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Proceedings of the 56th Meeting of the Coastal Engineering Research Board

9-11 June 1992

Newport, Oregon

Hosted by U.S. Army Engineer Division, North Pacific
U.S. Army Engineer District, Portland

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Prepared for Headquarters, U.S. Army Corps of Engineers

July 1993

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U.S. Army Engineer District, Portland

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Final report

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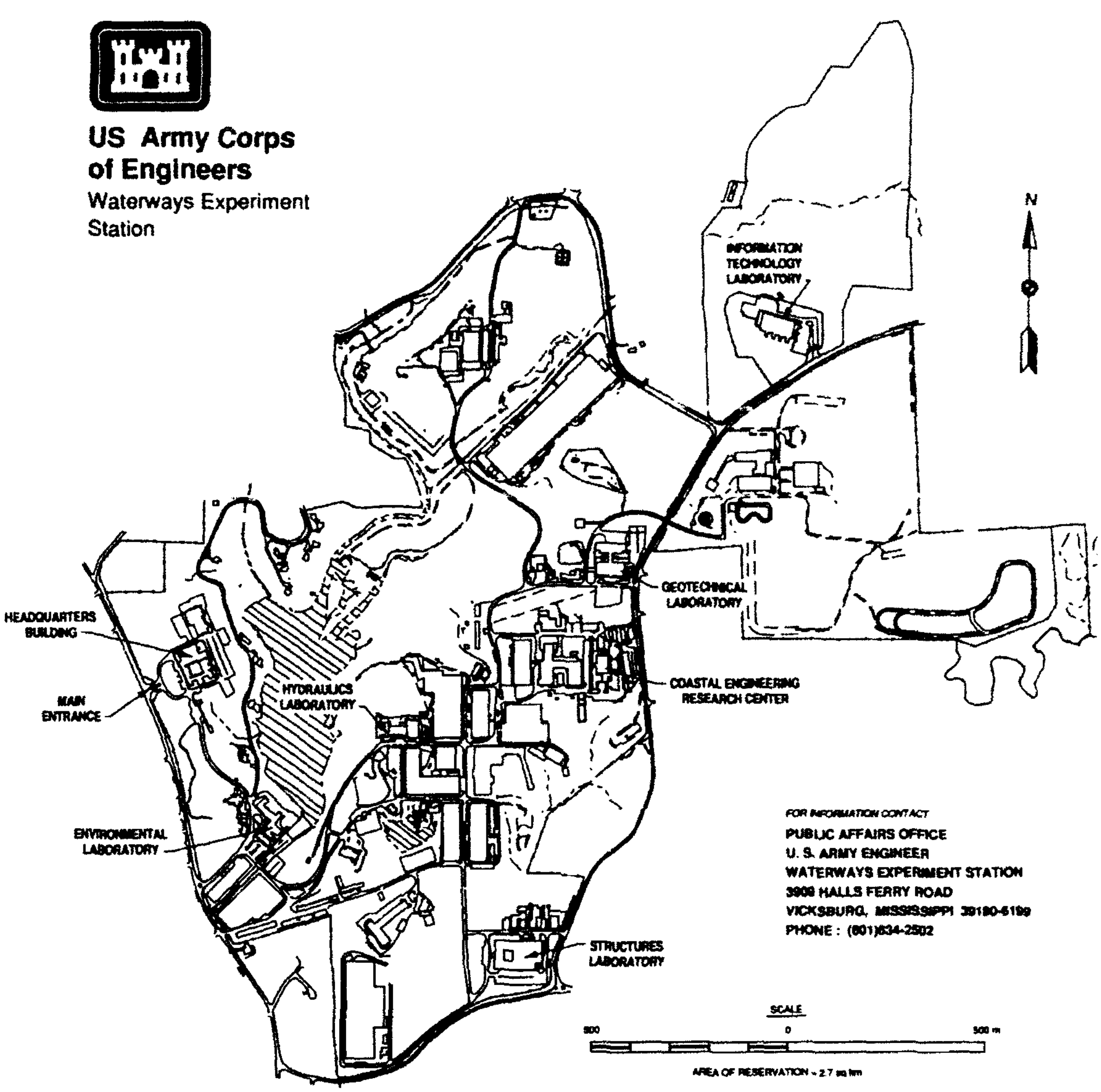
US Army Corps of Engineers
Waterways Experiment Station



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Contents

Preface

The Proceedings of the 56th Meeting of the Coastal Engineering Research Board (CERB) were prepared for the Office, Chief of Engineers, by the Coastal Engineering Research Center (CERC), of the U.S. Army Engineer Waterways Experiment Station (WES). These proceedings provide a record of the papers presented, the questions and comments in response to them, and the interaction among program participants and the CERB.

The meeting was hosted by the U.S. Army Engineer Division, North Pacific (NPD), under the direction of MG Ernest J. Harrell, Commander, and the U.S. Army Engineer District, Portland (NPP), under the direction of COL Charles A. W. Hines.

Acknowledgements are extended to Mr. John G. Oliver (NPD), who assisted with the coordination of the meeting and field trip, and to the following from NPP: Ms. Rosalee Schiewe, who assisted with the coordination of the meeting; Messrs. Stephan A. Chesser and Bruce J. Duffe and Ms. Laura L. Hicks, who assisted with the coordination of the meeting and field trip; Messrs. William E. Branch and David J. Illias, narrators on the helicopter tour; Ms. Diana Sorenson, who assisted with registration and various administrative details; Ms. Joan Ouchida, graphics support; Mr. Joe Herrera, photographer; and Messrs. Stephen R. Smith and Bill Johnson for their audiovisual support. Special thanks are extended to all participants. Thanks are extended to Mrs. Sharon L. Hanks for coordinating and assisting in setting up the meeting and assembling information for this publication; Mr. Andre Z. Szuwalski for preparing the draft proceedings from the transcript; and Ms. Janean Shirley of the Information Technology Laboratory for editing these proceedings, all of whom are at WES. Thanks are extended also to Ms. Dale N. Milford, Certi-Comp Court Reporters, Inc., for taking verbatim dictation of the meeting.

The proceedings were reviewed and edited for technical accuracy by Dr. James R. Houston, Director, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Director, CERC. COL Leonard G. Hassell, Executive Secretary of the Board and Commander and Deputy Director, WES, provided additional review.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

Stanley G. Genega

STANLEY G. GENEGA
Brigadier General (P), US Army
President, Coastal Engineering Research Board

Agenda

Theme: Coastal Structures

Monday Evening, June 8

6:30 - 8:30	Registration and Icebreaker at Shilo Inn

Tuesday, June 9

7:00 - 8:00	Registration
8:00 - 8:10	Opening Remarks MG Arthur E. Williams
8:10 - 8:25	Welcome to North Pacific Division and Portland District MG Ernest J. Harrell COL Charles A. W. Hines
8:25 - 9:00	Review of CERB Business COL Leonard G. Hassell
9:00 - 9:30	Impacts of the Coastal Engineering Research Board Dr. James R. Houston, CERC
9:30 - 10:00	Coastal Inlets Research Program Mr. E. Clark McNair, Jr., CERC
10:00 - 10:15	Break
10:15 - 10:45	SUPERTANK Laboratory Data Collection Project Dr. Nicholas C. Kraus, CERC
10:45 - 11:00	Introduction of Coastal Structures Theme Mr. C. E. Chatham, CERC
11:00 - 11:30	Overview of Corps Problems Related to Coastal Structures Mr. James E. Crews, HQUSACE
11:30 - 12:00	North Pacifice Division Coastal Structures Mr. John G. Oliver, NPD
12:00 - 1:00	Lunch
1:00 - 1:45	**Introduction to Research and Development (R&D) and Monitoring Efforts**

1:00 - 1:15	Overview Mr. Jesse A. Pfeiffer, Jr., HQUSACE
1:15 - 1:45	Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program Mr. James E. McDonald, Structures Lab, WES
1:45 - 2:15	Coastal Components of REMR Mr. D. Donald Davidson, CERC
2:15 - 2:45	Coastal R&D/Monitoring Completed Coastal Projects (MCCP) Program Ms. Carolyn M. Holmes, CERC
2:45 - 3:00	Break
3:00 - 5:00	**Site-Specific Projects/R&D/Monitoring - Synergism**
3:00 - 4:15	Crescent City
	Overview and Assessment of Dolos Movement and Breakage Mr. Thomas R. Kendall, SPN
	The Crescent City Prototype Dolosse Study Mr. Jeffrey A. Melby, CERC
	Physical Modeling and Monitoring of Crescent City Mr. Dennis G. Markle, CERC
	Concrete Armor Unit Design Mr. Jeffrey A. Melby, CERC
4:15 - 5:00	Yaquina
	Yaquina North Jetty Overview Ms. Laura L. Hicks, NPP
	Monitoring of the Yaquina Bay North Jetty Dr. Steven A. Hughes, CERC
5:00 - 5:30	Wrap-up Mr. Jesse A. Pfeiffer, Jr., HQUSACE
5:30 - 5:45	Closing Remarks and Announcements MG Arthur E. Williams
5:45	Recess for day
6:30	Dinner (Social at Gracie's Restaurant)

Wednesday, June 10

8:00 - 8:10	Opening Remarks MG Arthur E. Williams
8:10 - 8:40	Monitoring Completed Coastal Projects Evaluation of Spur Jetties Performance at Siuslaw River, Oregon Ms. Cheryl E. Burke, CERC
8:40 - 9:00	Field Trip Overview Mr. Stephan A. Chesser, NPP
9:00 - 3:30	Field Trip

3:30	Return to Hotel
4:00 -	Board in Executive Session

Thursday, June 11

8:00 - 8:15	Opening Remarks MG Arthur E. Williams
8:15 - 8:30	Discussion of Field Trip
8:30 - 9:45	Board Comments and Recommendations CERB
9:45 - 10:15	Public Comment
10:15 - 10:45	Closing Remarks BG Roger F. Yankoupe
10:45	Adjourn

Attendees

Board Members
MG Arthur E. Williams
BG Ralph V. Locurcio
BG Roger F. Yankoupe
Professor Robert A. Dalrymple
Professor Fredric Raichlen
Professor Robert O. Reid

Headquarters, U.S. Army Corps of Engineers
Mr. Paul D. Barber, CECW-E
Mr. James E. Crews, CECW-O
Mr. John G. Housley, CECW-PF
Mr. Jesse A. Pfeiffer, Jr., CERD-C
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Mr. John G. Oliver, CENPD-TE
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Mr. Walter Clay Sanders, CESAJ-EN-A
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Mr. Thomas R. Kendall, CESPN-PE-W

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Ms. Cheryl E. Burke, CEWES-CD-SE
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Mr. C. E. Chatham, Jr., CEWES-CW
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Mr. James E. McDonald, CEWES-SC-R
Mr. E. Clark McNair, Jr., CEWES-CP-D
Mr. Jeffrey A. Melby, CEWES-CW-R
Mr. Andre Z. Szuwalski, CEWES-CR-A

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Mr. Harold D. Herndon, Portland, OR

Dr. Robert A. Holman, Oregon State University, Corvallis, OR
Dr. Paul D. Komar, Oregon State University, Corvallis, OR
Mr. Michael F. McCormack, U.S. Coast Guard, North Bend, OR
Dr. William G. McDougal, Oregon State University, Corvallis, OR
Dr. William J. Reynolds, SAIC, Bothell, WA
Mr. David P. Simpson, CH2M-Hill, Belleview, WA
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Proceedings of the 56th Meeting of the COASTAL ENGINEERING RESEARCH BOARD

Introduction

The 56th Meeting of the Coastal Engineering Research Board (CERB) was held at the Shilo Inn in Newport, OR, on 9-11 June 1992. It was hosted by the U.S. Army Engineer Division, North Pacific, under the direction of MG Ernest J. Harrell, Commander, and the U.S. Army Engineer District, Portland, under the direction of COL Charles A. W. Hines.

The Beach Erosion Board (BEB), forerunner of the CERB, was formed by the Corps in 1930 to study beach erosion problems. In 1963, Public Law 88-172 dissolved the BEB by establishing the CERB as an advisory board to the Corps and designating a new organization, the Coastal Engineering Research Center (CERC), as the research arm of the Corps. The CERB functions to review programs relating to coastal engineering research and development and to recommend areas for particular emphasis or suggest new topics for study. The Board's four military and three civilian members offically meet twice a year at a particular coastal Corps District or Division to do the following:

a. Disseminate information of general interest to Corps coastal Districts or Divisions.

b. Obtain reports on coastal engineering projects in the host (local) District or Division; receive requests for research needs.

c. Provide an opportunity for state and private institutions and organizations to report on local coastal research needs, coastal studies, and new coastal engineering techniques.

d. Provide a general forum for public inquiry.

e. Provide recommendations for coastal engineering research and development.

Presentations during the 56th CERB meeting dealt with coastal structures. Documented in these proceedings are summaries of presentations made at the meeting, discussions following these presentations, and recommendations by the Board. A verbatim transcript is on file at CERC, U.S. Army Engineer Waterways Experiment Station.

The Coastal Engineering Research Board

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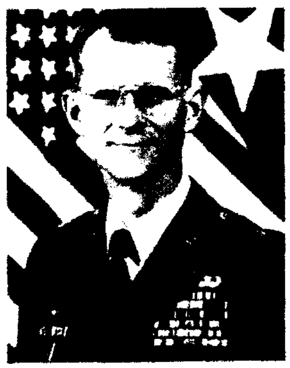

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Department of Oceanography
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College Station, TX 77843-3146

Opening Remarks and Welcome

MG Arthur E. Williams opened the 56th Meeting of the Coastal Engineering Research Board and welcomed attendees to the meeting. He introduced the Board members, BG Roger F. Yankoupe, Commander, South Pacific Division; BG Ralph V. Locurcio, Commander, Pacific Ocean Division; Professor Robert O. Reid, Texas A&M University; Professor Robert A. Dalrymple, University of Delaware; and Professor Fredric Raichlen, California Institute of Technology. He indicated that BG(P) Stanley G. Genega, Commander of the South Atlantic Division was unable to attend the meeting.

MG Williams then turned the podium over to MG Ernest J. Harrell, host Division Commander, U.S. Army Engineer Division, North Pacific (NPD). MG Harrell welcomed all attendees to NPD and to the Oregon coast, which he said is one the most scenic coasts in the world. He hoped attendees could take some time to visit it.

MG Harrell stated that his Division has the responsibility for Civil Works military construction in seven of the northwest states, plus Alaska. In area, that is the largest land and coastal area of any U.S. Army Corps of Engineers Division. NPD has been active in the Oregon coast area since 1866. The earlier works in this particular area, in addition to public works, were fortifications, including Fort Stevens, which was the only U.S. fort shelled by the Japanese during World War II in 1942. The Corps also constructed several lighthouses, which will be seen on the field trip.

To date, the NPD has constructed 22 jetties, consisting of about 28 miles, and several navigation channels throughout the Oregon coast. The jetties contain about 25 million tons of rock and concrete, and each year about 28 million operations and maintenance dollars are spent in maintaining these activities, to include dredging operations that average about 13 million yd of dredged material.

MG Harrell stated that there is a great need for research and development in design and maintenance of jettied inlets, and it is critical that some of the focus of the Coastal Inlets Research Program should be in this area.

Concern for environmental sensitivity must be included in all activities here in the basin. The coastal region embraces two distinct marine environments. One includes the offshore waters of the Pacific, the other is found in the estuaries of the coastal rivers where the saltwater emerges into the freshwater, and many marine species move between these two ecosystems, the best known being the northwest salmon.

MG Harrell then introduced COL Charles A.W. Hines, Commander of the U.S. Army Engineer District, Portland, who also welcomed the attendees to the Oregon coast.

Review of Coastal Engineering Research Board Business

COL Leonard G. Hassell, Executive Secretary
Coastal Engineering Research Board
Commander and Deputy Director
U.S. Army Engineer Waterways Experiment Station
Vicksburg, MS

There were several action items resulting from the 55th Coastal Engineering Research Board (CERB) meeting in Mashpee, MA. The list in Appendix B covers the status of action items from the Mashpee meeting and continuing action items from previous Board meetings. All other action items have been completed. We will continue to update the status of action items prior to each meeting, and provide a list to the Board as read-ahead material. At our 47th CERB meeting in Corpus Christi, TX, we were asked to formalize the action item list. A master list showing actions taken since that meeting is maintained at the Coastal Engineering Research Center (CERC).

I will now cover the status of action items from our last meeting.

Item 55-1. **Advise and periodically brief Board on how the Waterways Experiment Station (WES) integrates the Dredging Research Program (DRP) and other coastal research and development (R&D) programs with other ongoing and future environmental research programs.**

In order to address this item, I must first briefly review our R&D system, particularly portions dealing with finite-length programs such as the DRP. In order for a program such as the DRP to come into existence, it must first address a well-defined problem. This process begins with the labs' work in concert with field and Headquarters personnel to define needs, technical approach, cost, and expected benefits. During this phase, outside advice such as from this Board is sought. After undergoing Headquarters, U.S. Army Corps of Engineers (HQUSACE), review and approval, the program is sent to the Assistant Secretary of the Army, Civil Works, (ASA/CW) for review and approval prior to sending it on to the Office of Management and Budget (OMB), where examiners review the program in detail. Once through OMB, the program appears as a line item in the President's budget and must then be defended on its merits and scope before Congressional committees. When approved by Congress, funds are usually appropriated. At any of these stages, the program can be modified or scrapped entirely. In the case of the Coastal Inlets Research Program, the ASA/CW reduced funding from $43 million to $20 million. Once the program is assigned a manager and implemented, it is overseen by a group of HQ Technical Monitors and a Field Review Group. The major point I want to make here is that a program is funded to address a specific problem, and the Corps and certainly the labs cannot unilaterally change the scope of the program. In the case of the DRP, its scope is limited to saving Federal dollars through improved dredging equipment, operations, and procedures.

At our last meeting, concern was stated that the DRP was not addressing new environmental problems as they arose. Generally these problems are outside the scope of the program. The Corps has programs such as the Long-Term Effects of Dredging Operations, Dredging Operations Technical Support, Wetlands Research Program, Environmental Impact Research Program, and the Aquatic Plant Control Research Program to address environmental problems.

Since the early 1970's, over $100 million has been spent by the Corps to conduct research on methods to accomplish our dredging mission in an environmentally sound manner. Until the DRP, there had never been a program designed specifically to address the efficiency of the dredging process. Obviously, the results of the program cannot be successfully implemented unless they are environmentally compatible. During the early planning of the program, WES's Environmental Laboratory was brought in on the team to ensure the approaches being considered were environmentally sound and that environmentally related physical processes needs were known. In fact, much of the work Dr. Nick Kraus is directing, which deals with the physical behavior of dredged material placed in open water, is driven by environmental needs. The WES DRP Program Manager, Clark McNair, works closely with the manager of environmental dredging programs, Dr. Robert Engler, to ensure proper coordination. As we move into applying the new DRP technology, we are working even closer with the Environmental Laboratory to ensure the technology is known and used by the entire environmental community. As Dr. Houston will discuss later, the technology is being recognized and used by the Environmental Protection Agency (EPA).

I have used the example of the DRP here, but all of our programs are closely coordinated with the environmental community. Periodically I will update you on how we are integrating our programs with environmental research programs.

Item 55-2. **Review current Corps practices relating to measuring sediment properties of material to be dredged and report the findings to the Board.**

A query was made of the Corps Districts by the Dredging and Navigation Branch in HQ concerning current practices of measuring sediment properties of material to be dredged. The Districts vary in their methods. Most Districts rely on historical sediment sampling information for their maintenance dredging projects in the 1970's, some perform periodic sediment analyses ranging from once every 4 to 5 years to once every 2 years. When a District has a project with new dredging work, it will generally undertake more extensive sediment sampling and analysis efforts.

During the dredging process, little information is collected that would describe the sediment properties of the dredged material. Hopper dredging of ocean inlet channels is most efficient when the dredge can lower its dragheads into the sediment and pump continuously until the hopper is full. Consequently, the dredge may be pumping material that will range from sandy silts to clean sands. Environmental concerns about endangered and threatened sea turtles have emphasized keeping the dragheads in the sediment to minimize the potential of taking turtles that may be in the channels. This criterion for hopper dredging contributes to mixing the sediment types found in the channels.

Where nearshore berm development or beach disposal is being considered, more detailed sediment property sampling is routinely performed.

Item 55-3. **Revisit issue of benefits which can be included in beach restoration and dredged material disposal projects and report to the Board.**

Beach restoration projects are justified based on benefits from hurricane and storm damage reduction and recreation. A number of factors limit the formulation of the projects, some in law, some in policy. An example of a policy limitation is that the hurricane and storm damage reduction benefits must provide more than 50 percent of the total benefits. An example of a legal limitation is that the seaward limit of a restoration project cannot exceed the historical limit, unless required for reasons of engineering stability.

When dredged material is placed on a beach, rather than in the least costly alternative, the project benefits must be greater than the costs and the state must pay 50 percent of the additional cost over the least costly alternative.

At the present time, the policy is that downdrift neighbors who may benefit from sand moving downdrift from a renourishment project are not considered in the benefit analysis.

Item 55-4. **Prepare a priority list of inlet candidates that can benefit from mitigation through Section 933 and 111 authorities and report to the Board.**

The data on inlets are still being collected and compiled; the final list will be presented to the Board at our next meeting.

Item 55-5. **Report on the Wetlands Research Program, beneficial uses of dredged material, and the EPA's Gulf of Mexico Program at the October '93 meeting, which will have the theme of "Coastal Wetlands."**

This, also, must be reported on at our next meeting.

Item 55-6. **Brief Board on the extent to which the Coast of California and the Coast of Florida Studies are integrated with the latest coastal research technology.**

Professors Raichlen and Dalrymple participated as principals in a one-day review of technical plans for the Coast of Florida Study on 29 May 92, with emphasis on the Study's proposed uses for coastal research products such as the Wave Information Study and GENESIS. They have provided verbal comments to the Jacksonville District, and the District is assessing those comments.

Item 55-7. **Periodically advise the Board of the general scope of research performed at CERC outside the General Investigations (GI)-funded Coastal Engineering Research Program.**

Later on today and tomorrow we will discuss the Repair, Evaluation, Maintenance, and Rehabilitation Research Program and other non-GI R&D activities related to structures.

Item 55-8. **Develop a fundamental hydrodynamic model of the developing plume that addresses the method of dredged material release, entrainment, stripping, and resuspension and that has the capability for serving as a meaningful basis for answering environmental questions.**

The DRP has recognized the potential of its short- and long-term fate models for addressing environmental concerns, including plume dynamics. Joint development efforts have begun among the DRP, the Corps of Engineers environmental elements, and the EPA to refine the DRP models to assure their applicability to a variety of environmental questions. The present short-term fate model is being extended to account for stripping, and these refinements serve as an introduction to more complex phenomena before attacking the three-dimensional (3-D) aspects in their entirety. It is considered more beneficial to obtain high-quality field data prior to full 3-D model development, and such data collection is proceeding through joint DRP/reimbursable project exercises. A DRP II program could be an ideal vehicle for 3-D development.

Item 55-9. **Conduct a high-quality field data collection program related to the short-term and long-term fate of dredged material.**

Several DRP activities are specifically devoted to data collection for understanding the fate of dredged material placed in open water. In addition to data collected within the DRP, an exchange of data is taking place with other agencies, specifically the National Oceanic and Atmospheric Administration and EPA. These data sets provide widely varying site conditions for the observation of behavior of dredged material. In addition to collection of field data using the latest and most sophisticated of instruments such as the PLUme MEasurement System (PLUMES) being developed in the DRP, physical models of dredged material releases from scows or hopper dredges provide significant insight into the physics of the descending cloud of material as the cloud approaches the bottom. PLUMES has been, and is being, used at reimbursable projects to obtain high-quality field data in both estuaries such as Tylers Beach, Virginia, and open coastal waters as in Mobile, AL; Miami, FL; Cook Inlet, Alaska, for refinement and calibration of the numerical models describing fate of dredged material. It is both necessary and cost-effective to perform precision laboratory calibration experiments for PLUMES acoustic instrumentation at this initial stage of PLUMES development, and a major laboratory calibration project is now in progress. Then, additional field data could be obtained by PLUMES during DRP II for verification of both short-term and long-term fate numerical models.

Item 55-10. **Verify the transport relations used in both short-term and long-term models.**

This will be done. Data sets are presently being accumulated by the DRP from field and laboratory observations of placement disposal operations, and from long-term monitoring of sediment mounds. They will provide verification data for the transport relations in the numerical models of dredged material fate. However, more detailed observations, particularly with cohesive sediments, are needed. The DRP is undertaking a limited study and data collection program to obtain the required information. A more theoretical work on cohesive sediment relationships is required, and this work should be supported by DRP II.

Item 55-11. **Develop an operational model for dealing with nearshore and offshore berm processes, including sediment transport and berm/wave interaction.**

The laboratory data collection project, SUPERTANK, has provided a wealth of high-quality data sets for both berm and bar movement, and for testing sediment transport relationships. Data analysis is actively under way in several DRP and Coastal Program work units by the CERC investigators and through contract. Work also is under way to analyze 9-year data sets of offshore beach profile surveys from Duck, NC. Additionally, berm monitoring efforts have been conducted during reimbursable studies for the Mobile and Wilmington Districts. High-quality field data obtained during these studies will support further analyses and development of algorithms comprising an operational model for berm process understanding, including the berm/wave interaction phenomena.

Item 55-12. **Continue emphasis of fundamental research on coastal hydrodynamics and sediment processes at inlets as proposed in the Coastal Inlet Research Program (CIRP).**

The CIRP presently consists of two Technical Areas with a total of nine work units. Each work unit is involved in fundamental inlet studies ranging from turbulence and point sediment transport to shoaling rates and morphology change. The work units are directed at collecting fundamental field and laboratory data sets, and theoretical analyses of essential inlet physical processes. Efforts are also directed at converting the knowledge gained into numerical models, improved physical model approaches, and innovative field data collection systems.

Professors Dalrymple and Raichlen attended a two-day meeting with CERC scientists and engineers and 25 field and HQ personnel to structure the program. The civilian members of the Board have been invited to the next CIRP review in July.

Item 55-13. **Fully integrate environmental considerations in CIRP.**

The scope of CIRP is primarily directed at the physical processes of inlets. The most significant interaction will be improvements to the flow and sedimentation computations used as part of water quality assessments. Environmental considerations have been, and will continue to be, integrated primarily through regular meetings of the CIRP and environmental program managers.

Item 55-14. **Conduct a pilot study to address the problems of at least two inlets in CIRP.**

Present CIRP plans call for studies at three time levels: one 5-year monitoring project; two 1-month intensive data collection projects; and up to ten 1-week projects where specific collection activities will take place. The studies will vary not only in length, but in complexity and in comprehensiveness of coverage. The program is not yet to the stage where specific inlets will be selected. The Corps' Division offices will be queried for nominations. Selection will be based on a variety of criteria such as type of inlet, class of problem, probability of successful field study, and geographic location.

Item 55-15. **Provide through CIRP a manual as soon as possible to assist the District offices in assessing adverse impacts to the beaches caused by projects located on inlets.**

One CIRP work unit is entirely devoted to the study and definition of shoreline impacts at and adjacent to inlets, and other work units support this effort. As the program progresses and products become available that will be of assistance to the Corps offices, that technology will be provided in the most appropriate and expeditious manner.

Item 55-16. **Address (in CIRP) sediment pathways, including movement over and through structures.**

At present, three work units in the CIRP specifically address this issue and others will contribute to the knowledge base. A work unit will study scour hole development adjacent to rubble-type inlet structures. From this work unit will come the identification of hydrodynamic conditions that support scour, predictive methods for the general configuration of scour holes formed under specific conditions, and laboratory procedures for modeling scour hole development. In a second work unit, various sediment theories will be tested against field data to identify the most appropriate sediment transport formulae for various numerical and analytical procedures. The third work unit will deal with the permeability of structures and the sediment that bypasses structures.

Older items from previous Board meetings on which action is ongoing include:

Item 54-6. **Establish a CERC rapid response team to coastal flooding events.**

A Corps-wide workshop has been planned for late June to finalize field needs, objectives, and team participation. The initial version of the resulting team concept will be in place for the 1992 winter storm season.

Item 54-7. **Conduct an interagency collaborative study to upgrade the hurricane wind model.**

CERC has taken three steps toward this item. First, a CERC representative visited two National Weather Service offices to discuss projects of joint interest. Second, CERC organized a workshop on tropical storm wind modeling, held at CERC, in which personnel from three Weather Service offices participated. Lastly, CERC took steps to create a committee of two or three Weather Service experts to provide technical oversight to CERC's wind modeling research. A collaborative Corps/Weather Service study of winds and hydrodynamics in two extreme storms is being planned for FY92 and FY93.

Item 54-12. **Conduct workshops to determine interest in CERC tools to improve planning for flooding emergencies.**

As reported at the last meeting, the Readiness Branch at HQUSACE asked us to expand this initiative to include other emergencies. The Branch also requested WES to review and summarize the recent Hazard Mitigation Team reports to assist in guiding development of an R&D Program. The Hazard Mitigation Team reports are prepared to assess the effectiveness of responses to declared disasters. These reports were reviewed, and a summary letter report was transmitted to the HQUSACE in early April. The Readiness Branch also requested field offices to nominate members for a Field Review Group. This group was formed, and the first meeting between WES representatives and the field group was held in Atlanta in late May. Work is proceeding at this time in formulating a proposed R&D Program. As an added note, at the next General Assembly of the International Union of Geodesy and Geophysics held in 1995 there will be a session on the International Decade for Natural Disaster Reduction. There is an opportunity for proposing a symposium to be held during this General Assembly.

Item 54-13. **Increase coordination of technical aspects (including data collection) of coastal flooding with other Federal agencies.**

An interdepartmental working group has been established under The Office of the Federal Coordinator for Meteorological Services and Supporting Research to develop a national plan for post-storm data collection. The CERC has developed a draft Statement of Purpose for the Terms of Reference for this group.

Item 54-15. **Conduct research on dynamic loading of expedient flood control structures.**

Funds have been authorized by the Readiness Branch at HQUSACE to refurbish WES' Big Black test facility to conduct static (hydraulic head) and dynamic (waves) load testing of expedient levee-raising structures. Refurbishing of the test facility and associated equipment now is under way. A letter has been sent to the Corps field offices requesting input as to the need for testing of new and/or existing flood-fight structures.

On other items that might be of interest to this meeting:

We have continued progress on the Automated Coastal Engineering System (ACES), which has been discussed at previous meetings. The latest version which has been released is version 1.06C. To date, 500 copies have been distributed, including about 100 copies to international users. The next version to be released will be 1.07 in late summer, and this will be the last version released, after which the ACES will go into maintenance mode.

A new initiative called ACES-2000 is just getting under way. Briefly, the objective of this initiative is to develop an integrated system coupling state-of-the-art prediction technology with databases and visualization techniques in a user-friendly environment on engineering graphics workstations. The Corps' Pilot Committee for ACES will provide outside guidance for ACES-2000 along with an internal CERC steering committee. We will have more on this initiative for you at our next meeting.

And finally, the COASTAL SHAREWARE bulletin board, which also has been mentioned in previous meetings, continues to provide Corps engineers with coastal computer programs developed at CERC. Access to the bulletin board is limited to Corps engineers and the programs residing on the bulletin board are generally new programs to be tested in the field.

Thank you very much and I look forward to serving this Board as their Executive Secretary.

Discussion

BG Roger F. Yankoupe asked how CERC identifies action items. *Dr. James R. Houston* responded by saying that most items are identified and discussed in the executive session and then CERC responds to them.

MG Arthur E. Williams asked, in relation to the Rapid Response Team, if CERC sent any of its engineers to the east coast after the heavy storms this past October and January.

Dr. Houston said that three teams were sent to the New England area and the teams performed several studies for the New England Division and the Federal Emergency Management Agency because they were concerned about subsequent storms. In addition, engineers went to the Baltimore District to aid the District in planning for rehabilitation in the Ocean City, MD, area.

MG Williams brought up the issue about benefits (Action Item 55-3) and the present policy that downdrift neighbors who may benefit from sand moving downdrift from the renourishment project are not considered in the benefit analysis. He asked if there is enough data to support and recommend a change in that policy. *Mr. John G. Housley* responded by saying that when he talked to the economic people in Headquarters, they said that if the coastal engineer could provide them with the exact track of what happens to all the sand grains going down the beach, then they can figure the benefits. However, right now, the Corps policy is that those benefits are considered incidental benefits to those neighbors downdrift and they are not figured into the analysis for the project.

Mr. Charles N. Johnson stated that he has been participating in Section 111 monitoring programs in the North Central Division to try to assess the benefits of nourishing downdrift beaches and to determine how far downdrift the adverse effects of long-term maintenance dredging of Federal harbors extends. He feels the Corps is getting tremendous benefits downdrift from mitigated beach nourishment efforts. He feels it is wise and fruitful to take the downdrift benefits into account, and CERC should take efforts to emphasize techniques and participate in monitoring efforts to properly assess those benefits.

Impacts of the Coastal Engineering Research Board

Dr. James R. Houston
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U.S. Army Engineer Waterways Experiment Station
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The Coastal Engineering Research Board (CERB) is an extremely influential advisory board. Historically, the Board and its predecessor, the Beach Erosion Board, have played a significant and active role in advancing coastal engineering, not only in the Corps, but also in the world. The Board, as constituted today, was mandated by Congress in 1963 in the same legislation that established the Coastal Engineering Research Center (CERC), now a laboratory at the U.S. Army Engineer Waterways Experiment Station (WES). Congressional interest in the Board is a result of the fact that the discipline of coastal engineering was established and developed by the Corps, and the Corps remains the world leader and principal advocate today.

Although the Board has always been active, there have been significant changes in its focus over the past few years. Many of the changes were brought about by the move of CERC from Fort Belvoir, VA, to Vicksburg, MS. By necessity, CERC became more responsive to field needs, resulting in the emphasis on more applied research. At the same time, there was recognition that there had to be a balance of applied and fundamental research to advance the discipline. The whole field of coastal engineering was scrutinized by the Board and the Corps' leadership to ensure our stewardship would have positive impacts for years to come. If we do not do it, no one else will!

MG C. E. Edgar III became President about the time of the CERC relocation. He was a very active President and personally worked closely with the CERC staff to develop initiatives and direction. He invited then Chief of Engineers, LTG E. R. Heiberg III, to attend the Sausalito meeting in November 1985 to give a charge to the Board on future directions for coastal engineering. This charge began a new era of the CERB that continues today.

In his charge, LTG Heiberg noted the decline of General Investigations Research and Development funding while the Operations and Maintenance (O&M) budget grew. He charged the Board to look at appropriate research in the O&M arena, and suggested dredging might be a big payoff. There had been some planning for the Dredging Research Program (DRP) but those efforts had been stalled for some time. The Board recommended that the concept of a DRP and its potential for cost savings be reevaluated. A task force was formed, and the positive findings of this group resulted in the development and implementation of the DRP.

LTG Heiberg said we must "grow our own" coastal engineering specialists and suggested a cooperative program between CERC and universities. This was the genesis of the Coastal Engineering Education Program (CEEP), a cooperative effort between Texas A&M University and CERC, through the WES Graduate Institute, providing field engineers a one-year course leading to a master of engineering degree. The first class of six graduated last year, and the next session will begin in the fall of 1993.

LTG Heiberg charged the Board to look at ways to fund basic research. This led to the initiative that resulted in obtaining funding from the Army Research Office (ARO) for universities to conduct basic research. The ARO recently announced that the University of Delaware would receive $2 million over the next four years to conduct basic research on coastal processes.

At the next regular Board meeting in Alaska, a task force was formed to look into the "health" of coastal engineering. The task force held six regional meetings and made a number of observations and recommendations to the Board. They included:

a. Coastal specialists should be provided and trained in the use of more state-of-the-art "tools." This recommendation led directly to the formation of the Automated Coastal Engineering System program.

b. The task force confirmed the need for the education initiative, and planning for the CEEP was accelerated.

c. It was found there is no "Coastal Engineering" designation in the Federal personnel system. Action has been taken to include "Coastal Engineering" under the Civil Engineering-810 series.

Also, at that meeting, Bill Murden, then Chief of the Dredging Division, made a presentation on the concept of placing dredged material in regular features in the nearshore area. The concept was endorsed by the Board, which became a big factor in having it accepted by resource agencies. The concept is widely used now, resulting in significant savings.

At the Corpus Christi, TX, meeting in May 1987, it was noted that the civilian members needed a more in-depth knowledge of all of the coastal programs to effectively provide guidance. The civilian Board members now routinely attend program reviews.

At several Board meetings, there were discussions on problems in and around coastal inlets. At one meeting, LTG Henry J. Hatch was asked what he saw as the primary coastal problem in the Corps. His response was, "Inlets, inlets, inlets." At the June 1990 meeting in Fort Lauderdale, FL, the Board recommended the Corps determine the feasibility of conducting a research program on inlets. The need was established and the Coastal Inlets Research Program will be initiated next FY, funded at a minimum of $20 million over the next 5 years.

As a result of a presentation at the Fort Lauderdale meeting on the aftermath of Hurricane Hugo, the Board strongly recommended that the roles of the Federal Emergency Management Agency (FEMA), the Corps, and other Federal agencies involved in storm-related data collection be determined and coordination be improved. At the Corps' initiative, a working group was formed consisting of representatives from FEMA, National Oceanographic and Atmospheric Administration (NOAA), U.S. Geological Survey, and the Corps under NOAA's Office of the Federal Coordinator. The purpose of this group is to develop an interagency plan for coordinating coastal storm data collection activities.

Technology has and is being developed in the DRP to predict and monitor the movement of dredged material placed in open water. Environmental Protection Agency (EPA) representatives were invited to two CERB meetings (New Orleans, LA, June 1991; and Mashpee, MA, October 1991) where DRP results were reviewed by the Board. Based on what was seen and heard at these meetings, EPA was convinced the work in the DRP was resulting in valid procedures, and they gave the Corps the lead in this area.

Also at the New Orleans meeting, the Board recommended improvements for emergency operations during coastal flooding emergencies, including improved planning, coordination, and research and development. At the direction of the Readiness Branch in Headquarters, efforts are under way to develop an Emergency Management Research and Development Program.

The examples just cited illustrate some of the significant input the CERB has had over just the past few years. We believe that this Board, deeply a part of coastal engineering history, will continue to be a driving force.

Discussion

BG Yankoupe asked if CERC had any illustrative displays describing the research work conducted at the Laboratory. *Dr. Houston* said that the DRP has a number of displays and videos that have been taken to numerous meetings. He said the displays are for the layman and are easy to understand. This is a major thrust in the DRP.

BG Yankoupe encouraged CERC to continue with such a program as it increases the Corps' credibility and gains the public's confidence.

Coastal Inlets Research Program

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Background

The Coastal Inlets Research Program (CIRP) is scheduled to begin in FY 93. Much planning has gone into the make-up of CIRP and though still tentative, the basic program has taken shape. Two workshops were held last year (February 1991 in LaJolla, CA, and November 1991 in Dallas, TX) with field; Headquarters, U.S. Army Corps of Engineers (HQUSACE); Coastal Engineering Research Board (CERB) civilian members; and Coastal Engineering Research Center (CERC) personnel in attendance. These workshops were structured to develop and thoroughly discuss approaches to inlets research that will yield the best research results and most appropriate user products relative to inlet processes and problems. The workshops were successful in that field problems were prioritized, present field practices were identified, and tentative approaches were laid out.

Between the first workshop and the second, the Assistant Secretary of the Army for Civil Works (ASA/CW) cited budgetary considerations and reduced the size of the proposed CIRP from $40 million plus with a seven-year duration to $20 million with a five-year life. The decision by ASA/CW to reduce the size of the research program carried with it the possibility of a phased approach to the research effort. Discussions with field and HQUSACE personnel indicated that a phased approach was acceptable, with the emphasis and content of the first phase being fundamental research and the second phase producing more advanced and sophisticated products. In addition, the progression of work from the first phase to the second should be logical and efficient.

The second workshop concentrated on the composition of Phase 1. Over 50 representatives, including two CERB members, considered a variety of issues and research approaches. Recommendations from the workshop were that CERC should prepare a program that emphasizes understanding of fundamental processes of inlet behavior and response, and that the program should incorporate field, laboratory, and analytical approaches.

The Program

Planning for CIRP is progressing very satisfactorily at CERC. The program is being organized similarly to the Dredging Research Program in that technical areas containing work units with related research objectives are managed by a senior research person. An overall Program Manager is appointed to serve as a central point of contact and as an advocate for the program to Corps of Engineers field offices, HQUSACE, and others. Mr. Clark McNair has been appointed Program Manager for CIRP.

There are two technical areas in CIRP. Technical Area 1 is presently called "General Inlet Studies" and is under the technical management of Dr. Nicholas Kraus. This technical area addresses the short- and long-term behavior and evolution of tidal inlets and their response to waves, tides, and currents, given their basic geological makeup. Included in this technical area is an *inlet data analysis* task that will compile and analyze data information from many sources. A *shoreline change at and adjacent to inlets* task will improve our ability to predict sediment transport rates and shoreline changes at adjacent open-coast shorelines as well as within the inlet proper. Sediment budgets, impacts of engineering activities, and effects of storm events are included in the predictive relationships. There is a task to study *inlet morphodynamics*, which is the first known attempt to take into account the long-term trends at inlets and incorporate these trends into navigation project design and maintenance. The geomorphic indicators from which long-term processes can be derived will be identified and suggestions for selecting the unique sets of these indicators for specific inlets will be provided. A study of *inlet dynamics* will concentrate on inlet channel shoaling, migration, and stability.

Technical Area 2 is called "Advanced Inlet Analysis Technology" and is under the technical management of Dr. Linwood Vincent. Technical Area 2 delves deeper into the physics and relationships of inlet behavior and will ultimately provide sophisticated tools for management of inlets for Federal navigation projects. One task, transferred from the Coastal Research Program, investigates *scour holes at inlet structures* and will further understanding of what hydrodynamic conditions cause scour holes to develop and what processes are occurring during such development. From this work will come a procedure for predicting the general configuration and major dimensions of scour holes formed under specified hydrodynamic conditions as well as laboratory procedures for modeling scour hole development and impacts on structural stability. An *inlet modeling system* task will produce an integrated method to numerically investigate the interaction of hydrodynamics and sediment transport at an inlet. A two-dimensional (2-D) depth-averaged modeling system that links wave, hydrodynamic, and sediment transport modules will be developed. In addition, a three-dimensional turbulence model will be produced to describe the local flow and turbulence intensity near structures. This turbulent flow model will be linked to sediment transport to predict scour near structures and will be applied as an inset within the 2-D model. The objectives of a *waves at inlets* task are to develop a robust, efficient inlet wave model for incorporation into the inlet modeling system task. Laboratory, field, and numerical modeling techniques will be employed in this work.

Field and laboratory studies are an integral part of CIRP. As the program develops, these studies will focus on identified needs of all work units, but will also include activities that will enhance their own contributions as diagnostic and predictive tools.

Planning has progressed to the stage that documentation for specific work units is in draft form with milestones, funding, and research products identified. These work units and other facets of the program will be reviewed at the upcoming Field Review Group/Program Review meeting scheduled for July 1992. The civilian members of the CERB are invited to attend the meeting.

Discussion

MG Williams asked what programs in CIRP would not get done or done on a smaller scale if funds for the program are not in the '93 budget. *Mr. McNair* answered that quite a number will not be done. However, there are two work units that are ongoing right now in the Coastal Program that will be shifted into the new program for FY93 if it is funded. But if the new program is not funded, there will be a level of effort that continues in those two ongoing programs.

SUPERTANK Laboratory Data Collection Project[1]

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Introduction

The design of beaches to protect against storm erosion, flooding, and wave attack requires quantitative prediction of cross-shore hydrodynamics, sediment transport, and beach profile change. Large wave tanks (LWT) capable of producing waves and beach profile change without scale effects provide an inexpensive means, as compared with field data collection, of obtaining data for developing mathematical models of cross-shore processes and for investigating fundamental hydrodynamics under controlled conditions. A limited number of LWT experiments on beach change have been performed since the pioneering study of Saville (1956), but none have taken advantage of the full range of modern instrumentation to capture the scope of processes acting across the profile.

In support of numerical model development activities for predicting storm-induced beach erosion, in 1987 the Coastal Engineering Research Center (CERC) began planning the SUPERTANK Data Collection Project using the LWT located at the O.H. Hinsdale Wave Research Laboratory (WRL), Oregon State University. This is the largest wave channel in the United States in which a sandy beach can be emplaced. SUPERTANK subsequently ran for the 8-week period of 29 July to 19 September 1991. With the first and last weeks dedicated to mobilization and demobilization, data were collected over the six weeks from 5 August through 13 September.

The channel of the LWT at the WRL is 104 m long, 3.7 m wide, and 4.6 m deep, into which a 76-m-long beach was constructed for the SUPERTANK project. The beach was composed of approximately 600 cu m of uniform-size quartz sand of 0.22-mm median diameter. The direct, digital-controlled, servo-hydraulic wave generator was equipped to absorb waves at the peak spectral frequency that are reflected from the beach and from structures, such as dunes and seawalls, placed on the beach. Broad- and narrow-band random waves and monochromatic waves were run with significant wave heights in the range of 0.2 to 1.0 m and with peak spectral periods in the range of 3 to 10 sec.

As planning of SUPERTANK progressed, it was realized that the offshore region would provide an ideal environment for hydrodynamic and sediment transport measurements needed by CERC research work units concerned with movement of dredged material. Thus, one unique characteristic of SUPERTANK was utilization of the entire length of the beach in the LWT channel, extending from near the wave generator and through the

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[1] This paper is essentially the same as the Abstract to be published in the Abstracts volume of the Twenty-Third International Coastal Engineering Conference, American Society of Civil Engineers, Venice, Italy, October, 1992.

surf zone to the limit of runup on the beach face, dune, or seawall.

Another characteristic of SUPERTANK that distinguishes it from previous LWT studies was that the project was conducted as a multi-institutional cooperative effort similar to cooperative field data collection projects first performed in the 1970s (e.g., the NSTS (Seymour and Duane 1978) in the United States, and the NERC project (Horikawa and Hattori 1987) in Japan). Cooperative efforts that pool expertise, instrumentation, and a wide range of research interests have led to advances unattainable by a single or small group of investigators. Participants joining CERC at SUPERTANK came from the Florida Institute of Technology, Naval Postgraduate School, North Carolina State University, Ohio State University, Oregon State University, QUEST Integrated, Inc., RD Flow, Inc., Seatech, Inc., U.S. Naval Academy, University of California at Santa Cruz, University of Delaware, University of Florida, and University of Washington. Participating foreign institutions were the Danish Hydraulics Research Institute (Denmark), Delft Hydraulics Institute (The Netherlands), and Nihon University (Japan). Corps of Engineers field office personnel and undergraduate and graduate students from institutions around the United States assisted SUPERTANK investigators in all aspects of the project.

Results

SUPERTANK is believed to be the most densely and comprehensively instrumented nearshore processes data collection project ever conducted in the laboratory or in the field. At the peak of data collection activities, the LWT channel was instrumented with 16 resistance wave gages, 10 capacitance wave gages, 18 two-component electromagnetic current meters, 34 optical backscatterence sensors, 10 pore-pressure gages, 3 acoustic sediment concentration profilers, 1 acoustic-Doppler current profiler, 1 four-ring acoustic benthic stress gage, 1 laser Doppler velocimeter, 5 video cameras, and 2 underwater video cameras. The resistance wave gages, capacitance wave gages, and electromagnetic current meters formed the core of SUPERTANK data collection and were maintained throughout the project. Synchronous sampling by separate data acquisition systems was assured by digital input of the WWV time code to all computer clocks.

Fluorescent sand tracer studies were also conducted, requiring support by SCUBA-equipped divers. During SUPERTANK, approximately 350 beach profile surveys were taken to record the response of the profile to wave action and to changes in shoreward boundary conditions. The surveys were made with an auto-tracking infrared geodimeter, which targeted a prism attached to a survey rod mounted on a carriage. The survey rod made contact with the bed via a pair of wide-tread wheels.

Of the 20 major data collection runs or "tests" performed (Table 1), most are defined as starting from a new beach profile. Wave conditions designed to produce erosion or accretion were selected through use of predictive criteria described by Kraus, Larson, and Kriebel (1991). Several tests had objectives separate from monitoring evolution of the beach profile, such as dedicated hydrodynamic, suspended sediment, and instrument tests that examined local fluid and sediment transport conditions. Representative wave conditions are listed in Table 1. For tests involving random waves, the wave height is the significant height, and the period is the peak spectral period. Sixty-six different wave conditions were run for a total of 129 hr of wave excitation; 70 percent of the wave conditions involved random waves.

Table 1
Description of SUPERTANK Tests

Test Number	Description	Date	Representative Signif. Wave	
			Height m	Period sec
ST_10	Erosion, Random Waves	8/05 - 8/09	0.8	3.0
ST_20	Acoustic Profiler Tests (Random; Monochromatic)	8/11 - 8/13	0.2-0.8	8.0-3.0
ST_30	Accretion, Random Waves	8/14 - 8/16	0.4	8.0
ST_40	Dedicated Hydrodynamics	8/19 - 8/21	0.2-0.8	8.0-3.0
ST_50	Dune Erosion, Test 1 of 2	8/22 - 8/22	0.5-0.8	6.0-3.0
ST_60	Dune Erosion, Test 2 of 2	8/23 - 8/23	0.5-0.7	6.0-3.0
ST_70	Seawall, Test 1 of 3	8/26 - 8/26	0.7-1.0	4.5
ST_80	Seawall, Test 2 of 3	8/27 - 8/27	0.7	4.5
ST_90	Berm Flooding, Test 1 of 2	8/28 am	0.7	3.0
ST_A0	Foredune Erosion	8/28 pm	0.7	3.0
ST_B0	Dedicated Suspended Sediment	8/29 - 8/30	0.3-1.0	10.-3.0
ST_C0	Seawall, Test 3 of 3	9/02	0.4-0.8	8.0-3.0
ST_D0	Berm Flooding, Test 2 of 2	9/03 am	0.7	3.0
ST_E0	Laser Doppler Velocimeter, Test 1 of 2	9/03 pm	0.2-0.8	3.0
ST_F0	Laser Doppler Velocimeter, Test 2 of 2	9/04 am	0.2-0.7	8.0
ST_G0	Equilibrium Erosion, Monochromatic Waves	9/04 pm	0.8	3.0
ST_H0	Equilibrium Erosion/Transition, Monochromatic Waves	9/05 am	0.5-0.8	4.5-3.0
ST_I0	Equilibrium Accretion, Monochromatic Waves	9/05 - 9/06	0.5	8.0
ST_J0	Narrow-Crested Offshore Mound	9/09 - 9/11	0.5-0.7	8.0-3.0
ST_K0	Broad-Crested Offshore Mound	9/12 - 9/13	0.5-0.7	8.0-3.0

Future Activities

Although data collection has been completed, reduction and analysis of the enormous (multi-gigabyte) data set remains. Significant effort has been dedicated to organize and clean the data set so that it may be accessed by all researchers, including those who did not participate in SUPERTANK. The first year after SUPERTANK is devoted to reduction of all major data sets — converting quantities to engineering units and cleaning and organizing the data. The following two years will include data exchange among SUPERTANK investigators and intense data analysis.

Advancements in engineering tools and practice, such as improvement of numerical models of beach change and wave transformation through the surf zone, as well as improved understanding of basic sediment transport and bottom boundary layer processes, are expected to emerge from these analyses. In September 1994, three years after SUPERTANK, the data will be available to the public.

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Discussion

Prof. Fredric Raichlen asked if this type of video which describes where research money is going, is given to congressional staffers for their information. *Mr. Jesse A. Pfeiffer, Jr.*, said it is not because it is too technical and data oriented, but he said it is a good idea to put one together especially for their interest and their technology level.

BG Ralph V. Locurcio commented that when he visited the U.S. Army Engineer Waterways Experiment Station recently, he was struck by the tremendous value of what is being accomplished, but he feels that it does not get out into the field and the affected public well enough. He said that an abbreviated version of this video would be extremely valuable to municipalities that are affected by coastal storms, and even valuable to schools where it can be used in science programs.

Dr. William E. Roper suggested that under the Corporate Outreach Program for the Corps, especially youngsters in high school and grade school, that videos such as the SUPERTANK video be considered for translating the interest, the science, and the energy that go into some of the work the Corps does.

Mr. Pfeiffer mentioned that in the Wetlands Program, the Corps is making a dedicated effort in putting together information that is directly aimed at children from kindergarten to the 12th grade. He said there is a real audience out there, and Wetlands is an ideal starting place. It is easy to understand, and shows a lot of things the Corps is doing. He said once the Corps gets a good feel for that, it will get into coastal and other areas.

Prof. Raichlen said that the type of wave machine at the SUPERTANK experiment does a good job in absorbing some of the shorter-period waves and the reflection process. He asked about the long-period buildup when you start running these tests for long periods of time. *Dr. Kraus* responded that on the shorter-period waves, even the steep waves, the longer-period scaling motion was minimal. He said the 20- and 40-sec seiche contributed fairly substantially on the foreshore.

Prof. Robert A. Dalrymple commented that this kind of an experiment is a very important activity of CERC. The science that is generated in this kind of experiment helps CERC's scientists, but more importantly, this collaborative research with universities and companies provides good visibility for CERC. He said that without CERC's leadership and participation, this experiment would not have happened, and it serves as a major milestone in laboratory data collection for coastal processes. He also said that the collaboration between the various institutions doing coastal engineering in the United States and abroad is extremely important.

MG Williams asked how any of the data that came out of SUPERTANK could be utilized with studies at Ocean City, MD. *Dr. Kraus* responded saying there is an outstanding data set from Ocean City that will be correlated with the SUPERTANK data when analysis begins.

Dr. Roper asked how data collected during SUPERDUCK compared with the SUPERTANK experiment. *Dr. Kraus* said most of the CERC measurements at SUPERDUCK and DUCK '85 were longshore transport experiments. SUPERTANK was cross-shore transport, so there's no direct correspondence. However, there were some other institutions, such as Oregon State and the University of

Washington, who participated in DUCK '85, SUPERDUCK, and SUPERTANK with their optical backscatter devices, and they will be doing some correlation between field data and laboratory data.

Introduction of Coastal Structures Theme

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While we have no accurate records of when the first coastal structures were built, we do know that the Vikings, the Phoenicians, and the Romans built coastal structures to provide protection for their early ports. With a single breakwater, the Phoenicians built their famous open-coast port at Tyre 4,000 to 5,000 years ago, using rectangular blocks tied together with copper dowels (Per Bruun 1981). In this country, the evolution of coastal structures is synonymous with the Corps of Engineers. Design methods were pioneered by such noted Corps employees as R. Y. Hudson, and design criteria were published in the Beach Erosion Board's TR-4, "Shore Protection Planning and Design" in 1954. Subsequent to TR-4, the *Shore Protection Manual* was published by the Coastal Engineering Research Center (CERC), Fort Belvoir, VA, in 1973, and by CERC, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, in 1984, with over 30,000 copies distributed worldwide. In addition, various engineer manuals on coastal structure design (breakwaters, jetties, revetments, seawalls, bulkheads, etc.) have been published and updated as a result of Corps research. Currently, planning is under way on publication of the *Coastal Engineering Manual* or "CEM," which will incorporate all Corps guidance on coastal structures into one document, with publication estimated in 1997.

The Corps' past history with coastal structures has been one of construction. We have participated in construction of major structures (both military and civil) along all U.S. coastlines, as well as around the world (Los Angeles-Long Beach Harbors, mouth of the Columbia River, numerous jetties on the Oregon coast, fishing harbors in Alaska, seawalls along the Gulf and Atlantic coasts for hurricane protection, jetties for inlet stabilization, Cleveland and a myriad of other harbors on the Great Lakes, Jubail Harbor for Saudi Arabia, etc.). This trend, however, has changed dramatically, with new construction an exception rather than the rule. This is true primarily because much of the nation's coastal infrastructure is already in place, and because of environmental/regulatory constraints (one only has to examine a history of the Corps' reimbursable project at Los Angeles-Long Beach Harbors to gain an appreciation of what it takes to construct "anything" in the coastal environment today).

Since new construction is minimal, current and future trends in the Corps are oriented toward maintenance, rehabilitation, and repair of existing structures. Many of our coastal structures are quite old, having exceeded their design life. Through deterioration, flawed (or antiquated) design criteria, or conditions that exceeded the design event, many no longer serve the purpose for which they were originally constructed. We need equipment/methods for inspection and evaluation (particularly underwater portions) of these structures, and we need research directed toward developing more practical and economical ways of rehabilitation/maintenance, so that their life can be extended.

More realistic "real world" design conditions and the incorporation of risk analysis and design optimization will result in designs that are more palatable to our cost-sharing partners. Better field data (supplementing wave climatology calculations) are being acquired, taking advantage of the rapid advances in field equipment and measurement techniques. We must conduct an assessment of our coastal facilities and their adequacy for meeting the needs of the 21st century, as well as maintaining state of the art in experimental procedures and numerical methodologies.

One possible future trend is pursuing the evolution of coastal structure types which are not presently in common use Corps-wide (reef breakwaters, berm breakwaters, tandem breakwaters, single layer armor, rib caps, composite structures incorporating multiple materials, new concrete armor unit shapes, etc.). Some recent examples of non-traditional rehabilitation designs include:

a. The Redondo Beach breakwater, where wave transmission and overtopping were brought to acceptable levels by use of smaller stone in a wider (rather than higher only) structure overlay with flatter side slopes.

b. The Burns Harbor breakwater, where we currently are investigating tandem breakwaters (incorporating a lakeward reef) as a method to reduce wave transmission, wave overtopping, and harborside armor displacement.

The Corps may need to reevaluate its methodologies (or lack thereof) for evaluating new proposed concepts.

From CERC's perspective, there have been several encouraging signs relative to the new trends in coastal structures that we see the Corps evolving toward. These include important (and practical) products/procedures from major field experiments such as the Crescent City Prototype Dolos Project and the Yaquina North Jetty Monitoring Completed Coastal Projects Program; upgrades of laboratory facilities/procedures at CERC (directional/spectral waves, laser doppler technology, movable-bed investigations of scour/foundation problems, mid-scale testing to minimize/eliminate scale-effects, etc); and research programs (Coastal; Repair, Evaluation, Maintenance, and Rehabilitation; etc.). Improvements in technology transfer also are taking place through automated coastal engineering, automating design procedures (concrete armor unit design), national and regional coastal workshops, and publication of the new *Coastal Engineering Manual*.

The presentations to follow will give an overview of current problems the Corps faces and of the directions in which we are headed with regard to coastal structures. One important theme to watch for is that of *synergism*, an essential ingredient for future success.

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(There was no discussion after Mr. Chatham's presentation).

Overview of Corps Problems Related to Coastal Structures

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As shown in Table 1, the U.S. Army Corps of Engineers maintains 362 projects with 696 major breakwaters and jetties in the nine Engineer Divisions with coastal responsibilities. The aggregate length of these structures is approximately 350 miles. More than one half are over 50 years old and some are over 150 years old.

These structures were generally built to provide protection to a local harbor or navigation pass from wave action. Jetties and breakwaters also quite often help to maintain channel depth and can even prevent shore damage. Consequently, these structures tend to reduce the cost of dredging and shore maintenance.

A major concern to us today is maintaining these structures to provide the benefits as originally designed and to maintain that level of service at minimal repair cost. Table 2 gives some figures for operation and maintenance (O&M) expenditures for the last eight years on the cost to maintain coastal structures and to dredge our waterways. Over this period, we spent an average of $29.9 million and $376.7 million for maintaining coastal structures and dredging, respectively.

In 1986, Congress passed a Water Resources Development Act (WRDA), which established the Harbor Maintenance Trust Fund to finance improvements and maintenance of coastal channels and harbors through user fees. This Act required that 40 percent of the O&M costs associated with coastal projects would be reimbursed from the trust fund. In the 1990 WRDA, Congress increased the user fees to 100 percent and now provides for total reimbursement of the monies expended for qualifying projects.

Across the entire Federal spectrum, resources are becoming more constrained each year. The Corps' total budget is likewise being constrained. Therefore, we need to explore ways to optimize use of limited O&M

Table 1
Coastal Structures by Division[1]

MSC	Projects	Jetties	Break-waters	Total	Feet
POD	14	1	18	19	26,500
LMVD	10	19	0	19	153,000
SWD	12	19	4	23	176,333
SAD	32	25	14	39	256,000
SPD	28	28	28	56	171,870
NED	52	35	48	83	154,185
NAD	58	72	26	98	161,500
NPD	49	35	74	109	255,786
NCD	107	103	147	250	481,570
Total	362	337	359	696	1,836,744

[1]References listed below.

Table 2
Expenditures for Coastal Structures ($1,000)

Year	Maintenance	Dredging
1985	29,969	414,385
1986	38,110	356,474
1987	26,993	367,396
1988	39,796	334,075
1989	37,145	340,576
1990	11,473	346,549
1991	25,772	425,534
1992	29,947	423,554
Average	29,900	376,067

funds. During the past few years, considerable research has been conducted that promises to increase maintenance efficiency, which hopefully will yield better and longer-lasting repairs. Some of this work was done under the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) I Research Program and will continue under REMR II.

Another important program in progress that is more oriented to immediate problem solving is the Monitoring Completed Coastal Projects (MCCP). The objective of this program is to improve design and repair methods, and determine the effectiveness of the individual structure systems. Promising side benefits include correlation between structures and dredging, and shore protection enhancement.

Two projects in the MCCP arena with studies well under way are the jetties at Yaquina Bay, OR, and the breakwaters at Crescent City, CA. What makes these two projects special is the amount of time and effort we have expended trying to find solutions to stabilizing these two structures. For example, Yaquina has undergone extensions or rehabilitation seven times since initial construction. Since 1966, we have expended over $16 million on O&M repairs alone.

To assist in prioritizing O&M funding levels for all projects, we have initiated the application of condition indices. Under this program, the condition of a breakwater or jetty will be quantified to a numerical rating between 0 and 100. The rating will be applied under a standard set of rules. The objective is to provide a condition evaluation that is comprehensive and repeatable. The condition index will be coupled with repair and maintenance costs in a computerized maintenance management system to determine preliminary rankings for prioritizing maintenance schemes.

As we implement new guidance procedures for the major rehabilitation of Corps projects, the rehabilitation of coastal structures will require much more information than in past practice. Basically this guidance calls for the justification of rehabilitation to be tied directly to the level of service provided and the reliability of that structure to perform as designed. Without these types of analyses, structures cannot be evaluated on an equal basis and compete for limited resources.

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Discussion

BG Locurcio asked what happens as resources are expended on projects with the highest benefit cost ratio (BCR) to those structures on the low end of the BCR scale. He said there is a Federal responsibility to maintain these structures. *Mr. Crews* responded that what might happen is that if the benefit is to a localized region, then the project should be maintained by the local people.

Dr. Roper asked if there was any provision in the legislation for the Harbor Maintenance Trust Fund for research and development support that would make more effective use of the active project expenditures in a similar way that the Highway Trust Fund supports research and development in pavement, pavement rehab, and new designs. *Mr. Crews* said that in reading the Act, it does not prohibit such support or say anything about it.

North Pacific Division Coastal Structures

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The North Pacific Division's activities in coastal engineering extend from the northern border of California, through the states of Oregon and Washington, to the southern border of Canada, and include our largest state, the state of Alaska.

Coastal structures in the North Pacific Division have been used for beach erosion control and for development of navigation. Navigation structures are the dominant Corps activities in the Division. Those features vary from the massive jetty system at the mouth of the Columbia River to boat harbors in semi-protected waters in Puget Sound and Alaska, where floating breakwaters are suitable structures.

The focus of this presentation is on the more massive open-coast structures. Jetty construction in the Pacific northwest was initiated in 1885 at the mouth of the Columbia River. The south jetty was placed over a period of several years and completed in 1914. The purpose was to fix the channel position, increase depths over the bar channel, and to moderate wave heights in the navigation channel. The north jetty was completed in 1917 and jetty A in 1939. The south jetty is 6.6 miles long and the north jetty is 2.5 miles long.

Early jetty construction was from railroad trestles. Pile bents were driven, then protected against scour. Rails were advanced and then jetty stone side dumped to bring the desired cross section to grade. Stone used was commonly quarry run and locally available. Reconstruction required driving new pile bents alongside the remnants of older construction and repeating the process. Eventually, a broad-based berm was developed that could support a superstructure.

By the late 1930's and early 1940's, the use of trestle-dump techniques no longer appeared to be a reasonable approach for rehabilitation. Concrete caps, concrete terminal blocks, and asphaltic mastic binders were used for rehabilitation. All of these attempts to increase the life cycle of structures met with limited success.

Coastal structures were not constructed or rehabilitated in the 1940's, but by the late 1950's, a new era of construction equipment had entered the picture. Large truck-mounted cranes and trucks capable of handling 40-ton materials were available and could be used at a reasonable cost.

The designed cross section was in vogue for new construction and rehabilitation. A bedding layer was introduced to act as a filter between sand foundations and superstructures. Large stones were placed as outer armor and inner layers of smaller stones were utilized to capture as high a percentage of quarry yield as possible. It was still, however, common practice to use local quarries where possible, and a number of structures were constructed or rehabilitated with sandstone that was easily abraded.

The early 1960's was ushered in with several significant changes in design. Rock quality became a factor in the design. Jetty heights were defined by what was expected to be a reasonable construction window for constructing from a finished grade. The principle of an arch was used as a basis for placing armor, i.e., long-axis parallelepiped stone was placed perpendicular to the slope. Adoption of rock quality standards and strict adherence to armor stone size forced barge transport of stone from the few quarries that were able to meet the standards.

The impact of jetty construction on estuaries, coastlines, and channels has been dramatic. Using the mouth of the Columbia River as an example, we have observed immense changes in channel depth and location. Shifts in sediments viewed over the 100-year period of manipulation are massive. The total estuarine and shoreline sediment circulation process has undoubtedly been modified.

The jetties originally extended to the 30-ft depth contour. They effectively isolated the navigation channel from the major effects of littoral transport processes. Large onshore shifts of bars lying outside of the channel influence occurred. In the channel-influenced area, bars shifted offshore and into the estuary. Remnants of some of the early mass movement still exist. Peacock Spit appears to be moving west and north and Sand Island, in the estuary, may still be shifting to Baker Bay.

Installation of the jetties must be viewed as a success from a navigation standpoint. The channel position has been stabilized. Channel depths with the aid of dredging, which started about 1935, have been shifted from 20 ft to 55 ft.

Dredging between construction cycles is nominally between 5×10^6 to 6×10^6 cubic yards per year. As side slopes adjust to new channel dimensions, it is expected that either an advance on depth will be made or that the total deeding requirement will decrease.

Discussion

Prof. Raichlen asked if in the Pacific northwest there are structures built with concrete armor units or that have been repaired using concrete armor units. *Mr. Oliver* responded that economics has forced the Corps to build rubble-mound structures. He said constructibility becomes a major issue when you move from rock to armor units. Because of the difference in construction methods and the difference in dimensions of the structure from which construction takes place, concrete armor units have not been economic to use in this area.

Panel

Introduction to Research and Development (R&D) and Monitoring Efforts

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Overview

Jesse A. Pfeiffer, Jr.

The previous theme presentations have shown the problems encountered in maintaining and repairing coastal structures in this region and throughout the country. The remaining presentations today will outline the steps being taken to accomplish this task in an efficient and economical manner. The first theme presentation will give you an overview of the Corps' broad research and monitoring programs in place to address the problems. At the last meeting, you asked to be periodically updated on activities not funded through the General Investigations (GI) Research and Development (R&D) Program. Note that both the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) and Monitoring Completed Coastal Projects (MCCP) programs are Operations and Maintenance (O&M) funded.

REMR was an immensely effective and popular program designed, as the title implies, to address O&M problems. The ongoing REMR II program is equally effective and the overview will be presented by Jim McDonald of the Structures Laboratory at the Waterways Experiment Station. The coastal component of the REMR is headed by D. D. Davidson of the Coastal Engineering Research Center (CERC) who will brief you on those activities. Finally, Carolyn Holmes, Manager of both the MCCP Program and the GI R&D-funded Coastal Programs, will review activities ongoing in those programs to address the theme.

After the break, presentations will be made on projects you will visit tomorrow at Crescent City, CA, and Yaquina, OR. Both sites are examples of the synergism that develops when the field and research communities work closely together. At Crescent City, a rehabilitation project led to one of the largest and most complex field studies ever undertaken by the Corps. This was followed by longer-term monitoring and physical model studies that feed into the R&D to develop a sound structural design procedure for dolos. We are pleased to have three of the principals of this work, Messrs. Kendall, Markle, and Melby, to make presentations.

Determining the cause of chronic damage experienced at the Yaquina north jetty has been a challenging joint effort between the Portland District, CERC, and experts in the academic community. Through monitoring conducted under the MCCP program, it now appears that the damage mechanism may have been isolated at Yaquina so that any future repairs can be designed with this knowledge. Laura Hicks will outline the Yaquina jetty problem in detail, and Steve Hughes will overview the monitoring effort and discuss gaps in our design and monitoring capabilities made apparent during the course of the study.

I believe you will find the problems being addressed at these sites to be of great interest. I hope that you will find of equal interest the multi-faceted approaches being taken to address the problems. We have left a half hour after the presentations to discuss in more detail all aspects of the problems and approaches. During that time and during your deliberations, I ask that you consider how the approaches outlined here can be used to address other specific and grave problems.

Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program

James E. McDonald

The U.S. Army Corps of Engineers was one of the first Federal agencies to recognize the need for research to address the nation's deteriorating infrastructure. Since 1983, the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program has clearly demonstrated the benefits of research in getting more value for the dollars spent on REMR activities. Technologies from the REMR Program have been used on more than 130 Corps projects to date with cumulative dollar savings estimated at $150 million.

In addition to dollar savings, the program has resulted in other benefits such as improved safety and reliability (advanced nondestructive testing and inspection and evaluation techniques), reduced manpower requirements (instrumentation automation technology and numerical models), and improved operational capabilities (REMR Operations Management System).

Due to its enormous successes, the REMR Research Program continues with a second phase launched in Fiscal Year 1991. This second phase is addressing new and different needs which were identified by Corps field offices and is concentrating on research with potential for large payoffs and widespread applications.

The overall objective of the REMR Research Program is to identify and develop effective, affordable technology for maintaining and extending the service life of U.S. Army Corps of Engineers civil works structures. However, many of the program's results can be applied to other projects.

REMR is a very broad-based research program and involves the combined talents of the six laboratories of the Waterways Experiment Station, the Construction Engineering Research Laboratory, the Cold Regions Research and Engineering Laboratory, and the Topographic Engineering Center. For management purposes, the research is organized into six problem areas: concrete and steel structures, geotechnical, hydraulics, coastal, electrical and mechanical, and operations management.

Studies under the *Concrete and Steel Structures Problem Area* are addressing improved nondestructive testing systems; dynamic stability assessment and upgrading concepts; and maintenance, repair, and rehabilitation of concrete and steel structures.

Under the *Geotechnical Problem Area*, primary concerns are maintenance and rehabilitation of earth structures and remedial treatment of foundation problems.

Investigations are being conducted under the *Hydraulics Problem Area* to improve navigation conditions and the effectiveness of hydraulic structures.

Under the *Coastal Problem Area*, evaluation and repair and rehabilitation techniques for coastal structures such as jetties and breakwaters are being addressed.

Primary concerns under the *Electrical and Mechanical Problem Area* are maintenance of corrosion-susceptible components of Corps structures through the use of proper coatings and cathodic protection systems.

Management systems for each type of Corps civil works structure are being developed under the *Operations Management Problem Area*. These systems include condition rating procedures, maintenance and repair alternatives, life cycle costing procedures, and automated data storage and retrieval.

Technology transfer has always been an important part of the REMR Research Program. The Federal Laboratory Consortium's *Special Award for Excellence in Technology Transfer* was awarded for the development and implementation of the REMR Technology Transfer Plan. The plan has served as a model for other large research programs.

Information is disseminated through seminars, workshops, meetings, demonstrations, videotapes, printed media, and electronic media. Publications include reports, an information bulletin, and a loose-leaf notebook with technical notes and material data sheets.

Coastal Components of REMR

D. D. Davidson

The Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program has been and continues to be a success in that benefits far exceed cost. The initial program (REMR I) encompassed several distinct problem areas, all of which had the primary purpose of identifying and developing effective and affordable technology for maintaining and extending the service life of existing Corps infrastructures.

The Coastal Problem Area is no exception because experience has shown that repair and rehabilitation of older coastal structures, such as breakwaters and jetties, require a variety of knowledge and expertise, some of which are different from those required in design and construction of new structures. In fact, design and construction procedures used originally may have contributed to present day problems so that restoring a structure to its original design condition using original construction techniques could result in reoccurring damages or failures. Specific knowledge developed under the REMR program contributes to more lasting repairs and more effective evaluation and maintenance. The Coastal Problem Area was a part of the original REMR effort (REMR I) and continues to play a part in REMR II.

The Coastal Engineering Research Center (CERC), along with the help of various Corps field offices, conducted research in five areas during REMR I and is presently responsible for four areas of study in REMR II. CERC also is assisting the Construction Engineering Research Laboratory (CERL) in development of a condition rating procedure for rubble breakwaters and jetties.

REMR I

Sealing of permeable breakwaters and jetties

Rubble-mound breakwaters and jetties are intended to protect harbors and navigation channels from excessive wave energy and to prevent shoaling of channels and boat mooring areas. The cores of many such coastal structures have deteriorated to such an extent that they do not serve their originally intended function.

A cost-effective alternative to traditional methods of rubble-mound structure sealing (i.e., dismantling to rebuild core sections, chinking layers along surfaces, additional armoring layers, etc.) was determined to be drilling and grouting (sealing) a vertical barrier curtain along the center line of the structure from the bottom to approximately mean higher high water.

Based on technology available through this study, Broward County sealed the south jetty at Port Everglades, FL, with chemical grout resulting in a savings of $314,000 over conventional methods.

Reducing wave runup and overtopping

Problems associated with runup and overtopping have occurred on about 20 percent of Corps' coastal structures and range from (1) excessive wave action on the lee side of breakwaters and jetties, (2) flooding and erosion on the backside of seawalls, sea dikes, and bulkheads, to (3) backside subsidence, erosion, and sometimes collapse of revetments.

Mathematical models and flume studies were used to evaluate and rank hydraulic performance of a number of seawall/revetment configurations and it was found that an attached low berm fronting a rubble revetment significantly decreased wave runup and overtopping. This technology was used at the Temple Emanuel project on the Chicago waterfront (resulting in a 12-percent savings over the costs of the traditional high berm revetment) and now is proposed for approximately 28 miles of highly developed shoreline along the Chicago lake front.

Rehabilitation of rubble-mound structure toes

Many breakwater failures have been attributed to failure of the toes of these structures. No firm guidance existed to aid Corps personnel in designing toe berms and most design work was carried out using limited local field experience with past successes and failures.

A series of two-dimensional (2-D) and three-dimensional physical model experiments was developed and conducted to address the sizing of toe berm and toe buttressing stone in breaking wave environments. Guidance for sizing toe berm armor stone was developed for a range of wave and still-water level conditions. Guidance for sizing of toe buttressing stone was addressed for a limited set of incident wave conditions on structure trunks. Use of this new guidance should eliminate wave-induced toe berm failures and result in significant dollar savings for the Corps.

Evaluation of damage to underwater portions of coastal structures

Effectiveness of techniques for inspection and evaluation of underwater damage is limited by severe conditions encountered in the zone surrounding coastal structures. Current technology and methods for performing inspections were examined, and guidance was developed, through testing and experience in actual field conditions. Training was provided to Corps personnel, and a prototype system called the Coastal Structure Acoustic Raster Scanner (CSARS) has been designed, constructed, and improved through field trials.

Use of dissimilar armor for repair and rehabilitation

Model tests have shown that overlays of concrete units such as dolosse and tribars over stone require larger sizes than if the structure were originally designed for those particular units. Thus, the design guidance for new structures is inappropriate for use in the design of repairs and rehabilitations involving dissimilar armor.

Stability tests were conducted of dolos overlays of stone-armored, dolos-armored, and tribar-armored breakwater and jetty trunks; tribar overlays of stone-armored breakwater and jetty trunks; and dolos overlays of stone-armored breakwater heads, subjected to breaking waves. Results from these tests can be used to design hydraulically stable, appropriately sized armor units for repair and rehabilitation of breakwaters and jetties.

REMR II

Continued monitoring of grout sealant durability specimens

During REMR I, a three-phase program was conceived and partly carried out to investigate the effectiveness of sealing rubble-mound breakwaters and jetties with cementitious and chemical grouts, and to determine the durability of these materials in the ocean environment. Phase 3 work is continuing under REMR II and has already yielded important results in that some of the chemical sealant specimens (sodium silicate-cement and sodium silicate-diacetin) have completely deteriorated, indicating that these previously popular sealants are not effective in the long term.

Toe stability in a combined wave and flow environment

The design and construction of a stable structure toe is as important in a repair or rehabilitation program for rubble-mound structures as is the design and repair of primary armor slopes. Previous work addressed the toe stability of rubble-mound structures under attack of breaking waves, but most structures have some component of river or tidal flow as well. The objective of current work is to evaluate the stability of toe stone repair when placed in a combined wave and flow environment. The work consists of fixed-bed/movable-bed physical model tests using regular and irregular waves with simulated steady-state river or tidal-induced flow.

Quantitative imaging and inspection of underwater portions of coastal structures

This work advances from the hardware identification, evaluation, and prototype design foundation laid in REMR I to refining the hardware and software tools needed to make quantitative (rather than qualitative) inspections of underwater portions of coastal structures a routine procedure. Emphasis is on simplifying this procedure to a minimum level of skill, training, and experience necessary to produce useful high-quality, high-resolution results. Present efforts consist of review of emerging new approaches and systems, refinement of the CSARS, and software development. These tools will provide decision makers with information for making better and more informed repair and rehabilitation decisions.

Breakwater concrete armor units for repair

Since no general structural design guidance for concrete armor units (CAUs) used in repair and rehabilitation of coastal structures presently exists, current CAUs must be designed either overly conservatively, (yielding high initial costs) or nonconservatively, (yielding high rehabilitation and repair costs). Work performed under other study efforts has broken the loadings on CAUs into three basic levels; static, pulsating, and impact. Some static and pulsating loads on dolosse have been addressed in these previous studies; however, actual impact loads caused by waves have not previously been addressed. The general objective of the present work is to provide repair and rehabilitation design guidance that incorporates all structural aspects to enable field offices to accurately determine safe CAU design stress levels. Present efforts include mid-scale 2-D breakwater modeling to address impact loading and quantify structurally related scale effects inherent in smaller-scale studies.

Condition rating procedure for rubble breakwaters and jetties

Within the REMR program, the CERL is responsible for developing a computerized maintenance management system(s) for coastal and waterway navigational structures, which will provide maintenance managers at all levels with tools for effective maintenance planning.

The objective of these REMR Management System(s) is to create uniform procedures for assessing the condition of structures and to create assessment methods that will allow the condition of structures, and their parts, to be expressed numerically for use in today's microcomputer systems.

The development of condition rating procedures and a management system for coastal navigation and protection structures has already begun and CERC was asked to assist CERL in these first coastal efforts (concentrated on breakwaters and jetties of rubble construction with either rock or concrete armor units). Future efforts will include system features for breakwaters and jetties of non-rubble construction and also seawalls, bulkheads, revetments, and groins.

Procedures now exist for determining structural and functional ratings for rubble breakwaters and jetties. These ratings are used to produce a Structural Index and a Functional Index for each reach of a structure. These two indexes then are combined to form a Condition Index (CI) for each reach, and the reach indexes are combined to form an overall CI for the structure. The index values range from 0 to 100, which is broken into appropriate descriptive levels of damage.

Discussion

Prof. Raichlen asked how the CSARS was calibrated. *Mr. Davidson* said that a base survey is conducted by conventional methods.

Prof. Raichlen commented that he was pleased to see that CERC was using the Oregon State facility. He said that the Oregon State facility is probably the biggest and best instrumented facility in the United States, and rather than construct other facilities of that size, to use that facility is in the best interest of the Corps, particularly for what it really can contribute, namely, to try to eliminate scale effects.

Coastal Engineering Research and Development (R&D) Program/Monitoring Completed Coastal Projects Program

Carolyn M. Holmes

Coastal Engineering R&D Program

The Coastal Engineering Research and Development (R&D) Program is the long-term research program in support of engineering activities required by the Corps to design, build, and maintain hundreds of coastal navigation, shore protection, and coastal flooding projects. The program is funded through General Investigations, with current fiscal year funding of approximately $5,700,000.

The R&D program develops techniques, equipment, and procedures for determining or predicting waves, currents, water levels, and sediment transport on the open coast and for predicting the interactions between shore materials, protective structures, and wave- and tide-induced currents. Procedures, methods, and guidance for effective design, construction, and maintenance of coastal structures are also developed.

The Coastal Engineering R&D Program incorporates four individual programs: Coastal Flooding and Storm Protection, Harbor Entrances and Coastal Channels, Shore Protection and Restoration, and Coastal Structures Evaluation and Design. These programs encompass 29 different work units including theoretical and analytical studies, numerical and physical model investigations, field studies, and instrumentation development.

The portions of the program to be discussed at this meeting are R&D activities in support of the repair and maintenance of coastal structures for shore protection, inlet stabilization, and harbor protection.

The Corps maintains approximately 2,000,000 lin ft of coastal structures. The majority of these are rubble-mound structures and, as a result, the Corps continues to research the stability and functional characteristics of these structures. Current efforts concerning rubble-mound structures are directed at determining wave grouping effects on structure stability, determining runup and overtopping, predicting scour at structures, and optimizing design of concrete armor units for structural integrity and hydraulic stability. Proposed for FY93 is research on selective placement of quarrystone armor units.

Structural stability criteria are most often stated in terms of extreme conditions that the structure must survive without sustaining significant damage. Design wave conditions are an integral part of those criteria. The coastal program is conducting research to improve measurements and estimates of wave conditions including wave breaking, decay, and wave-induced currents.

Technology transfer is an essential part of every successful research program. Useable products must be transferred to the field offices for the benefits of the research to be realized. A major effort in this area is revising, improving, and expanding the *Shore Protection Manual* to include technological developments of the last two decades and, where possible, to incorporate existing coastal engineering manuals. This new document will be called the *Coastal Engineering Manual*. Planning is also ongoing to upgrade, expand, and combine the Automated Coastal Engineering System and Coastal Modeling System to a workstation platform with integrated modeling capabilities and design modules.

Monitoring Completed Coastal Projects Program

The Corps, recognizing the need to monitor coastal projects to determine how well they accomplish their designed purpose, initiated a program in 1981 to monitor selected coastal projects. The program, called

Monitoring Completed Coastal Projects (MCCP), is an Operations and Maintenance-funded program to aid in the advancement of coastal engineering technology through monitoring, evaluating, and documenting the performance of coastal projects.

The stated objective of the program is to assure collection of adequate information through intensive monitoring of selected completed coastal projects to serve as a basis for improving:

a. Project purpose attainment.

b. Design procedures.

c. Construction methods.

d. Operations and maintenance techniques.

Monitoring sites are nominated by the field and prioritized by a standing field review group and the civilian members of the Coastal Engineering Research Board (CERB). The program manager recommends a monitoring program based on field and CERB priorities, funding projections, and Coastal Engineering Research Center review. Technical Monitors from Headquarters make the final selection of the sites to be monitored.

Since inception, 23 diverse sites have been or are being monitored. Monitoring is complete and final reports have been published for projects at Bodega Bay, California; Carolina Beach, North Carolina; Cattaraugus Creek, New York; East Pass, Florida; Manasquan Inlet, New Jersey; Oakland Beach, Rhode Island; Puget Sound, Washington; and Umpqua River, Oregon. Currently, the program is funded at approximately $2 million with nine projects being monitored and final evaluation under way for five projects. The current monitoring sites are:

a. Agat Harbor, Guam

b. Redondo Beach, California

c. Mouth of the Colorado River, Texas

d. St. Joseph, Michigan

e. North Jetty at Yaquina Bay, Oregon

f. Siuslaw River Spurs, Oregon

g. Crescent City Breakwater, California

h. Kahalui and Laupahoehoe Breakwaters, Hawaii

The types of data collected and the length of monitoring vary with the project and the monitoring objective. Generally, monitoring efforts do not exceed 5 years in length.

Lessons learned through MCCP are transferred to the field through reports and technical notes. MCCP results have been used to evaluate and verify existing procedures, identify problems and potential refinements, and validate innovative monitoring techniques for use in similar projects.

Discussion

MG Williams asked who composes the overview committee for the Repair, Evalation, Maintenance, and Rehabilitation Research Program. *Mr. Crews* answered that he himself and Mr. Tony Liu, from Engineering, are the overview committee.

Panel

Site-Specific Projects/R&D/Monitoring - Synergism Crescent City And Yaquina

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Crescent City Dolosse: Overview and Assessment of Dolos Movement and Breakage

Thomas R. Kendall

Breakwater failures have often been caused by or at least exacerbated by a structural failure of concrete armor units, especially when the units are the more slender type such as dolosse. The objective of the Crescent City Prototype Dolosse Study and follow-on monitoring and research is to develop structural design criteria for the dolos and other concrete armor units. This presentation and the following three will focus on: (1) San Francisco District experience with large dolosse, including District experience with assessing dolos movement and breakage (Kendall); (2) the collection of dolos strain data in a harsh prototype environment (Melby); (3) the verification of model technology for measuring wave-induced loads on dolosse and the continuation of monitoring in the prototype (Markle); and (4) procedure for concrete armor units (Melby).

Dolos Use Within San Francisco District

The first use of dolosse within the United States was by the San Francisco District in the early 1970's. The north and south jetties at Humboldt, CA, were armored with two layers of 42-ton dolosse around the head sections as part of their rehabilitation in 1973-1974. The economic advantages of the dolos unit were well-known at that time, as was the hydraulic stability characteristics of dolosse under wave attack. However, District engineers were concerned about the limited knowledge of dolos strength characteristics, and related requirements on dolos construction, such as whether steel reinforcing would be required.

The first dolosse at Humboldt were typically reinforced while those at Crescent City were unreinforced. Most of the Humboldt dolosse were reinforced with standard cage reinforcing (twelve No. 8 longitudinal and four No. 4 tie bars in each fluke and shank under a 6-in. concrete cover, representing 75 lb of 40-ksi steel per cubic yard of mix). However, analysis supported by field tests suggested that the quantity and strength of steel were not sufficient enough to contribute strength after concrete cracking. For the field tests, pairs of cage-reinforced, steel-fiber-reinforced, and unreinforced units were clamped together at the flukes and then forced apart with hydraulic jacks operating on the opposite flukes. These test results plus the added cost of reinforcing led to the decision to experiment with exclusively unreinforced dolosse at Crescent City.

The outer breakwater at Crescent City is a shallow-water breakwater which is subjected *to depth-limited breaking waves.* Water depths in the vicinity of the elbow formed by the main stem of trunk of the breakwater and the breakwater dogleg range from 20 to 30 ft. It was in this historically difficult-to-maintain section of the breakwater that dolosse were placed in 1973-74.

The initial Crescent City rehabilitation with dolosse, however, did not bring an end to maintenance problems. By 1984, approximately one third of the dolosse were estimated to be broken, the section was becoming increasingly vulnerable, and plans were again under way for rehabilitation. Physical model studies were initiated to determine an acceptable solution for the dolos section. The solution determined from the model studies was based on the 1984 condition of the structure. However, the structure's condition subsequently deteriorated as the relatively moderate winters of 1984-85 and 1985-86 increased the estimated breakage to approximately 75 percent. By the spring of 1986, the breakwater cap was being exposed and the decision was made to have 260 more dolosse cast in addition to the 500 already being cast per the model study recommendations.

The second rehabilitation with dolosse at Crescent City was completed in September 1986. A total of 680 steel-fiber-reinforced 42-ton dolosse were used in the repair. An extra 80 dolosse were placed on the lee side of the structure for subsequent repairs. None of the broken 40-ton dolosse were removed as part of the rehabilitation. Fiber reinforcing (80 lb of steel fiber per cubic yard of mix) was used, in part, as an experiment. Lab and field tests indicated that the fibers did not significantly increase the strength of the concrete, but did add toughness, which would help hold the units together after fracture. Besides the increased number of dolosse placed and the generally less uniform slope, the configuration of the repaired area was similar to the model study solution and included the use of trenching and buttressing (with stone) along the dolosse southern perimeter for increased stability at the dolosse-stone transition. The section consists of a minimum of two dolos layers on a variable slope that averages between 4H:1V and 5H:1V and extends to toe depths ranging from 25 to 30 ft. Above the main waterline, structure slopes are generally flatter than the average (approx 6H:1V); below the waterline, the slopes are typically steeper (approx 2.5H:1V).

Field Data Collection

The completion of the second dolos rehabilitation at Crescent City also marked the beginning of extensive field data collection under the Crescent City Prototype Dolosse Study.

In response to District needs and following Headquarters, U.S. Army Corps of Engineers (HQUSACE) approval of a monitoring proposal developed by the U.S. Army Engineer Waterways Experiment Station (WES) in 1984, the Prototype Dolosse Study used the 1986 rehabilitation to collect data on the dynamic and static structural response of dolosse in the prototype. The study was initiated as a joint effort by WES (the Coastal Engineering Research Center (CERC) and Structures Laboratory) with the San Francisco District. Overall management of the program was by a Test Working Group with representatives from the laboratories, Los Angeles District, San Francisco District, South Pacific Division, and HQUSACE. Technical management was by the Prototype Measurement and Analysis Branch of CERC. Initial plans for the project were presented to the Coastal Engineering Research Board (CERB) at the June 1984 meeting, and the final plans were presented at the August 1985 meeting. Initial findings were reported at the CERB meetings held in May 1987 and October 1989.

The primary element of the field data collection program was instrumentating 20 of the new dolosse installed in 1986 with internal strain gages. The installation of these gages, as well as the information they have provided on the structural response of dolosse, will be the focus of subsequent presentations.

In addition to the strain measurements, the District has been responsible for collecting supporting data on the overall performance of the breakwater, including detailed assessments of dolos movement and breakage. The methods used to collect these data and a brief summary of the findings are presented in the following section.

Assessment of Dolos Movement and Breakage

Post-construction monitoring of the breakwater performed by the District has included crane data and bathymetric surveys of the breakwater contours and surrounding bottom, side-scan sonar underwater surveys, aerial photography, high-resolution photogrammetry, and land-based surveys. These data are collated in a computer database, which allows both time series and cumulative movement of instrumented as well as non-instrumented dolosse to be studied.

Periodic aerial photography and low-altitude, high-resolution photogrammetry have been the primary tools used in the data collection. In addition, available nearby National Oceanic and Atmospheric Administration buoy records have been retrieved to track wave power offshore of Crescent City.

Targets were established on 26 dolosse. Eighteen of these are located in the instrumented section and eight are distributed uniformly throughout the remainder of the dolos field. Twenty-two of these dolosse are located in the upper dolos layer and have been marked with three targets each, which allows their movement to be described with six degrees of freedom. Each of the remaining four dolosse, which are located in the lower dolos layer of the test section, has only one clearly visible surface, which has been targeted for monitoring.

As it is not practicable to maintain targets on all visible dolosse, only select dolosse were targeted. Less precise data, however, can be collected from dolosse that are not targeted. Movement among non-targeted dolosse has been detected and quantified both by using photo overlays and by using a rather unorthodox application of time-lapse photography where the exposure from one flight is stereopaired with exposure from a subsequent flight.

A recent improvement in the acquisition of photogrammetric data at Crescent City has been the use of extremely low-altitude photogrammetry acquired from a helicopter. A mapping camera has been mounted on a helicopter in such a way that vibration- and motion-free aerial mapping photography can be collected. The width of the breakwater literally fills the low-altitude images collected in this way allowing very rigid stereo models to be set. Stereo images exposed from the low platform have scales on the order of 1 in. = 30 ft, as compared to the 1 in. = 100 ft scale obtainable from a fixed-wing platform.

The principal observations made from the data collected through 1991 are summarized below:

a. Storms that occurred early during the first post-construction winter season have produced the largest dolos movements to date. Reduced movement during subsequent storms indicates that the dolosse have consolidated and nested into a more stable matrix.

b. Surges in dolos movement, where evident, have tended to follow peaks in the wave power record.

c. Spatially averaged movement within the dolos test section has been comparable to that found outside of the test section; however, the region of high movement within the test section has been generally located further upslope.

d. The dominant direction of dolos movement has been upslope with slight settling plus rotation about the vertical axis (yaw). Upslope movement, i.e., movement dominated by wave run-up, is thought to result, at least in part, from the breakwater's mild slope.

e. Breakage, while typically associated with some amount of movement, has not necessarily been associated with significant movement and vice versa. For the large dolosse at Crescent City (which can have little residual strength), the extent to which movement causes a detrimental shift in boundary conditions has appeared more important than the absolute magnitude of the movement itself.

Discussion

BG Locurcio asked what is the residual strength of a particular concrete unit once it breaks and then wedges and nests in the structure. Does it have to be removed, repaired with a new one, or has it achieved its ultimate effect because it is nested in the structure and it is not going to move? *Mr. Kendall* said that observation has shown thus far that wedging seems to contribute to the overall stability.

He said the wedging is continuing to build up but at some point in time additional breakage could reduce hydraulic stability.

Prof. Raichlen stated that the major question is whether packing really increases the long-term strength of the structure or whether it actually may lead to deterioration.

Mr. Samuel B. Powell brought up the point that when waves crash on a jetty, the water dissipates itself amongst the interstices of the structure. Therefore, the more porous the structure the more dissipation of waves you can expect. However, if you choke up the interstices with broken dolos pieces the waves will reflect and that increases the forces on the structure, which could lead to reduced stability. *Mr. Kendall* said that there has been lab work conducted on a dolos structure where the wave period was continually increased to see its effect on stability. The tests showed a marked result in terms of reduced stability.

Dr. Roper commented that the Topographic Engineering Center has an airborne digital image analysis system that may be worthwhile looking at where you want to monitor the movement and change of items like dolosse. He said it is a Corps resource that should be taken advantage of.

The Crescent City Prototype Dolosse Study

Jeffrey A. Melby

The Coastal Engineering Research Board has been briefed several times on the Crescent City Prototype Dolosse Study, the most recent being the 52nd meeting, held in October 1989, at Redondo Beach, CA. However, the Board has never had the opportunity to visit the Crescent City breakwater. Therefore, the main purpose of this presentation is to summarize the prototype measurements conducted at Crescent City from January 1987 to May 1988, with particular emphasis on orientation for the subsequent tour.

At the inception of the Crescent City study in 1984, the state of knowledge concerning the structural behavior of concrete armor units was based on limited testing of individual units on dry land and some scaled units in physical models. Existing hypotheses about the behavior of prototype units in actual breakwaters were summarized by Burcharth (1984) and, together with the results of an international workshop held in early 1985, formed the basis for the overall Crescent City measurement design. Principal concepts were the need for system flexibility to accomodate the potentially large differences between conditions as hypothesized and as actually encountered, and the need for design robustness to assure that unanticipated conditions or significant system changes would not jeopardize functional performance.

The overall Crescent City prototype measurement program consisted of the following elements:

a. Individual armor unit measurements.

- (1) Internal strains during:
  - (a) Curing in the casting yard.
  - (b) Transportation to the breakwater.
  - (c) Placement in the armor unit matrix.
  - (d) "Normal" wave and tide conditions.
  - (e) Storms or other large wave events.
  - (f) Integration into the matrix over time.
  - (g) "Drop tests" on dry land.
- (2) Motion under large waves.
- (3) Displacement in the matrix over time.

b. Physical environment measurements.

- (1) Incident waves.
  - (a) Non-directional far- and near-field.
  - (b) Directional at breakwater.
- (2) Breakwater pore pressures.
- (3) Static water levels.

c. Site and condition characterization.

- (1) Near- and far-field bathymetry.
- (2) Side-scan sonar of breakwater toe.
- (3) Remote video and still imaging.

d. Concrete mix and materials properties.

The presentation will briefly describe the measurement approach used to address each element, the characteristics and relative success of each approach, and representative results.

Reference

Burcharth, H.F. (1984). "Fatigue in breakwater concrete armour units." *Proceedings, Nineteenth Coastal Engineering Conference*, 2592-2607.

Discussion

BG Yankoupe asked what implications are there for the design of the dolosse with respect to issues of reinforcing, proper positioning of reinforcing, and other options such as variations on fiber reinforcing. *Mr. Melby* said that the Coastal Engineering Research Center has developed a very comprehensive design procedure for dolosse based on the prototype dolos data collected to date and that at the present time, it is based on determining a design principal stress for the entire armor layer. He said there is no guidance for conventional reinforcement, but there is strength enhancement design guidance, which is somewhat different. There is a personal computer program that automates this design providing information for static and pulsating loads and probability distributions of stress.

MG Williams asked when will the monitoring program ongoing now at Crescent City phase out. *Mr. Melby* responded that under the Monitoring Completed Coastal Projects program, monitoring will continue at least through FY93.

Physical Modeling and Monitoring of Crescent City

Dennis G. Markle

Instrumented Model Dolos Study

A rehabilitation of the dolos area of the Crescent City Breakwater was completed in 1986. As part of the Crescent City Prototype Dolos Study (CCPDS), twenty of the six hundred-and-eighty 42-ton dolosse used in the rehabilitation were instrumented. During the two years following the rehabilitation, a wealth of data were collected. Among these data were the wave climate seaward of the breakwater and the wave-induced pulsating loads on the dolosse.

One of the primary tasks of the CCPDS was to develop a transfer function between incident wave conditions and the pulsating loads they produce in the instrumented prototype dolosse. The purpose of the physical model investigation was to develop and verify model technology for measuring wave-induced moments and torques at small scale. This objective was approached in the model investigation in the following manner:

a. Reactivate the three-dimensional breakwater stability model used during the 1985 model tests, modify the breakwater structure to match the geometry of the 1986 dolos rehabilitation, and remold the bathymetry seaward of the breakwater to match the most recent survey information.

b. Develop and construct instrumented model dolosse that reproduce the 42-ton prototype dolosse at the stability model scale and that are capable of measuring wave-induced pulsating loads.

c. Incorporate the instrumented dolosse into the model and measure and record the pulsating loads induced in the dolosse by irregular wave realization of the discrete spectra that were measured in the prototype.

d. Develop a transfer function between incident model waves and the pulsating loads they induce in the instrumented model dolosse in a similar manner as done for the prototype data.

e. Compare the model and prototype transfer functions and if needed, develop a scaling relation between them.

During the prototype data collection period, instrumented model dolosse were developed that reproduced the prototype dolosse at a scale of 1:57.5 (model to prototype). These dolosse were incorporated into a physical model of the Crescent City Breakwater and exposed to measured storm wave and water level conditions. Model wave conditions reproduced both the time and frequency domain statistics of prototype storm events recorded during January 1988. The pulsating moments and torques measured in the model dolosse were analyzed to determine the maximum principal stresses induced in each dolos for each storm event. The stress data were correlated to the time domain wave statistics in the same manner that the prototype data were being analyzed. The model transfer function between wave climate and maximum principal stress matched the prototype transfer function within a few percent. Thus, for the first time an instrumented model dolosse that has been validated with prototype data is available as a modeling tool to determine wave-induced pulsating loads on dolos armor units. This technology can be applied with confidence in the research area to conduct parametric testing on generic structures as well as being used on project studies to determine site-specific stresses induced by pulsating wave loading. With further research being conducted by the U.S. Army Engineer Waterways Experiment Station Coastal Engineering

Research Center, this modeling technology is being extended to provide quantitative insight in stresses induced by impact and static loads.

Monitoring of Crescent City Dolosse

At the close of the CCPDS, following the post-construction nesting of the dolosse, Kendall and Melby (1989) reported the dolosse cumulative average movement as leveling off, but some consolidation was still occurring in response to storm wave conditions. A set of static loading data collected in July 1989 showed that the rate of increase in static loads had decreased, but overall average static loads were still increasing.

The concrete used in the Crescent City dolosse had a 28-day flexural tensile strength of 984 psi (Kendall and Melby 1989). Static data collected up through July 1989 for Crescent City dolosse indicated tensile stress magnitudes as high as 469 psi. This meant that in some of the dolosse, close to one half of the dolos tensile strength was being used to resist static loads. Howell, Rhee, and Rosati (1989) have shown that pulsating wave loads for the Crescent City Breakwater could result in maximum principal stresses as high as 70 psi. Subsequent laboratory work by Markle (1989) and Melby (in preparation) revealed maximum principal stresses of up to 110 psi due to pulsating wave loadings. When the probable maximum pulsating stresses, as measured in the prototype and recreated in the model, were added to measured prototype static stresses, well over half of the tensile strength was being used to resist load-induced stresses.

As a result of the items discussed in the two preceding paragraphs, it was determined in FY 89 that a low-level dolos monitoring effort needed to be continued at Crescent City to define and document the continued cumulative dolos motions and changing static loads. Under the Monitoring Completed Coastal Projects (MCCP) Program, a work unit entitled Periodic Inspections had just begun and Crescent City was included. Results of photogrammetric surveys through May 1991 show that dolos movement is still continuing, but the magnitude of recently measured movement is very low.

In July 1990, the instrumented dolosse still working at Crescent City were monitored for one week to record static stresses. Data from the functional dolosse showed that there had been a significant increase in static stresses in five of the dolosse. A 500-psi static stress level was noted in one dolos and 400-psi static stress levels were noted in three other dolosse. When the probable pulsating or wave-loading stresses are added to these static stress levels, there is little or no reserve strength to resist possible impact-induced stresses or increased static stresses. The increase in static stress between 1989 and 1990 is reflected in the overall average static stress level. The average increase during this year was 32 percent.

Static stresses in the functional dolosse were again measured for one day in June 1991. These data again showed increases in stress for five of the dolosse, with the associated overall average static stress level increasing again by 8 percent.

In summary, before the CCPDS, it was postulated that dolosse go through a post-construction nesting period and then movement tends to slow down. The CCPDS and subsequent MCCP data confirm this. Prior to CCPDS, it was also felt that dolosse breakage was largely due to combined impact loads between dolosse and pulsating wave loadings, which over-stressed the dolosse and that static loads did not play a significant role. The CCPDS and MCCP data show that for larger sized dolosse, static stresses can use up a significant portion of a dolos's tensile strength and that the added pulsating loads in some cases could push the maximum principal stress levels near the postulated Crescent City 700-psi design tensile limit (Kendall and Melby 1989). Continued monitoring of Crescent City will aid in understanding and defining post- construction movement and static stress responses of dolosse. Static load measurements are scheduled for the summer of 1992 and continued monitoring under MCCP is tentatively scheduled through FY94. The information obtained in this study is being incorporated into the dolos design procedure developed for Crescent City, and it will also be used in the development of a general hydraulic and structural design procedure for concrete armor units (Melby, in preparation).

References

Howell, G. L., Rhee, J. P., and Rosati, J. III. (1989). "Stresses in dolos armor units due to waves." *Proceedings of Stresses in Concrete Armor Units*. American Society of Civil Engineers, Vicksburg, MS.

Kendall, T. R., and Melby, J. A. (1989). "Continued monitoring of 42-ton dolos movements and static stresses at Crescent City." *Proceedings of Stresses in Concrete Armor Units*. American Society of Civil Engineers, Vicksburg, MS.

Markle, D. G. "Crescent City instrumented model dolos study," in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Melby, J. A. "A dolos design procedure based on Crescent City prototype dolos data," in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Discussion

Prof. Raichlen said that as shown on the plots, stability of the dolos is increasing with time. He asked if there is a comparable plot of total energy per year or some measure of the wave activity relative to that stability plot. *Mr. Markle* said they have seen some fairly high storm conditions during the continuing monitoring, but after the initial nesting, movement has calmed. He feels that static loads and wedging loads in the structure are continuing to increase with time.

Concrete Armor Unit Design

Jeffrey A. Melby

The U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center is currently in the fourth year of concrete armor unit (CAU) design research subsequent to the Crescent City Prototype Dolos Study (CCPDS). This research effort is focused on providing comprehensive CAU design guidance, including structural design criteria, to the Corps District offices. The short-term goal of this research, which has already been achieved, is to provide District engineers with personal computer (PC)-based tools that can be used to efficiently design dolos. The PC-based program called CAUDAID (Concrete Armor Unit Design Aid) integrates conventional hydrodynamic stability design methods with recently developed structural strength design criteria and allows the designer to iterate to find the optimal dolos design. The mid-term research goal is to provide the Corps with comprehensive design methods for all widely used CAU shapes on the various types of Corps rubble structures. The long-term research goal is to provide the Corps with the most cost-effective and performance-efficient coastal structure armoring and the associated probabilistic design techniques.

Comprehensive CAU design methodologies have been slow to develop because of three primary factors:

a. Structural and hydrodynamic physics are complex.

b. The multitude of different armor unit shapes spreads design development efforts too thin.

c. The CAU design problem is unlike both typical coastal rubble-mound design and conventional structure design.

The complexity of the CAU engineering design problem primarily stems from random and broad-ranging boundary conditions and loading. This is also what makes CAU design unlike other more familiar civil design problems. Thus, any CAU design method must be probabilistic. Also, it is nearly impossible and would be very expensive to quantify the loads on individual armor units. So, conventional structural analysis, where the loads are applied and the response computed numerically, is not reasonable at this time. The most cost-effective strategy to develop a CAU structural response design method must therefore quantify the probabilistic distribution of stresses for the armor layer indirectly, using prototype and physical model measurements of stress. The statistics of these distributions can be deterministically calculated from analytical and numerical relations. This is the basis for the CAU design methodology described herein.

The initial CAU structural design development was done in the CCPDS where dolos stresses were measured in the prototype. Instrumentation was developed in the CCPDS that could measure stresses in small-scale model dolosse. The prototype data were used to determine the validity of scaling relations for the small-scale structural measurements for wave-induced pulsating loads. The small-scale model dolosse stress measurements were subsequently verified for static loading. Also in the CCPDS, numerical finite element models were used to develop deterministic relations for optimizing the dolos shape and for determining the allowable stacking depth of the units. These relations were used to modify the statistics of the static and pulsating probability distributions. This initial dolos design methodology is reported in detail in Melby (in preparation).

The initial efforts of the CAU research subsequent to the CCPDS were focused on extending this primarily site-specific dolos design methodology to the general case. The strategy used was to measure the dolos structural response for a wide range of typical wave and structure conditions using the verified small-scale model load cell. Stress probability distributions from this experiment have been incorporated into a computer program called CAUDAID, which can be used to predict a design stress for unreinforced dolosse. Impact stresses due to dolos rocking were not detected in the prototype because the dolosse were very stable. Thus, impact response is not included in the program.

Current work includes quantifying the impact stresses in the dolosse. The impact stress distributions will be incorporated in CAUDAID as they become available. Research is also being done to develop strength enhancement design guidance for high strength concrete, fiber reinforcement, and pre-stressing and post-tensioning. These strength enhancement strategies can be easily incorporated into the dolos design framework. Continuing work includes the following:

a. Establishing stress distributions for other commonly used Corps CAUs, including tetrapods and tribars, and the various types of Corps rubble structures, including overtopped structures.

b. Incorporating cost into the CAU design program.

c. Developing integrated hydrodynamic, stability, and structural numerical models that will allow shape optimization for any CAU shape.

d. Establishing distributions for measured moments and torques in the dolosse and determining appropriate load factors. Having moments and torques will allow the designer to detail conventional structural reinforcement, if necessary.

The presentation will include discussion of the dolos design methodology, the dolos design computer program, and current and future CAU design research.

Reference

Melby, J. A. "A dolos design procedure based on Crescent City prototype dolos data," in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Discussion

BG Locurcio asked if there is any possible fix for the damage that occurs to some of the units at Crescent City. *Mr. Kendall* said there are 80 extra dolosse stored at the site for subsequent repairs.

Prof. Dalrymple asked about the numerical wave tank and how research is progressing in that area. *Mr. Melby* responded that he is evaluating the programs of Kobayashi and Grilli. He will also be looking at a Boussinesq model.

Yaquina North Jetty Overview

Laura L. Hicks

The Yaquina Bay Authorized Project consists of a 7,000-ft-long north jetty, an 8,600-ft-long south jetty separated by 1,000 ft, a 40- by 400-ft entrance channel, which transitions to a 30- by 300-ft bay channel, one turning basin, two small boat basins, an 800-ft spur jetty, and five groins. Yaquina Bay is located 133 miles south of the mouth of the Columbia River and 87 miles north of Coos Bay. The bay is 3-1/2 miles long with a 1-1/2-mile maximum width at high tide. The width varies from 1,000 to 2,500 ft at mean lower low water (mllw). The project was originally constructed from 1889 through 1895. The jetties were aligned because of the natural barrier provided by the Yaquina Reef. The Yaquina Reef is 4,000 ft offshore parallel to the shoreline, extends northward approximately 17 miles, and is 55-ft-thick basalt. A portion of the reef lies in the southern half of the channel. Between 1955 and 1957, 12,000 cu yd of rock were blasted and removed from the reef. In 1963, the north jetty was extended to its current authorized length of 7,000 ft. The north jetty was again rehabilitated in 1978 and 1988. In 1978 and 1988, the jetties were rehabilitated 425 and 450 ft, respectively. Comparisons of the material losses versus time, between the 1978 and 1988 rehabilitations, were presented. The overall cross-sectional area for the rehabilitations did not change appreciably; they both had a 20-ft crest width, side slopes of 1 on 2 to mllw, and 1 on 1-1/2 below mllw. The only appreciable change was in the stone size.

Unit Weight of Jetty Stone in Tons

Year	Class A Select		Class A	
	Min	Ave	Min	Ave
1978	14.9	19.8	10.1	13.5
1988	29.7	32.5	20.6	25.8

The notch that is developing now was compared to data available after the 1978 rehabilitation.

Monitoring of the Yaquina Bay North Jetty

Dr. Steven A. Hughes

If we were coastal engineers in the make-believe world that so delights our children, then all our coastal structures would be perfectly designed, and each would withstand a hundred years of storms without damage. However, much to our chagrin, coastal engineers are burdened with the reality of a world where what we *do not* know about the design and stability of coastal structures far exceeds what we have managed to learn. Fortunately, we are aware of our ignorance; and through the Monitoring Completed Coastal Projects (MCCP) Program, the Corps of Engineers has taken a leadership role by giving those who design and construct coastal structure projects the opportunity to observe how the projects perform when they are set upon by forces of nature.

The *north jetty* at Yaquina Bay, Oregon, has suffered damage in the past, and this project aptly illustrates the difficulties of designing for a harsh coastal environment. After the most recent rehabilitation in 1988, monitoring was initiated at Yaquina under the MCCP Program. The objectives of the monitoring were to:

a. Determine the cause of problems at the north jetty.

b. Improve the Corps' design capability for similar harsh environments.

c. Obtain sufficient information to design a permanent repair at Yaquina.

The third objective was added when monitoring indicated that a "notch" was starting to develop on the seaward side of the jetty close to the tip.

The monitoring effort at Yaquina has three interrelated components. The first component is collection of information and data that characterize this particular site. Hydrodynamic data that have been collected consist of offshore and nearshore wave records. Accurate, detailed bathymetry and subbottom acoustic profiling comprise the geophysical data. The severe wave conditions known to exist at times near the jetty made acquisition of in situ measurements in the vicinity of the structure impossible, either because of doubts about instrument survivability or undue risk to personnel who would have to install and service the equipment.

The second monitoring component is obtaining information about the structure and its performance. Above the waterline, yearly flights have provided controlled aerial photography of the jetty that has been analyzed using standard stereo model techniques. This has allowed quantified mapping of changes in the structure profile as it settled and reacted to imposed wave forces. The aerial photography also provided the first indication that the new structure was starting to experience some damage, and it continues to provide a chronological sequence of structural damage. Below the water level, side-scan sonar readings of the bottom and the toe of the structure were acquired and interpreted in conjunction with subbottom profiling information.

The third, and perhaps most important, component of the monitoring program has been the convening of two technical workshops where internationally recognized coastal engineers and breakwater designers examined the monitoring data, proposed damage hypotheses, and recommended appropriate actions and modifications to the monitoring program. Much of what we now understand about the damage mechanism at Yaquina resulted from the workshops.

Over the course of the monitoring study, the gaps in our knowledge of coastal structure design and our need for better monitoring techniques became evident. Some of the areas where better understanding or techniques are warranted include:

a. Influence of bottom topography on armor stability.

b. Armor placement techniques.

c. Wave/current flows near and through coastal structures.

d. Wave breaking impacts on structures.

e. Improved physical modeling capability for toe stability on hard and sandy bottoms.

f. Capability to simulate scour in movable-bed physical models.

g. Better understanding of friction scale effect in toe stability physical models.

h. Development of numerical flow modeling capability near structures.

i. Improved underwater inspection techniques.

j. Improved documentation of "as built" condition.

k. Improved methods for field assessment of structure condition.

l. Development of rugged and simple scour gage.

Some of the identified problems are presently being investigated at the Coastal Engineering Research Center in existing research programs, and some are included in the proposed Coastal Inlets Research Program.

Discussion

Prof. Raichlen asked if the Coastal Engineering Research Center at the U.S. Army Engineer Waterways Experiment Station ever tried building models underwater or in the wet, to model real construction practices and then compare the results with models built in the traditional way, in the dry. *Mr. Davidson* said Hudson did in fact conduct such an experiment and he found out that, basically, he could build it in the dry, in the random-place manner, and get the same results that he got in the wet.

Mr. Powell commented that the shape factor of the stone is an important parameter. He said that the Corps deals with many different kinds of rock, such as basalt, sandstone, and granite and they all have different shapes, which are difficult to come by in the model sizes. He said the shape factor is one of the reasons stability coefficients are somewhat on the conservative side.

Prof. Raichlen stated that a physical model should be constructed of the same material that will be used in the project. He said the idea of a physical model is to try to model all aspects of the structure in the laboratory so that you believe the information that you get from the laboratory.

Monitoring Completed Coastal Projects Evaluation of Spur Jetties Performance at Siuslaw River, Oregon

Cheryl E. Burke
Coastal Structures and Evaluation Branch
Engineering Development Division
Coastal Engineering Research Center
U.S. Army Engineer Waterways Experiment Station
Vicksburg, MS

Entrance channel shoaling due to littoral current deposition is a problem common to many inlets. At the mouth of Siuslaw River, Florence, OR, twin rubble-mound jetties were extended 900 ft seaward in 1985 and 400-ft-long spurs were constructed at a 45-deg orientation to the seaward side of the jetties (Figure 1) to reduce entrance channel shoaling. This new jetty configuration evolved from physical model studies conducted by the U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC) of the Rogue River in southern Oregon. The studies indicated potential for the spur structures to direct littoral currents and sediment shoreward, or bypass material around the tips of the jetty and away from the entrance channel, thereby reducing maintenance dredging requirements in the navigation channel.

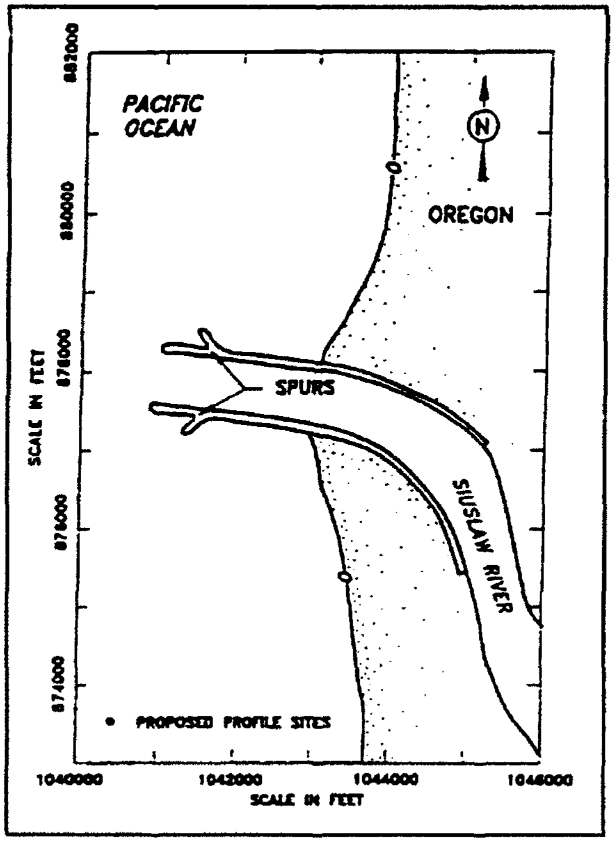

Figure 1. Spur Jetties at Siuslaw River, Florence, OR

Through the Monitoring of Completed Coastal Projects Program, CERC is analyzing collected data to evaluate structure performance. Monitoring efforts by CERC and the U.S. Army Corps of Engineers District, Portland, have included semiannual bathymetric surveys, surface dye circulation studies, and a new method of current measurement using a meter suspended from a helicopter. The helicopter platform allows bottom currents to be measured at several locations quickly, thus providing near-synoptic spatial resolution and an innovative method for identifying local current patterns. Monitoring began in 1981 and was completed in 1990. Analysis of the bathymetry data reveals deposition patterns similar to those predicted by the physical model.

Discussion

Prof. Raichlen asked how the survey crew knows when the lead line from the helicopter touches bottom. *Ms. Burke* said that underneath the helicopter there are counterweights on a pulley system and when the line is dangling and taut, this counterweight is up against the carriage. When the line touches the bottom, the person who's reading the level sees that the line goes slack and reads it at that point. She said that the Portland

District has a video showing how the system works.

BG Locurcio asked if there were design standards for optimum length of spurs on the jetty. *Ms. Burke* responded that at the present time there are no design standards. She said that model tests dictated the optimum design for the Siuslaw and Rogue Rivers.

Dr. Roper asked if a global positioning system was considered for locating the position of the helicopter. *Ms. Burke* said that at the time that these studies were done, it was unavailable.

An *Unidentified Speaker* asked if the change in the jetty structure actually decreased the amount of sand shoaling in the jetty system. *Ms. Burke* responded that there was less shoaling, thus reducing the volumes of material that needed to be dredged out of the channel.

Prof. Dalrymple asked what is the direction and magnitude of the sediment transport at the inlet. *Ms. Burke* responded that the net transport is zero in the region.

Field Trip Overview

Stephan A. Chesser
Operations Division
U.S. Army Engineer District, Portland
Portland, OR

The first jetties at the entrances to the Columbia River, Yaquina Bay, and Coos Bay were constructed in 1895. Since that time, the Corps of Engineers has built and maintained jetties and other coastal navigation structures at 12 projects along the Oregon coast. Total construction and maintenance costs have approached half a billion dollars. In the early part of this century, coastal ports in Oregon were the only avenue for commerce. Although this has changed today, these ports are still a vital part of the coastal economy.

Since you cannot possibly see all of the Oregon coast on one field trip, I will present a brief overview of all our coastal projects followed by a review of today's trip. We start our armchair tour at the mouth of the Columbia River. The south jetty is 6.6 miles long, containing almost 6 million tons of stone. Moving south about 40 miles, we come to the Nehalem River entrance. These jetties stabilize the river channel, but there is no authorized navigation channel. A few miles farther south is Tillamook Bay, where the north jetty was recently rehabilitated. Fifteen miles north of Newport is Depoe Bay, the "world's smallest harbor," protected by entrance breakwaters. Newport, on Yaquina Bay, is one of two deep-draft Oregon coastal ports south of the Columbia River. The entrance jetties are aligned with an opening in a nearly continuous offshore reef. Fifty miles south of Newport is the Siuslaw River at Florence with its unique "winged" jetties and the beginning of the largest littoral cell on the coast. Another 20 miles south is Winchester Bay and the Umpqua River, source of most of the sand in this littoral cell. Twenty miles farther south is mighty Coos Bay, the largest deep-draft port on the coast, second only to Portland. Twenty miles farther south is scenic Bandon on the Coquille River. The port is probably typical of the vital relationship between navigation and the local economy. Thirty miles south of Bandon is Port Orford, surely the most unique port in Oregon. Boats are hauled out and stored on the dock. A few miles farther south is Gold Beach on the Rogue River. The Rogue River Basin is the largest drainage area on the coast south of the Columbia River. Finally, only a few miles north of California lies Brookings on the Chetco River. It is fondly referred to by Oregonians as the "banana belt" because of its mild climate.

On the bus trip, we will visit the two jetty systems described in other presentations and some of the unique scenery that makes the Oregon coast so beautiful. The Yaquina north jetty is a half mile from the Shilo Inn. Along the way you can see fairly typical beach and bluff conditions. The wide beach next to the jetty is common on both sides of many jettied entrances. The access road on the jetty remains in good shape since the last rehabilitation in 1988. Most of the stones within the first few thousand feet were placed in 1965 and run from 17-20 tons each.

After leaving Newport, we will head south to Florence through some of the more scenic parts of the north coast. Rugged headlands separate pocket beaches and small streams until a few miles north of Florence where uninterrupted dunes stretch southward over 50 miles. This is the largest littoral cell on the Oregon coast, stretching nearly 60 miles from Hocota Head north of Florence to Cape Arago south of Coos Bay. There are Corps projects at Florence, Reedsport-Winchester Bay, and Coos Bay within the area.

The jetties at the Siuslaw River, in addition to stabilizing the river entrance channel, were also designed to minimize the amount of littoral sand entrained into the entrance. A study of beach and nearshore changes since 1981 shows that although there were effects from the jetty extensions, there has been no long-term or significant beach erosion. At lunch we will hear a representative from the Dunes National Recreation Area speaking about the sand dunes themselves.

On the drive back to Newport, we will make a stop at Cape Perpetua. There is an excellent visitor's center with exhibits and nature trails that tell much about the north coast natural and cultural history. There is a tidepool walk for those who wish to get closer to nature.

Discussion of the Helicopter and Bus Field Trips

Prof. Dalrymple noted that Oregon inlets are not like Florida or Delaware inlets in the sense that the east coast inlets have large lagoons and large tidal prisms, whereas the west cost inlets are most often associated with rivers and very small tidal prisms. He said you do not see or appreciate those regional differences by reading technical reports. He said that the utility of the field trips is very important and serves to provide that national perspective.

Prof. Dalrymple mentioned the use of offshore disposal. He said that the Oregon coast is not desperate for sand. There is certainly a surfeit of sand around. However, there is a significant volume of sand being disposed of offshore. On the east coast, the Corps of Engineers does the same thing. He said there is an awareness that we probably shouldn't be disposing this valuable resource offshore. He thought that perhaps on the Oregon coast we could look at the same thing, namely, placing some of this material on the shoreline if it's clean beach quality sand.

BG Locurcio said he was impressed by the variety of the challenges that are presented to the coastal engineering community, and most notably, because of the interaction with the natural setting. He said you can have standards and engineering principles but until you see and feel the actual setting and the interaction with that setting that the structure has to assume, you really do not appreciate the problems.

BG Locurcio was also impressed with the number of projects in the Pacific northwest. He said there are an awful lot of structures out there and he felt that the Corps needs to concentrate its future efforts on improved ways of maintaining those structures and reducing the cost of maintenance.

BG Locurcio also said the interaction of this Board and the Coastal Engineering Research Center with the population that the Corps serves is extremely important. He is amazed at how little the public truly understands what it is the Corps does. And unless we get down there on the ground and talk to people and give them specific examples of why we are here and how we are using their tax dollars, they do not have an understanding or an appreciation of how their government is really working for them. He concluded saying that the major importance of this field trip was interacting with the coastal community and the public that the Corps serves.

Prof. Raichlen noted that the types of structures he has seen along the southern California coast are different than the ones that he saw along the Oregon coast. He was impressed with the large number of rubble structures and large structures for relatively small ports and harbors of refuge. He noted that it was a relatively calm day but noticed quite a bit of wave activity on these structures and he could only surmise what the wave activity must be on some of these structures during the wintertime. He said that one can see from the photographs that were provided that these structures are exposed during the year to significant waves and therefore we should expect to see the damage that we see. He said the fact that there are so many features, both on the bottom as well as offshore, that are very difficult to define initially, and we have to face up to the problems of continually maintaining some of these structures.

BG Yankoupe said that an organization like the Coastal Engineering Research Board (CERB), that is acting in an advisory capacity and directing the priorities for coastal engineering research throughout the country, has to maintain a national perspective. He said the importance of seeing problems in situ with a regional perspective, is absolutely key to the way CERB addresses these issues.

Mr. Johnson said that one of the things that struck him most about the beaches in this area is the evidence of the elevated water table, the springs on the beaches and indicators that the sand deposits over the underlying cohesive and pervious material are very thin. *He said this is common with the vast majority* of the beaches in the Great Lakes region. He added that the rock beaches also have much in common with the reefs that dot the sites that are of concern to Pacific Ocean Division. He said that kind of beach, a thin deposit of sand or gravel over flat beaches of cohesive material, is very common throughout the United States and that the mechanics of such beaches are very important to understand. He said it is overwhelmingly important in the Great Lakes and urged that research be conducted to increase our understanding of the mechanics of such sites.

Mr. Powell said he was glad to see that the jetties have a useful life and are functioning properly and being modified as the studies indicate. But he worries that they are in jeopardy as to benefits and funding. He said we need to continue to study, to reduce the maintenance and find innovative and better ways of doing things which would be more cost-effective and lengthen the time between maintenance requirements. The main thing about the jetties on the Oregon cost is that, to rehab the jetty, you have to build a roadway above the height of summer storm waves, and that is very costly. And so, if you have a small amount of deterioration, you just cannot go out there and take care of it. Another point *Mr. Powell* mentioned was that you cannot extend the base of the jetty further than the crane can reach and handle the loads, because bidders will not bid on depositing material from barges. The standby time could be very costly and if storms come up rapidly, you have not got time to maneuver. He emphasized that research and surveillance are required to determine how to better protect the toes of these jetties from the undermining that happens as the waves move in obliquely to the jetty and carry sand away, allowing the stones to sink.

Board Comments and Recommendations

Prof. Robert O. Reid said he would like to focus his comments on a charge that the Board should have, namely, being an advocate for education in the field of coastal and ocean engineering, both within the Corps of Engineers and outside the Corps. He said the previous Board, the Beach Erosion Board, largely through the efforts of Dean O'Brien, was very instrumental in establishing the field of coastal engineering, and bringing about coastal programs within universities.

The Coastal Engineering Research Center (CERC) at the U.S. Army Engineer Waterways Experiment Station has developed some very good programs in the long-range educational initiative by allowing their people to go to universities to get advanced degrees. Recently, in response to comments by LTG Heiberg, CERC has established a graduate program in cooperation with Texas A&M University that will provide field people an opportunity of getting master of engineering degrees in one year. *Prof. Reid* said he would like to see that particular program expanded so that other universities are involved.

Prof. Reid also recommended the establishment of a Coastal Engineering Research Board or CERC graduate fellowship. This fellowship would be patterned after the Navy oceanography fellowships in which two- or three-year fellowships are awarded to individuals with bachelor's degrees in engineering, science or math, to study at a university of their choosing, in the field of ocean or coastal engineering. *Prof. Reid* suggested that the fellowship be named after Morrough P. O'Brien.

Prof. Raichlen commented that in the next decade one of the most important areas of coastal structures in the United States is going to be the rehabilitation of existing structures. He said the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) programs give, to some extent, attention to coastal structures in addition to a wide range of other problem areas within the Corps of Engineers, both inland as well as at the coast. However, he feels that there are many more research areas that can be given attention with regard to rehabilitation.

He said that some of the work that has been done on armor units already, and extending to problems with rubble-mound structures, may be areas which can be given more attention. More emphasis should be given, through the REMR Program, to a wide range of structures around the coasts of the United States.

Prof. Raichlen said that it is apparent through SUPERTANK work that the use of a large wave tank facility is extremely important to coastal engineering research in the United States and to CERC in particular. He was pleased to hear the fact that there are plans for the use of the Oregon State University (OSU) facility to investigate structures and thus minimize the effect of scale. He firmly believes that CERC should use existing facilities in the United States and not construct new laboratory facilities. He encouraged CERC to look more closely at some of the programs they get involved in, including reimbursable problems, where scale is important, and to use facilities such as OSU for their work where appropriate.

Prof. Raichlen applauded the CERC seminar program and said he would like to see it expanded. He suggested bringing in named researchers to allow researchers at CERC to get a first-hand look at what is going on in the outside world.

Prof. Raichlen also suggested a sabbatical program for CERC researchers, a program where CERC researchers can both expand their knowledge and bring to the place where they visit some specialized knowledge that they have.

Prof. Dalrymple addressed the issue of scientific publications. He noted that CERC has the largest collection of coastal engineers in the United States. He said these engineers have played an important role in the development of coastal engineering and the *Shore Protection Manual* (SPM). He noted that the SPM has served a vital role in the education of coastal engineers both in the United States and around the world.

He added that there are a lot of other major laboratories doing coastal engineering research, and he thinks that the visibility of CERC needs to be heightened vis-a-vis these other laboratories. He said that the international and national recognition of the scientific laboratory or any group of investigators is achieved through its presence in the scientific literature. Publication in scientific journals provides a view into that laboratory with respect to its research and the higher the quality of the journal, the higher the quality of the reputation of the laboratory.

Prof. Dalrymple feels that CERC scientists are not publishing their work in quality scientific journals; journals such as "The Journal of Fluid Mechanics," "The Journal of Geophysics Research," and "Coastal Engineering." He said although the primary role of scientific publications is technology transfer, they do provide an archival means of receiving credit for the work performed. *Prof. Dalrymple* said that with an expanded presence in quality scientific journals, CERC and its individual principal investigators will gain in scientific prestige and hence make CERC more attractive to coastal engineering students graduating from the universities who wish to focus on research. He said this greater scientific publishing effort means a greater workload on the individuals at CERC. In his experience, much of the work in getting a paper published in a journal happens after the science is done, so he feels that more incentives need to be put in place to encourage the investigators to publish in quality journals. These incentives could take many forms. One incentive, for example, could be greater recognition, within CERC, of who was published and where they have published. Publication in reputable journals could be a milestone in work units. Promotion could be tied to publication in reputable journals. Other incentives could be financial or temporal in nature; temporal in the sense of providing time for the investigators to prepare these papers, financial in the sense that a fund might be set aside for successful publishers of papers to either buy their time to do more writing or to buy more equipment to help support their research.

Prof. Dalrymple charged CERC to examine this question and explore the range of options available, keeping in mind that commitment to a program of greater scientific publication is a long-term effort. He said the tangible benefits will not be apparent immediately but the long-term benefits are very worthwhile in terms of the enhanced reputation of the laboratory.

BG Locurcio urged that the Pacific region and its island problems be considered and included in future research plans. In particular he stressed that storm impacts in the Pacific region are a severe problem. He said that a lot of time is spent working with Pacific islanders in the disaster recove y mode. There is significant impact on coastal structures from storms, and the Corps spends a good deal of time with the Federal Emergency Management Agency rebuilding structures.

Other areas of concern mentioned by *BG Locurcio* included storm impacts on coral reefs and more specific information on design wave heights, especially in depth-limited environments. He emphasized the need for accurate design wave heights because they so dramatically affect the size and cost-effectiveness of the structures constructed in the region.

BG Locurcio said that with respect to the Dredging Research Program, the environmental consequences are going to force the Corps into more offshore and ocean dumping. Consequently he would like to see more emphasis on researching the environmental impact of the effects of ocean dumping.

BG Locurcio's final comment dealt with rubble-mound structures and the skyrocketing costs of obtaining the appropriate rock. He urged research to search for alternatives as the Corps builds new structures and continues maintenance of the many existing rubble-mound structures.

BG Yankoupe said that the video of the SUPERTANK experiment was a superb video presentation depicting involvement with the academic community and the professionalism and tremendous talent that the Corps has working in coastal engineering research. He encouraged the continued use of this kind of a media and suggested a series of videos that capture the essence of what the Corps is doing in coastal engineering research.

BG Yankoupe also mentioned the operation and maintenance of Corps structures. Since there is a continuing need for resources in this area to conduct the necessary research he wants to explore the possibility of obtaining a share of funding from the Harbor Maintenance Trust Fund for use in Operations and Maintenance research and development.

Another topic mentioned by *BG Yankoupe* was techniques used in construction and inspection of Corps coastal structures. He said it is as much an art as it is a science. Quality inspection during construction comes only with a lot of experience in working in this area. He said there are not enough individuals in the Corps with that experience and he suggested initiating a program to train field engineers in the art and science of coastal construction and inspection. He said the instructors for the training program could be made up of senior Corps engineers and non-Corps engineers with expertise in coastal engineering construction and inspection. He suggested a series of field workshops to be held in various parts of the country, that would include classroom theoretical work and then inspection of actual structures.

Closing Remarks

Speaking for MG Williams, *BG Yankoupe* expressed his appreciation to the presenters at the meeting. He was particularly impressed with the use of Doctor Kraus' multimedia presentation and also the quality of the presentations and the media used to get that information across. Recognition was given to MG Harrell and the South Pacific Division staff for outstanding support provided for the meeting. He also expressed thanks to COL Hines and the Portland District for hosting the meeting; to Rosalee Schiewe, Steve Chesser, Bruce Duffy and Laura Hicks, for their coordination of the meeting, field trip, transportation and displays; to Diana Sorenson, for her assistance in registration; to Steve Smith and Bill Johnson for their electronic wizardry; to Joe Guerra, for his photography; and to Bill Branch and Dave Illias, as narrators on the helicopters. *BG Yankoupe* also expressed thanks to COL Len Hassell, Dr. James Houston, and his staff. Thanks was also extended to Ms. Dale Milford who recorded the meeting.

Finally, *BG Yankoupe* thanked Professor Bob Reid for his guidance, leadership and insight, over the tenure that he has had with the Board. The 56th Meeting of the Coastal Engineering Research Board was adjourned.

Appendix A
Biographies of Speakers/Authors

Cheryl E. Burke

Ms. Burke is a hydraulic engineer with the Coastal Structures and Evaluation Branch of the Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station. She graduated from Oregon State University with a B.S. degree in civil engineering and is pursuing an M.S. degree from Texas A&M University. Ms. Burke has been principally involved in research pertaining to structure interaction with sediment movement, wave field alteration, and beach response. Additionally, Ms. Burke is developing guidance for the design of nearshore berms.

C. E. Chatham

Mr. Chatham has been Chief of the Wave Dynamics Division since the Coastal Engineering Research Center (CERC) moved to the U.S. Army Engineer Waterways Experiment Station (WES) in 1983. He is responsible for experimental research in coastal engineering using CERC's two-dimensional and three-dimensional laboratory facilities. Mr. Chatham has been employed at WES since 1963, and previous assignments include Chief, Harbor Wave Action Branch; Chief, Wave Processes Branch; and acting Chief, Wave Dynamics Division, all located in the Hydraulics Laboratory, WES. He has a B.S. degree in civil engineering from Mississippi State University, and graduate courses in hydraulic and coastal engineering at the WES Graduate Center. He is a registered professional engineer in the state of Mississippi and a member of the American Society of Civil Engineers and Permanent International Association of Navigation Congresses.

Stephan A. Chesser

Mr. Chesser has worked for the Portland District since 1979 on a variety of coastal projects. He is presently with the Waterways Projects group of the Operations Division responsible for studies related to channel and harbor maintenance. Mr. Chesser previously worked on coastal engineering studies on the Atlantic and Gulf coasts. He received his M.S. degree in oceanography from Florida State University in 1974.

James E. Crews

Mr. Crews is the Deputy Chief, Operations, Construction and Readiness Division, Directorate of Civil Works, Headquarters, U.S. Army Corps of Engineers. He is responsible for formulating broad basic guidance, implementing policies, procedures and programs, consistent with the policy of the Assistant Secretary of the Army for Civil Works to ensure overall efficiency and technical adequacy of guidance and assistance for the operation and maintenance (O&M) of complex civil works projects throughout the nation and in overseas areas, civil works construction projects, the Department of the Army Permit Program for work in waters of the United States and for emergency management associated with natural and national disasters and the mobilization readiness of the Corps of Engineers. Prior to this position, Mr. Crews, as Chief, Operations Branch, was responsible for developing national policy for the O&M of all civil works projects involving flood control and hydropower, as well as managing the Corps' $1.5-billion O&M budget. Before coming to Corps Headquarters in 1985, Mr. Crews held many senior management positions; most notable — Senior Civil Engineer at the Corps Institute for Water Resources and Chief, Urban Studies Branch, Planning Division, Baltimore District. Mr. Crews started his career with the Corps in the Louisville District.

Mr. Crews graduated from Tennessee Technological University with a B.S. degree in civil engineering in 1965; from Catholic University of America in 1970 with a master's degree in civil engineering; from the Corps Planning Associates Program in 1974; and the Executive Excellence Program of the Federal Executive Institute in 1988.

Mr. Crews has received numerous awards. Some of these include: Young Engineer of the Year Award from the Baltimore Post Society of American Military Engineers in 1977; Baltimore District Engineer of the Year Award in 1978; North-Atlantic Division-wide Engineer of the Year Award in 1978; the Commanders Award for Civilian Service in 1979; and the Meritorious Civilian Service Award in 1991. Mr. Crews is very active in professional societies and serves on several committees of the American Society of Civil Engineers and the American Water Resources Association. He is a past president of the Baltimore Post Society of American Military Engineers and a past vice-president of the National Capitol Section, American Water Resources Association. Mr. Crews is a registered professional engineer in the District of Columbia.

D. D. Davidson

Mr. Davidson is Chief, Wave Research Branch, Wave Dynamics Division, Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. He holds a B.S. degree in civil engineering from Mississippi State University and has performed work on his master's degree in hydraulic engineering at the same institution. His background experience is in hydraulic modeling and research for coastal engineering where he has been involved in investigating problems pertaining to wave action on coastal structures and harbors. During recent years, he has concentrated primarily on development of design criteria and research problems relating to breakwater stability, wave forces, floating breakwaters, and landslide-generated waves. He frequently represents WES in his area of expertise, both within the United States and abroad. He has authored or coauthored several technical publications, which have appeared in various professional journals.

COL Leonard G. Hassell

COL Hassell became the 26th Commander and Deputy Director of the U.S. Army Engineer Waterways Experiment Station (WES) in Vicksburg, MS, in January 1992. Prior to his assignment at WES, COL Hassell was the Acting Commander of the Corps' Pacific Ocean Division at Fort Shafter, HI. He was commissioned a Second Lieutenant in 1968 from Jacksonville State University, Jacksonville, AL. COL Hassell has a bachelor's degree in business and double master's degrees in industrial management and marketing from Inter-American University of Puerto Rico. He also has a bachelor's degree in civil engineering from Saint Martin's College, Olympia, WA. He is a graduate of the U.S. Army Command and General Staff College and the U.S. Army War College. In 1991 he completed Harvard's Executive Program for Senior Officials in National Security. He is a registered professional engineer. COL Hassell has held numerous command and staff assignments including Civil Engineer Team Leader, 539th Engineer Detachment, 1st Special Forces Group (Airborne), Okinawa and Philippines; Unit Advisor and Engineer Staff Officer, U.S. Army Advisor Group (Puerto Rico); Company Commander and Executive Officer, 864th Engineer Battalion (Combat)(Heavy) and Operations Officer, 593rd Area Support Group, Fort Lewis, WA; Assistant District Engineer (military programs), Norfolk District; Deputy District Engineer (civil works), Norfolk District; Northern Area Engineer, Japan District; and Assistant to the Director, Office of Economic Adjustment, Office of the Secretary of Defense. His military decorations include the Legion of Merit, Defense Meritorious Service Medal, Army Meritorious Service Medal (two awards), and the Army Commendation Medal (two awards).

Laura L. Hicks

Ms. Hicks is a native of Illinois and graduated from Ohio State University in 1982 with a B.S. degree in civil engineering. Upon graduating, she went to work for the Huntington District of the Corps of Engineers. She spent approximately three years in Huntington, primarily in the Design Branch. In 1985, Ms. Hicks was transferred to the Portland District to work in the Coastal and Harbors Section of the Planning Division. She later worked in the Hydrology and Hydraulics Branch, and currently, she is on a detailed assignment in the Project Management Office.

Carolyn M. Holmes

Ms. Holmes is the Program Manager for the Coastal Engineering Research and Development, Monitoring Completed Coastal Projects, and Coastal Field Data Collection Programs at the Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station (WES). Previously, Ms. Holmes was the Assistant Program Manager for the Dredging Research Program, CERC, WES, and Chief of the Navigation Branch, Hydraulics Laboratory, WES. She received a B.S. degree in civil engineering from Auburn University and an M.S. degree in civil engineering (hydraulics) from Colorado State University. Ms. Holmes is a member of the American Society of Civil Engineers, the Institute of Electrical and Electronic Engineers, and the Oceanic Engineering Society.

Dr. James R. Houston

Dr. Houston is Director of the Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station (WES). He has worked at WES since 1970 on numerous coastal engineering studies dealing with explosive waves, harbor resonance, tsunamis, sediment transport, wave propagation, and numerical hydrodynamics. He is a recipient of the Department of the Army Research and Development Achievement Award. Dr. Houston received a B.S. degree in physics from the University of California at Berkeley, an M.S. degree in physics from the University of Chicago, and both an M.S. degree in coastal and oceanographic engineering and a Ph.D. in engineering mechanics from the University of Florida.

Dr. Steven A. Hughes

Dr. Hughes is a research hydraulic engineer in the Wave Dynamics Division, Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station (WES). He joined CERC in 1981 and has been involved in research activities related to shallow-water wave transformation, wave height distributions, wave kinematics, wave reflection, physical model similitude, and modeling scour at coastal structures. He also has served as an instructor in workshops, short courses, and the WES Graduate Institute. Dr. Hughes received a B.S. degree in aerospace engineering (1972) from Iowa State University of Science and Technology, an M.S. degree in coastal and oceanographic engineering (1978), and a Ph.D. degree in civil engineering (1981) from the University of Florida. He is a member of the American

Society of Civil Engineers (ASCE), and currently is Executive Committee secretary of the ASCE Waterway, Port, Coastal and Ocean Engineering Division. He is a registered professional engineer in the state of Mississippi.

Thomas R. Kendall

Mr. Kendall is a civil engineer in the Water Resources Branch, U.S. Army Engineer District, San Francisco, where he has been employed since 1984. Mr. Kendall manages a variety of coastal and navigation projects including structure condition surveys, breakwater and jetty rehabilitations, and coastal processes investigation along the northern California coast. Mr. Kendall received a B.S. degree in civil engineering and an M. Eng. degree in civil engineering with an emphasis on coastal engineering hydraulics, and coastal/estuarine modeling from the University of California at Berkeley. He has previous work experience both with the University of California and the private sector in hydraulic model research and offshore structure design. Mr. Kendall is a member of the American Society of Civil Engineers and the American Shore and Beach Preservation Association. He is a director of the California Shore and Beach Preservation Association and is a registered civil engineer in California.

Dr. Nicholas C. Kraus

Dr. Kraus is a senior scientist at the Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station, where he conducts basic and applied research in the area of coastal sediment processes. He joined CERC in 1984 and was formerly a senior engineer for 8 years at the Nearshore Environment Research Center, Tokyo, Japan. Dr. Kraus is Technical Manager of the Dredging Research Program area "Analysis of Dredged Material Placed in Open Water," heading a group of five principal investigators involved with the mathematical prediction and field measurement of the movement of dredged material. In the Coastal Research Program, Dr. Kraus was co-developer of the shoreline change numerical simulation GENESIS and the storm-induced beach erosion model SBEACH. He is a member of the American Society of Civil Engineers (ASCE), American Geophysical Union, and Society of Economic Paleontologists and Mineralogists. Dr. Kraus recently served as Chairman of the ASCE specialty technical conference *Coastal Sediments '91*. Present research activities concern beach-fill design and the use of groins together with beach fill.

Dennis G. Markle

Mr. Dennis G. Markle is the Chief of the Wave Processes Branch of the Wave Dynamics Division, Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The Wave Processes Branch conducts both research and development and reimbursable work relating to harbors, inlets, shore protection, coastal structures, and explosion waves. Mr. Markle earned a bachelor's degree in engineering from the University of Arizona in 1973 and has taken graduate courses from Mississippi State University toward a master's degree. He began his engineering career with the Wave Research Branch, Wave Dynamics Division, Hydraulics Laboratory, WES, in 1974. Mr. Markle is a member of the American Society of Civil Engineers and the National Society of Professional Engineers. He is registered as a professional civil engineer in the state of Mississippi.

James E. McDonald

Mr. McDonald is a research civil engineer in the Concrete Technology Division, Structures Laboratory, U.S. Army Engineer Waterways Experiment Station. He is the problem area leader for the Concrete and Steel Structures portion of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program and the principal investigator for three REMR work units. He has been involved with various aspects of concrete research for more than 30 years. Mr. McDonald received his B.S. and M.S. degrees in civil engineering from Mississippi State University.

E. Clark McNair, Jr.

Mr. McNair is Program Manager of the Dredging Research Program (DRP), Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station (WES). The DRP is an integrated, multidisciplinary research program that addresses the operational and managerial aspects of dredging. Several WES laboratories, as well as other Corps laboratories and Field Operating Activities, are actively involved in the DRP. New equipment and techniques will be identified, developed, or adapted for use by the Corps of Engineers for performing dredging operations more efficiently and economically. Mr. McNair earned a bachelor's degree in civil engineering from Mississippi State University and a master's degree in civil engineering from Texas A&M University. He is a member of the American Society of Civil Engineers, the Permanent International Association of Navigation Congresses, and the Western Dredging Association. He is a registered professional engineer in the state of Mississippi.

Jeffrey A. Melby

Mr. Melby is a research hydraulic engineer in the Wave Research Branch of the Wave Dynamics Division at the Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station. Mr. Melby joined CERC in 1987 after receiving an M.S. degree in ocean engineering at Oregon State University, and recently completed a year of study working toward his Ph.D. at the University of Delaware. Mr. Melby's work at CERC has concentrated on developing a concrete armor unit structural design procedure. As a graduate student, Mr. Melby developed and applied a wave force numerical model for dolosse. He has published several papers on the static and dynamic response of dolosse and has developed the Crescent City dolos structural design procedure. As the principal investigator in the Corps' Concrete Armor Unit Design work unit, Mr. Melby has extended the Crescent City design procedure to the general case, using a parametric physical study where the dolos structural response is measured by means of small-scale internal structural instrumentation.

John G. Oliver

Mr. Oliver is the Chief of the Hydraulics and Civil Design Branch of the U.S. Army Engineer Division, North Pacific, in Portland, OR. He has over 30 years of experience in coastal engineering, flood control navigation, and hydroelectric development in the Corps of Engineers. Mr. Oliver received his B.S. degree from Oregon State University and advanced training at the International Hydraulics Course in Delft, The Netherlands.

Jesse A. Pfeiffer, Jr.

Mr. Pfeiffer is currently General Manager for Civil Works Research and Development in the Directorate of Research and Development at Headquarters, U.S. Army Corps of Engineers, Washington, DC. Mr. Pfeiffer has a B.S. degree in civil engineering from the University of Texas at Austin. He is a registered professional engineer in Texas and a member of the American Society of Civil Engineers and the Permanent International Association of Navigation Congresses (PIANC). Mr. Pfeiffer is at present Chairman of PIANC Working Group 19 preparing a report entitled "Dredged Material, Beneficial Uses and Underwater Disposal." He has also been designated as General Manager of the Construction Productivity Advancement Research Program, a new Corps of Engineers cost-shared research program with the construction industry to develop technology to improve construction productivity.

Jane McKee Smith

Ms. Smith is a research hydraulic engineer at the Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station, where she works in the area of coastal hydrodynamics. Her research interests include spectral wave transformation, wave breaking, and nearshore currents. Ms. Smith has been involved in hydrodynamic data collection at the DUCK85, SUPERDUCK, Great Lakes '88, and DELILAH field experiments, as well as the SUPERTANK laboratory project. Ms. Smith earned a B.S. degree from South Dakota State University and an M.S. degree from Mississippi State University. She is a member of the American Society of Civil Engineers and the American Geophysical Union.

Dr. Charles K. Sollitt

Dr. Sollitt is the Director of the O. H. Hinsdale Wave Research Laboratory at Oregon State University, Corvallis, OR, and is a faculty member of the Ocean Engineering Programs in the Department of Civil Engineering. He conducts research in wave-structure interaction, rubble-mound structure behavior, and ocean wave measurement systems. He teaches undergraduate engineering courses in fluid mechanics and hydraulic engineering as well as graduate courses in wave mechanics, marine geotechniques, and ocean engineering laboratory procedures. Dr. Sollitt is a member of the American Society of Civil Engineers where he served as chairman of the Technical Committee on Ocean Engineering. Current research activities include stability studies of armored marine outfalls, experimental observations of pneumatically generated currents for oil containment, and analytical and physical modeling of permeable coastal structures.

Appendix B
Status of Action Items

CERB Action Items and Status			
Action Item	**Place and Date of Action**	**Responsible Agent**	**Action and Status**
55-1. Advise and periodically brief Board on how WES integrates the DRP and other coastal R&D programs with other ongoing and future environmental research programs.	Mashpee, MA 30 Oct - 1 Nov 91	CERC	The DRP Program Manager works closely with the Manager of environmental dredging programs to ensure proper coordination. As CERC moves into applying the new DRP technology, it is working even closer with the Environmental Laboratory to ensure the technology is known and used by the entire environmental community.
55-2. Review current Corps practices relating to measuring sediment properties of material to be dredged and report the findings to the Board.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-OD	Most Districts rely on historical (1970's) sediment sampling information for their maintenance dredging projects, some perform periodic sediment analyses ranging from once every 4 to 5 years to once every 2 years. When a District has a project with new dredging work, it will generally undertake more extensive sediment sampling and analysis efforts.
55-3. Revisit issue of benefits which can be included in beach restoration and dredged material disposal projects and report to the Board.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-P	At the present time, the policy is that downdrift neighbors who may benefit from sand moving downdrift from a renourishment project are not considered in the benefit analysis.
55-4. Prepare a priority list of inlet candidates that can benefit from mitigation through Section 933 and 111 authorities and report to the Board.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-E	Data on inlets are still being collected and compiled. A final list will be presented to the Board at the next meeting.
55-5. Report on the Wetlands Research Program, beneficial uses of dredged material, and the EPA's Gulf of Mexico Program at the October '93 meeting, which will have the theme of "Coastal Wetlands."	Mashpee, MA 30 Oct - 1 Nov 91	CERC/EL	This will be reported on at the October '93 CERB meeting.
55-6. Brief Board on the extent to which the Coast of California and the Coast of Florida Studies are integrated with the latest coastal research technology.	Mashpee, MA 30 Oct - 1 Nov 91	CERC	Drs. Raichlen and Dalrymple participated as principals in a 1-day review of technical plans for the Coast of Florida Study on 29 May 92, with emphasis on the Study's proposed uses for coastal research such as WIS and GENESIS. Verbal comments were provided Jacksonville District. District is assessing comments.
55-7. Periodically advise the Board of the general scope of research performed at the Coastal Engineering Research Center outside the GI-funded Coastal Engineering Research Program.	Mashpee, MA 30 Oct - 1 Nov 91	CERC	Will be discussed at this meeting.

CERB Action Items and Status			
Action Item	**Place and Date of Action**	**Responsible Agent**	**Action and Status**
55-8. Develop a fundamental hydrodynamic model of the developing plume that addresses the method of dredged material release, entrainment, stripping, and resuspension that has the capability for serving as a meaningful basis for answering environmental questions.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-OD CERC	The present short-term fate model is being extended to account for stripping, and these refinements serve as an introduction to more complex phenomena before attacking the 3-D aspects in their entirety.
55-9. Conduct a high-quality field data collection program related to the short-term and long-term fate of dredged material.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-OD CERC	The PLUme MEasurement System (PLUMES) being developed in the DRP has been, and is being, used at reimbursable projects to obtain high-quality field data in both estuaries and open coastal waters for refinement and calibration of the numerical models describing fate of dredged material.
55-10. Verify the transport relations used in both short-term and long-term models.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-OD CERC	Data sets are being accumulated by the DRP from field and laboratory observations of placement disposal operations, and from long-term monitoring of sediment mounds. They will provide verification data for the transport relations in numerical models of dredged material fate.
55-11. Develop an operational model for dealing with nearshore and offshore berm processes that include the sediment transport and berm/wave interaction.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-OD CERC	High-quality field data obtained during numerous studies will support analyses and development of algorithms comprising an operational model for berm process understanding, including the berm/wave interaction phenomena. Existing PC models are being upgraded as appropriate for field use application.
55-12. Continue emphasis of fundamental research on coastal hydrodynamics and sediment processes at inlets as proposed in the Coastal Inlet Research Program (CIRP).	Mashpee, MA 30 Oct - 1 Nov 91	CECW-O CERC	The nine CIRP work units are involved in fundamental inlet studies ranging from turbulence and point sediment transport to shoaling rates and morphology change.
55-13. Fully integrate environmental considerations in CIRP.	Mashpee, MA 30 Oct - 1 Nov 91	CERC	Environmental considerations have been and will continue to be integrated primarily through regular meetings of the CIRP and environmental programs managers.
55-14. Conduct a pilot study to address the problems of at least two inlets in CIRP.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-O CERC	The program is not yet to the stage where specific inlets will be selected.
55-15. Provide (through CIRP) a manual as soon as possible to assist the District offices in assessing adverse impacts to the beaches caused by projects located on inlets.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-O CERC	As the program progresses and products become available that will be of assistance to District offices, technology will be provided in the most appropriate and expeditious manner, including technical manuals.
55-16. Address (in CIRP) sediment pathways, including movement over and through structures.	Mashpee, MA 30 Oct - 1 Nov 91	CECW-O CERC	Three work units in the CIRP specifically address this issue and others will contribute to the knowledge base.
54-6. Establish a CERC rapid response team to coastal flooding events.	New Orleans, LA 4-6 Jun 91	CECW-O CERD CERC	A Corps-wide workshop has been planned for late June to finalize field needs, objectives, and team participation. The initial version of the resulting team concept will be in place for the 1992 winter storm season.

CERB Action Items and Status			
Action Item	**Place and Date of Action**	**Responsible Agent**	**Action and Status**
54-7. Conduct an interagency collaborative study to upgrade the hurricane wind model.	New Orleans, LA 4-6 Jun 91	CECW-E CERD CERC	CERC organized a workshop on tropical storm wind modeling, held at CERC, in which personnel from three Weather Service offices participated.
54-12. Conduct workshops to determine interest in CERC tools to improve planning for flooding emergencies.	New Orleans, LA 4-6 Jun 91	CECW-O CERC	A Field Review Group was formed and the first meeting between WES representatives and this group was held in May. Work is proceeding at this time in formulating an R&D Program.
54-13. Increase coordination of technical aspects (including data collection) of coastal flooding with other Federal agencies.	New Orleans, LA 4-6 Jun 91	CECW-O	An interdepartmental working group has been established under The Office of the Federal Coordinator for Meteorological Services and Supporting R search to devel p a national plan for post-storm data collection.
54-15. Conduct research on dynamic loading of expedient flood control structures.	New Orleans, LA 4-6 Jun 91	CECW-O CERD	Funds have been authorized by the Readiness Branch at HQ to refurbish WES' Big Black test facility to conduct static (hydraulic head) and dynamic (waves) load testing of expedient levee-raising structures.

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