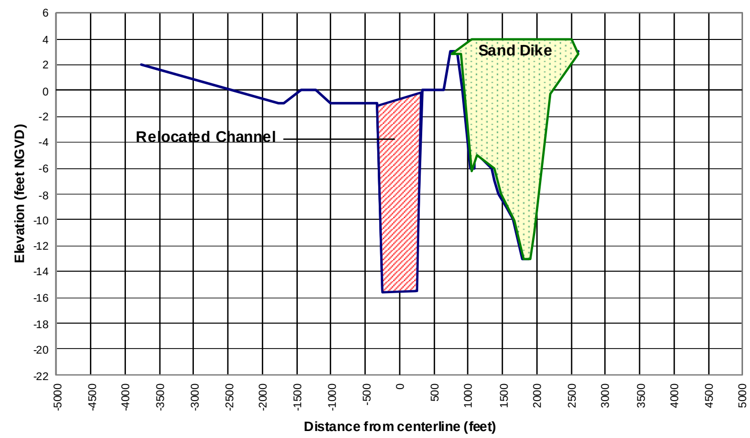
comparable to that of the existing inlet. With the new channel assuming the majority of the flow, the final adjustments in the inlet's cross-sectional area will be the same with or without the sand dike across the existing ebb channel. However, the time required for the adjustments to occur will be somewhat longer without the dike as residual flow would continue to occur in the existing channel thus slowing the rate of shoaling. There is also some degree of uncertainty that the new channel would become the dominant channel if the existing channel is not closed.

5.10. Estimates of the potential shoaling and scour in Bogue Inlet following the relocation of the channel are provided in Tables 5.1(a) and 5.1(b). These potential changes are based on the primary assumption that the existing conditions in the inlet represent quasi-equilibrium conditions and that the final adjusted cross-sectional area for each of the lines will be the same as existing condition. The possible shoal area for each of the cross-section lines (measured below 0-ft NGVD) was determined from assumed shoaling of the existing channel as illustrated by the three examples shown on Figure 5.8. The potential shoal areas given in Tables 5.1(a) and 5.1(b) were for the case without the sand dike. While the potential shoaling will take place over a period of time, the adjustments given in these tables assume that the changes occur immediately after completion of the new channel. With the cross-sectional area along each line reduced by the potential shoal area, the new channel was then assumed to adjust either by scour or shoaling so that the final cross-sectional area of each line was equal to the existing cross-sectional area.

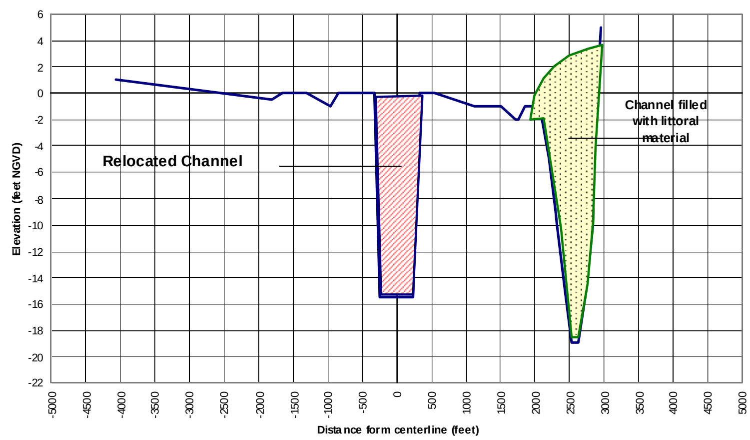
5.11. For the case without the sand dike, the existing channel would eventually be filled with sediment derived from the west end of Emerald Isle and the collapse of the ebb tide delta. A total of 1,493,000 cubic yards of sediment would be needed to completely fill the channel. This is approximately 72% of the volume of sediment expected to be eroded from the west end of Emerald Isle or transported onshore from the collapse of the ebb tide delta. If a sand dike is constructed across the existing channel in the vicinity of cross-section 35+00 as shown on Figure 5.7, 1,006,000 cubic yards would initially be deposited in the channel area seaward of the dike with an additional 184,000 cubic yards eventually working its way to the channel area landward of the dike. For the case without the dike, the numerical model (see discussion below) indicated that a substantial amount of residual flow would persist in the existing channel for some time, which would slow the rate of filling of the existing channel. In this case, the movement of material into the existing channel by wave action along the shore and onshore from the ebb tide delta would be partially offset by ebb tidal currents with the time required for the existing channel to completely fill ranging from 4 to 6 years. With closure of the existing channel, longshore transport would be essentially unimpeded by tidal currents as would the onshore movement of the abandoned ebb tide delta material. In this case, the existing channel is expected to be almost completely filled in 2 years with the sand spit rapidly forming off the west end of Emerald Isle.

5.12. With the flow being directed through the new channel, the cross-sectional area for each line would adjust to an area approaching that of the existing condition. These adjustments are represented by the potential scour/shoal areas and volumes reported in

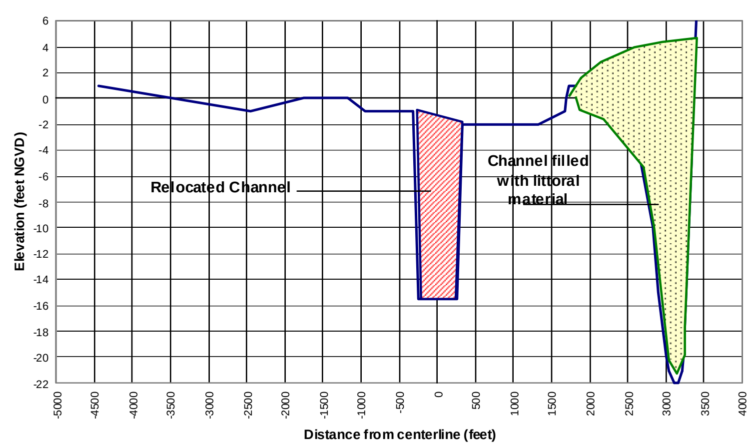
Station 35+00 Cross-Section with 15.5-foot NGVD Channel



Station 40+00 Cross-Section with 15.5-ft NGVD Channel



Station 45+00 Cross-Section with 15.5-ft NGVD Channel



Tables 5.1(a) and 5.1(b) for each of the six channel alternatives. Scour and shoal volumes are summarized for two sections of the channel, namely landward of station 40+00 and seaward of 40+00. For the two 13.5-ft NGVD channels, scour would be predominant in both channel sections even thought some minor shoaling would occur between stations 15+00 and 30+00. Note that these stations are located across the area where the existing channel bifurcates. For the other two channel depths, the channel section landward of station 40+00 would experience a minor amount of net shoaling with the predicted amount of scour seaward of station 40+00 decreasing as the size of the channel increases. The material scoured from the seaward portions of the new channel would be redistributed offshore and toward the sound based on the volume of water flowing through the new channel. Transport of the scoured material would be primarily along the bed of the channel as the material is too coarse to be carried in suspension. As the inlet and channel evolve toward a cross-section comparable to that of the existing inlet, ebb flow through the new channel would dominate. Therefore, the majority of the scoured material would be expected to be transported seaward where it would deposit at the seaward end of the channel and eventually be distributed over the outer portions of the ebb tide delta. The strong flood currents would also be capable of transporting some of the scoured material toward the sound. While a portion of the scoured material would deposit in the landward sections of the channel expected to shoal, the majority of the material would be carried farther back into the sound and deposit on the middle ground shoals, marsh islands, or wetlands. If the material is distributed in accordance with the present dominance of ebb versus flood, approximately 58% of the scoured material would be transported seaward and 42% transported toward the sound. This would result in the distribution of the scoured sediment as given in Table 5.2:

Table 5.2
Predicted Scour Volumes and Distribution of the Scoured Material for the Six Channel Alternatives

Channel Alternative	Total Scour Volume (cubic yards)	Volume to Ebb Tide Delta (cubic yards)	Volume to Sound System (cubic yards)
13.5-ft NGVD x 400 ft	570,000	331,000	239,000
13.5-ft NGVD x 500 ft	470,000	273,000	197,000
15.5-ft NGVD x 400 ft	420,000	244,000	176,000
15.5-ft NGVD x 500 ft	300,000	174,000	126,000
17.5-ft NGVD x 400 ft	270,000	157,000	113,000
17.5-ft NGVD x 500 ft	100,000	58,000	42,000

As a result of the assumptions used in this analysis of channel adjustments, i.e., the final adjusted cross-sections will equal the existing cross-sections, the total volume of material that would be redistributed as a result of the channel relocation project, either directly by the dredging operation or indirectly by subsequent channel adjustments, would be approximately 1.5 million cubic yards for all channel alternatives. The major difference would be the impacts associated with the uncontrolled deposition of the scoured material.

5.13. The material that would be scoured from the new channel area and eventually deposit on the outer portions of the ebb tide delta should not have a significant impact given the highly volatile nature of the ebb tide delta environments. Based on sediment transport rates for the Bogue Inlet area presented earlier, 66% of the material transported seaward would be expected to move to the west and help build the ebb tide delta west of the new channel. The remaining 34% would move to the east and contribute to the shoaling of the seaward portions of the existing channel as well as contribute to the reconfiguration of the ebb tide delta. With regard to deposition in the sound, material would be transported into Eastern Channel and the Dudley Island Channel by flood currents. Based on the distribution of flood flows in these two channels, 80% of the channel adjustment material would be expected to move into Eastern Channel and the remaining 20% into the Dudley Island Channel. With respect to the Eastern Channel, existing flood shoals extend 6,000 feet into the channel and cover an area of approximately 460 acres. The flood shoal area located between Island 2 and Dudley Island covers and additional 115 acres. If the material that is scoured from the new channel is distributed as discussed above, i.e., 80% to Eastern Channel and 20% to Dudley Island Channel, the resulting uniform depths of deposition in each channel would be equal to the depths given in Table 5.3. Of course, deposition in the sound will not be uniform as some areas would experience no shoaling while other could see depth changes of a foot or more. Also some of the scoured material could weld to Island 2 or deposit on the shoreline of Dudley Island. Accordingly, the average depths of deposition are only presented in order to provide tool for evaluating the relative impact of each channel alternative.

Table 5.3
Uniform Depths of Sediment Deposition in Eastern Channel and Dudley Island Channel Resulting from the Adjustments in the New Ebb Channel

Channel Alternative	Volume to Eastern Channel (cubic yards)	Uniform Depth of Deposition in Eastern Channel (feet)	Volume to Dudley Island Channel (cubic yards)	Uniform Depth of Deposition in Dudley Island Channel (feet)
13.5-ft NGVD x 400 ft	191,200	0.26	47,800	0.26
13.5-ft NGVD x 500 ft	157,600	0.21	39,400	0.21
15.5-ft NGVD x 400 ft	140,800	0.19	35,200	0.19
15.5-ft NGVD x 500 ft	100,800	0.15	25,200	0.14
17.5-ft NGVD x 400 ft	90,400	0.12	22,600	0.12
17.5-ft NGVD x 500 ft	33,600	0.05	8,400	0.05

5.14. Hydraulic Stability Analysis. The major concern with the design of the relocated channel is the assurance that the channel will capture the majority of the ebb flow through the inlet and remain open. The construction of the new channel will initially increase the overall cross-sectional area of the inlet, however, as discussed above, the inlet would eventually develop a cross-sectional area comparable to that of the existing inlet. The manner in which the inlet adjust will depend on the hydraulic efficiency of the new channel and whether or not the existing channel is closed with a sand dike or allowed to remain open. A detailed evaluation of the stability of Bogue Inlet is provided in Appendix C in which standard stability criteria (USACE 2000) were used to assess the propensity of the new channel to remain open. The stability analysis is based on two criteria, one involving the hydraulic stability of the inlet and the other the sedimentary stability of the inlet. The hydraulic stability criteria addresses the physical parameters that affect the flow carrying capacity of a channel, namely; cross-sectional area, friction, channel length, and entrance and exit losses. A hydraulic stability curve for Bogue Inlet was computed for a wide range of possible inlet cross-sectional areas with the resulting relationship between inlet cross-sectional area and maximum current velocities shown by

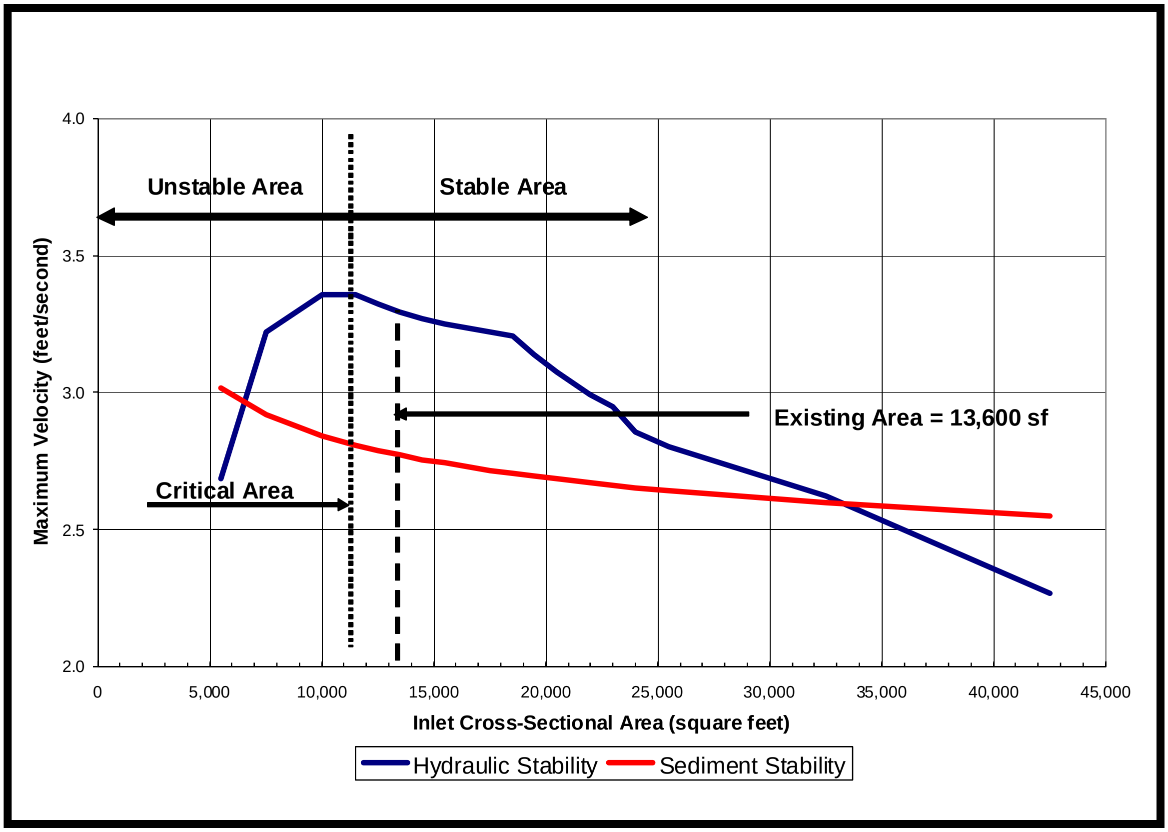


Figure 5.9 Stability Analysis – Bogue Inlet

the curve on Figure 5.9. The hydraulic stability criteria results in a critical area of 11,500 square feet that would produce the maximum velocity through the inlet. As indicated on Figure 5.9, channel areas to the left of the critical area would tend to be unstable, i.e., any change in the cross-sectional that would reduce the size of the channel would result in reduce channel velocities and reduced scour potential. Channel areas to the right of the critical area would be stable as any change in cross-section would result in either scour or shoaling that would return the cross-section back to its initial size.

5.15. The sedimentary stability criteria is fashioned from the relationship between an inlet's cross-sectional area and its tidal prism discussed previously. The velocity-area curve for the sedimentary stability criteria is also shown on Figure 5.9. The hydraulic stability curve and the sedimentary stability curve intersect at two points with cross-sectional areas ranging from 6,500 square feet to 33,500 square feet. While cross-sectional areas between these two values satisfy both the hydraulic and sedimentary criteria, cross-sectional areas between 6,500 square feet and 11,500 square feet would tend to be unstable.

5.16. The cross-sectional area of Bogue Inlet averaged over stations 10+00 to 50+00 (inlet throat section) that would be created immediately following the construction of the six channel alternatives and prior to the closure of the existing channel are given in Tables 5.1(a) and 5.1(b). All six of the cross-sectional areas are considerably larger than the existing channel area averaged for the same stations. As a result, the stability analysis indicates that the cross-sectional area of the inlet throat will immediately begin to shoal and adjust toward its present cross-sectional area. This is consistent with the cross-sectional change analysis presented above. For the case in which the existing channel is allowed to remain open, there would be some competition for the flow between the existing channel and the new channel. While the new channel should provide a more energy efficient path for waters exiting the sound, there is no guarantee that all of the shoaling necessary for the inlet throat to readjust to its present size will only occur in the existing channel. That is, there is still a chance that the new channel could shoal excessively given the reduced velocities associated with the two-channel system. For the case in which a dike is constructed across the existing channel, the effective cross-sectional area of the inlet would be immediately reduced to the values given in Tables 7.1(a) and 7.1(b) (Cross Sec. after shoaling). All six of the channel alternatives satisfy the stability criteria, however, the cross-sectional area of the inlet with the 13.5-ft NGVD x 400 ft channel would be very close to the critical inlet area and would not provide a very large margin for error. Finally, given the uncertainty associated with the prediction of shoaling patterns for the case in which the existing channel is allowed to remain open following channel relocation, the stability analysis strongly supports the mechanical closure of the existing channel.

5.17. <u>Horizontal Stability of New Channel</u>. The preceding discussion focused on the ability of the new channel to capture the majority of the flow through Bogue Inlet and develop cross-sectional flow characteristics that would assure hydraulic stability of the channel. Hydraulic stability, however, is not related to the horizontal stability or migratory tendencies of the channel. In this regard, the existing inlet and associated channel is hydraulically stable but the channel has displayed a high degree of horizontal instability. As discussed in the geomorphic section of this report, the channel has undergone significant changes in position over the years with these changes including major shifts in position over a relatively short period of time and the more recent trend in which the channel has migrated rather steadily to the east. The artificial repositioning of the channel to a more central location between Bogue Banks and Bear Island will essentially emulate a major shift in the channel location similar to that which occurred during the mid 1970's. The artificial reconfiguration of the inlet may forego a future shift in the channel to this central location but will not prevent the relocated channel from migrating either to the east or to the west. While the channel did migrate slightly to the west following mid 1970's natural repositioning, the primary tendency of the channel has been to move toward the east. Based on this historic behavior, the artificially repositioned channel will also have a dominant tendency to migrate to the east.

5.18. Analysis of the changes in the position of the main ebb channel of Bogue Inlet discussed in Section 3 found that the average rate of eastward migration of the channel between February 1984 and September 2001 was 93.3 feet/year (see Figure 3.10). This rather steady rate of migration was preceded by a major movement to the east of over 2,100 feet between September 1981 and February 1984 (a period of 2.4 years). The proposed centerline of the new channel would be located approximately 3,400 feet west of the end of Inlet Drive. If the new channel undergoes the exact changes as exhibited by the existing channel between 1981 and 2001, including the 2,100-foot shift in location over a 2.4-year period, the channel could return to its existing location in about 16 years. If the channel does not make an initial jump to the east and only migrates at the rate determined between February 1984 and September 2001, the channel would not return to its present position for about 36.5 years.

5.19. The time period used in the analysis of channel movements including some significant storm events and storm periods, most notably the active tropical storm period from 1996 to 1999. At the time these latest storms occurred, the channel was already in a position adjacent to the Pointe. Had these storms occurred earlier in the analysis period, they could have influenced the movement of the channel. However, the large shift in the position of the channel that occurred between September 1981 and February 1984 was not a particularly active storm period in terms of tropical events. Given the uncertainty associated with predicting the movement of the channel and using the past movements of the channel as a guide, the relocation of the Bogue Inlet ebb channel to a more central location should provide relief to the Pointe shoreline for a minimum period of 10 years and a maximum period of 35 years.

5.20. Numerical Model. The hydrodynamic evaluation of Bogue Inlet was performed using the Advanced Three-Dimensional Circulation Model for Shelves, Coasts, and Estuaries (ADCIRC, Westerink, et al., 1992). The version used for Bogue Inlet is a two-dimensional, depth-averaged model able to simulate the wetting and drying of shallow tidal flats. The model was constructed from a detailed hydrographic and topographic survey of the inlet obtained by CSE in September and October 2001 with supplemental soundings from the Corps of Engineers and National Ocean Service navigation charts. The model was calibrated and verified with tide and current data also obtained by CSE in September and October 2001. Details of the numerical model investigation are provided in Appendix D with the results summarized below.

5.21. Four (4) simulations were run in the model, namely: (1) Base or existing condition, (2) 15.5-ft NGVD x 500 ft channel, (3) 15.5-ft NGVD x 500 ft channel with a dike across the existing channel, and (4) 15.5-ft NGVD x 500 ft channel with the dike partially completed. While other channel depths and widths are under consideration, the 15.5-ft NGVD x 500 ft channel was considered to be representative of the flow distributions that would result from other channel depths and widths. Current velocities and discharges through various channel sections, corresponding to the same sections reported by CSE in its January 2002 report (CSE January 2002), were recorded from the model results. The location and numbering of the sections is given on Figure 5.10. For reference purposes, Section 6 extends across the existing ebb channel from the end of Inlet Drive to Island 1, Section 4 extends from Island 1 to Island 2 and represents the middle ground shoal of the inlet, Section 3A runs across the White Oak River Channel from the east tip of Bear Island to Island 2, Section 3B extends across the Dudley Island Channel, Section 2 crosses the Eastern Channel between Dudley Island and the Bogue Banks sand spit, and Sections 8 and 9 are located between the inlet and the Atlantic Intracoastal Waterway.

5.22. Comparative results of the numerical model simulations for the Base condition, 15.5-ft NGVD x 500 ft channel, and the 15.5-ft NGVD x 500 ft channel with the Dike are given in Tables 5.4 and 5.5. Table 5.4 provides the model tidal prisms for the inlet and the tidal prisms for the various sections as well as the percent change in the various tidal prisms through each section relative to the base tidal prisms. Table 5.5 presents the model flow distributions through the various sections in terms of the percent of the flood, ebb, and average tidal prism of the inlet measured for that particular condition. For the Base condition, over 70% of the ebb flow passes through Section 6, the existing ebb channel, with Section 4 only carrying about 23% of the flow (Table 5.5). Under base or existing conditions, Section 6 accounts for almost 60% of the total volume of water passing in and out of Bogue Inlet while the middle ground shoal area (Section 4) carries about 35% of the total flow. The model runs for the 15.5-ft NGVD x 500 ft channel with the existing channel open resulted in an overall increase in the tidal prism of the inlet of about 45% (Table 5.4). Even with this overall increase in the tidal prism, the total volume of water flowing through Section 6 decreased by almost 21% compared to the base condition while the flow through Section 4 almost doubled. The percentage of the total flow passing through Section 6 decreased by 26% compared to the base flow distribution with the flow being rerouted through Section 4. While the new channel did capture a significant portion of the total flow, particularly the ebb portion, flows and currents remained fairly high in Section 6 with the average tidal prism for Section 6 only about 21% less than the Base condition (Table 5.4). Over time, the existing channel would be expected to shoal significantly and eventually close, however, with the post-construction velocities and flows remaining rather high in this channel, there would be a continuing threat of erosion along the Pointe shoreline for some period of time, perhaps up to a year or more, following the relocation of the channel. Also, as discussed above, with both channels competing for the flow, there is no guarantee that the new channel would win out over the existing channel. The increased tidal prism of the inlet with both channels open could impact the sound ecosystem by causing frequent flooding in areas that are presently only flooded infrequently. For example, the 45% increase in the tidal prism of Bogue Inlet would increase the tide range in the sound by about 0.5 foot resulting in approximately 0.25-foot increase in the average water levels at high tide. If these higher water levels persisted through most of the 4 to 6 year adjustment period predicted for the without dike case, plant and animal species that are sensitive to water levels would be adversely impacted.

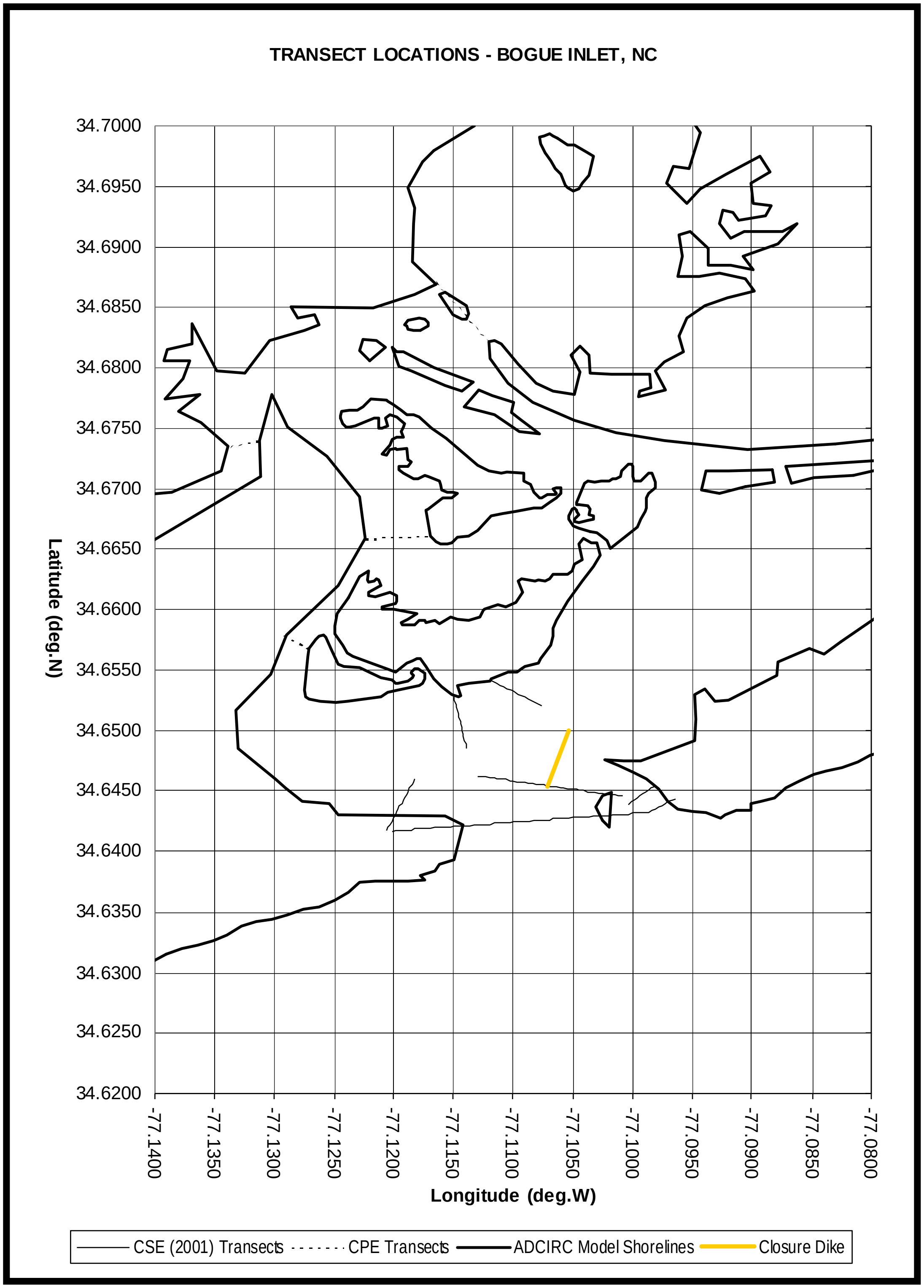


Figure 5.10 Model & Prototype Transect Locations – Bogue Inlet