The National Beach Preservation Conference (NBPC 2000)

Royal Lahaina Resort, Kaanapali, Maui, Hawaii, USA
August 6-10, 2000

Sponsored by

The American Shore and Beach Preservation Association
University of Hawaii Sea Grant College Program
Hawaii Dept. of Land and Natural Resources, Land Div., Coastal Lands Program
The County of Maui
Maui Community College
American Coastal Coalition
Coastal Zone Foundation
Kaanapali Beach Resort Association
Hawaii Coastal Zone Management Program
California Shore and Beach Preservation Association
U.S. Army Corps of Engineers, Coastal and Hydraulics Laboratory

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Conference Agenda

Tuesday, August 8

7:00 - 8:00 am	Continental Breakfast, Maui Ballroom
8:00 - 8:30am	Welcome, Opening Remarks Rob Mullane, conference co-chair, *Hawaii Sea Grant* Mayor James Kimo Apana, *Maui County* Sam Lemmo, *Hawaii State Department of Land and Natural Resources, Coastal Lands Program* Greg Woodell, conference co-chair and president, *American Shore and Beach Preservation*
Plenary Session I – The National Beach Preservation Experience, Maui Ballroom	
8:30 - 9:00am	Featured Speaker 1 – **William Stronge**, *Florida Atlantic University*, THE ECONOMICS OF BEACH PRESERVATION
9:00 - 9:10am	Discussion Period
9:10 - 9:40am	Featured Speaker 2 – **Howard Marlowe**, *American Coastal Commission*, NATIONAL TRENDS IN BEACH PRESERVATION – THE VIEW FROM WASHINGTON
9:40 - 9:50am	Discussion Period
9:50 - 10:10am	**BREAK**
10:10 - 10:30am	Pratt, A., *Delaware State Department of Natural Resources*, THE NATIONAL SHORELINE STUDY: STATUS AND PLAN
10:30 - 10:45am	Hatheway, D., *Dewberry & Davis*, NATIONAL COASTAL EROSION HAZARD ANALYSIS AND MAPPING STUDY BY THE FEDERAL EMERGENCY MANAGEMENT AGENCY: PHASE ONE MAPPING RESULTS
10:45 - 11:00am	Leatherman S., *Florida International University*, EVALUATION OF EROSION HAZARDS ALONG THE U.S. COASTLINES
11:00 - 11:10am	Discussion Period
11:10 - 11:30am	Griggs, G.B., *University of California - Santa Cruz*, ERODING SHORELINES AND BEACHES: SEARCHING FOR LONG-TERM SOLUTIONS
11:30 - 11:50am	Richmond, B.M., *U.S. Geological Survey, Pacific Science Center*, NO RETURN TO PARADISE – TRYING TO UNDERSTAND HAWAIIAN BEACHES WHEN CHANGE IS CONSTANT
11:50am - 12:00pm	Discussion Period
12:00 - 1:30pm	**LUNCH, Alii Room** – Representative Patsy T. Mink, *U.S. House of Representatives*
Plenary Session II – Regional Challenges in Beach Preservation, Maui Ballroom	
1:30 - 2:00pm	Featured Speaker 3 - **Bodge, K.R.**, *Olsen-Associates, Inc.*, ENGINEERING DESIGN FOR BEACH NOURISHMENT
2:00 - 2:10pm	Discussion Period
2:10 - 2:30pm	Rogers, S., *North Carolina Sea Grant*, BEACH NOURISHMENT FOR HURRICANE PROTECTION: NORTH CAROLINA PROJECT PERFORMANCE IN HURRICANES DENNIS AND FLOYD
2:30 - 2:50pm	Lemmo, S., *State of Hawaii Dept. of Land & Natural Resources*, HAWAII'S EMERGENT COASTAL EROSION MANAGEMENT PROGRAM
2:50 - 3:00pm	Discussion Period
3:00 - 3:20pm	**BREAK**
3:20 - 3:40pm	Kulchin, A., *City Council-City of Carlsbad, CA, SANDAG Shoreline Erosion Committee*, SAN DIEGO ASSOCIATION OF GOVERNMENTS SHORELINE PRESERVATION STRATEGY
3:40 - 4:00pm	Hwang, D., *Reinwald O'Connor & Playdon*, GUIDELINES FOR MANAGEMENT OF THE COAST – LESSONS LEARNED
4:00 - 4:20pm	Discussion Period

Tuesday, August 8

4:20 - 4:40pm	Humiston, K.K., *Humiston & Moore Engineers*, TWO EXAMPLES OF BREAKWATER TECHNOLOGY APPLICATION FOR EROSION CONTROL
4:40 - 5:00pm	Ewing, L., *California Coastal Commission*, CHANGING PERCEPTIONS OF THE COAST AND THE CALIFORNIA EXPERIENCE
5:00 - 5:10pm	Discussion Period
6:00 - 8:00pm	**Welcome and Awards Dinner, Alii Room**

Wednesday, August 9

7:00 - 8:00 am	Continental Breakfast, Maui Ballroom

Plenary Session III – Coastal Sedimentary Processes, Maui Ballroom

8:00 - 8:30am	Featured Speaker 4 - **Inman, D.**, *University of California - San Diego*, KAANAPALI REVISITED
8:30 - 8:40am	Discussion Period
8:40 - 9:10am	Featured Speaker 5 - **Sallenger, A.H.**, *U.S. Geological Survey, Center for Coastal Geology, St. Petersburg, FL*, NATIONAL ASSESSMENT OF COASTAL CHANGE HAZARDS
9:10 - 9:20am	Discussion Period
9:20 - 9:40am	Komar, P.D., *Oregon State University*, THE LONG-TERM INCREASE IN WAVE ENERGY ALONG THE U.S. WEST COAST AND THE GROWING THREAT OF PROPERTY EROSION
9:40 - 10:00am	Boudreau, R.H., *Moffatt & Nichol Engineers*, THE RELATIONSHIP BETWEEN SHORE-LINE EROSION AND FLOOD CONTROL IN KIHEI, MAUI, HAWAII
10:00 - 10:10am	Discussion Period
10:10 - 10:40am	**POSTER VIEWING**
10:40 - 11:00am	Field, M.E., *U.S. Geological Survey Pacific Science Center*, SEDIMENTATION PATTERNS ON THE FRINGING REEF OFF SOUTHERN MOLOKAI, HAWAII
11:00 - 11:20am	Harney, J.N., *University of Hawaii - Manoa*, CARBONATE SEDIMENT SUPPLY ON OCEANIC ISLANDS: A MODEL AND ITS APPLICATIONS
11:20 - 11:40am	Rooney, J.J., *University of Hawaii - Manoa*, A CENTURY OF SHORELINE CHANGE ALONG THE KIHEI COAST OF MAUI, HAWAII
11:40 - 11:50am	Discussion Period
12:00 to 1:30pm	**LUNCH, Alii Room** – David Blane, *Director, Hawaii State Office of Planning*, THE HAWAII COASTAL ZONE MANAGEMENT PROGRAM

Breakout Session I – Coastal Sedimentary Processes, Molokai and Lanai Rooms

1:30 to 1:50pm	Sloop, R., *Moffatt & Nichol Engineers*, PREDICTING SHORELINE EFFECTS OF A NEW TIDAL INLET AT BOLSA CHICA, CALIFORNIA.
1:50 to 2:10pm	Erickson, K.M., *Applied Technology and Management Inc.*, A SOLUTION TO INLET MIGRATION AT WRIGHTSVILLE BEACH, NORTH CAROLINA: THE MASON INLET RELOCATION PROJECT
2:10 to 2:20pm	Discussion Period
2:20 to 2:40pm	Hampton, M.A., *U.S. Geological Survey, Menlo Park, CA*, LARGE SEDIMENT DEPOSITS ON THE REEF FRONT AROUND OAHU

Breakout Session II – Engineering and Planning Practice, Oahu Room

1:30 - 1:50pm	Curtis, W.R., *U.S. Army Engineer R&D Center*, NATIONAL SHORELINE EROSION CONTROL DEMONSTRATION PROGRAM OVERVIEW
1:50 - 2:10pm	Chrzastowski, M.J., *Illinois State Geological Survey*, CHICAGO'S WORLD-CLASS URBAN SHORE-LINE: A UNIQUE MODEL FOR COASTAL CITIES
2:10 - 2:20pm	Discussion Period
2:20 - 2:40pm	Bucher, W.E., *Oceanit Laboratories, Inc.*, DEVELOPMENT OF AN EROSION CONTROL SCHEME FOR KUALOA REGIONAL PARK, OAHU

Wednesday, August 9

Breakout Session I – Coastal Sedimentary Processes, Molokai and Lanai Rooms

2:40 - 3:00pm	Ogston, A.S., *University of Washington*, OBSERVATIONS OF PHYSICAL PROCESSES AND SEDIMENT TRANSPORT ON A SHALLOW REEF FLAT: SOUTH-CENTRAL MOLOKAI, HAWAII
3:00 - 3:10pm	Discussion Period
3:10 - 3:40pm	**POSTER VIEWING**
3:40 - 4:00pm	Lillycrop, L.S., *U.S. Army Corps of Engineers, Mobile District*, THE NORTHERN GULF OF MEXICO REGIONAL SEDIMENT MANAGEMENT DEMONSTRATION PROGRAM
4:00 - 4:20pm	Leadon, M.E., *Florida Department of Environmental Protection*, DEVELOPMENT OF A STATEWIDE SEDIMENT BUDGET FOR THE COAST OF FLORIDA
4:20 - 4:30pm	Discussion Period
4:30 - 4:50pm	Dodd, N., *University of Hawaii*, MORPHODYNAMICAL MODELING OF HAWAIIAN BEACHES
4:50 - 5:10pm	Wamsley, T., *U.S. Army Corps of Engineers, Waterways Experiment Station*, SHORELINE MONITORING PROGRAM ON THE TEXAS COAST UTILIZING A REAL-TIME KINEMATIC DIFFERENTIAL GLOBAL POSITIONING SYSTEM
5:10 - 5:20pm	Discussion Period
5:30 - 7:30pm	**Luau (Optional)** – make your own reservations

Breakout Session II – Engineering and Planning Practice, Oahu Room

2:40 - 3:00pm	Barry, J.H., *Sea Engineering, Inc.*, SUNSET BEACH COASTAL ENGINEERING ANALYSIS
3:00 - 3:10pm	Discussion Period
3:10 - 3:40pm	**POSTER VIEWING**
3:40 - 4:00pm	Webb, C.K., *Moffatt & Nichol Engineers*, BEACH NOURISHMENT IN CALIFORNIA FOR THE NEW MILLENIUM
4:00 - 4:20pm	Moya, J.C., *Texas General Land Office*, THE TEXAS COAST EROSION PLANNING AND RESPONSE ACT AND THE FUTURE OF THE TEXAS COAST: THE INTEGRATION OF COASTAL EROSION PROJECTS AND HAZARD MITIGATION MEASURES INTO GIS
4:20 - 4:30pm	Discussion Period
4:30 - 4:50pm	Gaffney, D.A., *Synthetic Industries*, GEOTEXTILES IN THE MARINE ENVIRONMENT: STATE OF THE PRACTICE
4:50 - 5:10pm	Jones, S.R., *East Carolina University*, VALUATION OF BEACH NOURISHMENT: A PRELIMINARY ASSESSMENT OF NORTH CAROLINA PROJECTS
5:10 - 5:20pm	Discussion Period
5:30 - 7:30pm	**Luau (Optional)** – make your own reservations

Thursday, August 10

7:00 - 8:00am Continental Breakfast, Maui Ballroom

Plenary Session IV – National Diversity in Beach Preservation Practice, Maui Ballroom

8:00 - 8:30am Featured Speaker 6 - **Sullivan, S.**, *Sea Engineering, Inc.* HAWAII PILOT BEACH RESTORATION PROJECT COASTAL ENGINEERING INVESTIGATIONS

8:30 - 8:40am Discussion Period

8:40 - 9:10am Featured Speaker 7 - **Magoon, O.T.**, *Coastal Zone Foundation*, URBAN BEACHES

9:10 - 9:20am Discussion Period

9:20 - 9:50am Featured Speaker 8 - **Hussin, D.**, *Great Lakes Dredge and Dock Company*, DREDGING PRACTICE FOR BEACH NOURISHMENT

9:50 - 10:00am Discussion Period

10:00 - 10:20am **BREAK**

10:20 - 10:40am Keehn, S., *Coastal Planning & Engineering, Inc.*, MODIFYING A FEDERAL BEACH NOURISHMENT PROJECT TO RESPOND TO HURRICANE IMPACTS: PANAMA CITY BEACHES, FLORIDA NOURISHMENT PROJECT

10:40 - 11:00am Shabica, C.W., *Northeastern Illinois University*, PERFORMANCE OF ENGINEERED BEACHES ON URBAN COASTS: THE ILLINOIS SHORE OF LAKE MICHIGAN NORTH OF CHICAGO

11:00 - 11:10am Discussion Period

11:10 - 11:30am Guild, B.Q., *Sugar Cove Homeowners Association*, UPDATE OF BEACH RESTORATION AT SUGAR COVE MAUI, HAWAIIAN ISLANDS

11:30 - 11:50am Aceti, S., *California Coastal Coalition*, CALIFORNIA'S COASTAL COMMUNITIES ORGANIZE TO INCREASE STATE FUNDING FOR BEACHES

11:50 - 12:00am Discussion Period

12:00 - 1:00pm **LUNCH, Alii Room,** Brigadier General Randal R. Castro, Commander and Division Engineer, *Pacific Ocean Division, U.S. Army Corps of Engineering*

AFFILIATED WORKSHOP – ADVANCEMENTS IN SHORE PROTECTION TECHNOLOGY (THE PAST 20 YEARS) Sponsored by *U.S. Army Engineers, Coastal and Hydraulics Laboratory,* Tentative Agenda (For more info contact Bill Curtis CURTISW@wes.army.mil)

1:00 - 1:30pm OVERVIEW OF NATIONAL SHORELINE EROSION CONTROL DEVELOPMENT AND DEMONSTRATION PROGRAM AUTHORIZED UNDER SECTION 227 WRDA'96. Comparison between the Section 227 Program and the Low-Cost Shoreline Erosion Control Demonstration Program authorized under Section 54 WRDA'74.

1:30 - 2:30pm COASTAL ARMORING PANEL DISCUSSION (e.g., seawalls, bulkheads, revetments)

2:30 - 3:30pm NON-STRUCTURAL ALTERNATIVES PANEL DISCUSSION (e.g., beach nourishment, nearshore berms, beach dewatering, vegetative methods)

3:30 - 4:30pm EROSION CONTROL STRUCTURES PANEL DISCUSSION (e.g., groins, artificial headlands, nearshore detached or submerged breakwaters)

4:30 - 5:30pm OPEN FORUM FOR NON-PANEL PRESENTATIONS AND ADDITIONAL DISCUSSION

POSTERS

Wozencraft, J.M., *U.S. Army Corps of Engineers, Mobile District,* REGIONAL MAPPING FOR COASTAL MANAGEMENT: MAUI AND KAUAI, HAWAII

Vallejo, L.E., *University of Pittsburgh,* FAILURE MODES OF COASTAL SLOPES FORMING PART OF THE GREAT LAKES, SOUTHERN CALIFORNIA, ENGLAND AND MEXICAN SHORELINES

Moore, L.J., *Woods Hole Oceanographic Institution,* INTERANNUAL EVOLUTION OF A MULTIPLE LONGSHORE BAR SYSTEM: POTENTIAL EFFECTS ON BEACH AND BLUFF EROSION

Gibbs, A., *U.S. Geological Survey, Menlo Park, CA,* SEASONAL BEACH CHANGES IN HAWAII: RESULTS FROM FIVE YEARS OF BEACH MONITORING

Ahmed, M.H., *National Authority for Remote Sensing and Space Sciences,* ENVIRONMENTAL PROBLEMS, CONSEQUENCES, AND PROPOSED ACTIONS AT SHARM EL MOIYA BAY, GULF OF AQUABA, RED SEA, EGYPT

Yoon, I., *Research Institute of Industrial Science & Technology, Korea,* STUDY ON THE BEACH PROCESSES IN SONGDO, YONGIL BAY, KOREA

Winkelman, J., *U.S. Army Corps of Engineers, San Francisco District,* BOLINAS LAGOON: A METHODOLOGY FOR PREDICTING A TIDAL LAGOON'S FUTURE CONDITIONS

Schaaf, D., *U.S. Corps of Engineers, San Francisco District,* GIS TECHNIQUES USED TO ANALYZE SEDIMENT MOVEMENT IN BOLINAS LAGOON

McGehee, D.D., *Emerald Ocean Engineering,* CHARACTERIZATION OF COASTAL EROSION MANAGEMENT BY THE GULF STATES

Engstromm, T., *Norwegian School of Hotel Management,* RECREATIONAL USE OF THE NORWEGIAN BEACHES

Hapke, C., *U.S. Geological Survey, Pacific Science Center,* GOING DIGITAL: ERROR EVALUATION OF MEDIA AND SCANNER TYPES FOR AERIAL PHOTOGRAPHIC ANALYSIS FOR IN COASTAL CHANGE STUDIES

O'Meagher, B., *Trimble Navigation,* INNOVATIVE BEACH RESTORATION TECHNOLOGIES

Levine, H., *Papakea Resort AOAO,* MODIFICATION OF A SEAWALL TO PROVIDE A SCALLOPED BEACH AREA

Innes, S.I., *Moffatt & Nichol Engineers,* TECHNICAL CHALLENGES TO PREDICTING SHORELINE EFFECTS OF A NEW TIDAL INLET

Chavez, P.S., *U.S. Geological Survey, Flagstaff, AZ,* USE OF DIGITIZED MULTI-TEMPORAL AERIAL PHOTOGRAPHS TO MONITOR AND DETECT CHANGE IN CLEAR SHALLOW COASTAL WATERS, MOLOKAI, HAWAII

Steel, H., *County of Maui,* THE USE OF THE NEW RECYCLED GLASS PRODUCT AS A SUBSTITUTE FOR SAND

DeNaie, L., *Sierra Club Maui Group,* ACCURATE SHORELINE CERTIFICATIONS: FIRST STEP IN PREVENTING COASTAL EROSION: WHAT A CITIZEN SHOULD KNOW ABOUT CHALLENGING SHORELINE CERTIFICATIONS

ABSTRACTS

THE ECONOMICS OF BEACH PRESERVATION

Dr. William B. Stronge, Ph.D.
Office of International Programs
Florida Atlantic University
Boca Raton, FL

ABSTRACT

Beaches are an economic as well as a natural resource. They provide benefits at the shoreline and benefits away from the shoreline. Shoreline-based benefits include storm damage prevention and recreation. Storm damage prevention benefits are the reduction in losses due to storm damage or in the costs of alternative efficient storm protection measures. Storm damage prevention benefits are received by the owners of property upland of the beach. Recreation benefits are the values received by recreational users of a beach. They are received by persons who reside upland of the beach and also by users who reside away from the beach.

The presentation reviews a number of estimates of beach-based benefits for beaches in Florida. Prior to the construction of beach nourishment projects, projections of beach-based benefits are routinely made, especially for projects receiving Federal funding. A number of projections are reviewed. The presentation will also review a number of post-project analyses based on property value data. In an efficient market, beach-based benefits of beach projects will be captured by the values of benefiting properties. A post-project property value study will test the methodology for projecting beach-based benefits. The presentation discusses some of the reasons why the standard methodology under-estimates the benefits obtained from the property value approach.

Benefits away from the shoreline include economic and fiscal impact. Economic impacts differ depending on the level of the economy. Impacts tend to be largest at the local level and least at the national level. Local impacts include job and payroll creation, as well as increased profits for local businesses. In Florida, local government is primarily financed by property taxes. Because beaches improve property values, local taxes are increased. Because it is also true that beach communities use relatively little public services, because of seasonal use, relatively few children in the schools, and relatively few residents receiving government assistance, the impact of beach projects on the demand for local government services is relatively small. Therefore, local government finances are impacted positively by beach projects. In Florida, state government receives the major part of its taxes by taxing sales. Beaches attract out of state visitors and investors who pay state taxes, not only at the beach, but during their travel to and from the beach. In Florida, more than half of the 50 million out of state visitors use the beaches. While not all of these are attracted to Florida by the beaches, recreational use of the beaches is a major part of the stay for many tourists. The result is an increase in state jobs, payrolls and taxes. Finally, the Federal Government benefits from the tourism and investment of international beach visitors. This increases Federal taxes, the national economy and the balance of international payments.

The presentation will discuss the economic impacts of beach projects with special reference to Florida projects and communities. There will also be a discussion of some o the criticisms of beach projects in terms of "behavioral" reactions such as the extent to which beach projects stimulate over-development of the beach front.

REFERENCES

Stronge, William B., "The Economic Benefits of Florida's Beaches: Local, State and National Impacts", chapter in *Rethinking the Role of Structures in Shore Protection*, Proceedings of the 1998 National Conference on Beach Preservation Technology, St. Petersburg, Florida, 1998.

Stronge, William B., "The Economics of Government Funding for Beach Nourishment Projects: The Florida Case", article in *Shore and Beach, Journal of the American Shore and Beach Preservation Association*, Vol. 63 - No.3 - July, 1995, p.4-6.

Stronge, William B., "Beaches, Tourism and Economic Development", article in *Shore and Beach, Journal of the American Shore and Beach Preservation Association*, Vol. 62 - No.2 - April, 1994, p.6 – 8, Reprinted in Beaches, the Official Journal of the Florida Shore & Beach Preservation Association,Autumn 1994, p. 1 - 5.

Stronge, William B., "The Economic Analysis of Beach Restorations: The State of the Art", chapter in *The State of the Art of Beach Nourishment*, Proceedings of the 1993 National Conference on Beach Preservation Technology, St. Petersburg, Florida, 1993.

OUTLOOK FOR THE FEDERAL BEACH RESTORATION PROGRAM

Howard Marlowe, President
American Coastal Coalition
Washington, DC

ABSTRACT

Over the past five years, significant progress has been made toward directing a higher level of public resources to restoring America's beaches. The Federal government has doubled its level of appropriations for beaches at a time when Congress has imposed harsh spending limitations on almost all domestic discretionary spending. In addition, the Federal beach restoration program has been able to maintain its historic strength on the East Coast while it has begun to expand to the Gulf and West Coasts. Five coastal states now have made solid fiscal commitments to partnering with the Federal government to restore badly eroded beaches. Many local communities have also committed to impose taxes or other financing mechanisms to help fund the non-Federal share of beach restoration projects.

Nevertheless, restoring and maintaining America's beaches is a very low priority at the Federal level of government. The Administration refuses to recommend funding any new beach restoration projects. While Congress has not acquiesced to the Administration's position, its annual level of appropriations is the equivalent of the cost of two interchanges on the Federal highway system. As a nation, we are far more willing to spend money on roads and airports that will get us to the beach than we are to maintain those beaches.

Why is beach restoration such a low national public policy priority? This is a question that is especially perplexing given the fact that more than half of the U.S. population lives within 50 miles of a coast (including the Great Lakes) — a percentage that is increasing. Travel and tourism is the nation's second largest industry, and beaches are the #1 vacation destination. CoastalAmerica is an economic engine that produces local, state, and national revenues, as well as hundreds of thousands of jobs. Beaches produce hundreds of billions of dollars of business profits as well as local, state, and national tax revenues. The jobs of millions of Americans are dependent on beaches. With so much in jobs, tax revenues, and business profits at stake, why are beaches and most of the rest of the coastal infrastructure such a low priority?

BEACHES ARE PART OF A LARGER COASTAL INFRASTRUCTURE

In seeking answers to this nagging question, we first need to put it into context.

- Taken in their totality, U.S. coastal water resources consist of beaches, estuaries, lakes, ports, and related recreational facilities, as well as hotels, year 'round and vacation homes, recreational and commercial fishing, eco-tourism, and a wide variety of plant and animal species. Each of these resources is affected by national, state, and local policies, laws, and regulations.

- For the last few decades, Congress has continually decreased its financial commitment to maintain the nation's water resources. For example, Congress has acted to establish dedicated funding for our highway and aviation systems, even increasing these funds during the current period of stringent spending limits that the legislative branch has imposed on itself. If highways are overcrowded, we build more highways; if the ones we have are deteriorated, we spend money to repair them. If airports are overcrowded, we expand runways and terminals. But our entire system of water resources – from ports, to inland waterways and intracoastal waterways – is deteriorating. This water resource infrastructure is critical to both the commercial and recreational needs of the nation. Beaches are an integral part of that infrastructure. Their commercial and recreational functions will receive no better recognition from the Federal government than the rest of the nation's water resources.

- At the federal level, there are dozens of laws, hundreds of formal regulations, and an untold number of less formally-adopted agency policies which directly affect the coastal regions of the U.S. They are administered primarily by a half-dozen federal agencies whose missions are often at odds with each other. Sometimes, federal policies administered by a single agency are not consistent. For example, the

U.S. Army Corps of Engineers is responsible for constructing dams in West Coast states to control the supply and flow of water. However, these very dams also interfere with the natural flow of sand from the mountains to the sea. That flow is the primary means of natural sand replenishment. The Corps clearly interprets its mandate to erect dams. But, for many West Coast areas, its policies preclude it from mitigating the damage it has caused to beaches. Also, as another example, the Federal Emergency Management Agency will provide disaster relief to repair roads to beaches and structures on or near beaches, but it will not provide disaster relief to replenish beach sand. FEMA also has an active program to promote hazard mitigation, but it will do nothing to support local efforts to replenish eroded beaches as a means of mitigating the hazards of coastal storms. Other federal agencies involved with the coast such as the National Oceanographic and Atmospheric Agency (NOAA), the Fish and Wildlife Service (FWS), the U.S. Geological Survey (USGS), and the Minerals Management Service (MMS) have their own agendas and points of view about the nation's beaches. At best, these agencies do not communicate with each other or coordinate their activities well. At worst, they are at odds with each other.

• This disarray among federal agencies is complicated by the fact that, since 1995, the Administration has focused attention on this chaos of coastal policy by reducing or eliminating entirely federal assistance for the reconstruction and maintenance of sandy beaches. Congress has specifically rejected the Administration's efforts in 1995, 1996, and 1997 by the adoption of appropriations bills which fund water resource projects not requested by the Administration and by adopting the Shore Protection Act of 1996. The Administration has nevertheless pursued its opposition to shore protection and other water resource projects in a manner which has left many local communities confused, angered, and directionless. While the Administration's anti-shore protection policies are founded on the need for federal fiscal restraint, they are supported by those who believe that retreat is the best policy for many coastal regions of the nation.

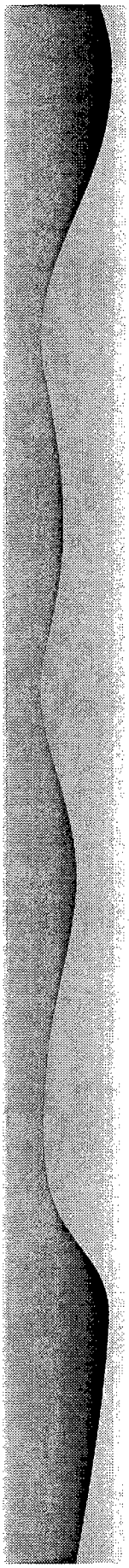
INHERENT WEAKNESSES IN OUR APPROACH TO BEACH RESTORATION

We must also look inward to understand some of the basis for the low priority our nation accords to beach restoration.

• Traditionally, the water resources policies of the U.S. have been carried out on a project-by-project basis. Port A is dredged to permit commercial and cruise vessels to continue to use that port. This dredging has a negative impact on the beaches of County A. At some point, County A will exert political pressure to get federal assistance for the renourishment of its beaches. There is no regional, or coastal (i.e., sand) systems approach to planning these two projects so the dredging does minimal damage to the beaches and may perhaps be done in conjunction with a planned program of beach replenishment. Unless beach restoration is treated as an integral part of the restoration and maintenance of the totality of our coastal water infrastructure, we cannot possibly receive the attention and priority we deserve from government policy makers.

• There is no single national voice for those resources. There is one national highway lobby and a fairly unified national aviation lobby. The same can be said for most of the other components of the national infrastructure. But the water resource community is badly balkanized. We have yet to accept the reality that it is only through unity that the ports, waterways, flood control, and beach restoration interests can each achieve its objectives.

• Those of us whose primary concern is beach restoration have an overwhelming tendency to talk to ourselves. There are others along the coast and inland who need to understand our needs, but we have done far too little to reach out to inform and persuade them. There are also those whose bottom line interests – be they commercial, recreational or environmental – depend on a healthy national system of sandy beaches have either not spoken up or have not spoken with sufficient effectiveness to plead our case. The reasons for this failure range from ignorance to apathy. Of course, those whose homes and businesses are in imminent danger of loss because of eroded beaches are the ones least likely to be either ignorant or apathetic. But even among this group, the willingness to assume that someone else will take care of the problem and the failure to take advantage of the opportunities afforded by the Federal beach restoration program defy the conventional political wisdom that necessity is the mother of political



activism and power.

• As much as we have bits and pieces of information about the impact of beaches on the national economy and environment, we lack hard data. Without reliable information from objective sources, we cannot hope to hold our own against those who say that the expenditure of taxpayer funds on beach restoration is wasteful and/or harmful to the environment. Our best hope to counter this data deficit lies in the National Shoreline Study authorized by Congress in the Water Resources Development Act of 1999 and recommended for funding (albeit at an overly-modest level) by the President. This study will catalogue the levels of erosion along our various coasts and the reasons for it. But it will also quantify the costs to the national economy and the national environment of beach erosion.

With this background, I will propose a plan of action for coastal elected officials, homeowners, business people, environmentalists, and other activists that will overcome ignorance and apathy, thereby raising the national policy priority for restoring and maintaining the nation's beaches.

THE NATIONAL SHORELINE STUDY: STATUS AND PLAN

Anthony P. Pratt, Program Manager
Shoreline Management Branch
Delaware Department of Natural Resources and Environmental Control
Dover, DE

ABSTRACT

The 1999 Water Resources Development Act authorized in Section 215 (c) a "Report on Shore of the United States". The specific language is:

(1) IN GENERAL- Not later than 3 years after the date of enactment of this Act, the Secretary shall report to Congress on the state of the shores of the United States.

(2) CONTENTS- The report shall include—

(A) a description of—

(i) the extent of, and economic and environmental effects caused by, erosion and accretion along the shores of the United States; and

(ii) the causes of such erosion and accretion

(B) a description of resources committed by Federal, State, and local governments to restore and renourish shores;

(C) a description of the systematic movement of sand along the shores of the United States; and

(D) recommendations regarding—

(i) appropriate levels of Federal and Non-Federal participation in shore protection; and

(ii) use of a systems approach to sand management.

(3) USE OF SPECIFIC LOCATION DATA- In developing the report, the Secretary shall use data from specific locations on the coasts of the Atlantic Ocean, the Pacific Ocean, Great Lakes, and Gulf of Mexico.

The inclusion of this language in WRDA came about as a direct result of requests made by The American Coastal Coalition, The American Shore and Beach Preservation Association and the Coastal States Organization. The National Shoreline Study provides an opportunity to address many of the issues that have caused debate over continued Federal involvement in beach management.

The Corps of Engineers intends to conduct the project as an inter-agency study, coordinating with other Federal agencies as well as non-Federal agencies. A steering committee made up representatives of these multiple interests will guide the study process. The report to Congress will address the economic and environmental benefits that beaches provide to the nation, and will consider the appropriate role of the Federal government in future shore management.

Funding for the Study is being sought this year for work to commence in the fall of 2000. The report to Congress is due within three years of the commencement of the work. The Corps will count on assistance from many agencies involved in beach management. It is urged that all that are called upon to assist in this effort do so in order to create as complete and thorough an examination of our nation's beaches as possible.

NATIONAL COASTAL EROSION HAZARD ANALYSIS AND MAPPING STUDY BY THE FEDERAL EMERGENCY MANAGEMENT AGENCY: PHASE ONE MAPPING RESULTS

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ABSTRACT

The National Flood Insurance Reform Act was passed into law on September 23, 1994. Section 577 of NFIRA requires that FEMA conduct an "Evaluation of Erosion Hazards" study that examines the economic impact of erosion and erosion mapping on coastal communities, and on the NFIP. The purpose of the study is to determine whether erosion hazard areas should be mapped for (1) risk delineation, (2) floodplain management, and (3) the establishment of flood insurance risk classifications that more directly reflect the effects of long-term erosion in the NFIP premium rates.

FEMA conducted the study in two phases. The first phase required that FEMA map erosion hazard areas in 27 coastal counties (distributed among 18 states). The second phase required three primary tasks; these include: (1) inventory structures located within the mapped erosion hazard areas; (2) conduct an economic impact analysis of erosion on coastal communities and on the NFIP; and (3) conduct an analysis to determine whether it is cost-beneficial to map erosion hazard areas through the NFIP. This paper focuses on the results of the first, "erosion mapping," phase of the study.

In order to conduct the first phase of the study, FEMA enlisted the aid of Coastal Zone Management programs from 18 states (or their designees) to conduct erosion hazard analyses and mapping for 27 coastal counties. These included counties from the Atlantic, Pacific, and Great Lakes areas. FEMA provided overall technical guidance, but much of the research approach was generally left up to the individual state program managers. As a result, final mapping products provided to FEMA varied widely, and the methodologies used in the erosion rate analyses also varied. The report and data sets delivered under the study provide a unique opportunity to compare, contrast and assess the various erosion analyses and mapping techniques currently in use by the States nationwide.

Each of the 27 coastal community erosion studies and final summary reports addressed or included the following information:

- Base map imagery shown at a scale of 1:6000 or better;
- Description of the methods utilized to analyze historical shoreline data, determine average annual erosion rates (AAER), and other specialized applications for this study;
- Description of the treatment of existing shore protection structures, beach nourishment and other shore stabilization projects in determining the project 60-year erosion hazard areas:
- Identification of transects and AAERs;
- Delineation and identification of selected erosion reference feature(s);
- Delineation of projected 60-year erosion hazard boundary for erosion reference feature(s);
- Delineation of all current and projected Zone VE flood zone boundaries;
- Delineation of all current and projected Zone AE flood zones within 500 feet of the projected Zone VE flood zone or erosion reference feature; and
- Identification of the base flood elevation for all current and projected flood zones.

As mentioned above, many different methods for erosion rate determination, mapping, and reporting of the erosion hazard analyses were performed, as per the State agency's preference. AAERs were determined by monitoring the historical movement of Shoreline Change Reference Features (SCRFs). The rates were calculated using the "end point rate technique" (two end point shorelines, one recent, the other historical), or linear regression (using all, or a subset of the shorelines). The high water line was the most commonly used SCRF in the Atlantic and Gulf Coasts. The top edge of the bluff line was the most commonly used SCRF in the Pacific and Great Lakes Coasts. The length of record of historical shoreline analyses varied from 17 to 147 years.

Erosion Reference Features (ERFs) were selected by the States and served as reference lines from which to measure and plot the landward boundary of the AAER. ERFs used in these erosion hazard studies were the (1) seaward edge of dune vegetation line, (2) seaward toe of shore protection structure, (3) top crest of shore protection structure, (4) top crest of primary frontal dunes, (5) landward toe of dune field, (6) seaward edge of frontal dune scarp, (7) seasonal mean high water line, (8) top edge of bluff, and/or (9) point of slope transition of bluff.

The base maps submitted generally used imagery that were rectified, "rubber-sheeted," or mapped on non-rectified aerial photographs, except in Ocean County, New Jersey, and Virginia Beach, Virginia which used detailed planimetric base maps (that contained building footprints) with no imagery. Erosion hazard mapping projections were presented as hand-annotated overlays to aerial photographs, as digitized projections of erosion hazard determinations on detailed base maps with no photographic imagery, or as automated digital ortho-photographic erosion projections of varying scales and resolution.

Tables 1 and 2 provide a listing of the 27 coastal county/community Phase 1 erosion hazard studies along the Atlantic Ocean, Gulf of Mexico, Great Lakes, and Pacific Ocean. The tables have been separated based upon the type of basic AAER determination methodologies applied for the study - linear regression (Table 1) or end point (Table 2). Each table presents the period of records of historical shoreline data analyzed to determine the AAER, the AAER for the respective study area(s), and the type of SCRF used to calculate the rate of erosion. It should be noted that for erosion studies in Florida, New Jersey, South Carolina, Washington, Ohio and Wisconsin, a center weighted smoothing algorithm was applied to the erosion rates prior to calculating 60-year erosion hazard areas. Also, the South Carolina study used both end point and linear regression AAER calculation methods, but has been listed in Table 2 with the end point methodology studies.

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Table 1. Erosion Hazards Studies Using Linear Regression AAER Calculation Method

County/Community, State	Length of Record Analyzed for Study (years)	Average Annual Erosion Rates for Study Area (Linear Regression)	Shoreline Change Reference Feature(s)
Plymouth Co, MA	147	33% Stable; 41% 1.5 ft/yr erosion; 19% 1.5 to 3.5 ft/yr erosion; 2% >3.5 ft/yr erosion; & 5% accretion	High water line
City of VA Beach, VA	58	**Sandbridge:** Avg: 7.3 ft/yr: **Virginia Beach:** Avg: < 2ft/yr	High water line
Brevard Co, FL	69	Avg: <1 ft/yr erosion; & Range: 6.6 ft/yr erosion to 16.9 ft/yr accretion	Mean High water line (FDEP database)
Lee Co, FL	17	Avg: <1 ft/yr erosion; & Range: 30 ft/yr erosion to 30 ft/yr accretion	Mean High water line (FDEP database)
Escambia Co, FL	68	Avg: <1 ft/yr erosion; & Range: 4.3 ft/yr erosion to 8.0 ft/yr accretion	Mean High water line (FDEP database)
Baldwin Co, AL	25	43% 1.2 to 5.8 ft/yr erosion; 3% accreting; & 54% no trend	High water line
Galveston Co, TX	114, 41	**Bolivar Peninsula:** Avg. 2.7. ft/yr erosion **Galveston Island:** Avg. 6.3 ft/yr erosion	Berm crest; Erosional scarp Vegetation line; or High water line
Brazoria Co, TX	66, 41	**Follets Island & Brazos Delta:** Avg.:1.3 ft/yr erosion	Berm crest; Erosional scarp Vegetation line; or High water line
Berrien Co, MI	20, 18	Avg: < 1 ft/yr erosion	Top of bluff - vegetation line
Sanilac Co, MI	56, 45	Avg: < 1ft/yr erosion	Top of bluff - vegetation line
Lincoln Co, OR	54	Avg: < 1 ft/yr erosion	Top of bluff; Landslide headwall; or Stream-mouth/dune vegetation line
Pacific Co, WA.	40	**Cape Shoalwater:** Avg: 7.3 ft/yr erosion **Fort Canby:** Avg: 1.95 ft/yr erosion **Grayland, Leadbetter Point, Ocean Park, & Long Beach:** Avg: 3.2 ft/yr accretion	Daily average High water line

Table 2. Erosion Hazards Studies Using End Point AAER Calculation Method

County/Community, State	Length of Record for Study (years)	Average Annual Erosion Rates for Study Area (End Point Method)	Shoreline Change Reference Feature(s)
Suffolk Co, NY	125, 123, 62	Avg: 1 to 2 ft/yr erosion	High water line
Ocean Co, NJ	95	57% 1 to 2 ft/yr erosion; & 43% stable to 1 ft/yr accretion	High water line
Sussex Co, DE	143	Avg: 3 to 4 ft/yr erosion - 5% < 1 ft/yr erosion; 47.5% 1 to 3 ft/yr erosion; 45% 3 to 9 ft/yr erosion; & 2.5% not used	High water line
Dare Co, NC	55, 50, 52	**No. Dare County:** 65% 11.5 ft/yr erosion; & 35% 0 to 3.3 ft/yr accretion **Hatteras Island:** 20% > 3.3 ft/yr erosion; 40% 0 to 3.3 ft/yr erosion; 30% 0 to 6.6 ft/yr erosion; & 10% not included	High water line
Brunswick Co, NC	54	52% 3.2 ft/yr erosion; & 48% 3.2 ft/yr accretion	High water line
Georgetown Co, SC	43	Avg: 2 to 3 ft/yr erosion	Toe of primary dune
Glynn Co, GA	84	Avg: 1 to 2 ft/yr erosion	High water line
Monroe Co, NY	104	Avg: 1 to 2 ft/yr erosion	High water line
Lake Co, OH	59	Avg: 1.6 ft/yr erosion	Top of bluff: or High water line
Racine Co, WI	39	Avg: < 1 ft/yr erosion	Mid-bluff contour
Manitowoc Co, WI	40	Avg: 1 to 2 ft/yr erosion	Mid-bluff contour
Ozaukee Co, WI	39	Avg: < 1 ft/yr erosion	Mid-bluff contour
San Diego Co, CA	62	Avg: < 1 ft/yr erosion; & Range: 0.1 to 1.9 ft/yr erosion	Top of bluff/cliff; Vegetation line; Seawall/rip rap; or Base of rounded bluff
Santa Cruz Co, CA	41	Avg: < 1 ft/yr erosion: & Range: 0 to 2.1 ft/yr erosion	Top of bluff/cliff; Vegetation line; Seawall/rip rap; or Base of rounded bluff
Honolulu Co, HI	47, 46	**Ewa Beach:** Avg. 0.7 ft/yr erosion; **Sunset:** Avg. 0.3 ft/yr erosion; **Oneula, Lanikai, & Kailua:** Avg: 0 to 1.3 ft/yr accretion	Toe of beach (base of swash zone)

EVALUATION OF EROSION HAZARDS ALONG THE U.S. COASTLINES

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ABSTRACT

Driven by a rising sea level, large storms, and powerful ocean waves, erosion wears away the beaches and bluffs along the U.S. oceanic and Great Lakes shorelines. Erosion undermines waterfront houses, businesses, and public facilities, eventually rendering them uninhabitable or unusable. By moving the shoreline inland, erosion also brings nearby structures ever closer to the water, often putting them at greater risk than either their owners or insurers recognize.

Over the next 60 years, erosion may claim one out of four houses within 500 feet of the U.S. shoreline. To the homeowners living within this narrow strip, the risk posed by beach erosion is comparable to the risk from flooding. The Federal Emergency Management Agency (FEMA) through the National Flood Insurance Program (NFIP), however, does not map erosion hazard areas to inform homeowners of the risk they face, nor does it directly incorporate erosion risks into its insurance ratemaking procedures.

Approximately 350,000 structures are located within 500 feet of the 10,000-mile open ocean and Great Lakes shorelines. This estimate does not include structures in the densest areas of large coastal cities, such as New York, Chicago, Los Angeles, and Miami, which are heavily protected against erosion. Of these, about 87,000 homes are located on low-lying land or bluffs likely to be subject to erosion over the next 60 years. Assuming no additional beach nourishment or structural protection, roughly 1,500 homes and the land on which they are built will be lost to erosion each year. Moreover, houses close to a rapidly eroding shore are worth less today than otherwise identical houses that are close to shorelines that are relatively stable. The increased risk of damage is reflected in sales price.

Without accurate information on erosion, state and local decision makers and the general public are not fully aware of the coastal hazards they face, nor are they able to make use of this information for land-use planning and erosion hazard mitigation. Also despite facing higher risk, homeowners in erosion-prone areas currently are paying the same amount for federal flood insurance as are policyholders in non-eroding areas. Incorporating the additional risk from erosion in the determination of actuarial rates in high-hazard coastal regions will eliminate the need for subsidies from other NFIP policyholders or taxpayers to cover expected erosion losses.

Presenters will discuss these and other results from The Heinz Center's Evaluation of Erosion Hazards study, which was recently completed for the Federal Emergency Management Agency under mandate from the U.S. Congress.

A link to the full report is available online at http://www.heinzcenter.org.

ERODING SHORELINES AND BEACHES-SEARCHING FOR LONG-TERM SOLUTIONS

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ABSTRACT

INTRODUCTION: THE PROBLEM

The coasts of the world are under increasing natural and human pressures as more people migrate to coastal regions. The costs of coastal natural hazards are climbing both nationwide and globally due to a combination of an increasing population at risk and the growing number and value of structures, businesses and other economic investments in coastal areas. Yet shorelines around the world have been retreating for the past 15,000 years in response to the rise of sea level resulting from melting of the late Pleistocene ice sheets and glaciers. Along the low relief U.S. Atlantic coast where average continental shelf width is ~90 to 150 km, shoreline retreat has averaged 6 to 10 m/yr for the past 15,000 years. In contrast, for the younger and tectonically active Pacific Coast, the continental shelf is much narrower, and the shoreline was ~15 to 30 km offshore 15,000 years ago, corresponding to an average shoreline retreat rate of 1-2 m/yr for this time interval. Evidence of the past and continuing retreat is widespread on all of our nation's coastlines.

While sea level rise rates have been significantly lower over the past several thousand years, indications are that sea level rise will continue for the foreseeable future, perhaps at an increased rate. In contrast to the present long term global sea level rise of ~2mm/year, however, are the somewhat infrequent but severe erosion-producing events such as hurricanes on the Atlantic and Gulf coasts and El Nino events on the Pacific coast, which are accompanied by short term but very significant rises in sea level. Impacts of sea level rise are very different, however, for the low relief barrier island shorelines of the Atlantic and Gulf coasts than they are for the dominantly cliffed shoreline of the Pacific coast.

The conflicts between a) higher coastal concentrations of people and the recent, more frequently occurring coastal hazard events, b) ongoing shoreline retreat and high density development of the shoreline, c) private property and public beaches, d) increasing recreational use and economic value of beaches but the reduction or obstructions in beach sand delivery systems, and e) the desire to armor the coast or hold the line and resistance or opposition to more seawalls, have reached crisis proportions in many coastal states. The debate continues, in large part because there is so much at stake.

THOUGHTS ON RESPONSES FOR THE FUTURE

There are no simple or easy solutions, but then there rarely are today. We need to take a long range perspective vs. a stopgap approach, begin to think of long term and sustainable solutions which benefit the public at large, and accept the reality that while we can engineer a solution to almost any problem or issue, that over time, the magnitude of natural processes will overwhelm us.

Two long term data bases need to be carefully evaluated and understood. One is the maximum elevation that sea level can be expected to reach within the present global warming and sea level rise cycle. In our debates about global warming, we often forget that the history of the earth has been one of constant climate change and thus continuous sea level change.Sea level fluctuations due to climate oscillations are analogous to the daily tidal changes but on a time scale that is several orders of magnitude longer and larger. Global climate doesn't stay the same because the forces that influence it are constantly changing, and as a result, sea level has constantly changed over the several billion year history of the oceans. Based on 1] our present climate relative to long term global climate variations determined for the past, 2] maximum sea levels of the last several hundred thousand years, and 3] the amount of ice cap and glacial ice that could melt with the continued warming trend, how much higher might sea level rise? Are we talking centimeters, meters or tens of meters? Responses or solutions to coastal hazards we choose

today should be informed by this longer term perspective in contrast to the more frequently utilized emergency responses or short-term fixes.

Another long term data base we need to develop and use in our coastal hazard planning is the combined impacts of maximum historic wave heights and storm surge or elevated sea level. We are experiencing not only the slow, gradual, world wide rise in sea level at about 2 mm/year over the last century, but also the more infrequent but severe erosion-producing events such as northeasters or hurricanes on the Atlantic and Gulf coasts and El Nino events on the Pacific coast, which produce significantly elevated sea levels and severe wave attack. We have ample historic records of greatly elevated sea levels that, when combined with storm waves, have seriously impacted specific coastal areas with extensive loss of property and life. While such inundation levels were accurately recorded, have these been respected in redevelopment activities and in coastal development permits in subsequent years?

On a global scale the shoreline is moving inland but we have built a significant part of our civilization within a few feet of sea level. Further exacerbating the problem, in many areas we have also diminished the sand supply that formerly reached the coast or upset the transit of sand after it arrives at the shoreline, thereby reducing this natural buffer to wave attack. Regional studies of shoreline retreat rates are crucial to both identifying hot spots and also in selecting the most appropriate response in recognized problem areas. Yet, for much of the Pacific Coast, long term shoreline erosion rates are not known which makes informed decision making on proposed oceanfront development or the approval of protection for existing development difficult.

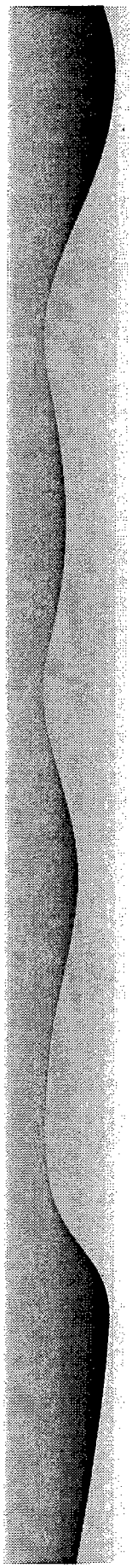
While seasonal fluctuations in beach width are well documented along the Pacific coast, there have been very few studies that have comprehensively and quantitatively looked at long term (50 year +) beach variations. Before embarking on any very costly beach nourishment program, we need to know what these long term trends are and whether nourishment is an effective solution. Which beaches are undergoing long term retreat and why? Is this the result of inland or shoreline sand impoundment or, as along significant portions of the southern California coast, were beaches naturally narrow, but artificially widened due to historic dredging and beach disposal projects that have been greatly reduced?

While funding for beach nourishment continues to be advocated as a solution to shoreline erosion problems, there are a number of issues that remain unresolved. Artificial nourishment is very expensive, and in California, where typical littoral drift rates are on the order of 250,000 m^3/yr, life spans of nourished beaches can be expected to be relatively short.Sources and costs for large volumes of acceptable beach quality sand, impacts of large scale dredging or quarrying and transport operations, and half-life of the nourished material on any particular beach are questions that have not been resolved for California.

Shoreline armoring, while the most common approach to coastal erosion over the past half century, has come under increasing scrutiny in recent years. The issues of visual impacts, restrictions on beach access, reduction of sand supply from previously eroding coastal bluffs, as well as beach loss through placement and actual and perceived impacts of seawalls on beaches have all heightened the awareness of the question of whether private property owners should be allowed to impact public beaches as they attempt to protect their own property. Several states, notably North Carolina, now have policies which prevent or discourage emplacement of any hard protection structures on beaches, and this trend appears to be increasing. It is also important to realize that no seawall was ever built to protect a beach and that shoreline or cliff erosion and beach erosion are two very different issues.

There may be local areas where protection of coastal areas or development may be feasible and of a high priority, at least for the short term, but the large-scale combined forces of global climate and associated natural disasters, the gradual rise of sea level and the impacts of storm waves cannot be significantly reduced or affected over the long term and we need to look for permanent and sustainable approaches. We need to accept the fact that hurricanes, ENSO events, sea level rise, and earthquakes will continue to occur, and that there are locations where we simply cannot afford to stop the shoreline from retreating and that development will have to be relocated or abandoned.

Replicating or recreating natural processes or systems will be a more sound and cost-effective long-term approach than attempting to meet nature head on as we have so often done in the past. Virtually



everyone supports beaches; few would argue that to the degree we can increase the amount of littoral sand or beach width, that we are expanding both recreational usage and shoreline protection. We can accomplish this by either 1] restoring or increasing the amount of sand reaching the shoreline, or 2] trapping littoral drift such that more sand stays on the beach. While artificial beach nourishment can provide short term benefits, but at very large costs, we need a permanent solution which requires returning to sustainable natural systems. Removing obsolete dams and allowing sand to flow naturally to the coast is a more cost-effective, long term and environmentally sensible approach than trucking sand from inland sites or dredging it from offshore. A number of investigations have been completed and others are now underway that identify those reservoirs that no long serve their originally intended purposes of either flood control or water supply due to sediment impoundment that are good targets for removal.

Another approach to shoreline stabilization that has been used in the past, but which potentially creates at least short-term downdrift impacts, has been the emplacement of groins. Groins essentially mimic natural headlands, and while there are a number of issues and design criteria which need resolution prior to emplacement, they have been effectively used at a number of locations in California. There are a number of other locations where groins could be emplaced, and initially charged with sand so as to avoid downcoast impacts, that could provide significant shoreline protection as well as additional recreational area. Hundreds of thousands of cubic yards of sand leave the coast of California each year at the downcoast end of each littoral cell through the numerous submarine canyons which indent the continental shelf. Trapping this sand through the use of well-planned and placed groins could provide major public benefits.

NO RETURN TO PARADISE – TRYING TO UNDERSTAND HAWAIIAN BEACHES WHEN CHANGE IS CONSTANT

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ABSTRACT

Hawaiian Island coasts are characterized by narrow insular shelves, micro-tidal range, and a very energetic open-ocean wave and current regime.Seasonal variations in wave climate result in dramatic fluctuations in wave approach direction, height, and period, which is further punctuated by extreme events. Superimposed on seasonal variations are medium-term (decadal+) local and regional climate variations caused by such phenomena as ENSO events and shifts in the Pacific Decadal Oscillation. These perturb the "normal" wave/current field around the islands causing a corresponding shift in beach response. A number of studies have documented shoreline change using aerial photograph interpretation, beach profile monitoring, and field observations.

Using end-point averages derived from vertical photographs collected in the early 1950's and late 1980's, the historical record of shoreline change (position of the vegetation line) was documented for the main Hawaiian Islands by Sea Engineering Inc. (1988) and Makai Ocean Engineering Inc. and Sea Engineering Inc. (1991). We have summarized their data (Table 1) for 108 beaches on 6 islands (466 individual transects) to obtain an average accretion rate for all the main islands of +0.001 m/yr (+0.04 ft/yr). The individual island averages are shown in Table 1. The resultant averages are typically much smaller than the minimum resolvable distance for an individual measurement. The change along individual photo transects ranged from an erosional maximum of –3.4 m/yr (-11.11 ft/yr) to an accretional maximum of +2.22 m/yr (+7.3 ft/yr). A subsequent more detailed analysis of five selected shoreline segments for the island of Oahu by Coyne and others (1999) gave an average mean net shoreline change rate of 0 m/yr for 873 individual photo transects where the beach step crest, rather than the vegetation line, was used as the shoreline change reference feature. Recent high resolution historical photograph studies for the Kihei coast of Maui (Rooney and Fletcher, 2000) show a mean, long-term, end-point rate of –0.135 m/yr (-0.443 ft/yr) for the beach step crest erosion reference feature.

Table 1. Average accretion and erosion rates on Hawaiian Islands

	m/yr	ft/yr
Kauai[1]	+0.004	+0.093
Oahu[1]	-0.001	-0.029
Molokai[1]	+0.007	+0.025
Lanai[1]	+0.043	+0.140
Maui[1]	-0.150	-0.500
Hawaii[1]	-0.062	-0.201
All Islands (average)[1]	+0.001	+0.040
Oahu[2]	0	0
Kihei, Maui[3]	-0.135	-0.443

[1] Original data from aerial Sea Engineering Inc. (1988) and Makai Ocean Engineering Inc. and Sea Engineering Inc. (1991). Endpoint averages determined from aerial photographs from the 1950s and 1980s, on 466 individual transects and 108 beaches. Erosion Reference Feature (ERF) = vegetation line.

[2] From Coyne and others, 1999. 873 individual photo transects on five selected shoreline segments. ERF = beach step crest.

[3] From Rooney and Fletcher, 2000. ERF = beach step crest.

There are several interesting similarities from the above studies:

1) Island-wide, mean shoreline change rates are low and for the most part are within statistical uncertainties of the methods used. This suggests that overall net change during the last ~40 years is highly localized and the islands' beach sediment budget is near balanced.

2) For most of the beach or coastal segments studied, erosion and accretion events occurred during the studied time intervals presumably as a result of local variations in sediment supply or transport. In other words, any given coastal segment is likely to be undergoing both erosion and accretion simultaneously.

3) Few beaches demonstrated a clear long-term erosion or accretion history (e.g. 8% and 9% respectively in the Coyne and others (1999) study). Again, this illustrates the dynamic and localized nature of change on Hawaiian shorelines and the apparent absence of a significant widespread trend. This does not mean, however, that there is no serious erosion problem. Severe erosion problems exist but tend to be localized.

Beach profiles were established in the early 1960's along a number of Hawaii State beaches (Moberly and Chamberlain, 1964) and later re-established on Oahu and Maui in 1994 as part of a cooperative beach monitoring effort between the USGS and University of Hawaii (see Gibbs and others, this volume). Maximum observed beach volume variation of the bi-annual profiles over the last five years for the island of Oahu varied from a low of 6 m^3/m for a protected south-shore beach to over 181 m^3/m for an exposed leeward shore. Although no long-term trend in beach volume change was identified in the five years of profiling, clear seasonal and/or event signals in profile variation are evident. Beach dynamics, as expressed through continuous change, complicate the identification of meaningful long-term trends.

From existing historical shoreline position and beach profile data we can draw some inferences for medium-scale shoreline changes. For example, on some Hawaiian beaches it is common to have a situation where there is little apparent net long-term loss of the beach (or reduction in the amount of beach sediment) yet locally have a retreating beach due to variation (or longshore migration) in erosional and accretional patterns. These longshore variations may be caused by local changes in wave/current forcing either through natural variations in seasonal patterns, impact of a large event, longer-term weather patterns (ENSO and PDO shifts) or human influences to the sediment budget (Fletcher and others, 1997).

The spatial and temporal scale of beach change is extremely important for understanding beach dynamics and subsequent beach management. Data of spatiotemporal scale appropriate to resolve short- to medium-term coastal fluctuations are not available for the Hawaiian Islands. Recent studies of seasonal and storm effects along tens to hundreds of kilometers of sandy coasts of the continental U.S. have revealed poorly-understood patterns of alongshore beach erosion and accretion. For example, shoreline change data collected bi-weekly over 45km of Cape Cod shoreline using a SWASH system (Surveying Wide Area Shorelines) document large-scale (>500m) coherent zones of alternating erosional and accretional profile change (J. List; http://woodshole.er.usgs.gov/projects99/list33240.html). Stretches of coast undergoing large amounts of erosion (~20m) during storms were also sites of high accretion (~20m) during recovery phases. In another example, 1200 km of the U.S. West Coast were imaged by airborne laser altimetry as part of an El Niño coastal impacts study (A. Sallenger; http://coastal.er.usgs.gov/lidar). Comparison of open-coast beach topography between October 1997 (pre-El Niño) and April 1998 (post-El Niño) show medium-scale (100's meters) rhythmic patterns of erosion and accretion. No such data exists for the Hawaiian Islands, but it is reasonable to assume that similar processes affect Hawaiian beach systems. It is also clear that because Hawaiian beaches are in such a close balance between inputs and outputs that any perturbations in local sediment supply, either natural or artificial, can have dramatic consequences to the shoreline.

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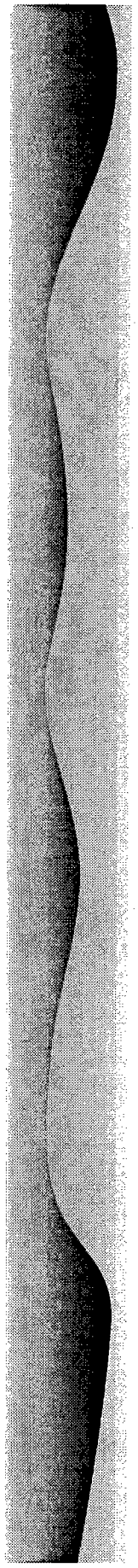

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ENGINEERING DESIGN FOR BEACH NOURISHMENT

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ABSTRACT

PART ONE: DESIGN AND PERFORMANCE OF BEACH NOURISHMENT PROJECTS.

Along eroding shores, beach management strategies typically center upon armoring, retreat, and/or beach nourishment. *Armor* (seawalls, revetments, etc.) is generally least preferred, or the method of last resort, as it protects the upland at the expense of the beach, unless the armor is routinely kept out of contact with the sea. *Retreat* may not result in a pristine shoreline, or is unjust in cases where the erosion is induced by man (such as downdrift of navigation projects, etc.), or may result in costly litigation, or is not realistic where the community's economy is based upon oceanfront access.

Mainly since the mid-1970's, among coastal engineers, *beach nourishment* is the preferred alternative, where practicable. In our firm's experience, the performance of these projects can be predicted, provided that the project is properly designed and is constructed per design. Monitoring results from typical projects designed by our firm are highlighted below. The "predicted" values are from each project's pre-construction engineering estimate. The predictions generally agree with the measured values within 25% or better, typically, within 10% or less. Given the uncertainties of nature, and that none of these project areas had previously been nourished, the agreement is quite good. Each of the projects has been impacted by typical or severe storms over the monitoring period.

Project	Length (miles)	Fill Vol. (mcy)	Predicted No. Life	Volume Loss (cy/yr) Predicted	Volume Loss (cy/yr) Measured	Mhwl Beach Width / Year after construct. Predicted	Mhwl Beach Width / Year after construct. Measured
Hilton Head Is., SC (1990)	6.8	2.0	8 yrs	-164,000	-167,300	—	—
Hilton Head Is., SC (1997)	7.2	2.2	8 yrs	-164,000	-160,000	—	—
Amelia Is., FL (1994)	3.3	2.2	6 - 8 yrs	-220,000 to -275,000	-290,000	100 ft @ yr 5	215 ft @ yr 5
Bonita Beach, FL (1995)	0.26	0.3	6 yrs	-31,000	-31,700	100 ft @ yr 3	88 ft @ yr 3

Additionally, each of some 15+ headland-stabilized projects (not listed), dating from 1991, have likewise performed per predictions. The nominal life of each was predicted as about 10 years; however, none have yet required renourishment, despite impacts from severe storms such as Hurricanes Andrew and Floyd.

From our experience, some elements central to successful design and performance of beach nourishment projects include the following:

1) Understand the root cause(s) of the beach erosion. This highly influences the scope of the solution and the probable project performance. For example, erosion caused by man's encroachment upon the natural beach is difficult to solve; and project life in these instances is short. Erosion caused by downdrift sand starvation requires mitigation of prior erosion, plus mitigation of the ongoing impact. *Et cetera.*

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2) Proper nourishment generally requires a LARGE sand volume; i.e., a high sectional fill volume. This is particularly important where there is a pre-existing sand deficit, such as along armored shorelines. Here, the majority of the sand fill may be required to simply return the profile to a healthy shape; i.e., where there is at least *some* residual dry beach left, let alone a net increase in beach width.

3) Make a realistic prediction of the fill's initial equilibration. The placed construction template will repose to a more natural beach profile extending to deeper water offshore. Bars and other features endemic to the local shore will form. Closing the profile equilibration too close to shore (i.e., assuming that it will intersect with the existing profile feature) is imprudent. We normally rely on natural healthy profile shapes to predict post-project equilibration rather than upon equilibrium profile equations.

4) Base erosion predictions upon a post-nourishment scenario; not upon data from an eroded, pre-project condition. Pre-project erosion rates will almost always under-predict project erosion, because the pre-project beach almost always represents a sand-starved environment. Erosion rates taken from a Amodel@ calibrated to *pre-project* data will likely *underpredict* the project's loss rates.

5) Predict local project performance through examination of variations in the alongshore transport potential and breaking wave energy density. We compute these factors directly through wave refraction analysis that carries the wave field directly to the breakpoint. (Toward this end, we periodically utilize GENESIS for *academic* investigations; but, we more typically rely upon direct examination of the computed net and gross alongshore transport gradients, and upon gradients associated with acute (storm) wave conditions).

In all these issues, it is noted that our *principal* reliance is upon engineering experience, and not upon academic models. While we certainly utilize such models as an aid to the design, the project's final construction drawings reflect coastal engineering intuition and experience. It is recognized that existing models are not capable of capturing all of those natural phenomena that affect a project's potential performance but which may be otherwise intuitively understood by an experienced design engineer. There is a perception that these computer-based models drive coastal engineering project design. This is presumably because discussions of these models dominate the literature – which is naturally dominated by academia and government reserachers. But, academics and researchers do not design projects nor seal construction plans. In short, in the world of *successful* practice, such models play an ancillary role. Designs that are taken from Nature, wherever and however possible, consistently appear to provide the most successful and well-predicted project performance.

PART TWO: BEACH RESTORATION IMPROVEMENTS FOR WAIKIKI BEACH

The bulk of recent money for beach restoration in Hawaii has been spent on studies of Waikiki Beach (some $2M); yet, to-date, no recent improvements have been built or are presently scheduled for construction. Sand placement here commenced in 1939, and the most recent nourishment was in 1972, with minor fill placement in the mid-1980's (Wiegel, *Shore and Beach*, Vol. 63, No. 4; Oct. 1995). In early 2000, the author was engaged by the State of Hawaii to conduct a value-engineering study of proposed beach improvements at Kuhio Beach, along central Waikiki, and to comment on the general, overall restoration strategy for Waikiki Beach.

Waikiki Beach is approximately 2+ miles long, of which only 69% features dry, accessible beach at high tide. Neglecting Fort DeRussy (federal park), less than half of the public-park portion of this beach (from Sans Souci through Kuhio) features any dry, sand beach at all. Nonetheless, Waikiki Beach is inarguably among the most famous resort/tourist beaches in the world, at least in name.

A critical first step in proper management of Waikiki Beach is to recognize and quantify the economic value of the beach resource. Such a study should be conducted promptly by an individual with prior specific experience in resort/beach economics (with input from a local firm knowledgeable of the resource). There is considerable anxiety in Hawaii about the cost of beach restoration, particularly in regard to the cost of sand. However, this concern may be overshadowed by the value of the beach to the economic community, and by the cost of doing nothing to preserve and improve this resource.

A second, equally important step is to conduct an engineering study with the specific objective

(deliverable) of developing one or more sand sources, with specific engineering and biological detail sufficient for permitting and for construction drawings.

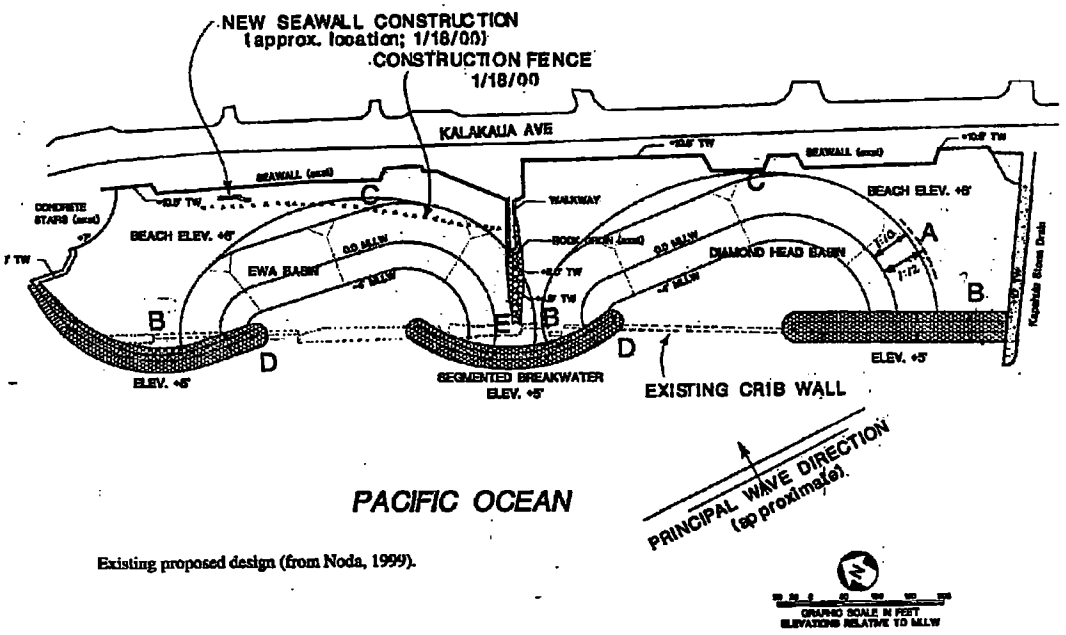
Waikiki Beach is already compartmentalized physically (by long groin-type structures) and economically (by private vs. public oceanfront development). The divisions mostly coincide. Beach improvement planning and design can, and should, take advantage of this compartmentalization in terms of (1) physical design, (2) scheduling, phasing, prioritization, and (3) cost-sharing. Removal of, or significant reductions to, the existing long groins that compartmentalize the beach is neither physically realistic nor of clear physical benefit.

By priority, the author recommends improvements to (1) Kuhio Beach, (2) Queens Beach (3a) Halekulani (Aston Waikiki through Sheraton Waikiki), and (3b) Royal Hawaiian to Kuhio Beach. Specific recommendations briefly include the following:

- Removal of derelict groins and abandoned outfall pipes along and west of Sheraton Waikiki
- Rock T-head groins (at least two) are recommended on either side of the Halekulani channel, lest beach sand placed here will not be stable
- Spur structures attached to mid-points of the existing long groins
- Beach nourishment with or without stabilizing structures Ewa of Kuhio Beach
- Re-design of the Kuhio Beach plan (see below)
- Landward relocation of the seawall along Queen's Beach South (Snack Bar to the Aquarium).

Further description of these conceptual recommendations, as well as discussion of the Natatorium project will be presented in the paper.

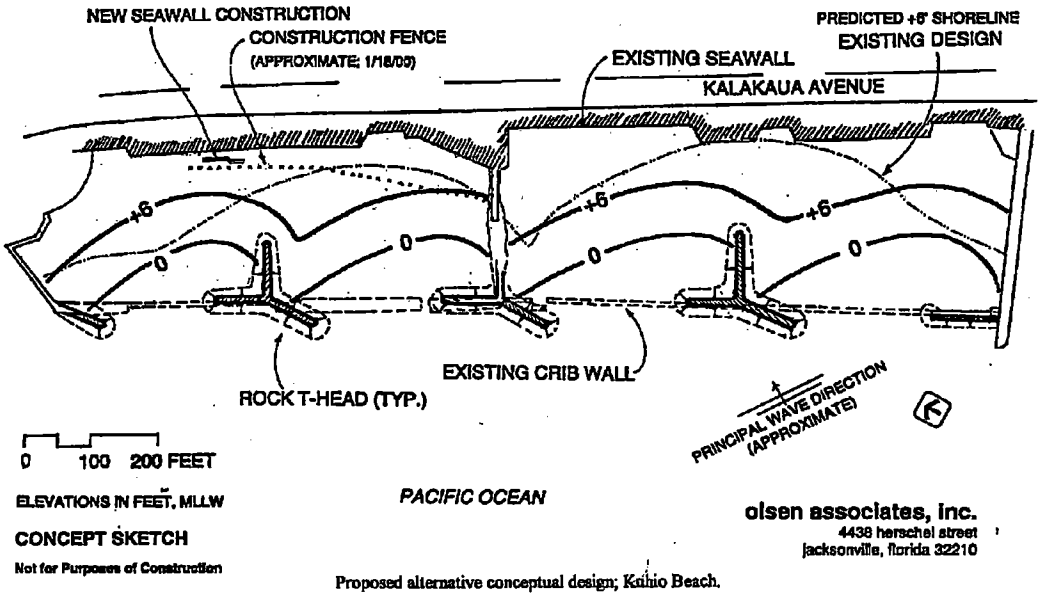
Review of the improvement plan proposed for Kuhio Beach concluded that the present, proposed design is subject to frequent wave overtopping and consequent erosion of the design berm. The design would also result in narrow "pinch points" in beach width (i.e., minimal beach width in front of the existing seawall) at locations that presently feature minimal beach width. The existing design estimated the sand-fill requirement to be less than half of the probable required value, based upon a survey of the beach. An alternative design is proposed that features 0.6 acres more dry (stable) beach area than the original design, with the same fill volume, but with an approximate $275,000 *decrease* in construction cost. The "pinch points" of narrow beach width are also greatly reduced, and the project shoreline is



Existing proposed design (from Noda, 1999).

aligned more naturally with the sea. The existing and proposed alternative designs are sketched in the following figures. Rationale for the design will be presented in the paper.

Existing Proposed Design (by others)



Proposed alternative conceptual design; Kuhio Beach.

Proposed Alternative Design (by author)

BEACH NOURISHMENT FOR HURRICANE PROTECTION: NORTH CAROLINA PROJECT PERFORMANCE IN HURRICANES DENNIS AND FLOYD

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ABSTRACT

Since 1996 southeastern North Carolina seems to have been a magnet for hurricanes. In four hurricane seasons, four storms made landfall at Cape Fear near Wilmington, N.C., and a fifth passed nearby (Figure 1.) In 1996, Hurricane Bertha arrived, with Hurricane Fran only about a month later. After a quiet year in 1997, Hurricane Bonnie made landfall in 1998. This paper reports on the erosion threats to oceanfront buildings during Hurricanes Dennis and Floyd in 1999 and on the relative performance of five beach nourishment projects during those storms.

After Hurricane Dennis passed just offshore Cape Fear, it became stationary for five days, 150 miles offshore of Cape Hatteras. It caused moderate shoreline erosion statewide in passing. Conditions were significantly worse north of Cape Hatteras due to the duration of the storm. Because the highest winds remained offshore, the shoreline conditions were similar to an unusually severe northeast storm. Storm surge levels were generally less than 5 feet above normal but offshore wave heights exceeded 40 feet.

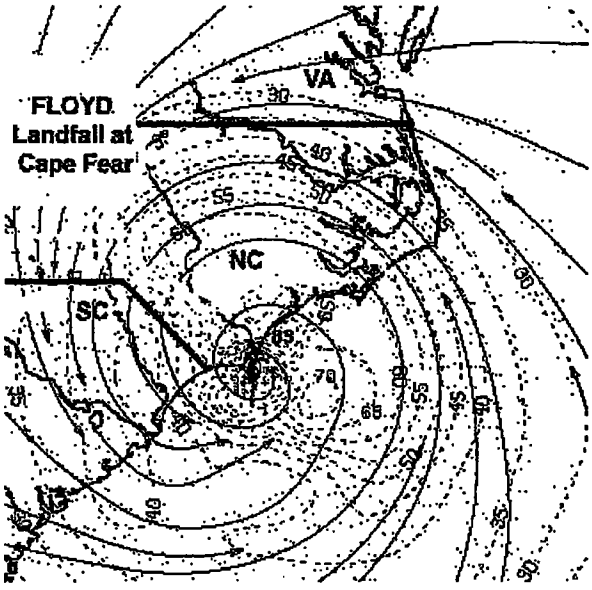

Figure 1. Floyd's landfalling winds (mph) at Cape Fear.

Two weeks later, Hurricane Floyd made landfall at Cape Fear as a Category 2 hurricane. The peak storm surge exceeded +10 feet NGVD. Based on National Flood Insurance Program predictions the storm surge return frequency was 75 years. This combination of closely timed storms caused coastal flooding, shoreline erosion and wave damage along the entire North Carolina coast. Approximately 300 miles of shoreline were affected.

DESTROYED AND THREATENED BUILDINGS

The severity and chaos of the earlier hurricanes unfortunately made tallies of building damage a low priority immediately after the storms. However, by the time Dennis and Floyd hit, local governments were well practiced in storm preparation and recovery. For the first time, local governments had the luxury of documenting major structural damage to buildings. Destroyed buildings were identified using FEMA's substantially damaged definition (> 50 percent damaged) and were considered unrepairable. Communities identified structurally damaged but repairable buildings by various labels, such as condemned, uninhabitable or power disconnects. With few exceptions, the common condition among the buildings was that at least part of the foundation had been undermined by erosion during one of the storms.

The degree of damage to buildings classified as threatened varied considerably. Most of the buildings were single-family houses constructed on piling foundations with elevated living floors over under-house parking and storage. In some cases, only a single piling or row of pilings experienced erosion, with erosion depths as shallow as one foot. Repair could be as simple as replacing a set of steps to meet the building code requirement of two means of access. In the other extreme, a significant share of the threatened houses experienced wave-induced erosion landward of the building. Vertical erosion losses

around the seaward side of the foundation could be as much as 8 feet. Most of the buildings were somewhere between those extremes. Those classified as threatened generally are expected to be repaired by the following spring. The state's oceanfront setback line for new buildings is based on the long-term erosion rate rather than an individual storm's erosion, but the requirement uses the seaward line of stable dune vegetation as a reference line to measure landward for the setback. The erosion-relocated vegetation line is a significant repair incentive as the setback line has been moved far enough landward to make many of the most eroded lots at least temporarily unbuildable for new construction.

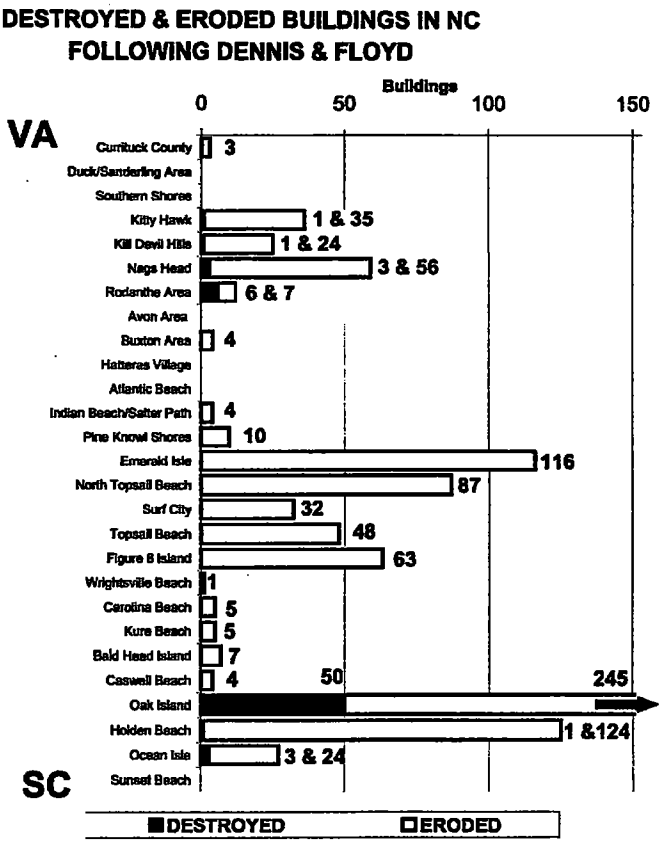

Figure 2. Locations of destroyed and threatened buildings.

The survey results are summarized in Figure 2. Communities are listed from north to south. Dennis and Floyd combined to cause damage along the entire North Carolina oceanfront, from Virginia to the South Carolina border. Statewide, local governments determined that 65 buildings were destroyed or substantially damaged. The survey identified 903 additional oceanfront buildings as erosion-threatened. Although the buildings affected by Dennis and Floyd are scattered down the coast, they generally cluster near historical problem areas for long-term erosion. The storms significantly broadened the previous problem areas and damaged many buildings that previously had been only close to the edge.

BEACH NOURISHMENT PROJECTS

Several North Carolina coastal communities have used beach nourishment over the past 35 years. Nourishment has been conducted for several different purposes and practiced on several different scales. There are three hurricane protection projects designed by the U.S. Army Corps of Engineers; two somewhat smaller-scale — but regularly maintained — public/private projects; one very large port-dredging beach-disposal site; and several hundred small, unmaintained beach-disposal fills from nearby navigation projects. The building inventory following Hurricanes Dennis and Floyd provides a unique opportunity to look at the performance of the larger nourishment projects and compare the protected areas with other natural shorelines nearby.

With local sponsorship, the Corps built separate 2.6-mile nourishment projects for Wrightsville Beach and Carolina Beach in 1965. Initial construction and maintenance costs, as well as the benefit/cost ratios are based primarily on hurricane protection for buildings rather than any recreational beach benefits. Both projects have construction cross sections 250 feet wide, with a dune crest 25 feet wide and an elevation of +13.5 feet NGVD. The plans call for maintenance by adding sand to the lower beach width every two to four years to offset the pre-existing long-term erosion and other project losses. The dune and part of the beach width is designed to provide the building protection during hurricanes. Maintenance is expected to take place before the minimum protection cross-section is eroded. Funding coordination problems for both towns halted maintenance in the 1970s, allowing a reversion to severe, pre-project erosion threats on some sections of the shoreline. Both projects were substantially rebuilt about 1980 and maintenance has been conducted on a regularly scheduled basis since that time. The Corps designed a

similar cross-section for 3 miles of shoreline in Kure Beach and the south end of Carolina Beach. The project was advertised for bids when Hurricane Fran hit. Kure Beach lost approximately 20 houses, with many more threatened. The nourishment project was redesigned for the post-Fran shoreline conditions and completed before Hurricane Bonnie in 1998.

The Corps uses a cost-optimization method for design rather than a return frequency, but for these projects the equivalent design frequency is on the order of 50 years. Hurricanes Fran and Floyd, with return frequencies of 120 and 75 years, appear to be the first storms exceeding design-level to hit any U.S. beach nourishment project designed around manmade dunes for hurricane protection of coastal buildings.

Because design levels were exceeded by the two storms, some degree of damage to the nourishment project and to the protected buildings is to be expected. The dune and beach are designed as sacrificial features that may be consumed during the duration of the storm. Some sections of the manmade dunes were completely eroded in both storms. The dunes were rebuilt to the design cross-section during the regularly scheduled maintenance in 1998, about 18 months after Fran. The new Kure Beach project was constructed at about the same time. All three Corps projects were tested again by Bonnie's 37-year storm surge with minor erosion of the lower beach but no significant erosion of the dunes. In some cases, Bonnie's overtopping and wind transport raised the elevation of the manmade dune. During Floyd, some sections of the manmade dunes were flattened again, but less extensively than during Fran.

The inventory of destroyed and threatened buildings can be used as a simple measure of the effectiveness of the beach nourishment projects. Wrightsville, Carolina and Kure Beaches appear to have received Floyd's highest storm surges, yet show marked reductions in threatened and destroyed buildings compared to unnourished communities both north and south.

The benefits are actually more dramatic than implied in the figure. All of the threatened buildings listed for the three communities were located outside the nourishment project limits or in transition areas at the ends of the projects where the dunes were not constructed. Hurricanes Floyd and Dennis threatened or destroyed 968 buildings outside the three Corps-designed nourishment projects' manmade dunes. Remarkably, not even one building behind the project dunes was threatened by erosion — that's ZERO.

The actual value of building damage would be a better measure of the success of the hurricane-protection nourishment projects. Efforts are underway to complete that analysis for all of the recent North Carolina hurricanes. This study documents only the reduction in erosion threat to individual building foundations in hurricane conditions up to a 75-year storm surge. However, previous studies have shown that the highest building loss rates and most severe damage will occur in the storm-eroded areas closest to the ocean (Rogers, 1990). The three nourishment projects prevented all erosion damage to the protected buildings. Even in areas where the manmade dune was eroded, peak wave heights under the buildings were obviously reduced. More detailed damage studies are certain to show major reductions in damage costs.

Figure Eight Island has had its beach nourished on an irregular basis since 1979, through private funding by property owners. Beach nourishment also has been used for erosion control on Bald Head Island. Project widths vary but have typically placed 100 to 150 feet of new berm, without any dune. Sections of Figure Eight had been filled several months prior to Floyd. Following the storm, 63 houses were threatened by erosion. Bald Head has relatively few beachfront buildings but seven were threatened. These smaller projects may have reduced the erosion and number of threatened buildings but appear to offer far less protection than the larger cross-sections and higher dunes of the hurricane-protection projects.

Atlantic Beach has been fortunate to receive beach nourishment as part of dredging from the nearby state port in Morehead City. Clean sand dredged for channel maintenance is placed in an inland, diked disposal area. When the disposal area fills every eight to 10 years, sand is moved to the shoreline of Atlantic Beach, allowing the disposal area to be reused for more frequent maintenance. Volumes have been as high as 4 million cubic yards placed as a wide berm. Over time, the beach has widened on the order of 300 feet. Dunes have not been constructed but have naturally developed seaward of the existing buildings. Atlantic Beach was in the fringe of both Dennis and Floyd and was not tested as severely as the other nourishment projects. However, no buildings were threatened or destroyed during the two hurricanes.

CONCLUSIONS

The beach nourishment projects in North Carolina designed for hurricane protection by the U. S. Army Corps of Engineers performed as expected in the flurry of recent hurricanes. The building survey following Hurricanes Floyd and Dennis found that no buildings were threatened by erosion inside the project dunes, while 968 buildings were threatened and destroyed outside the protection. Properly designed and maintained beach nourishment is clearly an effective tool for hurricane protection. The only question is how overwhelmingly beneficial the projects will prove in economic terms.

Damage analysis from Fran can be expected to show even greater benefits than Floyd's tally. Preliminary reviews indicate not one building behind the project dunes was destroyed by Fran's waves or erosion. Outside the project limits, in similar surge conditions, an estimated 500 oceanfront buildings were destroyed. Smaller nourishment projects have historically been successful against moderate rates of long-term erosion but should not be assumed to provide significant erosion and wave protection during infrequent but severe storms like hurricanes.

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HAWAII'S EMERGENT COASTAL EROSION MANAGEMENT PROGRAM

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ABSTRACT

After years of human impact and neglect, many of Hawaii's beaches suffer sediment deficiencies and are now narrow and eroded. These offer poor storm surge protection, little recreational opportunity, and the indigenous littoral ecosystem that once characterized the shore is severely altered. Article X of the Hawaii State Constitution mandates the state to conserve and protect Hawaii's natural resources for the benefit of present and future generations. As the trustee of Hawaii's beaches, the Department of Land and Natural Resources, working with the state Coastal Zone Management Program has initiated a new and comprehensive effort, the Coastal Lands Program (CLP), to save this precious natural resource for the future. This effort is guided by the doctrine of sustainability promoting the conservation, management, and restoration of Hawaii's beaches. Focusing upon interagency coordination, the state has attained several notable goals since late 1997 when the CLP was created. These include raising public awareness, publishing new criteria for shoreline alteration projects, implementing a coastal erosion committee, publishing a plan for erosion management and obtaining unanimous endorsement by state and county stakeholder agencies, and the creation of a special fund for beach restoration with specific sources of revenue.

Ongoing efforts include identifying sustainable sand resources and beach restoration technologies, mapping and monitoring the shoreline and analyzing critical erosion areas, public education, enforcement, legal and economic analysis of management issues, streamlining permitting, enhancing interagency coordination, and developing restoration demonstration projects in a framework of innovation and public participation.

The main purpose of this presentation will be to highlight the importance the CLP program as a means to overcome many political, technological and institutional obstacles so that we can attain a reasonable balance between shoreline development and beach preservation.

The DLNR Coastal Lands Program, with statutory means, can chart it's own destiny by generating funds for beach restoration, from the appropriate use of coastal lands. However, the political, technological and institutional structures in which it **emerges** will define the ultimate purpose or success of the Coastal Lands Program.

For instance, shoreline management issues are complex and politicized. The complexities arise from both a lack of really definitive data on coastal processes, disagreements over what information is important, lack of workable land use policies and development criteria, and conflicts over private property rights and the State's responsibility to protect beaches. When these issues cannot be resolved within the common institutional framework of government, they become politicized. People suddenly have agendas and ulterior motives and charges are leveled from both sides. With these potential pitfalls in mind, it has been a goal of the CLP to provide a common yoke, or the "missing link" to tie the whole shoreline management issue together. However, the politicalization of an issue or issues can damage the credibility of a program and result in counter legislation and efforts to destroy it. The success of the program, therefore, depends on how well it can respond to these situations.

There are equally technical problems that must be addressed and resolved in a comprehensive manner. The CLP can address these issues on a statewide basis and assist County governments and coastal communities in developing options and solutions for their shoreline management problems. For example,

sand resources must be developed if we are to pursue beach nourishment as one management option. Sand resources lie in inland areas of each of the islands and in the offshore area. The CLP can facilitate the investigation of these resources statewide and develop costs estimates for extraction and delivery for specific beach sectors anywhere in the State. If its just a matter of developing the optimal technology, for instance, to pump sand directly to a beach from the offshore area, CLP can work with the University and industry leaders to provide the optimal technology that matches our local conditions. The success of the program will be directly related to our ability to avail ourselves of this technology and to wield it properly in the local theater. This will spin-off new industries as the market tries to capture a new niche. These new markets will respond to basic economic forces, which see beach restoration and protection as a wise investment in an economy based on coastal dependent tourism.

The institutional problems are also significant. Budgeting, finance, too much government bureaucracy, home rule vs. State oversight, over regulation. The CLP can survive and thrive in this environment if it shows leadership in dealing directly and responsibly with shoreline erosion management issues. On such example is a proposed State Program General Permit (SPGP) to streamline the permitting process for small-scale beach nourishment projects. Another example is the Coastal Erosion Subcommittee comprised of individuals from all sectors or society. The Committee tries to cut across jurisdictions (State/County/Federal), private landowner or activist to address and resolve broad ranging issues related directly to coastal erosion management.

The presentation will focus on some of the recent achievements of Hawaii's new program, such as the SPGP, an emergent offshore sand exploration program, small but successful beach nourishment pilot efforts, Federal funding to begin restoration of Waikiki Beach, and others. The presentation will also provide a blueprint for the program's future and how this will be achieved by focusing on new innovative ways of doing things, including new funding initiatives, the development and improvement of interagency coordination as a core mission, development of sand sources and engineering technologies for restoration, community focus with a core mission of raising public awareness, and enhancing the opportunities for public participation in the process of beach preservation and restoration.

SAN DIEGO ASSOCIATION OF GOVERNMENTS SHORELINE PRESERVATION STRATEGY

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ABSTRACT

Beaches are an important environmental, economic, and fiscal resource in the San Diego region. They attract significant tourist expenditures and jobs, and immeasurably enhance the environmental quality of life for the region's residents. Both visitors and residents consistently rate beaches as one of the main attractions of the San Diego region.

Prior to the late 1970s, most people took area beaches for granted. An extended period of calm coastal weather obscured erosion problems. However, a number of forces were consistently contributing to sand loss. Development on both the shore and inland, including water reservoir and dam building, flood control systems and sand mining, kept streams and rivers from transporting sand to the coast. Rising sea levels also contributed to the problem.

Towards the end of the '70s, coastal weather patterns began to intensify, increasing the rate of shoreline erosion. This brought beach disappearance to the attention of local officials and the public. Communities throughout the county began to voice their concerns about sand loss.

In response to these concerns, the San Diego Association of Governments (SANDAG), the local association of the region's 18 cities and county government, took steps to address the problem of shoreline erosion. SANDAG created the Shoreline Erosion Committee, a group of elected officials and resource agency representatives, to provide a forum for discussing coastal issues.

During this time the U.S. Army Corps of Engineers began its six-year, $6 million study of the San Diego region shoreline. The Coast of California Storm and Tidal Waves Study was initiated to quantify natural and man-induced coastal processes within California. The study covered an 85-mile stretch of coastline from North San Diego County to the international border. The results of the study were subsequently made available to the public to aid in decisions regarding the utilization of the California coastal zone. Information from this study provided an important foundation for the Shoreline Preservation Strategy, adopted by SANDAG in 1993 and carried out by the Shoreline Erosion Committee.

The Shoreline Preservation Strategy consists of several objectives. These focus on the management of the region's shoreline to preserve environmental quality and provide recreation and property protection, as well as to develop and implement shoreline management tactics that are both cost-effective and equitable.

The Shoreline Preservation Strategy recommends beach building and maintenance as a primary shoreline management tactic for the San Diego region. Beach building and maintenance programs emphasize the nourishment of eroded beaches with sand to make them wide enough to provide increased property protection and recreational capacity, and the periodic re-supply of sand to these beaches in order to maintain them. The strategy calls this the most effective and environmentally beneficial method of combating shoreline erosion.

An estimated 30 million cubic yards of sand is required to fulfill the initial beach building needs in the San Diego region. The capital cost for this program is estimated in the range of up to $150 million.

Benefits from this investment include shoreline property protection, recreation and tourist revenue. The estimated value of these benefits is $53 million annually.

There are number of opportunistic sources of sand for beach building. These include harbor dredging, lagoon habitat enhancement projects, and water storage reservoirs. Since the adoption of the Shoreline Preservation Strategy in July 1993, 12 opportunistic sand projects have been completed. Also, several ongoing projects continue sand placement at local beaches. In total, the completed and ongoing projects have contributed approximately 5.39 million cubic yards of sand to the region's beach replenishment efforts. The value of this material is estimated at $80.9 million ($15 per cubic yard of sand).

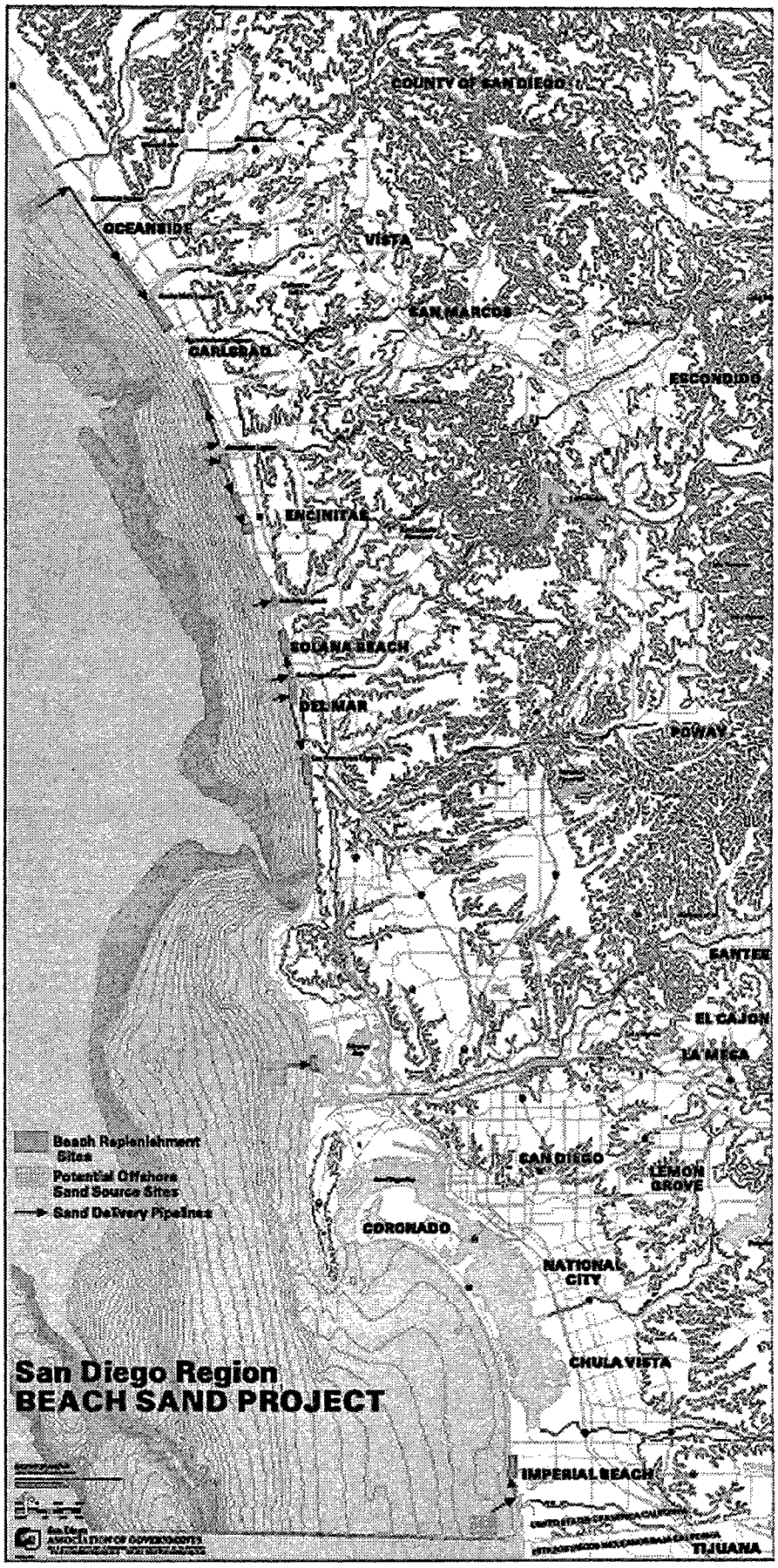
Besides these opportunistic beach building efforts, various large-scale projects have been proposed for the San Diego region. One such effort was the U.S. Navy's attempt to place sand on the region's beaches with the Homeporting Project. In order to accommodate berthing of one Nimitz-Class Aircraft Carrier, the Navy dredged sand from the North Island Naval Air Station berthing area, turning basin and the San Diego Bay navigation channel. The sand was originally intended for placement on area beaches. However, when munitions were found in the sand the material was disposed of at open ocean sites.

Following the Navy's effort, the Shoreline Erosion Committee proposed the Regional Beach Sand Project. The project was developed as a region-wide effort to restore sand to area beaches. This $15 million project will place two million cubic yards of sand on 12 area beaches in the spring of 2001. It is the largest comprehensive regional beach replenishment project ever carried out on the West Coast.

As part of the project, sand will be dredged from six borrow sites located about one mile offshore. This is to ensure that the dredged sand will be outside the depth of closure, the seaward edge of an active littoral cell. A littoral cell is the region where wave energy dissipates. Significant amounts of sand from coastal littoral cells do not usually travel outside of the depth of closure (i.e., into the deeper ocean).

Following dredging, sand will be placed on a number of receiver sites throughout San Diego County. These sites were selected from among the most eroded beaches in the region. Significant care was taken to ensure that sand placement at these sites would avoid impacting sensitive species such as least terns and boa kelp. Fisheries advocates were particularly concerned that placement did not affect those areas which provided habitat for young lobster.

Successful completion of the Regional Beach Sand Project will bring many benefits to the San Diego area. Wider beaches will offer storm protection to roads, parks, houses and businesses along the shoreline. They will also create habitat for area wildlife. Finally, replenished beaches will promote tourism and enhance the quality of life for everyone in the San Diego region.


COUNTY OF SAN DIEGO
OCEANSIDE
VISTA
SAN MARCOS
CARLSBAD
ESCONDIDO
ENCINITAS
SOLANA BEACH
DEL MAR
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SANTEE
EL CAJON
LA MESA
SAN DIEGO
LEMON GROVE
CORONADO
NATIONAL CITY
CHULA VISTA
IMPERIAL BEACH
TIJUANA
Beach Replenishment Sites
Potential Offshore Sand Source Sites
Sand Delivery Pipelines
San Diego Region
BEACH SAND PROJECT

GUIDELINES FOR MANAGEMENT OF THE COAST – LESSONS LEARNED

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ABSTRACT

In the management of the coastline, government and the private sector are frequently in conflict regarding the protection of private property versus the preservation of natural resources. Many of these conflicts could have been avoided. Coastal States and Pacific Islands need to adopt strategies and guidelines based on avoiding erosion problems, rather than attempting to mitigate mistakes that have been made. Yet, in the management of the coastline, critical decisions relating to the placement of structures are made far too late, with severe legal, economic and political consequences.

States need to focus on shoreline instability for each juncture related to the development and management of the coastline. The seven generalized stages in the management of the coast are: (1) State Zoning, (2) County Zoning, (3) Subdivision of Land, (4) Infrastructure Improvements, (5) Lot Purchase, (6) Home Construction, and (7) – Erosion Noticed – Remedial Options Evaluated. With each stage that passes without addressing potential erosion, major land use and construction avoidance options become foreclosed, until at Stage 7 – the government is faced with the familiar dilemma – save the beach or the property? Unfortunately, too much of the U.S. coastline has gone through Stages 1 through 6 with no consideration for potential erosion. These mistakes cannot be repeated because the consequences of poor planning will become more severe as seas continue to rise and coastal populations grow.

The earlier that shoreline instability is addressed, the less burdensome are the solutions to address the problem. For erosion to be addressed during the zoning and subdivision stage, the necessary data for planning must be available. This information can come from previous reconnaissance studies conducted pursuant to the Coastal Zone Management and Sea Grant Programs, the River and Harbor Act, or the Shoreline Protection Act of 1996. If suitable data for planning is not available, it should be made a requirement of the developer, planner or architect to get site-specific data before any decision is made on the zoning or subdivision of land. By obtaining a coastal impact study early, the need for homeowners to conduct many coastal studies later on can be avoided. Furthermore, the economic burden to conduct a coastal study is far less for a developer than if a homeowner needed to conduct one. The requirement to analyze coastal impacts could be a separate condition of a permit, or could be one of many issues to be addressed in an Environmental Impact Statement, if one is required for a project.

The more unstable the shoreline, the greater the need to address erosion during the zoning stage. For shorelines with continuous high erosion rates or those with gentle slopes that are especially susceptible to sea level rise (such as atolls), the need to address erosion early is especially important.

At each stage of development, a wide range of options and strategies should be developed for dealing with coastal erosion. Some important tools and strategies to be developed include shoreline setbacks, transferable development rights, rolling easements, notice to landowners of the State or Counties shoreline hardening policy and development of coastal industry standards.

The traditional method of dealing with potential erosion is with shoreline setbacks. There is a misperception that after the United States Supreme Court case, *Lucas v. South Carolina Coastal Council*, 505 U.S. 1003, (1992), setbacks cannot be used to control erosion. Setbacks remain an important tool as long as they are employed early enough to protect the beach and allow economically viable use of the land. This would require that setbacks be employed at the zoning and subdivision stages so that lots can be created that are large enough to accommodate future shoreline movements. Usually, setback laws are written so that they do not come into effect until Stage 6 - home construction, which is too late and leads to Constitutional takings problems when small lots are involved. To resolve this problem, a setback provision could be written in the zoning and subdivision regulations or can be made a condition of a

zoning/subdivision permit. For most zoning/subdivision regulations, there is sufficient authority in the regulations for this environmental issue to be addressed.

For jurisdictions that cannot pass an erosion regulation, or factor in erosion as a condition of a permit because of the political climate, the alternatives are to develop an industry standard for proper location of structures. The government can help to develop a standard by producing a guidance manual on factors to consider in safely locating structures.

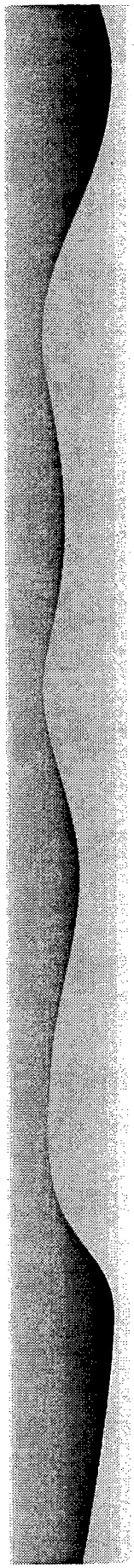
The concept of rolling easements is described in the article Rising Seas, Coastal Erosion, and the Takings Clause: How to Save Wetlands and Beaches Without Hurting Property Owners, (James Titus, 57 Maryland Law Review 1279). In many coastal states, the boundary between the ownership of private land and the public beach is at the high water mark or high tide line. Thus, the dry sand beach is privately owned but there is a common law easement that the public can use this area. The rolling easement concept is implemented when the government proclaims before construction that the publics right to the dry sand beach or the easement will not be impacted by shoreline hardening. With early notice to the developer, planner, architect or homeowner of this prohibition on hardening, future plans for the zoning, subdivision, and construction will take into account potential erosion. Furthermore, if the shoreline did recede sufficiently to cause structures to be in the water, the homeowner would be required to remove the structures. Rolling easements may be especially useful for very unstable coastal areas. Ideally, the concept of the rolling easement should be employed during the zoning and subdivision permitting stages of development.

A common practice to preserve environmentally sensitive areas utilizes a system of Transferable Development Rights ("TDR"). Under the TDR concept, developers are given the right to increase density in more urban and commercial areas in exchange for granting easements in environmentally sensitive areas, such as along the coast. This balancing has been viewed by many as means to direct growth to areas that are more suitable to the public and economically advantageous to the developer. At the same time, necessary open space is preserved for the well being of the community and the coastline. Application of the TDR concept would be most effective if implemented during the zoning and subdivision permitting stage.

The development of industry standards can apply to all stages in the development and management of the coastline. Industry standards refer to a group of standards that apply to many different professions (e.g., doctors, accountants, engineers, attorneys, architects, developers, planners, construction companies). Related to management of the coastline, industry standards could apply to developers and planners involved in Stages 1-3; planners and architects involved in Stages 3, 4 and 6; construction companies involved in Stages 4 and 6, and even real estate brokers involved in Stage 5. Industry standards develop when members in a particular profession, adopt through custom, a standard procedure. If a valid industry standard is developed, then following this standard establishes a minimum level of care required in that profession. Failure to follow the standard may result in a poor reputation and even liability.

The government can help to establish standards by (i) requiring coastal data be reviewed before zoning, (ii) espousing the government's position on shoreline protection and (iii) printing a guidance manual for development along the coast. Recommendations in a manual are more likely to become industry standards if they are well written, reasonable and take into account the burden on the professional to comply, the potential loss of not complying and the probability of harm.

For Stages 1-3, an important standard for the developer, planner or architect would be to address potential erosion before zoning or subdividing coastal property. This would require that zoning changes and subdivisions be designed in a manner that does not place future inhabitants at risk. For Stages 4 and 6, related to infrastructure development and home construction, specific architectural and construction standards could be developed related to: (i) preservation of the coastal dunes during construction, (ii) preservation of views and reasonable access, (iii) placement of structures as far inland as possible on the lots and, (iv) the types of foundations allowed on grade. Even for a realtor involved in the sale of coastal lots (Stage 5), a standard could be developed related to the requisite notice to be provided to a purchaser of coastal property on the potential for erosion and the state's policy on shoreline hardening.



In the rare instance where land use tools (setbacks, rolling easements, TDRs, industry standards) cannot address the erosion problem, the land could remain in conservation or low-density use. This would have to be decided in stages 1 and 2 and would require some balancing of the purpose of the government action versus the harm to investment-backed expectations of the landowner.

Conflicts are inevitable for developed land in which shoreline instability has not been planned for prior to construction (Stages 1 through 6). In this situation, actions are designed to mitigate past mistakes. Key in this situation is to develop the greatest number of options and permutations of options that deal with the protection of property and the preservation of natural resources. Thus, the beach replenishment option is an important tool and may have special application in island states in which the shoreline is protected by fringing reefs. Nevertheless, sand replenishment may not be an option for all beaches because of scientific, legal or economic factors. For this reason, other mitigation as well as compensatory mitigation options should be developed.

TWO EXAMPLES OF BREAKWATER TECHNOLOGY APPLICATION FOR EROSION CONTROL

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ABSTRACT

Loss of upland to erosion may be prevented with shore protection structures such as seawalls and revetments. These alternatives, however, harden the shoreline and are therefor often detrimental to the beach. Shore protection structures physically interfere with natural transport processes and often simply transfer the erosion problem to adjacent areas.

Conventional groins have both shore protection and erosion control functions. They may be successful at stabilizing the updrift beach, but once filled to design capacity, ongoing littoral transport occurs around the seaward end of the groin, in deeper water. This diminishes the supply of sand to the immediate downdrift beach which may erode more severely than without the groin in place. Additionally, conventional groins obstruct natural transport in either direction, and may be detrimental to updrift beaches during periods of littoral transport direction reversal.

Erosion control structures reduce erosion stress by modifying incident wave energy. The design beach will reach a state of dynamic equilibrium under which natural transport is maintained in either direction. The potential for downdrift impact is limited, and may be minimized by placing fill in conjunction with the placement of structures.

In the first case presented, a nearshore segmented breakwater was constructed in 1996 to stabilize the terminal end of a beach restoration project on Marco Island, Florida. A seawall had been constructed in 1958 to stop loss of upland, however, wave reflection off of the seawall accelerated sand loss into the adjacent inlet, Caxambas Pass. The breakwater was designed to create a beach salient at the south end of the beach nourishment project where sand was being lost into the inlet.

Because of tidal currents associated with the inlet, two short conventional groins were constructed to stabilize the salient configuration alongside a marginal flood channel. Preconstruction and postconstruction conditions are shown in Figure 1.

The breakwater was designed using empirical relationships derived from shoreline responses to other breakwater installations. Three years of monitoring have shown that a stable shoreline salient has been established. Monitoring has shown that sand loss from the adjacent nourished beach has been reduced by approximately 90 percent.

In the second case presented, , shoreline erosion rates of between 30 and 70 feet per year had been documented between 1982 to 1997 on the south end of North Captiva Island, Florida. This project area is also adjacent to an inlet, and the erosion is to some extent attributed to the removal of a substantial amount

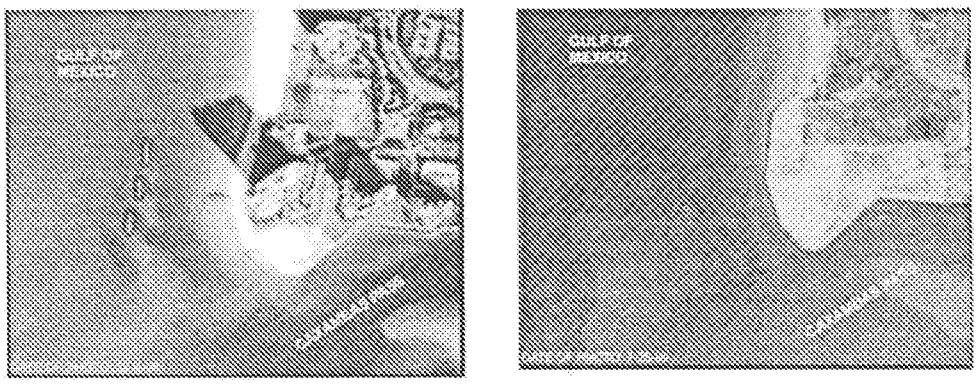

Figure 1. Marco Island Segmented Breakwater

of sand from the ebb tidal shoal for nourishment of the beach on the opposite side of the inlet.

Empirical breakwater design criteria were again applied, in this case to the design of the shore parallel segments of a system of T-groins. The design procedure was similar to that which was used for the segmented breakwater design, however, in this case the shore parallel sections are very close to shore with the expectation that a low tide tombolo would form. The shore parallel segments are attached to low profile shore perpendicular groins which serve to control longshore currents, while a tombolo forms, as well as during storm conditions. The profile of the shore perpendicular trunk section is sloped to conform to the grade of a natural beach slope, with a low weir section at the point of attachment to the T-head. The sloping low profile and trunk section allows efficient sand bypass even during mild wave conditions.

The design is unique in that the structures were constructed with steel sheetpile so that they would be impermeable, with precisely established crest elevations to allow for sufficient wave energy transmission and sand bypass to control the dimensions and elevation of the tombolo. The shore parallel T-sections were designed with a weir in the center to allow wave energy overtopping at the point of tombolo attachment, in order to prevent permanent attachment and promote sand bypass once the tombolo reached design proportions. The ability to bypass sand prevents the structures from filling beyond capacity on the updrift side. Overfilling beyond design capacity could result in sand spilling over or around the structure and potentially being lost into deeper water.

Two years of post construction monitoring have shown previous erosion rates of as high as 80 feet per year have been arrested. Pocket beaches have been established between the structures, and there are no downdrift impacts, indicating that the structures have reached an equilibrium condition and are efficiently bypassing sand.

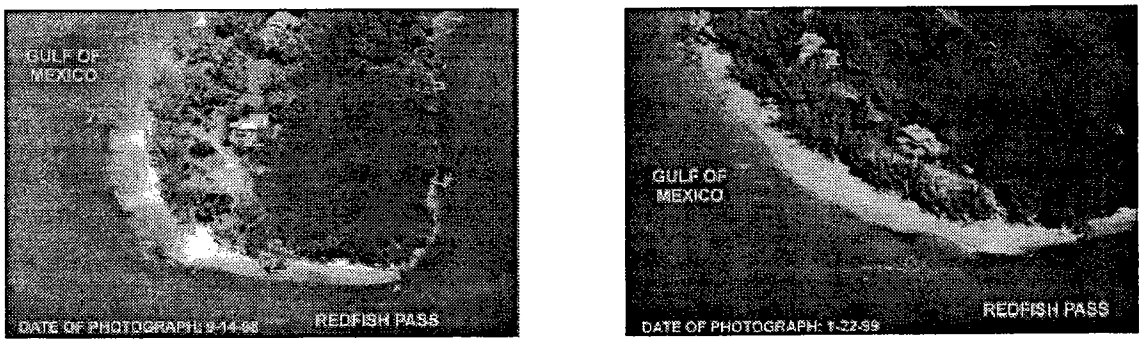

Figure 2. North Captiva Island T-groin Project, One month and Six Month Post Construction Conditions

CHANGING PERCEPTIONS OF THE COAST AND THE CALIFORNIA EXPERIENCE

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ABSTRACT

The coast is one of the original multi-use areas. The natural environment of the coast includes the ocean, beaches, bluffs, marine terraces, and dunes, estuaries, lagoons, rivers, and wetlands. These lands and waters have been used for fishing, shipping and commerce, aquaculture, farming, homes, businesses and recreation. Our coasts were usually some of the first areas to be developed and now support many of our major cities and commercial centers. This aspect of the coast was as true 50 or 100years as it is today; however, our demands on coastal lands and our perceptions of the coast are very different than they were 50 or 100 years ago.

WATER QUALITY

Fifty to one hundred years ago it was common practice for ships to dump all their trash into the ocean; we loaded garbage onto barges and disposed of it in the ocean, and we channeled our sewage and other liquid wastes into the ocean. The ocean was a convenient and inexpensive alternative to landfills or water treatment plants. About 30 years ago, the public started to recognize that while the oceans are vast, they are not infinite. And some of the things we had put into the ocean began coming back. For example, heavy metals in the garbage and effluent began to recycle through the food chain and swordfish began showing up with high concentrations of mercury. About 10 or 15 years ago plastics had become a large component of our trash and they too became marine problems. Plastics were washing up onto the coasts and were being found in the stomachs of marine mammals that possibly mistook it for food and ingested it. Five or ten years ago, we began to realize that the salt water in the oceans was not treating or killing all the pathogens in the effluent and water-borne bacteria and viruses on ocean water, were causing health problems. This has affected the perception of risk. Fifty to one hundred years ago, water quality was only an issue for freshwater and drinking sources. Now there is awareness that water quality is also an issue for ocean water concern and marine water quality problems include concerns about heavy metals, marine debris, contaminants and pathogens.

COASTAL WETLANDS

Fifty to one hundred years ago, coastal wetlands were called bogs and swamps. They were valued for what they could become – filled to create fastlands or dredged to create ports, harbors or marinas. The government has stopped paying property owners to drain wetlands, but the perception remained that wetlands had little, if any, value as wetlands. Over the past 20 to 25 years wetlands have been recognized as being ecologically valuable; unfortunately approximately 90% of the historic wetlands in California had already been filled or degraded. Thus, today wetlands are being restored or created to provide flood protection, to dampen storm energy, to treat polluted water, and to provide nesting and feeding habitat. Fifty to one hundred years ago, wetlands were essentially wastelands; today they are valued for their ecological richness. Remaining wetlands are being protected and complex projects are being undertaken to restore or create more wetland area.

COASTAL RIVERS

California has a Mediterranean climate. Rainfall is very seasonal and there is a large interannual variability in rainfall amounts. As California was being developed, many rivers were altered to provide flood control and/or water storage. Dams block sediments and keep them from reaching the coast; flood control efforts cut peak flow events and reduced sediment carrying capacity. Some of the reservoirs for these dams are filled with sediment and no longer serve any useful function. Others have greatly reduced storage capacity. Fifty or one hundred years ago, coastal rivers were perceived as being water supplies or

flood hazards and the focus was on the construction of dams and channeling of streambeds. More recently, the ecological value of rivers has been recognized. In the next 5 to 10 years, most coastal river projects will be focused on environmentally sound removal of structures or rehabilitation of the reservoirs to maintain effective storage and flood control.

COASTAL LAND USE – RESIDENTIAL

Fifty to one hundred years ago homes on the beach were small bungalows, vacation homes and rental properties. Over time, these homes have become full-time residences and property values have increased exponentially. Small bungalows have been razed to build large homes, and large homes had been razed to build large mansions. Recently a developer in southern California marketed "Mansions off the Rack" – 68 fully decorated and furnished million dollar homes with ocean views. Another trend is to purchase several small lots, tear down the houses, combine the lots and build 10,000 to 15,000 square foot homes. These all effect the coast differently. And planning efforts often are not flexible enough to address these changes.

Bungalows on the coast were small, often low-density development. They were used during weekends and summers and usually relied on septic tanks and leach lines to treat waste water. As bungalows were replaced by permanent homes, and as coastal property values increased, the density of development increased, but often the waste treatment systems remained the same. The increase in both permanent use and development density caused an increase on effluent and potential for ocean discharges. Over the past 50 to 100 years, the increases in both property value and homing costs increased the economic threat from storms and the financial incentive to protect vulnerable beachfront land. Storm protection shifted from shutters and sandbags to seawalls and revetments.

PORTS AND HARBORS

Ports have been important commercial hubs for millennia. In recent years, ports have become more specialized. Large, modern ships carry enormous amounts of cargo, but require deep draft channels to navigate. Modern shipping will concentrate in the ports that can handle these ships safely and quickly. Smaller ports will be used for fishing fleets or recreational boating. Another trend is to put housing adjacent to small boat harbors. However, people usually find commercial fishing and the ancillary facilities to be noisy and smelly so these residential marina facilities are usually only for small-craft and recreational boats.

COASTAL RECREATION

Recreation in general and coastal recreation in particular has changed dramatically over the past 50 or 100 years. Leisurely walks on the beach have become daily runs; casual games of beach volleyball have become professional sporting events. Recreation and tourism are now major economic factors. In California, coastal recreation and tourism was valued at $9.9 billion on 1992[1] and has increased since then. By 1995, the state's beaches contributed over $27 billion to the state's economy, through direct spending and multiplier effects[2]. This valuation has brought with it a more defined idea of the "coastal recreational experience" and people are more critical about what they expect from a beach than they were 50 or 100 years ago.

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[1] California Research Bureau, California State Library (1992) "Economic Assessment of Ocean-Dependent Activities," 57 pages.

[2] King, Philip, and Michael Potepan (May 1997) "The Economic Value of California's Beaches" Public Research Institute, San Francisco State University, 40 pages.

KAANAPALI REVISITED

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ABSTRACT

The beach and nearshore waters at Kaanapali, Maui, were surveyed and studied in 1963 and again in 1978 using the most modern procedures then available. The study included bathymetric surveys by fathometer and sextant, SCUBA bottom surveys and sampling, and consideration of historical photographs of the beach and coast, wave climate, and the budget of sediment including sources, transport paths, and sinks. The studies were made for American Factors, Limited (later Amfac Communities-Maui) with the primary objective of providing recreational/resort facilities that would have the minimum environmental impact.

It was found that both terrigenous (Hahakea Stream) and biogenous (Hanakaoo Point coral reefs) were important sources of beach sand. In the coral reef system, the circulation of water and sediment is onshore over the reef and through the surge channels, along the beach towards the awas (return channels), and offshore through the awas. The studies cautioned against any alteration of the reef and its circulation pattern of water and sand.

Comparison of the procedures and findings from these earlier surveys with the more sophisticated technologies available now (GPS positioning, computer simulation modeling, and extensive electronic databases) indicate that basic understanding of the natural processes remains the fundamental element in conducting coastal studies. Since most of the fundamental processes were known in 1978, more rapid and higher resolution surveys can save time, but do not alter basic findings. However, today's advances in beach profile mechanics would improve detailed recommendations of beach form and change, while recent confirmation of the decadal patterns in climate change provides significant improvement in estimates of future storm damage and beach stability.

Hawaii is subject to climate cycles of about 30 year duration associated with the Pacific Decadal Oscillation (PDO). The PDO is a sea surface temperature pattern associated with the persistence of La Niña vs El Niño phases of ENSO cycles (Walker, 1928; Goddard and Graham, 1997; Mantura, et al., 1997). The El Niño phase of the ENSO cycle is characterized by a weakening of the prevailing NE trade winds with a decrease in their northerly component in the latitude of the Hawaiian Islands. A generally La Niña dominant period with strong trade winds extended from the 1940's to the 1970's, followed by an El Niño dominated period with weaker trades and episodic Kona storms and the occurrence of hurricane Iniki. There is evidence that 1998 may have been the end of the El Niño-dominated period with a return to the climate that prevailed earlier.

Rainfall in the Hawaiian Islands is strongly influenced by the orographic effects which the island topography has on the flow of moisture laden air. Higher rainfall is associated with orographic uplift and rainfall (upslope convection) on the windward sides of the islands with plunging flow (adiabatic warming) and generally drier weather on the leeward slopes. Changes in trade wind direction result in orographic turning of the flow around the islands thereby shifting the regions of converging flow (uplift with precipitation) and diverging flow (subsidence with drying).

The persistent changes in strength and direction of trade winds during the PDO result in recognizable wet and dry climate periods, particularly on the windward side where these orographic effects are strongest. The signature of climate in rainfall data (Figure 1a) becomes more apparent when these data are expressed in terms of the cumulative residuals, Q_n, taken as the continued cumulative sum of departures of annual values of a time series, Q_i, from their long-term mean values $\overline{Q}$, such that $\sum_0^n (Q_i - \overline{Q})$. Figure 1b gives the cumulative residual of annual rainfall totals for windward rain gage stations on Kauai and Hawaii. Both records show that the La Niña dominated periods of the PDO, (1940-

70), correspond to periods of above average rainfall (positive cumulative departure from the mean). As orographic effects weaken during El Niño dominated climate, (1970-98), both windward rain gages record persistent below average rainfall (declining cumulative departures from the mean). At leeward gage stations (Figure 2) the long term cumulative residual of rainfall exhibits a weak inverse relation to the dry/ wet cycles of the windward stations. This is due to strong leeward adiabatic warming (drying) during La Niña dominated climate, and episodic Kona storms and tropical cyclones during El Niño dominated climate. Kona storms and tropical cyclones cause leeward sides to experience brief but intense upslope convection, resulting in large positive departures from mean rainfall during the El Niño dominated period of PDO.

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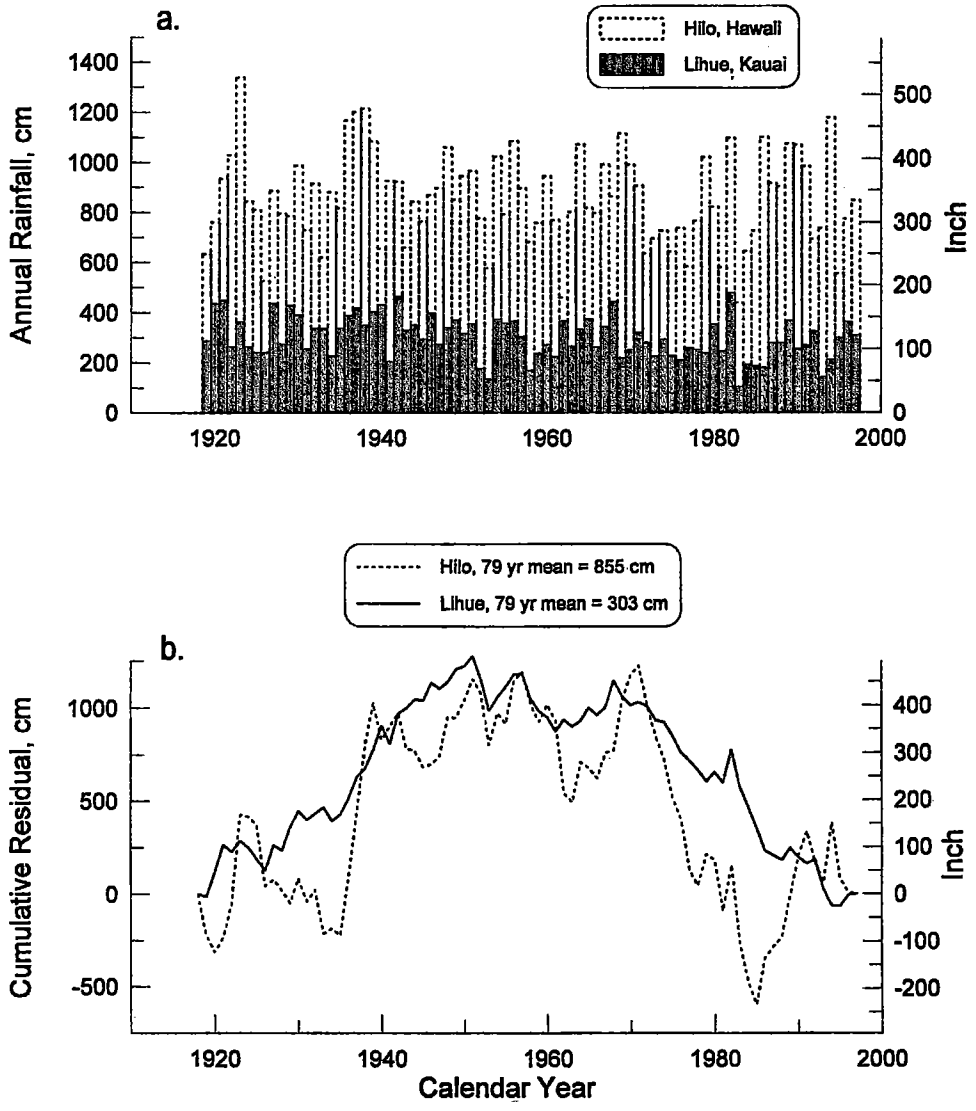

Figure 1. Windward rainfall records, Kauai and Hawaii. a. Annual rainfall. b. Cumulative residual (NOAA, 2000)

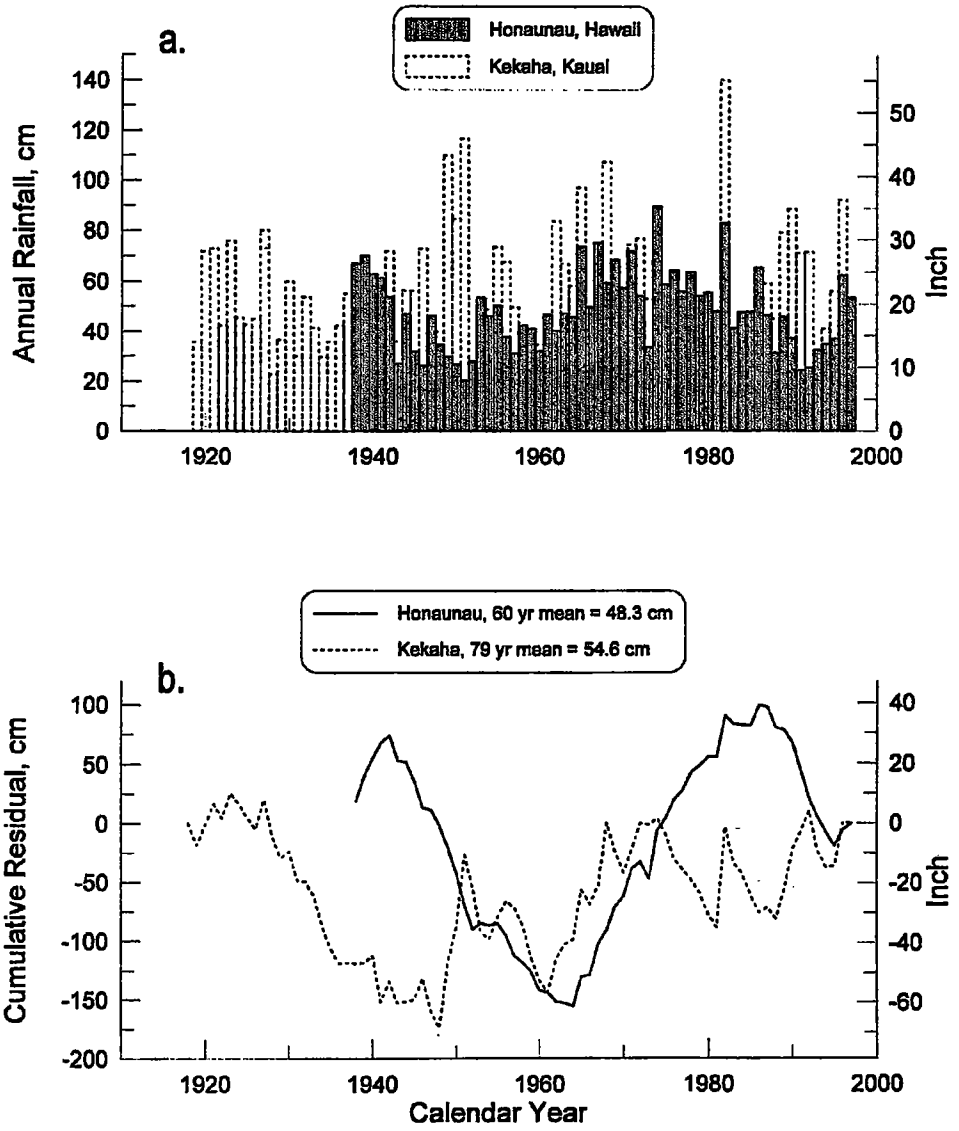

Figure 2. Leeward rainfall records, Kauai and Hawaii. a. Annual rainfall. b. Cumulative residual. (NOAA, 2000)

NATIONAL ASSESSMENT OF COASTAL CHANGE HAZARDS

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ABSTRACT

Most of the US coast is undergoing long-term (10^2 years) erosion due to a number of potential factors. These include gradients in longshore transport that are both natural and man-induced, deficit in sand supply to the coast caused by fluvial dams and by trapping of sand in estuaries, and the inundation and dynamic effects caused by sea-level rise. Erosional magnitudes vary widely around the country. For example, on the Gulf of Mexico coast in central Louisiana, barrier island shorelines are eroding over 20 m/year whereas the barrier island shoreline at Duck on the Outer Banks of NC has been essentially stable in historic times. Spatial variability is also important in that 16 km south of Duck at Kitty Hawk, the barrier is eroding nearly 3 m/yr. Such spatial variability on a 'relatively' uniform barrier island may be controlled by the underlying and inner-shelf geology.

Superimposed on these long-term trends are fluctuations in shoreline position at various shorter time scales. Storms can cause more than 50 m of shoreline retreat in hours, yet the beach may completely recover in a few weeks to a few months. Some beaches exhibit a distinct annual signal mostly due to the seasonal nature of storm activity. On the west coast, severe El Nino's and their associated storms occur on decadal scales and may induce decadal signals in coastal change records.

A major objective of the National Assessment of Coastal Change Hazards is understanding the magnitudes and processes of different time scales of change. How important is sea-level rise to coastal change over decadal time scales? What causes the spatial variability of impacts during extreme storms? How can we effectively and confidently discriminate long-term trends from short-term variance? Such improvements in understanding are enabled by the application of airborne scanning lidar[1], a relatively new technology used to survey and monitor beach changes.

AIRBORNE SCANNING LIDAR

The USGS, with our partners in NASA and NOAA, has been surveying coastal areas of the continental United States using NASA's Airborne Topographic Mapper (ATM). Such scanning lidars are revolutionizing our ability to assess coastal change hazards. These systems acquire spatially dense data consisting of estimates of elevation every few m^2 within a surveyed swath hundreds of meters wide. Systems with long baseline capability, such as the ATM, can survey hundreds of kilometers of coast in a few hours with a single GPS ground-based station. Acquiring such data with traditional means, such as ground-based range finders or traditional photogrammetry, would be prohibitively time consuming and expensive. Spatially dense data over regional scales are invaluable in determining patterns and magnitudes of beach erosion and accretion and understanding large-scale coastal behavior.

At present, approximately 70% of the oceanic coasts of the continental U.S. have been surveyed by the joint USGS-NASA-NOAA effort (Fig. 1). In an additional partnership, the Texas Bureau of Economic Geology has recently surveyed the Gulf coast of Texas.

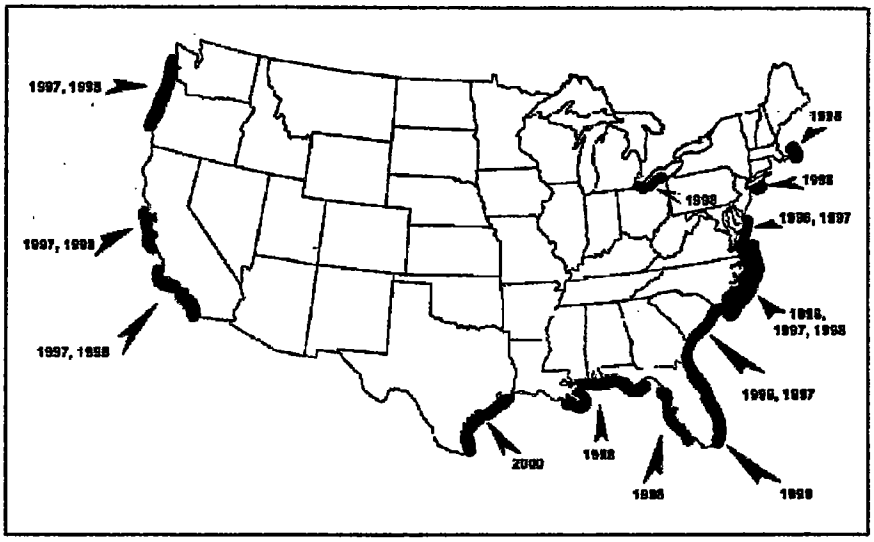

Figure 1. National topographic lidar coverage acquired as part of the USGS-NASA-NOAA cooperative effort and year of survey. The Texas coast was surveyed by the Texas Bureau of Economic Geology using an Optech system. The remaining coverage was acquired using NASA's ATM.

LONG-TERM COASTAL CHANGE HAZARDS

Long-term coastal change assessments are commonly based on visual interpretations of the wet-dry line or some other feature on aerial mapping photography that can be compared to similar data acquired at different times. (See a recent discussion of various methodologies in Crowell & Leatherman, 1999.) As a first step in assessing long-term change, we have developed a new technique for shoreline determination based on statistical fits of datums (such as mean high water) to shore-normal profiles constructed from lidar data. Using this technique, shoreline positions can be objectively calculated and compared to other lidar surveys from different times. Error bars are calculated so that tests can be performed on whether detected changes are statistically significant.

Lidar-based shorelines are being compared to the historical record to up-date assessments of coastal change. Using topographic lidar in the future, the Nation's coasts can be periodically resurveyed to provide consistent and objective monitoring of coastal change. These data sets will be used in testing hypotheses on the processes responsible for observed changes.

EXTREME STORM COASTAL CHANGE HAZARDS

The lidar surveys from around the country also serve as pre-storm baseline surveys to determine the impact of coastal storms. After major storms, the USGS-NASA-NOAA team resurveys impacted areas to detect changes. For example, for Hurricane Dennis which impacted the northern Outer Banks of NC in 1999, pre- and post- storm surveys detected extensive changes to protective foredune ridges that eroded as much as 30 m landward. Interestingly, the response was highly variable. Stable areas occurred within a few kilometers of severely eroding areas. These patterns appear to reflect the spatial distribution of large shoals immediately offshore that refract the incident wave field.

A major objective of the Extreme Storms task is to determine the vulnerability of the Nation's coasts to storm hazards. As a first step, we have calculated, for a demonstration area, the probabilities of wave runup exceeding certain geomorphic-elevation thresholds, such as the base and crest of the foredune ridge. These kinds of thresholds are the basis for a new scale that categorizes impacts to natural barrier islands resulting from tropical and extra-tropical storms (Sallenger, 2000). As critical thresholds are exceeded, processes and magnitudes of impact change dramatically. On regional scales, the lidar data provide unprecedented potential to accurately determine the spatial variability of critical elevation thresholds that can be directly compared to forcing processes such as the extreme elevations of storm wave runup.

FUTURE DIRECTIONS

The USGS National Assessment is evolving and developing additional tasks. For example, the national lidar coverage offers a unique opportunity to provide coastal change and topographic information for managing the National Park Service's National Seashores. Erosion of coastal cliffs that are ubiquitous to the West coast, Great Lakes and Northeastern US involves different processes than the erosion of sandy beaches and offers unique challenges in developing understanding. Assessing sea-level rise hazards over the next few decades to 100 years is a critical although difficult problem that will also be addressed.

INITIAL PRINCIPAL INVESTIGATORS

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Sallenger, A. H., (2000), Storm impact scale for barrier islands: Journal of Coastal Research, 12 pages, 4 figures, 2 tables.

THE LONG-TERM INCREASE IN WAVE ENERGY ALONG THE U.S. WEST COAST AND THE GROWING THREAT OF PROPERTY EROSION

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ABSTRACT

Based on wave dated collected up through 1996 by buoys offshore from the Pacific Northwest (PNW), Washington and Oregon, we had projected that the 100-year deep-water significant wave height would be approximately 10 meters. That height was reached or exceeded by one storm during the 1997-98 El Niño, and by four storms in the 1998-99 La Niña, including a storm on 2-4 March 1999 that generated a significant wave height of 14 meters. As a result, we have had to re-evaluate the 100-year projection, which is now estimated to be 16 meters.

Considerable erosion occurred along the PNW coast during both winters, part of which can be directly attributed to processes related to an El Niño, but the aspects of a La Niña important to coastal erosion are largely unknown. One difference is that during an El Niño the storms following more southerly paths than normal, mainly crossing the coast of south-central California, whereas during "normal" years or in a La Niña, the storm tacks pass more directly over the PNW. As a result of this difference, during an El Niño storm-wave energies will generally increase in California, while being reduced in the PNW, with a reversal during a La Niña. This pattern was not entirely followed during the recent events; as noted above, one major storm struck the PNW during the 1997-98 El Niño, and unusually high wave conditions were experienced along the entire West Coast during the 1998-99 La Niña.

With this seeming change in the West Coast wave climate, producing higher wave conditions, we decided to undertake a re-analysis of the ocean buoy wave data. Deep-water measurements of daily wave conditions spanning 20 to 30 years are now available from buoys of the National Data Buoy Center (NDBC) of NOAA. We selected six buoys for analysis, extending from the Gulf of Alaska in the north to Point Arguello in south-central California, chosen because they provide the longest records. The analyses show the expected latitude variations and seasonality of wave conditions, with the largest waves occurring in the Gulf of Alaska and offshore from the PNW where significant wave heights reach 14 to 15 meters.

Of special interest is the discovery of progressive increases in deep-water wave heights and periods. The results for the NDBC buoy off the Washington coast are shown in Figure 1, a graph of annual averages

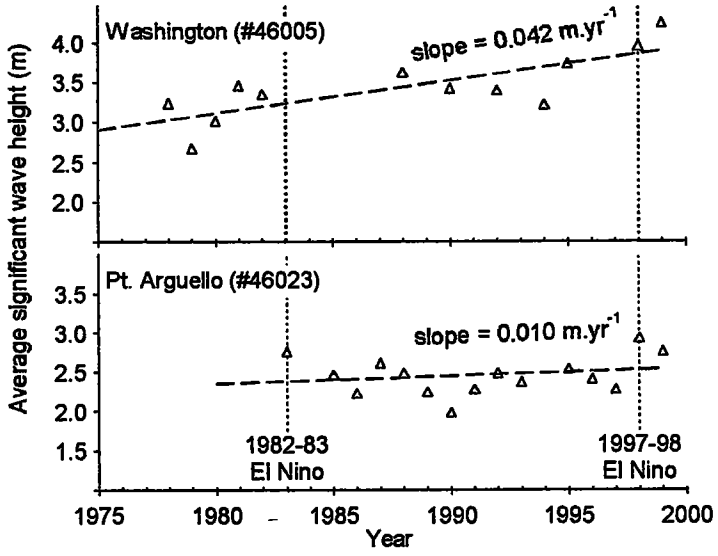

Figure 1. Annual averages of waves measured by the Washington and Point Arguello buoys during the winter months.

of waves measured during the winter months, October through March. A clear trend of increasing wave heights is apparent, increasing at a rate of 0.042 meters per year, representing a 1-m increase in average wave heights during the 25-year record of measurements. If the largest storm waves of the year are analyzed rather than an average, an increase of 2.5 meters is found.

This increase in wave heights varies with latitude, being greatest off the coast of Washington, while the increase is smaller off the coasts of Oregon and northern California, and is negligible in central and southern California, apparent in the results for the Point Arguello buoy also graphed in Figure 1. At Point Arguello, the graph shows unusually high waves during the 1982-83 and 1997-98 El Niños, demonstrating the importance of that climate event to wave conditions along the coast of southern California.

Attempts to relate the changing wave conditions to large-scale climate controls such as the East Pacific (EP) Teleconnection Index, a measure of the pressure difference between the Aleutian Low and Hawaiian High atmospheric centers, have yielded mixed results. While not providing an explanation for the long-term trends of increasing wave conditions, the EP is found to be related to annual variations in wave heights above and below the long-term trends, and to latitude differences in the numbers of storms experienced each winter. Also found to be important to wave conditions during any particular year and at a certain latitude is the range of climate events between El Niños and La Niñas as measured by the Multivariate ENSO Index (MEI). A stepwise multiple linear regression analysis has established a systematic latitude dependence of wave heights on the EP and MEI, with EP being most important to wave conditions in the PNW and in northern California, while MEI and the occurrences of El Niños are more important in central to southern California.

With wave records limited to 20 to 25 years, it is difficult to fully establish the climate controls on the wave conditions in the eastern North Pacific, and to answer important questions such as whether the long-term trend of increasing wave heights is a response to natural climate cycles or is due to global warming. Without a better understanding of the climate controls, we cannot confidently project whether the increases in wave heights measured during the past 25 years will continue during the next 25 to 100 years.

THE RELATIONSHIP BETWEEN SHORELINE EROSION AND FLOOD CONTROL IN KIHEI, MAUI, HAWAII

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ABSTRACT

Sand beaches are a valuable resource for both public recreation and natural shoreline protection. They are particularly valuable in Kihei, located on the Hawaiian Island of Maui, and one of the premier destination resorts for tourists from around the world. In addition, Kihei is relatively low-lying, placing greater importance on the beach to provide a natural buffer between the ocean and public and private property. Unfortunately, portions of the Kihei shoreline suffer from chronic erosion as the result of limited sand supply. Both natural processes and the intervention of man can be contributors to this problem.

This paper describes a study that evaluated the potential impact of County of Maui flood control practice on sand loss. Concern had been raised that methods to drain streams through an existing coastal dune system may have be causing sand loss from the littoral system. The purpose of the study was to review County flood control practices, make a determination of the potential detrimental impacts on the shoreline sand supply, and provide recommendations to reduce or eliminate those impacts. Other impacts to the shoreline in addition to those related to flood control were also considered.

KIHEI SHORELINE PROCESSES

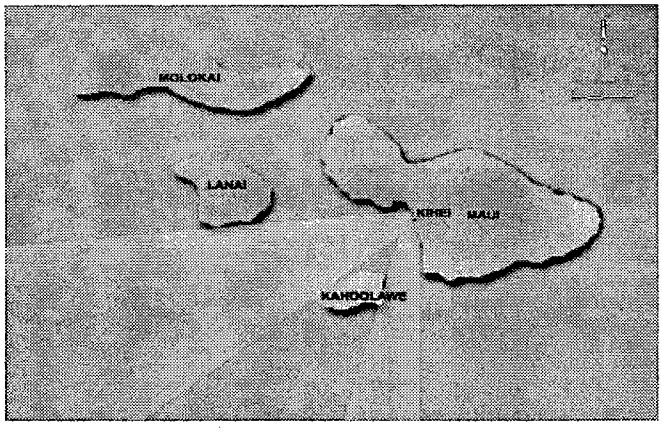

Figure 1. Kihei Wave Exposure

Kihei is exposed to wave action primarily from the south as illustrated in Figure 1. The net longshore sand transport direction due to waves is from south to north. Conversely, the frequent and energetic trade winds that blow from the northwest in Kihei transport a significant amount of sand across the top of the dry beach face back to the south.

The Kihei shoreline is afforded some coastal protection from the fringing reef that acts like a submerged breakwater. Fringing reefs can reduce the along-shore transport of sand by reducing wave energy on the sandy beach via breaking the larger waves. Reefs can also tend to refract the wave to a more straight onshore direction, thereby reducing the angle the waves break on the sandy beach which reduces the along-shore sand transport. Another important role they play is the actual production of beach sand. Unfortunately, destruction of coral reef over the last 50 years has contributed to increased sediment transport and reduction of sand production.

Coastal dunes play an important role in areas where they are intact, acting as reservoirs of sand to nourish the beach if needed, and providing protection against inundation from high tides and storm waves. Coastal dunes in Kihei also help keep sand on the beach by creating an obstacle to landward movement of windblown sand.

FLOOD CONTROL PRACTICE

Given the general understanding of the shoreline process, the next step was to investigate County of Maui flood control measures to ascertain potential impacts to the shoreline. Kihei is located along the coast at the base of the western slope of Haleakala, a large volcanic crater. Although the region is arid, infrequent but intense storms flood this low lying area. There are eight gulches originating on the mauka

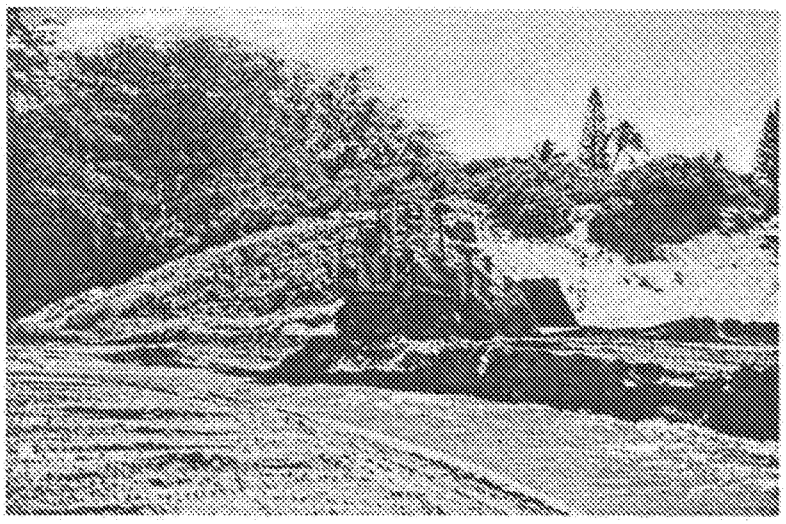

Figure 2. Typical Stream Drainage Operation (Viewing Inland)

(hillside) side of the City. Each gulch further divides into multiple forks that eventually discharge into the Pacific Ocean. These forks are often blocked at their mouths by deposition of sediment transported by the creeks and formation of bars by ocean waves and winds. Prior to the development of Kihei into a major residential area and tourist destination, drainage would accumulate at stream mouths until the water level was sufficiently high to breach the coastal dunes and drain naturally. With subsequent development, the backwater caused by these sand dunes during floods causes flooding in the low lying areas of the City. In addition, there has been a significant growth of algae at some of the fork mouths due to the nutrients brought in by these drainage ways. The County periodically drains the streams by using earth-moving equipment to breach the dune in order to allow runoff to flow freely and also to remove the algae. Figures 2 shows this process at one of the major drainages. Note the large volume of sand accumulation on the downwind side of the stream. This material is no longer available to littoral transport.

The frequency of dune breaching to drain the wetlands varies depending upon the amount of runoff to be drained as well as how quickly the breach plugs back up with littoral sediment. Littoral sediments that fill these dune gaps include both sand and coral rubble. Not until recently has there been a concerted effort to place the sand back into the littoral system. The coral rubble has historically been removed from the site and used by the County as road base material. Coral rubble stockpiles currently exist at some of the drainage sites.

ANALYSIS OF SHORELINE IMPACTS

Prior to the impacts of man, the Kihei shoreline was probably in a state of dynamic stability. That is, in the long run, there were no areas of significant erosion or accretion. This is at least partially borne out by the historic fishponds that remain in near proximity to the existing shoreline. However, there were likely episodes of regional erosion and accretion due to a short term imbalance of northward, wave-driven sand transport and southward, wind-driven sand transport, as well as periods of active storm events that can pull sand offshore and occasionally out of the littoral system.

Urbanization of Kihei upset this balance in a number of ways. Development in the low coastal area necessitated flood control via mechanical breaching of the coastal dune system. In addition, the simple act of the ever-increasing public accessing the beach across the dune system also caused damage by destroying the stabilizing dune vegetation. There was also the direct destruction of coastal dunes via coastal development. All of these actions of man caused loss of littoral sand inland via deflation, i.e. loss of beach sand due to wind.

The shoreline history and processes in Kihei are fairly complex. As a result, it is difficult to isolate the shoreline impacts associated with a specific action, in this case being the destruction of coastal dunes and associated sand loss out of the littoral system via wind transport inland. What we can do is use analytical methods to predict wind-blown sand transport and correlate estimates of annual volume loss with potential shoreline change using existing relationships between shoreline movement and associated change in beach volume. The intent is not to provide a detailed estimate of wind blown sand losses, but rather to get a feel for whether such losses are significant, such that decisions can be made regarding the

importance of remedial action.

Using standard methods described in the *Coastal Engineering Manual* (1998), sand loss due to wind blowing sand through dune gaps along the 4-mile Kihei shoreline is on the order of one foot per year, which is significant. In other words, the shoreline erodes on the average of one foot per year due to the practice of dune breaching. This analysis does not account for losses in other portions of the dune system resulting from public access.

The impact of these wind losses can be visualized as follows. During the winter, southern hemisphere swell and storm waves push sand northward. The trade winds, which typically predominate in summer, attempt to push the sand back to the south. However, the dune gaps present a partial to complete sink for this wind blown sand as illustrated in Figure 2. The net effect is a "one-way valve" in which sand is freely transported to the north, but cannot be effectively return back to the southern beaches. The beach sand volume is therefore being "ratcheted" to the north. The study also addresses other indirect impacts associated with dune destruction including the mining of coral rubble.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were provided in the study:

1. Educate flood control personnel and the public about coastal processes and the importance of the coastal dune system.

2. Keep the excavated littoral sediment from the stream mouths within the active littoral zone.

3. Use sand fencing in the vicinity of the dune breaches to reduce sand losses inland. The fencing could be placed on the upwind side of the breach, with sufficient area in the lee to collect a reasonable size stockpile of sand, while providing unimpeded lateral public access. Periodic sand management will be required through the use of earth moving equipment to scrape these temporary holding dunes and place the sand on the downdrift beach. Some field trials would be required to develop an effective system.

4. Restore and/or enhance the coastal dune system in order to "plug the sink," i.e. reduce or eliminate inland sand losses. Coastal dune enhancement will provide the added benefit of reduced wind blown sand on Kihei Road which is a public safety issue. Vegetation is the most effective method of stabilizing coastal dunes, especially in holding wind blown sand. In many cases, it is also the least expensive, most durable, most aesthetically pleasing, and only self-repairing technique available.

5. Construct dune walkover structures to protect the dune topography and dune vegetation from pedestrian traffic and allow for the natural reconstruction and re-vegetation of damaged or eroded dunes.

6. Incorporate sand management to fill erosional areas from areas of sand accretion.

7. Long term measures to be considered include improvements to the flood control system such as re-routing some or all of the flood flows to wetland areas for retention, ocean outfalls, use of public lands to defer, retain or detain stormwater, and others.

REFERENCES

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Shore Protection Manual (1984), U.S. Army Corps of Engineers, Coastal Engineering Research Center.

SEDIMENTATION PATTERNS ON THE FRINGING REEF OFF SOUTH MOLOKA'I, HAWAI'I

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ABSTRACT

THE PROBLEM

Terrigenous sediment run-off and deposition on coral reefs is recognized to potentially have significant impact on coral health in Hawai'i and other high islands in the tropical Pacific and Caribbean. Particulate matter can impact the health of corals by blocking light and thereby reducing productivity; mantling substrate and thus limiting recruitment sites; or by accumulating fast enough to bury and kill entire colonies. To evaluate and better understand the effects of increased terrestrial sediment run-off and the role of seasonal and event wave stresses on deposition, resuspension, and transportation of silt onto areas of live coral, we have initiated a study on the fringing reef on the south coast of Moloka'i, Hawai'i. This study is part of the U.S. Geological Survey's multi-disciplinary Coral Reef Project that addresses the health and geologic variability of coral reef systems. In support of the study, we are also mapping coral distribution and richness, and monitoring stations have been established by colleagues at University of Hawai'i Institute of Marine Biology (P. Jokiel) for determining changes to sections of the reef.

STUDIES UNDERWAY ON MOLOKA'I

The south coast of Moloka'i contains an extensive fringing reef nearly 50 km in length; it is arguably the longest and most extensive reef tract in the Hawaiian Islands. It also harbors a richness and density of live coral that are amongst the highest in the islands; many areas of the reef contain 90 to 95% live coral. A contributing factor to the success of corals in constructing a major reef structure on south Moloka'i is its setting. The reef is protected from damaging northerly storms, from persistent northeast trade winds, and from most southerly swell events by its south-facing exposure and shielding by neighbor islands to the east (Maui) and south (Lana'i). Natural patterns of rainfall and run-off follow a tradewinds-induced gradient from >120 cm/y on easternmost slopes to <15 cm/y at the west end. Precipitation is augmented on south-facing slopes by occasional "Kona" rain events that occur on a one-to-ten-year return frequency. Human habitation of the island has resulted in significant changes in the drainage basins and to coastal areas, and these changes have in turn influenced the volume of terrigenous and carbonate sediment released to the reefs. Human activities indirectly affecting reef processes include: extensive harvesting of sandlewood from mountain slopes; large-scale agriculture (e.g. sugarcane); extensive and unrestricted grazing by both domesticated and feral animals; excavations on the reef flat for fill material; and construction of an impermeable wharf.

Our approach to understanding sedimentation and its impact on the Moloka'i coral reef system includes three primary efforts: mapping terrigenous deposits and their sedimentologic and geochemical characteristics; measuring relevant processes that inject and redistribute sediment to the reef system; and real-time monitoring of sedimentation "events" and their impact to corals.

Thus far, over 700 observations of sediment thickness have been made and 250 surface sediment samples have been collected from the fore reef, reef crest, reef flat, and adjacent watersheds. Analyses of texture and sediment type were used, in conjunction with 23 transects measuring sediment thickness on the reef flat, to understand the sources, transport pathways, and sinks for sediment in this reef system. Turbidity and currents are being recorded on the reef flat by an instrumented tripod to assess the transport levels and direction (see Ogston et. al., this vol.).

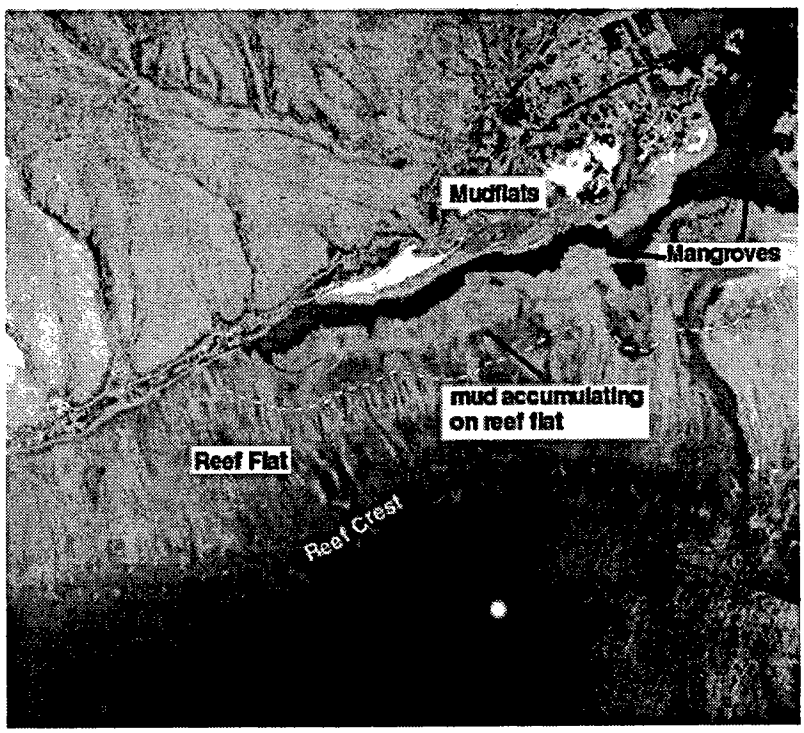

Figure 1. Aerial photograph (1993) of the central portion of the Moloka'i reef tract. The image shows changes on the reef tract due to large amounts of terrigenous sediment.

A 5-10 cm thick layer of predominantly terrestrial mud covers the majority of the innermost portion of the reef flat (see example in Fig. 1). This wedge of terrestrial mud typically pinches out within 150 m of the shoreline on an antecedent reef flat of unknown age (possibly late Holocene, but could be as old as oxygen isotope stage 5e). Micro-atolls with low percentages of live coral start to appear approximately 350 m offshore concurrent with the decrease in terrestrial material. The thickness of sediment cover becomes more variable further offshore due to variable relief on the antecedent surface. The outer portion of the reef flat is covered with a higher percentage of live coral growing along shore-normal ridges; intervening swales (or grooves) contain thick deposits of rippled sand derived largely from erosion of the antecedent reef flat. The type of terrestrial sediment varies along shore and typically decreases distally from the watershed sources. Historic fishponds act as natural groins on the inner reef, causing sediment to be trapped on the up current (east) sides and fines to dominate the areas just down current (west) of the fishponds. Overall, the mean thickness of sediment on the reef flat increases exponentially from east to west, reflecting the dominant net westward transport direction and the increase in available sediment sources (Fig. 2).

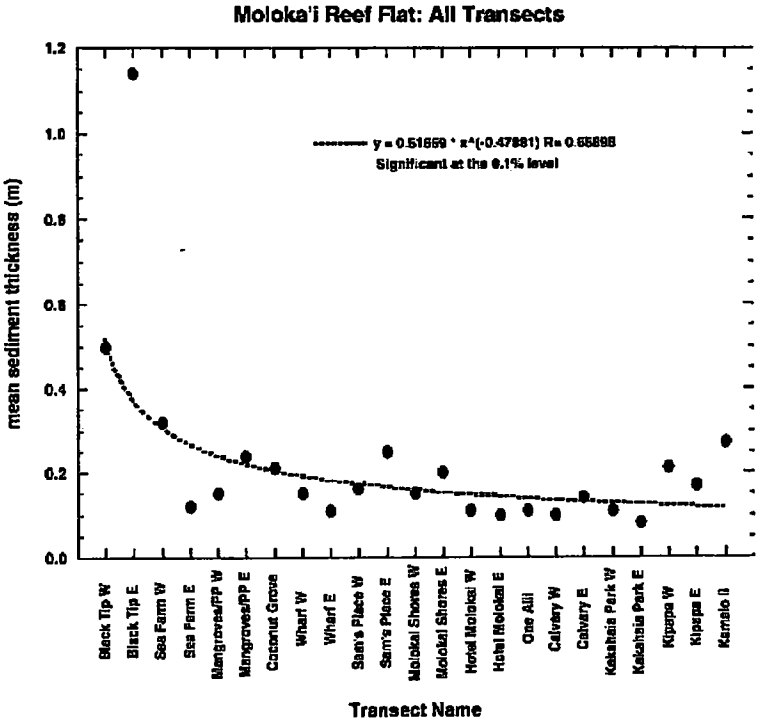

Figure 2. Plot of mean sediment thickness on the Moloka'i reef flat from west (left side) to east (distance represented is appx 25 km). Each point represents an average of dozens of measurements across *the reef flat. Note the large average amount of sediment on the three western-most transects.*

To better understand geologic and historical accumulation rates, we are examining the depth profiles of ^{210}Pb, ^{234}Th, and ^{137}Cs in sediment cores from reef areas where sediment is accumulating in relatively undisturbed areas. ^{210}Pb in short cores from isolated depressions in the reef flat ("blue holes"), suggest that these areas contain a sedimentary record for the last century; longer cores should provide pre-settlement information. Coupled with results from sediment traps now mounted at 10 m on the fore reef, we should be able to develop a more complete understanding of sedimentation on the Moloka'i reef tract.

CARBONATE SEDIMENT SUPPLY ON OCEANIC ISLANDS: A MODEL AND ITS APPLICATIONS

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ABSTRACT

A comprehensive sediment budget is a quantitative estimate of the production, storage, flux, and loss of particulates within a geographically well-defined natural system. On oceanic islands lacking a continental sand source, coastal sediments are detrital (derived from the erosion of volcanic rocks) or calcareous (the skeletal remains of reef-dwelling organisms). Sediment supply to highly-calcareous coastal settings is primarily controlled by carbonate productivity associated with coral reefs. This paper describes a comprehensive, field-based model for estimating reef productivity and calcareous sediment supply in Kailua Bay (windward Oahu, Hawaii) that can be applied to other coastal systems in Hawaii and in other oceanic island settings.

Beach and submarine sediments of Kailua are >90% biogenic carbonate produced by two means: growth and destruction of reef framework (coral and encrusting coralline algae) and 'direct' sedimentation through the biological activities of calcifying organisms (the green alga *Halimeda*, molluscs, benthic foraminifera, and the articulated coralline alga *Porolithon gardineri*). Despite modern carbonate production, biogenic sediments in Kailua are relatively old. Of 20 accelerator-radiocarbon ages, only one dates post-1950; twelve ages are 500–1000 calendar years before present (cal yr BP); five are 2000–5000 cal yr BP (Harney et al. 2000). Dominance of fossiliferous sand indicates long storage times for carbonate grains in the system and suggests that the entire period of relative sea-level inundation (~5000 years) is represented in the sediment.

To estimate biogenic sediment productivity, rates of growth and carbonate production by calcifying organisms were either directly measured using samples collected from Kailua Bay or were extracted from the literature on Hawaii's reefs (e.g. Grigg 1982, 1983, 1995, 1998; Agegian 1985). The distribution and abundance of living corals, coralline algae, and other carbonate-producing organisms were quantified by detailed substrate mapping and sampling over the fringing reef platform at depths of 0–25 m. Based on quantitative transect data and field observations, the 10-km^2 reef platform can be divided into 14 physiographic zones, each with a suite of physical and biogeological characteristics. To each zone, a series of equations is applied to determine rates of gross reef framework production, bioerosion, and direct sedimentation.

Gross framework production is the total mass of calcification accomplished by the skeletal growth of framework-building corals and coralline algae prior to any erosion or alteration. Gross production rates (GPR) of hermatypic corals in this model is broken into morphological components: encrusting corals (e.g. *Porites lobata* and *Montipora* spp.) produce carbonate at a rate of 2.8 kgm^{-2}y^{-1}, massive *Porites lobata* at 8.4 kgm^{-2}y^{-1}, stoutly-branching *Pocillopora meandrina* at 6.7 kgm^{-2}y^{-1}, and finger-branching *Porites compressa* at 10.7 kgm^{-2}y^{-1}.

Gross production (G in kgy^{-1}) by each coral growth form in each zone is calculated by multiplying its median percent cover (C) by the zone's habitat area (A_h) and by each form's gross production rate (GPR). For example, gross production by encrusting corals (G_e) is:

$$G_e = C_e \times A_h \times GPR_e \qquad \text{(Eq. 1)}$$

This calculation is performed for each coral growth form present in the zone and for encrusting coralline algae (using a GPR of 2.6 kgm^{-2}y^{-1} for *Porolithon onkodes*; Agegian 1985). These individual G values are then summed for each zone and totaled for all zones to arrive at an estimate of annual gross framework production by corals and encrusting coralline algae over the entire system (23190 ± 1391 x 10^3

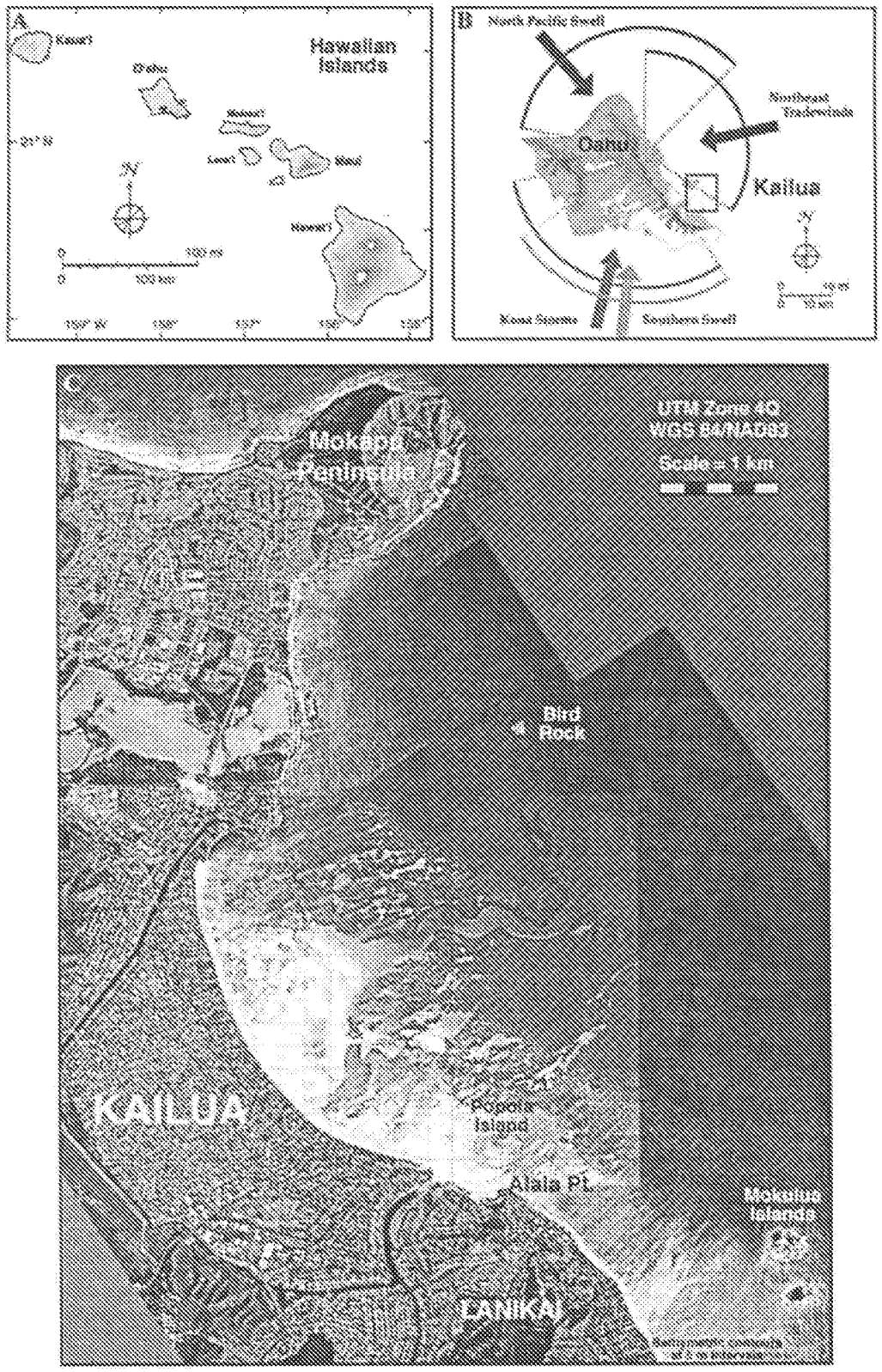

Figure 1. Location map of the Hawaiian Islands (A), the island of Oahu (B, after Moberly et al. 1965), and of the study area, Kailua Bay (C). The central, high-resolution region of image C is a mosaic of multispectral data (Isoun et al. 1999).

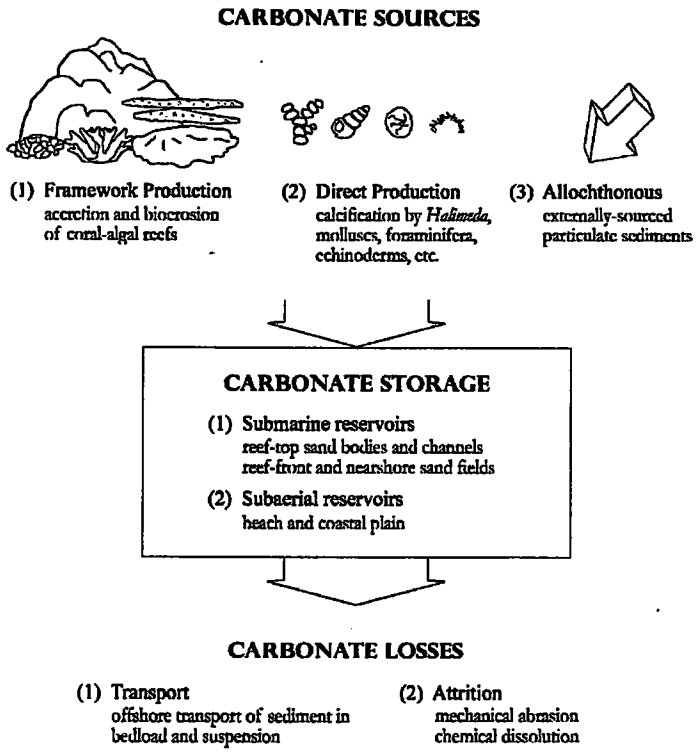

Figure 2. Conceptual model of a reef-based carbonate sediment budget.

kgy^{-1}). The reef edifice in each zone is eroded to unconsolidated sediment at rates of 0.2–0.9 $kgm^{-2}y^{-1}$ (estimated from drilled reef cores described in Grossman and Fletcher 1999), yielding 2983 ± 179 $x10^3$ kg of framework-derived sediment annually (or 2536 ± 337 m^3y^{-1}).

The average rate of gross framework production normalized over the entire study area in Kailua Bay is 2.77 $kgm^{-2}y^{-1}$, with 1.49 $kgm^{-2}y^{-1}$ contributed by corals and 1.29 $kgm^{-2}y^{-1}$ contributed by encrusting coralline algae, consistent with published observations of reefal carbonate production (e.g. Stearn and Scoffin 1977, Hubbard et al. 1990). Erosion of the reef framework occurs at an average rate of 0.36 $kgm^{-2}y^{-1}$ and results in the production of 1.29 $kgm^{-2}y^{-1}$ of sediment.

In addition to the erosion of coral and algal reef framework, unconsolidated carbonate sediments in Kailua Bay are also produced directly by the calcareous green alga *Halimeda*, molluscs, benthic foraminifera, and articulated coralline algae. Sediment production rates (SPR) for each organism are quantified using field-collected data on their 'standing crop' (in kgm^{-2}) and on the number of times per year the population experiences turnover (T in y^{-1}):

$$SPR\ (kgm^{-2}y^{-1}) = Standing\ crop\ (kgm^{-2}) \times Turnover\ rate\ (y^{-1}) \quad \text{(Eq. 2)}$$

Annual Sediment Production (ASP) is calculated by applying data on the distribution and abundance of each organism:

$$ASP\ (kgy^{-1}) = SPR\ (kgm^{-2}y^{-1}) \times Area\ (m^2) \times Percent\ cover\ (\%) \quad \text{(Eq. 3)}$$

Total direct annual sediment production in Kailua Bay is 4498.2 ± 565.0 x 10^3 kgy^{-1} (7039 ± 1172 m^3y^{-1}), 26% of which is contributed by *Halimeda* (1179 ± 140 m^3y^{-1}), 30% by molluscs (1332 ± 299 m^3y^{-1}), 8% by forams (376 ± 91 m^3y^{-1}), and 36% by articulated coralline algae (1616 ± 304 m^3y^{-1}). The average rate of direct production normalized over the entire study area is 0.54 $kgm^{-2}y^{-1}$.

The total rate of calcareous sediment production in Kailua Bay is thus the sum of framework (36%) and direct (64%) sources, amounting to 7481 ± 744 $x10^3$ kgy^{-1} (7039 ± 1172 m^3y^{-1}). Applying this rate over the 5000 years that Kailua Bay has been wholly inundated by post-glacial sea level (Fletcher and Jones 1996, Grossman and Fletcher 1998), an estimated 351.95 ± 58.62 x 10^5 m^3 of calcareous sediment has been produced in the system since the mid-Holocene.

This cumulative production volume is compared to that which is currently stored in submarine and subaerial reservoirs of the bay and coastal plain. The volume of sediment stored in the bay's various reef channels and pockets (calculated using areas and jet-probed thicknesses of submarine sediment deposits in 3–30 m water depths) is $3726 \pm 336 \times 10^3$ m^3, or 11% of that produced since 5000 yr BP. The volume of sand in the modern beach (estimated from profile data; Norcross et al. 1998) is $600 \pm 30 \times 10^3$ m^3 (2% of Holocene production). The volume of Holocene-aged sediment stored in the coastal plain is estimated, using core log data (e.g. Swain and Huxel 1971, Kraft 1984), to be $10049 \pm 1809 \times 10^3$ m^3 (29% of Holocene production). Combined, these reservoirs store $143.75 \pm 2174 \times 10^5$ m^3 of sediment, 41% (±7%) of the sediments estimated to have been produced since 5000 yr BP. By these calculations, 59% (±7%) of the sediments produced in our mid-to late- Holocene model are unaccounted for. Although transport and other means of loss are not directly assessed in this model, it is reasonable to suggest a significant portion of the 'missing' 59% of Holocene sediment production is the result of loss owing to particle transport out of the system, dissolution, and attrition.

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A CENTURY OF SHORELINE CHANGE ALONG THE KIHEI COAST OF MAUI, HAWAII

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ABSTRACT

Sandy beaches are an important economic, ecological, shore protection, and recreational resource in the Hawaiian Islands. Despite their significance, beaches on all the main Hawaiian Islands have been seriously degraded. On the island of Maui it has been estimated that one third of the original sandy beach has been lost or narrowed over the last half century. Recognizing the need for improved management of their beach and coastal resources, the Maui County Planning Department sought to identify shoreline areas that are likely to experience erosion problems over the next few decades. The project reported here grew out of that concern. We have examined patterns of shoreline change over the last century along a dynamically fluctuating segment of the Kihei coast, southwest Maui (Figure 1). The techniques and methods developed at this site are now being applied to all significant sandy shoreline areas on the island (approximately 50 km of open coast).

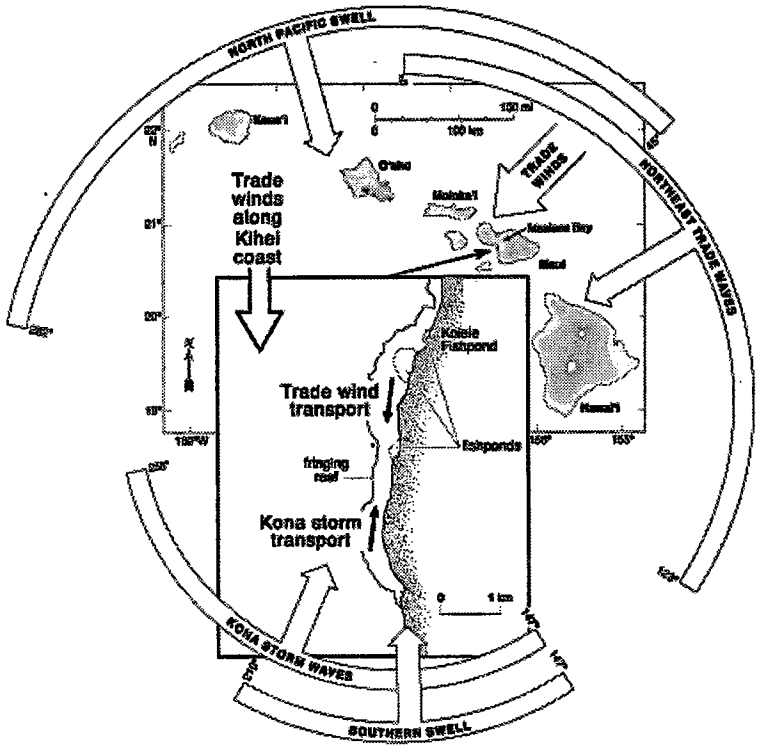

Figure 1. Halama Study Site

We quantified shoreline change by delineating the historic position of the crest of the beach step and landward boundary of the beach (vegetation line). These lines were digitized on georectified images of aerial photographs from seven different years between 1949 and 1997, and topographic survey charts from 1900 (covering the northern part of the study site) and 1912 (covering the southern part). Long-term (end-point) and annual erosion hazard rates (AEHRs) were calculated every 20 m along the coast. AEHRs were multiplied by 30. The resulting distances measured inland from the 1997 vegetation line delineate the 30 year erosion hazard line (see Rooney and Fletcher, 2000 for further details).

Our data indicate that there was severe erosion at the southern end of the site between 1912 and 1949, while a larger volume accreted at the northern end. The focus of erosion gradually migrated north and by 1997 was nearly 2 km up the coast from its original location. Meanwhile, accretion generally continued in the north. Altogether there was roughly three times more accretion than erosion along this coastal segment. Despite its erosion problems the site has apparently received and is storing a significant volume of sediment from other areas.

Delivery of sand to the beach from *in situ* sediment production on the fringing reef that fronts the site is estimated to account for about 6% of the net gain. Annual *in situ* production, approximately 530 m^3, is small relative to the volume of sediment transported along the coast. From this we infer that on time

scales of years to a century, sediment transport processes are predominate shapers of the coastline. On scales of hundreds to thousands of years however, sediment production becomes an increasingly important geologic process.

A series of major kona storms between 1960 and 1963 caused general erosion during this time, especially on portions of the study site more exposed to southwesterly waves. The kona events also induced significant south-to-north longshore transport, as evidenced by the impoundment of sediment, on the updrift side of a groin located in the middle of the study site. Concurrent erosion occurred on the downdrift side, in the area immediately north of the groin. The shore-normal walls of Koieie Fishpond, located at the northern terminus of the study site show a similar pattern during the 1960-1963 period, with the southern side accreting about 15 m while the north side eroded about 12 m. In 1900 however, the situation was reversed, with the shoreline north of the fishpond extending about 90 m further seaward than the shoreline to the south. This suggests that the dominant longshore transport that shaped that part of the coast prior to 1900 was southerly. By 1997 the offset had been reduced to less than 15 m, while 200 m south of the fishpond the coastline had prograded 100 m seaward. The bulk of the accretion on the south side of the fishpond occurred between 1900 and 1949. The relative positions of the 1900, 1912, and 1949 shorelines, over the 120 m of shoreline where they overlap, suggest that more than half the change between 1900 and 1949 may have occurred by 1912. Koieie Fishpond, although originally constructed centuries earlier, was last rebuilt in the 1700s[5]. The walls of this structure are still basically on the shoreline, suggesting that the area has not experienced significant net recession or progradation over the last several hundred years, despite apparently high rates of longshore sediment transport.

We will present numerical estimates of the rates and directions of longshore sediment transport within the site based on volumes of sediment accumulation and erosion occurring along the sides of shore-normal structures. We use different structures over different time intervals to minimize the impact of coastal armoring and reef flat rubble conglomerate accumulations, which tend to alter the "natural" longshore transport patterns. Rates of transport are normalized by the length of shoreline experiencing volumetric change to make values derived from different structures more comparable. Rates are assumed to be constant over the period of time between consecutive historical shorelines, and are shown graphically in Figure 2a.

Southwesterly kona storm waves move significant volumes of sediment northward along the coast, but a similar high volume mechanism is not known to work in the opposite direction. Within Maalaea Bay, on the leeward side of the island, the site is not exposed to large waves except from the south and southwest. The limited fetch in Maalaea Bay north and northwest of the fishpond preclude the generation of large waves in the Bay itself that could move significant volumes. Tradewind conditions however can and do move smaller volumes of sediment to the south within the site on a day-to-day basis.

The shoreline dynamics discussed above began prior to 1912 and a major portion of the total change had occurred by 1949, prior to significant human perturbation of the coastline. This suggests that natural rather than anthropogenic forcing is primarily responsible. By 1975 however, armoring of the coastline with seawalls and revetments was contributing to significant beach narrowing and loss, and overall erosion within the site. Patterns of shoreline change further suggest shifts in the dominant direction of longshore transport. There does not however appear to be any correlation between the shoreline change and the occurrence of El Niño conditions. However, observed patterns of sediment transport do appear to match up reasonably well with the Pacific Decadal Oscillation (PDO).

The PDO has been described as a giant, long-lived El Niño with each phase of the cycle lasting 20-30 years. Unlike El Niños, which most visibly impact climate in the tropics, the PDO has a more significant impact on the North American continent and the North Pacific. Although the Hawaiian Islands are well south of the primary focus of the PDO, it has been shown to significantly affect precipitation[2] and tropical cyclone activity[1] in the vicinity of Hawaii. The PDO, also called the North Pacific Oscillation (NPO) has two different phases. The NPO1 phase is El Niño-like, with horseshoe pattern of cooler sea surface temperatures (SSTs) and lower than normal sea-surface heights in the northern, western, and southern Pacific, with a wedge of warmer higher water in the eastern Pacific in between. During a shift to

the La Nina-like NPO2 phase, the warm and cool regions reverse. The relative strength of the PDO over time is described by an index based on SST, and is shown in Figure 2b. NPO1 phases have positive PDO index values while NPO2 phases are characterized by negative phases.

Climatic conditions during an NPO1 phase in Hawaii tend to include: increased El Niño activity, higher SSTs, enhanced tropical cyclone activity, less rainfall, and more persistent tradewinds. During NPO2 phases climatic conditions tend to be the opposite. One other factor of particular significance to the present study is the decrease of kona-storm activity during the NPO1 phase. Kona storms are large, low-pressure systems approaching the islands from the southwest or west and accompanied by rain-bearing winds. Striking areas normally in the tradewind lee of the islands, the occasionally strong kona storms have caused extensive damage to south and west facing shorelines, including the Kihei coast[6]. Mid-latitude disturbances, including kona storms, originate in the mid-upper troposphere in association with the trough, or rising portion of the Hadley cell. During the NPO2 phase, the trough tends to be located a bit south and west of Hawaii, enhancing the genesis of kona storms that track over the islands. During the El Niño-like NPO1 phase, Hawaii tends to be in the immediate vicinity of the ridge aloft, suppressing the development of kona storms, while the trough moves south and east, well away from the islands.

A number of studies[2,3,7] have found evidence for two full PDO cycles over the last century. They document NPO2 phases occurring from 1890–1924 and 1947-1976, and NPO1 phases from 1925-1946 and 1977 to at least the mid 1990s. Recent evidence suggests that this phase may have ended in 1999 (http://topex.www.jpl.nasa.gov/discover/PDO.html). Hereafter these will be referred to as Phases 1, 3, 2, and 4 respectively. We hypothesize that these cycles, modified by anthropogenic and natural sediment impoundment, are reflected in the patterns of shoreline change observed along the Kihei coast, as described below.

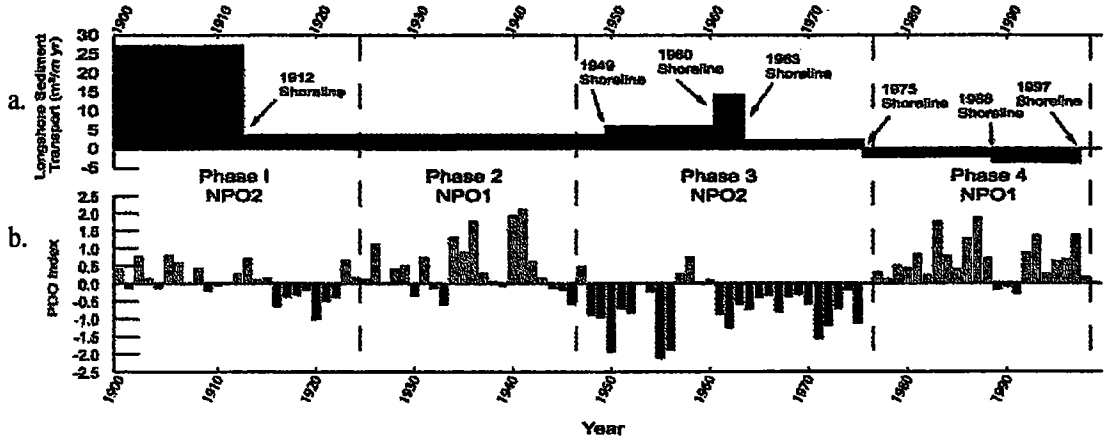

Figure 2. a. Longshore sediment transport rates, in cubic meters per meter of longshore distance per year. Note the timing of historical shoreline positions. b. From Mantura, et. al (1997). Pacific Decadal Oscillation (PDO). Dashed vertical lines show timing of phase shifts of the PDO.

During the Phase 1, a number of Kona storms occurred, causing major northward longshore sediment transport. Longshore transport during Phase 2 was primarily tradewind driven and to the south. Unfortunately, our estimates of longshore transport from Figure 2a are limited by the number of available historical shorelines. The apparently smaller but still northward direction of transport may reflect additional northward transport between 1912 and 1924 that is not resolved by the timing of historical shoreline positions.

Phase 3, the second period NPO2 period, corresponds to a period of higher kona storm activity and northward transport, particularly between 1960 and 1963, when several major kona events occurred. It was after these events that seawalls and revetments began to proliferate along this coastline. Private homeowners north of Kalama Park, in the southern half of the study site, had already begun this process by 1963. In the early 1970s the US Army Corps of Engineers constructed a 900 m long revetment actually

out into the ocean in front of Kalama Park. By 1997, 1.8 km of the shoreline was fronted by coastal armoring, impounding a reservoir of sand that would otherwise have been available to renourish the active littoral system.

In the northern portion of the site, an accumulation of reef rubble material began moving landward across the reef flat. First clearly visible in aerial photographs from 1975 (although they may have been initially deposited shortly after the 1960 photographs were taken) this material resulted in the formation of a tombolo along the shoreline. The rubble gradually moved landward and by 1997 had formed shore-normal, curvilinear, conglomerate tongues extending above mean sea-level and interrupting longshore transport of sediment. Both the conglomerate tongues and coastal armoring impounded sediment, reducing rates of sediment transport during the latter portion of Phase 3 as well as Phase 4.

The second El Niño-like period, Phase 4, corresponds to a period of southward transport, despite a major kona storm that occurred in January, 1980. Tradewind driven southward transport is believed to have been the dominant coastal process in operation at this time.

The above scenario describes a dynamic coastal sediment system characterized by periods of kona storm driven northward transport alternating with recovery periods dominated by lower rates of tradewind driven southward transport. The observed patterns of shoreline change, modified by natural and anthropogenic sediment impoundment, appear to match reasonably well with variations in kona storm activity predicted by shifts in the PDO. Efforts are underway to better resolve the kona storm record that will hopefully add credence to this hypothesis.

It has been suggested that we have recently entered another NPO2 phase. If this is the case and our hypothesis is correct, then we can expect increased kona storm activity over the next two or three decades, and renewed northward longshore transport along the Kihei coast. Under such a scenario, properties north of the armored section of the shoreline are likely to experience renewed and more serious erosion than they have encountered in the past.

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PREDICTING SHORELINE EFFECTS OF A NEW TIDAL INLET AT BOLSA CHICA, CALIFORNIA

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ABSTRACT

The Bolsa Chica wetland in Southern California is proposed for major restoration as mitigation for expansion in the Ports of Long Beach and Los Angeles. The preferred alternative includes a new tidal inlet at the south end of Bolsa Chica State Beach to convey flows to and from the ocean for improved marine habitat in the wetland. The attached figure shows the project site and vicinity. The new inlet will be stabilized with jetties, and will require a new bridge on Pacific Coast Highway over the inlet. A number of issues challenge the project such as a narrow eroding beach downcoast, potential sedimentation at the inlet and in bars in the lagoon and offshore, an intensely-used recreational beach upcoast, the need to maintain tidal hydraulics for habitat, and the need to convey floods from an upstream channel. As such, designing the project to minimize the impacts to the beach provides a significant technical challenge. This paper presents a brief overview of the project background and issues, and examines the predicted shoreline effects of the new inlet and proposed solutions.

BACKGROUND

The roughly 1000-acre site historically was connected to the ocean with an inlet. The inlet was intentionally closed by a duck hunting club in the late 1800's. The inlet has since remained closed, however a new connection was made to the ocean through the present location of Huntington Harbour in the early 1900's for flood control connecting to the ocean at Anaheim Bay. The wetland has subsequently received tidal flows from the entrance to Anaheim Bay, approximately 3.5 miles to the west of the project site as shown in the figure. Oil was discovered on the site in the 1920's and continues to be extracted today.

Wetland restoration planning for the site has occurred since the late 1960's. Restoration is constrained by limitations on hydraulics and water quality if the site continues to receive tides from Anaheim Bay. Water quality is improved and the wetland area to be restored is increased if the distance between the ocean and wetland is minimized. Therefore, resource agencies propose to relocate the inlet to a location along Bolsa Chica State Beach. Three alternative locations are proposed, with one preferred at the south end of the beach. The new inlet will include jetties for stabilization and a highway bridge. Due to the predicted impacts to the adjacent beaches, a study was commissioned to quantify the effects of the inlet and jetties and to identify possible mitigation alternatives.

THE PROJECT SITE AND VICINITY

Issues

Each inlet alternative faces a number of challenges. Each will modify sand transport along the coast, thus affecting adjacent beaches. A narrow and eroding beach exists to the south. Bluffs behind the eroding beach are gradually retreating and Pacific Coast Highway lies along the top of the bluffs. Also, a state beach lies to the north that supports high-intensity recreational use. Shoaling in the inlet, lagoon and ocean from inlet effects may cause beach narrowing adjacent to the inlet and adverse effects to the bluffs and recreational beach. Unless controlled, sedimentation in the lagoon may cause restriction of tidal and flood hydraulics and adverse effects to marine habitat.

Criteria that the project must meet include minimal interruption of State Beach operations and avoidance/relocation of facilities, avoidance of an existing wetland restoration project adjacent to the project site, and facilitation of continued oil operations. The southernmost proposed inlet minimizes interruption of State Beach operations and requires only minimal modification to State Beach facilities. The other two inlet locations, one in the center of the State Beach and the other at the north end, both cause significant effects to the State Beach. Each inlet location will avoid the existing wetland restoration project, and each will facilitate continuation of the oil operation on-site.

There were also several basic technical issues that had to be addressed prior to evaluating the shoreline response to the inlet. These items included the hydraulic design of the wetlands and entrance channel, design of the channel entrance structures, evaluation of the ebb-tide bar and flood-tide evolution, and water quality. A number of these issues were studied and quantified for use in the shoreline analysis. In addition to shoreline morphology, specific studies were done for hydraulics, bar shoaling, tidal muting, and water quality. The studies were interdependent, as results of the hydraulic study were required for the shoaling study and water quality study, and results of the shoaling study were required for the shoreline morphology study.

PREDICTED SHORELINE EFFECTS AND PROPOSED SOLUTIONS

The Shoreline Morphology Study commenced after initial results of the related studies became available. Modeling was done for an eleven-mile shoreline area between Anaheim Bay and the Santa Ana River. The study used the inlet design as input, and results of the shoaling study to determine shoreline changes from sand sinks at the ebb tide and flood tide bars. Shoreline modeling also considered historical shoreline evolution, wave climate, bathymetry and the sediment budget to generate results. Several project scenarios were modeled including:

Scenario A: Construction with pre-filling of jetties and the ebb bar, and long-term sand management by regularly maintenance dredging the inlet and flood bar and placing the sand onto the adjacent beaches;

Scenario B: Construction with pre-filling of jetties and the ebb bar, and no long-term sand management; and

Scenario C: Construction with no pre-filling of jetties and the ebb bar and no long-term sand management.

Modeling was done iteratively to quantify project effects under each scenario, starting from environmental worst-case (Scenario C) to environmental best-case (Scenario A). Results showed common trends regardless of the inlet alternative location. Under Scenario C, the shoreline retreated significantly along the majority of the study reach, with certain portions of the reach experiencing more severe retreat than others. Scenario B resulted in less erosion, but still significant retreat near the problem area of the bluffs. Scenario A resulted in no significant beach retreat throughout the project area, and a relatively stable shoreline position for twenty years into the future.

CONCLUSIONS

The study objective was to determine whether the future shoreline position after project implementation could be held to roughly within the range of existing natural fluctuations through management techniques. The study indicates that this is possible under a program of pre-filling the beach and ebb bar, along with long-term sand management performed on average every other year. The volumes and rates of sand management were calculated and are being used for project planning purposes. The project is undergoing environmental review at this time, and is scheduled for construction in late 2001.

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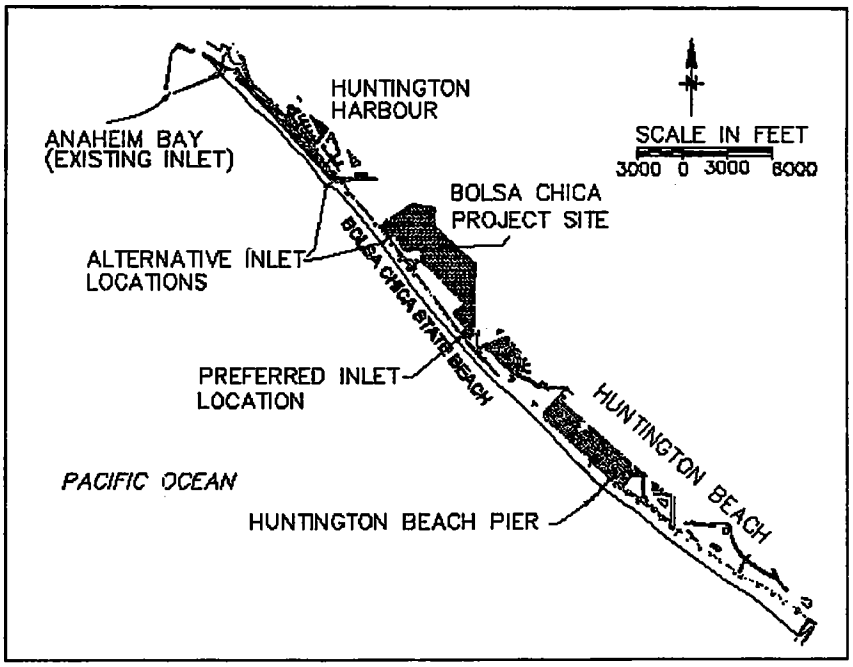
HUNTINGTON
HARBOUR
ANAHEIM BAY
(EXISTING INLET)
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PROJECT SITE
ALTERNATIVE INLET
LOCATIONS
BOLSA CHICA STATE BEACH
PREFERRED INLET
LOCATION
HUNTINGTON BEACH
PACIFIC OCEAN
HUNTINGTON BEACH PIER

A SOLUTION TO INLET MIGRATION AT WRIGHTSVILLE BEACH, NORTH CAROLINA: THE MASON INLET RELOCATION PROJECT

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ABSTRACT

INTRODUCTION

Over the past 30 years, Mason Inlet has migrated to the south. Now properties situated along the northernmost mile of Wrightsville Beach, North Carolina, are threatened. Since 1985, the migration has resulted in a loss of 2,200 feet of shoreline at the north end of Wrightsville Beach. If the migration of Mason Inlet is not stopped, 644 properties including the Shell Island Resort Hotel, 38 single-family homes, Wrightsville Dunes, Duneridge Resort, and Cordgrass Bay condominiums are at risk of total loss. With the Shell Island Resort and adjacent island properties, valued at $300 million, in imminent danger after a summer wrought with hurricanes, the design and permitting work to relocate Mason Inlet was begun in June 1999. Studies were developed and undertaken to determine if Mason Inlet could be designed as a reasonably stable natural inlet along a designated "inlet corridor" 3,000 feet north of the inlet's present position.

PROJECT DESCRIPTION

To accomplish the inlet relocation, Mason Creek, which is shoaled and essentially closed, will be dredged, and a new channel will be cut through Figure 8 Island approximately 3,000 feet north of the Inlet's present location (Figure 1). The resulting channel dredging will excavate approximately 790,000 cubic yards of beach quality sand from Mason Creek, the sedimentation basin and the new inlet channel. Closure of the existing inlet will be accomplished by placing approximately 400,000 cubic yards of this sand to bridge the existing inlet and rebuild the berm between the adjoining islands.

OVERVIEW OF MODELING AND ANALYSIS

The model studies included the application of the hydrodynamic model WQMAP to the study area, the calibration of the model using measured field data (i.e., water elevations and flow measurements), and the use of the model as a predictive tool to evaluate various project design scenarios. The model was used for the purposes of predicting the immediate post-project tidal prisms, current velocities and flushing characteristics for 20 different design alternatives. Field data collection for this project occurred during the summer of 1999. The field effort included: deployment of YSI instruments which measured water surface elevation, dissolved oxygen, salinity and temperature; the measurement of current velocities and flow at eight transect locations using ADCP instruments; and hydrographic surveys of the inlets, interior channels and the Atlantic Intracoastal Waterway. Additionally, geotechnical investigations of the site, including beach sand samples, core borings and material testing, were performed.

This large-scale hydrodynamic model of Mason Inlet and the surrounding estuaries and adjacent inlets was developed to evaluate differing geometries for two interior tidal channels, the sedimentation basin and the inlet channel. Based on the results of the modeling, the final recommended project design is a 4300-ft tidal channel (Mason Creek) configured as a 140-ft-wide and 10-ft NGVD deep channel, a 20-acre sedimentation basin and a inlet channel configured as a 500-ft-wide and 10-ft-deep channel. These model studies were used to evaluate potential positive and negative impacts of the inlet relocation on adjacent coastal marsh, fisheries and other biological resources. This presentation will describe the results of these studies in more detail.

WAVES AND LITTORAL PROCESSES

Changes to the existing ebb tidal shoal after inlet relocation and the impacts of the relocated inlet on adjacent beaches as the result of sand redistribution and equilibration of the littoral system were evaluated.

An inlet monitoring program and inlet management plan were developed that identified specific triggers and thresholds for implementation of inlet maintenance. Corrective measurements were developed to repair excessive sand losses along adjoining beaches. A description of the basis for establishing these specific thresholds will be provided in this presentation. Additional studies analyzed the ebb tidal shoal formation at the new inlet location in terms of total volume and deposition rate(s) over time. A comparison of two different methods to estimate the ebb shoal development, including an analysis of actual measurements of ebb shoal volume and tidal prism at the existing inlet, will be discussed and details presented.

CONCLUSIONS

In addition to protecting properties on Wrightsville Beach from loss, the project will provide sand for beach nourishment at Figure 8 Island. This project will prevent the adverse economic impact of a $237 million loss resulting from property and land losses, rental property and hotel revenue losses and tax revenue losses. This value represents the present worth value of these losses over 30 years. Mason Creek will reopen for navigational use and improved flushing of the Middle Sound Estuary. Beaches will be restored for public recreational use (swimming, fishing, etc). Relocating the inlet will provide an environmentally sound solution to a major problem without the construction of hardened structures such as groins or jetties. The project is currently in the final stages of the permitting phase, with construction work expected to begin in December 2000.

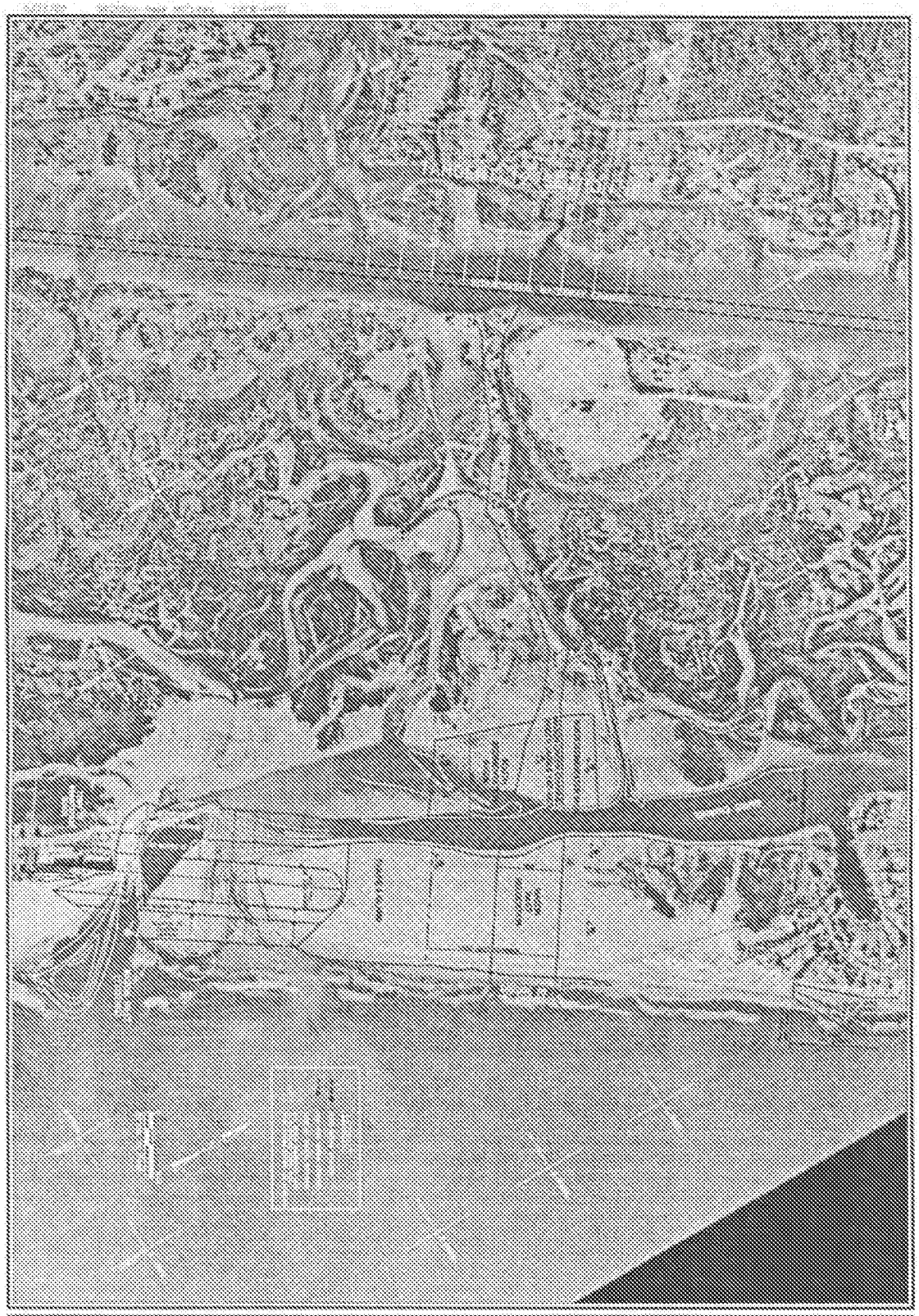

Figure 1. Proposed Project Plan View to Relocate Mason Inlet

LARGE SEDIMENT DEPOSITS ON THE REEF FRONT AROUND OAHU

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ABSTRACT

Large sediment deposits in water depths from about 20 to 100 m on the reef front around Oahu contain sand that perhaps can be used to replenish eroding beaches. The deposits have been studied as a possible sand resource for beach nourishment since the 1960s, primarily because suitable resources are scarce on land (Coulbourn et al., 1988). The deposits rest on numerous submerged terraces that comprise Quaternary lowstand shorelines and their adjacent carbonate platforms. We mapped the thickness and distribution of the deposits off parts of the windward (Kailua Bay), leeward (Makua to Kahe Point), and north (Camp Erdman to Waimea) coasts (Fig. 1). We also collected sediment samples from the Kailua Bay deposit and ran camera surveys across its surface.

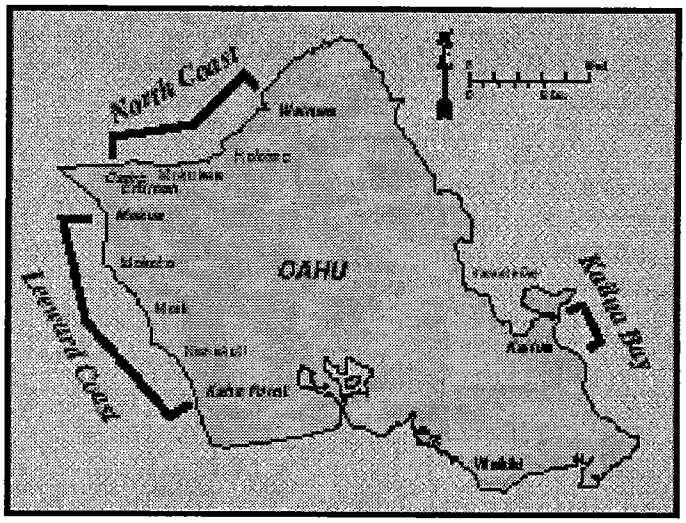

Figure 1. Location map.

The Kailua Bay deposit has simple morphology that serves as a reference for describing and interpreting the others. It forms a lens-shape blanket that extends for about 3 km along ancient terraces parallel to the reef front, achieving its maximum thickness of 40 m near the mouth of a sinuous channel that traverses the modern reef platform. The deposit thins and narrows in both directions away from the channel. The greatest thickness typically is near the landward edge of a broad terrace at about 70-m below sea level (the Makua terrace); the deposit thins toward the seaward edge, then locally thickens on deeper, relatively narrow terraces (Fig. 2). The mapped portion of the deposit comprises greater than 50 million m^3 of sediment, and the bulk of the deposit is in less than 100-m water depth.

We used geostatistics to analyze the spatial distribution of the thickness of the Kailua Bay deposit. First, variogram analysis was used to model the spatial variability of the sand thickness data. Then the variogram models were used as input to a stochastic simulation algorithm that generated a suite of 100 simulations of the sand thickness. The 100 simulations provide an estimate of the conditional distribution of the sand thickness at each point of the map. We summarized those conditional distributions by several statistics that include maps of the expected value and the variance of the conditional distributions, percentile maps, and probability of exceedance maps.

We collected vibracores (maximum length: 2 m) from the Kailua Bay deposit at 13 stations, in water depths from 28 to 79 m. Grain-size distribution was determined at the top and bottom of each vibracore. For comparison, we measured the grain size distribution of 5 samples collected along and across Kailua Beach. There are too few samples to fully evaluate the offshore deposit's suitability as a

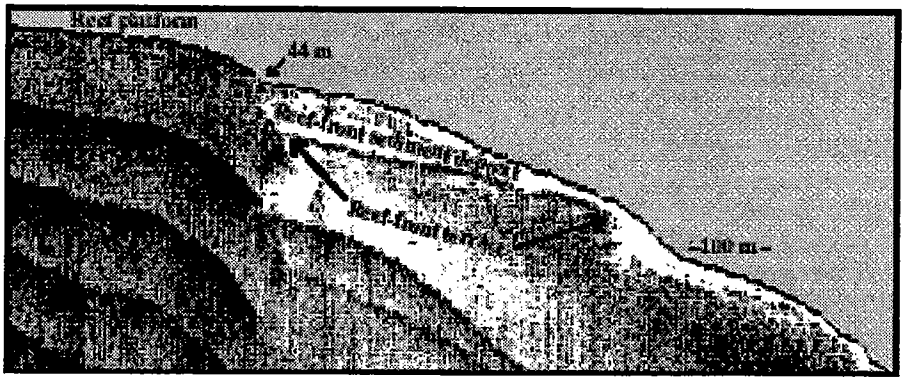

Figure 2. Subbottom profile across reef-front sediment deposit.

source for beach nourishment, but they might reveal a strategy for further exploration. A common specification for sediment that is to be used, unprocessed, for beach nourishment is that its grain-size be similar to or slightly coarser than the existing beach (CERC, 1984), or that the distribution fall within the envelope of those of the beach samples, with less than 10% clay + silt (fines) or gravel (e.g., Jantz et al., 1999). A total of 8 of the 26 offshore grain-size measurements, mostly from the shallower sea-floor depths, meet these criteria (Fig. 3). Most of the other samples fall slightly to the fine side of the envelope; nevertheless, they contain a significant amount of sand.

The color of sediment samples from the Kailua deposit is mostly tan to light-gray, similar to sand on Kailua beach. Preliminary chemical analysis of gray carbonate grains, which are undesirable for many replenishment applications, indicate that the color is imparted by iron sulfide, organic carbon, and/or aluminosilicate (clay) minerals.

We mapped several contiguous deposits off the leeward coast. They contain a total of 107 million m^3 of sediment with a maximum measured thickness of 23 m. Although most of the deposits issue from reef-platform channels, at least one apparently is sourced by sediment that washes over a long, uninterrupted reach of the platform edge. In places, the sediment is confined to the Makua terrace and seems to be relict from a previous sea-level lowstand. Elsewhere, this deposit is overlain by younger sediment that extends up to shallower terraces and the modern reef platform, suggesting that deposition is presently active.

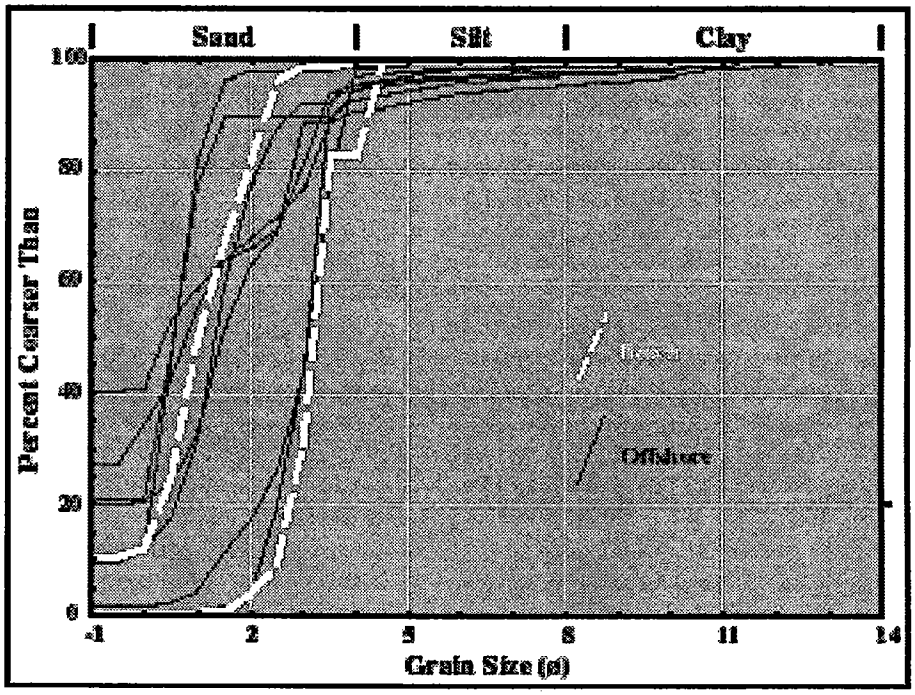

Figure 3. Cumulative grain size distributions.

Off the north coast, deposits issue from at least three channels, and more than 255-million m^3 of sediment of 21-m maximum measured thickness occurs within the mapped area. Terraces typically are less well developed compared to the other mapped areas, and the deposits tend to rest on a relatively rough surface of the reef front. Several long reef-front ridges interrupt these deposits, so the sediment cover is discontinuous.

Local engineering, environmental, resource-economic, and regulatory considerations place constraints on the resource potential of the reef-front deposits, but the need for sand looms large and is becoming evermore urgent (Coyne et al., 1996; Fletcher and Lemmo, 1999).

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OBSERVATIONS OF PHYSICAL PROCESSES AND SEDIMENT TRANSPORT ON A SHALLOW REEF FLAT: SOUTH-CENTRAL MOLOKA'I, HAWAI'I

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ABSTRACT

An instrument tripod was deployed off south-central Moloka'i (Figure 1) in 1.3 m of water to examine the physical processes and sediment transport regime on the shallow reef flat. This study was part of the U.S. Geological Survey's comprehensive and multi-disciplinary Coral Reef Project that focuses on the health and sustainability of coral reef systems. At the study site, terrigenous sediment has accumulated in an inner reef flat deposit in water depths of approximately 0 to 30 cm (Field et al, 2000). This study is investigating the amount and mechanisms by which terrigenous sediment is resuspended and advected along and off the reef flat into zones of active coral reef development.

The tripod carried a suite of sensors to measure waves, currents, suspended sediment, temperature, and salinity. From January through March of 2000 the tripod collected 8.5 minute data bursts at 2 Hz every hour. The period of deployment encompassed three complete spring-neap tidal cycles. Typically the months of January - March experience higher than average annual rainfall and lower than average annual trade wind activity, but in the past three years the island has experienced drought conditions. Rainfall records in January-March 2000 (Hydro-Net) show the period to have very little rainfall (11 mm). Trade wind energy was low in the initial part of the record, and increased in the latter part of the record. Mean water surface fluctuations due to tides (Figure 2a) were approximately 0.6 m while the maximum tidal range observed was almost 1.0 m. There was also a slight set-up of the water surface due to winds and waves in the latter part of the record. Across-reef and along-reef currents (Figure 2b) related to the semi-diurnal tides were typically on the order of 2 to 15 cm/sec. During the initial part of the record, the flow appears to be dominated by tidal fluctuations and was mainly expressed in weak oscillating along-reef flow. A few periods of stronger westerly trade winds were observed in this initial part of the record, typically causing alongshore to the west and offshore. During the latter part of the record, the flow appeared to be dominated by wind-driven currents, causing net flow to the west and off-reef. Near-bed RMS orbital wave velocities (Figure 2c) ranged between 3 and 14 cm/sec and appeared to be strongly modulated by tidal fluctuations of the water depth at the tripod location.The tidal modulation of near-bed orbital wave velocities and currents was significantly suppressed during these periods marked by strong alongshore winds to the west.

Suspended sediment concentrations (Figure 2d) ranged between 0 and approximately 50 mg/l over the initial part of the deployment period. During this tidal-flow dominated regime, peaks in suspended sediment concentration were correlated with both shallow water depths at low tide and the few peak velocities in the wind-driven currents. Due to the shallow depth, high temperature, and generally good water clarity, biologic growth on the optics of the sensors that measured suspended sediment significantly reduced the quality of the suspended sediment data in the latter part of the record. The limited turbidity data in the latter part of the record suggests increased suspended sediment concentrations during periods of high trade wind activity.

The near-bed flow and the presumed direction of sediment transport on the shallow reef flat appears to be primarily controlled by the interplay between waves and currents generated by strong, sustained westerly trade winds and tides, and the water depth. Strong trade winds may also super-elevate sea level over the reef flat due to wave- and wind-induced set-up which is balanced by offshore and westerly near-bed flow. In this initial deployment of the proposed year-long record, the data suggests that

periods of increased suspended-sediment transport occurred during peak trade winds, due to resuspension, and at times of low tidal elevation, hypothetically due to advection from the inner reef flat mud deposit. This supports a conceptual model in which one mechanism contributing to offshore flux of terrigenous sediment is resuspension and advection from the inner reef flat deposit. Continued deployment of the instrumented tripod in conjunction with spatial surveys of currents and suspended sediment concentrations are presently being conducted and will be used to evaluate the amount of suspended sediment moving along and across the reef. Ultimately, they will provide insight into the mechanisms by which terrigeneous sediment leaves the inner reef deposit and is transported out to the zone of coral growth.

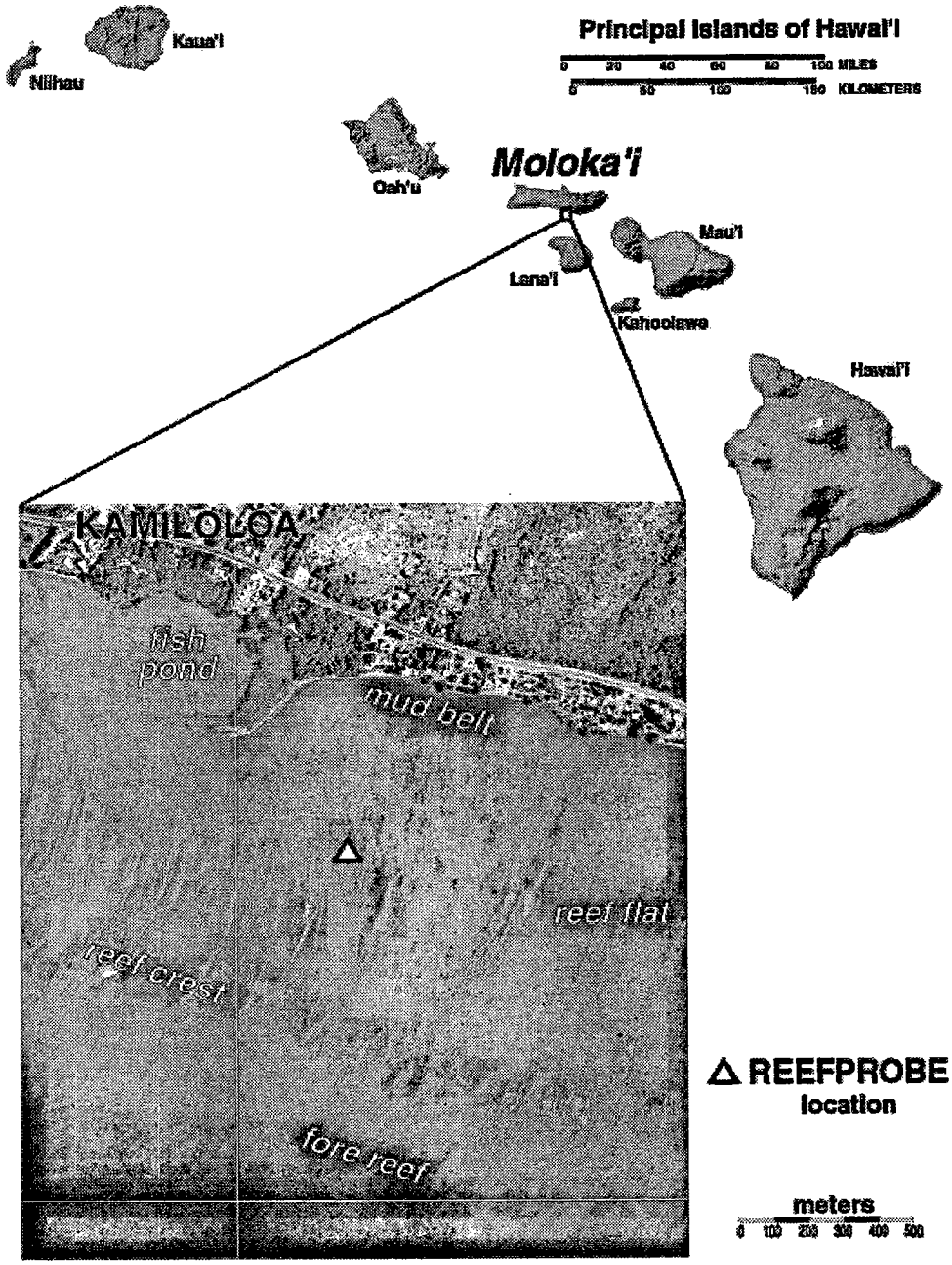

FIGURE 1. Study site located on south-central Moloka'i, Hawai'i. The instrumented tripod is located on the reef flat, offshore of the inner reef flat mud deposit. Active coral development is located just offshore of the tripod site.

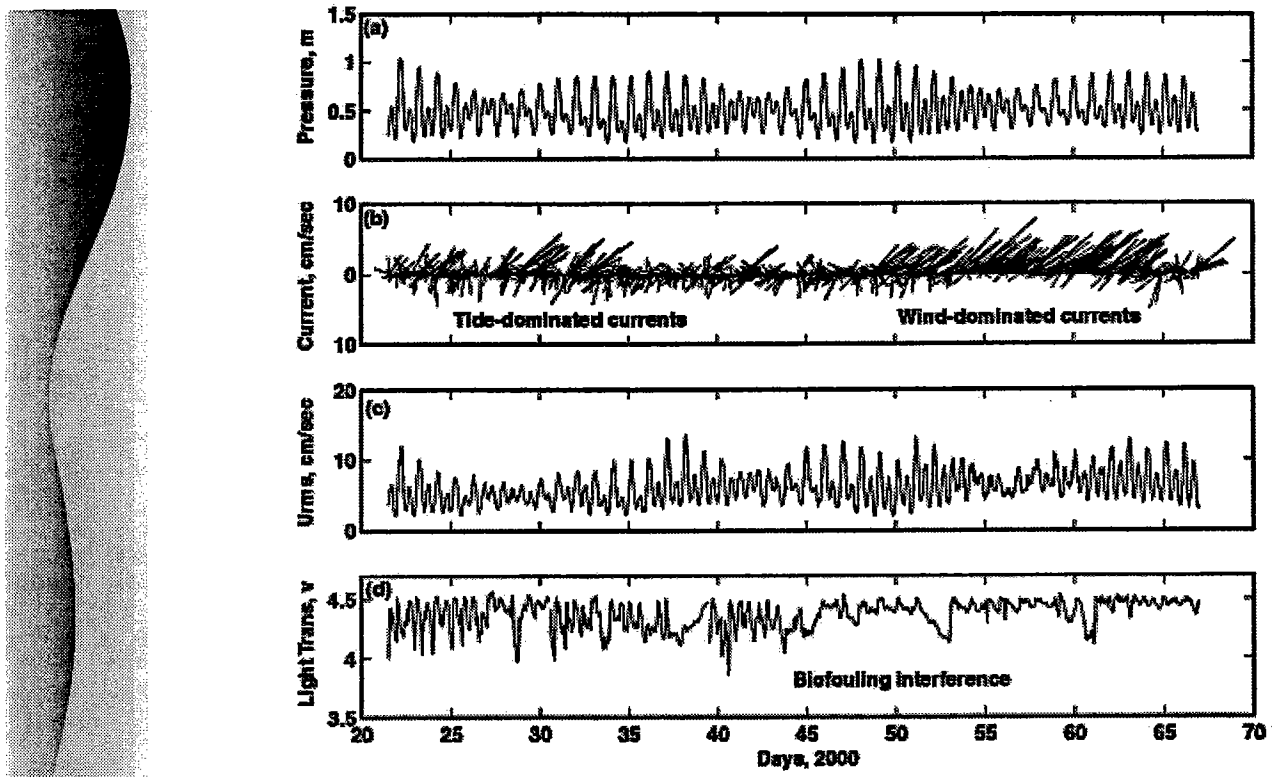

FIGURE 2. Time series data from the first deployment of the instrumented tripod: a) pressure, b) current vectors where a vector straight up on the plot represents currents along the reef to the West and a vector to the right on the plot is offshore, c) wave-orbital velocity, and d) light transmission in voltage where full voltage (4.5 v) represents 0 mg/l suspended sediment concentration, and lower voltage values represent sediment in suspension. Note that in the latter part of the record, bio-fouling made the transmissometer record unusable.

THE NORTHERN GULF OF MEXICO REGIONAL SEDIMENT MANAGEMENT DEMONSTRATION PROGRAM

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ABSTRACT

In the past, the US Army Corps of Engineers (USACE) has focused on managing sand at coastal projects on a project-by-project basis. This approach to sand management may not adequately consider the impact of individual projects on down drift projects. To address this issue, the USACE has initiated efforts to assess the benefits of managing sediment resources as a regional scale resource rather than a localized project resource. The concept of Regional Sediment Management (RSM) is a result of the 67th meeting of the Coastal Engineering Research Board held in May 1998. In October 1999, the US Army Engineer District, Mobile (SAM), initiated the USACE Northern Gulf of Mexico Regional Sediment Management Demonstration Program. The overall goal of the demonstration program is to change the paradigm of project specific management to focusing on a regional approach in which the USACE as well as state and local agencies stop managing projects and begin "managing the sand." The objectives of the RSM demonstration program are:

- Implement Regional Sediment Management Practices;
- Improvement of economic performance by linking projects;
- Development of new engineering techniques to optimize/conserve sediment;
- Determination of bureaucratic obstacles which have to be overcome; and
- Management in concert with the environment

The SAM demonstration region encompasses approximately 225-miles of coastal shoreline along the northern Gulf of Mexico, Figure 1. The region is bounded to the east by the St. Marks River, and Dauphin Island, Alabama, to the west. The region includes nine Federal projects, the Panama City Beach Nourishment project, eight State parks, the Gulf Islands National Seashore, Eglin and Tyndall Air Force Bases as well as many cities and counties. To accomplish the RSM goal, it is essential that partnering and coordination with agencies interested in the management of this coastal region be achieved.

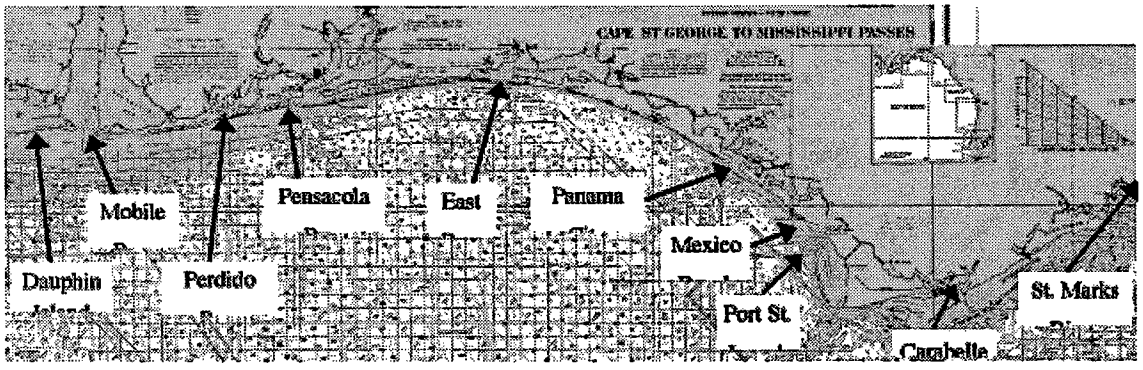

Figure 1. Northern Gulf of Mexico Regional Sediment Management Demonstration Region

To characterize the behavior of the demonstration region, a top-down approach was developed which first identifies activities that define the behavior of the entire region. Such activities include obtaining historical information and data, establishing a regional baseline dataset, development of a regional data management/GIS system, and development of a regional sediment budget. Refinement of the regional activities requires detailed examination on a sub-regional and project levels to assess how the current project specific management practices can be modified to regional management practices in an effort to keep the sand in the littoral system. Therefore, the region was divided into nine sub-regions based on coastal processes and geomorphic features. Management practices of projects within each sub-region are evaluated, modified to improve project performance, and monitored to evaluate the performance of the project modification. This iterative process continues until a balance between efficient performance and project constraints are reached. Those modified management practices that prove to be more efficient while providing greater benefits are implemented as common practice. Implementing this cycle for every project in the region requires cooperation and coordination with all agencies within the region. Information gained at the project level will be used to refine the regional level activities.

The product of the RSM demonstration program is a Regional Sediment Management Plan consisting of a calibrated regional sediment budget, a calibrated regional prediction system, and a regional data management and Geographic Information System. These tools will assist in making management decisions and increase benefits resulting from improved sand management throughout the region.

A key element for success of regional sediment management is to gain a firm understanding of the sediment transport processes and pathways over the entire region. Formulation of the regional sediment budget began with development of a database of historical and contemporary coastal information and data. An initial sediment budget was developed based on the available historical data and utilizing the Sediment Budget Analysis System (SBAS 2000), under development through the Coastal Inlets Research Program. This initial sediment budget quantified the knowns and qualified the unknowns relative to sediment transport over the region. Identification of the unknowns provided the initial focus for the program.

The hydrodynamic models STWAVE (Steady-State Wave) and GENESIS (Generalized Model For Simulating Shoreline Change) are being applied in conjunction with the ADCIRC (ADvanced CIRCulation) model to characterize wave conditions, tidal circulation patterns, and potential longshore sediment transport over the entire region. The historic and potential sediment budgets will be combined into an integrated regional sediment budget to provide an understanding of sediment transport over the demonstration region. The calibrated working sediment budget will be used to evaluate impacts of proposed changes over the region. Because development of the sediment budget is an ongoing process, the budget will be reevaluated and refined as information and data become available.

This paper reviews the SAM Regional Sediment Management Demonstration Program with a focus on formulation of the regional sediment budget.

DEVELOPMENT OF A STATEWIDE SEDIMENT BUDGET FOR THE COAST OF FLORIDA

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ABSTRACT

Initial work toward development of a statewide sediment budget for the coast of Florida is underway. Study efforts by the U.S. Army Corps of Engineers (USACE) in coordination with the Florida Department of Environmental Protection (FDEP) have begun to address sediment budget analysis on a regional basis with initial focus on Florida's Atlantic and Gulf (Panhandle) coasts. Analytical software recently developed by the USACE Coastal Hydraulics Laboratory (CHL), site-specific sand budget studies, and FDEP shoreline position and beach and offshore profile survey data have been used to test the regional approach and provide preliminary regional sand budgets.

There is interest on both the State and Federal level to perform regional management and conduct associated regional analyses. The Florida Legislature established public policy in Sections 161.088 and 161.091, F.S., regarding statewide beach management. The FDEP is directed to develop a management strategy that, among other things, encourages regional approaches, maximizes infusion of beach-quality sand into the system, extends the life of beach nourishment projects, and promotes inlet sand bypassing (Leadon and Devereaux 1999).

The Jacksonville District of the USACE and FDEP have developed a partnership to promote regional approaches to beach management which recognize sediment transport boundaries rather than political boundaries in the management of sediment resources. Opportunities for linking activities involving shore protection, navigation and environmental restoration projects are being pursued. The Corps has also recognized the potential for project cost savings through coordination of projects on a regional scale. Regional sediment management demonstration projects are currently being formulated in a number of coastal Corps Districts to investigate the long-term merits of a systems approach to coastal project management.

The U.S. Army Engineer Research and Development Center (ERDC) is conducting research aimed towards improving the USACE's ability to implement region-scale approaches. One of ERDC's goals is to develop regional-scale tools for reducing the cost to plan, design, construct, operate and maintain Federal navigation and shore protection projects. As a part of this effort, the Sediment Budget Analysis System (SBAS) was upgraded for regional application. This upgrade, called SBAS2000, was applied along Florida's East Coast as part of a proof-in-concept evaluation.

The initial development of regional sediment budgets for the Florida East Coast has been performed by CHL and the Jacksonville District in conjunction with a statewide Strategic Beach Management Plan (SBMP) development by FDEP. A regional sediment budget for the Florida Panhandle Coast is under development by CHL and the Mobile District of the USACE. Continued evolution and refinement of these sediment budgets will be needed; however, they provide the initial steps toward a statewide sediment budget for Florida.

As formulated in SBAS2000, the computed sediment budget is based on a balancing of volume changes associated with a specified control volume, in this case a coastal cell or series of cells, over a given time interval, generally annually, according to the following relationship:

$$Qsource - Qsink - \Delta V + P = Residual \quad (1)$$

in which all terms are expressed consistently as a volume or as a volumetric change rate, Q_{source} and Q_{sink} are the sources and sinks to the control volume, respectively, DV is the net change in volume within the cell, P and R are the amounts of material placed in and removed from the cell, respectively, and *Residual* represents the degree to which the cell is balanced. For a balanced cell, the *Residual* = 0.

In considering a large region such as the State of Florida, a first step in sediment budget process is to formulate a conceptual sediment budget (Kana and Stevens 1992), a qualitative model giving a regional perspective of inlet interaction and beach processes. Within this model, coarse sediment budget cells are defined, often specified on the scale of an inlet and its local region of influence, and the adjacent beaches. Then, data are analyzed to test and refine the conceptual sediment budget, or macro-budget, to ultimately develop a final budget.

There are approximately 70 tidal inlets along the Florida coast many of which have been stabilized by jetties and/or maintained for navigation. These coastal inlets provide a number of benefits, including navigational access to seaports, but also have deleterious effects on sand supply to adjacent beach areas. As a part of FDEP's beach management planning efforts, inlet management plans (IMPs) have been developed for many of the coastal inlets in the state. Primary products within these IMPs are sediment budgets comprising the area at and adjacent to each particular inlet. The IMP sediment budgets are useful in assessing sand management strategies for the inlets. The sediment budgets and sand management strategies from the IMPs have been incorporated into Florida's Strategic Beach Management Plan.

In the initial regional sediment budget work for the east coast of Florida, the sediment budgets from IMPs were used for the areas for which they were performed to create a series of "meso-budgets". Sediment budgets for the "connecting" beach areas between the inlet cells were developed through use of shoreline position data available from FDEP. Volumetric change rates for connecting beach areas were derived from shoreline change rates through analysis of beach survey and shoreline change data (and applying a conversion relationship of 1 cubic yard per foot of shoreline change). Artificial gains and losses from, for example, beach nourishment, sand bypassing, and dredging disposals were incorporated into the budget computations. On a larger regional scale, multiple meso-budgets of inlet and connecting beach areas were combined to form a macro-budget.

Results of the initial sediment budget analysis for Florida's East Coast provide a first step in the process of formulating a regional understanding of sediment transport, beach change, and associated engineering activity for these regions. Continued evolution and refinement of these budgets to resolve imbalances and account for all sand sources and sinks appropriately is needed.

The application of the SBAS2000 software was found to be beneficial in development of an initial sediment budget in Florida.Continued enhancement of this software is expected as further applications are conducted. Noteworthy findings from the Florida work to-date include: 1) a regional approach should aid in resolving current inconsistencies in site-specific budgets and longshore sediment transport (LST) rates, 2) shoreline and profile survey data must be collected in a manner to reduce error and provide consistency from survey to survey, 3) uncertainty in LST and budget values must be reported, and 4) a geo-referenced beach fill and dredge material disposal project database is needed for accurate formulation of sediment budgets.

The FDEP is changing its approach to coastal monitoring (e.g., acquisition of aerial photography and topographic/bathymetric survey data) to conduct regional monitoring in contrast to monitoring by political boundaries (e.g., county by county) as in the past. The regional approach to monitoring should aid in the effort to develop more reliable regional sediment budgets and conduct regional sediment management.

Future regional sediment budget work in Florida should continue refinement and integration of the work in the Florida Panhandle and East Coast and initiate work in the southwestern region of the State in pursuit of a statewide sediment budget. Additional work should include further evaluation of existing and new coastal monitoring data and beach fill and dredging projects, as well as, any necessary process-based analyses to improve sediment budget parameters, for example, LST rates.

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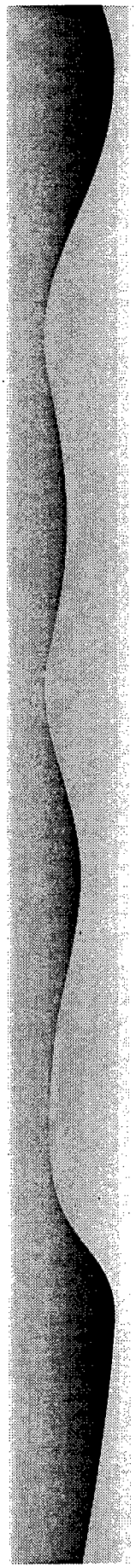

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MORPHODYNAMICAL MODELING OF HAWAIIAN BEACHES

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ABSTRACT

On many Pacific and Caribbean islands, beaches are an integral part of the local economyand tourism industry. Many of these islands are suffering from increasing beach erosion and shoreline recession problems, which have been documented in numerous field studies and monitoring programs (e.g., Makai Ocean Engineering, Inc., 1991; Fletcher *et al.*,1997). Understanding, let alone predicting these changes is a big problem. In part this is because they can be both *forced* and *free* (Dodd *et al.*, 2000). Forced motions are thosedue directly to some forcing mechanism, like increased wave activity, with the change being proportional to the amount of wave activity. Free motions, on the other hand, are inherent modes or trends of beach change. So, for instance, beach change due to human interference, like beach nourishment, might initially be a direct response. However, this interference might alter the inherent stability of the whole beach and the associated sediment budget.

Recent work on modeling long-term beach and coastline changes (e.g., FalquÈs *et al.*,1996; Deigaard *et al.*,1998; Dodd and Damgaard, 2000; Damgaard et al., 2000) hashighlighted the effectiveness of numerical models in understanding and predicting beach changes. Numerous approaches to long-term morphological modeling exist (Dodd *et al.*,2000); one of the most effective and promising is that based on the equations of theoretical morphodynamics, in which the wave field is linked to a beach change equation. These models have the advantage of being largely non-parametric, and can model both *forced*and *free* beach changes.

One area in which these types of models *are* parametric is in how they model the sedimenttransport rate. Usually, this rate is expressed as a function of the local mean current, and most expressions require a certain degree of calibration. So far, most of this calibration has been undertaken on sandy (silicate) beaches (e.g., Van Rijn, 1993, Yang, 1995), whereas beaches around tropical islands tend to be composed of calcareous sand, derived from the coral reef community. Recently, however, work undertaken in the Ocean and Resources Engineering Dept. at the University of Hawaii at Manoa has focused on obtaining practical, validated sediment transport models for calcareous sands (Smith and Cheung, 2000). Preliminary results, obtained in part by laboratory experiments conducted in the state-of-the-art recirculating flume at Washington State University, look promising. Another piece of the jigsaw that will also be in place here soon is the modeling of the wave conditions that drive beach changes. A project on the modeling of transformation and run-up of wind waves around the Hawaiian Islands, currently being undertaken by the authors, will provide the capability of obtaining a comprehensive, local picture of wave conditions around Pacific islands.

The time, therefore, now seems ripe for applying the morphodynamical models to tropical island beaches using sediment transport formulas for calcareous sand, and allowing for other recalibrations for steeper bathymetries. Moreover, the impressive work in the Coastal Imaging Lab. at Oregon State University (**http://cil-www.oce.orst.edu:8080/**) inmonitoring long-term beach changes (notably at Waimea Bay, on Oahu) would seem to provide an excellent opportunity to test the resulting beach change model.

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SHORELINE MONITORING PROGRAM ON THE TEXAS COAST UTILIZING A REAL-TIME KINEMATIC DIFFERENTIAL GLOBAL POSITIONING SYSTEM

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ABSTRACT

Due to shoreline erosion, approximately seventeen miles of Texas State Highway 87, located in Jefferson County Texas, have been repeatedly destroyed by storms and rebuilt. This paper describes a shoreline-monitoring program developed to obtain a comprehensive data set that will be used to define the coastal erosion problem and assist in the reconstruction of the roadway. An improved survey system similar to a concept developed by Beach et al. (1996) was designed and constructed for this project.

This paper discusses the improved survey system design and testing. The nearshore system utilizes a Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) mounted on a personal watercraft and integrated with a survey quality echo sounder. The nearshore system was tested by repeating transects in the nearshore. The repeatability of the profiles demonstrated a standard deviation of 6.2 cm from the mean absolute difference of 8.0 cm. The beach survey utilizes RTK-DGPS equipment carried by the surveyor in a backpack. The maximum expected error for the beach survey is approximately ±4 cm. The system is an accurate, mobile and efficient method to obtain beach profiles. Additional accuracy may be obtained by integrating a motion sensor and CTD profiler. The system used for surveys in the nearshore is shown in Figure 1. It illustrates the RTK-DGPS equipment as well as the computer mount that provides the navigation software display.

The survey data are processed using commercially available software packages and programs developed for this project. The processed data is integrated and stored in a geographic information system (GIS). Figure 2 shows typical results of the survey indicating the low elevation of the berm and proximity of the fresh-water wetlands to the active beach face. Figure 3 shows a photograph taken near the data presented in Figure 2. Notice the wide berm and the very mild offshore profile.

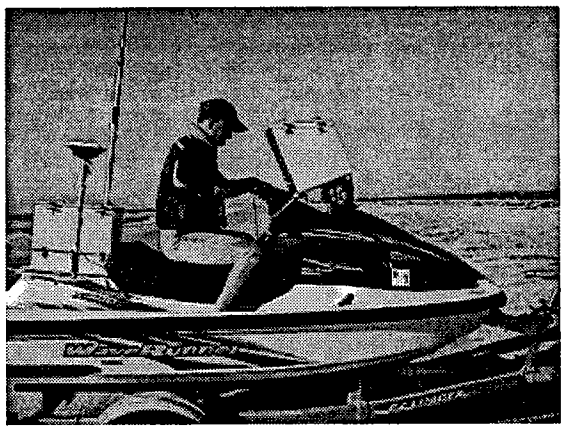

Figure 1. Watercraft with mounted equipment.

The data collected exemplify morphological features indicative of erosion due to overwash. This is consistent with visual observations and numerical model results provided by Howard (1999). The shoreline movement since 1996 is consistent with historical data and is related to storm events. Thus far one year of data have been taken with this system but there have not been any storms to create overwash events.

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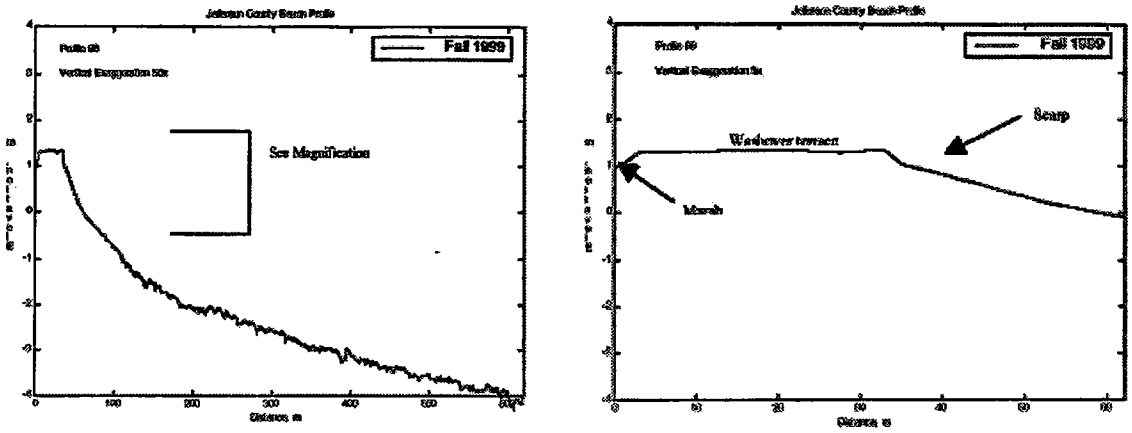

Figure 2. Typical beach profile.

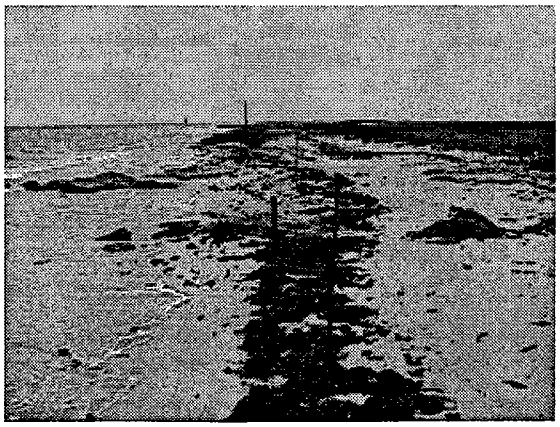

Figure 3. Shoreline along Northeast Coastline of Texas showing a wide flat berm, freshwater wetlands to the West and muddy outcrops on the beachface.

The current research has provided a survey system capable of performing fast, accurate surveys in the nearshore and a baseline data set. The survey system is fully operational and will be instrumental in the ongoing research related to the Highway 87 reconstruction project. The baseline data set, together with sediment analyses data and water level predictions, provides the foundation from which further investigations will be conducted and will provide information that can be used for the design of the new highway.

Mr. Ty Wamsley acknowledges permission granted by the Headquarters, U.S. Army Corps of Engineers, to publish this paper.

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NATIONAL SHORELINE EROSION CONTROL DEMONSTRATION PROGRAM OVERVIEW

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ABSTRACT

The National Shoreline Erosion Control Development and Demonstration Program of the US Army Corps of Engineers was established by Section 227 of the US Water Resources and Development Act (WRDA) of 1996 with initial funding appropriated in FY00. Section 227 provides a means by which the Corps can evaluate the functional performance of innovative or non-traditional approaches for abating coastal erosion and improving shoreline sediment retention at prototype-scale. A wide array of shore protection devices and methods will be constructed, monitored and evaluated at sites that represent varying energy conditions and shoreline morphologies. This program builds upon the experience and lessons of the "Low Cost Shore Protection Demonstration Program (Section 54)" of the 1970's. The Section 54 Program, authorized by WRDA 1974, focused on testing technologies for survivability in "low-wave energy" environments (USAE 1981).

Objectives of Section 227 are to assess and advance the state of the art of shoreline erosion control technology, encourage the development of innovative solutions to the shoreline erosion control challenge, and to communicate findings to the public. Through an extensive technical transfer effort, the Program will provide a means for furthering the use of well-engineered alternative approaches to shoreline erosion control. Emphasis will be placed on the evaluation of technologies from both functional and structural perspectives and will include bioengineered approaches.

Section 227 states that a minimum of seven demonstration projects will be constructed on various coastlines: two on the Atlantic coast, one on the Gulf Coast, two on the Pacific coast, and two on the Great Lakes. Project locations must be experiencing shoreline erosion at a manageable rate and have sufficient shoreline length to demonstrate the functional performance of the technology selected for testing at that site. Additionally, sites must have suitable control sections or pre-project monitoring records, and have identifiable spatial and temporal scales associated with localized coastal processes.

In addition to constructed demonstration sites, the program will also take advantage of "targets-of-opportunity" to monitor sites where innovative shore protection approaches may be installed through the sponsorship of others. That is, a site where another Federal or non-Federal organization has implemented an approach which shows engineering promise, but is not in a position to properly monitor or document project performance. The program will also sponsor the development of a database that documents installations and case example reports.

Selection criteria for demonstration technologies include applicability to project site, suitable and quantifiable performance prediction metrics, sound engineering design, and economic feasibility of construction and maintenance. Specific technologies identified as having a high priority for testing include groin configurations and permeability, reef breakwaters and breakwater configuration, armoring alternatives, bioengineered and vegetative approaches, cohesive and bluff shore treatments, and other sand retention methods and site management strategies. All demonstration projects must meet local permitting and regulatory requirements.

Nominations for demonstration sites and technological applications are being coordinated through the USACE coastal District and Division offices. The Section 227 oversight committee; consisting of the Civilian members of the Coastal Engineering Research Board, USAE Headquarters and ERDC staff; reviewed the 37 submitted site nomination packages and identified sites appropriate for further development. Technological advancements will be selected for demonstration based on scientific and engineering validity and economics. Performance of the applied technologies will be evaluated as related to interaction with the coastal system and other engineering considerations such as constructability,

structural stability and life-cycle cost. Evaluation of functional performance will be documented and widely disseminated to the coastal engineering community.

Based on availability of fiscal year 2000 funding, four sites were selected for project implementation plan development. The first of these four sites, located in the borough of Cape May Point, New Jersey was specified in the appropriations language of Section 227. Cape May Point is a 1.8 km long beachfront community located on the southern tip of New Jersey. Cape May Point is particularly vulnerable to storm damage due to exposure to waves from both the Atlantic Ocean and the Delaware Bay. Wave heights average 0.6 m in the summer and 1.2 m in the winter with much higher waves occurring during storms. The mean tide range is 1.2 m. Net longshore sediment transport is predominantly wave induced and is directed from east to west with an average transport rate on the order of 152,920 cubic meters per year. Existing shore protection structures along the shoreline at Cape May Point include a series of nine groins at ~150-300 m spacing and a rubble revetment armoring the shoreline in the easternmost groin cell (Figure 1A). While these engineered efforts have "held-the-line" in most shoreline sections with regard to erosion, that "line" is at a critical position. There is virtually no buffer from storm events, which can severely damage the area, and also contribute saltwater intrusion of a critical freshwater wetland.

The compartmentalized beach at Cape May Point presents an opportunity for researchers to evaluate the effectiveness of narrow-crested submerged breakwaters and sills to retain sediment on the active beach profile. In cooperation with the State of New Jersey Department of Environmental Protection, a project implementation plan is being developed that will consist of construction of continuous breakwaters and sills across selected groin compartments in an effort to retain beach fill material. An assessment will be made to determine the effectiveness of these structures when used to extend the renourishment interval by retaining sand on the active profiles contained in the groin cells.

The second demonstration site to be initiated this year is located on the Gulf Coast in Jefferson County, Texas, about 50 km west of the Texas-Louisiana border. The beach is representative of beaches of the western Gulf Coast, which vary in texture and composition from mud or thin sand veneer over mud with high concentrations of caliche nodules and shell material to dominantly sand with minor shell material. Typical topography consists of a relatively flat-sloped nearshore, a relatively steep beach, and a wash over terrace. The elevation of this wash over terrace, which is the highest point on the shore, is slightly above normal high tide elevation.

The mean significant wave height is 0.8 m in summer and 1.3 m in winter. Astronomical tides are chiefly diurnal with an average range of 0.4 m. Meteorological conditions strongly affect water levels in the area. Strong winter northers can depress Gulf water levels to nearly 1 meter, and hurricanes can produce storm surges of up to 4.3 m. No previous shore protection work exists in the area.

The principal cause for shoreline recession in the area is storm-related erosion. Under storm conditions, the protective veneer of sand is eroded and the underlying mud beach is exposed to waves for further erosion (Figure 1B). Due to a deficit of sand in the littoral system and storm-related down cutting of the cohesive material, the eroded profile never recovers to its post-storm state. The phenomenon of cohesive profile down cutting is not unique to the western Gulf coast; it also occurs in the Great Lakes and bay environments of the Atlantic and Pacific coasts.

In cooperation with the State of Texas General Land Office, the Jefferson County demonstration site will be designed with two primary shoreline erosion abatement goals in mind: prevention of cohesive bottom down-cutting and prevention of overwash. It is expected that these goals will be addressed though a combined use of sand and clay-filled geotextile structures, beach nourishment and vegetative methods.

The third demonstration project to begin the design process is Allegan County, Michigan. This shoreline is representative of many in the Great Lakes region. Receding bluffs carved into glacial tills or lacustrine deposits occupy over 60 percent of the shoreline (Figure 1C). Till bluffs exist also along the New England coast, in river valleys, and in countless lakes and reservoirs throughout the northern U.S. and Canada. In coastal scenarios, the blame for most slope movements is commonly placed on toe erosion created by storm waves. Although other factors, notably groundwater, are contributors to slope instability,

they are typically considered insignificant when erosion abatement strategies are planned. At this location, receding lake level from the toe of the actively eroding bluff puts groundwater at center stage as the cause of slope instability.

The project area has been monitored for the past four years with respect to slope displacements versus causative factors by investigators at Western Michigan University. Study results demonstrate the significance of groundwater activity as the prime contributor to bluff movements, and that slumps are most prevalent when perched ground water levels are high regardless of wave activity or lake level. Thus, bluff dewatering technology will be evaluated that this location to reduce or eliminate coastal bluff instability. If proven functional, the dewatering of shoreline bluffs will be an inexpensive, non-invasive, and effective method of erosion control.

The fourth full demonstration site to design an implementation strategy this fiscal year is Gilgo Beach, New York. Gilgo Beach is 4.8 km long portion of a barrier beach located on the South Shore of Long Island, New York, between Jones and Fire Island Inlets. Northeasters and hurricanes periodically impact the southern shores of Long Island. These storms produce tides and waves, which cause dune erosion. Offshore wave heights recorded offshore during the December 1992 storm were as high as 9 m. The only existing form of beach erosion control at Gilgo beach is the placement of sand material removed from Fire Island Inlet every two to three years. An engineered berm, with an elevation of approximately 3.6 m above mean sea level, provides protection to a roadway located immediately landward of the beach. Shore protection structures such as timber groins and bulkheads have been destroyed by wave action.

At Gilgo Beach, the New York State Department of Environmental Conservation will serve as a cooperating partner, and three methods of open-coast dune restoration and stabilization are proposed for investigation. The first is the combination of a timber or recycled plastic horizontal lattice structure and dune grass plantings. The concave-shaped lattice structure will be located in the seaward face of the dune. Vegetation will be planted between the plank members. The second method of dune stabilization investigated will be an expandable 3-D sand confinement grid system that is under development for use in inland flood control. The geosynthetic grid cells will provide a protective framework for the engineered dune, and dune grass will be planted within the cells of the structure. Dune restoration via use of recycled glass combined with vegetative plantings will also be demonstrated at this site.

The four demonstration sites will be constructed and monitoring programs initiated in fiscal year 2001. Implementation plans for remaining demonstration sites will be developed with construction targeted for fiscal year 2002. The performance of all demonstration projects will be monitored under the Section 227 Program for a minimum of three years. Additional information regarding the National Shoreline Erosion Control Development and Demonstration may be accessed via the Internet at http://chl.wes.army.mil/research/cstructures.

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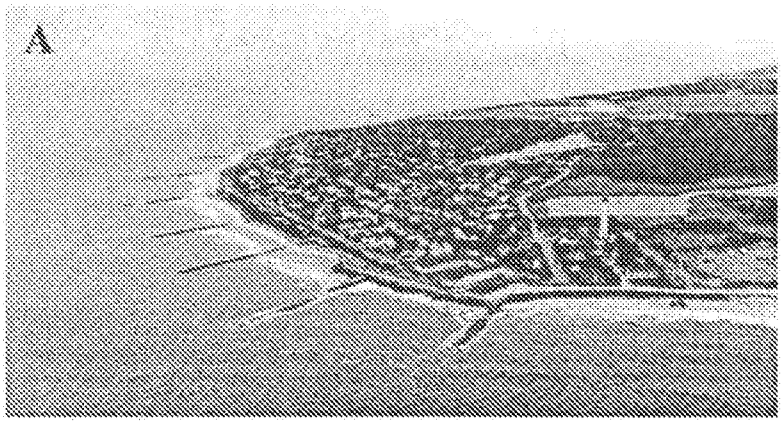

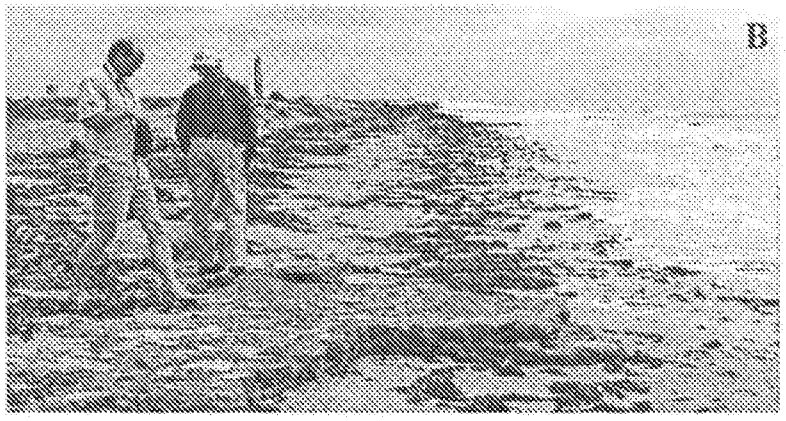

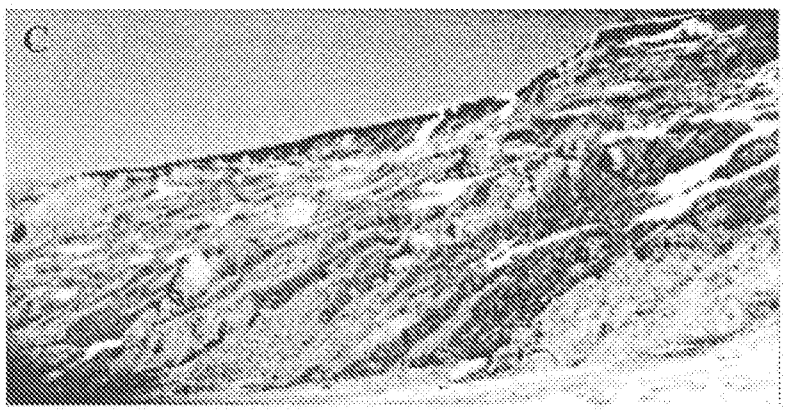

Figure 1. (A) Groin compartments at Cape May Point, NJ. (B) Eroded cohesive layer outcrop at Jefferson County, TX. (C) Frozen perched groundwater seeps in coastal bluff at Allegan County, MI.

CHICAGO'S WORLD-CLASS URBAN SHORELINE: A UNIQUE MODEL FOR COASTAL CITIES

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ABSTRACT

Chicago is a unique coastal city with a constructed shore dominated by public land devoted to parks, marinas, lagoons, and beaches, all designed for aesthetics and urban enhancement (Fig. 1). The shoreline stretches 27 miles (43 km) along the southern reach of the western shore of Lake Michigan between the city of Evanston on the north and the Illinois-Indiana state line on the south. Industrial, commercial, and residential land uses along the Chicago coast are limited to concentrated areas at the northern and southern reaches of the city shoreline, but even many of these non-public shore areas are segmented by neighborhood and street-end public parks and beaches. Long-term planning by the City of Chicago and the Chicago Park District proposes parkland and beaches along nearly all of the remaining non-public shore, in some places by making land acquisitions or requiring shoreline public access in redevelopment, and in other places by possibly constructing offshore island lakefills to create an uninterrupted park system that bypasses these private segments.

The history of building the Chicago lakeshore into one of the most accessible and aesthetic urban shorelines in the world is a unique case study. This history includes elements of ambitious landscape architecture and urban planning, innovative and extensive coastal engineering, and a government and private-sector commitment to a vision for more than 100 years.[1] Filling into the lake to make a new urban shore was the key factor, thus far resulting in 5.5 square miles (14 km^2) of lakefill that required a total estimated fill volume of 57 million cubic yards (44 million m^3). Local coastal geology provided a favorable setting for the construction. A gently sloping lake floor provided an opportunity to construct lakefills out to as much as 3/4 mile (1.2 km) offshore. Beneath a natural sand veneer, the subbottom is a thick sequence of compact clay (clayey till) well suited for driving and supporting wood or steel piles. Major offshore sand reservoirs at the southern end of the lake were readily accessible to hopper-dredge ships, which mined and delivered this sand for clean fill and beach construction. Local coastal processes posed several challenges. Storm waves may reach 10 to 12 feet (3 to 3.6 m) in the nearshore, coastal ice could destroy shore structures, and yearly and long-term lake-level fluctuation of several feet were necessary design and construction factors.

Coastal engineering began on the Chicago shore in 1833 when jetties were constructed to straighten the mouth of the Chicago River, then used as the city harbor. Associated problems of updrift (north) accretion and downdrift (south) erosion from the jetties resulted in a variety of engineering projects into the 1860s, including construction of an offshore railway on trestles to aid in erosion control along the downdrift shore. Although some lakeshore park projects were being constructed in the 1870s and 1880s, it was the 1893 World=s Columbian Exposition held on what is now Chicago's south lakeshore (Jackson Park) that was a benchmark event in influencing subsequent lakeshore development. The grounds of this exposition provided an opportunity for landscape architect Frederick Law Olmstead (1822-1903) and building architect Daniel H. Burnham (1846-1912) to demonstrate the possibility of creating a lakeshore urban park by sculpting the shore through dredging and filling. Burnham and an associate were subsequently commissioned in 1902 by the Commerce Club of Chicago to develop an urban plan for Chicago. Completion of this commission resulted in the 1909 publication of *Plan of Chicago*,[2] that included the design concept for constructing a grand-scale park system along Chicago=s shoreline by filling and dredging to make a new shore with islands, peninsulas, lagoons, and promontories. By the 1920s this plan was influencing lakeshore park development, and in the late 1920s the plan was closely followed in building lakefill for the second of Chicago=s world fairs, the Century of Progress World Fair, held along the shore in 1933-34.

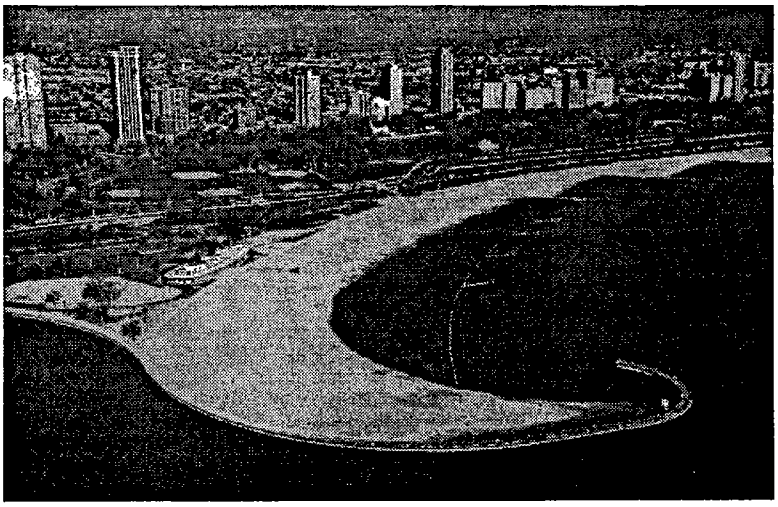

Figure 1. The groin at the downdrift (south) end of North Avenue Beach is one of several arcuate groins along the Chicago shore that provide form, function, and access. A submerged bulkhead supports this perched beach. The bulkhead is held by a series of emergent support columns that here look like a dotted line (Photo by Illinois State Geological Survey, May 2000).

The peak of lakeshore park construction occurred in the 1920s and 1930s (*i.e.*, between the two world wars). Some additional work occurred in the 1950s. The North Park and South Park Commissioners, consolidated into the Chicago Park District in 1934, designed and oversaw construction. The primary contractor was Great Lakes Dredge and Dock Company, then headquartered in Chicago. Their fleet of hopper-dredge ships, scows and barge-mounted pile drivers were critical in the construction that was primarily an offshore operation until all lakefilling was completed. All costs were paid by the City of Chicago and the Chicago Park District with an estimated $500 million to $1 billion invested between 1920 and 1940. Typical construction consisted of first building the lakeward edge for the lakefill by driving wood pilings to form a 20-foot (6 m) wide, rock-filled timber crib. Fill was placed landward of the crib. Overlying the crib was a series of 3.5- to 8-ton dolomite quarry blocks that formed an above-water, stepped revetment. These blocks provided public access along the water edge as well as erosion defense. The lakefill surface reached the crest of these blocks. The cribs were generally built in water 10 to 12-feet (3 to 3.6 m) deep, but some segments were in water as much as 20-feet (6 m) deep. By the 1950s, all construction used steel sheetpile for the crib walls. Consistent with Burnham's design concepts, the lakefill edge was built in a sculptured, curvilinear form to create a varied shore plan.

Deep water along the lakefill edge precluded the construction of beaches along many shore segments. Where many of the beaches were built, the lakefill was designed to re-orient the shore toward the principal wave approach (north-northeast) to minimize longshore transport and sand loss. A wide, pier-like groin on the downdrift (south) end of these beaches served the dual purpose of sand retention on the beach and providing public access for fishing and shoreline vistas. Perched beaches were also constructed. North Avenue Beach, built in the 1930s, is a perched beach stretching 5400 feet (1646 m) and held by a submerged bulkhead of steel sheetpile (Fig. 1). Although now one of the city=s most popular recreational beaches, the original purpose of this perched beach was primarily erosion protection for the adjacent Lake Shore Drive.

The quality of design and construction of Chicago's shore structures is well demonstrated by the fact that many of them still function today, even some of the timber structures built in the late 1800s which have now served for over 100 years. This is a tribute to the engineers who did the design and construction, much of which was done before coastal engineering manuals were available and while Chicago's coastal dynamics were still being learned. Trial and error was a factor, but the Chicago Park District also built its own wave tank to evaluate design concepts.

By the late 1980s, the growing deterioration of many sections of the timber crib revetments was apparent and became a major public issue (Fig. 2). Record-high lake levels (more than 3 feet [1 m] above the historical mean) combined with settling and localized collapse along the revetments posed an erosion threat to the city's lakefill edge. Through the early 1990s, design and engineering progressed on a lakeshore rebuilding effort that would eventually cover all 27 miles of Chicago shoreline.[3] Key to this project is rebuilding the shoreline revetments by placing steel sheetpile lakeward of the existing structures,

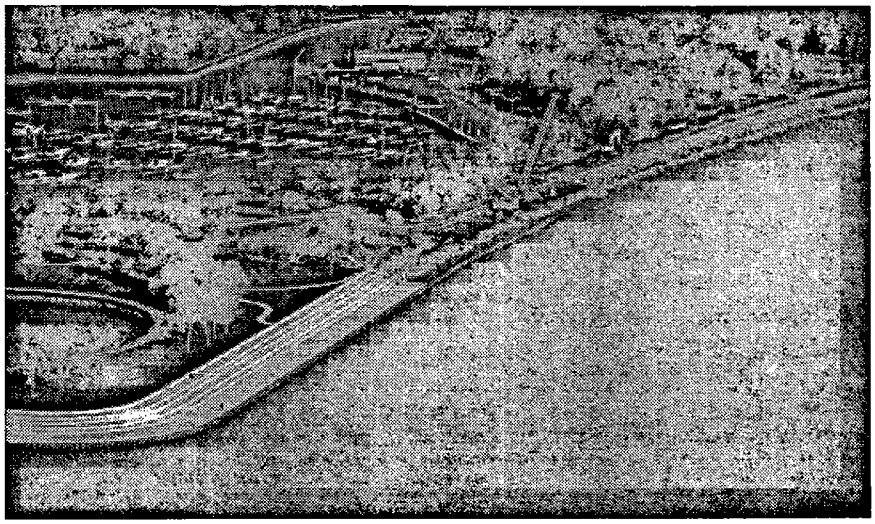

Figure 2. The rebuilding of Chicago=s revetments is systematically progressing along the shore. In this view near Belmont Harbor (upper left) a reach of deteriorated timber and quarry-stone revetment is visible on the right, a revetment segment being prepared for reconstruction is in the center, and a section of replaced revetment built with reinforced concrete and a steel-sheetpile edge is on the left (Photo by Illinois State Geological Survey, May 2000).

burying the existing structures under fill, and building new stepped revetments of reinforced concrete. The planned 10 to 15-year rebuilding effort is an estimated $300 million project involving a local, state, and federal partnership. The Chicago District of the U.S. Army Corps of Engineers is the lead agency. Federal interest in the project in part relates to protection of Lake Shore Drive, a segment of U.S. Highway 41, which extends along the length of the lakefill.

Chicago's park-dominated shore did not come about without conflicts, such as numerous legal actions needed to adhere to the commitment to this public land use.[4] However, several favorable factors were at work. For example, because of regional development trends, land uses associated with maritime commerce, transportation, and industry had shifted away from most of the Chicago lakeshore by the 1800s, freeing the shore from these traditional activities of an urban coast. State law allowed lakefilling for making public land. Furthermore, coastal development updrift of Chicago was hardening the shore and diminishing sediment input to the littoral stream, thus diminishing potential problems of the Chicago lakefill projects that would have occurred with a more robust littoral transport.

The Chicago coast is deserving of recognition as a world-class urban shoreline because of its unique combination of engineering and architectural design, the exceptional accessibility it provides to the public along nearly all of the city's shoreline, and its durability in withstanding both the impacts of natural coastal processes and high-volume usage of an urban setting. As the shore rebuilding efforts continue, it is a policy of the Chicago mayor's office to identify and pursue opportunities for recreational, educational, and aesthetic enhancements along the shore. Today the Chicago coast is in transformation to an even more durable, more functional, and more aesthetic resource than it ever was in the past.

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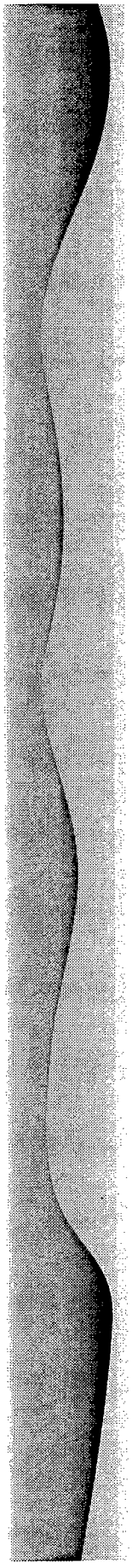

DEVELOPMENT OF AN EROSION CONTROL SCHEME FOR KUALOA REGIONAL PARK, OAHU, HAWAII

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ABSTRACT

Kualoa Regional Park, located on Oahu, Hawaii, has an "L" shaped shoreline approximately 4,000 feet long that has been eroding for over 100 years. Average shoreline erosion of 3-7 feet per year over the past 50 years has been estimated from aerial photographs. Kualoa Beach is fronted by an extensive shallow reef flat that limits wave heights at the shoreline to less than 3 feet.

Oceanit Laboratories, Inc. conducted bathymetric, sediment, wave, and current investigations and concluded that the erosion is caused by a relatively strong longshore current produced by the interaction of waves with local topography. The longshore current is driven by water pumped by breaking waves over the seaward edge of the reef about 2,000 feet offshore. The wave-pumped water flows parallel to the beach before returning offshore through a deep channel dredged in the reef. The current moves sediment suspended by relatively small waves and deposits it on nearshore sandbars.

A physical model with 1:100 horizontal scale and 1:20 vertical scale was designed and constructed at the J.K.K. Look Laboratory to evaluate proposed erosion control schemes. To reproduce the complex wave and current conditions in the model, two wave generators (at different angles) and a pumping system were used. Current patterns were reproduced by controlling the pumping rate and by using a system of inlet and outlet weirs on the model boundaries. A mathematical model was run in parallel with the physical model to simulate sediment transport and beach shape.

Model current patterns were determined by tracking floats with a video camera mounted above the model basin. Six to nine floats of varying shape and color were photographed and velocity determined using image processing software. Resulting beach shapes were photographed and measured.

Several erosion control schemes were evaluated and a preferred scheme optimized. The best performance resulted from a combination of groins, offshore breakwaters, and beach nourishment.

SUNSET BEACH COASTAL ENGINEERING ANALYSIS

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ABSTRACT

Sunset Beach is a popular beach on the north shore of O'ahu known for its natural beauty and large waves. The recent construction of a small park area on the *mauka*, or mountain side of the coastal highway is the first of proposed improvements by the City and County of Honolulu. Sea Engineering, Inc. (SEI), was asked to conduct a coastal engineering analysis of the site to be used as a basis for recommendations for the project. Engineering analyses included beach profile measurements, a wave height distribution analysis from historical wave data, wave refraction analysis, and a wave runup analysis.

Comparison of aerial photographs from 1949 to the present showed the gradual deterioration and recession of the vegetation line over the years from a once lush condition to its present degraded state. A 20-ft recession of the vegetation line in the late 1960's and early 1970's is thought to be attributable to the combination of one of the largest swell events on record coupled with a surge in popularity of surfing on O'ahu's North Shore. Photographs taken during the large northwest swell of December 1969 indicate inundation of the entire vegetated berm at Sunset Beach. This extreme wave event, combined with increased foot traffic due to the expanded popularity of surfing in the 1970's, probably initiated the destruction of most of the vegetation on the ocean (or *makai*) side of the highway.

The coastal highway itself is built on a 27-foot high berm behind the beach that is thought to have been built by waves during extremely high wave events. It was the desire of the City and County to build a sidewalk and decorative structures on the berm on the *makai* side of both the highway and the present vegetation line. In order to determine whether such structures were feasible to build given the site wave climate, SEI decided to calculate the recurrence of extreme wave run-up conditions.

Figure 1 is a beach profile taken at the site during a week of small wave conditions in the middle of the winter high surf season. Features labeled on the profile include a bicycle path (recently completed at that time), and beach features including the active beach profile, and a storm profile inferred to exist during extreme wave conditions when erosion of the active profile takes place. Elevations of key features are shown in Table 1. At the time of profile measurements the storm berm was almost 20 feet above the crest of the active profile, an elevation difference indicative of the dynamic range of this beach.

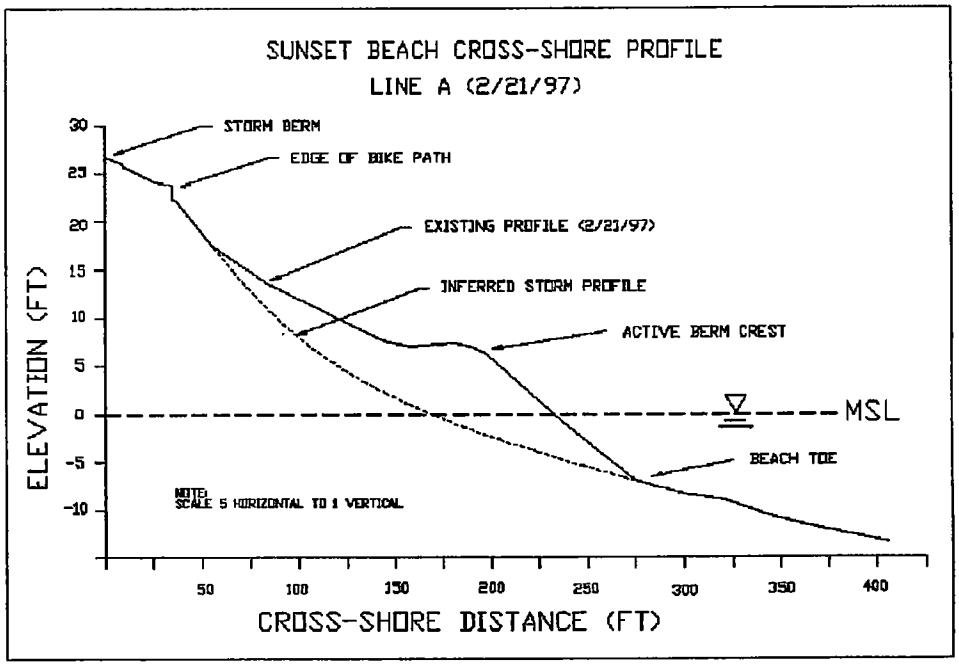


Figure 1. Beach Profile at Sunset Beach

Wave run-up is the furthest landward extend of wave

Table 1. Profile Elevations

Feature	Elevation (ft-MSL)
Road Crest (Crest of Storm Berm)	27.0
Bike Path (top)	24.0
Bike Path (bottom)	22.3
Active Berm Crest	7.4
Beach Toe	-7.0

Table 2. Return Period Wave Heights

Return Period (Years)	Significant Wave Height (ft.)
1	15.9
2	17.9
5	20.5
10	22.5
25	25.2
50	27.2
100	29.2

action, and its calculation requires a full suite of oceanographic input parameters: incident deepwater significant wave heights are transformed by refraction, shoaling, and wave breaking to wave heights incident at the shoreline. The water levels that control these phenomena are complicated by wave set-down and wave set-up caused by the breaking waves. The incident deepwater waves used were from a data set measured off of Barking Sands on the west side of the island of Kaua'i between 1982 and 1991. Yearly wave height maxima were plotted using Gumbel's first asymptotic distribution for extreme values, and used to generate Table 2, the return period of deepwater significant wave heights.

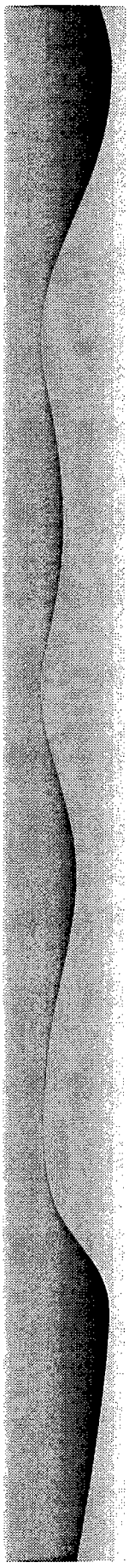
The numerical wave run-up model used was developed at SEI and combines the runup equation proposed by Mase (1989) with Saville's (1956) method of composite slopes used in the Shore Protection Manual (USACE, 1984). A total of 4,311 wave observations from a joint significant wave height and peak wave period distribution were input in to the model and used to calculate a wave runup distribution. An extreme value distribution was then calculated to generate the return period of maximum runup elevations shown in Table 3.

Table 3. Return Period of Runup Elevations

Return Period (Years)	Runup Elevation (ft.-MSL)
1	25.3
2	25.9
5	26.5
10	26.9
25	27.3
50	27.7

The 50-year runup value is only 2.4 feet, or less than 10 percent, higher than the annual extreme runup elevation despite the 50-year deepwater wave height being 70 percent higher than the annual extreme wave height. There are two reasons for this. First, the larger waves break offshore in deeper water, dissipating their energy well seaward of the shore. It is the high water levels due to wave setup generated by the large incident waves that allow higher wave heights to reach the shoreline and runup on the beach. Second, runup levels are strongly dependent on wave period, with longer period waves generating higher runup levels. It is not necessarily the highest waves that generate the highest runup: some of the larger incident northwest swells in Hawaii are generated by relatively nearby storms and consequently have shorter wave periods than slightly smaller incident waves that might have been generated by even larger storms many thousands of miles further away. The use of a joint distribution of wave heights and wave periods was therefore extremely important for this study.

The runup results show that, as suspected, the high berm behind Sunset Beach (and indeed along most of O'ahu's North Shore) was likely generated by sediment deposition by wave runup during extreme wave events. Overtopping of the bike path can be expected to occur annually, and much of the road can be expected to be overtopped every 10 years. As a result of these high runup values, SEI discouraged construction on the *makai* side of the highway. Instead, the City and County of Honolulu was encouraged to plant vegetation for landscaping, enhanced sand accretion, and guidance for foot traffic. Increased maintenance of the beach was also encouraged, whereby vegetation damaged by an erosion event would



be replanted, and the high storm berm replenished if necessary with sand from the active profile lower on the beach.

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BEACH NOURISHMENT IN CALIFORNIA FOR THE NEW MILLENIUM

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ABSTRACT

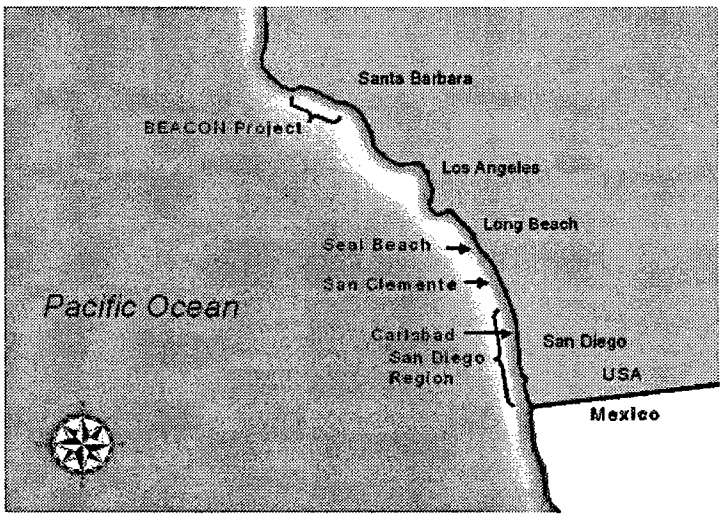
Approaches to beach nourishment in California continually progress to adapt to ongoing challenges. Sensitive resources adjacent to severely eroded beaches present conflicting interests to be addressed in beach fill planning and design. Lack of funding and sand sources also plague projects. Californians creatively address these issues, as demonstrated by the projects presented herein.

Three subtopics are presented. The first relates to planning the nourishment needs of an eroded region against constraints posed by extensive sensitive biology. The second is a non-traditional approach to obtaining sand as sources continue to become less available; and the third is maximizing project effectiveness and performance through consideration of sand quality as well as quantity. The attached figure shows the Southern California region within the State of California, and individual project areas discussed in the presentation.

REGIONAL NOURISHMENT

The San Diego Regional Beach Sand Project to be constructed by the San Diego Association of Governments (SANDAG) is to place two million cubic yards of sand on thirteen County beaches as a pilot regional nourishment project. The entire San Diego project region is basically an eroded shore with a deficit in the sediment budget. The project is proposed as an initial attempt to renourish the region based on needs identified in the regional Shoreline Preservation Strategy (SPS) (SANDAG, 1993). It is a pilot project to implement the concept of dredging from borrow sites offshore and pumping sand onto receiver sites. The SPS identifies the need for thirty million cubic yards of nourishment to provide beach widths sufficient to protect back shore areas from storm damage. The project is therefore a relatively small project in relation to the region's needs, but is important in that it represents the first major attempt to place beach fill amongst sensitive habitat areas.

Shoreline erosion over the last twenty to thirty years has left areas once covered with a sand layer as exposed bedrock. The bedrock areas have subsequently been colonized by marine habitat such as surfgrass and kelp, which are considered sensitive. The erosion has not only reduced beach widths, but has lead to conditions conducive to formation of considerably constrained areas for beach nourishment. Other biological constraints facing the project include five lagoons within the littoral cell. Lagoon restoration has occurred at one of the sites and is planned for two more. Another lagoon serves as the cooling water supply for a major energy supplier to the region. Needless to say, maintenance of the lagoon inlets is important for their vitality and to the habitat quality of the region.



Project areas for beach nourishment.

The project was planned to provide maximum benefit while minimizing impacts. The approach was to predict sand dispersion and spreading in the vicinity of

sensitive habitat areas and lagoon inlets, and modify the project if impacts were anticipated. Extensive analyses were performed to predict the sand spreading in three-dimensions. Three-dimensional numerical models do not exist to address the system as a whole, so a method was developed to use several linked modeling techniques to predict sand dispersion.

The technique involved using predicting a shoreline position using an accepted numerical model, then predicting the corresponding beach profile using analytical methods (National Research Council, 1995) and translating the results into a depth of sand cover over resources. The depths of sand cover were mapped, then compared with maps sensitive biology data to assess impacts. Several sites shown potential impacts to biology, so the project was modified as a result to minimize environmental impacts. Also, estimates were made of the increases in shoaling at lagoon inlets from the shoreline evolution analysis. Sand placement and quantities were adjusted through iterations to minimize impacts while still providing for the full quantity to occur for regional project to nourish the littoral cell.

Environmental review of the project has been completed and permitting agencies are considering approvals. The project is scheduled to be constructed in Spring of 2001. Extensive monitoring with beach profiling, habitat measurements and shoaling measurements will occur to quantify impacts. Mitigation will occur to offset impacts.

OPPORTUNISTIC BEACH FILLS

As another approach, opportunistic beach fill programs secure pre-approved permits to obtain surplus sandy material from upland construction projects, harbor maintenance projects and flood control maintenance projects as beach fill. If the fill material meets pre-arranged criteria, it represents is a low cost source of material. Three cities and one regional group are implementing opportunistic beach fill programs. The programs specify acceptable material gradation, chemistry, color, locations of placement, timing and rates of placement, concept designs and monitoring (Moffatt & Nichol Engineers, 2000). The programs serve to streamline permitting, maintain larger-scale nourishment projects and direct sand to starved coasts.

General permits would be issued to applicants that cover pre-arranged project scenarios. The general permits would provide limited discretion to the local agencies in approving potential projects, with advance notice being provided to permit agencies as each opportunity comes on-line. Implementation of the programs requires user-friendly information to be used by local agency (City or County) staff as a guide to project processing. For instance, guidelines are provided to staff in the form of a checklist that is used to screen each incoming local project application for potential as an opportunistic sand source. If a source is identified, staff then follows an established protocol to notify the agencies, and to implement projects while complying with requirements of the general permits. Implementation will include monitoring as needed.

Out of practicality, contractors historically dispose of surplus material in the least costly manner which is typically land-based. The City of Carlsbad is considering establishing incentives to reduce the costs of discharging the material at the beach if it is not the least costly option. These may include waivers to City processing fees or other mechanisms to reduce costs to contractors. The Beach Erosion Authority for Operations and Nourishment (BEACON) is recommending that local agencies pass ordinances requiring beach discharge of suitable upland material from projects, thus encouraging contractors to creatively reduce costs to meet the requirement.

PROJECT OPTIMIZATION

Finally, projects are being analyzed to optimize sand characteristics for nourishment. While a solution to a deficit in the sediment budget is typically adding sand to the system to restore the balance of the budget, sand quality is as important as sand quantity. Seal Beach is an eroding city that needed a certain sand quantity to restore its sediment budget. Shorefront development floods nearly every winter when high tides combine with high winter waves. Two sources of sand were available for consideration at the time: 1) fine-grained sand from an adjacent harbor channel and 2) coarse-grained sand from an inland river quarry. The fine harbor sand was much less costly than the coarse quarry sand.

Wave energy at the eroded City beach is higher than at nearby areas, so sand is more easily mobilized and transported downcoast. The City therefore considered larger-grained sand for nourishment to reduce downcoast losses. An analysis of equilibrium beach profile evolution with both sand sources was performed to determine the comparative benefit in beach widening from using the fine versus coarse sands (National Research Council, 1995). The analyses showed that using a smaller quantity of the coarse sand would create a wider berm with improved protection compared to using a larger quantity of fine sand.

The City purchased the greatest quantity of the coarse quarry sand possible with their budget (75 percent funded by the California Department of Boating and Waterways and the remaining 25 percent by the City) and built the project from Fall of 1997 through Winter of 1999, with a one-season interruption. Observations and measurements indicated that the coarse sand remained on beach throughout the El Nino winter of 1997-98, substantially widening the beach and preventing flooding of shorefront homes and public facilities (Moffatt & Nichol Engineers, 2000). The City will maintain the project by regular renourishment in the future using the coarsest sand available.

CONCLUSIONS

As large portions of the Southern California coastline are eroding, beach nourishment is increasingly sought to solve the problem. Various approaches are employed, ranging from large-scale regional approaches within an entire littoral subcell to smaller-scale approaches within local agency boundaries. Both approaches have merit, and face inherent challenges. One major challenge facing project proponents and regulators is weighing the importance of sensitive marine habitat versus the public benefits of wider beaches. Regional projects tend to have greater difficulty circumventing sensitive habitat issues than local projects due to the larger sand quantities involved and longer receiving shorelines. Local projects can isolate placement in less sensitive areas and typically propose less sand for fill. Techniques are available and are evolving to estimate environmental impacts of projects, and monitoring is required to confirm the predictions.

Opportunistic programs to nourish beaches with surplus construction material represent the first systematic and regulated attempt to steer contractors away from land-based disposal options. In this way, beach discharge may become a more common destination for upland material. Sediment that could have eventually been transported to the littoral cell under natural (pre-development) conditions can resume that path to nourish the beach. These programs have yet to be implemented so their success is yet to be determined.

Finally, nourishment projects can be successful if planned and implemented in close accordance with site-specific needs. Project success needs to be defined at the outset for objective assessment, and identification of needed modifications in the future. Project success at Seal Beach was defined as providing complete protection to back shore facilities during a severe winter storm, and this criterion was realized by using sand of a specific quality. Sand that was more costly and less abundant was used for fill. The City consequently had less sand for their project, but the sand was of a grain size more conducive to achieving project success. This occurred although a larger volume of less costly sand that was finer in grain size was also available. Understanding of site conditions, responsive planning and defining success criteria can help to improve chances of achieving success.

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THE TEXAS COASTAL EROSION PLANNING AND RESPONSE ACT AND THE FUTURE OF THE TEXAS COAST: THE INTEGRATION OF COASTAL EROSION PROJECTS AND HAZARD MITIGATION MEASURES INTO GIS

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ABSTRACT

The Texas General Land Office (GLO) is currently implementing the Coastal Erosion Planning and Response Program, which was authorized and funded by the 76th Texas Legislature in 1999 through the Coastal Erosion Planning and Response Act (CEPRA). This legislation has given Texans, for the very first time, the tools to fight coastal erosion in bays and on Gulf of Mexico beaches that threatens: (1) public beaches, (2) public infrastructure, (3) homes and businesses, and (4) coastal natural resources. The effort to develop the first Texas coastal erosion response program has required strong collaboration between the GLO, federal and local governments, and most important, the citizens of our coastal communities.

The first 27 CEPRA projects to be considered in the 2000-01 biennium were announced by Texas Land Commissioner David Dewhurst on February 2, 2000. The characteristics of these projects are very diverse and well distributed among bays and beaches (Figure 1). The projects include: bay shoreline erosion control, beach erosion control, marsh restoration, wetland restoration, beach nourishment, dune protection/restoration and enhancement, and beneficial use of dredged materials. The CEPRA program represents the state's coastal erosion response policy and must deal with a diverse coastal morphology shaped by very complex processes.

Historically, coastal erosion in Texas has had tremendous impacts to society and on natural resources. Texas has 367 miles of Gulf of Mexico beaches with about 90% located on barrier islands. Of these beaches, about 80 miles are fully or partially developed; 150 miles are Coastal Barrier Resource System Units, including wildlife refuges, state parks, and coastal preserves; and about 137 miles could be developed in limited ways. The range of long-term erosion rates (depending on location) is between two and 30 feet per year, having an average long-term rate of six feet per year.

In order to address coastal erosion and to guarantee the long-term success of the CEPRA program, project plans will include the consideration of coastal hazards and hazard mitigation measures. Also, the GLO has incorporated two main tools in the CEPRA process: the use of GIS technologies, and the short- and long-term hazard mitigation philosophy. The Coastal Projects division of the GLO is using geographic information systems (GIS) to monitor the impacts of coastal erosion and other potential coastal hazards. Also, mitigation actions are being included to protect against the erosion and storm impacts. Different scenarios determined by GIS data analysis are being created for long-term solutions to each project. The information used in bays and beaches for these scenarios includes: rates of erosion; updated aerial photos; geology; geomorphology; environmental sensitivity index; faulting; storm surge modeling; wetland inventory; historic shorelines changes; subsidence; washover features; ebb channels; historic storm impacts; public infrastructure; distribution of urban development; and state and local regulations as observed in the field.

Incorporated into daily functions of the CEPRA program, GIS is used as a tool to analyze, monitor, and illustrate dynamic coastal processes. GIS is effectively tracking shoreline changes and sediment budgets, when available. As part of the hazard mitigation component the GLO has defined the interactions between shoreline erosion and property damage. In the near future, GIS technology will be integrated with customized Web-based applications to provide CEPRA project information to the public on the GLO Web site. The locations of the projects, symbolized by point or area features on a map, will "hotlinked" to critical pieces of information—aerial and on-the-ground photographs, construction plans, text descriptions, informative charts—documenting the development and maintenance of erosion control projects on the

Texas coast. The information will provide a historical record and valuable insights on the techniques and benefits of effective and environmentally-sound erosion control practices. Other information accessible through the GLO Web page includes public concerns about each project, information suggested by local partners, legal information, historic records, and information on professional service providers.

In the big picture, the GLO is encouraging local partners in the CEPRA projects to improve their practices in hazard mitigation, as an important tool to properly manage coastal erosion and coastal hazards. Coastal processes and other considerations are being factored into planning for appropriate sustainable coastal development. These considerations include: erosion rates and washover locations; the use of historic information to determine how storms have affected coastal processes; the recognition that roads alter the flow of flood waters in beach front development; and the creation and maintenance of a healthy dune system through an effective dune management program. This last element has proved to be critical in effectively controlling coastal erosion. Experience with past storms has shown that natural dune systems have acted as a natural shock absorber for wave energy during storms, have offered protection to property landward while providing a sand source for the beach, have been a self-sufficient and low-cost alternative for erosion response projects, and have created an aesthetically-pleasing natural landscape after storms.

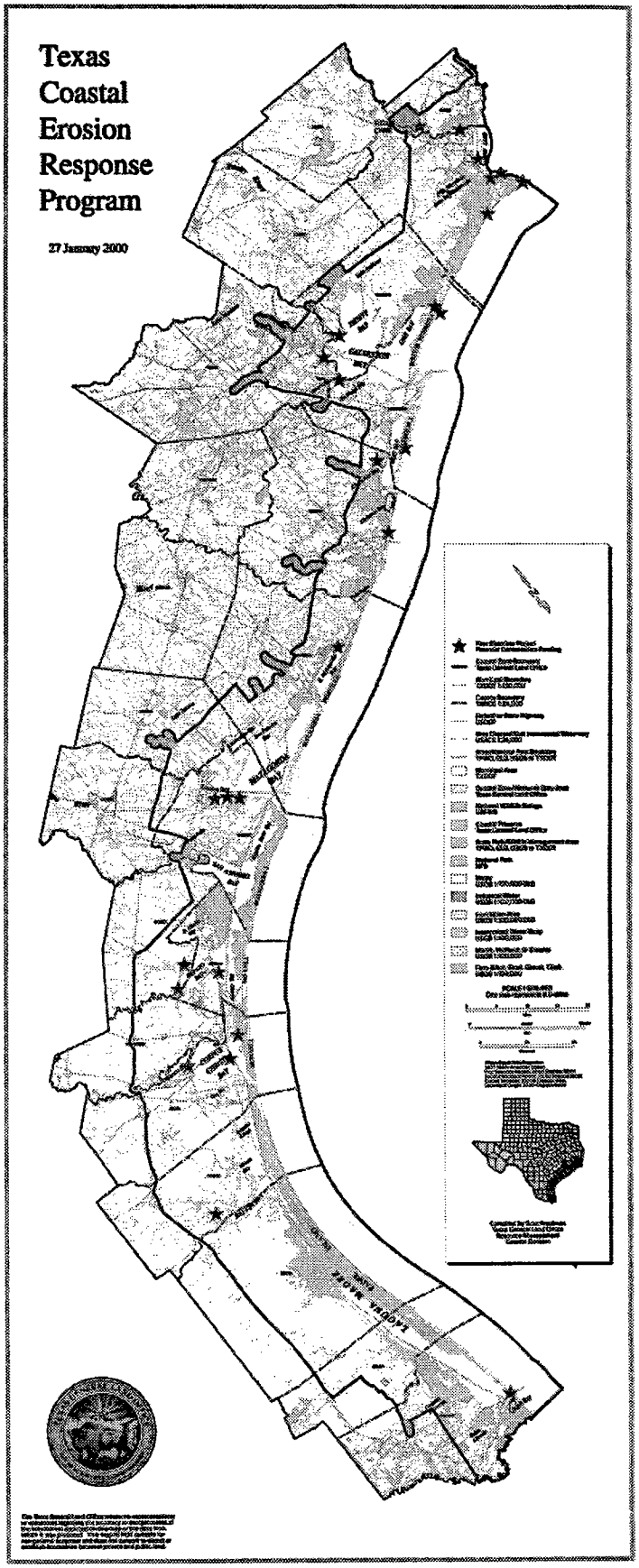

Figure 1. Distribution of CEPRA projects on the Texas coast.

GEOTEXTILES IN THE MARINE ENVIRONMENT - STATE OF THE PRACTICE

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ABSTRACT

INTRODUCTION

Geotextiles have been used in the marine environment, in a variety of applications, for at least 40 years. The first uses in the United States were filter fabrics designed to replace graded granular filters under revetment stone or block. The U.S. Army Corps of Engineers added considerable credibility to the use of woven geotextiles in the early years by publishing the first comprehensive specification for plastic filter cloths (Calhoun, 1972)[1]. Since that time, the use of geosynthetics has grown steadily, although design guidance has been sporadic.

Today there are a wide variety of woven, nonwoven and extruded geosynthetics used in coastal protection and waterway restoration projects. Geosynthetics include woven and nonwoven geotextiles, geogrids (marine mattresses), geowebs, geotextile tubes, large sand bags, and erosion control blankets to name a few. Such a wide variety of products can provide cost effective engineering solutions and can also be a source of confusion which can lead to misapplication.

There is an extensive history of projects from which lessons can be learned, and several projects that have been analyzed after decades of service life, such as Christopher and Valero, 1999[2]. These case histories show that when the right product is used in the right application, designed and installed correctly, geosynthetic products have performed well.

Geotextiles enhance the survivability of many restoration projects and coastal structures and can allow cost-effective construction in areas where traditional methods are either too expensive, too detrimental to the environment or just will not work. This paper reviews the state of the practice of geotextiles in marine applications, and describes in more detail the design considerations of geotextile scour aprons, large geotextile tubes, and geotextile underlayment for revetments and other structures.

The first component of any successful marine project hinges on the engineering design, specifically the geotechnical and hydraulic design, of the structure. Similar to constructing with natural products such as stone and sand, designers and installers must have some familiarity with manufactured products (such as pre-cast concrete units, sand-filled geotextile tubes or stone-filled marine mattresses) and how they work in the marine environment. Likewise, the quality of a manufactured product is as important as the quality of stone used in a breakwater or jetty. Manufactured products such as geosynthetics have the benefit of manufacturing quality control and index testing. ASTM test specifications exist for many of the most important strength and hydraulic design attributes, however applying the numerical value of those tests to a particular product to insure a well-designed coastal project is far from obvious. For example, two filter fabrics can have similar tensile strength, Apparent Opening Size (AOS) and permeability and yet one may have a higher propensity to clog under certain conditions, subsequently leading to failure. To aid the designer, both ASTM and the Geosynthetic Research Institute have published various guidelines and specifications for material properties, thus creating industry standards for particular applications.

FILTER FABRICS

The Coastal Engineering Manual, presently being revised at the Corps' Waterways Experiment Station, is expected to have a section on "geotextiles and plastics". This section will include references to ASTM test methods as well as some discussion on the use of geotextiles as filters. Of particular note, is

the reference to "piping resistance" which is the capability of a geotextile to retain soil while allowing water to pass (Calhoun, 1972).

Calhoun's work set the stage for an ongoing debate regarding the most appropriate type of geotextile to use as a filtration and separation fabric in coastal structures. That document recommended that "only woven filter cloths with distinct openings" be used, and that "in any application, the EOS (today more often referred to as AOS) should not be finer than the No. 100 sieve and the open area no less than 4 percent." These criteria define modern woven monofilament filtration fabrics. Additionally, Calhoun reported that the nonwoven fabric tested had a maximum clogging ratio of 1.98 with soil having 10 percent silt.

Clogging of a geotextile can result in excessive pore water pressure behind a structure resulting in failure during rapid draw down. Bulging of filter cloth behind a riprap, marine mattress or flexible concrete slope face is usually an indication of fine-grained particles clogging the filter fabric.

Among designers, however, the lines are sharply drawn. Nonwoven geotextiles are inexpensive and on steep slopes may exhibit greater friction with the armor layer. Most structures designed with nonwovens do not clog or result in a failure that is obviously attributed to the filter fabric. Woven monofilament geotextiles are slightly more expensive, however most designers consider that cost to be well worth the insurance against clogging that the monofilament fabrics provide. Woven geotextiles also tend to have greater resistance to abrasion when subject to sand-laden waves. Alexander (1998)[3] performed abrasion testing of various nonwoven geotextiles fabrics under dynamic loading. All the nonwoven fabrics were damaged during the test in a manner similar to that seen in actual installations.

The Hydraulic Engineering Circular No. 11 (HEC-11)[4] avoids the issue of nonwoven vs. woven monofilament by specifying that the permeability of the geotextile must be greater than the permeability of the soil, and by specifying a piping resistance based on AOS of the geotextile and the percent fines in the soil.

GEOTEXTILE TUBES

A use of geotextiles in the marine environment that seems to defy the logic of relating soil size to the AOS of the fabric is geotextile tubes. Geotextile tubes are large tubes fabricated from high strength, woven geotextiles. Tubes are used for constructing jetties, groins, and breakwaters, and can be filled with sand or dredged material. Dredged material is often fine-grained with poor construction qualities. Contained and reinforced within a geotextile tube, however, dredged material can be used beneficially to protect wetlands from wave energy or can form a perimeter dike for island restoration.

As the diversity of tube installations grow, it has been observed that the AOS of the geotextile has very little to do with the retention of sediment. Tubes are hydraulically filled, and the combination of pressure, surface tension, and saturated fill material result in efficient retention of very fine-grained sediments.

Similar to filter fabrics, high strength geotextiles used in the fabrication of tubes can be tested using ASTM test methods. Successful design, however, of geotextile tube applications in the marine environment requires more than index testing. It requires knowledge of the capabilities and limitations of the technology. The "Standard Practice for Installation of Geotextile Tubes Used as Coastal and Riverine Structures" developed by the Geosynthetic Research Institute[5] offers basic guidance to the coastal design professional.

Geotextile structures interact with the coastal environment in much the same way that traditional structures work. There are some subtle differences including reflection and energy absorption, and the impact of these structures on local scour. Stability and survivability of geotextile-based structures must also be addressed.

Wave reflection of a structure is often identified as a potential mechanism for scour. Important factors in the extent of wave reflection are wave energy absorption (whether the structure is smooth or rough, rigid or flexible, the response to wave impact, and elevation (as it relates to wave energy transmission), and the angle that the structure presents to the incident wave (vertical, sloped or curved

face).

The coefficient of reflection, C_r, is defined as the reflected wave height, H_r, divided by the incident wave height, H_i. Herbich and Ko (1969)[6] found that the reflection coefficient is dependent on wave characteristics, seawall slope and kinematic behavior of the wave, for example breaking or non-breaking. A vertical smooth wall could, in theory, have a coefficient of nearly 1.0. Herbich and Ko (1969) found coefficients of 30-35% for a smooth seawall at 15 degrees.

Beaches tend to have coefficients of reflection that are much less than most structures, dependent on the beach slope and bathymetric conditions. When the water level and waves reach the base of a dune, waves begin to reflect, therefore increasing the potential for scour.

At any particular point on the face of a geotextile tube, the geometry will affect the possible coefficient of reflection for a particular wave as shown in figure 1.

At 90°, C_r=1.0

At 15°, C_r=0.35

At 0°, C_r=0.0

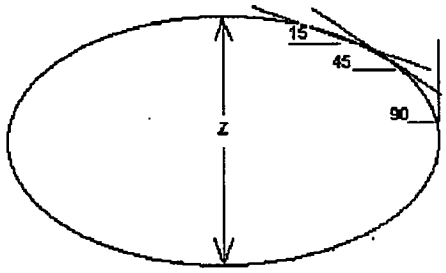

Figure 1.

If the wave height H is less than or equal to the height of the tube Z, then C_r= some function *f* of the surface of the tube. If H>Z, then a certain percent of energy overtopping the tube has a C_r=0. In the case of a stacked tube configuration (see figure 2), the angle that the tubes present to the wave could approximate a revetment with a 30° slope.

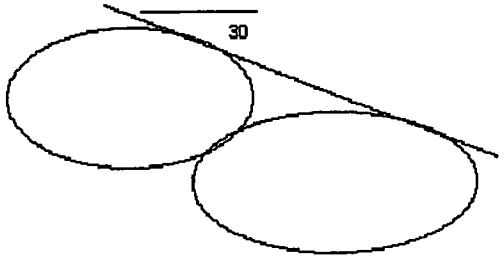

Figure 2.

Eckert (1983)[7] reported that the reflection coefficient is dependent on the structure's geometry and composition, incident wave steepness and relative depth, and foreshore slope. He differentiated between rubble-mound and concrete armor units which are high energy absorbers, and impermeable vertical structures, which are high energy reflectors. There is some question whether wave reflection, due to a dune, a geotextile tube, or a curved-face concrete seawall, has any significant bearing on scour. More recent work such as Kraus (1996)[8] concludes that reflection is probably not a significant contributor to scour.

Any shore protection structure is limited in its ability to protect upland property from damage. Damage occurs due to inundation and overtopping, direct wave attack, erosion and undermining, and wind. Inundation and overtopping are mostly a function of the structure's elevation and the superelevation of waves and tides which occurs during a storm. Wave attack, erosion and undermining are related to wave characteristics and pre-existing beach conditions. Therefore, a shore protection structure is designed to withstand these damage mechanisms up to a certain level, usually define by probability of exceedence. For example, a bulkhead or tube at equal elevations will be overtopped by the same storm event. Based on observation, it appears that more wave energy would be reflected by a bulkhead (affecting the seaward side of the structure) while more water would overtop the curved surface of the tube (affecting the landward side of the structure).

Scour protection is required at the base of any shore-parallel structure. The extent of scour is dependent on many of the hydraulic and geotechnical parameters described above. Typically bulkheads use stone for scour protection with a base width equal to twice the breaking wave height. Tubes typically use a high strength scour apron with a small tube sewn into the seaward edge for anchoring. The width is determined similar to a stone toe.

Other differences exist between bulkheads and sand-filled tubes. Bulkheads form a highly reflective surface thereby increasing wave heights at the structure and also scour potential. Tubes are not rigid and absorb some impact. Bulkheads have far greater depth of penetration into the foundation and are often anchored with tiebacks. Depth of penetration provides stability in the form of passive earth pressures. On the other hand, tubes rely on massive weight. A 30-ft. circumference tube will weigh approximately 4.5 tons per linear foot.

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VALUATION OF BEACH NOURISHMENT: A PRELIMINARY ASSESSMENT OF NORTH CAROLINA PROJECTS

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ABSTRACT

Property tax value increase, increase in tourism or tourist expenditures, increase in numbers of beach-users from within the region or state, creation of greater recreational opportunities, enhancement of environmental conditions and wildlife habitat, and other non-market values are ignored in the cost-benefit (C-B) analysis of nourishment projects. This paper argues that these non-market valuations are as important to the evaluation of beach nourishment projects as the storm mitigation procedures now in use.

Beaches are the number one choice of vacationers in the United States and a major attraction for foreign tourists (Stronge 1998, 1994). A recent study in North Carolina shows that there are approximately 140 *beach users* for every *beach property owner* (Levin 1999). Before exploring the willingness-to-pay for the non-market aspect of beaches, such as recreation, we must first establish the current (pre-nourished) value of the beach. This will be accomplished by extrapolating or transferring costs from earlier studies.

There are few studies published that examine the question of the value of beaches as recreation sites. These studies concern sites in Florida or specific recreation pursuits such as surfing.In North Carolina, we have relatively good surfing and transferring of data from one study to this one should be viable. Finally, while North Carolina beaches do not attract the vast quantity of tourists that Florida beaches do, tourism is the number one industry in North Carolina, so comparisons can be made.

In 1995 A. Myrick Freeman III reported finding only four studies of the economic value of recreational beach activities other than fishing. Two of these studies were from Florida (Leeworthy and Bell 1990; Leeworthy 1991) and two (Leeworthy and Wiley 1991; Silberman and Klock 1988) from New Jersey beaches. Two projects, one each from Florida and New Jersey, should be a good indicator of the consumer surplus or benefit of North Carolina beaches. The consumer surplus from these studies ranged from a high of $3,448 to a low of $4.57 per day. The median for the New Jersey study was $56.46 (Leeworthy and Wiley 1991) per day. Bell and Leeworthy's 1990 study of Florida's beaches yielded a consumer surplus, for out-of-state visitors, of $50.40 per day. Assuming the consumer surplus of in-state beach goers is at least half of the out-of-state visitors the median for the Florida beach would be $75.60 per day. Thus we may assume a consumer surplus of $66.03 for North Carolina.

Along with the WTP of beach users, we need to determine if there is an existence value for beaches. Silberman found an existence value for a recently nourished beach in New Jersey to vary between $9.43 per person and $19.65 per person. Between these two extremes is the average WTP of $14.54. The median WTP from New Jersey should indicate the lower boundary of the WTP in North Carolina.

One of the best studies that examined the cost of a project versus what people were willing to pay for that project was done by Moore & Humiston for the Knight Island nourishment project in Florida (Moore & Huniston 1995). The people who lived on Knight Island had to determine what they were willing to pay and how the payments would be allocated. With 131 beachfront owners of a total of 259 property owners, the allocation of cost per foot of nourished beach looks like this: oceanfront owners - $2.91; non-oceanfront owners - $0.72.The property owners of Knight Island were willing to pay $473.37 per foot for a newly nourished beach.To put this lower bound estimate of WTP in a different perspective, the cost of the project was $351.83 per foot of nourished beach. In North Carolina, the costs are much different. Wrightsville Beach and Carolina Beach have been nourished for the past thirty-two years at a total cost of $16.715 million and $26.580 million respectively. The cost per year per foot of beach is $37.31 and $59.33 respectively, well under the willingness-to-pay factors of the Knight Island project.

Other beach user WTP studies have been completed, such as surfing, which can be transferred to

North Carolina's beaches. In 1971 Morahan estimated the average value of a single surfing visit, in Hawaii, as $1.50. In 1981 Moffatt and Nicholas, Engineers, estimated this same value for California at $6.00. Assuming the Hawaiian $1.50 per visit is equivalent to the California $6 we can make some assumptions about surfing in North Carolina. If a North Carolina surfing visit is worth half of 1981 California or double 1971 Hawaii, then the average surf visit to a NC beach is worth $3 in 1999. Beach nourishment could effect the surfing quality of beaches and therefore the consumer surplus or benefit of those beaches. Using the engineering data on sufable waves and bottom configurations (Morahan 1971; Moffat and Nicholas 1981) the sub-aquatic portion of the project could be engineered to increase the surfability of waves. As the surfability of waves increased the demand for consumer use would increase.

Who should pay for this nourishment? By charging a fee for beach use or raising or implementing a property-based fee in the beach communities, the nourishment projects would be paid for by the user and the property owners a la Knight Island. What, then, would people be willing to pay to preserve North Carolina beaches? A recent survey in California of beach-goers might give us some idea. The average income of a Californian going to the beach is $40,000.00/ year, and the WTP was found to be $25.00. Dr. Levin adjusted the income figure for North Carolina to $34,000.00 per year, approximately 85% of the average Californian (Levin 1999). Using this same percentage to adjust the WTP we find WTP in North Carolina to be $21.25. Assuming this WTP figure is imposed as a user fee, then these fees would generate a $913.74 million fund *yearly* for beach nourishment/renourishment projects.

CONCLUSION

A number of studies demonstrate that there is a WTP for beaches and beach nourishment projects. The recreational value of our beaches is a major economic factor for coastal communities. Finally, the acceptance of nourishment as *the* engineering method of choice for beach mitigation and enhancement projects has been well established (NCR 1995). The issue then, is whether a particular beach is suitable for a nourishment project and whether that project is economically feasible using all available cost/benefit information. The paucity of information on these issues in North Carolina necessitates further studies with particular attention paid to the non-market value of the beaches.Surveys of coastal community property values, beach users, and an integrated approach to coastal management using economic, ecological, and effective land use are needed to determine the "state of our beaches" for the next millennium.

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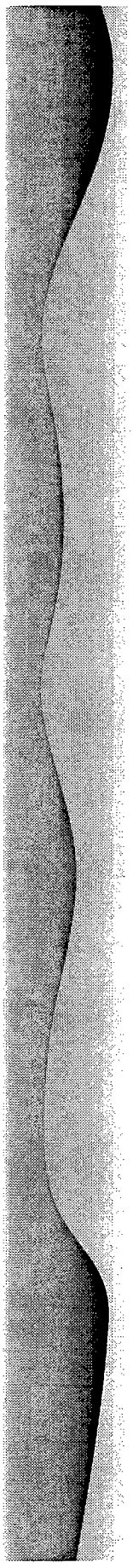

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HAWAII PILOT BEACH RESTORATION PROJECT COASTAL ENGINEERING INVESTIGATION

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ABSTRACT

INTRODUCTION

"Island beaches washing away" (Honolulu Advertiser headline, June 1996). A dramatic headline, but not far from the truth. Hawaii's sandy shorelines are beautiful, and like many beautiful things they are fragile and vulnerable. Characteristics and problems of Hawaii's sand beaches are the result of a variety of natural factors.

- Hawaii's sandy shorelines are very dynamic - subject to seasonal changes, long term recession, and variable alongshore and onshore/offshore transport.

- The wind and wave climate is also very dynamic – relatively high energy environment, considerable variability in wave energy and direction, and significant storm vulnerability.

- The island's shoreline geomorphology is complex and variable – bays and headlands, beaches and rocky shores, shallow reefs and deepwater close to shore – all in close proximity to each other.

Hawaii's sandy shorelines, similar to many island shores in the Pacific Basin, are coming under increasing stress by these natural forces, as well as stress due to population growth, coastal development, and the desire to live and recreate near the sea. A rise in the general level of the sea surface, predicted by some to be as much as 1 to 3 feet over the next 100 years, will accelerate the rate of beach loss. Shore protection by hardening of the shoreline using seawalls and revetments is one option for fixing the shoreline position and protecting the backshore from shoreline recession. Shoreline hardening is coming under increasing attack, however, because of its potential for adverse impacts to sandy shores if implemented improperly or in unsuitable locations. It is also unarguable that if you have long term, chronic erosion, or the sea level rises, and you have fixed the shoreline so that the beach can't migrate inland, you will lose the beach.

"Sand replenishment: a hopeful experiment" (Honolulu Advertiser editorial, March 2000).

The concept of beach restoration and nourishment is receiving increasing interest as a means of combating beach loss and shoreline recession. Constructing or nourishing a protective beach by placing suitable sand in an appropriately designed manner along a shoreline can be an effective and attractive means of mitigating beach loss, protecting against shoreline recession, protecting the backshore area, and providing for recreational and aesthetic enjoyment. Unfortunately, Hawaii has very little actual experience with beach nourishment projects. It is probably safe to say that we have removed considerably more sand from our beaches than we have placed on them. With the exception of Waikiki Beach and Ala Moana Beach Park on Oahu, and a few small private beach nourishment projects such as Sugar Cove on Maui, there have been no significant beach restoration projects in Hawaii from which we can draw "first-hand" conclusions regarding the problems, needs and viability of this concept. The question "beach nourishment-is it a viable option for Hawaii's shorelines" still remains largely unanswered.

PILOT BEACH RESTORATION PROJECT

In 1998 the State Department of Land and Natural Resources, in conjunction with the Coastal Zone Management Program, initiated a reconnaissance-level coastal engineering investigation intended to identify one or more candidate sites for the development and construction of a beach nourishment demonstration project. Coastal reaches on Oahu and Maui were investigated for their beach restoration

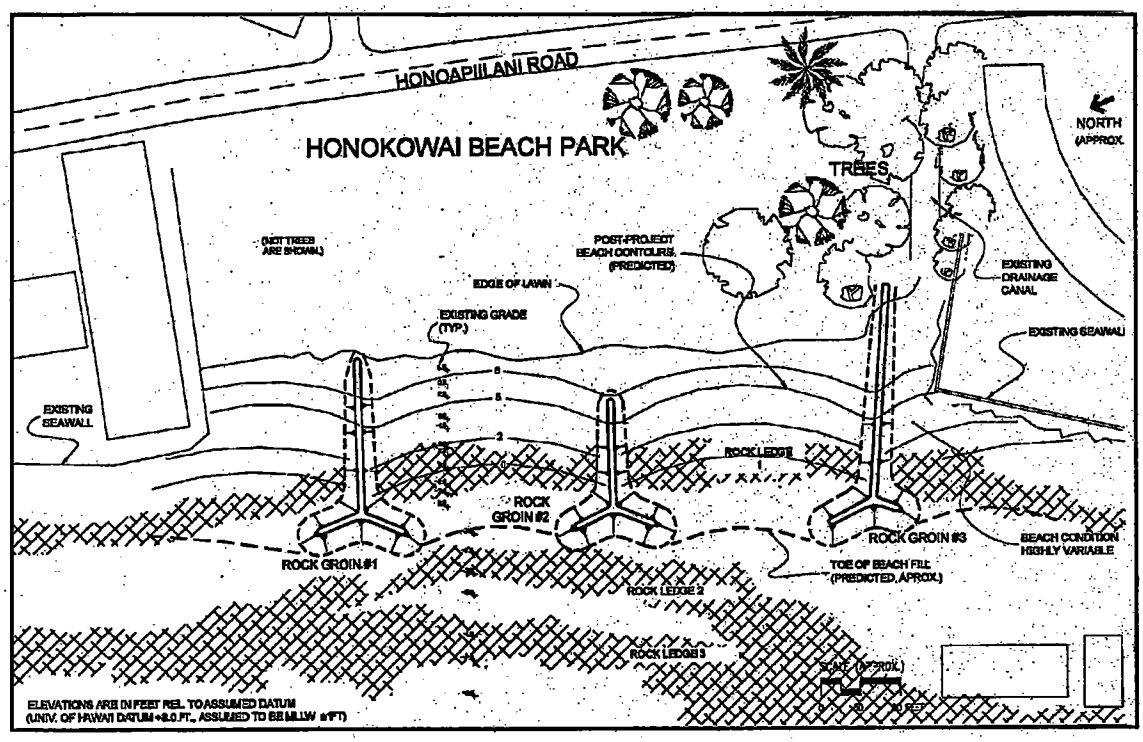

Figure 1.

demonstration potential, thus emphasis was placed on identifying sites and conceptual projects that would be small in size and modest in cost and complexity. The idea is to develop and construct a pilot project, one with a high potential for success, from which a learning curve can begin.

Site Selection Criteria. The parameters used to evaluate and rank candidate beach restoration sites included:

- A site for which the project's alongshore limits can be defined within obvious physical features, most preferably where at least one of the bounding features represents the end of a littoral cell;
- Reasonably low wave energy and currents, and where the nearshore seabed is shallow, gently-sloped, and preferably sheltered by an offshore reef;
- Initial sand fill requirements of 5,000 to 15,000 cy, with minimum project longevity of 5+ years before re-nourishment;
- Obvious need for beach restoration, particularly where a historically healthy beach has been replaced or reduced by shoreline hardening;
- Obvious public benefit or interest (e.g. recreation and/or protection of public property);
- Multiple beneficiaries, public and private, that are interested in beach improvements, and absence of significant potential opposition;
- Absence of oceanfront development that grossly encroaches upon the historical beach, and where beach erosion problems are the result of poor shoreline management;
- Minimal potential conflict with existing activities; swimming, surfing, fishing, boating etc.;
- Low environmental sensitivity (i.e. reasonably distant from known sensitive resources that might be impacted by a project); and
- Good accessibility for construction and future maintenance.

These are by no means all of the possible considerations, nor would any one site be expected to fully meet all of them, but they do represent a reasonable list of criteria by which possible candidate sites can be evaluated and ranked.

Project Design Considerations. In addition to the preceding site selection criteria, general planning and design considerations for each respective site include:

- Evaluation of site specific oceanographic design parameters (wind, waves and water levels) – potentially severe and typically variable;
- Stable beach design – how do you get the sand to stay where you put it – need for stabilization structures and/or periodic nourishment requirements;
- Required sand characteristics and where to obtain it - finding a suitable sand source is one of the biggest problems associated with beach nourishment in Hawaii;
- Environmental impact assessment – water quality, impacts on marine life, conflicting uses;
- Cost – both first cost of construction and future maintenance cost; and
- Permitting requirements – up to a dozen federal, state and county permits may be required before a beach project can be constructed.

SELECTED PROJECT SITES

In the course of the study, about a dozen sites were evaluated as potential beach nourishment demonstration projects. Specific observations and recommendations were tendered for each of these sites, including areas along Maunalua Bay, Lanikai, Kualoa to Laie (all on Oahu), and along Kamaole and Kalama Beach Parks, Maalaea Bay, Ukumehame, and Napili Bay (all on Maui); among others. Ultimately, three sites were recommended for pilot beach-restoration projects, and site-specific conceptual plans were developed for each. These included Honokowai Beach Park (west Maui) and Sacred Falls (south of Hauula, on Oahu's windward coast) as the primary recommendations. Ka'a'awa Beach Park (on Oahu's windward coast) was developed as a secondary recommendation. As an example, the plan for Honokowai Beach Park is briefly described below.

HONOKOWAI BEACH PARK CONCEPT PLAN

Site Description. Honokowai Beach Park (HBP) is located on the northwest shore of Maui, just north of this conference site. The park is located approximately midway along a 7-mile stretch of coast that is extensively developed for tourist and resort use. Chronic erosion has significantly narrowed the beach, exposed the roots of large trees, and created an erosional scarp 1 to 2 feet high separating the inland grass lawn from the narrow sand beach. This site has been recommended for a beach nourishment demonstration project based on its generally good conformance with the site selection criteria.

- The park consists of 500 feet of unprotected beachfront squeezed between several thousand feet of armored shoreline on both sides, thus the alongshore limits are well defined by manmade physical features.
- Wave energy at this site is typically moderate. It is partially exposed to refracted and diffracted summer south swell and winter north swell, which typically moves sand north and south, respectively, along this coast. The site is directly exposed to "kona" storm waves from the west, and potential hurricane storm waves, both of which have historically resulted in significant erosion of Maui's west facing beaches. Large scale coastal currents are weak, however the physical characteristics of this specific site result in strong currents along the beach. Bands of beach rock ledges extend above the bottom fronting the beach, and wave action results in a longshore current between the ledges and the beach, setting to the north and exiting through a gap in the beach rock. This feature contributes to the erosional processes. Seaward of the rock ledges the bottom slopes gently seaward, reaching the 18-foot contour approximately 1,000 feet offshore.
- The erosion problem appears to be chronic, aerial photo analysis shows that the vegetation line receded about 65 feet between 1961 and 1988. (The area around the park represents a classic case of building too close to a dynamic or unstable sand beach, and then having to armor the coast to prevent damage or loss of the buildings)
- Initial sand fill requirement is about 10,000 cy, and provided groin structures are used to stabilize

the beach, periodic re-nourishment needs would be reasonable. (Unstabilized beach fill is not recommended due to the erosion potential)

- Public use of the park is popular, and there is no other public beach or obvious shoreline access within a mile or so north or south. Beach improvements would benefit both the general public and the adjacent property owners and nearby hotel guests. Cause for potential opposition to improvements appears to be minimal. Both the State and Maui County have indicated support for beach improvements.

- The bottom seaward of the beach is composed of sand pockets and irregular patches of limestone reef rock with good coral growth, water quality and clarity is excellent for diving and snorkeling, and winter north swell occasionally presents offshore surfing opportunities. A properly designed beach restoration project would enhance the attractiveness of the park for water recreation activities.

- Construction and future maintenance accessibility of the site is very good.

Concept Plan. The proposed plan for the Honokowai Beach Park demonstration project includes three T-head groins and about 10,600 cubic yards of initial sand fill. This sand volume includes a 20% contingency (advance nourishment) plus a 45% overfill allowance for sand compatibility, assuming the use of the typically relatively fine sand from Maui upland sources. The groins would extend about 110 feet seaward of the existing high water line (130 feet from the grass), with heads about 60 feet wide, and spaced about 190 feet apart. The beach crest would be about +6 feet mllw and the groin crests about +5 feet, thus the landward ends of the groins would typically be buried and permit unimpeded access along the beach above the wave zone.

The conceptual design provides a nominal "dry" beach width of between 30 and 60 feet, between the grass and the wave uprush at high tide on a typical day (say to the +4-foot elevation). The dry beach area would be about 23,000 square feet, providing a 120 to 150 person capacity. The project would advance the mean high water shoreline seaward by 35 to 55 feet.

A preliminary estimate of the probable cost to construct the project is $450,000 to 630,000, excluding engineering design and permitting costs. Thus for the 500-foot shoreline the construction cost would be $900 to $1,200 per linear foot. The considerable uncertainty in the actual source and cost of the sand to be used for the project is the primary reason for the relatively wide range in the construction cost estimate.

SAND SOURCE

One of the primary keys, and unfortunately in Hawaii today one of the major hurdles, to a successful beach restoration/nourishment project is suitable sand. The closer it matches or is coarser than the native sand the more stable it will likely be, the less overfill will be required, the fewer the potential adverse impacts to marine life due to sand movement outside the project area, the less future maintenance will be required etc. Hawaii beach sand typically has a median grain size of 0.3 to 0.6 mm, is moderately well sorted, with rounded and polished grains of primarily calcareous material, ranging in color from almost white to brownish yellow. Honokowai Beach Park native sand has a median grain size of 0.3 mm. So the hurdle is – where do you get enough suitable sand? You can make it, you can mine upland dunes, you can "borrow" it from other beaches, or you can mine offshore sand deposits.

Man-made – Man-made sand of crushed coral limestone has been used in the past with very poor results. The angularity of the crushed grains, coupled with a percentage of limestone powder, results in dense packing and cementation. If you had seen the early morning mechanical raking of Fort DeRussey beach in Waikiki necessary to break up the "cement" beach after a beach restoration using man-made sand, you would agree I'm sure that it's not suitable sand.

Upland Sources – Significant deposits of upland sand available and suitable for beach nourishment are scarce, or presently unknown, on all the islands. On Oahu, inland dunes at Kahuku, Mokuleia and other locations have historically been mined. The Kahuku sand was particularly good, with a median grain size of 0.4 mm. To my knowledge, however, these sites are essentially tapped out. On Maui, upland dune sand is somewhat available, and has been used for beach nourishment. This sand is relatively fine with a median grain size typically less than 0.25 mm, and is dark orange/brown in color. Use of this sand would

result in an approximate 45% overfill requirement at Honokowai Beach. Grove Farm Rock Co. on Kauai presently sells upland dune sand with a median grain size of 0.3 mm, also orange/brown in color. This sand would work reasonably well for Honokowai Beach, however, being 150 miles by ocean away, it presents some cost problem. In summary, existing upland sources are of marginal use at best.

Beach Mining – Good luck! Seriously – mining existing beaches for sand has been done in the past. On Oahu, extensive sand mining was done at Waimea Bay up until the mid-1960's. Beach sand mining was permitted at Papahaku Beach on Molokai's west end for construction material for over 20 years, up until the 1970's. But past abuse, and an increased awareness and sensitivity to our under pressure beach resources has eliminated active beach sand mining. It may be a future possibility at selected beaches, provided it can be proven to be a naturally renewable resource and won't have significant adverse impacts, but it would likely be highly regulated - and rightly so. For the near term (and maybe over the long term), it seems safe to rule out beach mining as a sand source.

Offshore Sand – The offshore sand resources around Oahu have been investigated, mapped and sampled since the 1960's. The possibility of an offshore sand resource has been of interest both from its commercial value to the concrete construction industry as well as for beach nourishment. The investigations, however, have varied widely in their level of detail, precision and even accuracy. Some of the seismic reflection techniques used have later been shown to be in error, large areas have been mapped with widely spaced tracklines and poor positioning, thus the results were not always highly quantitative. The sand mapping was often done without sampling or ground truthing the remote sensing (seismic or aerial photographic) data, thus the characteristics of the sand deposits were often inferred and very qualitative. When sampled, most of the offshore sand sampled to date is finer grained than desirable for beach sand, friable (easily broken down to finer material), angular or platy in shape (not round as beach sand is by constant movement in the surf zone). Most of the offshore sand in deeper water appears to have never been on a beach, i.e. it is sand sized sediment of biogenic origin, not sand lost from the beach.

In summary, a reasonably available source of suitable offshore sand has yet to be identified.

RECOMMENDATIONS

- Continue to work toward the actual implementation of a pilot beach restoration project on one or several islands.
- Continue to seriously look for a beach sand source, with emphasis on offshore sand.

URBAN BEACHES

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ABSTRACT

The Urban Beach Initiative would provide for a mechanism to assist in developing, operating, and maintaining beaches near urban areas.

The majority of America's population lives and/or works in urban areas near our coasts, lakes or rivers. Additionally, population projections indicate that there is great likelihood that these populations will increase in the future. Unfortunately, there are few opportunities for wholesome natural recreation for urban dwellers. As a result, many urban dwellers must leave the cities for parks and wilderness areas to pursue outdoor recreation opportunities or travel great distances to natural beaches.

Beaches are important elements for providing health and physical and mental well being of the people of this nation. The proximity of beaches to our great centers of population would provide an opportunity for wholesome and necessary rest and relaxation not otherwise available. This initiative could also relieve some of the pressures on our already crowded rural parks and wilderness areas and also provide an incentive to restore the natural beaches long forgotten in our urban areas.

For urban areas located on United States coasts, lakes and rivers, the Urban Beach Initiative would provide comprehensive programs to establish our urban coasts as an integral recreational component of urban open space. This would include:

1. Recreating the coastal environment in an urban setting by creating, enhancing, and rebuilding urban beaches.

2. Providing the facilities, personnel, and infrastructure for safe, inexpensive and convenient access to and enjoyment of urban beaches.

3. Acquiring of public lands necessary to provide open beaches, coastal trails, river walks and other elements necessary for a fulfilling coastal experience.

4. Developing education programs to inform beach visitors about beaches and coasts.

The Urban Beaches Initiative will achieve this through the formation of the Urban Beaches Council. The Council responsibilities would include:

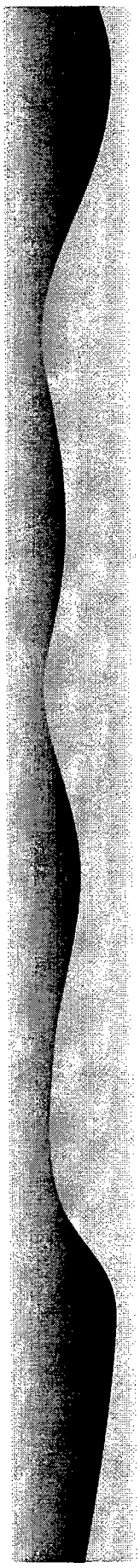
1. Coordination with non-Federal local entities such as Cities, Counties, and States.

2. Providing a mechanism for accepting funding from not-for-profit, private, Federal, and other public sources for implementing the Urban Beach Initiative.

3. Providing a board of knowledgeable advisors composed primarily of non-Federal members from, Cities, States, Counties, and not for profit organizations.

4. Providing staff from an existing Federal Agency responsible for coastal matters to a) prepare an annual report of activities to the congress, b) provide administrative support in accordance with appropriate U. S. government procedures, c) provide technical support in the design and construction of beaches.

5. Coordination with and support for existing programs integral to the goals of the Urban Beaches Initiative, including but not limited to clean water, clean beaches and urban coastal open space.



DREDGING PRACTICE FOR BEACH NOURISHMENT

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MODIFYING A FEDERAL BEACH NOURISHMENT PROJECT TO RESPOND TO HURRICANE IMPACTS PANAMA CITY BEACHES, FLORIDA NOURISHMENT PROJECT

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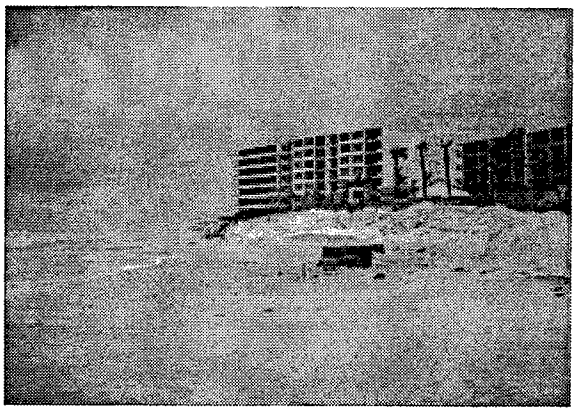
ABSTRACT

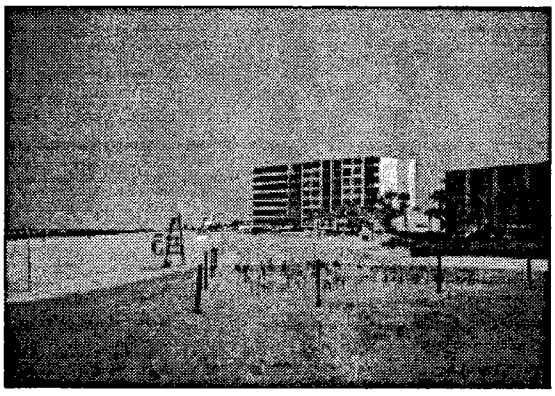
The Panama City Beaches Federal Beach Nourishment Project was constructed by Bay County in 1998-99 after 4 years of natural, administrative and design challenges. This project is a case study of what can be done when governments work together to overcome obstacles and re-establish an important tourist beach.



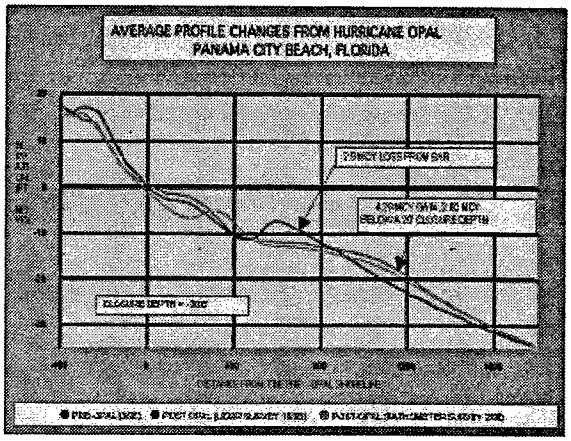
Panama City Beach is located in Bay County in the Florida Panhandle and is the beach destination for many tourists in the Southeast United States. The constructed project covered 17.5 miles of shoreline with 8.3 million cubic yards of sand making it one of the largest beach erosion projects ever built under a single contract and the first and largest Section 206 Federal reimbursable project. The project area is highly developed with nearly continuous beach development of hotels, condominiums, and private residential homes. Two sets of before and after photographs are included in this report.

The Corps of Engineers completed a draft General Reevaluation Report in 1994 that originally proposed a project beyond the local sponsor's ability to pay. While the Corps reformulated the project over the next two years, Hurricane Opal struck the Florida Panhandle in 1995, devastating the beach and tourist based infrastructure. The Corps completed their GRR in 1996, and recommended a smaller project affordable to the local sponsor.

In the aftermath of Hurricane Opal, all governments were supportive. The State provided special funding for Hurricane Opal recovery, the Corps completed the GRR and made post-storm investigations, and the local sponsor, the Bay County Tourist Development Council, created a special tax dedicated to a new beach. Due to presidential policy, the Corps was unable to move forward to construction. Therefore, Bay County decided to build the beach under the new Section 206 Federal authority, which allows local construction to qualify for Federal reimbursement.



As a result of government activity in 1996, the project was fully supported with funds to cover building the GRR plan, however this plan did not directly address the 2.7 million cy of sand lost to Hurricane Opal. Coastal Planning & Engineering was hired to plan, update the design and construct the project under Section 206 Authority. The challenges included qualifying the project for Federal

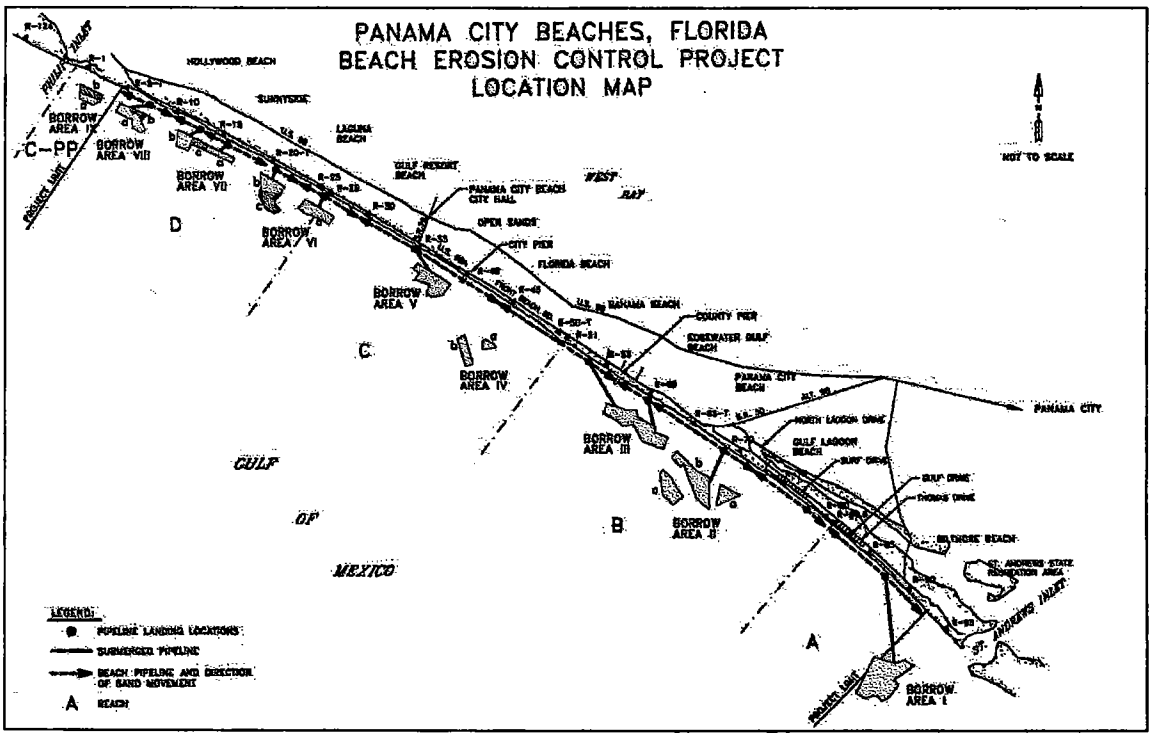


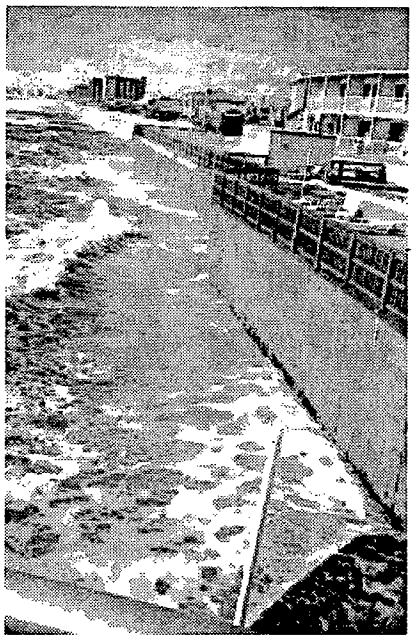
reimbursement under this new authority, the first of its kind, and reformulating the project design to compensate for Hurricane Opal impacts while keeping cost at the pre-Opal budget level.

The project cost goals were achieved by design strategies that improved sand quality, borrow area layout, permit conditions and construction contract provisions. Hurricane Opal caused a permanent loss of approximately 2.7 million cubic yards of sand, and cost escalation could not be avoided unless the project was redesigned. The sand loss in the Panama CityBeach was caused by the interaction of the large bar and trough system with the storm forces (see above figure). The storm sheared-off the entire bar, and transported the sand offshore into depths up to 45 feet. A portion of this loss is expected to return to the beach, but 2.7 million cy was lost beyond the closure depth and is permanent for all practical purposes. The State, Federal and local budgets were set for the project, and savings were needed to keep the project affordable.

A number of engineering strategies were used to make the project more affordable. The most productive strategy was improving the borrow areas. The original plan had 6 borrow area, with a mean grain size less than the native beach and maximum dredge pumping distance of 36,000 feet. A sand search was conduced to find closer and coarse borrow areas. Borrow Areas II and III (see above) were developed to cut the maximum and average dredge pumping distances in half. Borrow area I was develop to improve the grain size of the fill material. The project mean grain size was increased from 0.21mm to 0.27mm, which reduce the overfill quantity. These two strategies taken together reduced the quantity and unit cost sand needed to build the authorized Federal project. Cost savings were also achieved by securing a summer dredging permit, building the project under one contract, timing the bid to a lull in the industry and contract clauses formulated to keep the cost down.

Partnering among Federal, State, local authorities and consultants eased permitting and bureaucratic

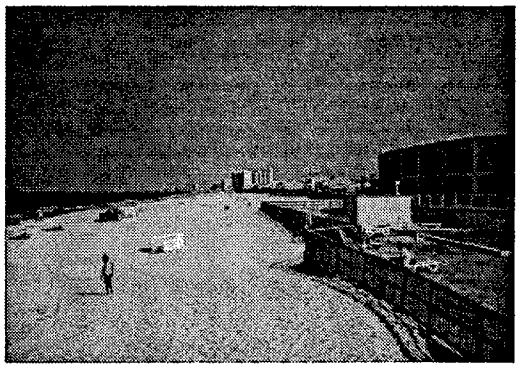




obstacles and allowed the project to begin construction in less than two years. Even though the TDC built the project, the assistance of the Corps and State was essential to the projects success.

The contract was awarded to the low bidder, Great Lakes Dredge & Dock, with a bid of $2 per cubic yard, among the lowest in recent memory. The local sponsor took advantage of this low bid, by extending the project another 3/4 of a mile to include two developments left out of the original plan.

Two hurricanes struck after only 2 miles of the project were complete. Construction of the project began in August 1998 and Hurricanes Georges and Earl struck in September. The constructed portion of the project weathered the storm very well, while the unconstructed sections suffered damages to seawalls and other shore front structures. In many locations, all the sand was striped from the beach up to the existing seawalls, buildings and under pile supported structures. By using the contractor's construction surveys, a quick assessment of losses was completed. The nearshore region lost approximately 10 cy per linear foot, but loss across the entire active profile could not be assessed with limited length construction surveys. The Bay County Tourist Development Council again took advantage of the low cost of sand, and increased the fill quantity in western beach segments to compensate for the loss. The project modifications were made possible with the assistance of the project partners.



Ultimately, the project placed 1.9 million cubic yards more sand on the beach than recommended in the Federal Plan at a total project cost under the initial cost estimate and budget. Innovative design and planning in conjunction with effective partnering built this successful project. The tourist economy of Panama City Beach has improved significantly with the project, and is the best direct measure of the projects success.

The last two photographs are before and after construction of the Treasure Island Motel.

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PERFORMANCE OF ENGINEERED BEACHES ON URBAN COASTS: THE ILLINOIS SHORE OF LAKE MICHIGAN NORTH OF CHICAGO

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Laura Dick, Terah Donovan, Jennifer D. Jones, Jessica Lynch
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ABSTRACT

The 61-mile Illinois shore of Lake Michigan is the most populated coastal reach in the Great Lakes and except for the northern 10 miles is fully engineered. North of the City of Chicago is the "North Shore," a 24-mile stretch of urban lakeshore with private and municipal properties historically protected by groin fields, seawalls and stone revetments and more recently, quarrystone breakwaters.

The North Shore coastal geology includes eroding Pleistocene glacial clay-till bluffs and lakebed containing about 10% sand. Photographs of the North Shore from the 1880s through the 1930s show extensive development of rock-filled wood crib piers along the shore. Constructed to provide access for boats, swimmers and sunbathers; the piers performed like groins, trapping sand fillets on their northern (updrift) sides. Constructed in an erosional, sediment starved environment, the groins along with harbor breakwaters and larger municipal piers trapped and held beaches for approximately 100 years.

In areas without shore protection structures, bluffs continued to erode and with few exceptions, beaches were narrow during low lake levels to nonexistent during average or high lake levels. Bluff recession rates reported by a number of authors average 1.5 feet per year in unprotected areas (approximately 8.3 yd^3 of sediment lost per linear foot of lakeshore per year). By the 1950s, most of the piers were replaced with steel sheetpile groins. With the progressive armoring of the lakeshore, the primary source of sand, bluff erosion was cut off. Littoral drift sand quantities thinned measurably by the 1980s exposing the nearshore lakebed clay in many places to the erosive forces of breaking storm waves (Shabica and Pranschke, 1994).

The deepened nearshore profile combined with reduced sand supplies rendered nearly all but the longest groins ineffective. Further, current scour pits at the lakeward ends of the steel groins began to undermine the ends of the groins as the bottom profile deepened.

In the late 1980s, coastal engineers recognizing the sediment-starved nature of the Illinois lakeshore, began engineering shore-connected, rubble mound breakwater "headlands" to maintain the shrinking beaches. All were designed to be artificially nourished with a grade of sand coarser than the native fine sand. Headland configuration ranged from 25 foot round stone piles at groin ends to shore parallel breakwaters 30 to 200 feet in length. At two newly constructed municipal beaches, regulators required annual beach and bathymetric surveys to assure no negative impacts to the already meager littoral drift system. The surveys also gave scientists the opportunity to compare performance of breakwaters and groins.

At Forest Park Beach, Lake Forest, a four-cell breakwater beach system engineered to be "sand neutral" was intensively surveyed from 1991 to 1995. The Illinois State Geological Survey reported a period of sand accretion during rising lake levels followed by a period of erosion during falling lake levels.

At Sunrise Park in Lake Bluff, a single cell breakwater system was monitored from 1992 to 1999 (5 years were required). A groin protected "control" beach was also monitored. During two periods of rising lake levels, the breakwater beach gained 0 to 1 yd^3 of sand while the control beach lost 0 to 2.6 yd^3 of sand per linear foot of lakeshore. During two periods of falling lake levels, the breakwater beach lost 1 to 4 yd^3 of sand while the groin beach lost 0 to 0.5 yd^3 sand per linear foot of lakeshore. Net loss of sand over the 7-year study period was 3.0 yd^3 at the breakwater beach and 3.3 yd^3 per linear foot of lakeshore at the

groin beach. Designed in 1990, the breakwater beach was engineered to lose 20% (1,600 yd^3) of the 8,000 yd^3 of new sand fill. The higher than predicted sand loss (3,300 yd^3 or 41%) is hypothesized to be partly due to a longer period of falling lake levels during the study and lake bed downcutting, a phenomenon not reported in the literature when the structures were engineered. Maintenance sand (average 250 yd^3 per year) was recommended to be added to the breakwater beach as necessary, to make up for the sand lost to the littoral drift system.

No evidence for adverse impacts on-downdrift beaches or shore protection structures was reported in either the Forest Park or Sunrise Park study. Monitoring will continue indefinitely at Sunrise Park and several other breakwater held beaches including a new breakwater facility that includes a sill to minimize the effects of lakebed downcutting.

Today more than 18 rubble mound breakwater-beach systems have been permitted in Illinois. Regulatory agencies require a 20% sand overfill to assure that there is no net gain of sand from the littoral drift system.

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UPDATE OF BEACH RESTORATION AT SUGAR COVE, HAWAIIAN ISLANDS

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ABSTRACT

The April-July 1999 issue of *Shore & Beach* presented the history of the deteriorating beach at Sugar Cove. It described three attempts to save the beach and property followed by the successful solution that restored it.

I have taken the liberty to tell of this project, not as I did in *Shore & Beach* as an engineer, but as one who lives close to this beach and has since November 1984. I see and hear the ocean day and night and waken to it every morning. Once we had an eroding shore. We tried three times to fix it—built walls of sandbags, rubber tires, and geotextile stretched behind immense boulders. And we goofed with each try.

My presentation will illustrate to some extent what I have learned and hope to share after working with this small project.

The poet, Robert Frost, said "Good fences make good neighbors." How true in the case of shoreline erosion. What a lesson for us all! It was especially true when Sugar Cove finally made peace with its neighbor, the ocean, by giving the ocean what it needed to shore itself up. What it needed was moveable material. What we gave it was sand with chunks of sandstone mixed in. We not only signed a peace treaty, but we got a nice beach in the bargain. Nevertheless, during this process, over a period of fifteen years, I learned much and now realize there is a simple law that governs shores and beaches—wherever land and water meet.

Here is the law:

In nature, water seeks to bind itself with a *band* of moveable material.

For me the Sugar Cove beach restoration project proved the validity of this law. Here's a way we can see it: Let's start with the ocean, a *body* of water, a liquid that runs all over the place if it is not contained. Because of this quality, the forces of nature work to keep it contained. But how do these forces tame this huge volume of water which spreads over so much of the earth; how do they keep it contained? Easy! Nature has designed a *band* to go around the ocean—a flexible band made of moveable material that some call a *buffer zone* (a barrier, fence, or wall). The grand architect having understood water's natural ability to move solid objects took note of this and felt confident the ocean could, when necessary, adjust and maintain the sides [walls] of its own container. So nature assigned to the *bandee* the job of *bander*—the job of keeping itself contained. Result: The ocean works constantly to keep itself shored up (to shore up its container), so we call this binding: *the shore.*

But how does the water do its work? What happens when there is a storm, and the waves are wind-tossed, and water is piled higher than the binding [wall] that previously held it? A cleverly conceived system goes into operation. The ocean seeking to keep itself bound goes to the *bank*, where extra material is stored for the ocean to draw upon when its wall needs *shoring* up. The ocean withdraws this material from its *bank account* and with it builds the wall higher. Voila! The ocean holds itself in check. Peace reigns once again between land and sea

CONCLUSION

Why do we all like a wide beach? Because instinctively we sense that the water will not overtake the land, will not let the roaring waves pass. We may not understand how a beach operates: that it is really a fence or wall designed to contain the ocean, but nevertheless the beach promotes in us a feeling of security and protection from furiously rushing waves, for we can see that the beach keeps waves from running too far onto the nearby land. A wide beach also invites a stroll, or a swim, or a look at the sunset—a place to be at one with nature and experience the phenomena that binds the ocean's water with a

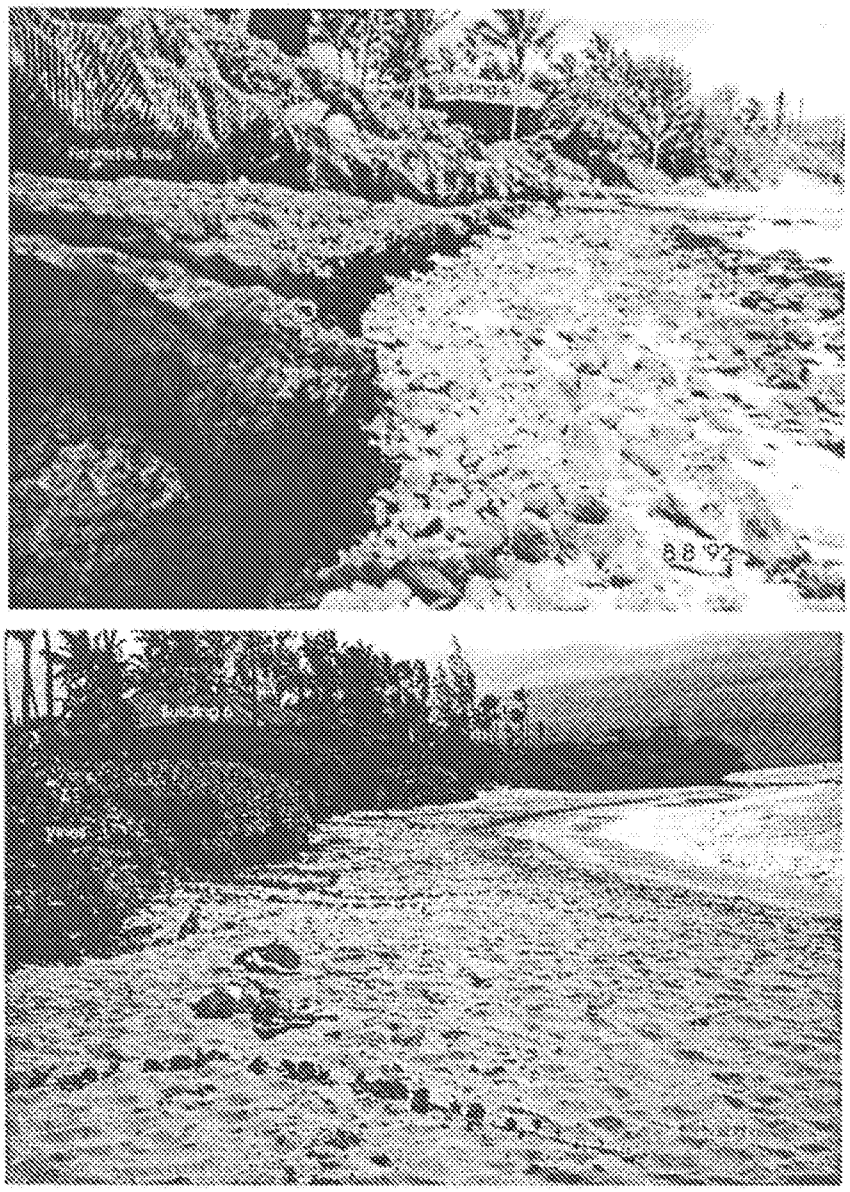


Figure 1 Before sand, Sugar Cove looking west showing tire wall and eroded shore (top), 8 August 1992; After sand, Sugar Cove looking west showing vine-covered boulder wall and beach (bottom), 16 June 2000.

buffer zone, that flexible barrier of moveable material encompassed by an underlying principle that operates unspent.

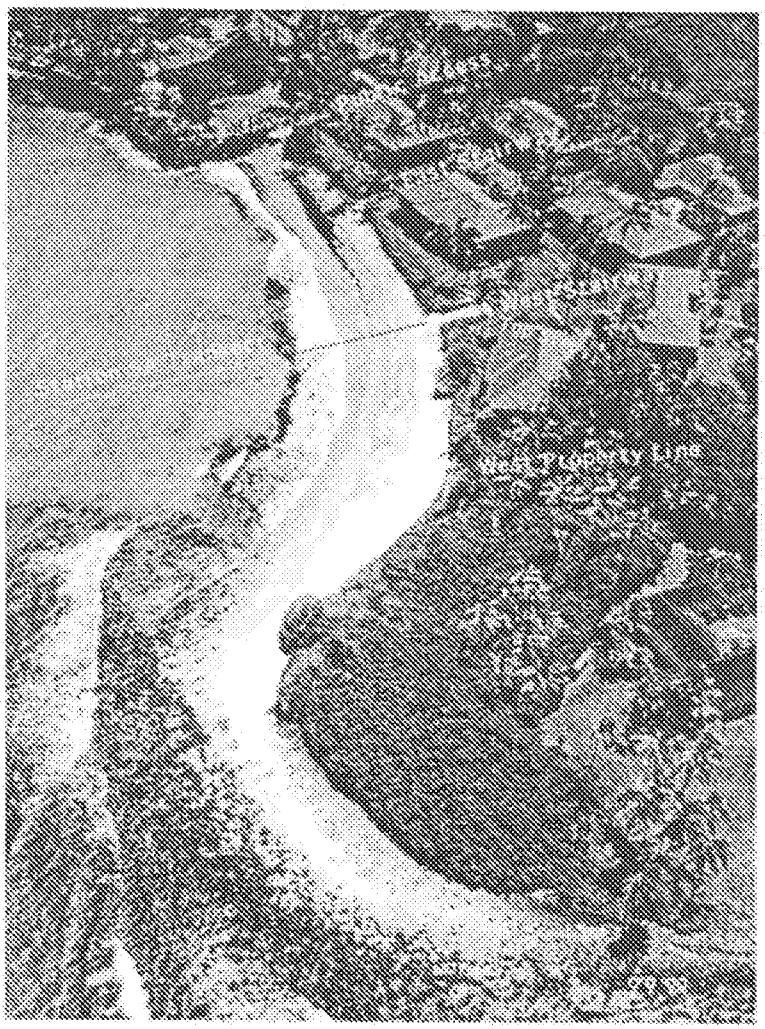
Mankind has done a good job of taking away or interfering with water's barricading-essentials. Today with shorelines eroding worldwide I propose we band ourselves together to try to figure out how to give water what it needs to keep itself together, to keep its fences in order. After all, water is our neighbor on every shore, whether it be at the edge of an ocean, lake, river, pond—or even a trickling stream. Wherever we find water we need to keep peace with it.

What man has wrecked, man must correct.

INVITATION

You are invited to see the beach at Sugar Cove (near Maui's main airport) in Spreckelsville. From Kahului head toward Hana until you reach highway-marker *five*. Turn on Nonohe Place toward the ocean to Paani Place (second left), then follow it to the end. On the county shoreline access path that leads to the beach you will see this year's beach nourishing material. Compare this to the sand on the beach, and you will see how the ocean has converted this sand into excellent beach sand. Look at the wall, take a stroll, go for a swim, come see for yourself why people are happy on this beach.

While in the area you might like to see *Baby Beach* (a quarter-mile east of Sugar Cove) where beach rock forms a lagoon and marks the former shoreline. It will give you an idea of how much the beaches have eroded on this part of the coast due to decades of sand removal.



Aerial view of Sugar Cove, 9 September 1998.

Sand Adding Events

Start date of sand addition	Tons of sand added	Total tons added
11/30/1995	128	128
12/26/1995	112	240
6/21/1996	4320	4560
8/1/1996	3200	7760
5/30/1997	3200	10960
1/29/1998	160	11120
5/25/1998	8000	19120
6/21/1999	1956	21076
5/1/2000	2791	23867

Table 1. Data of Sand Adding Events, 30 November 1995 - 1 May 2000.

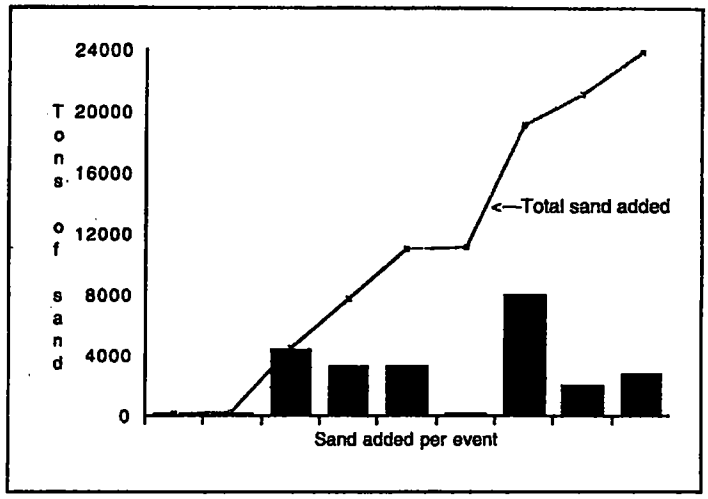


Figure 3 Tons of Sand Added per event and Total Tons, 30 November 1995 - 1 May 2000.

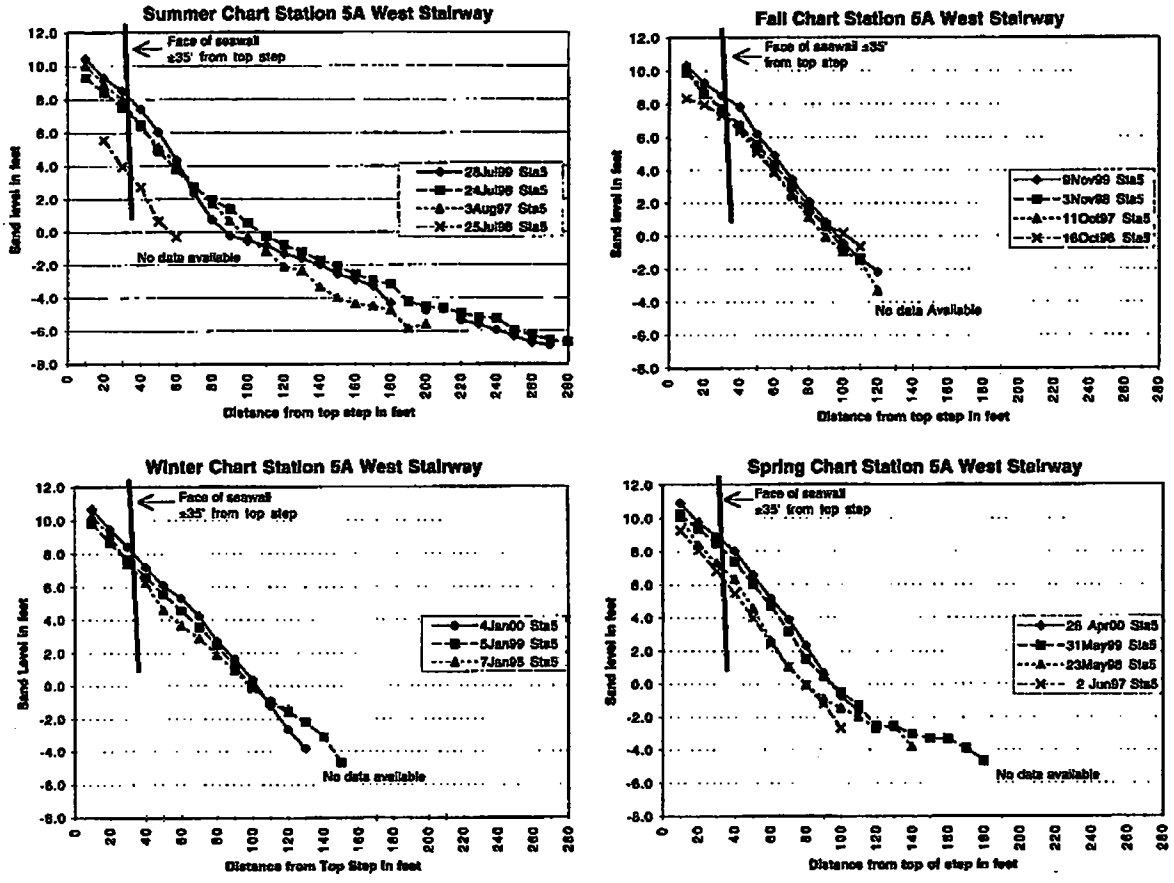


Figure 4 Seasonal Beach Surveys for Station 5A West Stairway, 25 July 1996 - 26 April 2000.

CALIFORNIA'S COASTAL COMMUNITIES ORGANIZE TO INCREASE STATE FUNDING FOR BEACHES

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ABSTRACT

California's beaches are eroding at an alarming rate. Over the past few decades, there has been a lack of commitment on the part of the state to restore this resource which is so critical to California's environmental and economic well-being. With the creation of an advocacy group by coastal communities, however, that may be changing.

Most of the wide, sandy beaches that have made California famous were created artificially, the beneficiaries of large harbor and marina construction projects undertaken from the 1930's to the 1960's. The massive amounts of artificially-placed sediment derived from those projects was supplemented for many years by beach-quality sediment flowing to the shoreline from upland rivers and streams. Over the past three decades, however, the beaches have been deprived of sand, an essential ally in fighting erosion. Beach nourishment projects are no longer as large or as frequent as they had been. Jetties, groins, dams, flood control projects, and the urbanization of California's coastline have interfered with sediment transport, severely hampering the ability of beaches to rebound from changes in sea level and winter storms, particularly the recurring "El Niño" events that are unique to the West Coast. Although efforts are currently underway in Ventura and Malibu to restore natural sediment flow to the coast by decommissioning dams (Matilija and Rindge, respectively), it is clear that California's beaches will need substantial amounts of artificial nourishment in order to overcome the effects of structures and urbanization.

By law, the California Department of Boating and Waterways (DBW) is responsible for rehabilitating eroded beaches, but over the past three decades, the agency's beach restoration efforts have been severely under-funded. Research conducted in 1997 compared the amount of money being spent by California vis-a-vis other coastal states for shoreline protection. As reflected in Table 1, the research showed that California's financial commitment to its beaches was significantly less than that of Florida, New Jersey and New York.

Without a dedicated funding source of its own, California has been unable to attract its share of federal shoreline protection projects, which require non-federal sponsors to share in the cost. As shown in Figure 1, over the past five years California has received significantly less than its coastal counterparts in Florida, New Jersey and New York, all of which have well-funded beach restoration programs.

Proponents of sand replenishment commissioned San Francisco State University to ascertain the impact of beaches on California's economy. The results were impressive. SFSU estimated that the state's beaches were responsible for $14 billion in direct spending, $1 billion in state taxes and more than 500,000 jobs. Spending by beach-goers, with a multiplier effect, is almost 3% of economic activity in the state and beach-related jobs constitute 3.5% of the state's employment.

Armed with this information, coastal communities formed the California Coastal Coalition (CalCoast) in July, 1998 to advocate for increased funding for beach restoration. The group currently has 28 cities and 5 counties as members, as well as a number of businesses, trade groups, associations and

[1] Any opinions expressed in this article are those of the author and should not be construed as being endorsed by Scripps Institution of Oceanography.

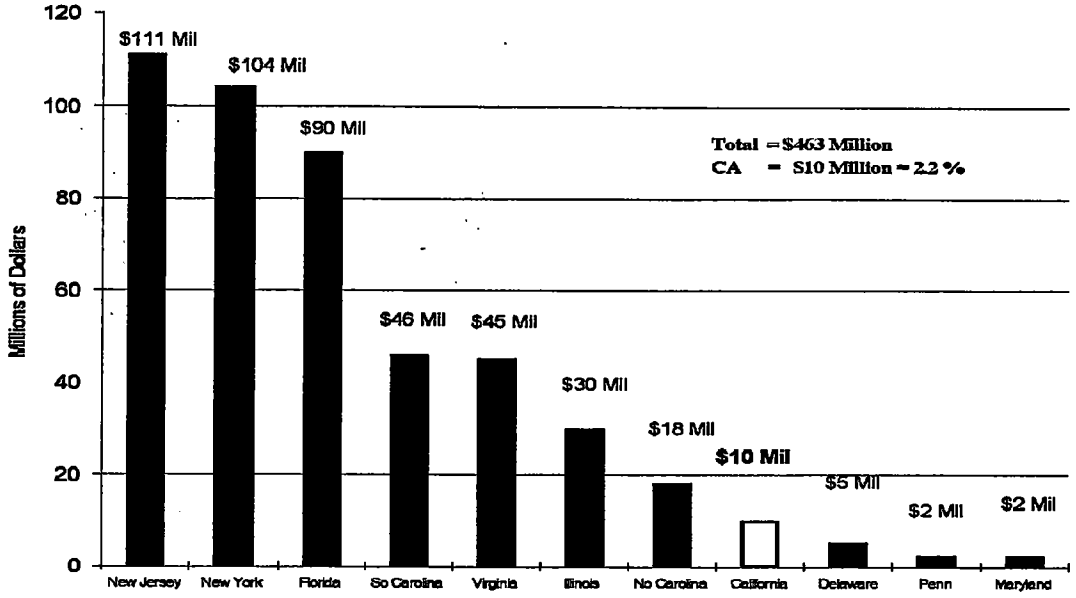

Fig.1. Federal Shore Protection Appropriations FY 1995-1999
Source: American Coastal Coalition, Washington, D.C.

individuals. Last year, CalCoast introduced "The California Public Beach Restoration Act" (AB 64) to create a state fund for sand replenishment projects.

The effort to establish a state beach preservation program benefited significantly from the existence of local and regional organizations up and down the coast. With a solid network in place, CalCoast was able to develop a support base for letter-writing campaigns and the other activities necessary to pursue a grass-roots lobbying effort. The organization also attracted a broad-base of support from groups such as Surfrider Foundation, the California Coastal Commission, the California Chamber of Commerce, engineering firms and several tourism industry trade associations.

As originally drafted, AB 64 would have established a sand replenishment program at a funding level of $105 million over three years. The funding was reduced to $7 million by the Assembly and the Senate and eventually to $500,000 through the state budget process.

After a hard-fought campaign, CalCoast succeeded in creating a state-sponsored beach restoration program. Convincing the state to increase its financial commitment to the program will be one of the challenges facing coastal communities this legislative session. CalCoast is currently the sponsor of AB 2748 (Bates), which would allocate $35 million for beach restoration, and, as of this date, there is $10 million in the proposed state budget for this purpose. During the past year, CalCoast has also been working to create funding for wetlands restoration and ocean water quality projects.

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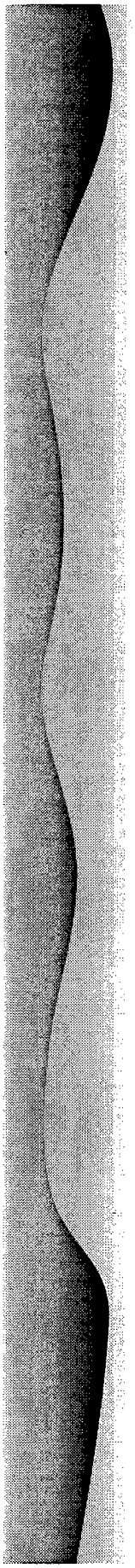

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POSTERS

REGIONAL MAPPING FOR COASTAL MANAGEMENT: MAUI AND KAUAI, HAWAII

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POSTER

Recent advancements in lidar technology now allow for near-synoptic, regional scale mapping of the coastal zone. The US Army Corps of Engineers SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system simultaneously collects bathymetry and adjacent shoreline topography using a blue-green laser.SHOALS collects individual soundings every eight meters and surveys at a rate of 400 soundings per second, or 16 km^2 per hour. In 1999, SHOALS fully mapped the nearshore regions, from the shoreline to the 30-m depth contour, surrounding the islands of Kauai and Maui in Hawaii, USA. This survey included a variety of coastal features including sandy beaches, rocky beaches, harbors and bays, and coral reefs. This paper presents the SHOALS surveys collected in Hawaii and discusses the value of lidar mapping to the coastal community.

The SHOALS system is an airborne lidar (LIght Detection And Ranging) bathymeter that uses a laser to collect water depths (see Figure 1). SHOALS emits pulses of light into the forward flight path of an airborne platform. A scanning mirror directs the light pulses in a pattern perpendicular to the flight path. A portion of each light pulse is reflected from the water surface to receivers on the platform. The remainder of the light pulse travels through the water column to reflect from the sea floor back to the receivers on the platform. The time difference between the reflected signals is analyzed to determine a water depth. The position of each water depth collected by the system is given by differential or kinematic GPS. Since its field-testing in March 1994, the rate of data collection has increased. The SHOALS system can now be deployed either on a helicopter for very high-density data collection (on the order of one meter) or on a fixed wing aircraft for less dense data collection (on the order of 8 m). SHOALS data processing algorithms were enhanced so that beach elevations as well as water depths could be determined from the lidar returns.

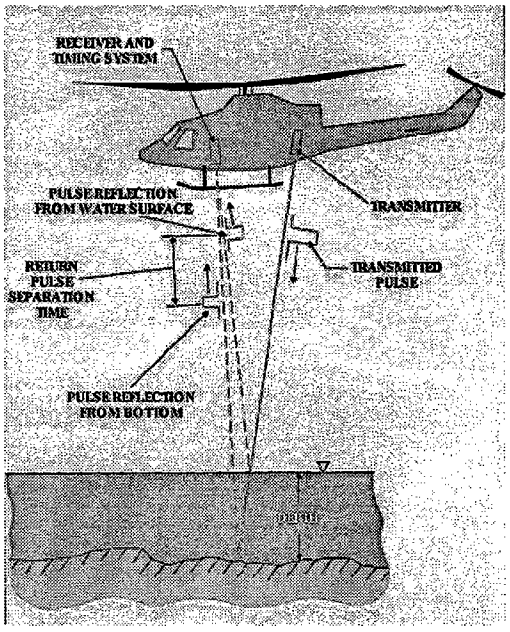


Figure 1. SHOALS operating principle.

The SHOALS group demonstrated these capabilities in a survey mission in the Hawaiian Islands in early 1999. Survey data were collected for US Army Engineer District (USAED) Honolulu and the US Geological Survey (USGS). The specific survey missions were to provide an accurate base map for numerical simulations used in hurricane evacuation management (USAED Honolulu) and to provide high-density bathymetry data to help with coral reef mapping

and studies (USGS). These missions were completed in 40 operational days between 21 February 1999 and 23 April 1999.Sixty flights comprising 215 hours of operation were required.The ratio of data collection to data processing is generally one-to-one for the SHOALS system, but the removal of false lidar returns from whitewater (generated by the wave climate along the shoreline and over coral reefs) increased the ratio to two hours of processing for each flight-hour. A total of 25 million soundings were extracted from the lidar data.

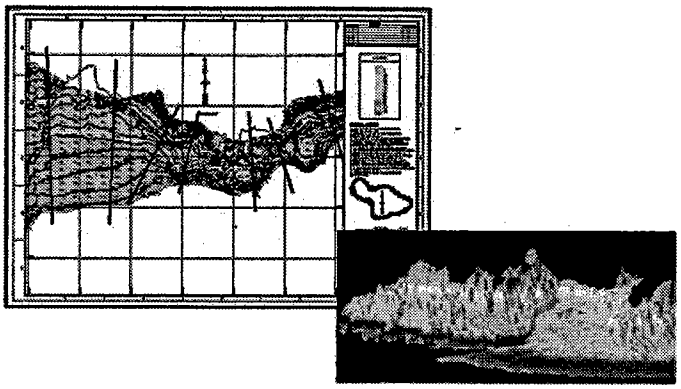
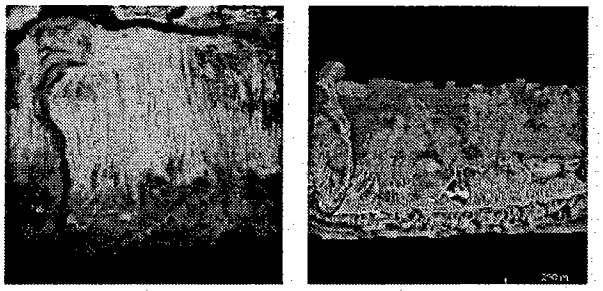


Figure 2. SHOALS data collected for USAED Honolulu.

An example of the data collected for USAED Honolulu is shown in Figure 2. Data were collected along the entire shorelines of Maui (200 km) and Kauai (150 km). The data extend from the shoreline to offshore depths of 30 m. Figure 2 shows one of the 165 maps provided to the district. Sample profile locations for use in the numerical simulations are superimposed on the map. Figure 2 also includes a three-dimensional representation of the data in the map. The data were requested by the National Ocean Service to update the 1927 data on nautical charts for the islands of Maui and Kauai.

An example of the data collected for USGS is shown in Figure 3. The photo on the left is a portion of a natural color photo digital mosaic generated by the USGS. The photo corresponds to the two-dimensional color contours on the right generated by the USGS using the SHOALS data. The digital photo image maps and SHOALS bathymetry data were collected to map coral reefs off the coasts of Maui, Molokai, and Oahu.



Natural Color Color-Coded Bathymetry

Figure 3. SHOALS data collected for USGS (figure supplied by USGS).

Several reasons why SHOALS is ideal for this type of surveying are depicted graphically in Figure 4. First, the speed with which data can be collected for large areas such as the islands of Maui and Kauai provides an impression of the regional terrain at a particular instance in time. Consecutive surveys may be compared to monitor changes in bathymetry and topography that occur over time, such as beach and cliff erosion, coral reef damage, and navigation channel and harbor shoaling. Second, because lidar is a non-intrusive remote sensing technique, conditions that are hazardous for survey vessels, like the shallow rocky shorelines and coral reefs of Hawaii, are easily surveyed by an airborne system. And finally, the density of SHOALS survey data reveals linkages between processes such as changes in offshore bathymetry affecting the shape of the shoreline.

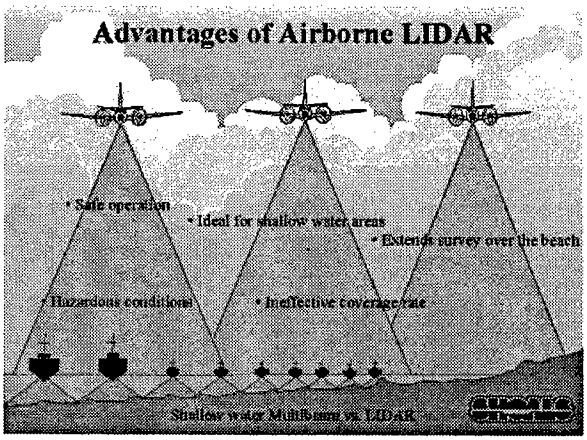


Figure 4. Advantages of SHOALS over shallow-water multibeam.

FAILURE MODES OF COASTAL SLOPES FORMING PART OF THE GREAT LAKES, SOUTHERN CALIFORNIA, ENGLAND AND MEXICAN SHORELINES

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POSTER

Field investigations were carried out to study the mechanics of retreat of coastal slopes forming part of the shorelines of the Great Lakes, Southern California, England, and Mexico. The slopes selected for this study in the Great Lakes region are located on the western coast of Lake Michigan at the location of Port Washington. These slopes are made of glacial till. The slopes in southern California are located near the city of Del Mar. These slopes are made of cemented sands. The slopes studied in England are located in Dover and are made of chalk. The slopes studied in Mexico are located in Tulum. These slopes are made of limestone.

Wave action at the toe of these slopes is the primary factor responsible for their erosion and the resulting changes in slope geometry. The waves introduce oscillatory pressures in the material in contact with the lake or ocean water. The pulsating forces cause oscillating shearing strains in the slope material affecting its strength and resistance to erosion (Vallejo and DeGroot, 1988). When waves attack the toe region of the coastal slopes, two types of related forces act on the face of the slopes. One is a normal force to the face and the other is a tangential force to the face that acts when the water retreats. The tangential force causes the removal of material from the toe of the slopes. After these two forces act at the toe of the slopes, they develop a notch in their profiles. Fig. 1 shows a notch developed by a coastal slope in Tulum Mexico.

Figure 1. Notch developed by a coastal slope in Tulum Mexico

The notch in a coastal slope acts a stress concentrator that increments the value of the gravity induced stresses (due to the weight of the slope material) acting on top of the notch. If the slope fails, the failure will be initiated at the tip of the notch where the stresses are the highest (Vallejo and Liang, 1994). Thus, the notch will dictate the way a coastal slope fails. An example of a notch induced slope failure can be seen in Fig. 2. This slope is very close to the one shown in Fig. 1. A field analysis indicated that the failure was induced by a tensile crack that started at the tip of the notch and propagated at an angle of 90 degrees toward the surface of the slope.

Field investigations of slope failures in slopes located in Dover, England; near Port Washington on the Lake Michigan shoreline; and at Del Mar in southern California indicated that the slope failures were the result of notch and gravity induced stresses and were similar to the one shown in Fig. 2. Thus, an analysis of the effect of notches in slope failure is important if one wants to understand the way shorelines retreat.

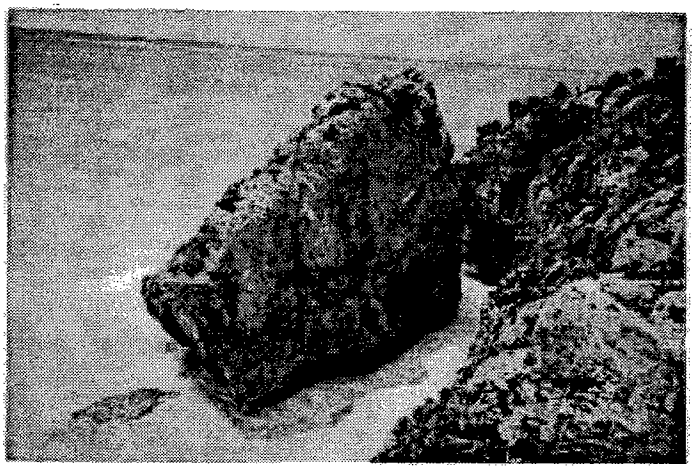

Figure 2. Failure in a coastal slope in Tulum, Mexico.

The type of stresses induced by a notch and the overburden pressures in a slope can be seen in Fig. 3. This figure shows the type of stresses acting on an element of intact material near the tip of the notch. The element is located at a radial distance **r** which is inclined at an angle **q** with respect the horizontal axis of the notch.

The stresses on the element near the tip of the notch are: a tangential stress σ_θ, a radial stress σ_r, and a shear stress $\tau_{r\theta}$. Of these three stresses, the tangential stress causes the failure of the intact material and is used to obtain the direction of crack propagation from the tip of the notch. The tangential stress can be obtained from the following relationship (Vallejo and Liang, 1994)

$$\sigma_\theta = \frac{1}{\sqrt{2\pi r}} \cos\frac{\theta}{2}\left(K_I \cos^2\frac{\theta}{2} - \frac{3}{2}K_{II}\sin\theta\right) \quad (1)$$

In the above equation, K_I and K_{II} are the stress intensity factors. The value of these stress intensity factors can be obtained from the following relationships (Vallejo and Liang, 1994)

$$K_I = 1.12\,\sigma_n\,(\pi c)^{1/2} \quad (2)$$

and

$$K_{II} = 1.12\,\tau\,(\pi c)^{1/2} \quad (3)$$

Where σ_n is the normal stress that acts perpendicular to the horizontal axis of the notch, τ is the shear stress that acts parallel to the horizontal axis of the notch, and c is the notch length.

The notch propagates following the direction of r in Fig. 3 when the value of σ_θ reaches its maximum value at certain value of θ. To obtain the direction of $\theta = \alpha$ at which σ_θ reaches its maximum value, one only needs to differentiate σ_θ with respect to q and make the whole differentiation equal to zero ($d\sigma_\theta/d\theta = 0$). If this is done the following relationship is obtained

$$K_I \sin\alpha + K_{II}(3\cos\alpha - 1) \quad (4)$$

where α is the value reached by θ when crack propagation from the notch takes place.

Eq. (4) can also be written in the following way,

$$\sin\alpha + \left(\frac{K_{II}}{K_I}\right)(3\cos\alpha - 1) = 0 \quad (5)$$

Using Eq. 5, a plot between the angle of crack propagation α and the ratio $\left(\frac{K_{II}}{K_I}\right)$ is shown in Fig. 4 . This figure shows that the angle of crack propagation from the tip of the notch can have values that varied between 90 and 180 degrees as indicated in Fig. 3. The slope with a notch located in Tulum, Mexico failed due to a tensile crack that propagated from the tip of the notch in a direction equal to 90 degrees with the horizontal axis of the notch (Fig.2).

The present paper has used the principles of Fracture Mechanics to understand the way coastal slopes having a notch at their toes fail. The theoretical analysis proved very effective in the interpretation of the failure mode of a coastal slope located in Tulum, Mexico.

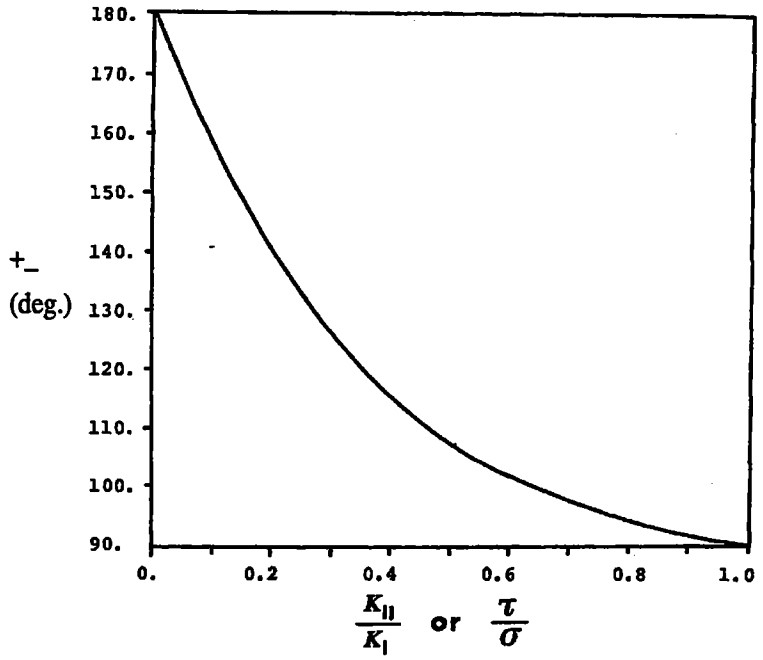

Figure 4. Angle of crack propagation a versus ration ($\frac{K_{II}}{K_I}$).

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INTERANNUAL EVOLUTION OF A MULTIPLE LONGSHORE BAR SYSTEM: POTENTIAL EFFECTS ON BEACH AND BLUFF EROSION

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POSTER

The interannual evolution of a multiple bar system in Cape Cod Bay, investigated using orthorectified vertical aerial photography, serves as a basis for considering mechanisms responsible for the formation and persistence of multiple bar systems. Similar relatively persistent multiple bar systems occur in a range of nearshore environments and provide natural beach protection by dissipating wave energy. Theories invoking breaking waves, standing waves, nonlinear wave processes, wave reflections, and edge waves have been proposed to explain multiple bar formation and maintenance. A consensus regarding which formation mechanisms and maintenance mechanisms dominate in particular coastal environments has yet to emerge. The analysis presented here discounts several theories of multiple bar formation for the Truro bar system, but is not inconsistent with formation and maintenance by wave breaking, standing infragravity waves, evanescent modes trapped by a sharp change in shoreface slope just seaward of the outermost bar, or reflection of wave energy from the shoreline and the bars.

The multiple longshore bars off Truro, Cape Cod, MA extend along a 15 km stretch of coastline and form in a sheltered bay with a 3 m tidal range. The bars are 0.30 – 1.5 m in amplitude, 6-10 in number, have wavelengths of 45 – 150 m (increasing with distance from the shoreline), and extend offshore a distance of up to 660 m (Figure 1). Aerial photographic analysis reveals that since 1960 bar orientation has not changed relative to the shoreline and ranges from oblique in the south to parallel in the north. In contrast, the bars have remained parallel to 4 m and 6 m depth contours (offshore of the bars). The alongshore change in bar orientation relative to the shoreline is accompanied by a change in bar morphology from linear, single features in the south to interconnected and branching features in the north, perhaps owing to the effects of tidal drainage. A particularly interesting feature of this multiple bar system is an unbarred zone in the northern portion of the study area. This zone nearly doubled in size and offshore extent between 1960 and 1994 (Figure 2). There has been an increase in beach and bluff erosion along this 500 m stretch of coast (Shaffer, 1998) possibly related to reduced dissipation of incoming wave energy in the unbarred zone.

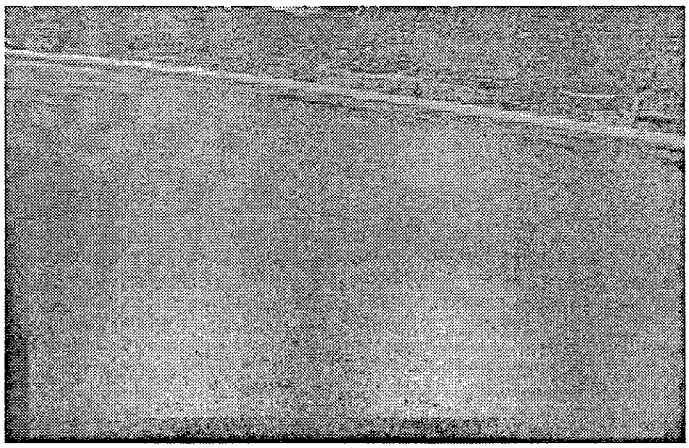

Figure 1. Multiple longshore sand bars off Truro, Cape Cod Bay, MA (Aubrey 1980).

4/20/60
54,020 m²

2/27/84
90,540 m²

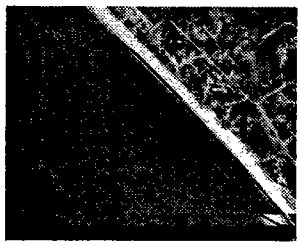

Figure 2. Aerial photographs of the nearshore in Truro. The sand bars extend from the shoreline to about 6 m water depth. The unbarred section is delineated by the white curve near the center of each photograph. Dates (month/day/year) and approximate area of the unbarred section are listed above each photograph.

Detailed field observations of waves, currents, bar bathymetry, underlying geology and sedimentary structures, is planned to determine the mechanisms responsible for the formation and maintenance of the multiple bar system. A better understanding of these mechanisms will provide insights regarding the enlarging unbarred zone and perhaps provide a basis for predicting future effects of the unbarred zone on the corresponding beach and bluff.

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SEASONAL BEACH CHANGES IN HAWAII: RESULTS FROM FIVE YEARS OF BEACH MONITORING

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POSTER

The Hawaiian Islands host some of the most dynamic beaches in the world; large volumes of sediment are eroded and accreted seasonally in response to changing wave and weather conditions. Annual changes in beach width and volume give an indication of beach response to variations in wave energy levels and sediment exchange rates between the beach and adjacent environments. The ability to constrain the boundaries of the active beach and determine if a beach is seasonally dynamic but stable, versus undergoing net change, is important from a management standpoint in terms of planning coastal development and hazard mitigation. In Hawaii, the timing, magnitude, and long-term trend of these changes, however, have been poorly documented.

In an effort to establish baseline conditions and understand the dynamics of beach change in Hawaii a program of beach and nearshore monitoring was initiated in 1994 on the islands of Maui and Oahu. Five years of biannual (approx. summer/winter) profiles on forty-two Oahu and thirty-seven Maui beaches are used to evaluate the morphologic changes and "state of the beaches" on these islands.

Seasonal beach volumes were calculated and the maximum observed profile change over the five-year study was determined. Twenty-seven Oahu beach sites are shown in Fig. 1 where they have been subdivided into four different coastal segments based on orientation, wave climate, and beach response. The maximum observed profile volume change for these beaches is shown in Fig. 2. Minimum, maximum, and average values for each coastal reach are shown in Table 1. Along high-energy beaches, large fluctuations in beach volume, characterized primarily by the formation and erosion of berms, dominate the change signature. Beaches along more protected stretches of coastline show much less variation in profile morphology. Over the study period, beaches on the west (leeward) coast of Oahu experienced the most extreme profile volume variation, followed by the north shore, east (windward) shore, and south shore beaches.

Table 1. Maximum observed volume change (m^3/m) on Oahu Beaches: August 1994 to July 1999

	Minimum/Location		Maximum/Location		Average
Leeward coast	28	Pokai Bay	181	Maili	117
North shore	12	Alii, Haleiwa	92	Waimea Bay	54
Windward	8	Hauula	116	N. Waimanalo	40
South coast	6	Kahala	39	Ewa Beach	19

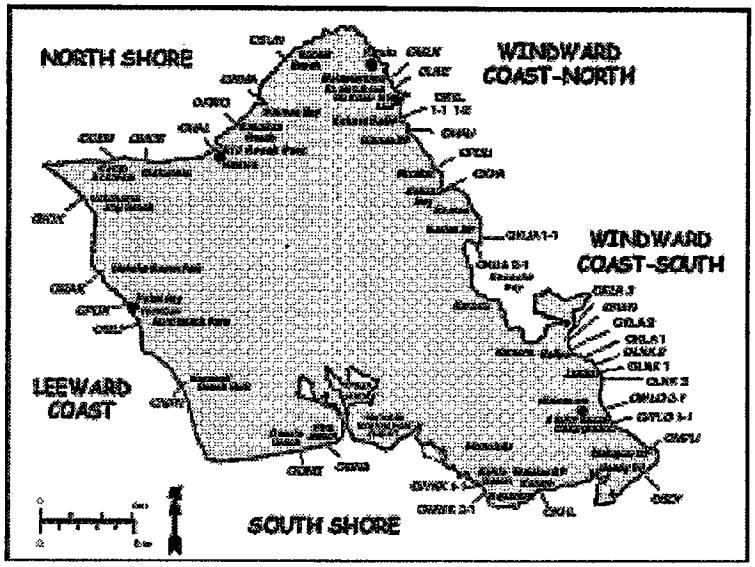

Figure 1. Beach monitoring profile locations on Oahu. Maximum observed volume variation from sites in italics *are included in Figure 2.*

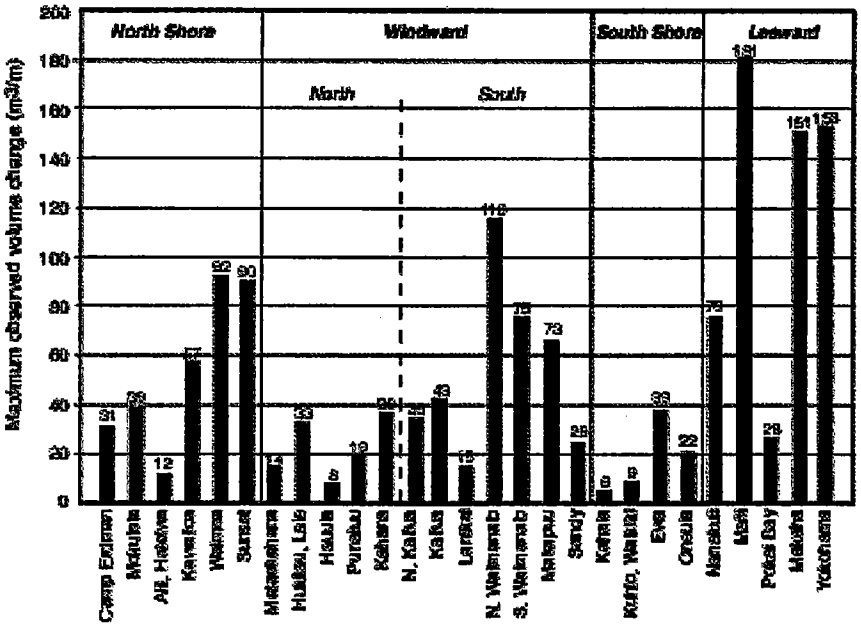

Figure 2. Maximum observed volume change on Oahu beaches over five years of biannual beach profiles. Leeward (east) side beaches experienced the greatest amount of profile variability, followed by the north shore, windward (west) shore, and south shore beaches.

In general, seasonal fluxes in beach volume followed a summer accretion/winter erosion pattern on most of Oahu's beaches. Sites along the northern-windward coast (Hauula to Kahana), Waimea Bay, and Pokai Bay showed a weak winter accretion/summer erosion trend, and several sites (Camp Erdman, Haleiwa, Laie, Makapuu, Kahala, and Nanakuli) showed no apparent seasonal correlation (Fig. 3).

Although some beaches showed net gain or loss during the study period, most beaches remained relatively stable with change limited to a finite envelope. No island wide beach erosion or accretion trends were observed during the study period. No extreme events, such as tropical storms or hurricanes, directly influenced the Hawaiian Islands during the study period. This data set should therefore be considered as representative of typical annual beach activity. Greater variation, and likely long-term change, would be expected during extreme events.

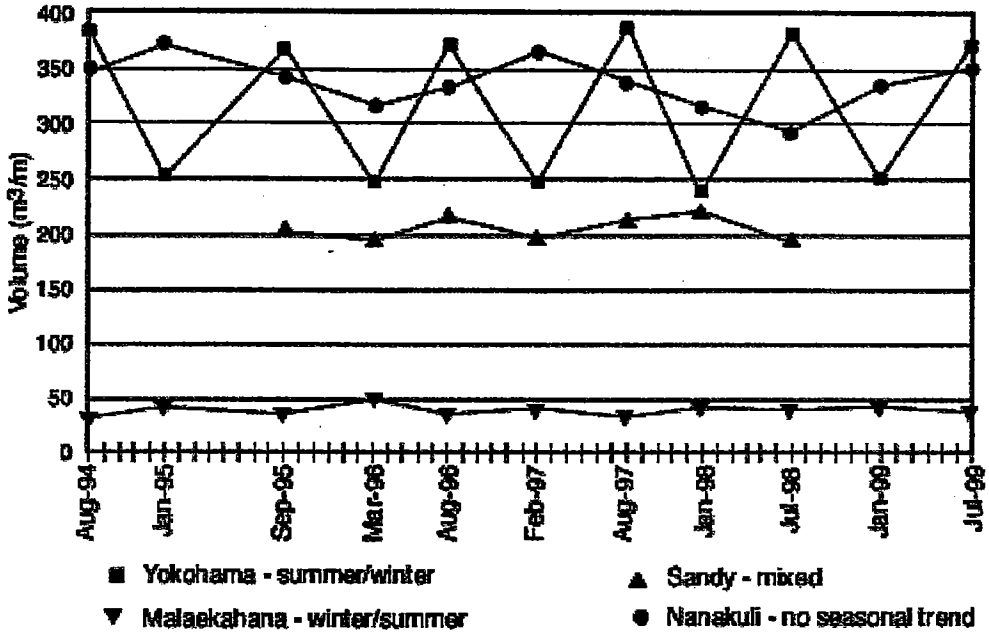

Figure 3. Seasonal beach volume variability around Oahu. Yokohama Beach, the northernmost beach on Oahu's leeward shore, shows the most regular and well-defined seasonal correlation to volume change of any Oahu beaches. Malaekahana is one of the few sites to show the opposite winter erosion/summer accretion trend. Sandy Beach on the south shore shows a mixed seasonal response, and Nanakuli on the leeward side shows no obvious correlation to changes in seasonal conditions.

ENVIRONMENTAL PROBLEMS, CONSEQUENCES, AND PROPOSED ACTIONS, AT SHARM EL MOIYA BAY, GULF OF AQABA, RED SEA, EGYPT

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POSTER

Dramatic water, sediment and air pollution has been documented at Sharm El Moyia bay at the Gulf of Aqaba, Red Sea, Egypt. These problems have seriously affected the tourism industry at the vacinity of the bay. Occasionally, international residents complain from hydrocarbon odor, floating diesel fuel on water surface, heavy oily sediments on the seabed and beach face along the shoreline. This study aims to identify different sources of pollution, evaluate impact consequences on the marine ecosystem of the bay, and proposing several alternate actions to control and/or remedy the identified problems. Two main sources of pollution have been identified in the bay. The first is located under water of the vicinity of the unused old jetty west of the bay where an accumulation of contaminated sediments are observed in the sea bottom of this area. The second source is the liquid fuel leakage from the rocky plateau at the site of the former power plant. In addition, serious large quantities of health hazard asbestos are inspected spreading the site of the power plant.

Extensive field survey program was carried out to spatially locate the configuration of the thickness of the highly contaminated bottom sediments of the first source. Beach profile survey combined with current measurements and sea level variations was recorded. Wave characteristics and the initial velocity of sand motion were computed using computer models. Several alternate actions were proposed to control and/or remedy the identified problems.

STUDY ON THE BEACH PROCESSES IN SONGDO, YOUNGIL BAY, KOREA

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POSTER

INTRODUCTION

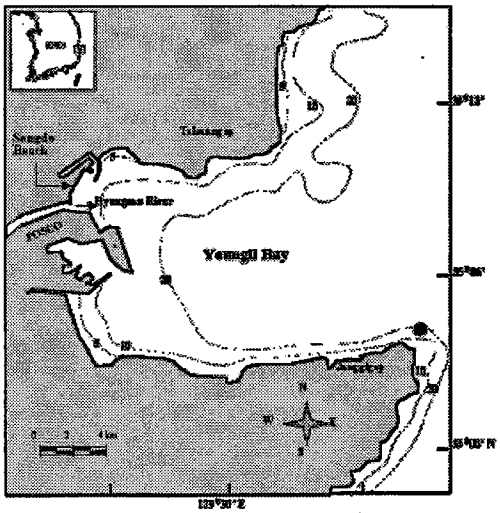


Figure 1. Location map of Songdo Beach and wave observation station (•)

In the last three decades, marginal shape of the Youngil Bay has been modified due to construction of industrial facilities and development along the shoreline. The Youngil Bay is located at the southeastern part of Korean Peninsula and its average depth is about 20m. Songdo Beach is located at the inner part of the Youngil Bay with about 2.5km of length and 50m of width (Figure 1). The beach experienced two severe beach erosions on Feb. 1979 and Sept. 1998. Since the first erosion on Feb. 2, 1979, three pieces of 100m long groin have been constructed in order to trap the littoral drift of sand.

This study was to investigate the causing factors of the beach erosion occurred in Sept. 16, 1998. Field observation, analysis of present data and shoreline modification using aerial photograph were performed to investigate the short and long term beach deformation mechanism in Songdo Beach.

DATA COLLECTION AND FIELD OBSERVATION

The maximum spring tidal range in Youngil Bay was about 26.5 cm and the tidal current speed was less than 10 cm/s. The result of long-term analysis of tidal data over past 3 decades in the Youngil Bay showed the tendency of rising by an average of 1.4 mm/yr (Son., 1999). The tidal action and sea level rise were thought to be negligible in Youngil Bay.

The data of directional wave rider buoy observation were obtained from KORDI (Korea Ocean Research and Development Institute). From the data, the significant wave height during the beach erosion was about 4m, which was about 4 times higher than that under the normal condition (Figure 2). Also, two times longer wave period was observed during the beach erosion.

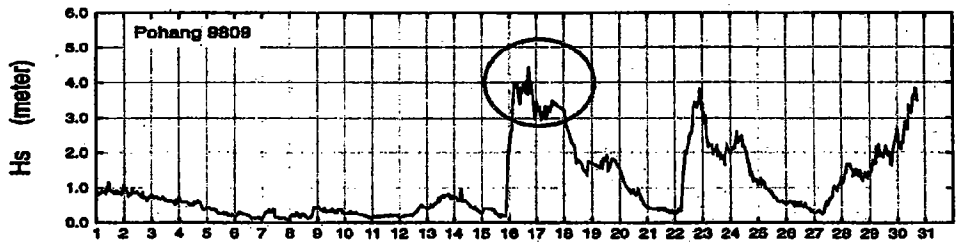
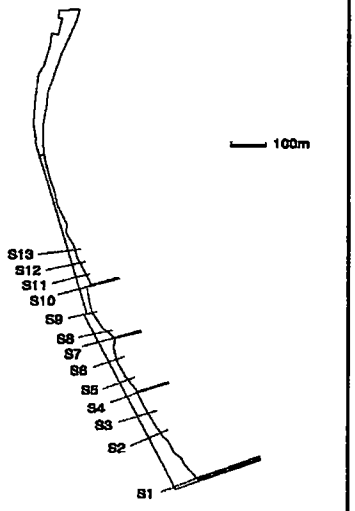


Figure 2. Time series of significant wave height at the observation station (September 1998, Provided by KORDI)

Eulerian and Lagrangian flow field observations in the Youngil Bay were carried out and the results showed the general known trend of the circulation in the Youngil Bay very well. The surface current showed the reverse direction against bottom layer current because wind was the major current driving force in the surface layer. Current velocity and direction were observed in surface and bottom layer, which were about 85 cm/s eastern and 10 cm/s western, respectively. Additionally permanent current in the Youngil Bay was anticlockwise from northeast to southwest direction. The results of field observation were in good agreement with other previous reports.

Beach width measurements on Songdo Beach were also carried out at 13 lines normal to the shoreline. The result showed that beach width on Dec.16 was longer than that on Sept. 1 in all lines (Table 1). From this result, restoration of the beach was assumed to be in process.

Table 1. Variations of beach width on Songdo beach



Section No.	Observed on Sept. 1, 1999 (1)	Observed on Dec.16,1999 (2)	Difference (2)-(1)
S1	71.35	77.27	5.92
S2	44.41	50.56	6.15
S3	44.89	46.14	1.25
S4	57.68	49.37	8.31
S5	35.77	37.27	1.50
S6	29.48	30.16	0.68
S7	54.39	51.09	-3.30
S8	40.67	41.71	1.04
S9	23.97	37.44	13.47
S10	26.75	38.56	11.81
S11	33.95	48.25	14.30
S12	24.64	35.64	11.00
S13	18.92	30.30	11.38

ANALYSIS OF AERIAL PHOTOGRAPH

Aerial photographs taken in the year of 1967, 1977, 1987, and 1996 by National Geographic Institute were analyzed for the purpose of variation detection of coastline width on Songdo beach, The modification of beach width was evaluated according to following three steps. Firstly a cross-range profile of coastline collected from the four aerial photographs was examined using digital photogrammetric workstation called Intergraph ImageStaion and to determine whether the sand has been sedimented or eroded. Secondly the trend of its relative change was analyzed after setting inner boundary of the beach in 1996 as a baseline. Finally the volume and surface area of the beach at each time were estimated and compared. By means of photogrammetric process above, features such as coastlines, spot heights and inner boundary of beach were collected and the data were visualized using GIS tool.

From the analysis of the cross-range profile, it was apparent that the beach change at the center of beach was negligible between 1967 and 1996. At the north of Songdo Beach, however, shoreline advance of about 200 m to the sea occurred (Figure 3 & 4). Similar result was derived from the calculation of surface area and sand volume change (Figure 5).

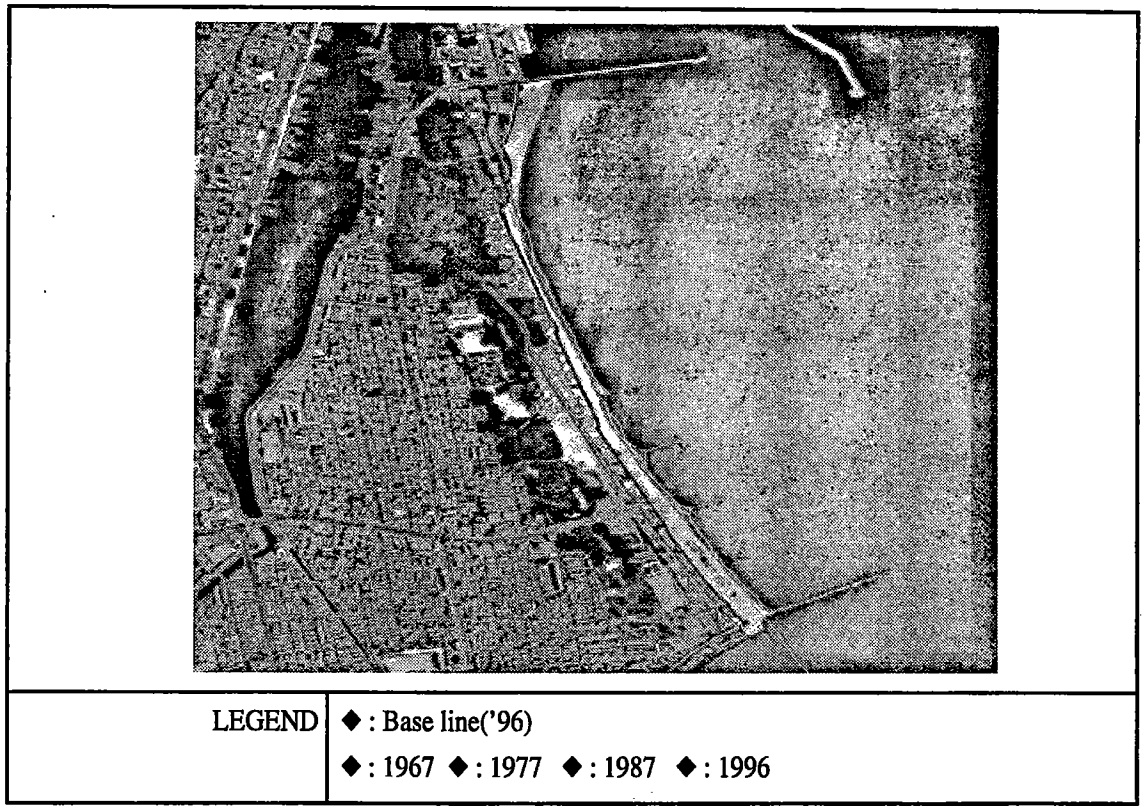


Figure 3. Analysis of aerial photographs during 1967- 1996

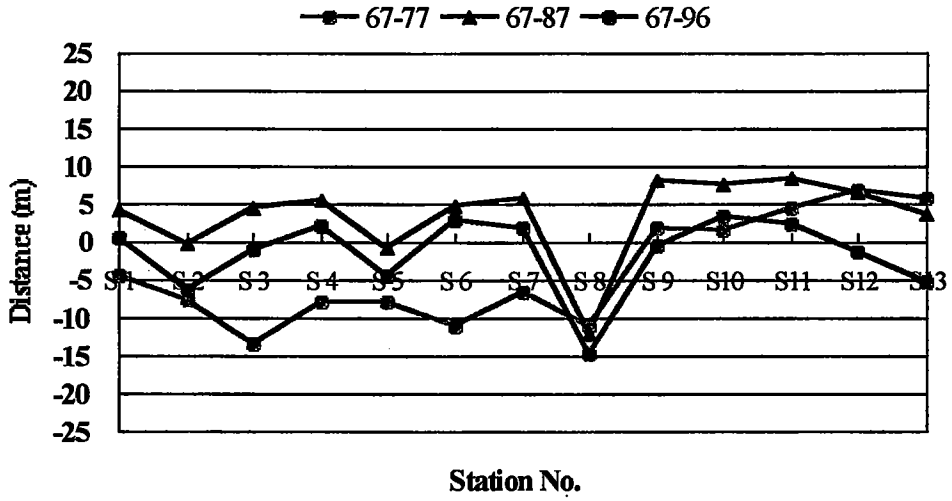


Figure 4. Variations of beach width between 1967 and 1996 in the central part of Songdo Beach (Details of station number were stated in Table 1).

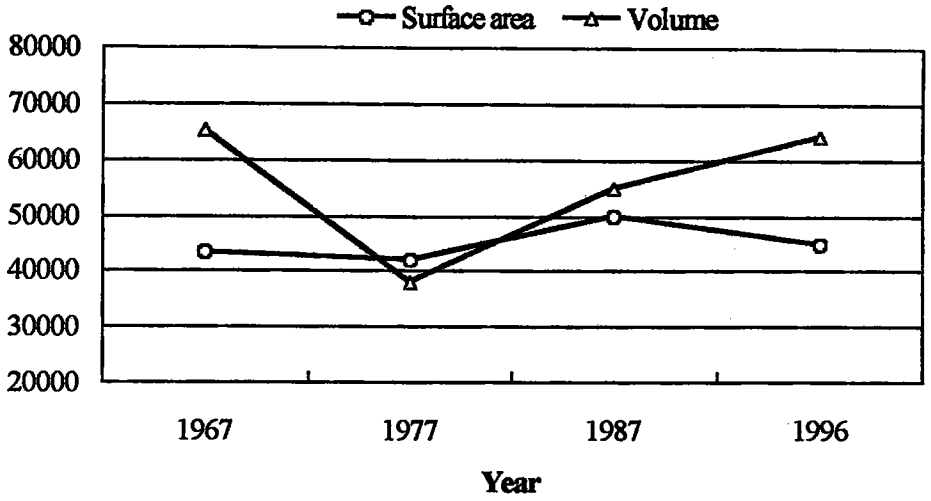


Figure 5. Variations of surface area and total sand volume between 1967 and 1996 at the Songdo Beach.

CONCLUSIONS

The short-term beach deformation in this study area depended strongly on the characteristics of incident waves. During the beach erosion, there were 4 times higher significant wave and 2 times longer wave period than under normal conditions.

Although the coastline was moved inward from 1967 to 1977, the movement of coastline has not shown any trend since 1977. Similar result was derived from the calculation of surface area and sand volume change.

Consequently it was assumed that there was no detectable deformation pattern such as erosion or deposition at Songdo Beach during last 3 decades.

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BOLINAS LAGOON: A METHODOLOGY FOR PREDICTING A TIDAL LAGOON'S FUTURE CONDITIONS

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POSTER

Bolinas Lagoon is located approximately fifteen miles north of San Francisco, CA, and is currently the focus of a U.S. Army Corps of Engineers ecosystem restoration project. As with many lagoon/ estuarine systems, Bolinas Lagoon has suffered environmental degradation from activities in its watershed such as logging, grazing, farming, development, fire roads, etc. These activities have caused above normal sedimentation rates in the lagoon, which have led to the accelerated losses of tidal prism and sub-tidal/inter-tidal habitat. Also, as a direct consequence of the loss of tidal prism, the stability of the lagoon's inlet has been reduced.

To help improve the functionality of the lagoon, several restoration alternatives have been designed to increase tidal prism and sub-tidal/inter-tidal habitat levels. In order to have a base line to judge the effectiveness of these alternatives, the without-project condition needed to be determined. This consisted of determining how the lagoon would look in fifty years without further human impact or unexpected natural alterations to the system.

Three main indices were chosen to measure the progression of the lagoon system:

1. Tidal Prism (Effective and Potential)

Potential tidal prism was found using projected sedimentation rates. Effective tidal prism was estimated using the projected values of potential tidal prism in conjunction with tide data recorded at various times in the lagoon's history.

2. Expected Inlet Closure Date

The inlet closure date was estimated by applying O'Brien's Closure Index criteria to the projected potential tidal prism volumes.

3. Habitat (Volume and Surface Area)

Habitat was determined using predicted water levels and lagoon bathymetric survey data.

A key piece of information needed in all of the above calculations was the prediction of future water levels within the lagoon. The determination of this vital piece of information will be the main focus of our presentation.

As a lagoon/estuary system fills with sediment and loses potential tidal prism, the tidal exchange becomes less efficient due to increased friction, inlet cross-section reduction, and increased channelization. Using tidal data and bathymetric surveys from 1968 to 1998, a mathematical relationship was developed directly linking the change in the lagoon's diurnal tide range to the change in potential tidal prism. This relationship used in conjunction with predicted potential tidal prisms, provided a means to predict future water levels within the lagoon.

Provided in Tables 1 and 2 is a summary of the information used and the predicted values for water surface elevations within the lagoon for both Spring and Neap tides.

TABLES 1 AND 2. WATER SURFACE ELEVATION PREDICTION

Spring Tide

Year	Potential T.P. million ft³	Ocean High feet-NGVD	Lagoon High feet-NGVD	Lagoon High %	Ocean Low feet-NGVD	Lagoon Low feet-NGVD	Lagoon Low %	Spring Range feet
1968	175.24	3.15	3.00	0.95	-3.45	-1.70	0.49	4.70
1978	153.80	3.15	2.79	0.87	-3.45	-1.35	0.40	4.12
1988	145.57	3.15	2.62	0.83	-3.45	-1.28	0.37	3.90
1998	139.07	3.15	2.54	0.81	-3.45	-1.18	0.34	3.72
2008	132.75	3.15	2.46	0.78	-3.45	-1.09	0.32	3.55
2018	126.61	3.15	2.38	0.75	-3.45	-1.01	0.29	3.38
2028	120.65	3.15	2.30	0.73	-3.45	-0.92	0.27	3.22
2038	114.86	3.15	2.23	0.71	-3.45	-0.84	0.24	3.07
2048	109.29	3.15	2.15	0.68	-3.45	-0.76	0.22	2.92
2058	103.89	3.15	2.08	0.66	-3.46	-0.68	0.20	2.77

Neap Tide

Year	Potential T.P. million ft³	Ocean High feet-NGVD	Lagoon High feet-NGVD	Lagoon High %	Ocean Low feet-NGVD	Lagoon Low feet-NGVD	Lagoon Low %	Neap Range feet
1968	133.31	2.25	2.08	0.92	-2.05	-1.11	0.54	3.19
1978	113.74	2.25	1.94	0.86	-2.05	-1.25	0.61	3.19
1988	107.23	2.25	1.89	0.84	-2.05	-1.30	0.63	3.19
1998	99.27	2.25	1.84	0.82	-2.05	-1.36	0.66	3.20
2008	92.95	2.25	1.79	0.80	-2.05	-1.41	0.69	3.20
2018	86.81	2.25	1.75	0.78	-2.05	-1.45	0.71	3.20
2028	80.86	2.25	1.70	0.76	-2.05	-1.49	0.73	3.20
2038	75.08	2.25	1.66	0.74	-2.05	-1.54	0.75	3.20
2048	69.50	2.25	1.62	0.72	-2.05	-1.58	0.77	3.20
2058	64.09	2.25	1.59	0.70	-2.05	-1.62	0.79	3.20

* Shaded values were predicted or interpolated

Potential tidal prism was calculated using bathymetric surveys and data from the Presidio Tide Station (4290), for 1968, 1978, 1988, and 1998. From this data, the rate of potential tidal prism loss was determined and then extrapolated sixty years to 2058. Lagoon tide data was taken from data recording sessions in 1968 and 1998. Using the ocean and lagoon tidal data, the lagoon's water surface elevation was converted to a percentage of the ocean's elevation. This combined with the measured change in potential tidal prism, was used to determine the ratio of change in lagoon water surface elevation to change in potential tidal prism i.e. (1998 water level – 1968 water level)/(1998 potential tidal prism – 1968 potential tidal prism). With this ratio, the lagoon's water surface elevation could be determined simply by multiplying the measured or predicted change in potential tidal prism by this ratio (Tables 1 and 2 and Figure 1).

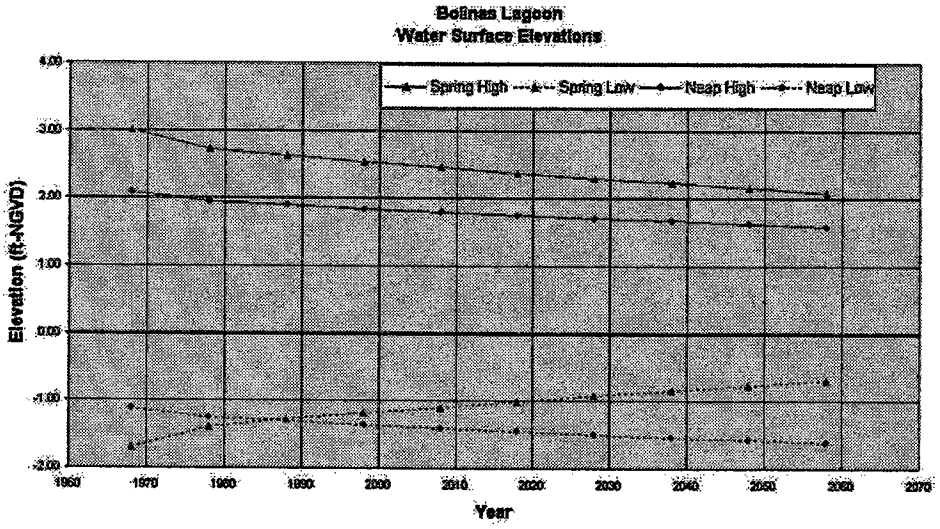

Figure 1. Bolinas Lagoon Water Surface Elevations

Note the cross over of the neap low tide reaching lower elevations than the spring low tide. This phenomenon has been observed in recorded data and explanations for this will be discussed at the conference.

In addition to the obvious limitations in accuracy, the use of what is essentially linear interpolation and extrapolation to represent a process that would be more suitably represented by some type of polynomial function, introduces further error. If tidal data were available for 1978 and 1988, a better mathematical relationship would have been developed. With increased application and study, there is potential for developing this further into a generalized empirical equation for use on estuaries with limited historical data.

For this study, we found that using numerical models (hydrodynamic and sedimentation) to estimate the lagoon's condition fifty years in the future would have been cost prohibitive and no more accurate than the methods used here. By using the methods described, significant cost and time savings were realized.

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GIS TECHNICES USED TO ANALYZE SEDIMENT MOVEMENT IN BOLINAS LAGOON

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POSTER

Bolinas Lagoon (Marin County, California) is a highly dynamic estuary that has lost tidal prism and subtidal/intertidal habitat caused by above normal sedimentation rates. The San Francisco District of the US Army Corps of Engineers (USACE) is currently analyzing the lagoons transformation over the past 150 years and designing various restoration alternatives to help return the lagoon to a more natural condition. These analyses look closely at the volumetric changes and spatial movement of sediment throughout the lagoon system.

Utilizing GIS tools, USACE staff is able to visualize the historic changes to the lagoon and determine the possible effects from proposed restoration alternatives. Horizontal movement of sediment is analyzed by grid to grid comparisons, while volumetric changes are analyzed by creating volume to elevations rating curves for the 1968, 1978, 1988 and 1998 bathymetric survey Triangular Irregular Networks(TINs). GIS is also used to create the project alternative model meshes, which is proving to be a true time savers.

The GIS uses recent and historic aerial images, detailed bathymetric surveys, and computer model (RMA-2) results to generate graphical and quantitative results. Software used on this project are ESRI's ArcView, ArcInfo, Spatial Analyst and 3D Analyst, AutoDesk's AutoCAD Map, Civil Survey and CAD Overlay and ER Mapper.

Because the data for this project is from multiple sources, data quality and compatibility is key. Using GIS makes it possible to incorporate all the project data into a common system. Error has been minimized by a tight QA/QC process and survey control. Because this is new territory for many of the engineers involved, using GIS was a risky project decision. The learning curve on this project has been quite steep; however, using GIS to assist engineers is proving to be both highly beneficial and cost effective.

CHARACTERIZATION OF COASTAL EROSION MANAGEMENT BY THE GULF STATES

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POSTER

A report characterizing the manner in which each of five Gulf of Mexico states treats problems arising from coastal erosion and regulates methods to mitigate such problems. The characterization considers the integrated meaning of pertinent laws, regulations, and written policies together with the application of such to specific permitting decisions, lawsuits, or other visible actions. It is intended to express a general philosophy and a projection for each state, which has: a) a basis in each state's historical treatment and regulation of such problems, and b) an anticipated long-range outcome in terms of each state's relation to the management of its coastal zone.

RECREATIONAL USE OF THE NORWEGIAN BEACHES

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POSTER

Outdoor recreation is part of the Norwegian cultural heritage. The Right of Common Access - the right to stay temporarily almost anywhere in the outdoors - is a fundamental principle of Norwegian traditions for outdoor recreation. This right is based on a respect for nature and for considerate behavior with respect to environmental values, landowners and other users. However, even though this kind of behavior is rooted in Norwegian culture and history, it does not prevent the impact of outdoor activity on natural resources.

This study investigates who the users of the beach area are and their use of the Jærbeaches on the Norwegian west coast, a 70 km long protected area. More specifically this study analyzes particular types of beachexperience ; perceptions of crowding, motivations, and satisfaction with the experience and perceived negative impacts.

The study uses a questionnaire and does not have an experimental design, rather it uses survey methodology with an investigative intention. The study was divided into three steps where the initial part used local media mail-in-questionnaires and internet surveys in order to map patterns of use. In the second part questionnaires were administered directly to the users on the parking lots after the beach visits. Finally the third part is using a technique called Visitor Employed Photography (Cherem, 1978) – where disposable cameras are distributed to the beach users, who are asked to take pictures of specific topics. This technique is used in order to analyze perceptions of positive and/or negative impacts in the area.

The results from the study gave us some characteristics of the beach users. There was no distinct contrast between females and males using the area. The users were predominantly local people from the area around Stavanger and their age ranged from 17 to 67 years.The sample were mainly being full time employed carrying a university degree, but a large amount of students were also present. The most common use of the beaches was together with friends in groups of two or three people.

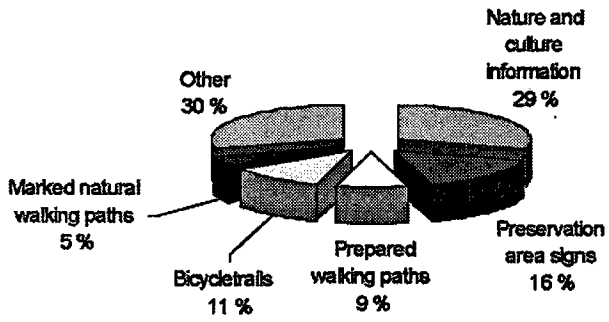

Figure 1: Prioritized list of visitor management initiatives

61.1% of the Norwegian sample believed that there was a need for increased visitor management. When forced to choose one single initiative, the results show that information in the form of natural and cultural information (see Figure 1), do's and don'ts together with ethical behaviour towards loose dogs and the use of horses along the beaches were the most important. Further, when ranking all visitor management initiatives and caluclating an overall perceived need for initiatives, almost 100 % wanted to have prepared paths in order to guide users not to walk in areas where nature is scarce.

MOTIVATIONS

The original motivation scale was developed by Kearsely (1996). For the purpose of tis study it has been translated and adjusted to suit the Norwegian culture. In general the motivations for beach tramping were very diverse and easier related to the individual than to a group.

The primary motive for enjoying the beaches the "landscape/tramping experience" followed by "exercise/sport", "peace of mind", "sun/bath" was the beach users got when walking on the beaches. Scenic beauty was the second strongest motive, and exercise was close behind on number three. As

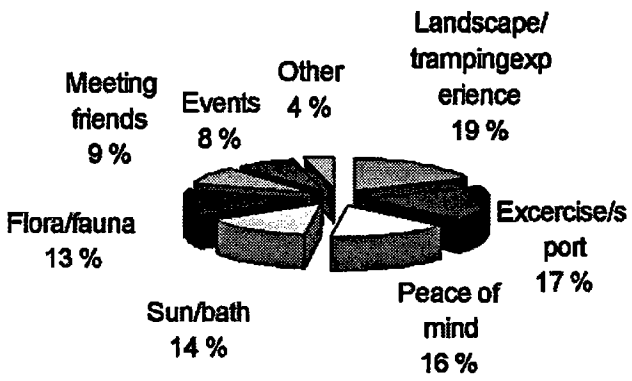

Figure 2: Motivations for using the beach

PSYCHOLOGICAL BENEFITS

A modified inventory for perceived psychological benefits (Grahn, 1999) was integrated in the survey. The results reported was perception of increased "physical fitness", "increased closeness to nature" and that they became "more relaxed" by being in the outdoors on the beach.

THE FIVE SENSES

The majority of the respondents report "sight" as the sense that makes the greatest impression, examples given are, seeing flowers, water power, sea grass moving, animals and seabirds etc. Hearing is also a sense that makes great impression, with examples reported like, birds, water waves, wind etc. Some respondents reported use of all senses, and creative examples like the taste of blueberries, smell of freshness and nature and finally, a feeling of luckiness was reported.

Manning (1999) states, it is typical that more than one motivation is sought and realized from recreational participation, which was also shown in our results.

BEACH SELECTION

When it comes to selecting which beach area of visiting, there are two out standing reasons, the "expected value of beach experience" and the "distance from home". Availability of "parking" and perception of "crowding" are also taken into consideration (see Figure 3).

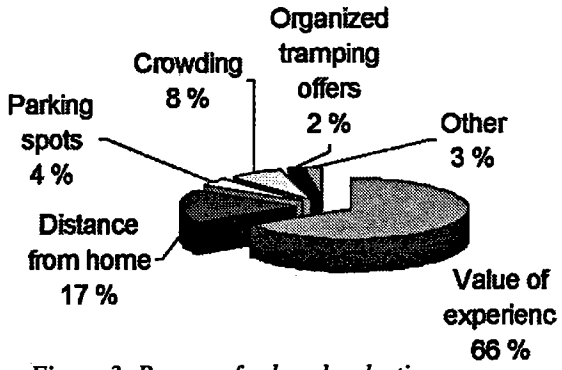

Figure 3: Reasons for beach selection

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GOING DIGITAL: ERROR EVALUATION OF MEDIA AND SCANNER TYPES FOR AERIAL PHOTOGRAPHIC ANALYSES IN COASTAL CHANGE STUDIES

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POSTER

Aerial photography is commonly employed in coastal studies to establish the positions of historical and modern features-of-interest (e.g. shorelines, cliff edges, spit or dune positions, etc.), to delineate hazard areas and setback lines, and to study coastal dynamics. The recent proliferation of digital photogrammetry and GIS software has greatly increased the accessibility of aerial photograph analysis; many packages can be run on a standard desktop computer and do not require formal training in photogrammetry or GIS. Using such software requires obtaining aerial photography and scanning it to convert to digital format. There are several options as to the media of the aerial photography and the choice of scanners, all of which may have noticeable impact on the spatial accuracy of the final orthophotograph. This study provides a quantitative assessment of the accuracy of aerial photography media types and scanners currently available to coastal researchers and makes recommendations based on the scope of a particular research objective.

The first step in digital aerial photograph analysis is to convert the photograph into a digital format. Researchers have several options for scanning photographs but little information is available as to which types of scanners are suitable for photogrammetric/photographic analyses. The high-end choice, a geometrically-correct photogrammetric scanner, will produce minimal distortion. This ensures that the exact spatial distribution of objects in the original photography is reproduced in the digital version. True photogrammetric scanners, however, are expensive and while this task may be contracted to a professional scanning firm, the per-image scan cost is still quite high. Therefore, it is not uncommon for researchers to use high-end graphic design scanners or even desktop scanners as a substitute. Graphic and desktop scanners are not designed to assure geometrically accurate data conversions, and thus may introduce distortion to the digital imagery, which results in non-systematic positional errors in the resulting orthophotograph. In addition, standard aerial photography is typically available from the original negatives in 2 different media: contact (paper) prints and diapositives (positive film transparencies). Although contact prints cost less and are readily available, the paper may undergo stretching, shrinkage, and warping, resulting in positional errors. Diapositives are a much more stable media, as transparent film is much less likely to undergo similar distortion. This study is designed to quantify the potential errors introduced by non-photogrammetric scanners and stretching or shrinking of paper contact prints, in order to provide guidance to coastal researchers and managers on appropriate media and scanners to use for coastal investigations.

For this study, we acquired one aerial photographic stereo pair (1:12,000 scale) in both contact print and diapositive media. The diapositives were first scanned on a photogrammetric-grade scanner at 20 μm (approx. 1270 dpi) to produce control images with which to compare the other scanning methods and media. The diapositives and contact prints were subsequently scanned on a high-grade graphic design scanner and on a large desktop scanner, at 1270 dpi and 800 dpi, respectively. It is important to note here that one limitation of desktop scanners is that the scanning resolutions rarely exceed 800 dpi; most photogrammetric workflows recommend 1200 dpi or higher.

Each data set was fully orthorectified using a stereo-enabled photogrammetric workstation. Full rectification includes 1) collection of fiducial marks to remove camera system distortions, 2) tie-point collection to remove camera position distortions and to tie the photos to each other, and 3) ground point collection and aerotriangulation, which relates the images to real ground space. Ground control points

were collected using GPS and have decimeter or better accuracy. The photogrammetric workflow also includes the generation and editing of a Digital Terrain Model (DTM) in stereo to completely remove relief distortion from the photography. The results of the photogrammetric processing for the different media and scanner types are shown in Table 1. The RMS values shown are for checkpoints, which are surveyed ground control points whose positions were measured on the images, but were not used in the solution. Therefore, they represent the difference between the real-world coordinate system position and the position where they were measured on the rectified images. These points are the best indicators of absolute positional errors based on a least squares solution, which is the standard for error calculations in digital photogrammetry software packages.

Table 1: RMS Aerotriangulation Error for Checkpoints

Scanner/Media Type	*XY RMS Error (m)*
Photogrammetric/Diapositive	**0.49**
Graphic Arts/Diapositive	1.36
Graphic Arts/Contact Print	0.97
Desktop/Diapositive	1.43
Desktop/Contact Print	2.43

In order to put the RMS values in Table I into perspective, consider the National Map Accuracy Standards (NMAS), which state that in order to conform to these standards, 90% of identifiable stationary objects should be accurate to within the RMS calculated using Equation 1,

$$E_{rms} = H/f_{xy} \qquad (1)$$

Where E_{rms} is the RMS error, H is the flying height of the aircraft, and f_{xy} is the accuracy criteria factor specified by NMAS (see Falkner, 1995). For 1:12000 scale photography, the RMS error should not exceed 0.67m. Therefore, the *only* combination of scanner and media type that conforms to NMAS is the diapositive scanned on a photogrammetric scanner. For the remainder of this study, the orthophotograph and DTM derived from this scanner/media combination was held as the control against which errors on the other orthophotographs were measured.

In order to statistically evaluate positional error in the orthophotographs and elevation errors on the DTMs, we constructed a 65 m^2 grid, identified test points within each grid cell, and compared the x, y, and z coordinates of 64 test points against the control orthophotograph and DTM. The resulting RMS value for each orthophotograph, based on the 64 points, is shown in Table 2.

The results of the RMS analysis show that the RMS error increases with the lower precision scanner and with the use of contact prints versus diapositives. Although RMS errors ranging from 0.85m to 2.42m (for contact prints on a desktop scanner) do not seem excessively large, even the smallest error shown in Table 2 exceeds NMAS. The standards also require that the maximum error at any given point, either horizontal or vertical, does not exceed triple the magnitude of the RMS, or 2.01m for this study. Table 2 shows that in each scenario tested, this value is exceeded almost always in the X and Y, and in every case in the Z direction. If the coastal mapping application involves delineation of absolute position (e.g. establishing set-back lines, determining hazard zones to the level of individual property boundaries, etc.), or if it is to be published where it could be used for such applications, then it is especially important to use a technique that adheres to the NMAS. In these cases, it is important to use diapositive film that is scanned on a photogrammetric scanner.

Table 2: RMS Errors and Maximum Offset for Test Grid Points					
Scanner/Media Type	XY RMS (m)	Z RMS (m)	Max. X Offset (m)	Max. Y Error (m)	Max. Z Error (m)
Graphic Arts/Diapositive	0.85	1.42	1.75	2.00	6.10
Graphic Arts/Contact Print	1.05	1.61	5.47	1.60	6.64
Desktop/Diapositive	1.22	1.68	1.97	1.20	4.55
Desktop/Contact Print	2.42	2.23	10.28	9.40	8.50

For other types of coastal applications, errors in the 0.85m to 2.42m range may be quite acceptable (i.e. rate calculations, especially over long periods of time). It is very important to note however that there may be large non-systematic errors that exist within the final orthophotograph. In Table 2, the maximum offset in the position of one of the test grid points exceeded 10m. These types of errors may not be uncommon and occur regardless of how well an image is orthorectified. These non-systematic errors are most likely due to stretching or shrinking of the contact prints (note the high offsets associated with the contact prints in Table 2) or to errors introduced by the scanner. In every combination of media and scanner type, the elevation errors are fairly large (4.6m – 8.5m). If elevation data is being extracted for a study (dune height change, beach elevation change, etc.), then elevation errors of this magnitude may not be acceptable.

Table 3 summarizes our preferred scanner and media choices for a variety of coastal research activities utilizing aerial photography. It should be noted here that the image quality of scanned contact prints is significantly degraded as compared to scanned diapositives, regardless of the quality of the scanner. This may result in the inability to measure ground control points and tie points accurately. Therefore, we recommend that diapositives be used whenever possible.

TABLE 3: Recommended Scanner and Media Types for Coastal Research	
Project Scope and examples	***Recommended Scanner & Media***
Absolute position: set-backs, hazard zones, elevation changes, short-term changes	**photogrammetric scanner/diapositives**
Long-term erosion rates : bluff or shoreline change studies	graphic arts scanner/diapositives
Thematic mapping: vegetation, land use, watershed mapping	desktop scanner/diapositives

Our results suggest that through the use of a full photogrammetric workflow that includes precise GPS ground control and DTM editing, the errors associated with non-photogrammetric scanners are small enough for many coastal mapping applications. If the processing does not involve aerotriangulation and DTM extraction then the errors may be significantly greater than those presented here. Full orthorectification can remove some of the error that is introduced from the geometric inaccuracies of scanners and the warping of paper contact prints. In all cases, we recommend using diapositives instead of contact prints due to issues of both image quality and non-systematic errors. In general, when small magnitude coastal changes are expected and high accuracy is necessary, or the final product is to be used for management decisions on the scale of individual properties, we highly recommend using diapositives and true photogrammetric scanners.

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INNOVATIVE BEACH RESTORATION TECHNOLOGIES

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POSTER

As Real-Time Kinematic (RTK) GPS becomes more widely accepted in the surveying world, this technology is steadily replacing conventional survey systems and techniques. Real-Time Kinematic GPS provides surveyors with the ability to determine, to centimeter level accuracy, the three dimensional position of a moving platform. It is the ability of RTK GPS to calculate the height of a survey vessel that is bringing big improvements in the accuracy, efficiency and safety of surveying beach profiles.

This paper will discuss two recent projects where RTK GPS and application specific software is being used ahead of conventional systems in the marine environment to improve the accuracy, efficiency and safety of surveying beach profiles and shipping channel clearances.

MODIFICATION OF A SEAWALL TO PROVIDE A SCALLOPED BEACH AREA

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Lahaina, HI

POSTER

Papakea is a Hotel-Condominium Resort in the Honokowai (West Maui) area. Prior to 1980, Papakea had a sand beach about 1,000 feet long by 100 feet wide (aerial photo). In 1980 a major storm stripped the beach of sand and eroded part of the property shoreline. Because the ocean-front buildings were too close to the eroded area based on the best engineering knowledge available at that time, a made to preserve the shoreline by the construction of the present seawall rather than to use a revetment. The wave action against the seawall and the resulting undertow keeps washing away any sand deposited by the N-S current. The beach area is now a lightly sanded rocky surface bounded by a vitrified sand bar. The sand bar is parallel to the seawall and about 50 feet away from the wall.

This proposed project is intended to restore only 200′-225′ of sand beach to Papakea. There are wide grass areas between the ocean-front buildings (A-F and F-L). The proposed construction should enclose an area about 75 feet square between the F and L buildings, starting at the seawall and extending back into the land area. The portion of the enclosing walls subject to wave action would be slanted, the entrance should be smoothly curved. The wall structure enclosing the beach area onshore should be no lower than the present seawall. About 225′ of seawall would be demolished.

A "tee-head" groin would extend from each end of the wall opening, outward toward the ocean. The enclosed area would be graded to assure sand retention. A rock base would underlay the sand layer. The material required should be available in the rubble in the alluvial fan of the Honokowai Stream that exits at the south end of Papakea property. Normally a sand dune builds up in the stream exit (extended concrete channel walls seem to act as groins). This clean sand plug (500-1000 cu. yds.) could be used later as a sand refreshment source. Now the plug is washed out after heavy rainstorms. The areas between the groins, and the small areas north and south of the groins should be filled with new sand to avoid initial sand depletion downstream.

TECHNICAL CHALLENGES TO PREDICTING SHORELINE EFFECTS OF A NEW TIDAL INLET

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POSTER

The Bolsa Chica wetland in Southern California is proposed for large-scale restoration. A new tidal inlet is proposed as part of the restoration to connect the site to the ocean. The inlet is expected to modify sand movement along the coast, thus affecting the existing adjacent beaches.

A study was done to provide direction to government agencies for construction and management of the coastal features of the project to maximize success and avoid impacts. Methods used within this study for predicting the shoreline evolution and developing mitigation measures are presented and discussed.

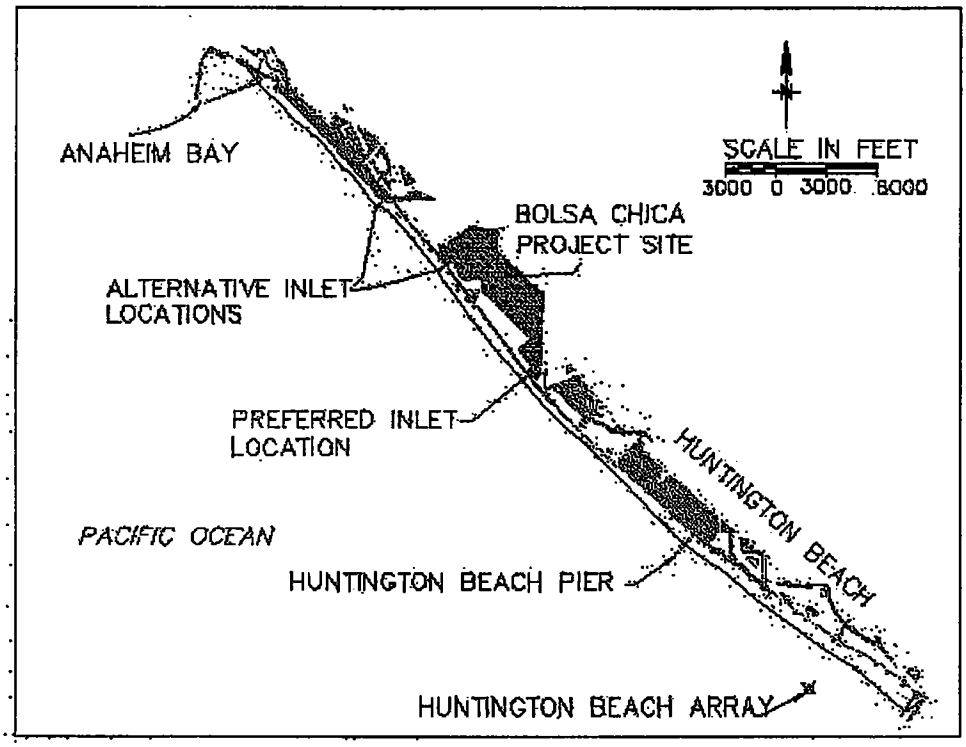

Figure 1. Bolsa Chica Project Reach with Proposed Inlet Alternatives

BACKGROUND

The 1000-acre site shown in Figure 1 has been used for oil extraction since the 1920's, and was purchased and proposed for a large marina and commercial development in the 1980's. Environmental groups eventually pressured the landowner and government to modify the plan to exclude development altogether and to restore the site to a historic wetland condition. A tidal inlet once connected the wetland to the sea, but was closed by landowners in the late-1800's. As mitigation for the expansion of the Ports of Long Beach and Los Angeles, a new tidal inlet was proposed to re-establish historical tide levels and provide inter-tidal habitat at Bolsa Chica, California. The proposed inlet will include non-surf zone piercing jetties for stabilization and a highway bridge. A major study was commissioned to predict impacts of various inlet configurations and specify mitigation (Moffatt & Nichol Engineers, 1999). This study

included aspects of:

- Hydraulic design of the wetlands and entrance channel;
- Ebb bar and flood shoal evolution;
- Shoreline response & mitigation;
- Water quality; and
- Bridge design.

In order to achieve some detail in the discussion, only the shoreline portions of the studies are further considered below.

STUDY APPROACH

A unique aspect of this project is the abundance of data available and the accompanying level of effort given to incorporate that data into the shoreline analysis. For example, the project vicinity has five years of quality wave gage data coupled with numerous aerial photograph sets, and beach profile surveys. The shear scale, sensitive environmental and recreational resources, and intense public interest were an impetus to pursue high quality analysis and modeling. What technical challenges does one face when assessing this quantity of information and what methods are performed to maximize confidence in the results? Some aspects of the shoreline analysis included quantifying the wave climate, shoreline position changes, longshore sediment transport, shoal evolution offshore and within the restored lagoon, and numerical shoreline modeling.

The shoreline studies began with a detailed review of previous studies, as the same location had been numerically modeled at least twice previously for similar projects. This was followed with analytical methods of determining historic and predicted future trends of coastal processes and shoreline evolution. Some of these data were used as input to numerical shoreline evolution modeling. The numerical model was used to predict future shoreline trends without the project, with the project, and with the project and mitigation, for various inlet location alternatives. An emphasis was placed on the requirement for management flexibility based on monitoring rather than relying entirely on analytical or model predictions.

SHORELINE TRENDS

Historic shoreline positions along the project reach were determined from aerial photographs, measured profile data, and previous studies. These positions were used to determine erosion or accretion rates and used as input to the numerical model. Predictions for future shoreline evolution within the model should be based on typical environmental conditions. Shorelines from the calibration period (1992 – 1997) were compared with longer-term records to verify that the calibration period was typical.

The mean lower low water shoreline was developed by shifting the digitized wetted bound from the aerial photographs to match profile surveys taken in the area. The resulting shoreline showed signs of both erosion and accretion, depending on the time period and location under consideration. Special attention was given to key locations where an inlet and jetties were proposed. If the region is accretional, the jetties may be less of an impediment to longshore transport. However if the region is erosional, they could hold a large quantity of material updrift thereby inducing downdrift erosion. The jetties were designed to be short to have minimal shoreline effect.

WAVE CONDITIONS

Wave data were available from numerous sources in Southern California. These include wave hindcasting (wave predictions based on historic weather patterns) and at least twenty recording wave buoys and pressure arrays in the area. The wave data source that best met project requirements was located in thirty feet of water directly seaward of the study area and seven miles southeast of the project site. This wave array recorded representative directional wave data including sea and swell for more than five years. As this array only measured one point along the reach, a transformation was required in order to apply the data along the entire reach. The data were back-transformed to deeper water and then forward transformed using the REF/DIF numerical model. To increase confidence, the accuracy of the wave transformation was confirmed in three different ways. First, the 2-D surface plots were viewed for

anomalies. Second, a comparison was made at the wave array location between the original wave record and the transformed wave record. Finally, sample REF/DIF output along a contour line was compared with output from a wave transformation performed with a different model for a different project. Extensive statistical analysis was performed to determine the seasonal variation of the recorded wave data, whether there were bimodal peaks, how to best combine them, and if the recorded data was representative of typical wave conditions in the area. Since the recorded wave data were determined to be representative, it was used to develop a 20-year wave record for numerical modeling into the future.

LONGSHORE SEDIMENT TRANSPORT

Estimates of the net and gross longshore sediment transport rates as well as volumetric shoreline change were compiled from previous studies. In addition, new estimates of these quantities were developed for this study. The volumetric change was developed based on historic shoreline position and an assumed volume associated with a cross-shore shoreline change. Two methods for estimating longshore transport were used: (1) wave data alone were used to predict the longshore transport "potential" assuming idealized sediment and beach properties, and (2) a hybrid method used waves and shoreline position together. This resulted in net transport directions being opposite depending on the method used. This was initially puzzling, but since the net transport is much less than the gross, the overall net transport is relatively close zero and directions should be expected to reverse.

SEDIMENT SINKS AND SOURCES

The proposed wetland involves opening an inlet through the existing beach. This could create a sediment trap, removing sand from the longshore drift to form the ebb and flood shoals. The quantities and rates of sand removal from the system were calculated using other analytical tools and the RMA 2 hydrodynamic model. The tidal and flood characteristics of the wetlands, inlets, and nearby flood control channels were modeled for each alternative. These results were used in combination with wave statistics to develop estimates of the flood shoal evolution. The ebb-bar model was calibrated with measured historic data from other Southern California wetlands including the recently restored Batiquitos Lagoon. Additional losses of sediment to the system were expected to occur due to modifications of wave breaking patterns resulting from development of the ebb bar. These were considered with further REF/DIF wave transformation modeling and input into the numerical shoreline model.

NUMERICAL MODEL

All of the above data for shorelines, waves, longshore transport, and sediment sources and sinks were input into the Generalized model for Simulating Shoreline change (GENESIS), which is one of a suite of programs within the Shoreline Modeling System developed by the US Army Corps of Engineers (Gravens, 1991). These data were used to calibrate the numerical model to match historic shoreline positions and gross and net longshore sediment transport rates. A verification run was also performed over a different time period to determine the predictive capability of the model. Sensitivity studies were performed to quantify which parameters were most important to shoreline prediction. The most sensitive parameters were wave direction and amplitude.

The numerical model was run for a representative period of up to 20 years into the future without the project to develop a baseline upon which to compare predictions of the shoreline with project modifications. With the addition of an inlet, significant shoreline erosion was predicted on surrounding beaches. With regular beach nourishment and initial beach and ebb shoal nourishment during construction, the numerical model predicted shoreline variability to be maintained within the natural fluctuation of the area.

ADDITIONAL QUALITY CONTROL

Methods and results of the study were scrupulously examined by a technical review committee of experts from the U.S. Army Corps of Engineers, local academia, and other engineering firms. Modifications to the study, as suggested by the committee, were incorporated to further bolster the reliability of the methods and results.

CONCLUSION

Funding, abundant data, previous site studies and related investigations, and a group of qualified experts were available to provide the basis for completing this state of the art study. The study is significant in that it sets direction for government agencies to construct and manage this ambitious project along an urbanized coast. Project requirements of maximum success with minimal impact or consequence can be accomplished by following direction yielded by this study.

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USE OF DIGITIZED MULTITEMPORAL AERIAL PHOTOGRAPHS TO MONITOR AND DETECT CHANGE IN CLEAR SHALLOW COASTAL WATERS, MOLOKA'I, HAWAI'I

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OVERVIEW

The U. S. Geological Survey is using remotely sensed image data to help map and study shallow clear water coral reef environments. Our initial efforts involve the use of digitized aerial photographs and airborne digital SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) bathymetry data covering portions of the island of Moloka'i, Hawai'i. Two sets of digital image maps with one and three tenth m resolution respectively were generated using the aerial photographs. The digital georeferenced image maps are being used as a guide for extensive field work that includes on-the-ground validation and interpretation of the remotely sensed data. Areas covered by sediment or hard bottom can be mapped in water depths less than approximately fifteen m. Some key advantages of the airborne image data are: locating features on the reef, helping map the local geomorphology, and providing a geographic base to plot field study results. A promising application is the monitoring of change on the bottom in the clear shallow waters of the reef flat, crest, and inner fore reef (i.e., in water depths of less than approximately seven meters).

EARLY CHANGE DETECTION RESULTS

Digitized natural color aerial photographs collected in September 1993 and January 2000 were used to generate digital image mosaics/maps covering most of the coast and reef track of southern Moloka'i, Hawai'i. Portions of the georeferenced digital image maps are being used as input to digital change detection and analysis using a one-meter pixel resolution. Figure 1 shows a portion of both the September 1993 and January 2000 image maps, and the corresponding digital change image generated using these data. Black and white image products are shown due to the limitation of color reproduction, however, the color information was used in the analysis. The near-shore inter reef water depth ranges from approximately one to two meters and various cover types can be seen in the aerial image maps including fine grain sediments, sand, algae, coral, and coral ruble. One of several fishponds in the area is located towards the top center of the image. On the outer reef crest (water depth ranges from about one to three meters) sand and hard rock are visible in the two images. Information about sand and hard rock cover is likewise visible on the deeper fore reef where water depth ranges from three to ten meters.

The digital change image shows areas that have under gone change between September 1993 and January 2000. At this stage we can not determine whether the changes are related to long-term impacts or short-term seasonal effects. An important aspect of the results is that they verify that the procedure we have developed can detect changes in this environment using these types of data and image manipulation techniques. Areas A and B highlighted in figure 1 were visited in June 2000 to inspect locations that showed a substantial change in brightness/color. On the shallow reef flat (A in figure 1 and shown at full resolution in figure 2), it appears that the majority of the changes detected are related to a change in the amount of algae cover. A small amount of sea grass (*Halophila hawaiiana*) was present just to the east of area A and close to the fishpond, but not within area A. The dominant algae type in this area is *Acanthophora spicifera*, with some *Schizothrix*/cyanobacteria also present. Outside of area A closer to Hotel Moloka'i the dominant algae is *Schizothrix*/cyanobacteria with several others present (e.g., *Ulva*

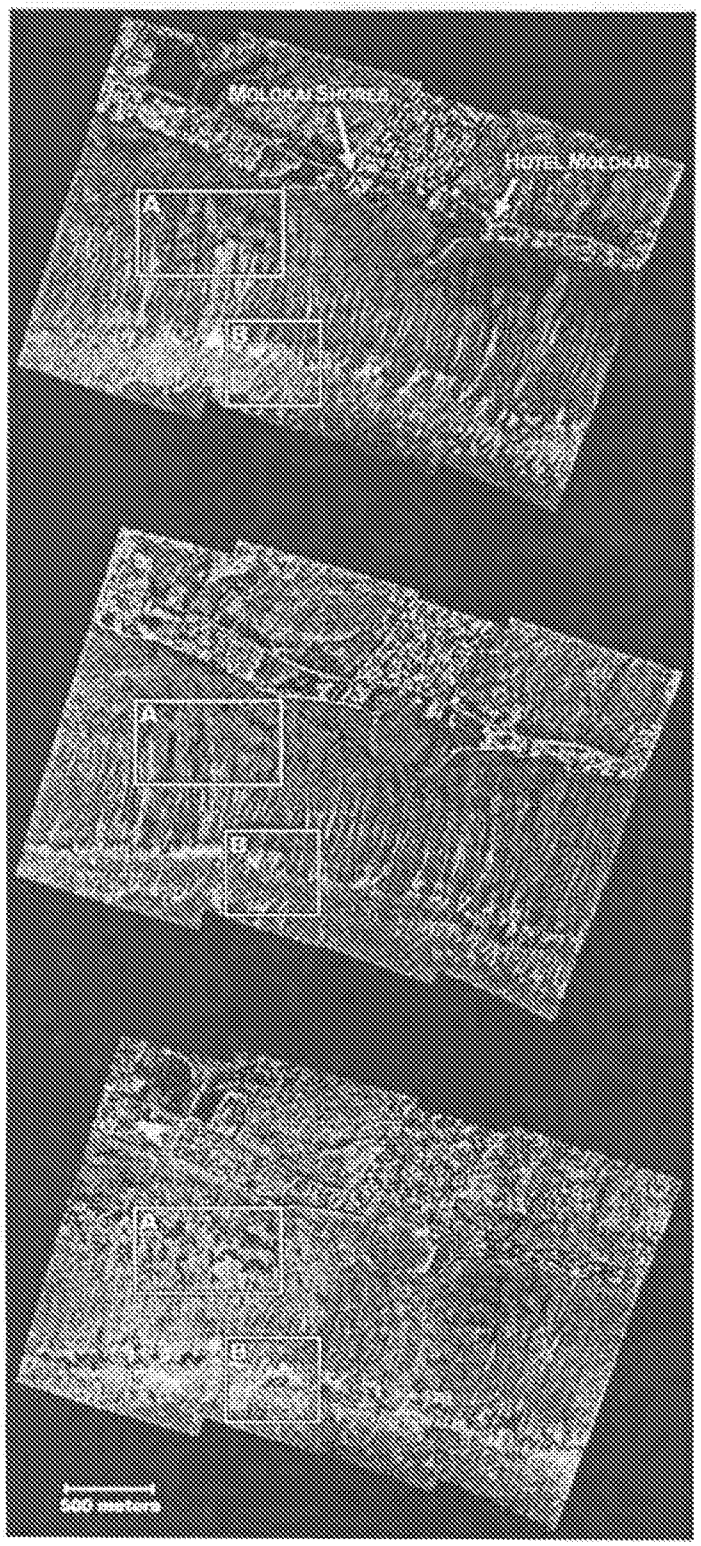

Figure 1: Southern Moloka'i Aerial Image Map
Shown are portions of the September 1993 and January 2000 blue spectral band component of the natural color digital image maps, as well as the digital change image generated using these data. The areas labeled A and B are those visited in June 2000 and are shown in figures 2 and 3 at full resolution.

Figure 1a: September 1993

Figure 1b: January 2000

Figure 1c: Change Image Spetember 1993 verses January 2000

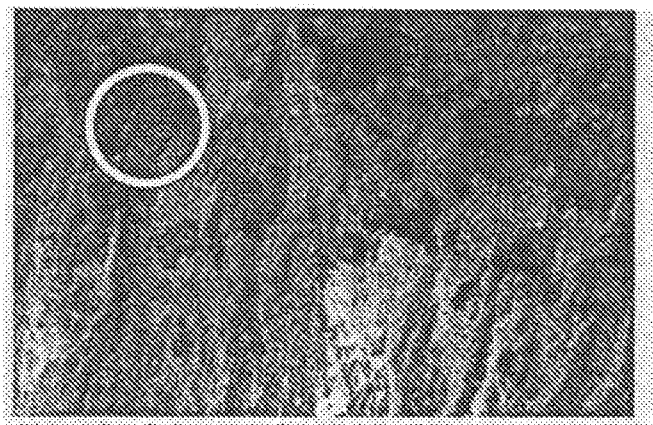

Figure 2a: Subarea A, September 1993

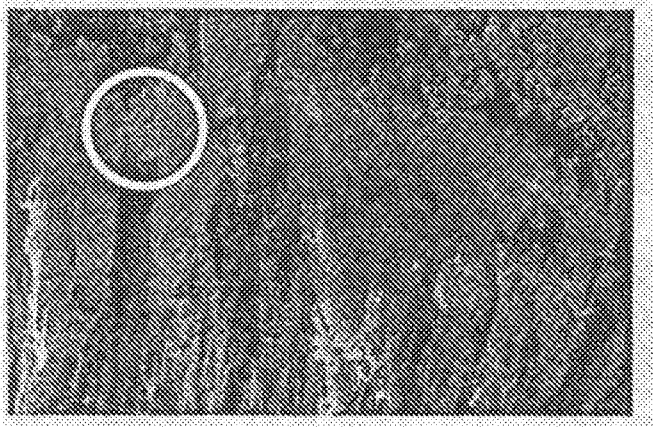

Figure 2b: Subarea A, January 2000

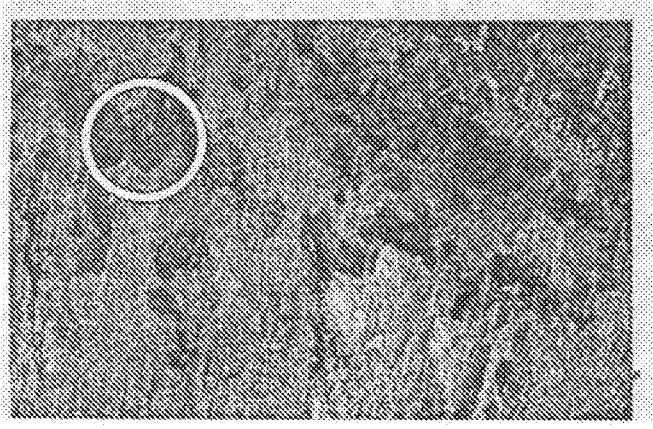

Figure 2: Shown is the inter reef area A at full resolution. Notice the brightness differences seen within this area and how the digital change image has detected and mapped these areas.

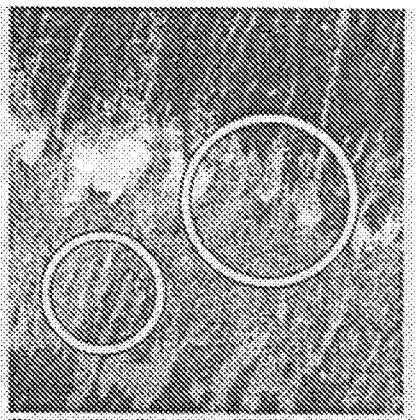

Figure 3a: Subarea B, September 19

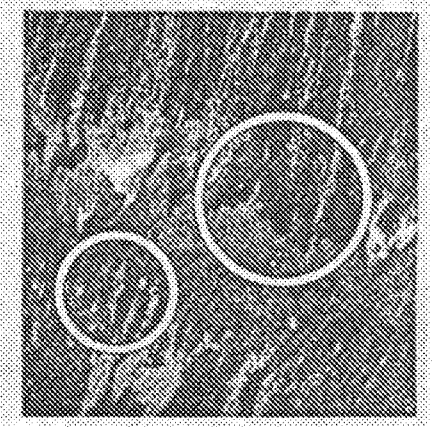

Figure 3b: Subarea B, January 2000

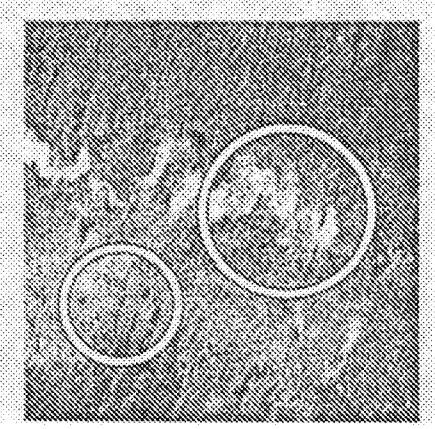

Figure 3: Shown is the outer reef crest area B at full resolution. Notice the brightness differences seen within this area and how the digital change image has detected and mapped these areas.

fasciata, Padina australis, and *Acanthophora spicifera*). The results show that there is less algae cover in January 2000 than September 1993.

On the outer reef crest area (B in figure 1 and shown at full resolution in figure 3), it appears that the majority of the changes are related to the amount of sand cover over hard rock. Divers confirmed that the area is a rocky irregular old reef surface having a patchy distribution of sand and algae, with very few coral colonies. Ribbons of sediments and ripples of sand cover the slightly deeper drainages. This area has high wave energy and the amount of sand cover over hard rock probably changes on a daily basis, with substantial change possible during large storms. At this stage we can not eliminate the possibility that some of the changes detected in this part of the image map are related to algae growth.

Further investigations into the use of very high resolution remotely sensed images for detecting change in shallow clear waters is continuing. The change detection work done so far indicate that in certain water depths these types of data could be used to detect and map areas affected by large coastal storms. We will continue to investigate the applicability of these data to detect and map long-term versus shorter-term seasonal changes in clear coastal shallow waters.

THE USE OF THE NEW RECYCLED GLASS PRODUCT AS A SUBSTITUTE FOR SAND

Hana Steel, Ph.D., Recycling Coordinator; Irene Cordell, Recycling Specialist; and Tom Reed, President
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POSTER

Silicates, borates or phosphates. Mix, heat, mold, and there you have it, a glass container. That same glass container properly processed then becomes a *new pulverized glass product.* The goal of our presentation is to pose the question, "Is the *new pulverized glass product* an appropriate substitute for sand in beach restoration projects?" If the new pulverized glass product does meet specifications, would we want to use it for this purpose? If so, why? If not, why not?

According to EPA's "Characterization of Municipal Solid Waste in the United States, 1997 Update Executive Summary," glass comprises 5.9%, or 12.4 million tons, of the Municipal Solid Waste Stream. Could this "waste" material become a useful material in our shoreline communities?

Most important, what would be the economics of using locally processed recycled glass, as compared to trucking it in, or in the case of Waikiki, barging it in from Australia? Will we always be disturbing the surface of the earth to restore our beaches?

We were all trained to stay away from broken glass. This is part of our conditioning. What would the public perception be if the *new recycled glass product* was used to restore beaches? What would the liability issues be? Would it be too risky to even consider? Would fear prevail if beach enthusiasts could hold pulverized glass in their hands, just like sand, and not get cut?

We have no answers, just the question, and about 1,500 tons of the *new pulverized glass product* a year that could be used in a research project. We challenge The National Beach Preservation Conference and attending research organizations to discover the answers.

ACCURATE SHORELINE CERTIFICATIONS: FIRST STEP IN PREVENTING COASTAL EROSION: WHAT A CITIZEN SHOULD KNOW ABOUT CHALLENGING SHORELINE CERTIFICATIONS"

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POSTER

BACKGROUND

Hawaii's Coastal Zone Management policy sets guidelines for determining where the public shoreline ends and a private landowner's property begins. Once that line is determined, each County has its own building setback requirements from the certified shoreline. If a certified shoreline does not accurately portray the natural tidal influences in a shoreline area, any future site improvements have a great chance of being put in jeopardy by being sited within the tidal hazard zone. This can lead to increased erosion of developed shoreline parcels and downshore areas. It also can place private properety owners in the position of demanding to build protective structures (sea walls, groins etc) that can accelerate future coastal erosion in the area.

Since the property owner hires surveyors to conduct the shoreline survey, the resulting boundary is very likely to be as near to the water as can be justified, thus maximizing the owner's usuable land area and minimizing the setback from the water's edge. This fact can result in questionable/deceptive practices being used in the process of the shoreline survey.

Some examples of questionable practices include:

1. Coaxing saline tolerant vegetation to grow nearer the water's edge than it normally would be found through deliberate planting and irrigation before the survey is taken, thus creating a new "shoreline" considerably seaward of the wave's normal wash area.

2. Ignoring the actual curves of the natural shoreline and delineating the coastal boundary for certification purposes with a straight line that privatizes what would legitimately be public property.

3. Overlooking consistent evidence of high wash marks (debris lines, etc) in favor of a more makai vegetation line (the supposition being that if plants are growing on beach sands, there isn't regular wave wash in the area and therefore the private property begins at the vegetation line.)

4. Actual bulldozing, grading and site work performed on public land before shoreline certification submittal. The pupose being to create artificial barriers that retard natural wave action and confine the natural wash to a narrow area, enhancing the size of the owner's private property property area. Such practices often negatively impact public access

SCOPE: This poster will offer photographic illustrations of common questionable/deceptive practices. It will illustrate how private citizens who are familiar with a coastline, can challenge certifications based on CZM guidelines and help them become more accurate. It will also indicate several possible solutions available for State and County regulatory bodies to bring shoreline certification practices more in line with the original intention of the CZM laws: preservation of public and private shoreline through accurate observation of natural tidal movements and sensible planning policies that minimize coastal erosion, loss of public access and other environmental impacts.

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