore transport) and the hydraulic and wave energy conditions of the project area. Furthermore, construction frequently alters the shoreline configuration and/or bathymetry at the project site and occasionally up or down coast, by modifying the littoral transport system. In many instances, these modifications are the objective of the design process.

Water quality impacts involve changes in the characteristics of the nearshore waters rather than changes in shoreline configuration or local bathymetry. These impacts are manifested on both a short-term and long-term basis. The construction process is often responsible for increases in local turbidity levels, changes in salinity, releases of toxicants or biostimulants from beach fill materials, introduction of petroleum products, and/or the reduction of dissolved oxygen levels. These impacts are short-lived, and ambient water quality conditions will rapidly return unless long-term changes in the hydrodynamics and hydraulics have occurred. It is these long-term impacts that must be identified during the design process. The long-term impact on water quality of nonstructural alternatives is generally negligible, whereas structural alternatives have a range of potential impacts.

Nearshore marine and estuarine *biological systems* are diverse and complex. Shore protection projects may benefit one or more components of the biological system while adversely affecting others. Biological assessments of shore protection projects are used to predict the kind of ecosystem and importance, spatial extent, and severity of expected biological changes. In practice, analysis usually focuses upon species of commercial or recreational importance; rare, threatened, or endangered species; and sensitive or highly productive habitats. The construction of shore protection measures usually produces short term physical and water quality disturbances. These perturbations directly affect biological communities and may result in long-term impacts, both positive and negative. For example, some ecosystems damaged by construction or water quality degradation may recover slowly and take years to achieve preconstruction levels of development. Many of these impacts are unavoidable. However, construction activities can often be timed to avoid critical events such as turtle and shorebird nesting and fish or shellfish migrations, or located to avoid sensitive areas.

Coastal shore protection projects affect *aesthetic* characteristics of the environment through changes caused by construction and maintenance activities, the presence of the coastal structures, and changes in public use patterns. Changes in public use patterns include the increased use of the coastal area for recreation or increased use of an area resulting from the protection afforded by the coastal structure. The aesthetic value of an environment is determined by the combination of landscape components, *e.g.,* water resources, vegetation, and the perceptions and expectations for the resource user or visitor. Again, most, if not all beach nourishment work is accomplished to avoid critical biological lifecycle periods and peak recreational use—thereby minimizing the adverse ecological as well as aesthetic impacts.

Cultural resources are the physical evidence of past and present habitation that can be used to reconstruct or preserve human history. This evidence consists of structures, sites, artifacts, and objects that may be studied to obtain relevant information. Regulations of the Corps require all actions involving unavoidable effects on National Register or eligible historic properties to be fully coordinated with the State Historic Preservation Officer and the Advisory Council on Historic Preservation.

Environmental Management Techniques

Table 10 lists the major environmental changes caused by shore protection projects, the resources potentially affected, and the best management techniques which are used to minimize or eliminate adverse effects (WES, 1984). It should be noted that these management techniques are only undertaken in areas of Corps projects. It is conceivable that the natural destruction of a beach from a large storm has a far larger and longer—lasting adverse ecological and aesthetic effect than controlled beach nourishment.

Environmental Coordination

During study, design, and construction, extensive coordination between USACE districts and numerous Federal, state, and local agencies is required by the National Environmental Policy Act of 1969 (Public Law 91-190), Federal statutes and Executive Orders. This coordination is summarized in Table 11.

Case Studies

Environmental case studies were developed for 10 of the 56 large shoreline protection projects (Corps, 1996). These projects are:

Ocean City, Maryland;
Virginia Beach, Virginia;
Carolina Beach, North Carolina;
Tybee Island, Georgia;
Duval County, Florida;
Broward County, Florida, Segment III;

Table 10. *Environmental considerations.*

Item	Consideration
Environmental changes	Dune stabilization and beach plants Beach hardness Sand deposition in the intertidal area Placement of equipment Change in beach sediment composition Sedimentation Burial and removal of offshore bottom dwelling animals Excavation and burial of cultural resources
Resources potentially affected	Dune plants and animals Sea turtles Shorebirds Marine bottom communities Shoreline rocks and corals Fish and other motile animals Seagrasses Corals Offshore subtidal bottom animals Cultural resources
Best management techniques	Plant beach plants Restrict seasons for construction Reduce beach hardness Avoid nearshore rocks and corals Place material near shore Reduce silt Selection and placement of equipment Select borrow site distant from sensitive habitats Avoid cultural resources

Palm Beach County, Florida, Delray Beach Segment;
Manatee County, Florida;
Pinellas County, Florida, Sand Key Segment; and
Presque Isle, Pennsylvania.

The key findings of these ten environmental case studies are as follows:

(1) There were no long term adverse environmental impacts associated with these projects.

(2) Two of the projects produced environmental benefits. The Manatee County, FL project increased the sea turtle habitat from less than five acres to about 78 acres and the Presque Isle, PA project was considered to be an environmental protection project in that one of its objectives was to protect an ecological preserve.

(3) Construction activities are modified to plant dunes with beach grass and salt meadow cordgrass, to use less noisy vibratory drives in construction of bulkheads, to limit height of protective measures to minimize adverse visual impacts, and to shift borrow areas to avoid impacts to wildlife refuges.

(4) Nourishment activities are conducted whenever possible to exclude those times when juvenile fish and sea turtles are nesting and when right whales are calving. If performed during these periods, all precautions are taken to ensure that adverse impacts do not occur, also, a sea turtle nest monitoring and relocation program which has been approved by the U.S. Fish and Wildlife Service is undertaken.

(5) Magnetometer surveys are undertaken in culturally identified areas (*e.g.* shipwrecks, cultural artifacts, etc.) and, as necessary, appropriate modifications to borrow areas are made.

Final Study Conclusions

Final study conclusions are as follows:

- The USACE shoreline protection program covers a very small portion of the nation's coastline. As of July 1993, the program consisted of 82 completed projects which collectively cover 226 miles of shoreline. This represents eight percent of the nation's 2,700 miles of critically eroding shoreline.
- The USACE shoreline protection program has shifted from primarily "hard" structures (groins, seawalls, breakwaters, etc.) to primarily "soft" structures (beach restoration and nourishment through placement of sand).
- While the spending has varied considerably from year to year, annual Federal spending on the shore protection program has historically been about two percent of the total annual USACE Civil Works Budget. To place the magnitude of the Corps' program in perspective, it would be useful to compare it with the expenditures of other nations.
- From the standpoint of program cost and volumes of sand emplacement, an evaluation of the long-term performance of the program shows that it is a well-managed and cost-effective program. Overall costs were slightly less than estimated (4 percent), and overall quantities of sand were slightly higher than estimated (5 percent).

Table 11. *Environmental coordination.*

Coordination	Requirements
Coastal Zone Management Act of 1972 (Public Law 92–593), as amended	Any proposed dredging activity is rquired to comply with, and be conducted in a manner consistent with this Federal program.
Endangered Species Act of 1973 (Public law 93-205), as amended.	Requires all Federal agencies to seek to conserve endangered and threatened species and to utilize their authorities to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved and to provide a program for the conservation of such endangered and threatened species. Also requires the USACE to coordinate with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.
National Historic Preservation Act of 1966 (Public Law 89-665), as amended and Executive Order 11593, 13 May 1971 (Protection and Enhancement of the Cultural Environment)	Requires the identification of potential and known sites and properties within the area of a project that are eligible for inclusion in the National Register of Historic Places and to coordinate all activities with the State Historic Preservation Office.
Section 404 of the Clean Water Act of 1977 (Public Law 95-217)	An evaluation in compliance with this section must be performed and included in all Environmental Impact Statements.

- Initial beach restoration measures demonstrated a higher level of estimation accuracy both in terms of costs and quantities of sand than did periodic nourishment measures.
- Projects costing over $50 million exhibited more estimation accuracy than those costing less, both in terms of costs and quantities of sand.
- Recreation was the primary benefit category used to justify shore protection projects from 1965-1980. Thereafter, subsequent Administration policies and changes in the law required that shore protection projects be justified by storm damage reduction.
- Because of the highly variable and largely unpredictable nature of coastal storms, the "actual" storm damage reduction benefits of shore protection projects can differ greatly from those forecasted during planning and design.
- Three specific economic analyses were applied to determine whether USACE shore protection projects induce development in the areas they protect. None of the approaches could verify that there is a measurable induced development link. The analyses demonstrated the primary determinant of development on beachfront communities is growth in beachfront demand based on rising income and employment in non-coastal areas, rather than the presence or absence of a shore protection project.
- Beach restoration and nourishment is the most environmentally compatible shore protection measure.
- Historically, funding has not been provided to perform post-storm surveys of beach nourishment areas. Therefore, USACE districts have been unable to routinely measure project performance of completed projects. Post-storm damage surveys are conducted only sporadically.
- There is no funding mechanism to maintain a national data base of Federal shore protection projects. This makes it difficult to access the costs and other project specifics of the program and respond to inquiries from the Administration, Congress, and others.
- There is limited public awareness of; the Federal shore protection program, where Federal projects currently exist, and the involvement of the USACE in reducing risks through project construction.

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References

CORDES, J.J. and YEZER, A.M. Department of Ecomomics, George Washington University, Washington, DC, *Shore Protection and Beach Erosion Control Study, Economic Effects of Induced Development in Corps-Protected Beachfront Communities,* IWR Report 95-PS-1, February 1995.

KAUFMAN, W. and PILKEY, O.H., JR., *The Beaches Are Moving, The Drowing of America's Shoreline,* Duke University Press, Durham, NC 1983.

NATIONAL RESEARCH COUNCIL, Committee on "Beach Nourishment and Protection," *Beach Nourishment and Protection,* Marine Board Commission on Engineering and Technical Systems, Washington, DC, 1995.

PILKEY, ORRIN H. and NEAL, W. J., *Save the Beaches,* Issues in Science and Technology, Spring 1992.

SKAGGS, L.L. and MCDONALD, F.L., *National Economic Development Procedures Manual, Coastal Storm Damage and Erosion,* IWR Report 91-R-6, September 1991.

SUDAR, R.A.; POPE, J.; HILLYER, T.; and CRUMM, J., *Shore Protection Projects of the U.S. Army Corps of Engineers,* Shore & Beach, v.63, No.2, pp3-16, April 1995.

U.S. ARMY CORPS OF ENGINEERS, *Environmental Engineering for Coastal Protection,* EM 1110-2-1204, 10 July 1989.

U.S. ARMY, CORPS OF ENGINEERS, *Shoreline Protection and Beach Erosion Control Study, Phase I: Cost Comparison of Shoreline Protection Projects of the U.S. Army Crops of Engineers,* IWR Report 94-PS-1, January 1994.

U.S. ARMY CORPS OF ENGINEERS, *Shoreline Protection and Beach Erosion Control Study, Final Report: An Analysis of the U.S. Army Corps of Engineers Shore Protection Program,* IWR Report 96-PS-1, June 1996.

U.S. ARMY WATERWAYS EXPERIMENT STATION, *Shore Protection Manual (SPM),* 4th ed., Vol. I and II. 1984, Coastal Engineering Research Center, Vicksburg, MS.

U.S. WATER RESOURCES COUNCIL'S *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies,* March 10, 1983.