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Observations Of Rate Of Change In Sediment Concentration With Respect To Changing Hydraulic Conditions At Head Of A Reservoir

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OBSERVATIONS OF RATE OF CHANGE IN SEDIMENT CONCENTRATION WITH RESPECT TO CHANGING HYDRAULIC CONDITIONS AT HEAD OF A RESERVOIR

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Introduction. A study to correlate data on the rate of change in suspended sediment concentration with respect to changing hydraulic conditions in the backwater reach at the head of a reservoir has been initiated for the purpose of better understanding the phenomena associated with development and growth of a delta at the head of a reservoir and to aid in eventual development of a reliable method for computing the rate of growth, location and volume of a delta. The backwater reach as defined for this study, is the transition at the head of the reservoir between the natural river channel and the level reservoir pool.

Scope. Field data used in this study are from several reservoirs and include suspended sand, silt and clay concentrations at ranges through the backwater reach and mean depth, water surface slope and mean velocity at the same ranges. Suspended sediment concentration decreases in a downstream direction through the backwater reach, and the transport characteristics change in a similar manner. The transport characteristics used in this study are (1) the mean velocity, V; (2) a shear velocity $\sqrt{DSg}$, where S is the water surface slope, D is the mean depth of flow and g is the acceleration due to gravity; and (3) the Froude number $F = V/\sqrt{gD}$. A ratio C_n/C_1 of the sediment concentration, C_n, at selected ranges through the backwater reach to the sediment concentration, C_1, in the

river channel upstream from the influence of backwater is developed. Also developed are ratios V_n/V_1, D_nS_n/D_1S_1, and $V_n/\sqrt{gD_n} + V_1/\sqrt{gD_1}$ for the hydraulic conditions at each range to those in the river channel up stream. The sediment concentration ratios for sand, silt and clay are plotted against the hydraulic ratios in an attempt to obtain a dimensionless relation which will represent the change in sediment concentration with respect to changing hydraulic conditions through the backwater reach.

Use of Results. The completed graphs are intended to furnish a basis for computing delta growth when certain basic factors are known. Entering the graphs with known hydraulic conditions in the river up stream and at selected ranges in the backwater reach, and known sediment concentration in the river upstream from the reservoir, the sediment concentration may be estimated at each range in the backwater reach. The quantity and location of sediment deposited in the delta may then be computed from the difference in sediment concentration at adjacent ranges.

Garrison Reservoir Data. A survey was made by Garrison District on 6-9 July 1954 for the purpose of obtaining data on the suspended sediment concentration and hydraulic conditions in the backwater reach at the head of the Garrison Reservoir pool. Suspended sediment samples were taken at each of 8 aggradation ranges, which covered a distance of about 45 miles through the backwater reach at the head of the Garrison Reservoir pool, during a two-day period when the pool level and reservoir inflow were relatively stable. At these same ranges, water surface slope, water surface elevation and area of flow section were obtained for determining the hydraulic conditions through the backwater reach. Discharge, stage

and suspended sediment samples were obtained at the old Sanish bridge during the study for a record of conditions in the river upstream from the influence of backwater. Sediment and hydraulic data collected during the survey are shown in Figures 1 through 5 and Tables 1 and 2.

Data From Other Reservoirs. Garrison and Fort Peck Districts cooperated in the collection of sediment and hydraulic data from the backwater reach at the head of Fort Peck Reservoir, 2-12 June 1953. These data are presented in Figures 6 through 12 and Tables 3 and 4. Data for Fort Randall Reservoir were obtained from a report, "Observations on Sediment at Fort Randall Reservoir, 1953," prepared by Omaha District, and are presented in Figures 13 through 15 and Tables 5 and 6. Data for Denison Reservoir were obtained from Interim Progress Report on Sedimentation Investigations in the Tulsa District, September 1946, Second Interim Progress Report, Sediment Investigations, Tulsa District, February 1949, and Report of Sedimentation Survey, Denison Dam and Reservoir, Tulsa District, June 1950. These data are presented in Figures 16 through 21 and Tables 7 and 8.

Relation of Sediment and Hydraulic Conditions. The ratio, C_n/C_1, of suspended sediment concentration, C_n, for sand, silt and clay at selected ranges through the backwater reach, to the concentration, C_1, in the river channel upstream from the influence of backwater, is plotted against the ratio of the hydraulic conditions at the corresponding locations to establish a relation between sediment and hydraulic conditions through the backwater reach. This relationship assumes that the discharge and sediment inflow are constant and changes in each result from the transition between the natural river channel and the level pool of the

reservoir. The hydraulic conditions used are: mean velocity, V, plotted on Figures 22-24; shear velocity, $\sqrt{DSg}$ reduced to DS, on Figures 25-27; and the Froude number, $V/\sqrt{gD}$, on Figures 28-30. Data from Garrison, Fort Peck, Fort Randall, and Denison Reservoirs are plotted on all graphs.

The data from Denison Reservoir is scattered on all the concentration-hydraulic condition relationship graphs. This is because the hydraulic conditions are computed from estimated sections based on measurements obtained at times other than when the samples were taken. Areas and widths for the channels in 1946 and 1947 when the sediment samples were taken were obtained from estimated cross sections based on soundings made in 1939, 1940 and 1948 at each range, except for the cross section of range 49 which was available from a September 1946 survey.

The concentration-hydraulic condition relationship data from Fort Randall Reservoir line up well with Fort Peck and Garrison Reservoir data. A range was sounded and sampled in a single day, but data were collected from only one range each day and the discharge changed from day to day.

The range cross sections in Fort Peck Reservoir were sounded over a period of several months and the work was completed several months prior to taking samples. However, check soundings were made at the location and time each sample was obtained and range cross sections were adjusted to these check soundings. The samples for each of the three runs were taken over periods of three, two and one days, respectively, and there were changes in discharge from day to day and during each day.

In Garrison Reservoir, the samples were taken at all ranges in two days and the ranges were sounded on the three following days. In order to simulate a constant sediment and discharge inflow condition, the ranges

were sampled in a downstream direction and the sampling boat was moved from range to range to approximate the flow travel time between ranges.

One of the problems encountered in developing a concentration-hydraulic condition relation was selection of the value, identified by the subscript "1", to represent average inflow conditions upstream from the influence of backwater. Generally insufficient field data were collected to determine a good value. Ratios on Figures 22-30 which are greater than "one" indicate that the value used did not represent average conditions. Also, it indicates an increase, rather than the expected progressive decrease, in sediment concentration and hydraulic conditions. In some cases, ratios greater than "one" may result from redistribution of sediment in the delta area. It is doubtful whether that is the case for any of the data presented here; however, further study of this phase of the problem is contemplated by collection and analysis of additional pertinent data during the next survey.

The best grouping of the Garrison, Fort Peck and Fort Randall Reservoir data was obtained by the Froude number ratios on Figures 28-30, inclusive. The average curve shows that sand, Figure 28, begins to drop out of suspension immediately and rapidly with a small reduction in hydraulic (or transport) conditions. Silt, Figure 29, drops out of suspension very slowly, until there has been an appreciable reduction in hydraulic conditions. Clay, Figure 30, is even slower to respond to the reduction in transport forces. After the initial lag, the slope of the silt and clay curves approaches that of the sand. This may have significance if equations are developed for the three curves. Insufficient data are available at this time to establish the average curves adequately; however, collection and study of additional data is contemplated.