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SEDIMENT-CONTROLLING IRRIGATION INTAKE STRUCTURES*

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SUMMARY

An attempt has been made in this paper to review the practice and some sediment-control methods adopted in Turkey. Here, only representative structures and main principles governing their design with respect to the sediment control will be stated and discussed.

Special emphasis has been laid on the advantages of setting up "frontal intakes" instead of intake structures which divert the water sideways from the main stream. High efficiency of this type of derivation has been demonstrated by prototype structures as well as hydraulic model tests, in case more than half of the water is diverted.

RESUME

Un effort a été fait dans ce rapport pour passer en revue la pratique et les méthodes de contrôle de sédiment adoptées en Turquie. On ne traitera ici que des structures représentatives et des principes essentiels qui caractérisent leurs dessins.

On a appuyé sur les avantages d'établir les "prises frontales" au lieu des prises d'eau qui détournent les eaux du cours principal. On a démontré la haute efficacité de ce type de dérivation aussi bien par les structures prototypes que par les essais hydrauliques modèles, dans le cas où plus que la moitié d'eau est détournée.

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INTRODUCTION

Natural equilibrium between soil and water resources has been extensively upset due to the destruction of vegetation cover and cultivation for the agricultural purposes in the upstream parts of rivers to meet the requirements of rapidly increasing population. As a result of this, erosion is increased, and natural channels are being filled by the heavy sediment load. Serious problems with respect to this are faced for taking sediment-free water from rivers as well as flood problems in the agricultural and populated areas.

Two rivers having completely the same morphologic and hydrologic characteristics cannot be found in practice and thus special measures, dictated by local conditions, must be considered besides the general principles of sediment control. In some cases, getting sediment-free water from rivers must be chosen as the most important factor which governs the design of the diversion dam. Otherwise, the operation and maintainance problems being faced at channels will result in very high expenditures compared to the initial capital investment.

Apparently, the most effective solution for taking clear water is to keep bottom material and coarse suspended silt out of the intakes or in other words, sediment must be controlled at the intakes. Irrigable large lands in Turkey are generally lying on shore plains where rivers having large slope debouch to the plains from mountain and in this area there is an active sedimentation. Sedimentation is more serious for the hydro-electric power plants and irrigation projects in inland plains located in mountainous areas. Hence, sediment control has vital importance almost for every intake.

In this paper different types of intakes have been examined and discussed from the viewpoint of the sediment control, giving particular references to practice in Turkey. These are:

(*a*) Classical intakes which divert the water sideways from the main stream (or so called "Lateral intakes"),

(*b*) Frontal intakes.

2. LATERAL INTAKES

2.1 MAJOR COMPONENT PARTS OF THE LATERAL INTAKE

Using classical lateral intakes which generally make an angle of 15°–30° to the river flow is a common practice to take water raised by means of spillway or movable gate.

Besides sluiceways, some conventional measures on the lateral intake structures taken for the purpose of sediment control are summarized in the following paragraphs.

1. Entrance sill

The sill of the canal headgate is raised above the sluiceway floor to protect against bed load transported along the bottom. Efficiency of the provision of the undue high sill is doubtful. Canal discharge and entrance velocity being given, the area of the inlet section is fixed; consequently any increase in the sill height necessitates wider intake sections. The flushing effect of the sluiceway is obviously decreased with increasing distances from the weir and a very wide intake section, the desilting of farther parts of the sill cannot be secured.

2. Breast wall

For protection against debris, breast walls are used, the lower edges of which usually extend down to a depth of 0.20–0.25 m below the raised water surface. Breast walls are made of reinforced concrete and do not have an important function besides that of keeping floating matters off the canal.

3. Settling basin

Settling basin permits settlement of bed load of water-borne material. The head-control structure is usually situated at the beginning of the canal and settling basin is located below this structure. In this case, settling basin is a section of canal made wider and deeper than the rest of it. Unless special measures are taken (such as mechanical devices) this sediment exclusion work cannot be considered as a settling basin and it is better named as "Approach channel".

4. Sluiceway channel

Sluiceway channel is a structure at the downstream end of the settling basin for sluicing the deposited sediment and it is provided with a gate which is operated permanently or from time to time. Sluiceway gates are more effective when they are permanently open, but in many cases it is not possible due to lack of water in dry seasons.

2.2 PROVISIONS FOR LATERAL INTAKES WITH RESPECT TO SEDIMENT CONTROL

The joint application of high sill and sluiceway gives no substantial relief. Further measures in addition to those mentioned above, must be taken, such as "guide levees" and "bottom vanes".

Use of dividing walls, guide levees, and bottom vanes are mainly based on giving an artificial curvature to flow, so that surface streams of water is diverted towards the canal and the bottom streams to spillway or to movable gates. As a result, only the water of the upper, more clarified layer of the river enters the canal, and the bottom silt is carried away from the inlet by the bottom current and does not enter the canal.

Sediment control measures adopted for the Cevdetiye and Derbent Diversion Dams, taking into consideration the basic concepts and conclusions to be achieved, are reviewed below.

2.3 THE CEVDETIYE DIVERSION DAM

The Cevdetiye Diversion Dam was constructed on the Ceyhan River, one of the largest rivers located in the south of Turkey.

The major components of the project consist of a closed weir 109.60 metres long and 5.0 metres high above apron having a crest elevation of 58.80 m across the Ceyhan River, flanked on the left side with a levee of 300 metres length to protect the land from flooding. Radial gates, 3.70 m high, will be installed on the crest after the construction of Aslantas Hydro-electric Power Plant on the upstream of the Cevdetiye Diversion Dam for the purpose of daily regulations of power-plant releases. The maximum capacities of left and right intakes are 105.2 m^3/s and 40.825 m^3/s respectively, and on both sides of the Ceyhan River 139, 782 ha land will be irrigated. It is estimated that a flood of 1,990 m^3/s could reach the Cevdetiye Dam once in 100 years. Construction of Diversion Dam costed 24×10^6TL. (or 1.6×10^6 U.S. $).

General layout of the Diversion Dam is given in Figure 1. Hamis Creek, crossing to the Ceyhan River on the left side, 600 metres above the Diversion Dam, carries heavy sediment and introduces problems especially for the left intake. Control works across the Hamis itself had to be avoided due to economic reasons. According to the experimental results carried out by the Research Department of State Hydraulic Works (DSI), the diversion dam was constructed and the following measures had been taken.

2.31 Position of dividing wall

Moving water body available in front of intakes will result in drawing bottom sediment and silt towards to intakes. To overcome this difficulty, still-pond regulation must be resorted. In the case of still-pond regulation, undersluices in the pocket are entirely closed and the canals draw their water from the still-pond in the pocket. Still-pond regulation creates an artificial curvature in front of intakes. To get the best efficiency from the still-pond regulation, the top of the dividing wall must be higher than high water level and overtopping must be prevented. Still-pond regulation has been illustrated in Figure 2.

Dividing walls in different length and angle to the river current were tested and an angle of 14° non-overtopping dividing wall was constructed, as shown on the general layout of diversion dam. Experiments showed that other sediment control measures, besides dividing walls and still-pond regulation, must be taken to provide adequate supplies of relatively clear water at all stages of the river, such as "Guide levees" and "Bottom vanes".

2. Guide levees and bottom vanes

River cross section at Dam-site has rather wide flood channel, closed by a semi-pervious fill and left intake is located in flood channel as shown in Figure 1. In this case, approach conditions of riverflow to the left-hand side intake is unfavourable and it was observed that intake draws its water from inside of curve created by this unfavourable approach conditions. This demerit was eliminated by a "curved guide levee". Curved training levee to form an approach channel to the intake and sluiceway has been found to be efficient in excluding sediment from channels. The guide levee has been illustrated schematically in Figure 3.

The radius of curvature and the position of the guide levee with respect to the intake and river currents were developed from model studies. Various

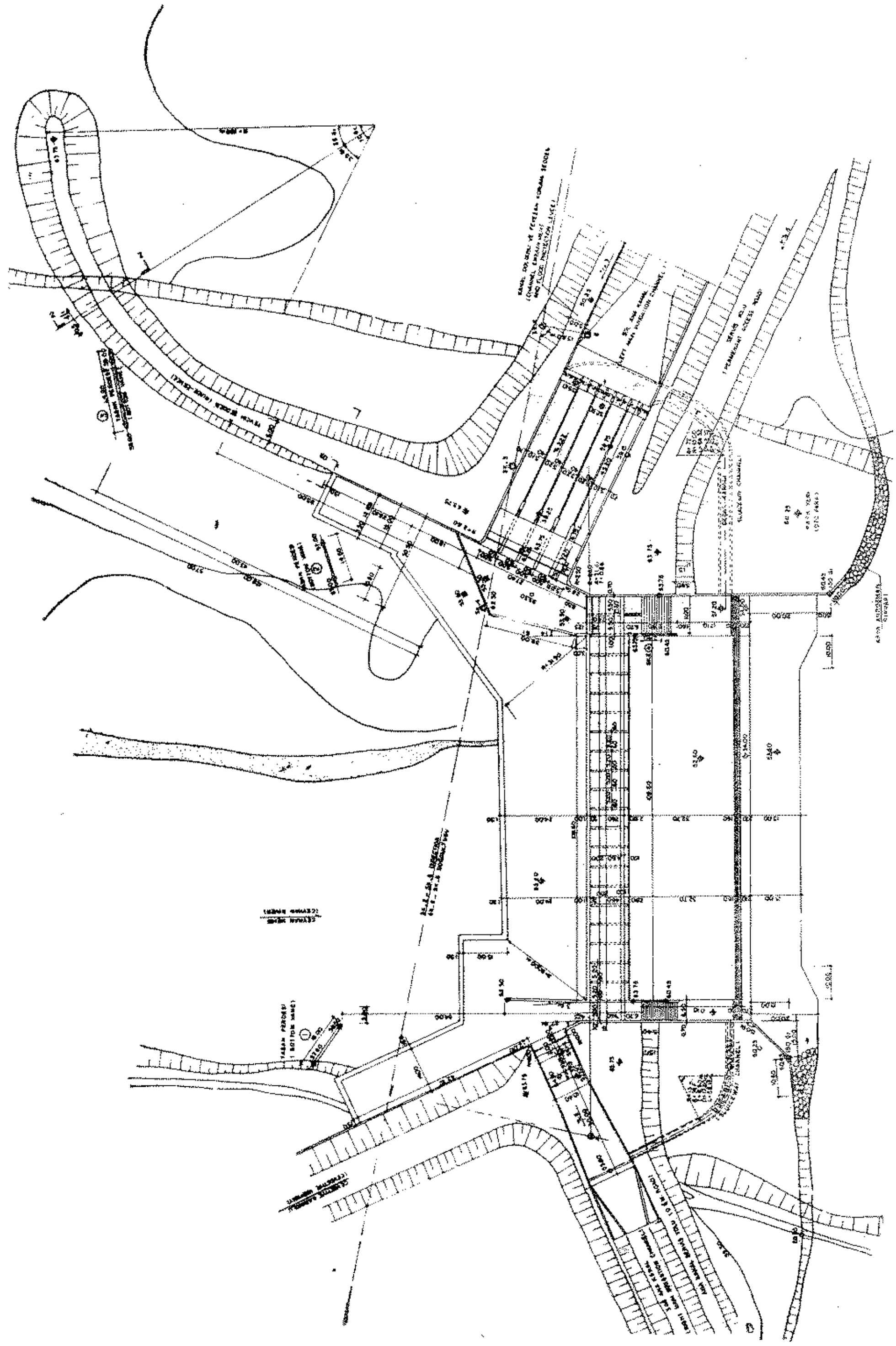

FIGURE 1 : Layout of the Cevdetiye Diversion Dam

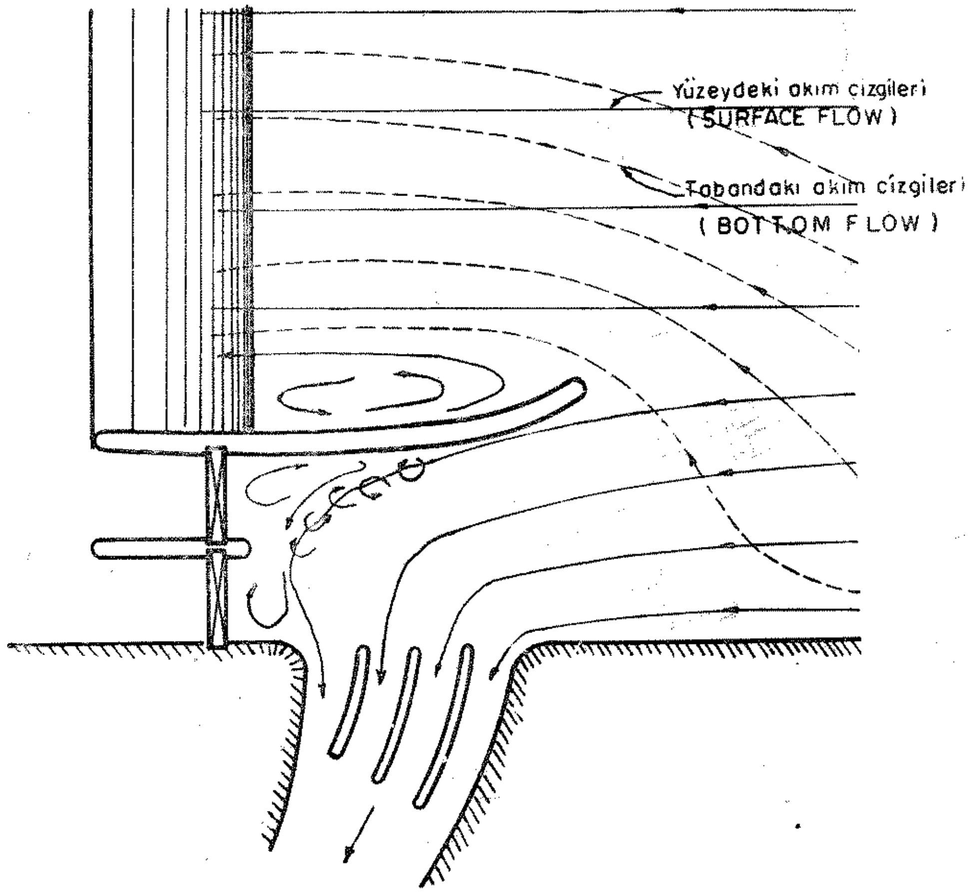

FIGURE 2 : Still-pond regulation

arrangements were tested and the best possible design was adopted for site conditions as shown on Figure 1. Section of the levee is given on Figure 4. It was also concluded from the vane studies that "Bottom vanes" are effective to keep sediment out of intakes. Tests were made on bottom vanes to determine spacing, height and number of vanes. Position and section of the bottom vanes are given on Figure 1 and Figure 4 respectively.

Since the construction of Cevdetiye Diversion Dam was completed in 1972, observations made on prototype covering long period are not available. But short-period observations have generally proved that measures mentioned above have given satisfactory results with respect to sediment control.

2.4 THE DEREENT DIVERSION DAM

It is observed that after heavy floods a lot of minor channels in river bed, interlacing round sand banks, occur and a new river channel is exposed to view in the pool created by Diversion Dam. In this case, it is frequently

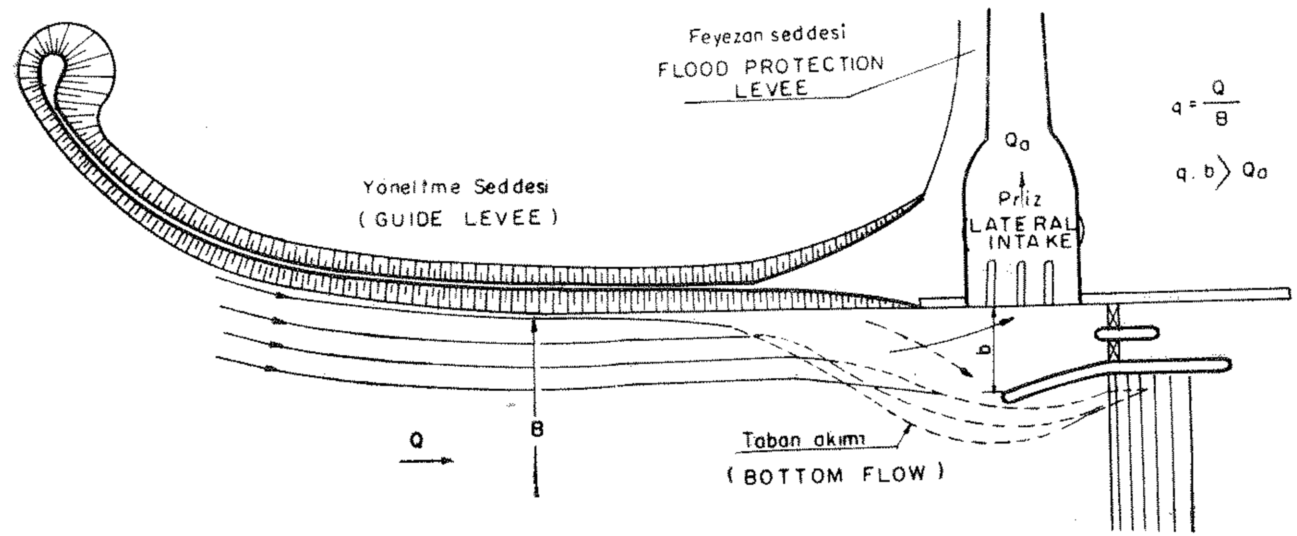

FIGURE 3 : Sediment control by means of a guide levee

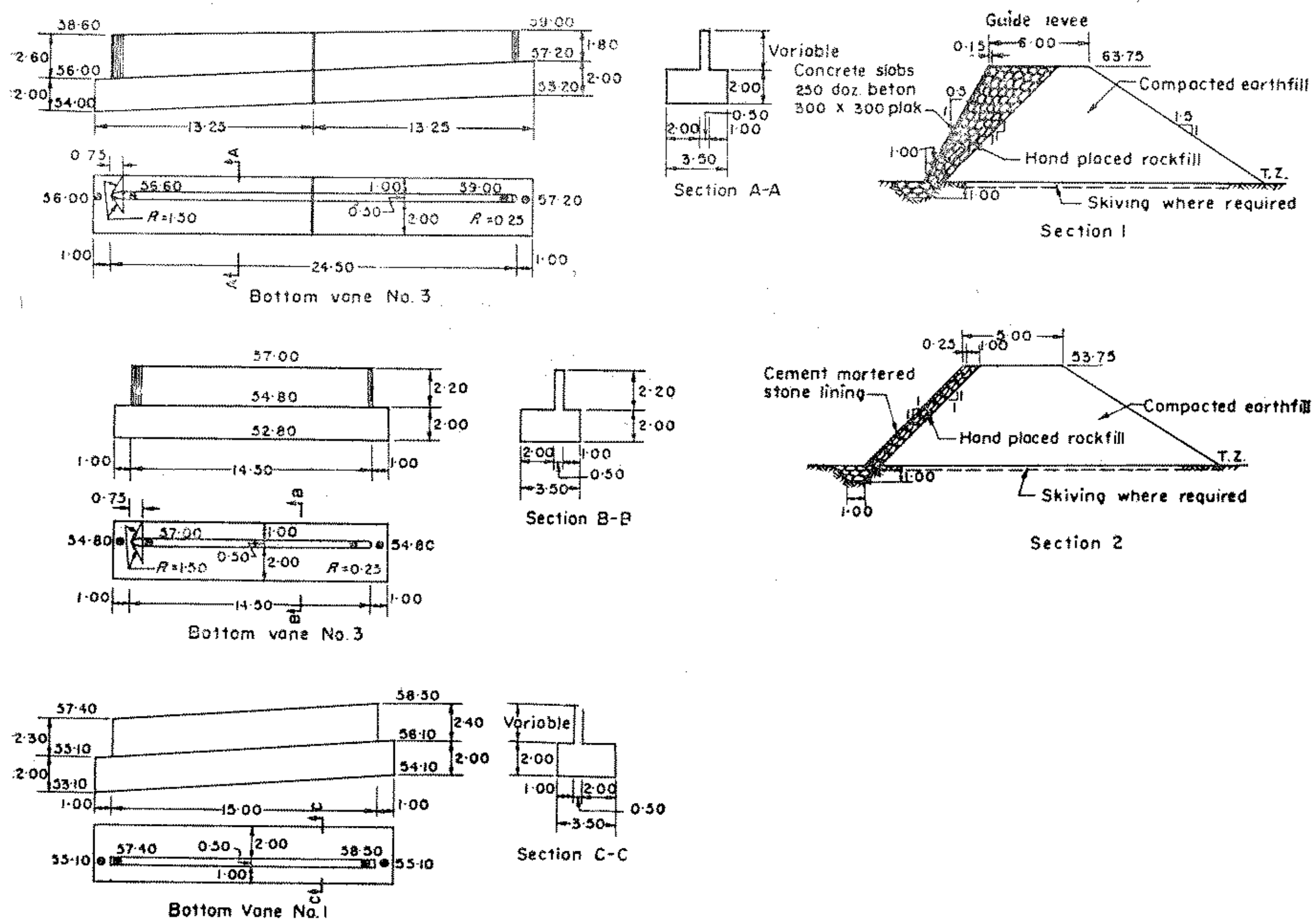

FIGURE 4 : Cevdetiye Diversion Dam—Sections of bottom vanes and guide levee

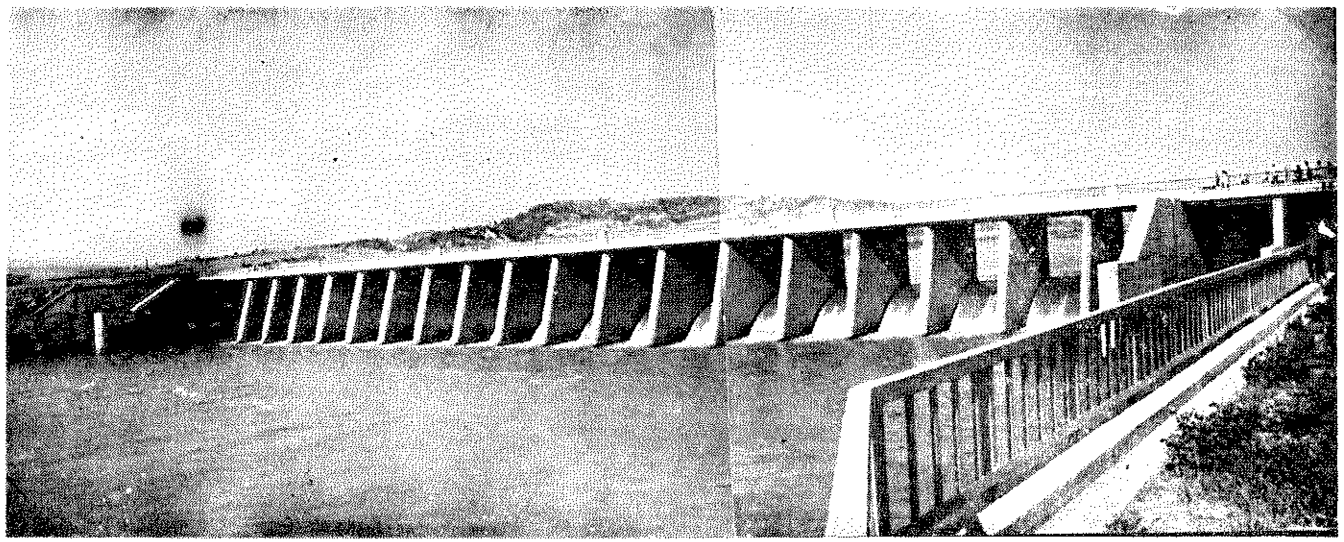

FIGURE 5: Downstream view of the Cevdetiye Diversion Dam

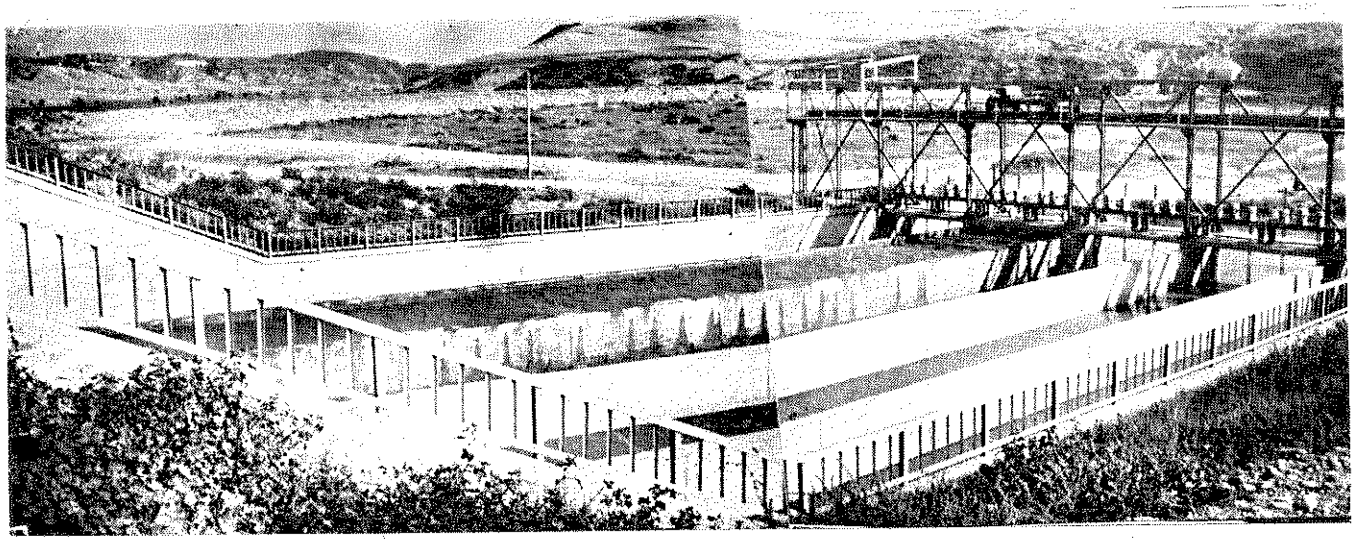

FIGURE 6 : Settling basin of the left intake

experienced that one of the intakes is being located on the inside of curvature. On the other hand, at low water stages there are a lot of minor channels in river bed and also an intermittent change in approaching conditions towards the canal intakes

Taking water separately from both sides of the river may not be convenient for the sediment-control purposes due to the above mentioned reasons. Drawing the total water requirements from one intake and convey it to the other bank might be more appropriate and efficient from sediment control standpoint.

Taking into consideration of the foregoing points as well as economic reasons, the Derbent Diversion Dam, located on the Kizilirmak River, was planned to irrigate 40,000 ha of lands on both sides of the river. In the very near future this project will be realized according to the results of model experiments. The cost of the Diversion dam has been estimated at 48×10^6 TL (3.4×10^6 U.S.$).

The major components of the project consist of a semi-pervious fill dam, 425 m long, across the Kizilirmak River, flanked on the left side with levees to protect the lands from flooding and on the right side by a gated spillway which also serves a sluiceway (which is flanked by a canal headworks of 35.8 m^3/s capacity).

The diversion structure has been designed to pass a flood flow of 3,500 m^3/s.

The spillway control structure has two clear openings, each 13 metres wide by 16 metres high. The general layout of the Dam is shown in Figure 7. Irrigation water would enter the right Spillway Channel and pass over a skimming weir, 31 m long having an elevation of 34.40. Flow to the left main irrigation canal would pass through a 2.70-m inverted syphon to a trapezoidal canal crossing the downstream face of the Dam. Flow to the right main canal would pass directly through a control gate to a rectangular concrete delivery canal. Capacities of canal intakes are 23,6 m^3/s and 12.4 m^3/s respectively.

The design of the proposed diversion structure at Derbent, as shown on Figure 7, gives full weight to the operational problems associated with heavy sediment loads. The crest of the skimming weir (34.40 m) is 13.90 m higher than crest elevation of control structure (21.50 m). During low flows (up to 400 m^3/s) the gate in the right hand channel would be kept close and the gate on the left spillway channel would be used to regulate the normal upstream water level (37.60 m) under normal operation conditions; the velocity in the right spillway channel is practically zero and the canals draw water from the still-pond and still-pond regulation has been introduced to get sediment free water.

At periodic intervals, accumulated sediments would be sluiced out by opening the gate in right-hand channel and at the same time closing the gate in the left channel. In the great part of the year, the discharge in the river bed will not exceed 400 m^3/s and regulation will be made by operating the left gate. It was decided to divide the gate into two parts sliding over each other due to the difficulty in operating very large and high gate. The gate,

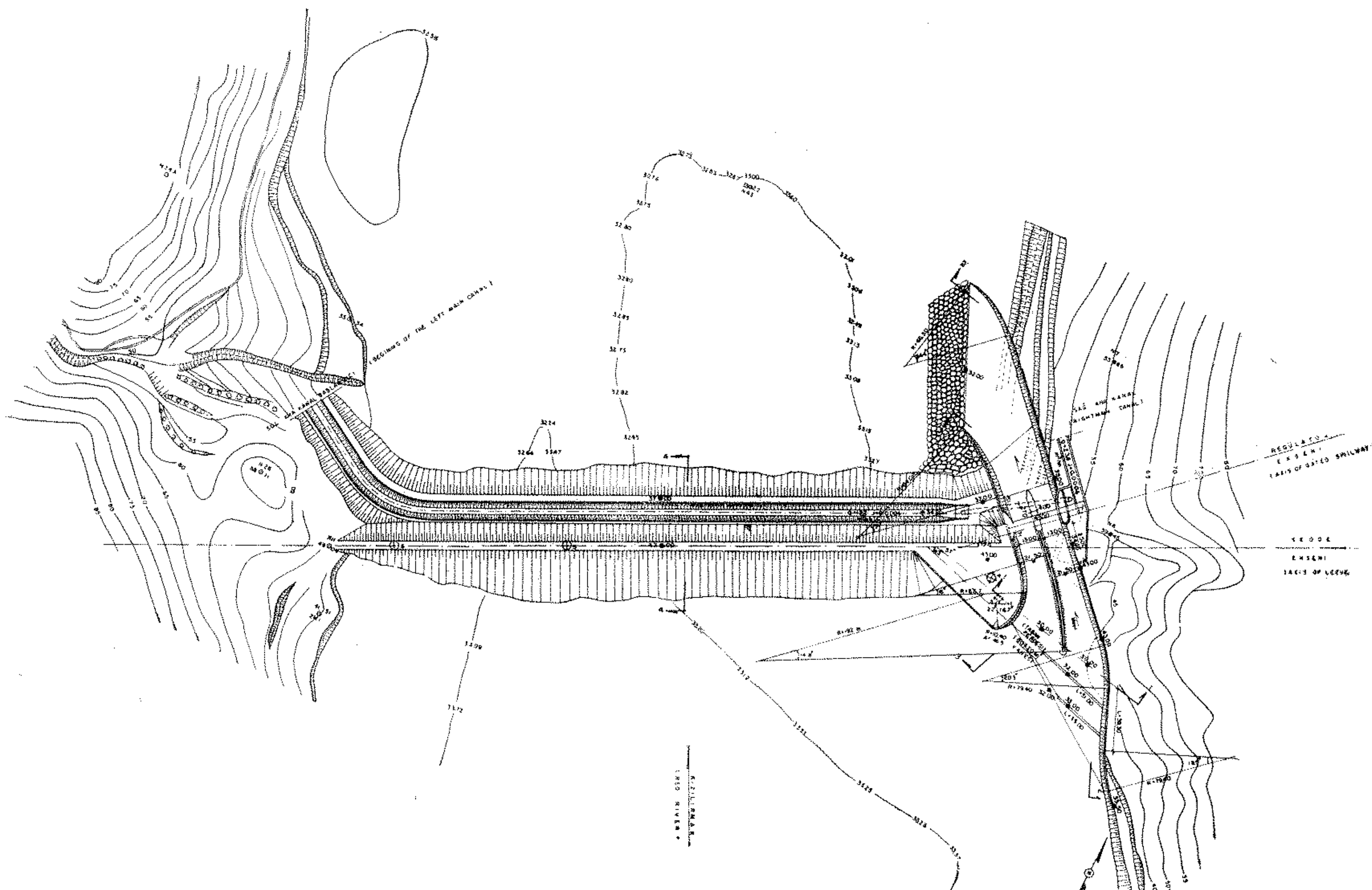

FIGURE : 7 Layout of the Derbent Diversion Dam four metres high, will be operated up to 300 m^3/s and for larger than this discharge both gates will be used for regulation.

During flood flow of 3,500 m^3/s, the upstream and downstream water surface elevations will be 42.0 and 36.4 metres respectively and both gates would be kept entirely open.

Connection between earthfill and left abutment of the spillway, upstream approach walls and intermediate pier which consist of approach channel alinement was planned to direct streamline flow according to the results of model studies. Two "bottom vanes", shown on general layout of Dam (Figure 7), are provided to keep the sediment out of the right spillway channel and direct towards to the left opening as sluicing capacity of this opening is better.

In brief, it was observed that the design of Derbent Dam best satisfies the conditions to be met in the diversion of water from the Kizilarmak River with respect to sediment problems as well as other advantages and decided to construct in near future.

3. FRONTAL INTAKES

3.1 GENERAL PRINCIPLES

When dealing with sediment control problems, due consideration has to be given to the ratio between diverted discharge and the discharge conveyed in the river. As this ratio increases, measures, reviewed in previous section and mainly based on creation of an artificial curvature in front of intake, lose their significance largely. In case more than half of the water is diverted, it is very difficult to take clear water by means of classical intakes which divert the water sideways from the main stream and it is more suitable to use "frontal intakes" especially when we want to divert almost all of the water.

In Turkey, during summer months when irrigation is badly needed, almost all of the river discharge is being diverted to the channel intakes and consequently the danger of drawing sediment into the canal is always encountered.

Because of the reasons mentioned above, studies on "Frontal Intakes" have gained importance in Turkey during the last ten years. Frontal intake was first proposed by Prof. Dr. Kazim Geçen. The model studies were carried out at the Hydraulics Laboratory of Istanbul Technical University and first applied to take water for Ikizdere Hydro-electric Power Plant. Later on, frontal intake was used in the Karabük Diversion Dam constructed on the Soganli Creek which carries heavy burden, for the supply of 3 m^3/s water to the Karabük Steel Production Factory. Model studies of the project, proposed by Design and Construction Department of D.S.I., were performed at the laboratory of the Research Department of DSI and after having obtained satisfactory results, project was realized. The Diversion Dam began functioning in 1973.

3.2 COMPARISON OF LATERAL AND FRONTAL INTAKES

Under the same conditions, two types of intake structures were tested, The ratios of sediment diverted into frontal and lateral intakes were compared and the results of experiments are given in Figure 8.

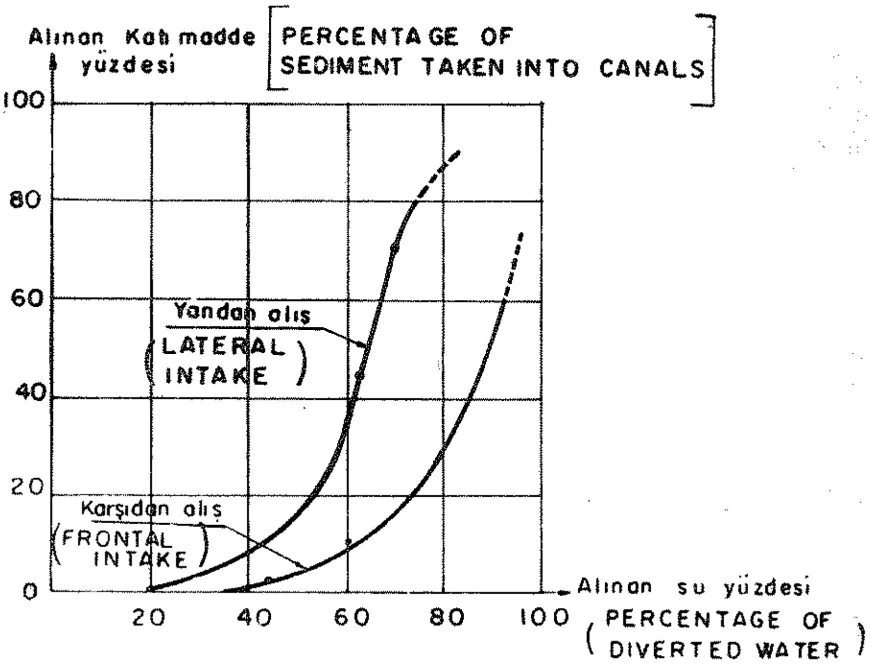

FIGURE 8 : Fluctuations in the amount of sediment taken versus amount of water diverted

Merits of frontal intakes can be seen clearly from the Figure 8. For example, if 75 per cent of discharge is diverted, 80 per cent suspended material in the river has been drawn to the "Lateral intake"; for the same amount of water, suspended material taken to the frontal intake is only 16 per cent.

One of the main advantages of "Frontal Intakes" is that water is drawn from upper layers where the sediment concentration is less.

It is a well-known fact that for the case of uniform flow the concentration of suspended material decreases from bottom to the upper layers and has insignificant values at places close to the surface of water. Nevertheless, this situation exists where no secondary currents take place. When secondary currents occur, even at the points close to the surface of flowing body, heavy concentration of suspension material might be observed. The sediment concentration in the water diverted into a frontal intake can be considerably reduced as a result of the elimination of secondary currents by means of suitable vanes. Bottom guide vanes located at the entrance of sluiceway whose shape, length, and height should be determined through laboratory tests, may prove to be useful, especially for fixed crest weir.

3.3 KARABUK DIVERSION WEIR

For the purpose of water supply to the Karabük Steel Production Factory,

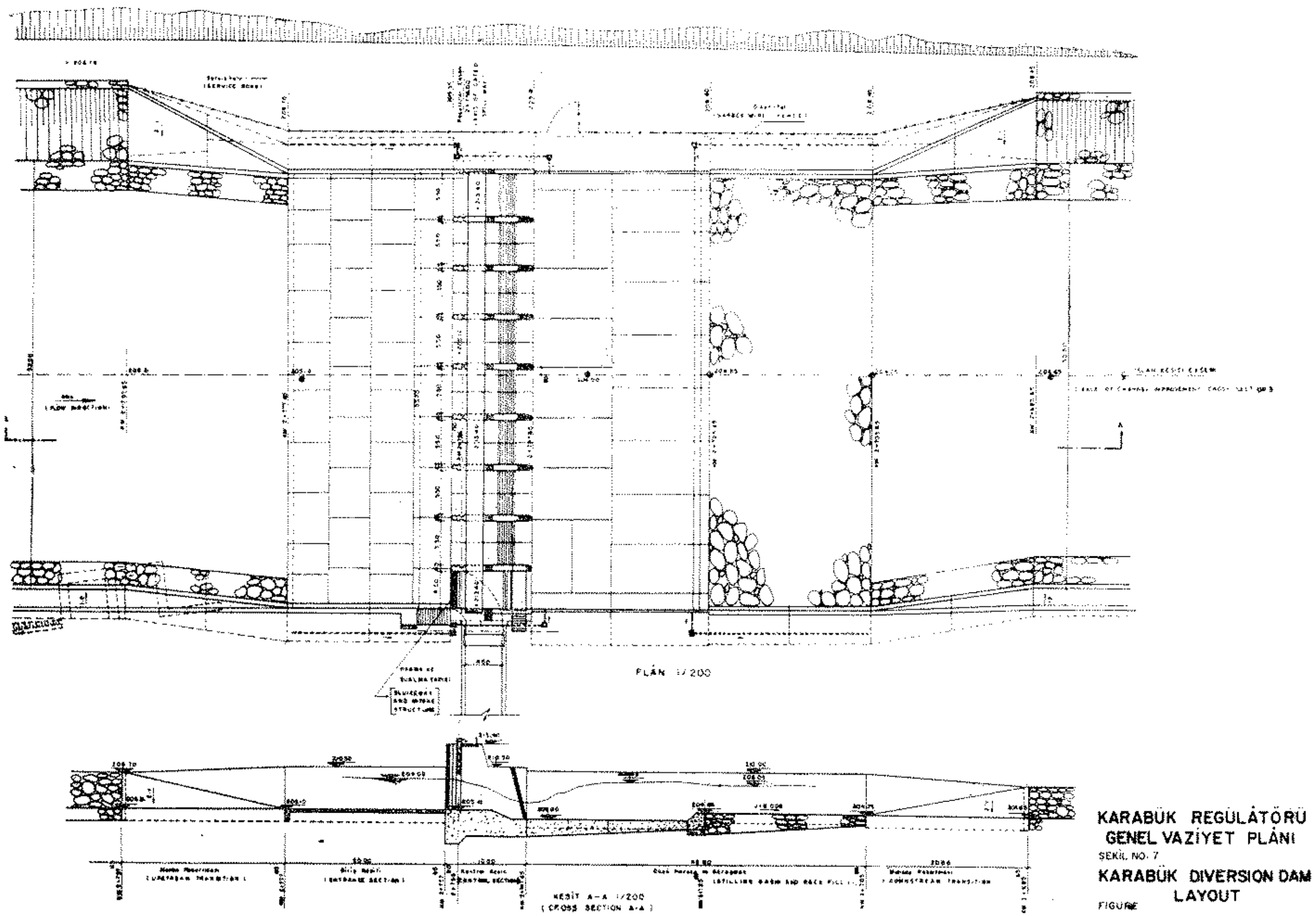

FIGURE 9 : Layout of the Karabuk Diversion Dam

a diversion dam having "frontal intake" had been constructed by State Hydraulic Works (DSI). It costed 4.2×10^6 TL (300.000 U.S. $) and started functioning in fall of 1973.

The Diversion Dam has eight clear openings, each 5.50 m wide, provided with gates, 3.90 m high by 5.50 wide. The general layout and sections of the Diversion Dam are given in Figure 9 and Figure 10, respectively.

The diversion structure had been designed to pass a flood flow of 800 m^3/s and calculated heading up in the normal operating level of 209 will be 0.60 metre while passing the flood flow through the fully open gates.

As shown on the cross section of intake structure in Figure 10, canal intake, just located above the sluiceway, has a shape of mouth closed at top which permits transfer of debris over the intake structure to the downstream of the river. Diverted water, after 90° turn, is conveyed to the settling basin parallel to the axis of dam. The results of model tests have indicated that there is no need for streamlined bottom vanes at the entrance of sluiceway. Since the diversion dam went into operation in late 1973, detailed prototype investigations have yet not been completed. But Ikizdere Hydroelectric Power Plant has been under operation since 1961. The observations made at the above mentioned structure revealed that the sediment problem to be encountered is mainly related with operation and maintenance. Water taking system briefly explained above operates efficiently and gives satisfactory results from principle and design aspect. One of the most important points to be noted here from the operational standpoint is that flow velocity in sluiceway must be as low as possible and that intake structure must be fully submerged.

For this purpose, the sluiceway gate should not be kept open more than the diameter of the largest particle of the gravel and sluiceway gates should be opened to a minimum in order to make the trash racks submerged and the entrance velocity minimum. If the operation of sluice-gate is done in the reverse case, that is, sluiceway gate is kept as open as possible in order to permit diversion of water to intake, high velocities occur in front of intake and vortices become much stronger. For getting optimum efficiency, the points mentioned above should be strictly followed.

To control whether the sluice-gate is open in desired height which is less than or equal to the dimension of the largest dragged stone, the lower part of the gate will be viewed from the downstream face to see if a stone grain is plugged within the gab of the gate. If there are stone particles plugged or stuck in the gate opening, then the gate will be opened a little bit higher, just enough to let the particles to be flushed. In this manner the minimum opening height of gate might be determined and surplus water from diverted will be spilled over the weir or discharged through undergate downstream.

4. CONCLUSION

Giving particular reference to practice in Turkey conclusions to be reached are summarized in the following:

(1) Classic lateral intakes, with the help of dividing wall, guide levee and bottom vanes, may give satisfactory results, with respect to sediment control.

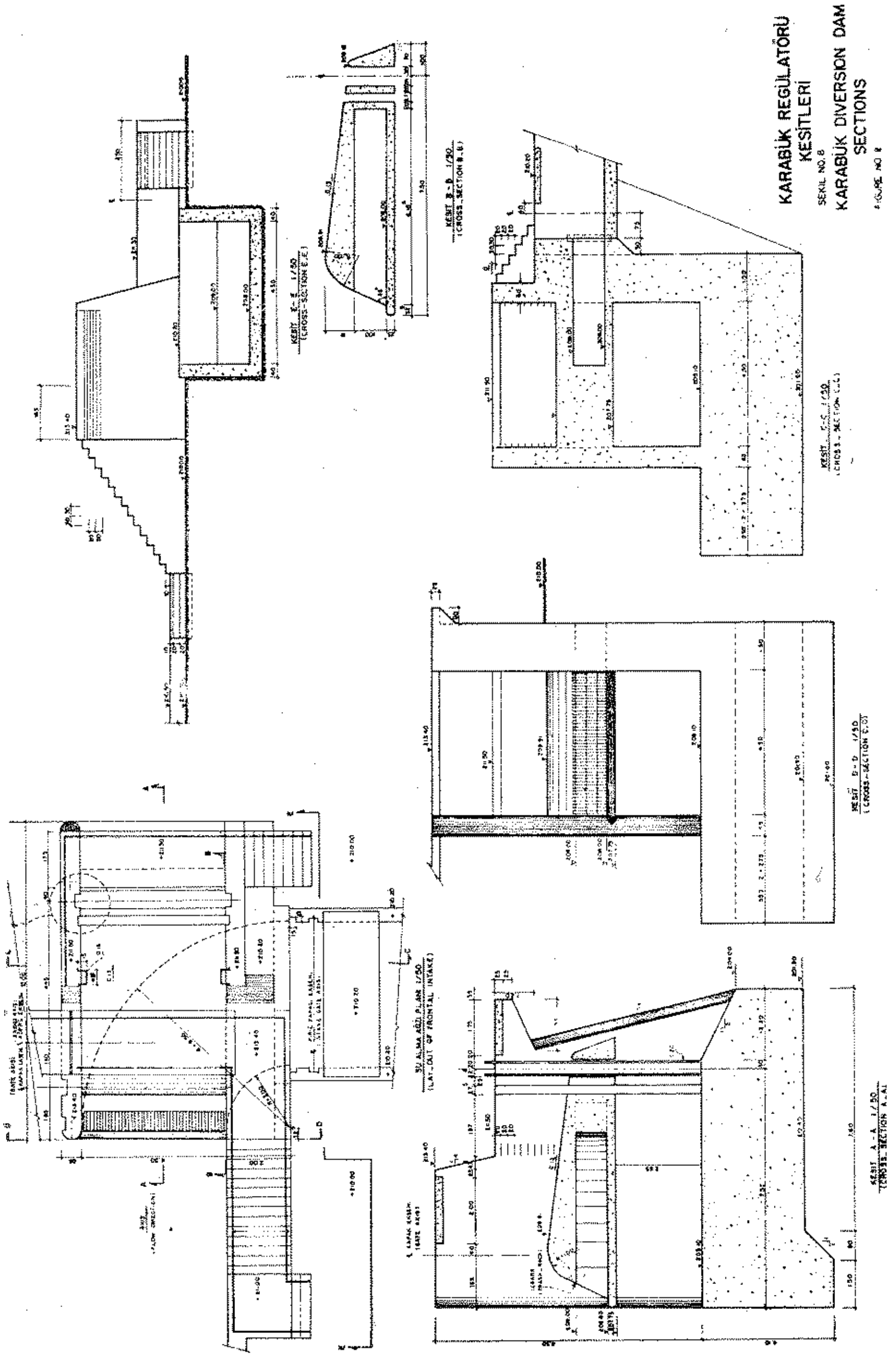

FIGURE 10 : Sections of the Karabuk Diversion Dam

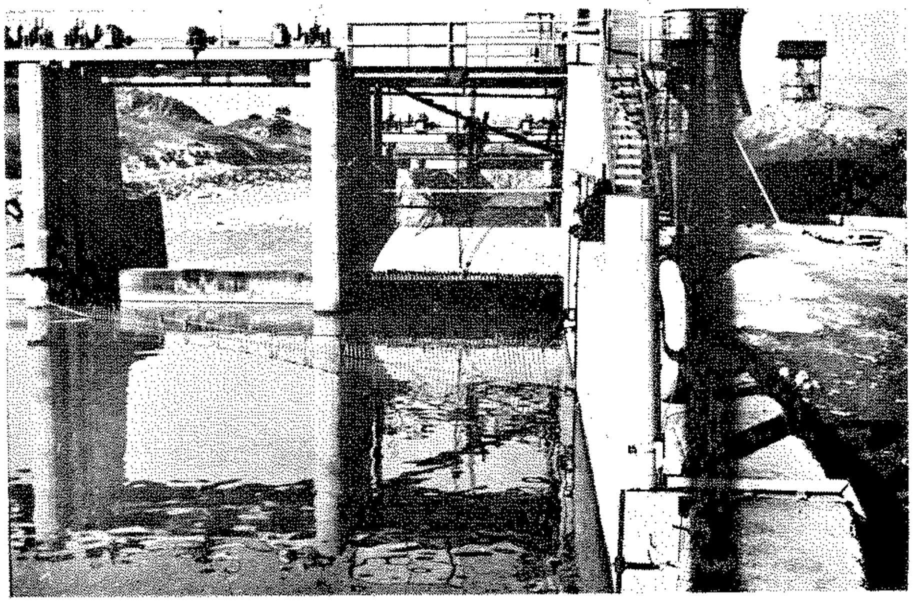

FIGURE 11 : Viewed towards the Frontal Intake of the Karabuk Diversion Dam·

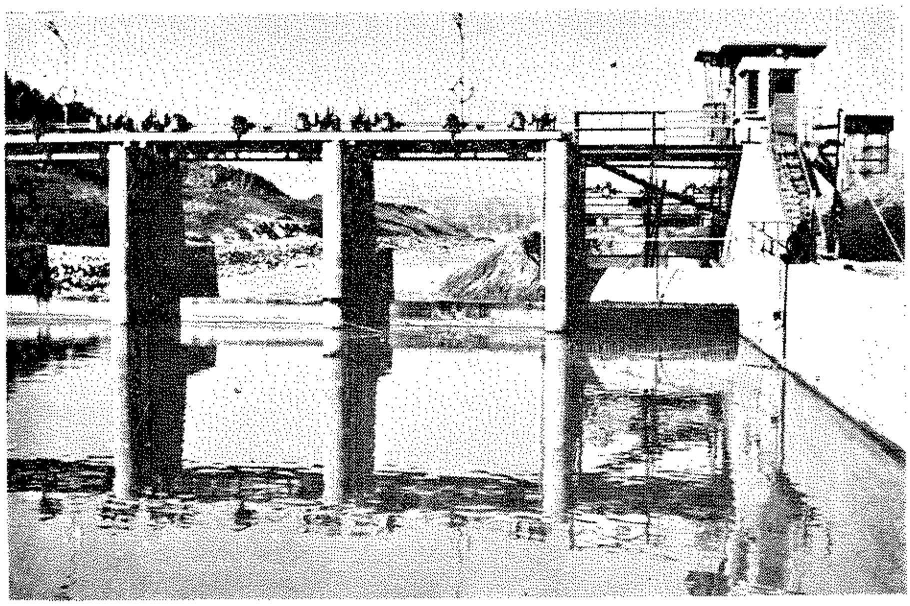

FIGURE 12 : Viewed towards the frontal Intake of the Karabuk Diversion Dam

(2) Depending on river characteristics, derivation of total irrigation requirements from one side of river might be more effective instead of setting up two seperate intake structures.

(3) Dealing with sediment control problems, it should be always in mind that measures taken to provide an artificial curve might be ineffective in case all or most of the water in the river bed is diverted to the intake structure.

(4) Frontal intakes have proved their high efficiency in order to get clear water.

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