HYDRAULICS DIVISION
TECHNICAL NOTE

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TITLE: Environmental Monitoring System for the Tapscott Stormwater Pond

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REASON FOR REPORT: Requested by the Borough of Scarborough and the Ministry of the Environment.

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1.0 INTRODUCTION

The Borough of Scarborough intends to implement the recommendations of the stormwater management study for the Tapscott Industrial District as proposed by Andrew Brodie Associates. The major recommendation of the study is to build a stormwater pond which would reduce the peak runoff discharges from the new development and provide some control of pollution loads in runoff. The pond is designed for the full development of the district and such a level of development may require eight to ten years to accomplish. It is expected, however, that about 10% to 20% of the district area (i.e., 40 to 80 hectares) may be developed during the first year after the construction of the pond. Thus in the early years, the pond would receive runoff from a gradually urbanizing catchment.

The Tapscott stormwater pond offers a good opportunity to study runoff processes in an urbanizing catchment and to study the effectiveness of stormwater storage in improving stormwater quality. The study of such problems is of direct interest to the Borough of Scarborough, Ministry of the Environment and the National Water Research Institute. Apart from the environmental concerns and research interests of these three parties, there is a recommendation of the regulatory agency (of the Ministry of the Environment) that the proposed Tapscott stormwater pond be properly monitored.

The technical note that follows addressed the feasibility of environmental monitoring of the proposed pond. If the note is accepted by the parties involved, it will be necessary to amend the pond construction contract to accommodate various needs of the proposed monitoring system.

2.0 STUDY OBJECTIVES

The general objective of the proposed study is to monitor the impact of progressing urbanization on surface runoff from the Tapscott Industrial District. Towards this end, it would be desirable to monitor the following phenomena:

1. Rainfall in the district.
2. Quantity and quality of runoff from the district (this represents the inflow into the pond).
3. Water quality in the pond.
4. Quantity and quality of outflow from the pond.
5. Background water quality, e.g., in the 600 mm bypass pipe, or in the receiving waters.

The monitoring of the above phenomena and collection of basic catchment and pond data would make it possible to fully assess the runoff quantity and quality for the district and to evaluate the effectiveness of the pond in runoff quantity and quality control. Although a proper monitoring program will have to be developed at an appropriate point in time, the immediate concerns may be limited to the monitoring of pond inflow and outflow (items 2 and 4). Such concerns may require an amendment of the pond construction contract.

3.0 MONITORING OF STORMWATER POND INFLOW AND OUTFLOW

Continuous monitoring of pond inflow and outflow in conjunction with the monitoring of pond conditions (e.g., stored volume, water quality, sediment accumulation) will make it possible to evaluate the effects of storage on runoff quantity and quality.

Particularly the water quality aspects are of interest because the quantity aspects can be well described by the existing theories. A brief description of facilities for monitoring of pond inflow, outflow, and water level follow.

3.1 Inflow Monitoring

The inflow to the pond (see Fig. 1) is conveyed by a twin box culvert with dimensions (2) 3.66   3.05 m. The culvert is designed for a total discharge of about 140 m /s (4900 cfs) which is conveyed by a super-critical open-channel flow. Approximate rating curve of the culvert is shown in Fig. 2. Considering the flow regime in the culvert, any flow monitoring equipment should be placed at the upstream end.

The monitoring of pond inflow is proposed in two stages. The first stage would be used in the early phase of the district development (say less than one half of the district developed). The second stage would then be implemented once the district development exceeds one half of the total area. Details of both stages follow.

In the first stage, it is proposed to block partially one of the culvert boxes and to place a rectangular flow-measuring weir in the other box (see Fig. 3). Such an arrangement would allow accurate measurement of flows at relatively low costs.

The barrier placed in the right-hand box would be 1 m high. In the left-hand box, a 1-m high weir would be erected in the transitional flume, about 12.5 m downstream of the inlet. At this point, the culvert invert is about 1 m below the inlet invert and thus for weir heads up to 1 m ($Q\sim10.5$ m^3/s), only one half of the culvert will be in operation. It is expected that for such weir heads, the flow can be measured fairly accurately. For higher flows, the weir head becomes too large compared to the weir height and the measurement accuracy worsens. It would be possible, however, to estimate higher flows (say up to 20 m^3/s, both boxes discharging) with an acceptable accuracy (±10%).

Estimating the inflow, with a one-year return period, from a fully developed catchment as 40 m^3/s (1500 cfs), it appears that the proposed flow measuring system could be used for up to 50% of the catchment developed. At the same time, the maximum flow capacity of the installation would be about 114 m^3/s (4000 cfs) for open-channel flow. Such capacity corresponds to 80% of the design discharge for the fully developed catchment. Thus the proposed arrangement does not reduce the design safety for partly developed catchment (say less than 80% developed).

The proposed flow measuring system may require several considerations with regard to the pond construction contract. Some provisions should be made for the installation of the weir (e.g., make a groove in the culvert bottom and sidewalls by inserting a steel channel) and for installation of the blocking barrier in the other half of the culvert. Also the concrete surface below the weir (say 5 to 10 m downstream of the weir) may require some protecton.

It would be desirable to improve access to the weir by placing an instrument vault on top of the culvert in the vicinity of the weir. The vault would be connected to the culvert by a manhole. This manhole would not only provide better access to the weir site, but it would also be used for placing of cables and tubings connecting the instrument sensors with recorders and samplers. A sketch of the facility is shown in Fig. 4.

To drain the storage upstream of the weir, it is proposed to place a circular opening (D = 200 mm) at the bottom of the weir and to keep this orifice open all the time. Considering the full head of 1 m, the discharge capacity of the orifice is about 0.084 m^3/s, or 7260 m^3/day. The discharge through the orifice can be calculated from the measured head and added to the weir discharge. Should the proposed opening be too large, it can be reduced at a later stage.

Once the development starts to approach 50% of the total area, the proposed flow measuring system will become less accurate and may excessively constrict the flow area. Consequently, it will be necessary to remove both the blocking barrier and the weir. This stage of flow measurement is referred to as the second stage. For the anticipated high discharges, it will not be possible to insert any constrictions into the culvert. It would be possible to estimate the discharge from the measurements of the depth of flow at the sudden break in the bottom slope (16.4 m from the inlet). This depth should correspond to the critical depth which is uniquely defined for the open-channel flow in the culvert. Verifications by field measurements with current meters are possible.

Besides the measuring weir, it will be necessary to install a water level recorder. Among the instruments to be considered, one could name capacitance probes, ultrasound probes, and air-bubblers with electric output signal. When making the final selection, one should consider the relatively high flow velocities in the range from 4 m/s to 5.5 m/s. The same water level recorder can serve both phases of flow measurement.

The composition of runoff water will be monitored by sampling. It is proposed to install a submerged pump in the vicinity of the measuring weir and to lift stormwater to the instrument vault where a conventional automatic sampler would be used. The submerged pump will be switched on automatically during wet weather periods. The automatic sampler will be operated in a flow-proportional-sampling mode. The sampler should have a refrigeration unit for sample storage.

All the instruments will be inside an instrument vault which will be connected to the access manhole. Hydro power service should be available.

3.2 Monitoring of Pond Conditions

Surveys of water quality in the pond, including sediment accumulation, should be carried out at certain intervals. For this purpose, standard procedures will be used and no special provisions need to be made at this time. It would be, however, desirable to monitor the depth of water in the pond continuously. Such a depth should be monitored in a stilling well (a standpipe) close to the outflow. This depth could also be used to estimate outflow discharge as described later.

3.3 Outflow Monitoring

Accurate measurement of flows in the pond outfall is rather difficult. At the upstream end, the inlet weir structure departs from typical weir configurations because of the presence of the oil skimmer (partly blocking the flow area) and because of a sudden flow channel contraction. At the other end of the culvert, there is a sharp bend and the flow is affected by backwater propagating from the river channel. In the intermediate part of the culvert, the discharge will be conveyed in the form of the super-critical flow. Thus considering the flow conditions in the outfall, it is unlikely that the outflow could be monitored accurately using conventional approaches. It is proposed to implement an inexpensive flow measurement system with somewhat reduced accuracy of flow measurements. Details follow.

It is recommended to modify the overflow wall in the pond outlet by placing a sharp-edge extension on the top of the concrete overflow wall. Such a modification could be achieved by bolting a modified steel-channel (i.e., with the upper flange cut off) on the top of the concrete overflow wall (see Fig. 5). The overflow edge would be maintained at the same elevation as in the original design. The sharp-crest weir formed by this addition should be calibrated in a scale model in the hydraulics laboratory. The need for such a calibration follows from highly unconventional inflow to the weir. For weir head measurements, same approaches as described earlier (Section 3.1) may be used.

It is expected that the proposed weir will remain fully functional for discharges up to 5 m^3/s. For higher discharges, the uncertainty in flow measurements will increase substantially and, eventually, the proposed weir will become inoperative. In the absence of data on routing of flood waves through the pond, it is not possible to estimate the return period of the outflow of 5 m^3/s. Note, however, that as the flood waves propagate through the pond their hydrographs will be flattened and thus the outflow of 5 m^3/s corresponds to a longer return period than the same discharge at the inflow.

For discharges higher than 5 m^3/s, the choice of flow measuring techniques is quite limited. Constriction flow meters are not feasible because they will suffer from similar limitations as the proposed weir. A dual mode flow meter (i.e., a flume/orifice device) would significantly reduce the culvert discharge capacity and such devices have been used only for small cross-sections. One possibility would be to use a velocity sensor for measurements of point velocity which can be then used in conjunction with the measured depth of flow to calculate the discharge. Alternatively, one could establish an approximate rating curve of the whole outflow and overflow structure which consists of the culvert and the broad-crest weir. Such a rating curve could be established in a scale model in the hydraulic laboratory. The accuracy of such a curve is estimated at ±10% to ±20%, with most uncertainties arising from the operation of the broad-crest weir. The model should be based on the "as built" dimensions.

Using the above outflow rating curve and water depth measurements in the pond close to the outflow, it will be possible to estimate the pond outflow discharge. Somewhat reduced accuracy of outflow discharge measurements may be acceptable because of additional checks on the basis of inflow measurements and pond storage.

The water quality of outflow should be monitored by sampling. An automatic sampler will be used to collect outflow samples. The arrangement of the outflow monitoring station should be similar to that of the inflow (see Fig. 4). Instruments will be kept in a hut. It would be highly desirable to have hydro power available.

4.0 SUMMARY AND RECOMMENDATIONS

The establishment of two monitoring stations is recommended for the study of the operation of the Tapscott stormwater pond. The first station is located at the inflow culvert. The inflow discharge is measured by means of a rectangular weir in one half of the culvert, with the other half being partly blocked. Stormwater samples are collected by a submersible pump and an automatic sampler. All the instruments are kept in an instrument vault which is connected through a manhole to the culvert.

In later stages of the catchment development (more than 50% of the catchment developed), it will become necessary to remove the measuring weir and use a simple relationship for the critical flow to estimate culvert discharges.

The second monitoring station is at the outflow culvert. Lower discharges can be measured by a non-standard weir in the outflow inlet. High discharges will be estimated from the rating curve of the outflow structure with both the outlet and overflow operating. The depth of water in the pond is measured in the vicinity of the outlet and used in conjunction with the outflow rating curve. Samples are collected by an automatic sampler. All the instruments are kept in an instrument hut of similar design as that at the inflow culvert.

If the proposed methodology is accepted by the Borough of Scarborough and MOE, the conceptual design of monitoring stations will be finalized.

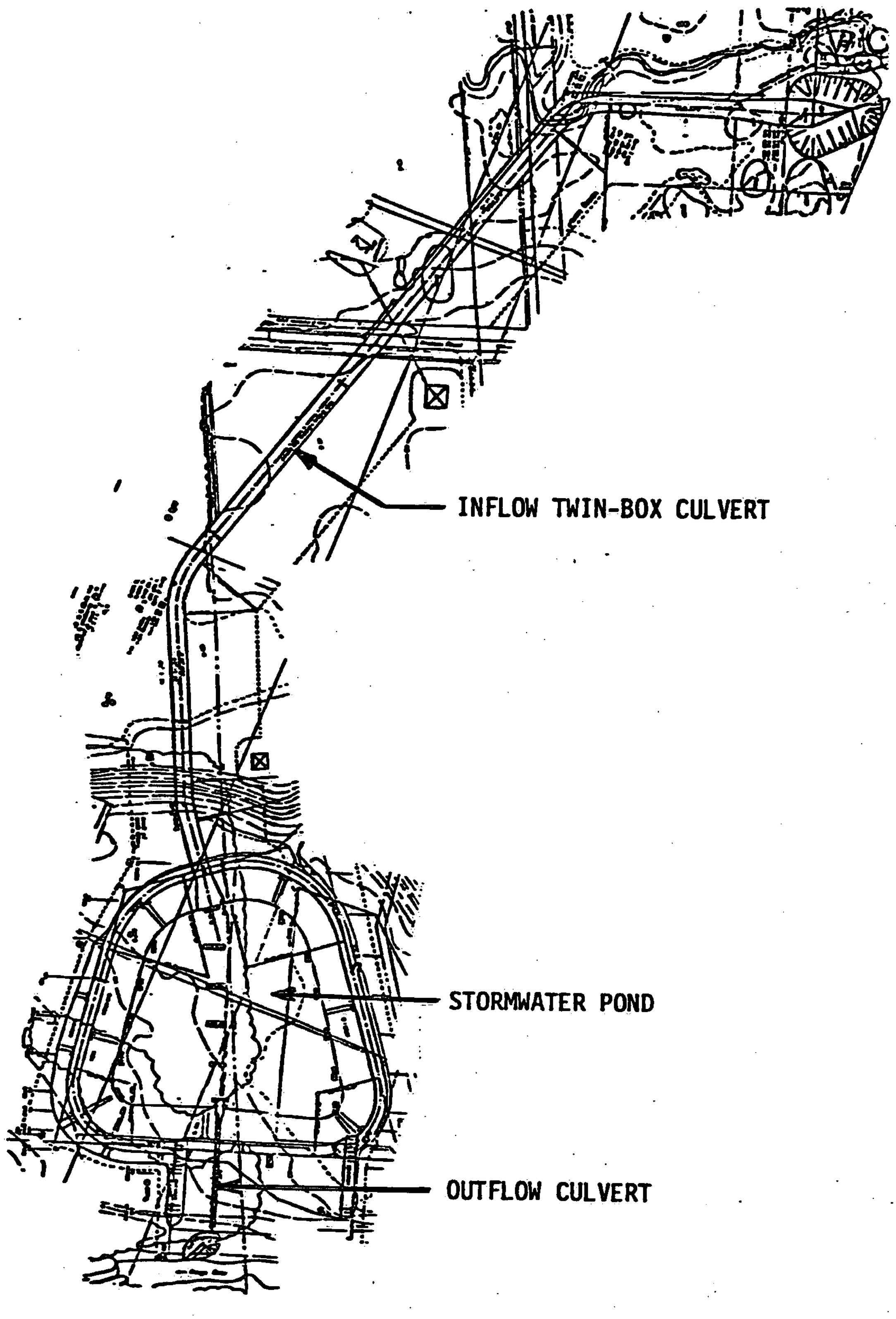

Fig.1. Tapscott Industrial District - Stormwater Pond

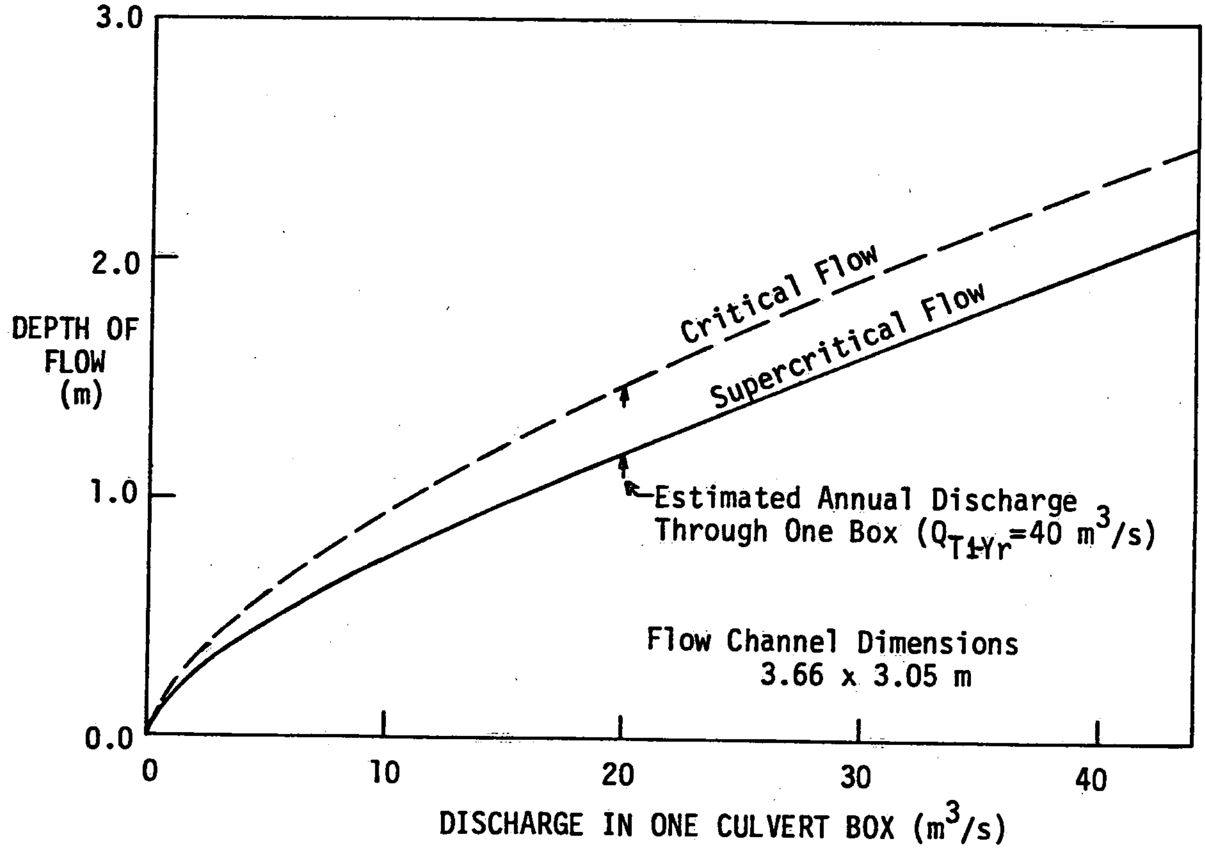

Fig.2. Rating Curves for the Inflow Twin-Box Culvert

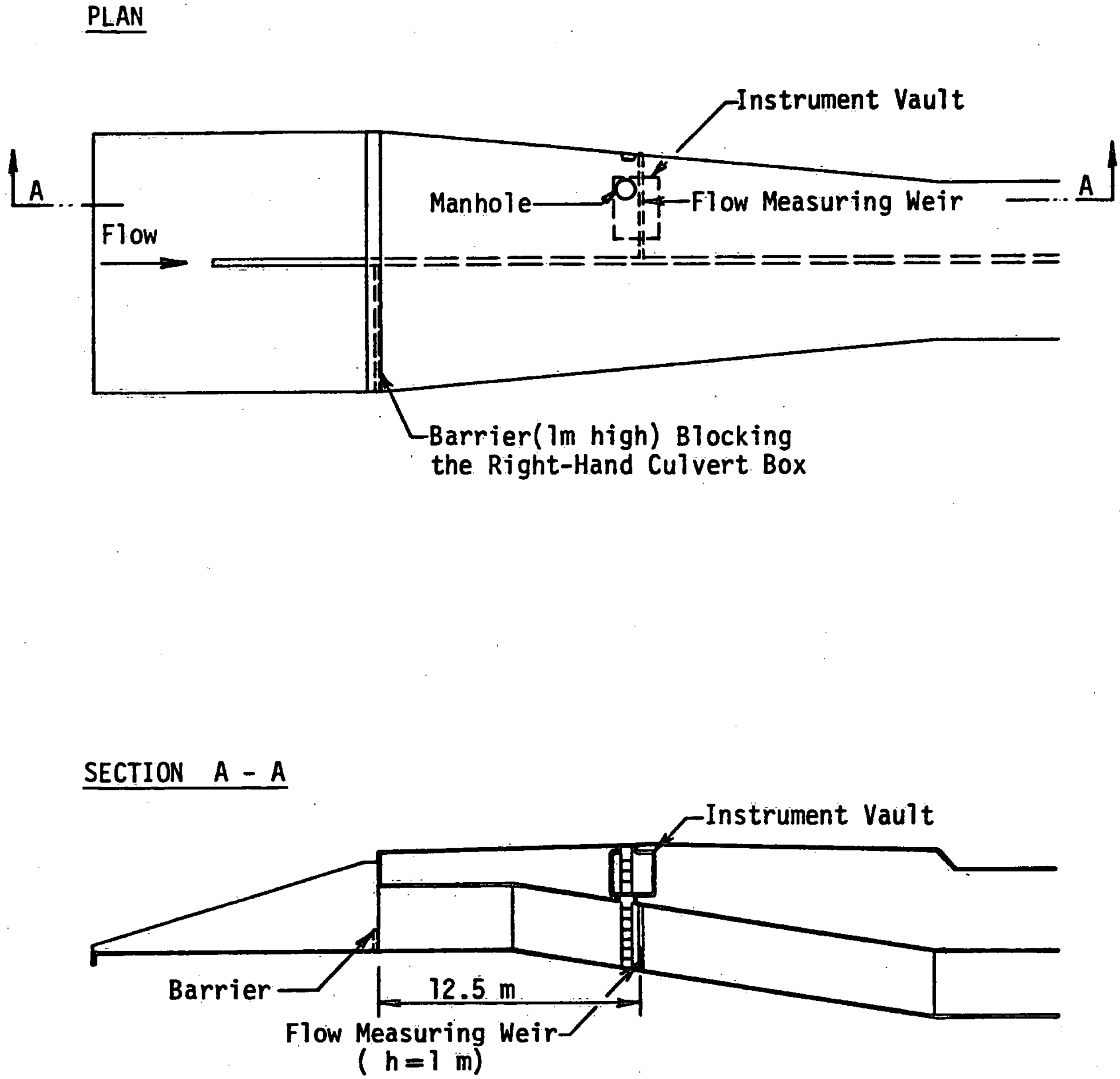

Fig. 3. Flow Measurement System Proposed for the Inflow Twin-Box Culvert

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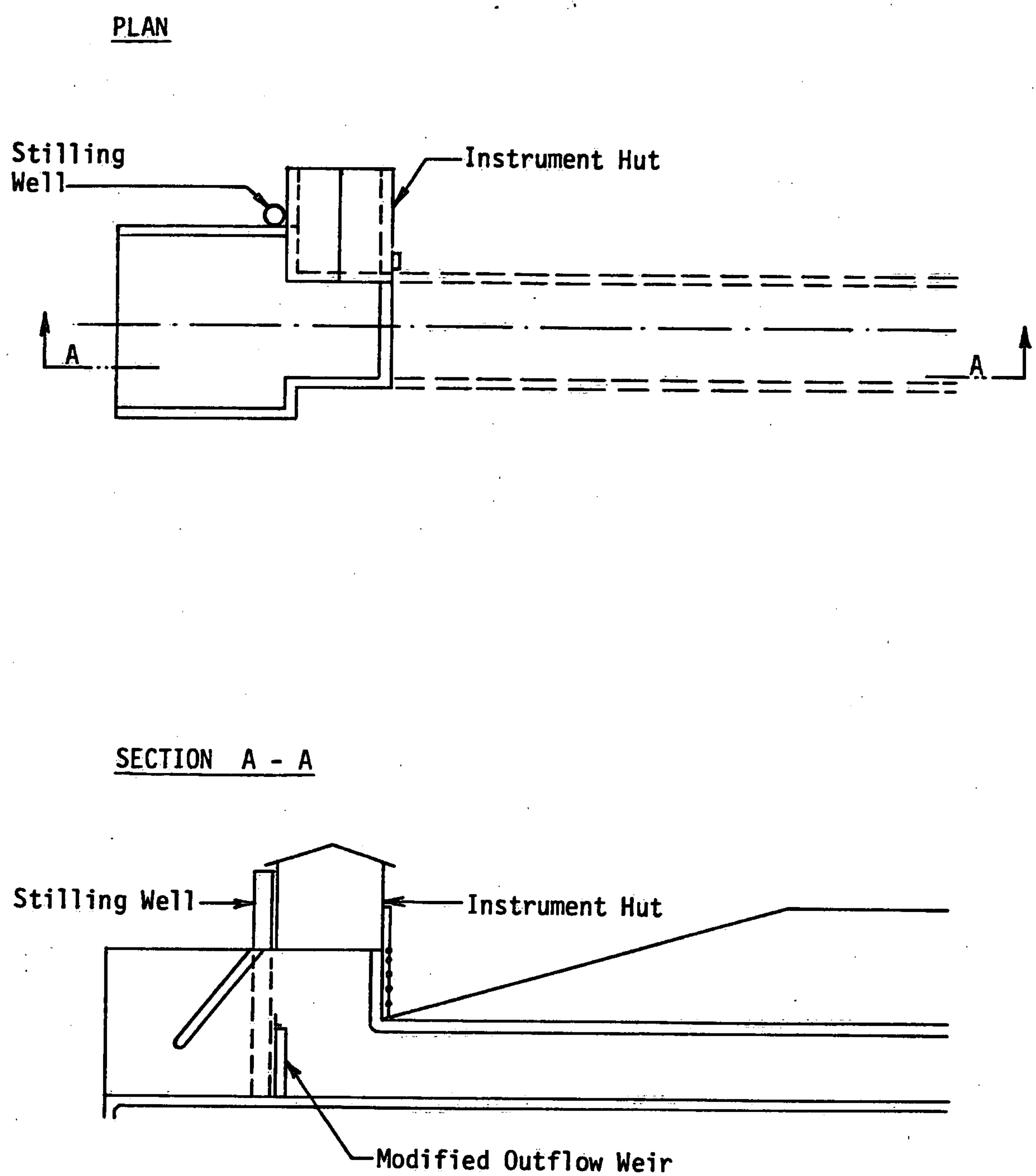

Fig.4. Monitoring Station at the Pond Outlet