Transactions on Ecology and the Environment vol 17, © 1998 WIT Press, www.witpress.com, ISSN 1743-3541

Birecik Dam & HEPP
Downstream River Arrangement

R. Naderer, G. Scharler
Verbundplan GmbH, 5021 Salzburg, Austria
e-mail: scharlerg@verbund.co.at

Abstract

Birecik Dam & HEPP on the Euphrates river in Turkey is currently the world's first major BOT scheme with an overall investment and financing sum of about DM 2.3 billion.

The project includes a downstream river excavation with a length of about 12 km and an excavation volume of about 12 million m^3, with the aim of increasing the head available for energy production. At the design discharge of 1900 m^3/s the head can be increased for about 3.2 m, which makes more than 7 % of the total gross head.

The topography of the natural river bed was transformed in a 3-dimensional model in CAD. After calibration of the backwater model for the natural river, the sensitivity of the tailwater elevations on the geometry of the excavation was investigated. Comprehensive cost-benefit studies were performed, varying all parameters of dominating influence. With this procedure a significant reduction of excavation volumes and project costs compared with the preliminary design could be achieved.

The alignment of the excavated channel follows the natural riverbed as close as possible, the side slopes of the trapezoidal channel are designed with an inclination of 4h:1v.

The long-term behavior of sediment transport was analyzed for the whole reach down to Karkamis Dam & HEPP (about 40 km), which also is currently under construction. A sonar survey of the riverbed delivered the basis information for these computations. Also the influence of the rapidly varying turbine flows on the sediment transport was estimated by means of unsteady flow computations.

1 Introduction

Birecik Dam & HEPP is located in the south-eastern region of Turkey, about 80 km downstream of the well-known Atatürk Dam at the Euphrates river. It is part of the South-east Anatolia Project (GAP), a development plan which contains a number of dam projects on the Euphrates and Tigris for irrigation and power generation. The dam structure is more than 2.5 km long and consists of earth-fill dams on both sides of the Euphrates, with a central concrete gravity dam integrating spillway, intake structure and powerhouse. The maximum height above foundation will be 62.5 m, six Francis turbines with 112 MW each will deliver an annual energy output of about 2.5 billion kWh.

The project includes a downstream river excavation with a length of about 12 km and an excavation volume of about 12 million m^3, with the aim of increasing the head available for energy production. At the design discharge of 1900 m^3/s the head can be increased for about 3.2 m, which makes more than 7 % of the total gross head.

The hydrological main data of the Euphrates river at the dam site are as follows:

catchment area of reservoir	100,702 km^2
mean annual discharge	963 m^3/s
25 years flood discharge	4,290 m^3/s
100 years flood discharge	5,440 m^3/s
probable maximum flood	17,353 m^3/s

The objective of this paper is to give an overview about the design works performed.

2 Optimization of Design

At the time of signation of the contracts for the erection of the plant only a preliminary design was existing for the river excavation, since no detailed topographic survey was available then. Excavation volumes had been estimated on the basis of 12 surveyed cross-sections as about 19 million m^3, and a cautious estimate for Manning's n (0.028) had been used in the computations for the tailwater rating curve of the power plant. This rating curve had become part of the contracts.

2.1 Model and calibration analyses

After the official start of the project a detailed survey of the riverbed including the banks and islands was performed and the design had to be updated. From all surveying data available contour lines with 20 cm difference in height were generated in the riverbed and a 3-dimensional topographical model was developed with AUTOCAD.

The natural riverbed was modeled in HEC-2 with 47 cross-sections. The monthly discharge-depth measurements for 20 years at Belkisköy station which is located about 800 m upstream of the dam axis have been used for the calibration of the model. The resulting values of Manning's n which were then used for the optimization of the excavation design are given in Figure 1.

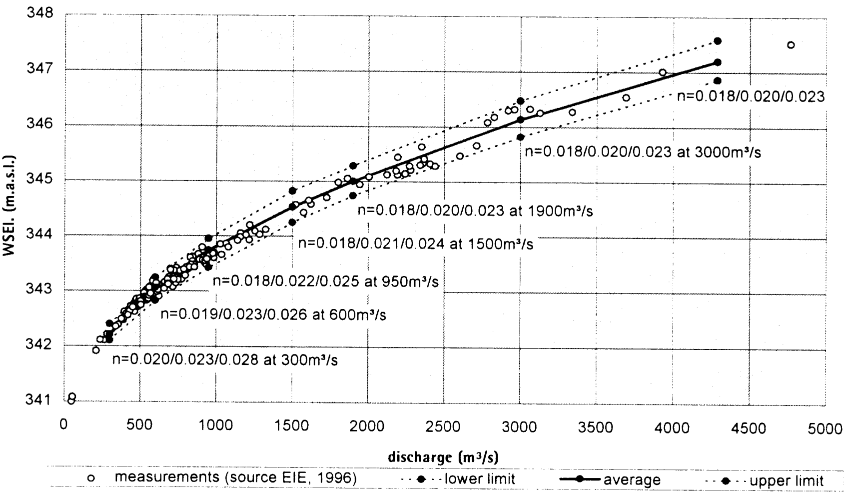

Figure 1: Belkisköy station - values of Manning's n for the natural riverbed

2.2 Optimization studies

For to find the most economical solution fulfilling the contractual requirements for the tailwater rating curve at the powerplant comprehensive sensitivity studies varying all parameters of dominating influence were performed. Backwater analyses and calculations of excavation quantities were carried out for the whole reach down to the next powerplant. 53 cross sections were used for modeling the reach length of 33.6 km in HEC-2.

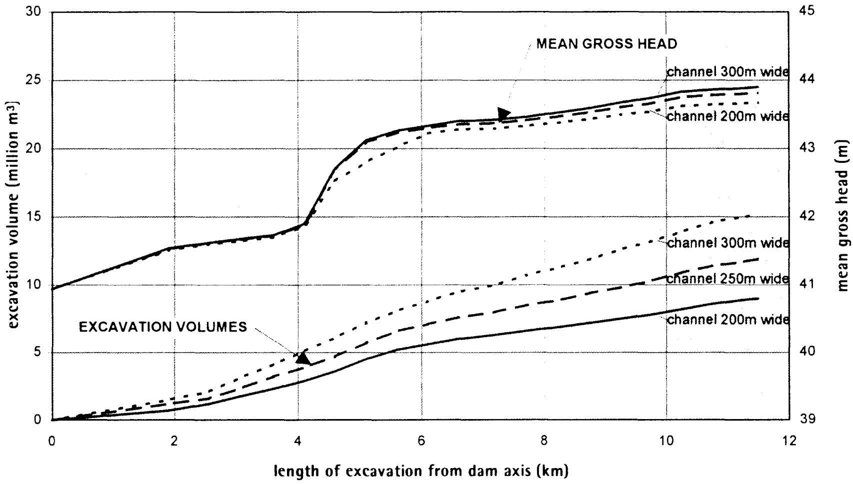

Figure 2: Excavation volumes and mean gross head for different widths and lengths of excavation

The maximum depth of the river excavation was limited by outcrops of the rock surface which had been explored by a sonar survey of the riverbed as well as by the pumping capacity of the dredging equipment which had already been ordered at that time. The influence of different excavation lengths and widths, operation periods, energy prices and actualization rates on present gross benefit, present net value, benefit/cost ratio and internal rate of return were computed. As an example, the influence of different excavation lengths and widths on the gross head is given in Figure 2.

Finally it was decided by the owner to select the design with a channel width of 250 m and a length of 11.6 km which was found to bring the maximum net present value after an operation period of about 40 years (Figure 3). So the necessary quantity of excavation could be reduced from 19 million m^3 in the preliminary design to 12 million m^3.

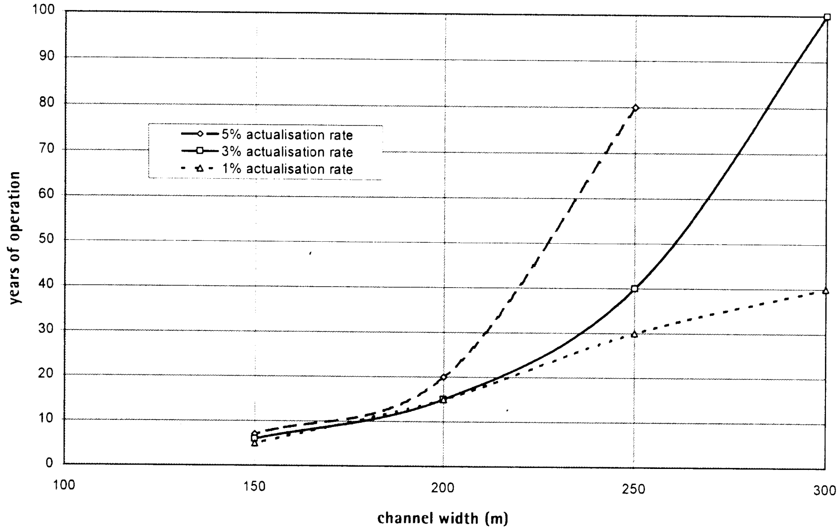

Figure 3: Excavation width with the maximum net present value after x-years of operation

3 Channel Stability

The long-term behavior of the excavated channel (for 50 years) was investigated under various hydrological and geological scenarios with the software HEC-6 (scour and deposition in rivers and reservoirs) and the influence of the changes in channel geometry on the tailwater at Birecik Dam was analyzed.

The following hydrologic scenarios were calculated:

- series H1** average years with the design discharge of 1900 m³/s in month 5 (for 30 days)
- series H2** 3000 m³/s over 10 days in month 5 every second year in addition to case 1
- series H3** 4290 m³/s (25-years flood) over 10 days in month 5 every tenth year in addition to case 2
- series H4** 5440 m³/s (100-years flood) over 10 days in month 5 in year 21 in addition to case 3
- series H5** series H1 plus 3000 m³/s over 0.6 hours every day, simulating the effect of operating surges
- series H6** series H4 plus 3000 m³/s over 0.6 hours every day, simulating the effect of operating surges

The effect of rapid changes of the operating discharge was estimated by an unsteady flow analysis with the software FLORIS (flood routing in river systems). The tractive forces for a surge caused by increasing the turbine discharges from 500 to 1900 m^3/s in 10 minutes were analyzed, and a discharge producing similar tractive forces (about 3000 m^3/s) was introduced in the analyses of sediment transport.

The soil samples from the river bed showed the following classifications:

- medium coarse gravel (for 11 of 25 samples, 44%)
- medium and fine medium gravel (for 6 of 25 samples, 24%)
- fine sand (for 3 of 25 samples, 12%)
- fine sandy silt (for 5 of 25 samples, 20%)

Based on the locations of these samples and on the evaluation of the 17 recorded tracks four typical gradations were determined and allocated at the cross sections in three geological scenarios, in order to check the sensitivity of the results on different gradations of the bed material. Series G2** presents a worst case scenario for degradation (fine sand, fine sandy silt and fine medium gravel as bed material), series G1** is a comparative case to show the influence of varying the gradation along the river axis (medium coarse gravel as bed material) whereas series G3** presents the most probable case (realistic distribution of the gradation curves along the reach length).

In general scouring of the river bed was found to occur for all investigated scenarios in the upper reach down to km 12 at Birecik bridge and deposition in the Karkamis reservoir from km 18 to 29.

The computed changes in the profile of the channel after 10, 25 and 50 were computed. For the most unfavorable combination of fine gradation of the bottom material and inflow hydrographs including flood events as well as daily modulating turbine discharges (case H6G2) the computed scour depths reach about 1.5 m at km 0.5 at the tailrace of Birecik dam and about 1.3 m at Birecik bridge after a computation period of 50 years (Figure 4). Average depth of scouring along the profile down to the Birecik bridge becomes about 0.65 m after 50 years.

The development of scour at km 0.5 (tailrace of Birecik dam), at km 7 and at km 12 (Birecik bridge) over time is given in Figure 5.

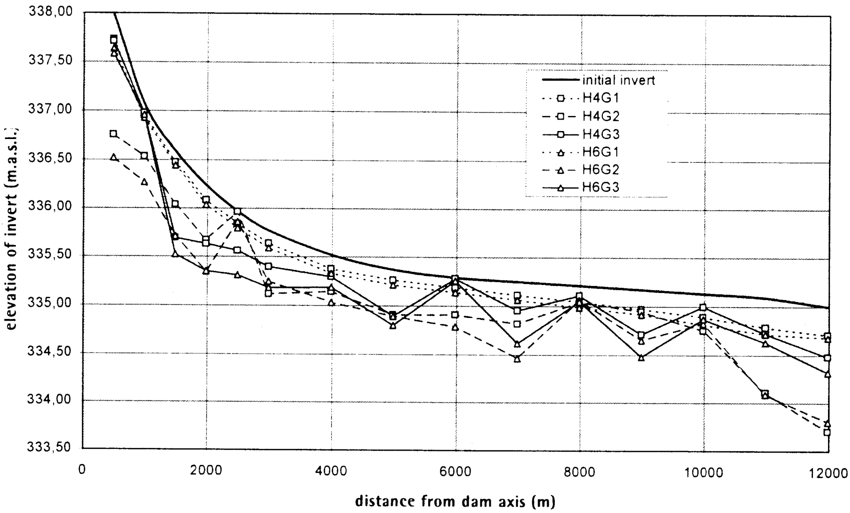

Figure 4: Computed changes in profile after 50 years (series H4 and H5)

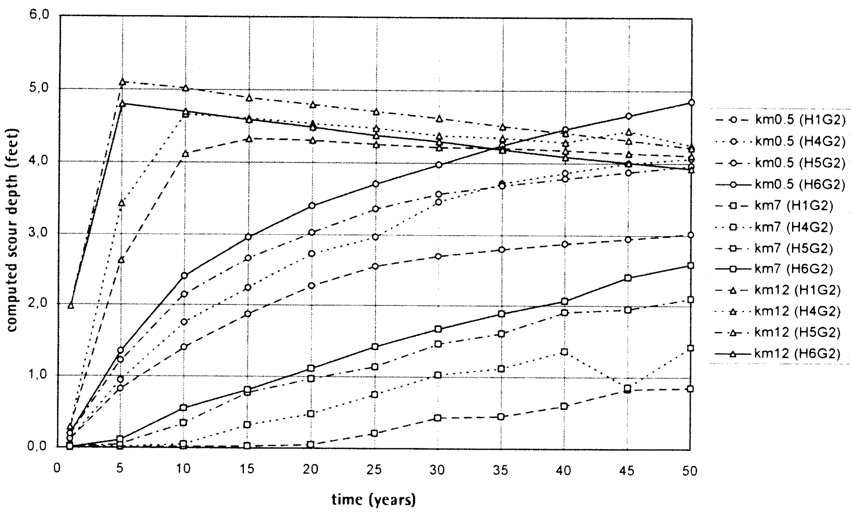

Figure 5: Computed scour depths for series **G2 at km 0.5, 7 and 12 from the dam axis

The maximum annual rate of scouring occurs immediately downstream of the dam with 31 cm/year for case H5G2 between year 0 and year 5, whereas a tendency of curing can be observed for the following years (see Figure 5). In general the annual rate of scouring (in cm per year) reduces with time and reaches the following values between year 40 and 50 for the scenarios H4** and H6**:

	at km 0.5	*at km 7.0*	*at km 12.5*
series H4G1/H6G1	0.3 / 0.5	0.3 / 0.2	0.6 / 0.2
series H4G2/H6G2	0.6 / 1.2	0.2 / 1.6	-0.1 / -0.5
series H4G3/H6G3	0.4 / 0.6	1.7 / 1.9	2.1 / 0.1

The maximum increase of the bottom elevation caused by deposition of the eroded bed material was calculated at km 25 with about 1.3 m after 50 years.

4 Summary

In summary the following conclusions can be made:

- The necessary excavation quantities for the downstream river arrangement could be reduced from about 19 to 12 million m^3 after calibration of the backwater model and performing comprehensive design studies.
- The selection of the final design of the excavation was verified by analyzing the most important economical parameters and checking their sensitivity on shape and volume of excavation.
- The development of a digital 3-dimensional topographic model was extremely helpful for these studies, which had to be prepared in a very short time.
- No global problems concerning the stability of the excavated channel are expected for the chosen design, since average scour depths after 50 years were calculated with about 0.7 m under unfavorable assumptions.
- Nevertheless, locally larger scour depths may occur and some provision for maintenance works (e.g. local slope protection) should be foreseen.
- The influence of scouring on the tailwater elevations at the Birecik dam was analyzed and found to be negligible.
- The analyses showed, that the scour at Birecik bridge at the downstream end of the river excavation may reach depths of about 1.5 m in a relatively short period of 5 years (without taking into account the local effects at the bridge piers). It was therefore recommended to survey the development of scouring at the Birecik bridge in regular intervals and to prove that the actually occurring scour does not become critical for the stability of this structure.