

Monitoring Completed Coastal Projects: Status of a Program

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ABSTRACT

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For too long, coastal works were built with no intent to determine the success of their performance. It was an unusual structure that was monitored once completed. The need to better understand performance of coastal projects and, therefore, be better able to evaluate success of accepted design procedures has been long accepted. Until 1981, though, there was no organized program to satisfy that need in the United States. That year, the U.S. Army Corps of Engineers established the Monitoring Completed Coastal Projects Program to provide evaluations needed by planners, designers, and builders of coastal projects.

ADDITIONAL INDEX WORDS: *Sediments, models, sonar, photogrammetry, tides, waves, littoral transport, inlets, structures, inspection.*

INTRODUCTION

In 1984, at the Nineteenth Coastal Engineering Conference in Houston, Texas, Dean Morrough P. O'Brien regretted that "There are few complete records of the design, construction, maintenance, and demise of protective coastal structures." (O'BRIEN, 1984). The need for monitoring had been realized, though, by the U.S. Army Corps of Engineers (CE). Recognizing, as Dean O'Brien noted in his keynote address, that data from various structures experiencing different conditions would "yield valuable data—not only for the continuing treatment of particular locations but also for basic studies," (O'BRIEN, 1984) the CE initiated a program of monitoring coastal projects in 1981. By 1984, the program had begun monitoring at a number of projects throughout the United States, but it had yet to produce results and was, therefore, known to only a few individuals outside the CE.

Called the Monitoring Completed Coastal Projects (MCCP) Program, its purpose is to aid in the advancement of coastal engineering technology by determining how well projects accomplish their purposes and resist attack of the physical environment. These determinations,

combined with concepts and understanding already available, will upgrade the credibility of predictions of cost-effectiveness of engineering solutions to coastal problems; strengthen and improve design criteria and methodology; improve construction practices; and better operation and maintenance techniques. While the program is managed by the U.S. Army Waterways Experiment Station (WES), Coastal Engineering Research center (CERC), it is a cooperative effort between CERC, Headquarters, CE, and the CE's numerous coastal Division and District offices. (HEMSLEY, 1987).

The direction of the program was guided by an ad hoc committee of coastal engineers and scientists. The committee's objectives included formulating the program's objectives, developing its operational philosophy, recommending funding levels, and establishing criteria and procedures for project selection. A significant result of their efforts was a prioritized listing (Table 1) of problem areas to be addressed. Initially, the listing included only the first 20 items.

PROJECTS AND RESULTS

Periodically, the CE coastal offices are invited to nominate projects for monitoring

Table 1. *MCCP Program areas of interest.*

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1. Shoreline and nearshore current response to coastal structures.
 2. Wave transmission by overtopping.
 3. Prediction of the controlling cross section at inlet navigation channels.
 4. Wave attenuation by breakwaters (submerged and floating).
 5. Bypassing at jettied and unjettied inlets.
 6. Wave refraction and steepening by currents.
 7. Beach fill project monitoring.
 8. Stability of rubble structures—investigations to determine causes of failure.
 9. Comparison of pre- and post-construction sediment budgets.
 10. Wave and current effects on navigation.
 11. Dynamics of floating structures.
 12. Wave reflection.
 13. Effects of construction techniques on scour and deposition near coastal structures.
 14. Diffraction around prototype structures.
 15. Wave runup on structures.
 16. Onshore/offshore sediment movement near coastal structures.
 17. Harbor oscillations.
 18. Wave transmission through structures.
 19. Material life cycle.
 20. Ice effects on structures and beaches.
 21. Model study verification.
 22. Wave translation.
 23. Construction methods.
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under the program. Nominations are reviewed and prioritized by a selection committee comprised of representatives of Headquarters, CE, CERC, and the coastal Division offices. Since 1981, data have been, are being, or will be collected at 21 diverse sites around the country. Five additional projects were selected but canceled for a variety of reasons. Table 2 lists the projects selected for monitoring to date, the areas of interest addressed by each project, and the period from selection through monitoring to report publication.

Data being collected are nearly as varied as the projects. Table 3 shows data being collected in support of the monitoring objectives for each project.

Monitoring has been completed at ten of the projects: Bodega Bay, Burns Harbor, Carolina Beach, Cattaraugus Creek, Cleveland Harbor, East Rockaway, Oakland Beach, Puget Sound, and Umpqua River. Final reports have been published for Carolina beach (JARRETT and HEMSLEY, 1988) and Puget Sound (NELSON and HEMSLEY, 1988). Reports are in preparation for the remaining eight projects. Preliminary results from these and other MCCP Program projects are already being used by the District offices involved in the monitoring efforts to improve design, operation, and maintenance of these and similar projects. As data

are analyzed and the results published, they become available for use by the coastal engineering community for planning, design, construction, operation, and maintenance of coastal projects.

The following is a description of the 21 active projects, addressed chronologically beginning with the earliest projects. As a part of the description, significant results already identified will be mentioned.

Cleveland Harbor, Ohio

Among the first projects selected for the program was the rehabilitation of the eastern-most 4,400 feet of the Cleveland Harbor, Ohio, breakwater. Improvements were made to the breakwater using two ton, unreinforced dolosse, and the monitoring program was intended to evaluate the performance of those dolosse units. Wave gages were deployed lake-ward and shoreward of the structure, selected units were surveyed to map their motions, broken units were identified, and the underwater portions of the structure were inspected (POPE and CLARK, 1983; ZWAMBORN, 1984; and POPE, 1984). Two significant results of the monitoring effort are apparent. First, the performance of the armor units was critically evaluated. Based on information about unit break-

Table 2. *Monitored projects.*

Project	Areas of Interest Addressed	Period of Funding
Agat Harbor, GU	10, [†] 17, 21, 22	1986-1994
Barbers Point, HI	8, 10, 17, 21	1984-1989
Bodega Bay, CA	3, 17, 18, 22	1987-1989
Burns Harbor, IN	2, 4, 8, 10, 13, 17, 18, 20, 21, 23	1985-1990
Carolina Beach, NC	3, 5, 7, 9	1981-1988
Cattaraugus Creek, NY	1, 3, 8, 13, 16, 20, 21	1983-1989
Cleveland Harbor, OH	2, 8, 20, 21	1981-1989
Colorado River, TX	1, 3, 5, 8, 10, 16	1988-1994
Crescent City, CA	8, 23	1989-1992
East Pass, FL	1, 3, 5, 8, 9, 10, 16, 19	1986-1990
East Rockaway, NY	1, 7, 9, 13	1981-1990
Fisherman's Wharf, CA	1, 4, 10, 12, 13, 14, 17, 18, 21, 22	1986-1991
Folly River, SC	1, 3, 5, 8, 10, 16	1989-1991
Manasquan Inlet, NJ	1, 3, 5, 8, 16	1982-1990
Oakland Beach, RI	1, 7, 12, 16, 21	1982-1990
Ocean City, MD	1, 2, 3, 4, 5, 6, 8, 9, 13, 14, 16, 21	1985-1991
Puget Sound, WA	4, 11	1985-1988
Redondo Beach, CA	10, 12, 21	1989-1994
Siuslaw River, OR	1, 3, 5, 13, 16, 21, 23	1986-1991
Umpqua River, OR	1, 3, 10, 13, 21	1983-1989
Yaquina Bay, OR	1, 6, 8, 10, 13, 14, 15, 18, 21, 23	1989-1994

[†]See Table 1 for explanation.

age and stability provided by the repeated surveys, an informed decision could be made concerning the rehabilitation of further sections of the breakwater. Results of the data collection showed that while the units were probably able to protect the structure from waves approaching the design storm, they were not sufficient for the design storm. Second, the effect of ice on the units was more significant than expected, possibly making the structure more susceptible to damage. Continued rehabilitation of the breakwater was performed using larger armor units than had been considered for the initial section.

The most widely accepted product of the program is the use of side-scan sonar as an inspection tool for coastal structures (PATTERSON and POPE, 1938; MORANG, 1987; and CLAUSNER and POPE, 1988). The use of side-scan sonar helped solve the most worrisome problem associated with the monitoring of the Cleveland Harbor breakwater. In order to evaluate the motion of the armor layer below the waterline, it was necessary to have some idea of what was happening to the armor units below the surface. Lake Erie is often opaque, unfortunately, and visual inspections are impossible during much of the year. The search for a solution led to side-scan sonar. Typically used for surveying bottom

features, the sonar seemed to have some value in making qualitative inspections of structures. Discussions with manufacturers' representatives were encouraging, so a 500 kHz unit was used at Cleveland in a test of the usefulness of the imagery in determining the condition of the underwater portion of the structure. In an attempt to gain experience, all types of structures in the Cleveland area were surveyed including dolos and rubble armored structures, timber crib structures, and sheet pile walls (PATTERSON and POPE, 1983).

Considerable experience with side-scan sonar was gained during subsequent surveys at Cleveland and Manasquan Inlet, New Jersey, where jetties had been rehabilitated using dolosse. With proper control, sonar produced very usable results. Comparison of survey results, each taken repeating the previous survey track as nearly as possible, revealed changes in subsurface layers. Individual armor units could not usually be seen, but patterns produced by the units were used to identify abnormal areas, such as spots without armor, areas where the armor layer extended past the toe of the structure, or changes in the layer since the last survey. These conditions could then be used to help explain changes in the armor layer above the water surface. Under

Table 3. *Data collections.*

	Aerial Photographs	Armor Unit Motion Surveys	Broken Dolosse Surveys	Current Speed & Direction	Littoral Environment Observations	Photography/Video Tape	Photogrammetry	Salinity	Sediment Samples	Side-Scan Surveys	Structural Surveys	Tidal Prism	Tides	Topo/Hydro Surveys	Underwater Inspections	Wave Direction	Wave Height & Period	Wind Speed & Direction
Agat Harbor	X					X							X	X	X	X	X	
Barbers Point	X					X									X	X	X	
Bodega Bay	X					X							X				X	
Burns Harbor	X					X		X	X	X					X		X	
Carolina Beach	X					X			X		X		X	X			X	
Cattaraugus Creek	X			X	X			X	X					X	X		X	
Cleveland Harbor	X	X	X			X			X						X	X	X	X
Colorado River	X			X	X			X	X	X	X	X	X	X	X	X	X	
Crescent City	X		X			X	X		X	X							X	
East Pass	X			X		X		X	X		X	X	X	X	X		X	
East Rockaway	X			X	X			X					X	X			X	
Fisherman's Wharf	X			X	X	X				X		X				X	X	X
Folly River	X			X	X			X	X	X	X	X	X	X	X	X	X	
Manasquan Inlet	X	X		X	X	X			X		X	X	X	X	X		X	X
Oakland Beach	X			X	X			X		X				X			X	
Ocean City	X				X			X	X	X	X	X	X			X	X	X
Puget Sound				X	X								X					X
Redondo Beach	X																X	X
Siuslaw River	X			X		X		X		X	X	X	X	X		X	X	
Umpqua River	X			X		X	X	X	X	X	X	X	X				X	
Yaquina Bay	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

some conditions, individual dolosse could be seen. At Cleveland, it appeared that single dolosse, sitting on the bottom away from the structure, could be identified. The size of the units at Manasquan Inlet helped make individual dolos more identifiable. The characteristic shape of the units can be seen in the imagery even, in places, on the face of the structure.

As a result of these tests, much has been learned about the limitations of side-scan sonar, as well as about its uses. Side-scan sonar is a qualitative tool; at this time it does not produce quantitative results. In shallow water, the imagery can be distorted by wave action. Wave heights more than a few feet are transmitted through the two cable to the sonar fish. The scope of the two cable must be short for shallow water use, so it fails to dampen the wave motion. Operation of the sonar in shallow water often requires that the fish be close to the bottom, making the unit more susceptible to dam-

age from rocks or other projections from the bottom.

Sonar surveys are a quick, simple means to get qualitative information about portions of a structure that otherwise are not likely to be inspected. At three knots, an extensive structure can be surveyed quickly and inexpensively, compared to the cost of more detailed surveys. When the imagery indicates a problem, an inspection of the suspicious area can be made using divers or video equipment. A particular use for side-scan sonar is the inspection of a structure during construction and for final acceptance. A sonar survey would identify misalignment of the structure toe, loss of armor or other rock, or other problems associated with construction under water. Because of its demonstrated usefulness, side-scan sonar has now been used at seven MCCP Program projects and is scheduled for use at three more. Through the MCCP Program, the usefulness of side-scan

sonar as an inspection tool has been demonstrated to the CE, where its use is becoming more widespread.

Carolina Beach, North Carolina

Another project selected for monitoring in 1981 was the beach nourishment at Carolina Beach, North Carolina. Much of the nourishment sand for the project was taken from a source inside the inlet to the north. An intent of the monitoring was to determine if enough sand would be collected in the resulting hole, a sediment trap, to support subsequent renourishments. At the same time, information was gathered to test the overfill ratios used for the project, verify the sediment budget, and test Jarrett's equation for the prediction of the inlet's tidal prism (JARRETT, 1976).

It was found that while the inlet trap had performed nearly as expected, it did not trap sufficient sand to renourish the beach. Data collected indicated that locating the trap farther back in the throat of the inlet could produce the desired results. Analysis of the monitoring results also revealed that the overfill ratio, predicted by the *Shore Protection Manual* (USAE WATERWAYS EXPERIMENT STATION, 1984), was shown to be quite accurate at Carolina Beach. The sediment budget was compared to the actual data acquired and adjustments have been made to predict better the actual renourishment requirements.

In 1976, Mr. Thomas Jarrett, an engineer at the CE's Wilmington District in North Carolina, developed an equation (JARRETT, 1976) to calculate the tidal prism based on a modification of the classic work of O'Brien (1931). The equation was first tested in the MCCP Program at Carolina Beach and subsequently at Manasquan Inlet, New Jersey, and Umpqua River, Oregon. The data collected have shown that the predictions using made Jarrett's equation agreed well with the measured flow through the inlets, providing more confidence in the technique. Additional tests of the equation are also being made at Ocean City, Maryland, and East Pass, Florida. When all data are collected, the equation will have been tested at jettied and unjettied Atlantic coast inlets, a jettied Gulf coast inlet, and a jettied Pacific coast inlet.

East Rockaway, New York

The last of the projects selected in 1981 was the 6.2 mile beach nourishment project at East Rockaway, along the Atlantic coast of Long Island in New York City. Information collected at the project has been used to refine the sediment budget to predict the renourishment needs along this beach. Analysis of the enormous data set continues in cooperation with research efforts underway at CERC. Results of the analysis are expected to add to the understanding of beach processes.

Oakland Beach, Rhode Island

Two projects were selected for monitoring in 1982, a small beachfill with groins and a revetment at Oakland Beach, Rhode Island, and the dolosse rehabilitated jetties at Manasquan Inlet, New Jersey. Oakland Beach proved to be an example of a project that was particularly well designed. Performance of the project was exceptional. The beach created by the structures and the fill was maintained without damage to the downdrift shoreline in one direction or increased shoaling to the adjacent channel in the other. The success of the project is a testimony to the methods used in the project design. Without wave data, the design wave was developed numerically using winds from a nearby airport. Wind data were acquired during the monitoring effort both at the beach and from the airport and are being used to test various relationships between winds measured over land to those at a coastal site.

Manasquan Inlet, New Jersey

The jetties at Manasquan Inlet were rehabilitated using 16 ton, reinforced dolosse. Through the monitoring program, the stability of these rehabilitated jetties was evaluated, and the design was shown to be successful, surviving a design storm with very acceptable levels of damage. The shore connected jetties offered an excellent opportunity to observe the motion of dolosse armor units, since access was uncomplicated and the site was close to the CE's Philadelphia District. Initially, it was planned to use standard leveling techniques to measure the displacement of selected armor units on the

structure. A total of 65 dolosse on the south jetty and 95 on the north jetty were selected for monitoring.

The successful use of side-scan sonar at Manasquan Inlet, New Jersey, has been discussed. Another monitoring technique, pioneered at this site, that has gained considerable acceptance is the mapping of armor unit motions through photogrammetry. Fortunately, during the time that the monitoring plan was being developed, a contractor, A.D.R. Associates, presented the results of photogrammetric mapping the firm had performed of some New Jersey beaches. The applicability of photogrammetric mapping of dolos movement was discussed and seemed possible with existing technology.

In order to test the accuracy of the photogrammetric techniques, the leveling and mapping were done independently. Neither the surveyors nor the mappers had access to the other's results until they had been compared by Mr. Jeffrey Gebert of the Philadelphia District. The possibility of mapping the jetties was particularly interesting because cost projections were comparable to those for the leveling, and mapping produced positions on all the armor units, not just the selected ones.

Comparing the photogrammetric results with those of the standard leveling techniques, it was found that photogrammetry was more than adequate in evaluating armor unit stability. Vertical accuracy was shown to be within ± 3.1 cm (0.1 ft) and horizontal accuracy was ± 9.1 cm (0.3 ft). These results have encouraged consideration of the use of photogrammetry for periodic inspections of coastal structures to allow detection of incipient or progressive failure before the problems can be readily detected during site visits (GEBERT and CLAUSNER, 1985). Photogrammetry has subsequently been used at the extensive dolosse monitoring effort at Crescent City, California, and is planned for several additional MCCP Program efforts.

Cattaraugus Creek, New York

Two projects were selected for monitoring in 1983. They were Cattaraugus Creek, New York, on Lake Erie, and Umpqua River, Oregon. Cattaraugus Creek was an unusual project for the program. The jetties designed for the navigable stream were intended to maintain a channel, but the channel was designed more to

prevent flooding than to allow continuous navigation. Each spring ice in the stream would break up and move toward the lake. Lake ice was normally dispersed by the time the stream ice was breaking up. Stream flows would push the ice onto the bar at the stream mouth, where it would dam. Resultant flooding would affect communities on both sides of the stream. As a part of the design process, the proposed structures were physically modeled. Those tests indicated that the jetty design selected would maintain the navigation channel and, therefore, prevent the annual flooding. Data collected at the site included waves, profiles of the beach and structure, bathymetry of the channel, and videos of the ice breakup. As might have been expected, the first year of monitoring was during an ice free winter. Subsequent winters proved to be more cooperative. During the next two years, the ice breakup was observed. The successful performance of the structures was documented. Only when the lake ice had not dispersed was there any flooding.

Umpqua River, Oregon

The jetties at the mouth of the Umpqua River underwent a series of modifications to reduce shoaling in the river mouth and improve navigation conditions. Originally designed to provide a wide entrance to the river, the jetties had become quite permeable, allowing considerable sand to move through the structures into the channel. Because of their width, the jetties did little to reduce wave heights and cross currents in the channel. Improvements to make the jetties less permeable and generally improve conditions in the river mouth were physically modeled. During the monitoring, wave data were collected both offshore and inside of the structures, currents were measured in the entrance, and profiles and bathymetry were collected. Data collection verified the success of improvements. One product of the effort was the development of a simple model that related the waves offshore to those in the entrance. While the model is site specific, the approach may be applicable to other locations.

Barbers Point, Hawaii

Only one project was selected in 1984, the deep draft harbor at Barbers Point, Hawaii.

When this project was originally proposed, the monitoring emphasized the performance of the rubble wave absorber placed inside the harbor entrance and along portions of its sides. Wave gages were so located, but they were also designed to evaluate surge within the harbor. Waves have not proven to be a problem in the harbor, but surge has already caused problems. The harbor has been found to have energy peaks at periods of about one and two minutes. In one event, a Coast Guard vessel was damaged attempting to dock in a floating drydock inside the harbor. Since identifying the long period waves problem, additional gages have been installed inside and outside the harbor in an attempt to better understand the causes of the harbor response. Data collected in this monitoring effort will be used to calibrate a numerical model, called HARBD (CHEN and HOUSTON, 1987), that predicts harbor response. HARBD is a hybrid element model developed to calculate linear wave oscillation in and around coastal harbors. The model is applicable to arbitrary depth water waves from shallow to deep water waves, but uses monochromatic waves. The model will be run using input data actually collected at the harbor. Comparison of the model results with oscillations measured in the harbor will be useful in determining how well the model actually predicts the oscillations and improving those predictions if necessary. Data collection will continue through the 1989-90 winter; the model will be run in 1990.

Puget Sound, Washington

Three projects were added in 1985: an assessment of floating breakwaters in Puget Sound, Washington, jetty improvements at Ocean City, Maryland, and the breakwater at Burns Harbor, Indiana. The effort in Puget Sound was simply one of observation. Six floating breakwaters were visited repeatedly during the two years of the monitoring. The operation of the breakwaters was observed and those observations have resulted in several changes to the ways floating breakwaters are designed and operated. They included observations of the adequacy of the corrosion protection system for the mooring chains, a proposal that the corners of concrete breakwaters be rounded to prevent impact damage, and that the structures be

designed for mooring of large vessels on the unprotected side of the breakwater.

Ocean City, Maryland

At Ocean City, Maryland, the south jetty had deteriorated, allowing sand to pass through the structure into the navigation channel. Because this was the downdrift side of the inlet, this not only caused navigation problems, but allowed the steady erosion of the north end of Assateague Island. The continuing erosion threatened to breach the island at the shoreward end of the south jetty. To solve the problems, the south jetty was reconstructed to be impermeable and three segmented offshore breakwaters were constructed in the bay at the north end of the island to insure the island was not breached from the bay side.

Data collection is nearly complete at Ocean City. Profiles have been acquired south of the jetty, bathymetry has been obtained in the inlet, and the structure has been surveyed using side-scan sonar. Directional and non-directional wave data have been obtained as well. These data are being analyzed while the final phase of data collection is being prepared. Ocean City Inlet is an excellent location for a wave-current interaction experiment. Such an experiment is being planned for late summer 1989. A line of wave and current meters will be installed from offshore through the inlet into the bay. These meters will be supplemented with tide gages in the ocean and bay. It is planned to have NASA overfly the inlet during the data collection period with their remote sensing instruments. The results of the efforts at Ocean City are expected to be published during 1991.

Burns Harbor, Indiana

Monitoring at Burns Harbor, Indiana, was initially designed to look at suspected subsidence of the structure. There was an opportunity to look at wave transformation through the structure as well, so gages were located inside and outside the harbor. Shortly after initiation of data collection, complaints were received from a company operating inside the harbor and experiencing waves at their dock that were damaging their barges and ships. The wave data collection effort was expanded to include

data collection in front of the dock. While data analysis continues on the geotechnical aspects of the monitoring program, the wave data have been analyzed and some conclusions drawn. The breakwater cross-section had been physically modeled, so the transformation coefficient had been predicted by the model. Experience at the dock, though, indicated that much larger waves were being transmitted by the structure. However, the data collection revealed that waves transmitted by the breakwater were as predicted by the model tests. It was only at the dock, where wave heights were increased by reflection off sheet pile walls, that there was a problem. So, the structure was performing as designed; it was the dock, built some time after the breakwater, that was the principle cause of problems with moored ships.

Agat Harbor, Guam

Plans were developed to monitor four projects in 1986—Agat Harbor, Guam; East Pass, Florida; Fisherman's Wharf in San Francisco, California; and Siuslaw River, Oregon. Data collection is nearing completion at each of these projects except Agat Harbor. The small boat harbor at Agat will only be completed in 1989, so monitoring has yet to begin. Agat Harbor was designed using the HARBD model (CHEN and HOUSTON, 1987). Gage placement in the actual channel and harbor was determined with the model in mind. The monitoring effort at Agat is intended to test the model with field data. Comparisons made will be another good test of how well the model predicts oscillations resulting from irregular waves. At the same time, other gages will measure the transformation of waves across a coral reef. It has been long felt in the Corps' Pacific Ocean Division that reefs provide more protection than generally accepted. This monitoring effort will test that concept. Data collection is scheduled to begin early in 1990.

East Pass, Florida

The weir at East Pass, in the Florida Panhandle, is an item of some controversy. It was placed in the west jetty after considerable argument. After years of questionable performance, a decision was made to close the weir. Whether a weir was needed and where would be deter-

mined after the beaches responded to the structures without a weir. Hydraulic data were collected in the inlet and at the weir before closure to establish the flows with the weir in the west jetty. Once the weir was closed, those flow measurements were repeated, profiles of the beach up and down coast of the inlet were obtained, and bathymetry in the inlet was taken. Directional wave data were also collected. Data collection will be completed late in 1989 and a report prepared in 1990.

Fisherman's Wharf, San Francisco, California

Another project that was physically modeled was the sheet pile breakwater at Fisherman's Wharf. For years, waves entering through the Golden Gate were causing problems for fishing boats moored at the commercial docks and for the historic fleet maintained by the National Park Service. The breakwater was designed to protect those ships while maintaining circulation in the Fisherman's Wharf complex. Wave, surge, and current data will be collected in the harbor area into 1990. Preliminary indications are that the structure is protecting the ships, has not caused any long wave problems, and has not adversely affected circulation in the area. Although considerable analysis must yet be performed, it appears that this breakwater is an example of a successful design resulting from a physical modeling effort.

Siuslaw River, Oregon

Data collection continues into 1990 at Siuslaw River as well. While the jetties at the Siuslaw River were not modeled, they were designed using the results of jetties for the Rogue River, which were physically modeled. These jetties are quite innovative, incorporating a spur on each jetty about $\frac{1}{3}$ of the way back from the head and angling seaward. The spur is intended to turn the longshore current back updrift, causing the sand it carries to deposit beside the jetties rather than in the channel. Wave data are being collected at the site to define the wave climate. Numerous profiles, both offshore and across the structures, are being obtained to quantify the nearshore changes caused by the spurs. Because of the large waves typically experienced along the Oregon coast, the sur-

veying is being accomplished using a helicopter borne system developed by the Corps' Portland District. Although it appears that the spurs are having an effect, it is too early to say whether they are working as designed.

Bodega Bay, California

The last project at which data have been collected was added to the program in 1987. At Spud Point in Bodega Bay, California, a marina was protected by an unusual breakwater. From the surface, the structure appeared to be just a concrete sheet pile breakwater. But the concrete panels did not extend to the bottom, only the support piles did. The structure was based on the theory that in short, low wave conditions, sufficient protection could be provided without extending the structure to the bottom. A short-term experiment involving ship wakes showed the effectiveness of the design. The preliminary conclusions drawn were that, at high water, the structure is effective in protecting the harbor from any waves likely to be generated within Bodega Bay and, during low water, the extensive mud flats in front of the structure would prevent the generation or propagation of damaging waves. As a side benefit, the structure has little effect on circulation in the Bay. The report should be completed in 1989.

Colorado River, Texas

During 1988, one project was planned: the jetty system at the mouth of the Colorado River, Texas. Planning is underway for four additional projects—Crescent City, California; Folly River, South Carolina; Redondo Beach, California; and Yaquina Bay, Oregon. Data collection will begin at each of these projects in 1990 or 1991, in the case of Yaquina Bay. The projects at the Colorado and Folly Rivers are similar in purpose, in that they are both designed to help better understand the dynamic interaction between waves, currents, and sediments at an inlet. Folly River is a natural inlet, though, while the Colorado River is jettied. At both, waves and currents will be measured and profiles obtained. An attempt will be made to measure sediment transport using presently available instrumentation, including an acoustic doppler current profiler and optical backscatter meters.

Crescent City, California

In 1989, the extensive dolosse monitoring effort at Crescent City, California (HOWELL, 1988), being conducted by CERC for the U.S. Army Engineer District, San Francisco will be completed. Under the MCCP Program, a less intensive program will be continued to determine if the armor units continue to move. Monitoring will consist of periodic surveys supplemented by photogrammetry and side-scan sonar surveys. Monitoring will begin late in 1989.

Redondo Beach, California

Early in 1988, the breakwater at Redondo Beach was damaged in a severe storm. During the design of the structure's rehabilitation, it once again became apparent that current methods of predicting design wave heights are limited in areas where the bathymetry is complicated. The entrance to King Harbor at Redondo Beach is at the head of a submarine canyon, so designers are quite concerned about the accuracy of their estimates of the design wave. Beginning in 1990, the MCCP Program will deploy sufficient wave gages to quantify the transformation of waves from offshore to the structure. These data will be used to test and refine the predictive numerical model RCPWAVE (EBERSOLE *et al.*, 1986). RCPWAVE is used to solve linear, monochromatic wave propagation problems outside the surf zone over arbitrary, albeit regular, contours. It is hoped that the data will either confirm the adequacy of the model for use with more irregular bathymetry or suggest modifications that will result in improved performance.

Yaquina Bay, Oregon

Repeated repairs required on the jetties at Yaquina Bay provide a more difficult problem for the MCCP Program. Unlike other projects monitored under the program, it is not clear what should be monitored at Yaquina Bay. Causes of the problems at the jetties appear quite complex, so considerable effort is being expended to identify those mechanisms and develop a monitoring plan for the project. The monitoring plan is scheduled to be completed early in 1990.

SUMMARY

The need for a program to obtain performance data from prototype coastal projects has been recognized and that program has begun producing results useful to the engineering community. Reports on the first monitoring efforts to be completed are in preparation and two have been published. Additional projects are being or are about to be monitored. Results from the MCCP Program are being used to test the state of the art and assist those who plan, design, construct, operate, and maintain coastal projects. Support for the program continues to grow, insuring its continued expansion.

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□ RÉSUMÉ □

Durant trop longtemps, les ouvrages côtiers ont été construits sans déterminer le succès de leur efficacité, qui n'était contrôlée qu'une fois les ouvrages parachevés. Il a fallu du temps pour accepter l'idée de la nécessité de mieux connaître l'efficacité des projets côtiers, donc de mieux évaluer leurs chances de réussite quand un type de projet avait été accepté. Jusqu'en 1981, il n'existait pas de programme qui satisfasse à ce besoin aux Etats Unis. Cette année, le US Army Corps of Engineers a établi un "programme complémentaire de surveillance des projets côtiers" afin de permettre aux planificateurs, aux concepteurs et aux bâtisseurs de programmes littoraux d'effectuer toutes les estimations dont ils ont besoin.—*Catherine Bressolier (Géomorphologie EPHE, Montrouge, France)*.

□ ZUSAMMENFASSUNG □

Zu lange wurden Küstenbauwerke errichtet ohne die Absicht, den Erfolg ihrer Konstruktion zu kontrollieren. Solche, die nach der Fertigstellung überwacht wurden, waren eher selten. Allerdings ist seit langem die Notwendigkeit anerkannt, daß die Erfolge der Konstruktionen bewertet werden müßten. Bis 1981 gab es jedoch in den USA dafür kein Programm. Im Jahre 1981 hat das U.S. Army Corps of Engineers jedoch ein Überwachungsprogramm für fertiggestellte Küstenbauwerke erstellt, um den Anforderungen der Planer, Designer und Konstrukteure von Küstenbauprojekten zu entsprechen.—*Dieter Kellert, Essen/FRG.*