CHAPTER 92

EFFECT OF CHANNEL DEEPENING ON SALINITY IN THE JAMES ESTUARY

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SUMMARY

The effect of a 10-foot channel deepening on the salinity distribution and net flow were studied in the James Estuary to predict estuarine-wide changes that might disturb the natural conditions favorable to oyster production. A hydraulic model was employed to determine the physical changes; then the potential biological consequences were evaluated by integrating the model data with corollary field and laboratory observations.

THE ESTUARY AND MODEL

The James is relatively shallow, averaging less than 11.5 ft. Estensive shoals have formed between the shore and central channel and, in the middle estuary, oyster bars grow on these shoals in the salinity range of about 5 to 15 $^{o}/oo$. Mean range of the tide is 2.5 ft. and estuary water varies from partly-mixed to well-mixed. The proposed channel which would run 87 miles inland for a width of 300 feet. This is part of series of deepenings that have proceeded with development of the estuary.

The "580-foot" long model reproduced to scales of 1:1000 horizontally and 1:100 vertically, the entire tidal James. To accommodate variable salinities in lower Chesapeake Bay, the model was extended seaward 34 miles from the estuary mouth to nearly constant salinity in the ocean. By varying freshwater inflow and sump salinity like that in the natural estuary, successive roughness adjustments were made to reproduce the mean salinity over a tidal cycle (at 1:1) with time as well as over a range of river inflow. Verification showed that the mean salinity difference between model and prototype was less than + 0.9 and - 1.8 $^{o}/oo$.

EFFECTS OF DEEPENING

Tests were run before and after deepening at several levels of steady freshwater inflow, 11,500, 3,200, and 1,000 cfs at Richmond, and at relatively stable salinity. These conditions were selected because they are critical to control of oyster predation and disease.

The salinity change, though small, was most pronounced in the middle estuary where the major cut was performed (Rocklanding Shoal, Fig. 1). Deepening produced a slight freshening of near-surface water, mainly over the shoals, and an increase of salinity in near-bottom water of the channel. With greater stratification, vertical mixing between upper and lower estuarine layers was reduced. Of the three inflows tested the salinity change was grestest (up to 1.2 $^{o}/oo$ locally) and most widespread at conditions of intermediate flow (3,200 cfs). However, changes were not of sufficient magnitude to cause a significant change in oyster production.

Velocity measurements made with a miniature Price meter in the model over a tidal cycle displayed so much variation within a single cross section and from test to test, they were not satisfactory to calculate changes in the net volume transport produced by deepening. Instead, salt balance equations of Pritchard (1965) were used. Results showed a trend of reduced net trend of reduced net transport in both upper and lower layers reaching 20% in the cross section of the major channel cut.

DISCUSSION

Depth is one of the important parameters - in addition to width, tidal velocity and river inflow - that control estuarine circulation. When other parameters are held constant, the effect of increasing depth is to increase the cross-sectional area of flow, particularly below the level of no-net-motion. Consequently, the same tidal velocities will flush a smaller volume through the section. With greater stratification produced by deepening, tidal forces are less effective in mixing water between the two estuarine layers and consequently net volume transport (up and downstream) is reduced. The overall effect of increasing depth is to shift the salinity regime and circulation pattern from a well-mixed toward a partly-stratified type.

As the need for deeper channels may be expected to continue in the future, it is pertinent to ask: How deep can we go in an estuary before a marked change takes place? Is there a critical or threshold depth beyond which salinity will greatly increase? Further, what optimum river inflow produces the greatest change? These are among the questions formulated for future study in the James, as well as in a new model proposed for all of Chesapeake Bay.

Conference discussion of this and related papers pointed up a need to demonstrate the accuracy and confidence of model results. Hydraulic changes studied by comparing "before and after" conditions demand rigid control of model operation. For example, the ability of a model to establish the same stable salinity conditions over a certain time should be repeated. Then too, what scale is most effective for analyzing salinity regimes in a model? Essential details of the James Estuary model study (1964-1966) as summarized above will be reported in a forthcoming publication. An evaluation of model operation and accuracy is underway.

REFERENCES

Pritchard, D.W., (1965). Dispension of flushing of pollutants. In Evaluation, present state of knowledge of factors affecting tidal hydraulics and related phenomena, C.F. Wicker, editor, Comm. on Tidal Hydraulics. Rept. 3, Chapt. VIII, p. 33-34.

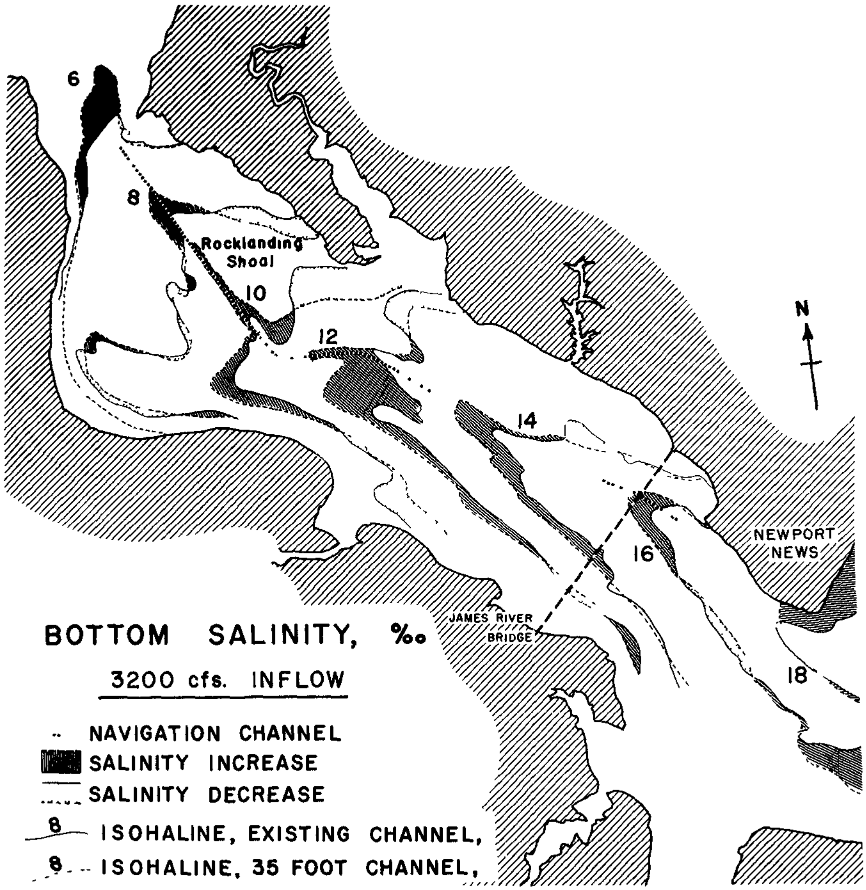

Fig. 1. Distribution of bottom isolines in the model before and after the 10-foot channel deepening.