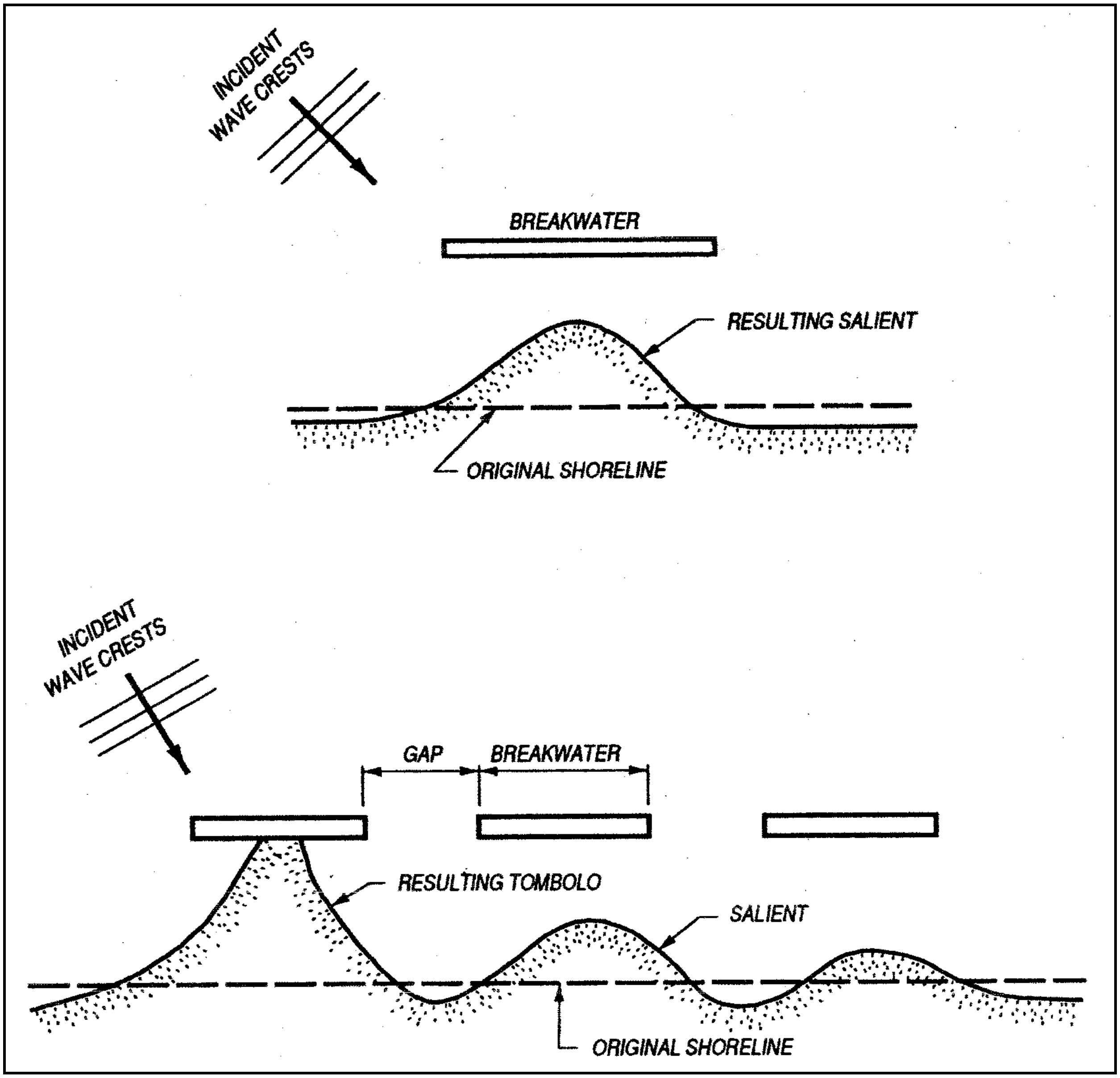

Figure V-3-17. Types of shoreline changes associated with single and multiple breakwater (from EM 1110-2-1617)

information and references on other breakwater classifications can be found in Lesnik (1979), Fulford (1985), Dally and Pope (1986), EM 1110-2-1617 and Chasten et al. (1993).

(2) Physical processes.

(a) Normal morphological responses. Waves breaking at an angle to the shore produce time-averaged, longshore (littoral) currents and longshore sediment transport. Consider the left breakwater in Figure V-3-20 with wave energy in the plus direction. Physical processes at macro-level scales in the vicinity of the breakwater for normal wave and water level conditions are as follows. The breakwater shelters the coast immediately behind the structure and adjacent areas (diffraction) from the incoming waves. Breaking wave heights are smaller in the sheltered areas. The exposed, gap areas have larger breaking wave heights. The

a. Salient with eroded downdrift (longshore drift is from bottom to top)

b. Deteriorated breakwater allowing wave transmission

Figure V-3-18. Santa Monica, California, breakwater and salient (circa 1967). Littoral drift from bottom to top (from Chasten et al. 1993)

Figure V-3-19. Breakwater construction and salients; two views of Presque Isle, Pennsylvania (from Mohr 1994)

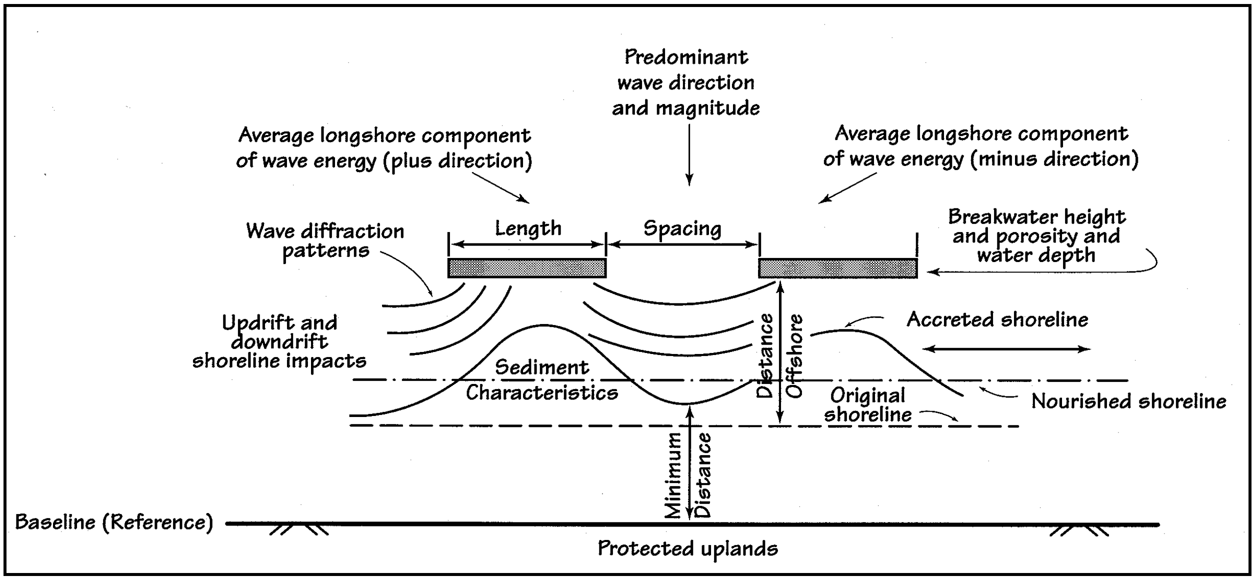

Figure V-3-20. Definition schematic for nearshore breakwaters

wave induced, mean water level change (setup) in the exposed, gap areas is larger than in the sheltered areas. Longshore variability in the wave setup produces gradients in the mean water surface. Water flows from the elevated levels in the gap area towards the lower, sheltered area to accelerate the longshore current flowing towards the sheltered area behind the structure from the left side. These gradients also change the direction of the current which is driven away from the breakwater in the region immediately downdrift of the breakwater (right side). These two current systems (littoral current and setup current) merge behind the structure to give rise to complex circulation patterns. The acceleration of the littoral current updrift causes initial erosion of the beach on the updrift side. The same occurs in the area immediately downdrift. These currents carry the eroded material towards the sheltered area, where it deposits. These mechanisms cause the patterns of deposition behind and erosion on either side that is observed in nature (see Figure V-3-20). The above physical description had been confirmed by a two-dimensional, numerical (horizontal plane) joint processes (waves, currents, sediment transport) morphological modeling system (Zyserman et al. 1998).

(b) Storm processes and response. Protection afforded by the breakwater will limit erosion of the salient during significant storms. The exposed gap area will be eroded with sediment dragged offshore during storms. Breakwater height, length, wave transmission characteristics and distance from shore contribute to its effectiveness to provide a minimum dry beach width, as discussed further in the following paragraphs.

(3) Functional design. Prototype experience for the functional design of nearshore breakwaters in the United States is generally limited to sediment-starved shores with fetch-limited wave climates on the Great Lakes, Chesapeake Bay, and Gulf of Mexico shores (Pope and Dean 1986). Table V-3-4 is a summary of U.S. projects up to 1993 (Chasten et al. 1993). Nearshore breakwaters for shore protection have also been used extensively for shore protection in Japan and Israel (Toyoshima 1982; Goldsmith 1990 (unpublished))[1] and in Denmark, Singapore and Spain (Rosati 1990). Detailed summaries of the literature, previous projects, and design guidance are provided in a number of references (Lesnick 1979; Dally and Pope

[1] Goldsmith, V. 1990. "Engineering Performance of Detached Breakwaters Along the Coast of Israel," *draft report*, Coastal Engineering Research Center, Ft. Belvoir, VA.