delaware estuary study

TESTING AND SAMPLING PROGRAM TO DETERMINE THE NATURE AND SOURCE OF SHOALING IN THE DELAWARE ESTUARY

Dr. Alvin R. Morris
Gilbert M. Horwitz

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

TESTING AND SAMPLING PROGRAM TO DETERMINE THE NATURE AND SOURCE OF SHOALING IN THE DELAWARE ESTUARY

Dr. Alvin R. Morris
Gilbert M. Horwitz

Delaware Basin Study
321 Chestnut Street
Philadelphia, Pa. 19106

October 26, 1967

Colonel W. W. Watkin, Jr.
District Engineer
U. S. Army Corps of Engineers
Custom House, 2nd & Chestnut Sts.
Philadelphia, Pa. 19106

ATTN: Mr. Lewis Caccese
Special Assistant to the District Engineer

Dear Colonel Watkin:

SUBJECT: Testing and Sampling Program to Determine the Nature and Source of Shoaling in the Delaware Estuary

In reference to your letter of May 2, 1967, regarding above subject matter, Dr. Alvin Morris and Mr. Gilbert M. Horwitz of our staff have proposed the following program. Our recommendations relate to Sub Study #2 "The Nature and Source of Shoal". Brief reference was made to those areas of investigation which are presently included in the plan. We have discussed more extensively those methods of testing and analytical determinations which we feel should be implemented into the program. Your attention is directed to three main areas of discussion. First, a determination of the rate of entry of solid matter is mentioned under the paragraph titled "Determination of the Source of the Shoal". This simple analysis will provide an approximation of the rate of entry of solids from the sea with little or no additional sampling required. Second, a discussion of how zeta potential measure ments may provideiinformation relating to the degree of flocculation is presented under "Determination of the Causes of Shoaling". Third, a statistical method of determining the effect of tidal range, tempera ture and fresh water on the amount of silt in suspension in an estuary is presented under "Thermal Effects". This analysis may be performed with available suspended solids, temperature and fresh water flow data

I trust the attached report will assist you in carrying out your progr in this field.

Sincerely yours,

Edward V. Geismar
Project Director

TESTING AND SAMPLING PROGRAM TO DETERMINE THE NATURE AND SOURCE OF SHOALING IN THE DELAWARE ESTUARY

DETERMINATION OF THE NATURE OF THE SHOAL

Composition

The "Organic Sediment Index (OSI)", the product of the percent organic carbon and percent organic nitrogen found in sediment samples normally gives an excellent indication of the relative organic or inorganic nature of the solid material. For example, an OSI of 5-10 indicates actively decomposing sludge, fresh sewage, matted algae or packing-house waste. At the low end of the scale, an OSI of 0 to 0.5 indicates sand, clay or stable sludge[1].

Chemical analysis should be performed on both bottom sediments and water samples. The following analyses will provide the required data for determining the Organic Sediment Index and the quantity of nutrients present:

A. Bottom Samples

(1) Total phosphate
(2) Total iron
(3) Total nitrogen (a) Organic
(b) Ammonia
(c) Nitrate
(4) Volatile Solids - % of dry weight
(5) COD (organic carbon)
(6) Oil and grease
(7) Eh

Analysis of water samples will provide information for determining the quantity of coagulants and nutrients present[2].

B. Water Samples

(1) Cations - Na, K, Ca, Mg, Al, Fe and Mn
(2) Anions - SO_4, PO_4, Cl, NO_3, and HCO_3
(3) Silica
(4) Suspended Solids (a) Fixed
(b) Volatile
(5) Total dissolved solids (a) Fixed
(b) Volatile
(6) Total nitrogen (a) Ammonia
(b) Organic
(7) pH
(8) DO
(9) Phenols
(10) Conductivity
(11) Total coliforms
(12) BOD
(13) Eh

Particle Size

Particle size is an important parameter as it relates to flocculation in an estuary. A variation of flocculation rates is encountered with differences in particle size and with differences in concentration. Also, determination of particle size trends along the estuary may yield information as to the source of solid material. Grab samples of bottom material may be sieved to determine the diameter of the particles and then classified as clay, silt, sand and gravel. Percentages of each fraction of the total dry weight may be determined. Samples should be collected at varying stages of tide along the estuary.

Density

Density relationships are of considerable importance in the calculations on the balance of solids in the estuary. Analysis of dredging spill for moisture content will yield the density. Knowing the volume of material removed the dry weight of solids may be assessed.

In addition to sampling the dredging spoil, grab or core samples of bottom deposits should be analyzed for moisture content. These samples should be taken in key reaches of the estuary and in special areas such as docks. The Thames Estuary Study revealed a relationship between moisture content and the content of organic matter.[3]

DETERMINATION OF THE SOURCE OF THE SHOAL

Rate of Entry of Solid Matter

An approximation of the quantity of the sources of solid material may be made. The mass of material known to be entering the estuary from land sources is compared with that removed by dredging (an approximate allowance is made for the decomposition of solid matter). The difference between the two values is a crude estimate of the quantity of matter entering the estuary from the sea. However, it is suggested that these values be used as a first approximation until such time as testing results allow refinement of the figures.

The known sources of solid matter are the Del. River above Trenton, tributaries sewage effluent and industrial discharges. The U.S.G.S. can provide data on the first 2 sources and the Delaware Basin Project the last two.

The known losses of solid material are dredging and decomposition. It has not been possible to directly determine the rate of deposition in estuary studies to date. It is, therefore, necessary to assume that the rate of deposition is equal to the long term average rate of removal by dredging. The Delaware Basin Project will provide an estimate of decomposition of solid material.

DETERMINATION OF THE CAUSES OF SHOALING

Hydraulic Causes of Shoaling

There are numerous difficulties inherent in the mechanics of sediment transport by streams even under well-controlled laboratory conditions. Tidewater sedimentation problems are more difficult by another order of magnitude. As a result, prediction of the rate of transport of shoaling materials in estuaries cannot be attempted until a large number of variables pertinent to the problem are much better understood than at present.[4]

Successful time-of-travel measurements of sediment have been made by the U.S.G.S. by means of tracing solid particles of a desirable particle size impregnated with a fluorescent dye. An alternate method would be to use natural fluorescent minerals for tracing. However, even with time-of-travel information definition a number of variables remains.

Electrochemical Effect

It would appear from a preliminary appraisal of the Delaware Estuary that the physico-chemical process of flocculation is a prominent cause of shoaling. Negatively charged clay minerals flocculate in sea water especially under the influence of polyvalent ions such as Ca and Mg. If the electrolytic potential of a particle decreases below a critical value coagulation occurs. Flocculation may occur upstream of the salt boundaries because of the presence of polyvalent cations in industrial wastes and excessive amounts of particulate organic sewage which act as a binding substance for fine grained particles.[5]

The phenomena described above suggests a testing program which includes measurements of zeta potential in suspected flocculation areas and chemical analysis for the presence of polyvalent ions such as Ca, Mg and Al.

Because of structural differences, every type of clay mineral may flocculate in a different manner. The most common clay types are kaolinite, illite, montmorillonite; less common are vermiculite and chlorite. The latter mineral is frequently found in marine sediments. Identification of clays in the estuary may provide some information as to mineral source

Experiments have shown that flocculation of kaolinites and illites is mainly completed at very low chlorinity whereas flocculation of montmorillonite increases gradually with increasing chlorinity.

Zeta Potential Measurements

Zeta potential measurements may provide useful information relating to the degree of flocculation occurring in a critical shoaling area. If the electrolytic potential of a particle decreases below a critical value coagulation occurs. Zeta meter readings may indicate a large amount of flocculation contribution to the river bed. If this is the case then continuous readings should be taken. Also, analysis of water samples for pH and alkalinity should be performed since these two parameters affect the flocculation process.

Just as water treatment plants take steps to maintain a zeta potential close to zero to promote flocculation, we may take steps to raise the zeta potential above the critical value to reduce flocculation. For example, restricting entry to the estuary of chemical polyvalent compounds and clays which are the constituents of the floc may alleviate the shoaling problem.

Thermal Effects

In general, the solubility of solids in liquids increases as the temperature increases. Based on this solubility principle suspended solids content would be highest during the winter months. Determination of seasonal variation of suspended solids concentration should confirm this phenomena. The British Transport Docks Research Station has designed and made instruments which continuously record the concentration of silt in suspension.[6] Using these records a regression analysis was performed with the average silt in suspension over a tide as the dependent variable and tidal range, river temperature and fresh water entering the estuary as the independent variables. Significance testing was performed to assess the relative importance of each of the three independent variables on the silt concentration. Temperature and tidal range were found to exert more influence on silt concentration than fresh water.

Sampling

A copy of a sampling program to determine the effects of dredging in Cleveland Harbor on the water quality of Lake Erie has been forwarded to the Corps of Engineers, Philadelphia, from the Buffalo Corps of Engineers. This program appears to be adequate for application to the Delaware Estuary. Therefore, repetition of these methods will be omitted from this paper.

Ecological Effects of Dredging on the Estuary

The following material will discuss the important components of an ecological study with reference to the effects of dredging on the estuary. It will define the types of programs felt to be most valuable and give the reasons behind the suggested sampling program. However, this paper will not define exactly how samples are to be gathered because the organization doing the work will have certain preferences in collecting apparatus and also final selection of sampling techniques will be contingent upon the exact area to be sampled and the collection program finally decided upon.

Study of the ecological effects of dredging gives use to three general considerations. The geographical areas that are affected, a quantitativ and qualitative appraisal of the organisms involved, and whether the effects are of long or short duration.

Short term effects are those of generally minor importance taking in the order of 2-4 weeks for recovery after dredging ceases. Long term effects are those in which remedy would require months to years to recover.

The organisms affected by dredging fall into five general groups: (1) bottom organisms, those predominantly living on or in the bottom material, (2) plankton and periphyton, floating and attached microscopic plants and animals, (3) zooplankton, the smaller invertebrate animals predominantly found swimming in the water column, (4) aquatic vertebrate in this case predominantly fish, (5) terrestial wildlife and waterfowl.

For economic, ecologic, and water quality reasons the estuary may be split in two parts, the upper and the lower, with the Delaware Memorial Bridge forming the division.

Upper River

In the upper river there are two existing phenomena which are acting to depress the number of species present. First is the natural transit from fresh water species to marine species. Thus as one proceeds down an estuary the number of fresh water species gradually declines and the salt water species gradually increase. The number of species which can inhabit the transition zone is not as great as the numbers which can exist in either fresh or marine habitats. Second, the large existing pollution load in the upper river has severely affected all organisms. Existing information indicates that the benthic organisms are of very few species and low in quantity[7], the zooplankton are of very few species and quite seasonal in occurrence[8], and the fish are of low quantity and quality[9]. The major affect of dredging on wildlife in the upper river is the filling of marshland thus completely eliminating feeding areas and habitat. This is of little significance in upper river as most marshland used by wildlife has already been destroyed. This leaves the floating and attached organisms as the only ones which could show an affect of dredging.

A Sampling Program, however, can be used to get data on three possible ecologic effects: (1) temporary effects from depressed dissolved oxygen, (2) effect on existing plankton and periphyton, (3) inferred damage by sampling silt fall-out.

Suggested Sampling Program

It is suggested that sampling points be established at 2000 foot intervals from the dredge to a distance of 10,000 feet on 90^{o} radii from the dredge and that samples be spaced before, during, and after the dredging occurs. Representative sampling points should also be established in the locations affected by return water from spoil areas.

(1) Periphyton (attached growth) or secondarily plankton studies to show the variation in types and numbers of all attached forms not just one sub group, e.g. diatoms.

(2) Bottom sampling with a corer or Peterson-type dredge. This will give an indication of how much and where the disturbed material settles and thus be an indicator of the area where fish spawning beds would be silted and where bottom organisms would be covered and hence killed.

(3) Dissolved oxygen measurements 5 feet below the surface and 5 feet off the bottom. This would permit evaluation of localized oxygen depletion which can be lethal to the indigenous biota.

Turbidity and temperature measurements would be useful in interpreting the above data.

Lower River

While the upper river, is for several reasons, virtually a biological desert, the lower river is just the opposite. In fact it has been reported as ranking just below some of the most productive marine areas of the world[8]. More than 150 species of finfish and 10 species of shellfish have been collected[10]. The annual harvest of finfish and shellfish is approximately eight million dollars.

The effect of dredging in the lower river would probably have the most drastic effect on the benthos by destroying the habitat of bottom dwelling organisms such as the oyster, crab, and clam. Thus we feel it would be advantageous to sample changing benthic conditions in a way that will show what is there before dredging, what remains after, and how long the bottom takes to recover.

In the lower river the large zooplankton populations form a major part of the food of many of the fish species. If the effect on the zooplankton is pronounced, it might have serious effect on the area fisheries, e.g. weakfish, and menhadden.

Another part of the picture will be provided by the floating and attached plants (i.e. plankton and periphyton) which are the main food of the zooplankton and some fish. If the microscopic plants are affected, the organisms which are dependent upon them will be affected too.

While the fish may be affected because of detriment to the organisms on which they feed, they are mobile enough to move away from the influence of the dredging. Hence unless the area of dredging is extremely large the fish probably would not be grossly affected.

Wildlife would be affected primarily by filling of habitat and feeding areas with dredging spoil.

Suggested Sampling Program Lower River

The following program is suggested for sampling points spaced when possible, on 90^{o} radii around the dredge at 2000 foot intervals to a distance of about 10,000 feet. After initial sampling is completed, the sampling points may have to be adjusted to give a more adequate description of the affected area.

1. Bottom sampling with a Peterson dredge, (possible augmented with a corer) Sampling before and after dredging and continuing until the bottom is repopulated with organisms.

    (a) determine what organisms inhabit the area and in what density.

    (b) how long is required for repopulation to occur.

    (c) whether repopulation is by the same organisms as were present prior to dredging and whether the population densities are changed.

    (d) how extensive (area covered, depth) is the area affected by siltation.

2. Vertical and horizontal net tows for zooplankton. By comparing the results of affected and control stations it should be possible to describe the affect on this important part of the food chain. More specifically one should be able to say whether any affect was directly on the zooplankton or on the food organisms fed on by them.

3. A study of the attached and or planktonic microscopic plants including all species present not just limited to one sub-group e.g. diatoms. This information will provide information of the primary producers, i.e. the basic plants upon which all other organisms depend.

Coupled with the above should be physical-chemical samples of temperature, turbidity, and dissolved oxygen at depths of 5 feet from the top and bottom.

It is felt that the above program will give a moderately wide spectrum analysis of the ecological effects of dredging. The results should indicate the magnitude of the damage and give some indication of whether more specific work is required.

References

1. Ballinger, D.G., G.D. McKee: Chemical Characterization of Bottom Sediments, FWPCA Report, unpublished

2. Sampling Program, Buffalo River Dredging and Pilot Disposal Area Buffalo Harbor, New York, unpublished

3. Thames Survey Committee and the Water Pollution Research Laboratory; Effects of Polluting Discharges on the Thames Estuary, 1964

4. Ippen, A.T. et all: Estuary and Coastline HydroDynamics

5. Lauff, G.H.: Estuaries, Publication No. 83 American Association for the Advancement of Science, Washington, D.C 1967

6. Jackson, W.H.: Effect of Tidal Range, Temperature and Fresh Water on the Amount of Silt in Suspension in an Estuary, Nature, March 7, 1964

7. Delaware Estuary Comprehensive Study Records, unpublished

8. Cronin, L.E., J.C. Daiber, and E.M. Hulbert: Quantitative Seasonal Aspects of Zooplankton in the Delaware River Estuary. Chesapeake Science, Vol. 3, No. 2, January 1962

9. Malcolm, J.W. Fish Studies: A Progress Report. Presentation at the Annual Delaware River Basin Water Resources Conference October 19, 1964

10. DeSylva, D.P., F.A. Kalber, C.N. Shuster: Fishes in the Shore Zone and Other Areas of the Delaware River Estuary, University of Delaware Marine Laboratories, Pub. #5, 1962