A Comparison between Dredge Induced Sediment Resuspension and that Produced by Natural Storm Events

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Abstract

Field observations indicate that the effect of dredge-induced resuspension on sediment transport within small estuaries is generally negligible in comparison to the transport induced by natural storm events. Data obtained in the Thames River, near New London, Connecticut show dredge-induced resuspension to be essentially a near field phenomenon. The resultant plume of material increases total suspended load in the river by approximately 25% but extends over less than 2.5% of the total estuarine area. In contrast storms are observed to increase total suspended load by a factor of three, influencing concentration levels throughout the estuary. These factors, in combination with the lower frequency of dredging vis-a-vis significant storm events, appear to effectively limit the influence of dredge-induced resuspension.

Introduction

During the past ten years dredging operations intended to maintain the viability of navigable waterways within the northeastern United States have often been surrounded by intense environmental debate. These coastal areas typically contain sediments contaminated by a variety of organic and inorganic pollutants and concerns have centered on both the short and long-term biological impacts associated with dredge-induced resuspension and disposal related dispersion of these materials. In many cases these concerns have served to slow project completion, forcing rescheduling and, on occasion, have provided a basis for legal injunctions, completely blocking further dredging.

Unfortunately, many of the above activities have proceeded despite the absence of hard data. This has been particularly true for the case of dredge-induced resuspension where, until recently, essentially no information has been available detailing the characteristics of the downstream plume of materials or the significance of this source of suspended sediments vis-a-vis naturally occurring storm events. Within the past three years this situation has improved to some extent and several investigations have been conducted providing insights into the factors governing the distribution of dredge resuspended sediments and the spatial extent of the resultant plume (Bohlen, 1978; Bohlen, et al., 1979). In addition, the increasing amounts of field data have also served to provide a basis for the development of predictive modeling schemes applicable to both clam-shell (Cundy and Bohlen, 1979) and hydraulic (Wilson, 1979) dredging operations.

The detail provided by the above investigations is sufficient also to permit an initial evaluation of the magnitude of dredge-induced resuspension relative to that produced by natural storm events. This paper presents the results of such an evaluation.

Study Area

Since 1974 the Thames River estuary (Fig. 1) located in southeastern Connecticut, approximately 120 km east of New York City, has been the site of several major dredging projects. This stream represents a typical small New England estuary. Annual streamflow varies between 70 and 76 m^3/sec while the mean tidal range equals 0.78 m at New London. The combination serves to distribute sediments supplied from both upstream terrestrial and downstream marine source areas. Typically, these materials consist of fine sands and silts with minor fractions of clay. The effect of winds on these distributions in the estuary appears to be negligible.

Sediment deposition and the resultant shoaling requires periodic dredging to maintain the assigned depth of the navigational channel. Operations usually employ floating cranes equipped with large volume (10 m^3) clam-shell buckets. Spoils are placed in hopper barges for transport to an offshore disposal site. The frequency of those operations over the past six years has provided ample opportunity to study the characteristics of dredge-induced resuspension.

Survey Methods and Procedures

The characteristics of the suspended material field within the Thames River have been the subject of intensive study since 1974. During 1974-76 surveys of a network of 12 stations (selected numbers shown in Fig. 1) were conducted monthly to determine ambient concentrations and the degree of spatial and temporal variability. At each station water samples were obtained at the surface, mid-depth and near bottom, using a 5 ℓ Van Dorn bottle. Samples were placed in pre-washed and rinsed glass bottles and returned to the laboratory. By weight concentrations of total suspended solids were determined for each sample by vacuum filtration, using dried and preweighed Nuclepore filters (0.40 μ pore size, 47 mm dia.) mounted in a standard Millipore filtration apparatus. After careful washing to remove salts each filter was dried and reweighed. Surveys were, in general, confined to the ebb tidal cycle.

In 1977-78 primary emphasis was placed on determinations of the characteristics of the dredge-induced plume of sediments. Several surveys were conducted while the dredge operated near the northern limit of the study area (Fig. 1). The methods used in the surveys have been described in detail in an earlier paper (Bohlen, et al., 1979). Very briefly, optical techniques were used to define the limits of the plume and to establish a network of stations along the defined centerline. Sampling techniques employed at each station and the procedures used to determine the suspended material concentration in each sample were the same as those used for the large scale surveys described above. Here again surveys were conducted only during the ebb phase of the tidal cycle.

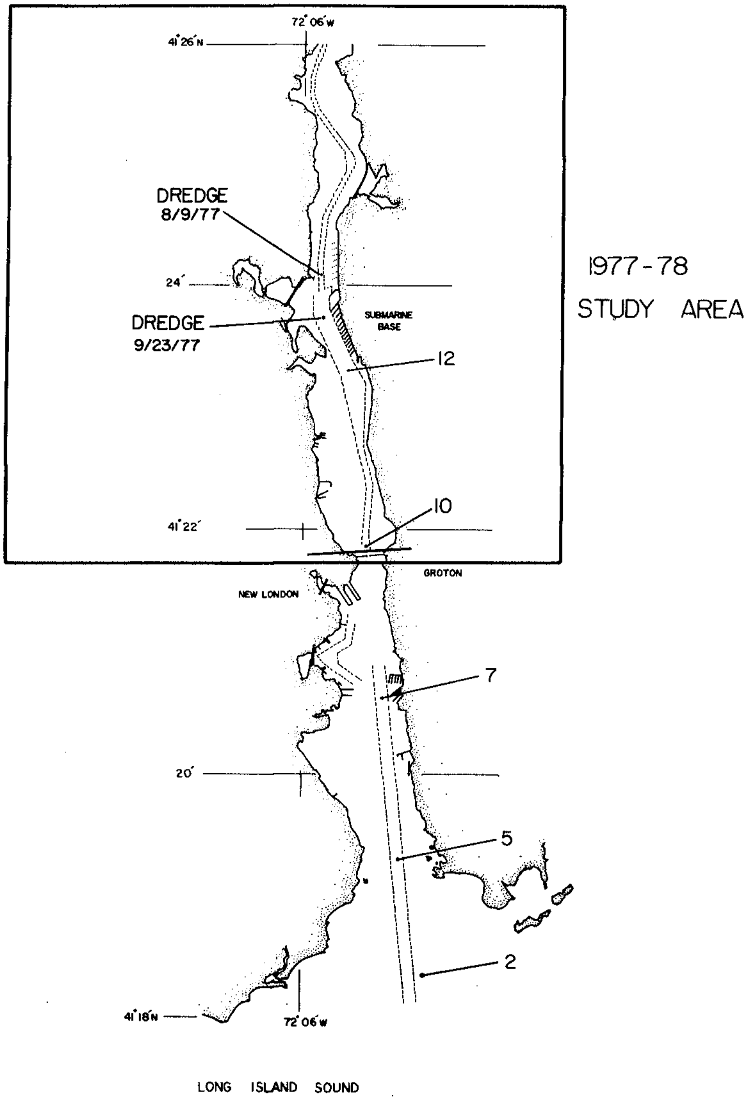

Fig. 1. Lower Thames River Estuary

Results and Conclusions

a. Storm induced resuspension: The suspended material field within the Thames River displays no well-defined seasonal variability (Fig. 2). At each of the main channel stations concentrations averaged between 4.0 and 5.0 mg/ℓ during the major portion of the survey period and displayed only minor variations over the vertical.

The first major concentration anomaly, contrasting sharply with the otherwise persistent homogeneity, occurred on February 1, 1976 coincident with a major storm event. This storm, characterized by long periods (i.e., >24 hrs) of high wind stress and relatively minor precipitation, served to increase material concentrations within the lower river by a factor of four. Proceeding upstream, the magnitude of the increase becomes progressively less with concentrations simply doubling by Station 12. This trend implies that the observed increase is produced by an upstream transport of sediments resuspended by the storm within adjacent Long Island Sound rather than either local resuspension within the estuary or streamflow driven downstream transport. These latter factors would favor distributions differing sharply from that observed. Significant local resuspension tending to produce perturbations of similar magnitude at each station while streamflow dominated transport would favor upstream rather than the observed downstream maxima. This dominance of the offshore source area appears representative of the majority of coastal embayments in southern New England.

A second storm event occurred during March 1977. However, the resultant increase, despite similar storm intensity and duration, was substantially less than that observed during the February event and was largely confined to near bottom waters. Again concentrations decreased progressively with distance upstream further supporting the dominance of the offshore source area.

The response of the suspended material field in the Thames River to the events of February and March, 1976 indicates that storms have the potential to significantly increase the mass of sediments in suspension throughout much of the estuary. At concentrations of 5 mg/ℓ, a reasonable background value (see Fig. 2), approximately 25 X 10^7 gr of sediment would be suspended in the estuary. The storm event of February 1, 1976 increased this load by approximately a factor of three to 75 X 10^7 gr. This was an estuary-wide increase and persisted for nearly two days, the duration of the storm. It is against this response that the effects of dredge-induced resuspension should be evaluated.

b. Dredge-induced resuspension: In contrast to the large scale effects of storms, dredge-induced resuspension appears to be essentially a near field phenomenon. Although the field surveys (Figs. 3 and 4) show that concentrations in the area immediately adjacent to the dredge exceed background by more than a factor of 40, values tend to decrease rapidly with distance downstream. Surface concentrations decay most rapidly and appear to reach background within 200 m downstream of the dredge. Mid-depth and near-bottom values are persistently higher than surface values and approach background within approximately 700 m downstream of the dredge. Under those conditions the surface area impacted by the dredge resuspended plume equals less than 2.5% of the total area of the estuary.

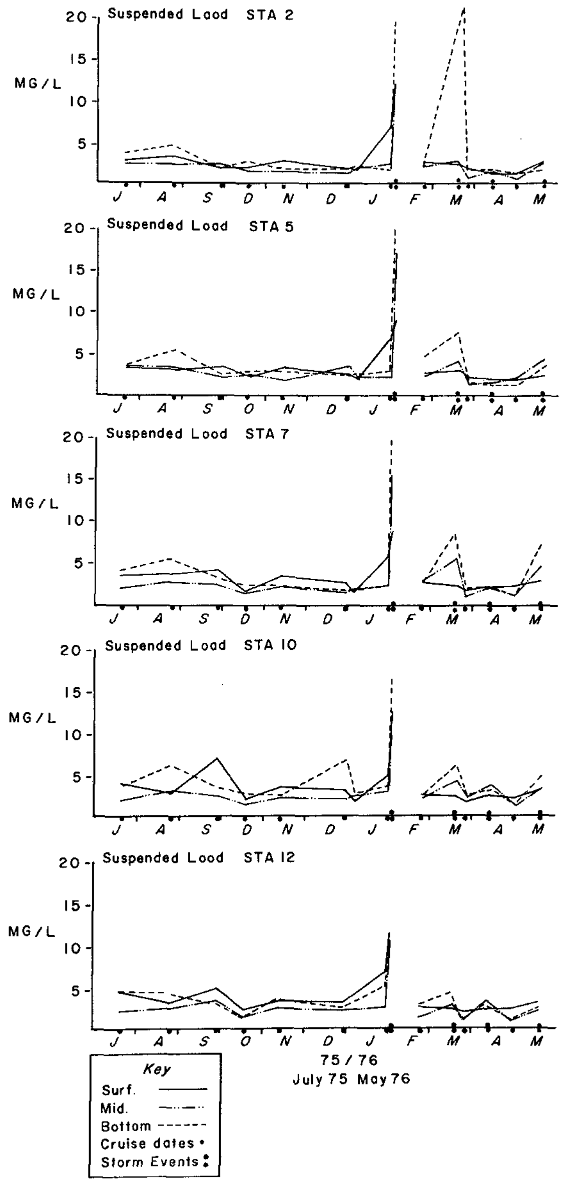

Fig. 2. Suspended Material Concentrations
Thames River 1975-1976

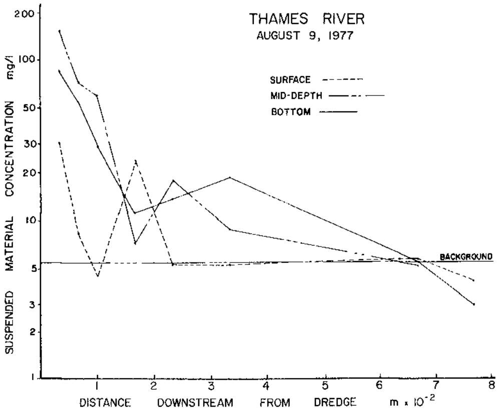

Fig. 3. Suspended material concentrations along the centerline of the plume downstream of the operating dredge. August 9, 1977. (from Bohlen, et al., 1979).

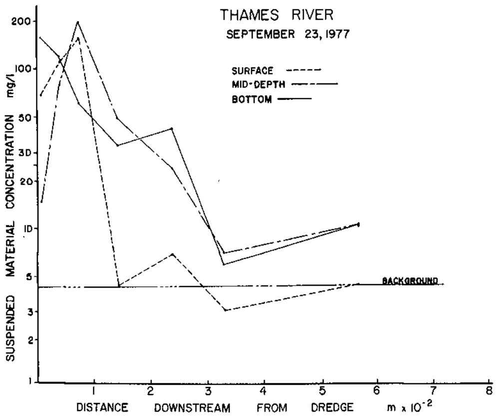

Fig. 4. Suspended material concentrations along the centerline of the plume downstream of the operating dredge, September 23, 1977. (from Bohlen et. al., 1979).

Estimates of the mass of sediment contained in the dredge-induced plume cannot be simply realized since the field measurements were confined to the longstream axis and provide no indication of the cross-stream distributions and concentration levels. Using the optical data to define the plume width, a "worst-case" estimate can be developed assuming that the suspended material concentrations are constant across each lateral section. Using the observed centerline values to define the concentrations at each section, this approach indicates that the plume contains approximately 6 X 10^7 gr of sediment. Comparison of this value with the above estimate of total suspended load indicates that the dredge has the potential to increase the mass of sediment suspended in the estuary by approximately 25%. In terms of transport, however, these resuspended sediments must be considered to be of negligible import since they settle rapidly affecting an extremely small area.

Discussion - Dredge vs. Storm Induced Resuspension

The above observations suggest that the effect of dredging on the suspended material field within the Thames River is generally negligible relative to that produced by naturally occurring storm events. The mass of sediment introduced by the storm exceeds that suspended by the dredge by nearly an order of magnitude. In addition the storm affects an estuary-wide increase whereas the dredge impacts an area representing less than 2.5% of the total river. Dredge effects appear to be further reduced by the characteristic frequency of occurrence of storms as compared to dredging. Reviews of the local meteorological data indicate that storms having an intensity similar to that of the February and March 1976 events can be expected to occur 1 to 3 times each year. Dredging, on the other hand, typically recurs at a rate of once every ten years or so. This combination of light sediment load, small spatial extent and low frequency of occurrence effectively limits the impact of the dredge resuspended plume on the local sediment system.

These conclusions, however, cannot be presented without some qualification. In particular, it's important to remember that this analysis concerns only the suspended sediment transport system and the relative effects of dredging and storms on that system. Although this system will also affect the local biological community and the variety of geochemical cycles, conclusions regarding its response to storms and/or dredging should not be applied haphazardly to these latter systems. The processes governing the interactions beteen sediment resuspension and the local biological community and geochemistry are clearly complex and require additional work. The above comparison is only intended to provide some initial physical insights to complement this work.

Acknowledgements

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References

Bohlen, W.F., 1978. Factors governing the distribution of dredge-resuspended sediments. Proc. 16th Coastal Eng. Conf., Amer. Soc. of Civ. Eng., Hamburg, Germany, 1978, 2001-2019.

Bohlen, W.F., D.F. Cundy and J.M. Tramontano, 1979. Suspended material distributions in the wake of estuarine channel dredging operations. Estuarine and Coastal Marine Science, 9:699-711.

Cundy, D.F. and W.F. Bohlen, 1979. A numerical simulation of the dispersion of sediments suspended by estuarine dredging operations. In: Estuarine and Wetland Processes: with Emphasis on Modeling. Plenum Press (in press).

Wilson, R.E., 1979. A model for the estimation of the concentrations and spatial extent of suspended sediment plumes. Estuarine and Coastal Marine Science, 9:65-78.