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SUBJECT PRELIMINARY REVIEW OF THE FRASER RIVER STUDIES AND RIVER IMPROVEMENTS. (AS REQUESTED IN LETTER OF DECEMBER 18, 1961, FROM DEPARTMENT OF PUBLIC WORKS).

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PRELIMINARY REVIEW OF THE FRASER RIVER STUDIES AND RIVER IMPROVEMENTS. (AS REQUESTED IN LETTER OF DECEMBER 18, 1961, FROM DEPARTMENT OF PUBLIC WORKS)

INTRODUCTION

From 1949 to 1950 an outdoor model of the tidal section of the Fraser River was constructed on the campus of the University of British Columbia, to study, for the Department of Public Works, improvement schemes for deep-sea navigation in the Fraser River estuary. The N.R.C. constructed and commenced the operation of the model in cooperation with the University. In 1953, the Department of Public Works took over the operation and financial control of the project with the scientific supervision and support of the University.

During ten years of operation, a number of projects, proposed by Department of Public Works, private industry and other public bodies, were studied in the model and some structures were installed in the prototype, such as the Steveston Harbour development, the Deas Island tunnel, the Annacis Island Causeway, and dredging was done in the Port Mann-Sapperton area. Recommended, but not yet implemented, are two of the major schemes, - the trifurcation scheme for improving the section of the river at and below New Westminster and the Steveston plan for developing a navigation channel of adequate width, depth and alignment at the mouth of the river.

In 1961, the University required the model site for campus expansion. By the end of the year most of the model was dismantled and the remaining testing facilities are to be removed by March 1962.

METHODS EMPLOYED IN RIVER AND MODEL TO IMPROVE CHANNELS

From the time of the earliest improvements for navigation until the present, the methods used were:

(a) dredging;

(b) restricting the flow by training structures such as groins, dykes, and closing off river arms in the delta.

The first recorded dredging was done in 1892 and the first groins were built in 1907 at the upstream end of Annacis Island. Since then, dredging has increased to 3,000,000 cu.yd. annually and a number of flow restricting structures, such as the Steveston Jetties, the Annieville Dyke, the groins for the grain elevators and closures for greater and smaller delta arms were installed. These same basic methods were employed in designing the large-scale improvement schemes in the model. The trifurcation scheme proposes a 35 percent restriction in the cross-section of the river channel and the Steveston plan calls for more than two dozen groins and dykes to restrict the outflow from the main channel into the Strait of Georgia.

From the historical records and from the structures installed, it may be concluded that from early times it was realized that dredging alone had no lasting effect, because the sediment load of the river, amounting to an estimated 18,000,000 cu.yd. annually, is sufficient to easily replace any material dredged. Restricting the channels with the intention of compressing the flow into a narrower channel, creating greater velocities and greater transporting forces along the bed of the channel to maintain greater depths, appeared to be the logical solution. Unquestionably, this thinking has since guided the engineers concerned with the river improvement.

This procedure is well known and is in world-wide use; for example, in maintaining irrigation channels in India, in training the Mississippi River and in aligning the rivers in alluvial soil on both sides of the Alps. These applications, however, are limited to channels in which the forces for transporting the sediment are generated only by the energy gradient of the river slope. In the tidal section, where the controlling energy is that of the tide propagating into the river system from the ocean, flow restricting measures have normally an adverse effect on the transport capacity of the system.

THE ENERGY STRUCTURE OF THE LOWER FRASER RIVER

The Fraser is a mountain river with great seasonal variations in run-off. During the winter months the discharge at Hope may be as low as 20,000 c.f.s., but during normal flood periods it may increase to 300,000 c.f.s. Exceptional floods in excess of 400,000 c.f.s. create potential flood dangers to lowlands of the valley.

The Lower Fraser Valley extends from the Strait of Georgia to Harrison Mills, below Hope (Fig. 1). Upstream of Harrison Mills, the slope of the river is steep but downstream the mean slope is very flat, the breaking point being between Harrison Mills and Stonehouse Bay (Fig. 2). This point is also the upstream limit of the tide intrusion, for the steep rise in the river bed checks its progress.

The ratio between the slopes upstream and downstream is 50 to 1. The grade of the slope is an indication of the amount of energy involved in the river flow. In the tidal section, the energy of the river flow is therefore only 2 percent of that upstream of the breaking point. Sand and gravel carried down from the mountains could not be transported to the sea by the small forces of this energy if there were no additional forces created from some other source of energy. The energy which takes control in the tidal section and which therefore supplies most of the forces is that of the tide.

It is believed generally that floods have a greater effect than tides. Certainly, greater floods will impose their energy on the tide energy and so modify, temporarily, the energy structure, particularly in the upper section of the river. The magnitude of the modification, however, is not as great as would be expected. In New Westminster, the energy of a flood of approximately 300,000 c.f.s. is not much greater than that of a tide having a 6-ft. range. The tide, however, acts continually, the floods only a few weeks of the year.

The energy of the tide in the river system originates in the tide of the ocean. It propagates upstream from the river mouth where it is greatest and gradually decreases due to friction and configuration losses, finally ceasing at the breaking point in the river slope.

The energy of the tide is imposed on the small energy of the river left in the channel. The ratio between them is shown on Figure 3. Progressing upstream, the ratio on January 23 and 24, 1952 was 30 to 1 in New Westminster, 7 to 1 at Whonock, and 3 to 1 at Nicomen Slough.

The tide energy is composed of two parts, the kinetic and the potential. The kinetic energy represents the energy of the horizontal motion of the water, i.e. that of the velocity, and the potential energy, the energy of the vertical motion, visible as a fluctuation in water level.

The forces from the kinetic energy, which generate the current velocities, are those mainly involved in transporting the sediment. The ratio between this energy and that of the river flow is understandably smaller but still, as shown on Figure 3, is 14 to 1, 1.3 to 1 and 1 to 1, at the locations mentioned previously.

The question often asked, is: Does a tidal flow which, by itself, is but a periodic motion in which a particle of water or sand will be moved some distance upstream and an equal distance downstream, help to transport sediment? The question may be best answered by two examples of tide current recordings collected in Saint John, N.B. (Fig. 4). The maximum velocities in the second example are slightly greater than in the first. The river flow in both is the same and the velocity at which the sediment starts to move is approximately 2.1 ft./sec. The transport capacity is assumed to be in a third power relationship of the velocity, which is in good agreement with nature. The shaded area within the dashed line (Fig. 4) represents the amount transported in and out during a tide cycle. In (a), no transport upstream has taken place, only downstream. In (b), sand and silt were also carried inward during flood due to slightly greater tide velocities. Nevertheless, the residual transport downstream in (b) is twice that in (a). The important contribution of the tide therefore is in picking up the sediment and keeping it in motion. The mass transport from the river drainage is then capable of moving the material out to sea. It is therefore obvious that for a tidal river such as the Fraser, it is of vital importance to maintain sufficient tidal energy to keep the bed load moving.

A decrease in tide energy would be followed by a reduction in tidal velocities. As a result the transporting capacity of the system would decrease and, consequently, the bed of the river would rise and floods would have higher levels.

Structures which restrict the flow so that they confine the entrance of the tide may create local improvements but they create the opposite effect, and the more so, the farther downstream they are located.

The most sensible approach to a tidal river, such as the Fraser, is to search for a means of increasing the kinetic energy of the tide wave. In this way, the river would increase its depth to the benefit of navigation and flood control.

THE EFFECT OF FLOW RESTRICTING STRUCTURES ON THE TIDAL RIVER SYSTEM

An example of a restrictive structure is the Deas Island tunnel crossing the Main Arm of the Fraser River just upstream of Ladner Reach. The tunnel was designed to lie with most of its structure above the river bed for a distance of about 1000 feet. At the deepest point of the river, the tunnel crest reaches a maximum height approximately 20 ft. above the bed. As shown in Figure 5, the tunnel restricts 16 percent of the cross-sectional area of the river channel. A similar percentage of tide energy is therefore prevented from entering the river system. Considering the total energy of both the North and the Main Arm, the tunnel reduces the tide energy in the river upstream by approximately 10 to 14 percent. The transporting capacity is decreased by at least this amount and, as a result, the bed of the river must have risen since the construction of the tunnel began, by 15 percent of the original average depth of the channel. The tunnel is therefore estimated to have increased the flood danger by at least a 0.5 to 1 ft. rise in the flood water in the upstream part and a 1 to 2 ft. rise in the downstream section. It is estimated that the amount of sediment accumulated due to the tunnel must be in the order of 15 to 20 million cubic yards.

The many width-reducing structures and closures installed in the river have similar effects, but most of smaller magnitude. These structures have served to improve local flow conditions, but have created a general rise in the river bed without increasing the mean depth. To maintain the depths required by navigation, dredging was increased. The dredging records compiled in Report FRM-233 tend to confirm this statement.

In the Fraser River Model, the two most important improvement schemes tested were the Trifurcation Improvement and the Steveston Plan.

In the Trifurcastion Scheme (Ref. 2 & 6), a number of dykes and groins are proposed which would restrict the flow in the Main Arm by more than 35 percent (Fig. 5). The consequences of such restrictions would be basically similar to those described for the Deas Island tunnel. To meet the increased risk of flooding in the Fraser Valley due to this scheme, it is estimated that 223 miles of flood-control dykes would have to be raised an average of at least 1 to 2 feet. Deep-sea navigation upstream of New Westminster, now under consideration would be expected to be impractical due to the loss in the transporting capacity of the river.

The Steveston Plan, which is similar in principle, appears to us to suffer from the same hazard, for here the restrictions would be located at the mouth of the river.

CONCLUSIONS AND RECOMMENDATIONS

We therefore conclude that, although the restrictive training structures and closures installed or proposed for implementation in the Fraser River are measures to improve local conditions by re-directing the flow, they have "in general an adverse effect on the tidal river stystem as a whole. We believe they will raise the river bed, decrease the average depths and in this way increase the flood danger in the densely populated valley.

These measures are contrary to the principles for improving tidal rivers as far as these latter apply. The Fifth Conference of the Permanent International Association of Navigation Congresses arrived at the following conclusion pertaining to the improvement of estuaries:

"The size and depth of a tidal river being mainly due to the tidal flow, any works which increase its volume and extend its influence, such as the removal of obstructions, dredging hard shoals, and the lowering of the low-water level by deepening the channel, effect an improvement in the navigability of the river; whilst any works which restrict the tidal influx, even though producing a local deepening by scour, are liable, unless under exceptional conditions, to injure the general navigable capabilities of a tidal river."

While, in our judgment, the proposals to place restrictions in the tidal reach of the river are unsound, a quantitative comparison of the alternative philosophies can only be established with model experiments. We recommend that, if at all possible, the restrictive works be postponed until such model work can be done. Such an investigation is now in progress at the National Research Council as part of the hydraulics programme.

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