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Guidelines Based on Physical and Numerical Modeling Studies for Jetty Spur Design at Coastal Inlets

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Abstract

A jetty spur is a relatively short structure that extends from the beachside of a jetty and diverts sediments from entering a navigation channel. A series of physical model laboratory tests with waves and currents was conducted in that varied spur length, spur crest elevation relative to the jetty structure, and spur orientation. Wide and narrow breaker zones were simulated. These experiments were augmented with numerical modeling that coupled waves, depth-averaged current, sediment transport, and morphology change at an inlet. Results indicated that a submerged spur was as effective as a surface-piercing structure in deflecting the seaward-moving current along the jetty, potentially saving construction and maintenance costs. Also it was noted that if the angle of the spur was such that the approaching waves broke initially at the seaward end and progressed breaking in an upcoast direction along the spur face, the ability to deflect a current moving along the jetty axis was enhanced. Recommendations for jetty spur location, elevation, length and angle are discussed.

Keywords: Jetty Spur, Physical Modeling, Numerical Modeling, Inlets and Navigation Channels, Sediment Transport, Morphological Change

Mathematics Subject Classification: 93A30, 93B12, 93B51

JEL Classification: C15, C92.

1 Introduction

A jetty spur is a relatively short structure added to a jetty that flanks and protects a navigation channel through an inlet. The jetty spur may be perpendicular to the jetty, or may be oriented at some angle on either side of the spur perpendicular, usually within ± 45 deg. The spur may be added on the beachside of a jetty to prevent sediment from entering the inlet or may be placed on the channel side to divert the tidal current away from the jetty to reduce scour and possible jetty instability. This paper discusses spurs placed on the beachside (or seaside), of a jetty, as shown in Figure 1.

The spur diverts sediment that would potentially shoal in the channel, back towards the beach, where it can nourish the beach, and thus reduce maintenance dredging volumes. Spurs are usually constructed of rock rubble similar to the connecting jetty. If long-shore sediment transport is primarily unidirectional, sediment will deposit on the up-coast side of

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14. ABSTRACT

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15. SUBJECT TERMS

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the inlet and erode the down-drift beach. For this case, spur jetties can provide a protected area within which land- or water-based equipment can dredge and bypass the accumulated sediment. The spur acts as a deflector for the nearshore current generated from waves breaking at an angle to the main axis of the jetty from, alongshore wind stress, and from tidal current. This current may entrain sand from the beach. The spur's basic function is to alter the path of the sediment-laden current, redirecting it shoreward and up-drift.

Other approaches to addressing sediment-handling at inlets include reorientation of the jetty itself, such as in a dog-leg configuration, where reflected waves from the dog-legged structure create a short-crested wave field that enhances sediment movement along the structure (Silvester 1975) towards the down coast side of the inlet. However, the entrance channel may intercept a part of this sediment and that would contribute to channel shoaling.

Ideally, sediment will eventually be deposited on the beaches adjacent to the jetty. Typically, long-shore and tidal currents are turned seaward as they approach a coastal inlet jetty. Flow is usually seaward along the side of the jetty and, in the absence of a spur, it is typically drawn into the navigation channel during flood tide flow. The region on the beach side of the up-drift jetty may have a fillet, as sand accumulates against the jetty. This sediment may be entrained and carried around the jetty tip and eventually encroach on the navigation channel. During ebb tide, the long-shore flow diverted seaward by the jetty may be parallel to the ebbing channel current, and sediments from the shore side of the jetty can be entrained into the ebb current and delivered to the ebb shoal, where it potentially can bypass naturally to the down-drift beach. However, this sediment may be transported back into the navigation channel by the flood current and result in shoaling or continued transport.

2 Background

A spur can also act as a breakwater and provide wave height reduction along the local shoreline and main jetty, and minimize seaward sediment transport. When added to a weir-jetty system (Seabergh 2002), the spur may provide wave reduction for dredging operations in the deposition basin and minimize sediment transport seaward of the weir (Seabergh 1983). Another possible benefit for a new jetty system with spurs, is that the outer tips of the jetties may not need to extend seaward as far as a system without spurs, because seaward transport along the jetty is minimized (Bottin 1981).

The spur jetty may also be included as part of a beach nourishment plan to aid in maintaining and protecting the sediments in the beach area (Walther and Dombrowski 1999). Beach fill projects tend to saturate the nearshore with sand, and, until equilibrium is reached, excess sediments may move toward the navigation channel. A spur may keep the excess material in the beach zone. The spur could be used on a downdrift jetty, as well as a more typical updrift jetty, if it was thought that the nourished down drift beach might have a tendency to locally feed back along the down coast jetty towards the navigation channel. This could be due to refraction of waves over the ebb shoal. Also, the down-drift spur would function during wave-direction reversals.

Kraus and Heilman (1997) also considered spur jetties for Packery Channel, Texas/USA, to provide beach protection near the jetties. They tested functioning of the spur design with the shoreline response model GENESIS (Hanson 1987; Hanson and Kraus 1989; Gravens et al. 1991). The spurs were eliminated from the design because of concern about the expense of bypassing sediment that would accumulate behind the spurs; the conclusion was that dredging the channel would be less costly.

Previous work concerning spur design is somewhat limited. Sasaki and Sakuramoto (1984) discussed prototype experiments for "rip current barriers," or spurs, at two small-craft harbors in Japan. They recommended that length of the spurs be greater than the surf zone width and that they be located outside the surf zone.

3 Existing Spur Jetties

Spur jetties have been constructed at Bakers Haulover Inlet, FL (Figure 2a), Ft Pierce Inlet, Florida/USA (Figure 2b), at Siuslaw River Inlet, Oregon/USA (Figure 2c), and Shark River, New Jersey/USA (Figure 2d). The north jetty at Bakers Haulover Inlet (Figure 2a) shows a spur placed at the end of the jetty. The south jetty at Bakers Haulover (Figure 2a) also appears to be a form of spur due to its outward flare. The shoreline response on both sides of this inlet is similar. Note that the spur at Ft. Pierce (Figure 2b) is on the down-coast side of the inlet where the shoreline is offset landward from that of the shoreline at the top of this figure. The spur construction was associated with a beach fill project placed on the south beach (bottom portion of the photo) and prevents beach fill from moving into the navigation channel.

The spurs at the Siuslaw River (Figure 2c) were designed to divert sediment back to the beach on both sides of the jetty system. A monitoring study of this project by Pollock et al. (1995), indicated that spur implementation onto the existing jetties was successful in reducing channel maintenance significantly. The Shark River spur is associated with a beach fill on the down coast side of the inlet. The beach extends to the spurs' connection with the jetty. Table 1 summarizes the characteristics of these spurs with regard to length, angle with the jetty, and location along the length of the jetty. Typically spurs are located about 75 percent of the jetty length from the local shoreline. The Bakers Haulover jetty spur is at the end.

4 Physical Model Experiments of Spurs

The field monitoring study of the Siuslaw Inlet project by Pollock et al. (1995) indicated good agreement with physical model results of Bottin (1981, 1997). The field monitoring indicated that at high water the flow patterns were circular eddies and there was a strong seaward-flowing rip current along the jetty. At lower tide stages, and dependent on wave height, there might be an "S"-shaped flow pattern. The results were similar in the physical model study of Bottin. Based on this information it may be noted that wave height, tide stage, and water depth are probably significant design parameters for determining the hydraulic response to spur jetties and most likely the sediment circulation response.

A pilot study of spurs was initiated in the Coastal Inlet Research Program physical inlet model (Seabergh and Krock 2003). The physical model facility (Seabergh 1999) is a large experimental basin (46 m wide by 99 m long) with an idealized inlet and smooth offshore contours (Figure 3). Short-period waves and tidal currents can be simulated in this facility. A scale of 1:50 is applied to this generic inlet configuration. Twin parallel jetties were placed at the inlet entrance, with various spur conditions added to jetty. Wave height, wave period, and tidal currents were varied to produce different surf and along-shore-current conditions.

Experiments included measurement of wave height, measurement of currents in the region on the seaside of the jetty with dye and acoustic-Doppler current meters, and examination of sediment pathways with a lightweight sediment tracer. Initial, or base, experiments collected data for the parallel jetty configuration. Short spurs were then constructed (on the order of 50 m in length, if a 1:50 model to prototype scale is applied). The complete testing program is reported on in Seabergh (2006).

5 Water Circulation Along Beachside of a Jetty

Figure 4 shows a photograph in the laboratory of wave-generated longshore current (emphasized with dye) deflecting offshore along a jetty. Figure 5 shows plots of current magnitude and current direction measured at two different jetty types. One side of the inlet is shown, with incident monochromatic waves (2 m, 11-sec) in relatively deep water approaching initially at a 20-deg angle with the shoreline. The left-hand current vector plot is for a jetty that is porous with respect to wave reflection, typical of rubble-mound breakwaters, and the right-hand current vector plot is for a jetty with a highly reflective surface, typical of vertical sheet pile. In each case the longshore current was deflected seaward. For the porous breakwater, the current approached the jetty and was then deflected seaward along the jetty. For the highly reflective jetty, the reflected waves promoted a clockwise circulation cell along the jetty, shifting the rip current from the beach to about 100-m upcoast. For either jetty type, the alongshore current flowed toward the tip of the jetty, potentially contributing to local beach erosion and channel shoaling.

6 Spur Jetty Effect on Currents

As can be noted in Figure 6, wave breaking was at a distance offshore of about one-half jetty length for the illustrated cases. The modeled wave was 2 m, 11-sec. and 20-deg angle The current generated from this breaking wave was the only forcing condition. A flood tidal current was not reproduced in this set of experiments. The waves plus flood current were included in the sediment tracer experiments. These spurs were constructed in the range for successful design according to Sasaki and Sakuramoto's (1984) guidance. However, many of the spur lengths were shorter than Sasaki and Sakuramoto's suggested guidance (spur length greater than width of the surf zone). Shorter lengths were examined to see if a small footprint structure could effectively deflect the current.

For the illustrated configurations (Figure 6a-6d), the current was strongly deflected ("strong" meaning significantly different direction than the base, 0-deg current) at angles greater than 30-deg from the jetty. The range of current deflection varied from 30- to 90-deg, as measured counter-clockwise from the seaward pointing main axis of the structure. Even a submerged spur (Figure 6b) deflected the current back upcoast due to wave breaking on the spur structure. The crest of the submerged spur was at 0.0 m (low-water datum), with the water surface +1.5 m in a total depth of 4.5 m.

The shoreward angled spur configuration (Figure 6c) was examined in anticipation of creating a counter-current along the seaward face of the spur. This current could potentially be developed if the wave crest would initially make contact with the spur near its attachment to the jetty. As the wave crest moved shoreward, its contact point with the spur traveled upcoast, developing a current as it broke along the structure. This current then helped deflect the longshore current back upcoast. A possible additional benefit is that reflected wave energy, instead of providing greater energy toward the navigation channel in terms of wave height and sediment movement in front of the spur, was directed away from the entrance channel.

The short-crested wave field developed by the incident and reflected wave in front of a coastal structure has been shown to create sediment paths parallel to the structure (Silvester 1975; Seabergh 1983) in the direction of short-crested wave propagation. The angle of the spur was increased relative to the incident wave for this to occur. The spur angle, measured counterclockwise from a perpendicular to the shore (Figure 7), should be greater than the local wave angle, measured in the same manner to the wave crest, in order to create the possibility of a current along the front of the spur structure that is moving away from the channel. Also the short-crested wave field created by the incident and reflected waves will propagate away from the channel, reducing the likelihood of sediment movement toward the channel in the region in front of the spur. Figure 7 illustrates this discussion and Figure 8 shows a sequence of photos with a dye patch moving away form the channel. Note that a berm-type structure creates a platform for waves to break and create the upcoast current movement away from the navigation channel.

7 Sediment Circulation along a Jetty

The current described above would be expected to entrain sediment when combined with the oscillatory current of the incident waves and transport it toward the channel. With the addition of a flood current, there would be additional sediment transport and curvature of the current vectors toward the inlet around the jetty tip. Figure 9 shows the result of an experiment with waves and a flood current using a coal sediment tracer in the physical model. The sediment tracer moved from the upcoast beach face, where it was introduced into the physical model in the surf zone, toward the jetty. The tracer then turned seaward and moved from the base of the jetty towards the jetty tip. The flood current transported the tracer around the jetty tip and into the navigation channel. It should be noted that a flood current need not be present for the sediment to be introduced into the channel. Conditions with waves only will wrap the sediment around the jetty tip, as wave crests are diffracted into the lee of the jetty. The wrapping effect is somewhat dependent on the depth at the jetty tip and the magnitude and direction of the wave.

This section and the previous one illustrate currents that may move sediment from the beach adjacent to a jetty and the resultant sediment movement that may induce navigation channel shoaling. The tendency for sediment movement into the navigation channel follows the popular notion that a coastal inlet is a sink, or depository for coastal sediments.

Figure 9 summarize results of sediment tracer experiments for the same spur configurations discussed previously. However, in addition to the wave-generated current, a steady-state flood flow was set up to simulate a maximum flood current (scaled as 1.0 m/sec in the navigation channel) entering the inlet. This situation would create the greatest potential for sediment to enter the navigation channel. The experiments were run for the same time duration of 30 min for comparability among the various configurations. Also, after 30 min the tracer had relocated and was no longer moving significantly. A qualification for using these results for selection of the best system was the fixed-bed nature of these experiments. In the field, there would be bathymetric change over time that might create an evolving response, e.g., create a morphology that would change the sediment pathway over time. However, the energetic nature of this region would likely reinforce similarity of sediment transport for a lengthy period of time. As seen in Figure 9, only the angled spurs (b) and (c) show no tracer movement on the channel side of the jetty. Figures 9a and 9d indicate tracer accumulated on the channel-side of the jetty (bottom portion of photos). The reinforcing current generated by breaking waves on the seaside of the shoreward angled spur helped deflect sediment back upcoast away from the jetty tip.

8 Numerical Modeling of Spurs

Numerical simulations of waves were performed for a variety of spur configurations. Wave modeling was performed with a CMS-Wave, previously WABED (Wave-Action Balance Equation Diffraction), (Lin et al. 2006; Demirbilek et al. 2007a, b). Circulation and sediment transport modeling is conducted with the CMS-Flow, previously CMS-M2D (Buttolph et al. 2006), a two-dimensional local circulation and sediment transport model. A jetty and three spur configurations were investigated (Figures 10 and 11). The length and width of the jetty is 100 m and 20 m, respectively. The spur is approximately 60 m long and 10 m wide. Two wave conditions were simulated with Hs (significant wave height) = 1 m, Tp (significant wave period) = 8 sec, Dp (primary wave direction) = 30 deg, and Hs = 2 m, Tp = 12 sec, Dp = 30 deg. Wave radiation stresses from CMS-Wave were input to CMS-Flow to calculate wave-induced current and sediment transport. Tides were not included in the simulations. Examples of calculated current fields and bed change patterns are shown in Figures 10, 11 and 12. Qualitatively, numerical model results show similar circulation patterns as compared to the physical model. The effect on currents of a submerged spur is seen in Figure 9 compared to an emergent spur. Areas of potential bed accretion and erosion are clearly visible in the numerical model simulation (Figure 10). A region of strong erosion occurred near the tip of spur and inner side of the inlet jetty.

9 Summary and Conclusions

Spurs on the beachside of jetties can deflect littoral sediment and the longshore current back towards the upcoast direction, potentially reducing shoaling in the navigation channel and perhaps increase navigability. These structures also have the potential to provide wave protection to the beach in the lee of the spur. In certain coastal settings, the spur-jetty system could be designed to support land-based or jet pump dredging equipment to bypass the accumulated sediments to the downcoast or eroding beach. However, the expense and benefits of such an integrated dredging system must be evaluated.

Physical and numerical models were applied to develop and optimize spurs for site-specific conditions. For site-specific design, modeling is most likely necessary to understand complex current and sediment circulation due to varying wave parameters of height, period and direction. Also the effect of offshore bathymetry may be critical in controlling current and sediment circulation in the region just upcoast of the jetty.

The guidelines developed based on this study for practical applications of jetty spurs are summarized next.

Spur Location. The location will depend on local conditions near the jetty, such as bottom slope, wave climate, and proximity of the shoreline. These factors will determine where waves are breaking and where sediment transport will be greatest. The spur should be located seaward of the mean breaker position. For relatively short jetties or a flat bottom slope, wave breaking can occur seaward of a jetty system and sediment transport will be strongest in many cases at the location of the breaker. A spur may not be as useful if this situation is frequent, as there is little opportunity to intercept/divert sediment pathways. For this situation, the jetty may need lengthening. For longer jetties, in order to maximize the likelihood of returning sand to the beach, the spur may need to be placed at some location closer to shore, or multiple spurs could be constructed. However multiple spur design should be carefully studied to ensure diversion of the longshore current in an upcoast and shoreward direction.

Spur Elevation. Spur elevation might typically be expected to be similar to the attached jetty. Dependent on wave climate, the spur can serve as a fishing platform if access is provided. As demonstrated herein, submerged spurs may provide similar benefits as a surface-piercing spur, yet are less costly. However, depending on channel maintenance operations and recreational boaters, a submerged spur may create a navigation hazard, and must be appropriately marked.

Spur Length. The length of the spur should be long enough to promote a diversion of flow from along the jetty and keep sediment in the nearshore area rather than move it offshore towards the jetty tip. Typically one would not want the shoreline to accrete to the spur in order to keep the potential for sand transport on the seaside of the spur minimal. If the shoreline accretes too much, the potential for sediment to work its way to the jetty tip increases. Sasaki and Sakuramoto's (1984) recommendation that length of the spurs be greater than the surf zone width appears to be reasonable. In order to keep length reasonable, a decision based on frequency of occurrence of wave height and period (and thus surf zone width) would likely need to be made.

Spur Angle. If the spur was positioned at jetty tip, then a sharp angle was effective and created a current, due to breakers on the spur, moving away from channel that added to the deflected longshore current on the shoreward side of the spur. Also, wave energy was reflected away from the entrance channel, thus more likely to push sediment shoreward. If a spur location shoreward of jetty tip would be desired, other angles including perpendicular or obtuse to the jetty may prove effective.

Littoral Drift Direction Jetty spurs might be considered beneficial for a region of coast that has a balanced littoral drift environment. This is to say that typically there would be little need to bypass sediment to an eroding down coast region if longshore transport was balanced. The spur concept is to maintain/keep sediment on one side of a jetty, reducing its likelihood to shoal an inlet navigation channel. Spurs would probably direct sediment to a location that would permit its movement back to the beach during a wave direction reversal. Rather than being impounded in the shadow of the jetty, the sediment would be more accessible to sediment reversal wave action.

If bypassing were desired, the spur could potentially direct sediment to a location for dredging. Spurs appear to be useful for beach fill projects adjacent to coastal inlets. As the beach is adjusting to a new equilibrium shape, there is much sediment transport occurring. The spur would reduce the potential for this sediment to enter the navigation channel while the beach fill equilibrates.

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References

Bottin, R.R., Jr., 1981, Siuslaw River Jetty Extension, Oregon, Letter Report, September 1981, Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Bottin, R.R., Jr., 1997, Monitoring Completed Navigation Projects, Lessons Learned III, Coastal Engineering Technical Note CETN VI-29, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Buttolph, A.M., Reed, C.W., Kraus, N.C., Ono, N., Larson, M., Camenen, B., Hanson, H., Wamsley, T., Zundel, A. K., 2006, Two-Dimensional Depth-Averaged Circulation Model CMS-M2D: Version 3.0, Report 2, Sediment Transport and Morphology Change**,** Technical Report ERDC/CHL-TR-06-7, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.

Demirbilek, Z., Lin, L. and Zundel, A., 2007a, WABED in the SMS: Part 2. Graphical Interface. Coastal Inlets Research Program, ERDC/CHL CHETN-I-74. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Demirbilek, Z., Mase, H., Yamada, F., Zheng, J., 2007b, WABED: A Nearshore Spectral Wave Processes Model for Coastal Inlets and Navigation Projects. Coastal Inlets Research Program, ERDC/CHL TR-07-xx (in preparation), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Gravens, M.B., Kraus, N.C. and Hanson, H., 1991, GENESIS: Generalized Model for Simulating Shoreline Change, Instruction Report CERC-89-19, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hanson, H., 1987, GENESIS – A Generalized Shoreline Change Numerical Model for Engineering Use, Report No. 1007, Department of Water Resources Engineering, University of Lund, Lund, Sweden.

Hanson, H. and Kraus, N.C., 1989, GENESIS: Generalized Numerical Modeling System for Simulating Shoreline Change; Report 1, Technical Reference Manual, Technical Report CERC-89-19, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Kraus, N.C. and Heilman, D.J., 1997, Packery Channel Feasibility Study: Inlet Functional Design and Sand Management. Report 1 of a two-part series, Technical Report TAMU-CC-CBI-96-06, Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, Corpus Christi, TX.

Lin, L.,Mase, H., Yamada, F. and Demirbilek, Z., 2006, Wave-Action Balance Diffraction (WABED) Model Tests of Wave Diffraction and Reflection at Inlets. Coastal Inlets Research Program, ERDC/CHL CHETN-III-73. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Pollock, C.E., McGehee, D., Neihaus, R.W., Jr., Chesser, S.A., Livingston, C., 1995, Effectiveness of Spur Jetties at Siuslaw River, Oregon: Report 1, Prototype Monitoring Study, Technical Report CERC-95-14, Coastal Engineering Research Center, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Sasaki, T.O. and Sakuramoto, H., 1984, Effect of Rip Current Barrier on Harbor Shoaling, *Proceedings of the Nineteenth Coastal Engineering Conference*, American Society of Civil Engineers, ASCE Press, New York, 2,091-2,106.

Seabergh, W.C., 1983, Weir jetty performance: Hydraulic and Sedimentary Considerations, Hydraulic Model Investigation, Technical Report HL-83-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Seabergh, W.C., 1999, Physical Model for Coastal Inlet Entrance Studies, Coastal Engineering Technical Note CETN IV-19, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Seabergh, W.C., 2002, Weir Jetties at Coastal Inlets, Part 1: Functional Design Considerations, ERDC/CHL CHETN IV-53, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Seabergh, W.C., 2006, Jetty Spur Functional Design at Coastal Inlets; Effects on Nearshore Circulation and Potential Sediment Movement, ERDC/CHL CHETN IV-66, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Seabergh, W.C. and Krock, J., 2003, Jetty spurs at coastal inlets for reduction of navigation channel shoaling, ERDC/CHL CHETN IV-61, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Seabergh, W.C., Lin, L. and Demirbilek, Z., 2005, Laboratory Study of Hydrodynamics Near Absorbing and Fully Reflecting Jetty, ERDC/CHL Technical Report, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Silvester, R., 1975, Sediment Transmission Across Entrances by Natural Means, *Proceedings, 16th International Association Hydraulic Research Congress I*, 145-156.

Walther, M.P. and Dombrowski, M.R., 1999, Ft. Pierce Inlet Spur Jetty Performance, *Proceedings 12th Annual National Conference on Beach Preservation Technology*, Florida Shore & Beach Preservation Association, 127-142.

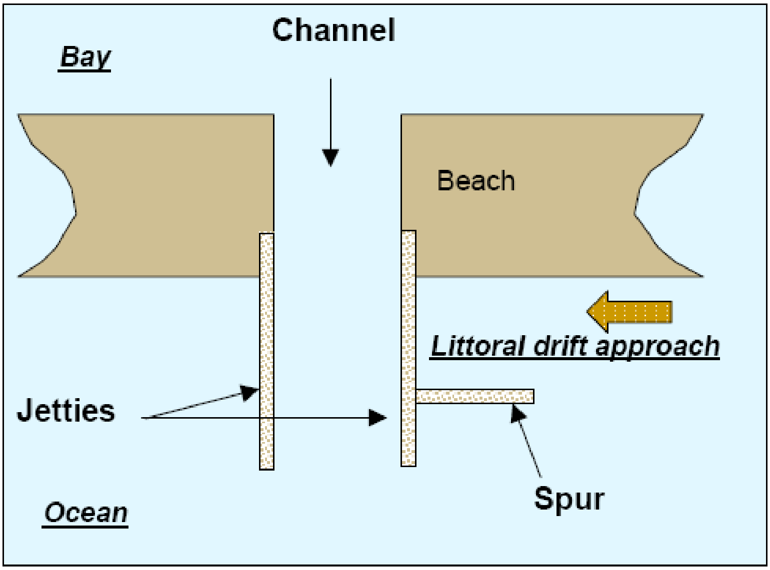

Figure 1: Definition sketch of spur jetty, attached to main jetty that parallels the entrance channel.

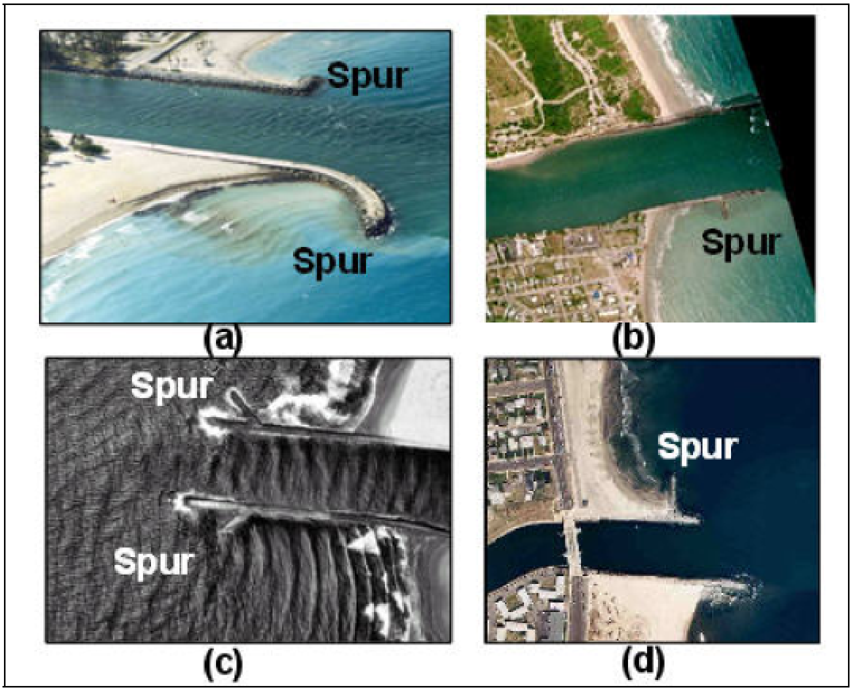

Figure 2: Examples of jetty spurs at (a) Bakers Haulover, FL, (b) Fort Pierce, FL, (c) Siuslaw River, OR, and (d) Shark River, NJ.

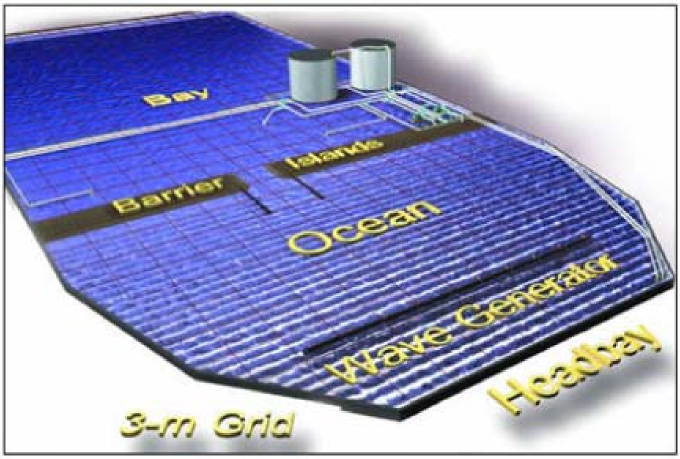

Figure 3: Coastal Inlet Research Program physical inlet model.

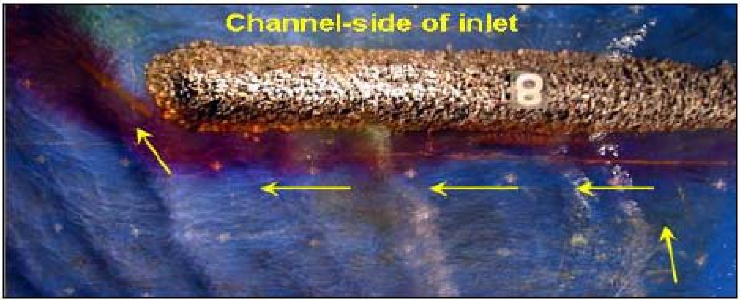

Figure 4: Arrows show direction of water movement due to the alongshore current being deflected offshore by a jetty

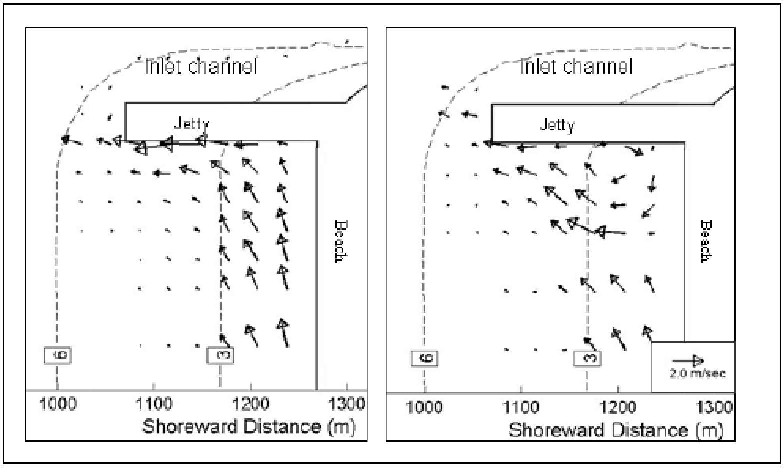

Figure 5: Current vectors produced by wave-generated current approaching a porous, wave absorbing jetty (left side) and a highly reflective jetty (right side). The incident wave angle is 20-deg, in relatively deep water with a 2-m wave height and an 11-sec wave period (data from Seabergh et al. 2005).

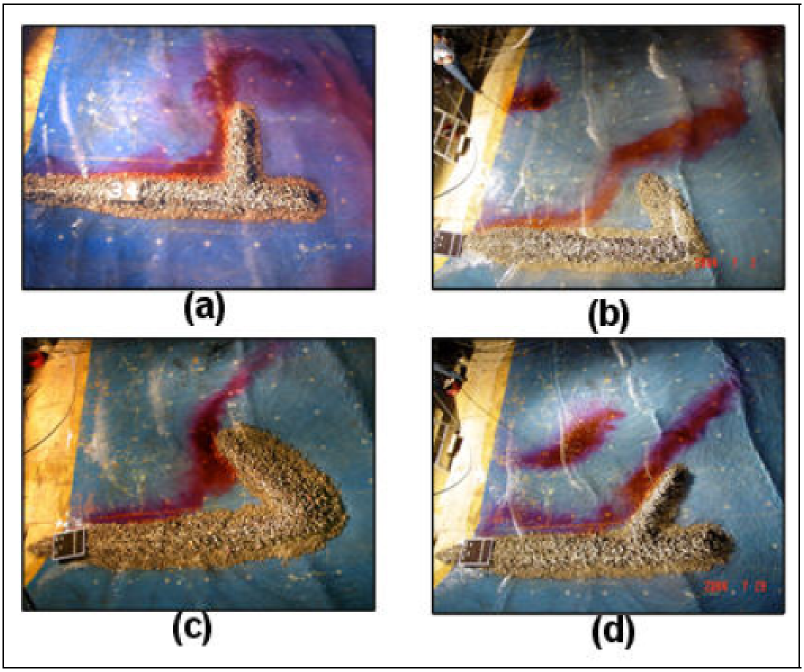

Figure 6: Examples of current deflection by spurs attached to jetties showing the dyed longshore current that moved alongshore toward the jetty and was diverted offshore by the jetty and spur configuration. The current was created by a 2-m high, 11-sec period, breaking wave. Note that (b) is a submerged spur.

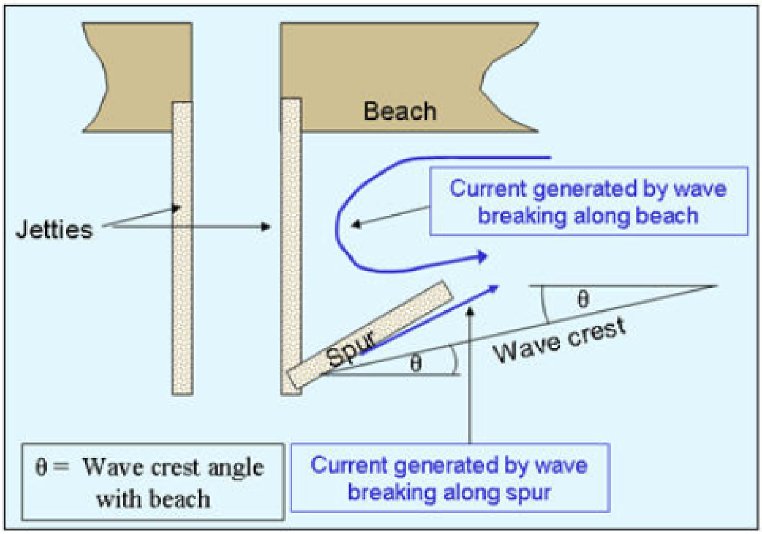

Figure 7: Angled spur helping create breaker-generated current away from entrance channel.

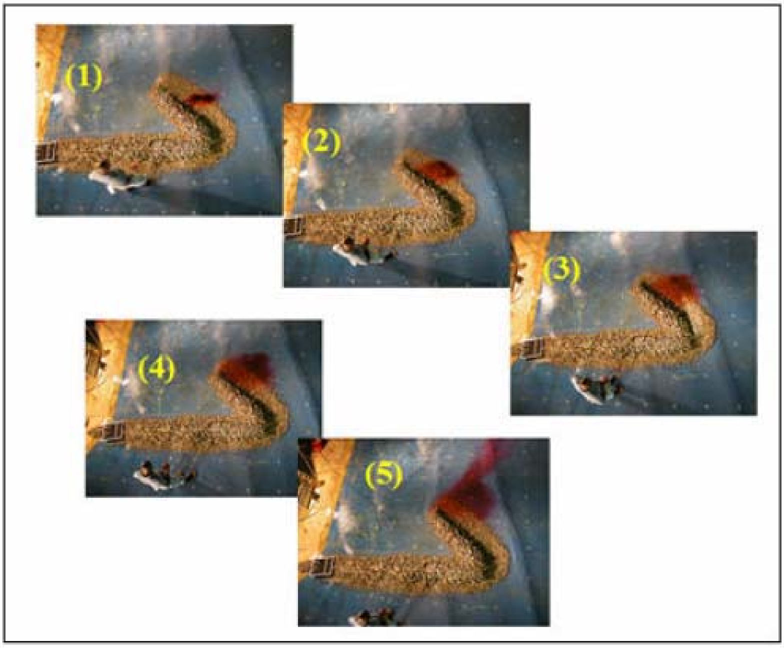

Figure 8: Angled spur showing dye movement along seaward face, upcoast, away from navigation channel (note incident wave approach). Photographs are in sequence 1-5.

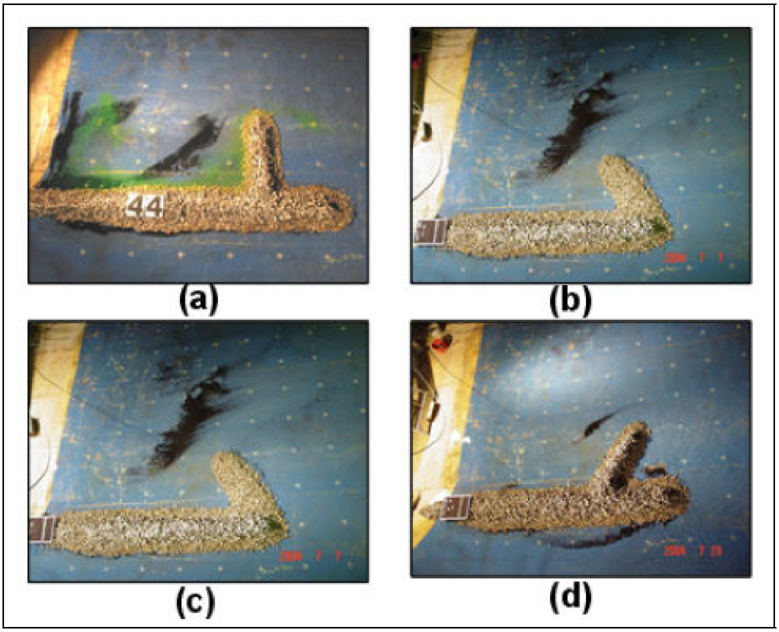

Figure 9: Coal sediment tracer experiments show differences in potential sediment transport by wave-generated and flood tidal currents for spur configurations.

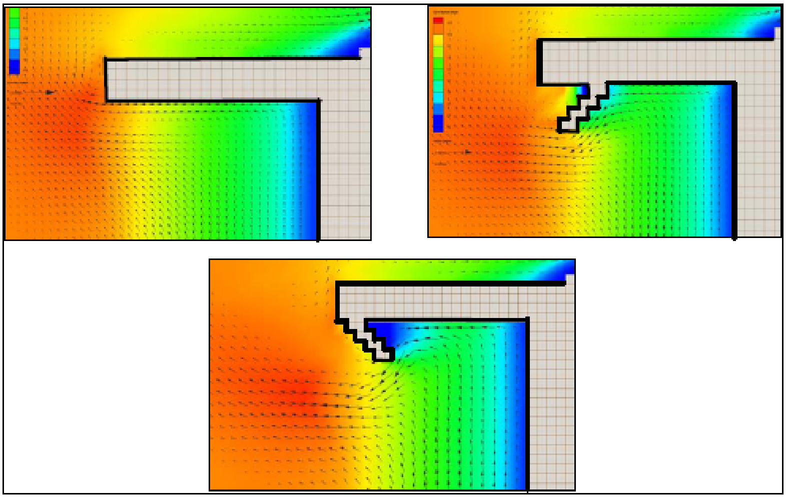

Figure 10: Numerical model results showing longshore flow along jetty without and with spurs.

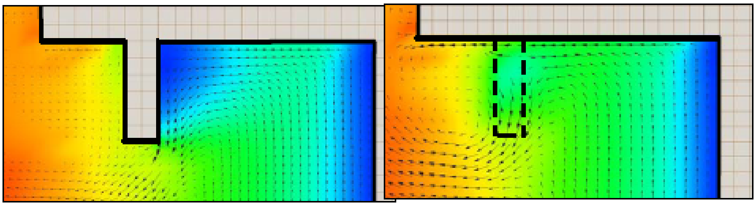

Figure 11: Numerical model results showing currents due to surface-piercing 90-deg spur (left-side) and submerged 90-deg spur (right-side).

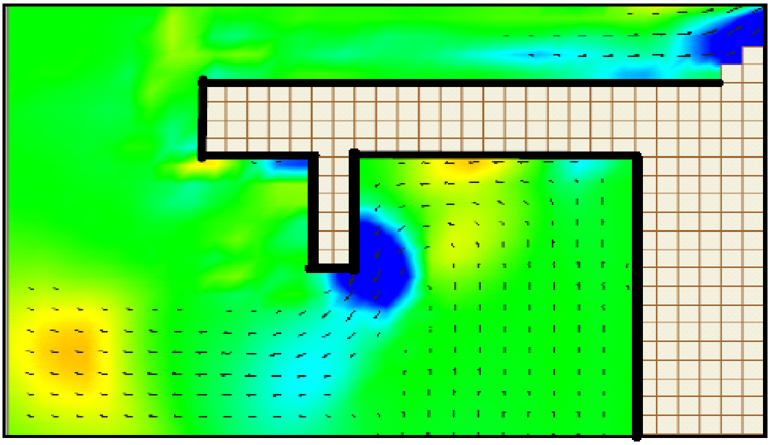

Figure 12: Numerical model results showing morphology change with spur. Dark areas are scour and light areas indicate fill (vectors are velocity).

Table 1. Existing Spur Jetty Installations in United States.

Location	Spur Length, m	(1) Spur Distance From Local Average Shoreline, m (2) Length From Jetty Tip to Local Average Shoreline, m	Ratio of 1 over 2 (from panel to left)	Ratio of Spur Length to Spur Distance from Average Shoreline	Angle (deg) of Spur Relative to Jetty
Siuslaw River, Oregon, USA	North jetty spur-122 or 86 m ⊥ to jetty	(1) 480 (2) 650	0.74	0.18	45 (seaward flare)
	South jetty spur-122 or 86 m ⊥ to jetty	(1) 640 (2) 800	0.80	0.13	45 (seaward flare)
Shark River, New Jersey, USA	North jetty spur-50	(1) 120 (2) 160	0.75	0.42	90
Ft. Pierce Inlet, Florida, USA	South jetty spur-60	(1) 220 (2) 350	0.63	0.27	90
Bakers Haulover Inlet, Florida, USA	North jetty spur- 35	(1) 60 (2) 60	1.00	0.58	90