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ADVANTAGE OF NATURAL BARRIER IN LOCATING INTAKE IN RIVER AN EXAMPLE STUDY

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Abstract: *Proper location and orientation of Intake well is very important for its trouble free performance. While locating Intake in a river main aspects to be considered are minimum and maximum discharge and corresponding water-level, behavior of the river in the upstream as well as in downstream reach, type of bank etc. To augment drinking water supply to Bhopal city, it was proposed to draw 3.94 m^3/s of required raw water from a suitable location in river Narmada near Shahganj, Madhya Pradesh. The location was to be decided on the basis of analysis of data and site conditions. The site was visited and it was noticed that the presence of elevated rock-outcrop near a place known as Bandrabhan was acting like a natural weir. Analysis of cross-sections revealed that due to turbulent action of rock-outcrop, there was no deposition upstream of this location along right bank. This natural barrier was also creating a pool of water in its upstream reach, even at the time of minimum flow in the river*. Giving due weight-age to presence of natural barrier and o*n the basis of river morphology appeared in past years in Satellite imageries, analysis of minimum water level data, presence of other tributaries in the vicinity, and condition of bank material the location and hydraulic design of intake was finalized. This Paper deals with hydraulic aspects of locating the intake site and its hydraulic design. Effect of various parameters with particular emphasis on location with respect to natural barrier would result in providing economical and accurate design for intake.*

Keywords: *natural barrier; river morphology; satellite imageries; minimum water level.*

INTRODUCTION

A water supply scheme was proposed to augment the present drinking water supply for Bhopal city. It was proposed to draw raw water from right bank of river Narmada near village Hirani. The water would be carried upto the service reservoir in 3 stage pum ping and also th rough gravity flow in between for 45 km. Total distance from Intake well to the service reservoir is about 65 km and vertical lift of 275m. The exact location and hydraulic design of intake was to be finalized on the basis of analysis of river cross-sections, minimum/maximum water level and corresponding discharge data, sediment data and river morphology in the past years.

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BASIC REQUIREMENT FOR INTAKE LOCATION AND HYDRAULIC DESIGN

The Intake location and its hydraulic design were carried out on the basis of following analysis:

i) River cross-sections and L-section
ii) River discharge and corresponding water –levels
iii) Satellite Imageries for different years
iv) Bed and Bank material
v) Suspended sediment concentration
vi) Observations during site inspection

RIVER CROSS-SECTIONS AND L-SECTION

The river cross-sections for a reach of 4 km upstream to 2 km downstream of proposed intake location were studied. Fig.2 shows river cross-sections at the proposed intake location. Analysis of the cross-sections revealed that deep channel was along right bank from 1200 m upstream of proposed location to the 2000 m downstream. At the proposed location river bank on the right side was steep and firm. The right bank at this location was about 16 m higher than the minimum water level and deepest bed level was 3.0 m below minimum water level.

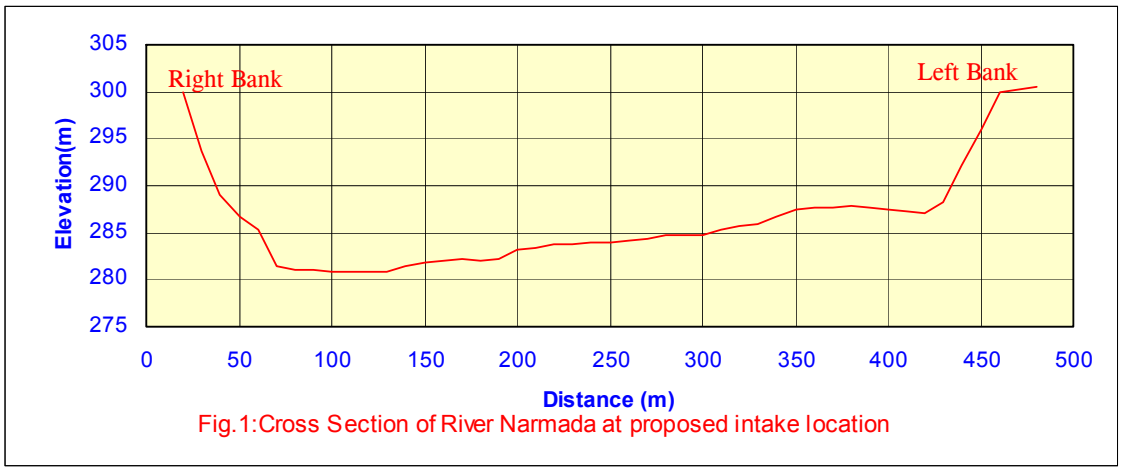

Fig.1:Cross Section of River Narmada at proposed intake location

Longitudinal section of deep channel of river Narmada was taken from Bandrabhan i.e. about 2 km downstream of proposed intake location to 5 km upstream of the proposed location, (Fig.3). The minimum bed level at the cross-section near rock out crop 2 km downstream of proposed location was 5 m higher than that at the proposed intake location and rock out crop was acting like a natural weir and thereby providing a good amount of pondage in its upstream. Therefore, even during the period of low flows, when many intakes have been found starving for required water depth, sufficient water depth would be available at this location for efficient /trouble free functioning of Intake.

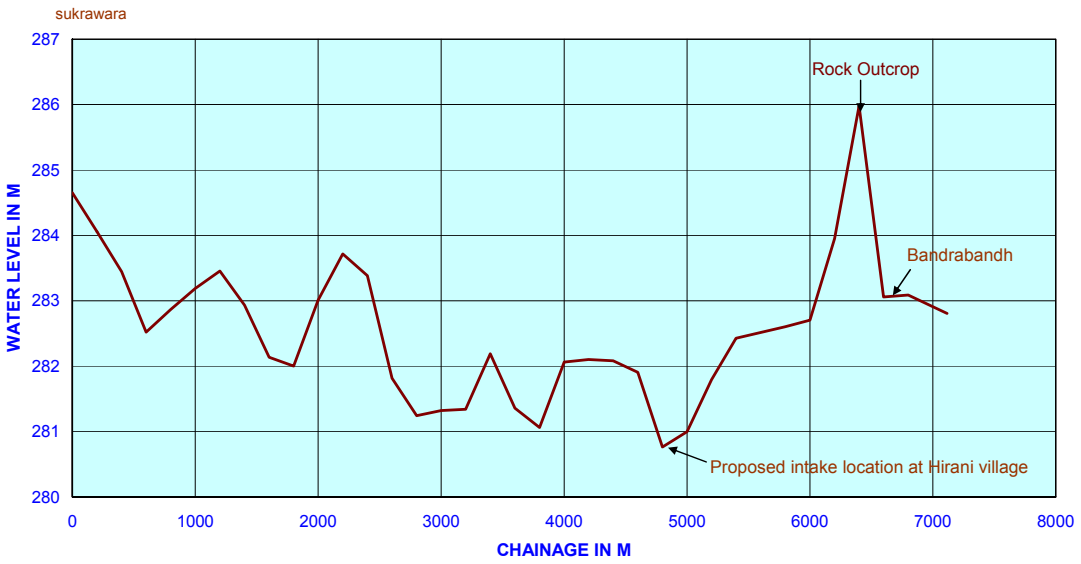

Fig. 2 : Longitudinal Section of deep channel of Narmada river from Sukrawara to Bandrabandh

RIVER DISCHARGE AND CORRESPONDING WATER-LEVELS

The daily discharg e data at the CW C gauging site at Hoshangabad, which was about 10km downstream of the proposed intake location, was available from year 1987 to 2001. Record of annual maximum and minimum flows and corresponding water-levels was also available from 1973 to 2001 as presented below in Table – I.

TABLE 1. Year wise Max. and Min. Discharge/Water Levels

Year	Max. R.L. in m.	Discharge in m^3/s	Min. R.L. in m.	Discharge in m^3/s
2000-2001	290.32	5600.00	284.24	70.00
1999-2000 --		26483.00	--	42.00
1998-1999 --		18000.00	--	49.00
1997-1998 --		10870.00	--	125.50
1996-1997	288.50	(2775)* 3450.00	284.19	87.39
1995-1996	292.30	(9990)*10100.00	284.56	102.60
1994-1995	296.16	(18859)*20200.00	--	114.00
1993-1994	293.34	(9707)*12100.00	--	49.00
1992-1993	292.01	(9221)* 9750.00	--	56.58
1991-1992	296.40	(18966)*20000.00	--	59.70

1990-1991	293.50	(10473)*12810.00	--	50.00
1989-1990	292.53	(9573)*10800.00	--	18.87
1988-1989	295.09	(15945)*16800.00	--	15.07
1987-1988 --		8623.00	--	15.00
1986-1987	296.25	20680.00	--	20.10
1985-1986	298.19	11687.20	283.96	19.00
1984-1985	298.61	28600.00	283.93	27.90
1983-1984	296.20	22020.00	284.155	26.90
1982-1983	294.55	16885.00	283.935	22.20
1981-1982 290.47	5	5853.00	283.895	20.00
1980-1981	296.40	21893.00	283.77	14.90
1979-1980	294.345	11200.00	283.77	**(Min.) 14.30**
1978-1979 295.89	5	18400.00	283.885	27.00
1977-1978	296.045	15436.00	283.77	15.20
1976-1977 292.99	5	10350.00	283.775	15.00
1975-1976	295.21	13865.00	283.805	19.40
1974-1975 300.80	5	28435.00	283.805	22.40
1973-1974 300.62	5	**(Max.) 31600.00**	284.13	26.70
1972-1973	297.160	--	284.135	23.50

* Shows data retrieved from the daily G-Q data of CWC

Estimation of minimum water level near the intake site is important for hydraulic design of intake. The sill level of intake has relevance to the minimum water level from the point of view of submergence requirement at pump-sump. It has been experienced that many existing intakes were starving for water on account of inadequate submergence. And this was due to incorrect estimation of minimum water level at design stage.

The analysis of discharge data indicated that minimum flow of 14.3 m^3/s was observed in May 1980 at Hoshangabad and the corresponding water level was R.L. 283.77 m. Considering some unforeseen worst circumstances, minimum water level for deciding lowest level opening in intake, has been taken as R.L. 283.50m.

The discharge data analysis also revealed that monthly maximum discharges varied between 26,483 to 24 m^3/s during 1986-2001. The highest flood observed was of the order of 33,593 m^3/s in the year 1973. The water level for this flood at proposed intake site was at R.L.302.415 m. The formation level of the pump floor was therefore, suggested above this level. For locating intake in deep channel this peak discharge was considered for working out foundation level.

SATELLITE IMAGERIES OF THE NARMADA RIVER

Satellite imageries for the years 1988, 1995, 1999 and 2005 were studied to see the charge in river course.

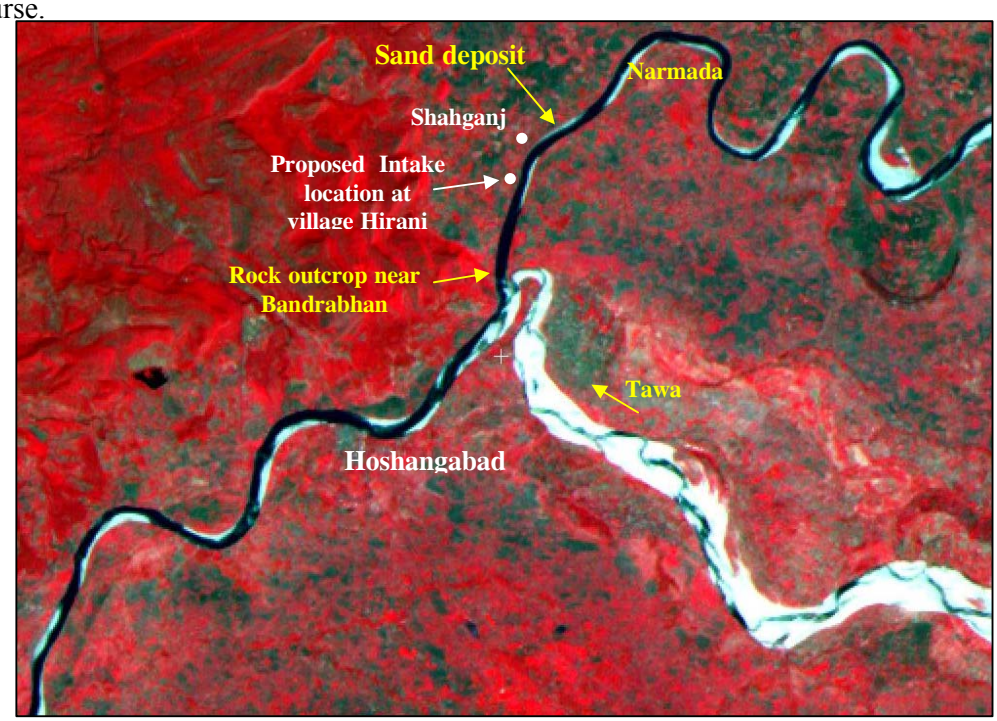

Fig 3 : Satellite Imagery of river Narmada near Hirani village for the year 1988

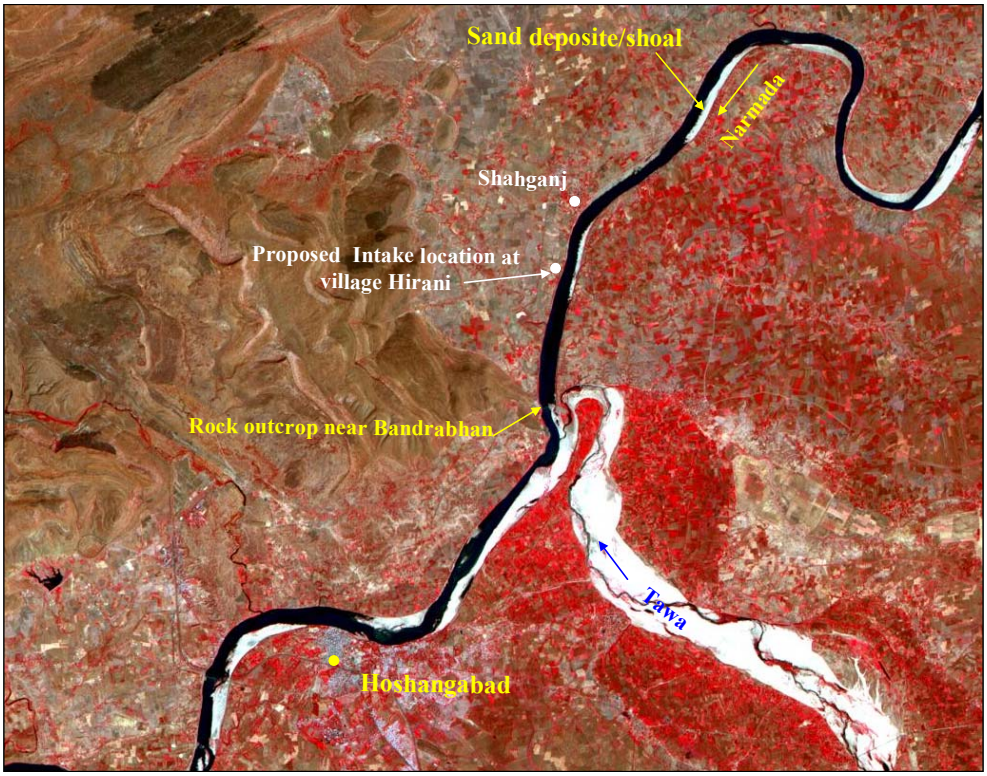

Fig 4 : Satellite Imagery of river Narmada near Hirani village for the year 2005

Fig.3 & 4 show satellite imageries for 1988 and 2005 respectively covering a river reach of 25 km upstream of proposed intake location to 15 km downstream. It also showed that all through these years deep channel has been along the right bank near proposed intake location. River was flowing in a fairly straight portion at the proposed location and there was a control point (rock out crop) at about 2 km downstream. At this point river flow was through a comparatively narrow section. From the satellite imageries it could also be seen that downstream of rock out crop, river Tawa joins Narmada river and creates sand deposits in a fairly long reach. Therefore, the reach in the downstream was not considered for locating intake.

RIVER BED AND BANK MATERIAL

The Narmada river bed in vicinity of proposed intake location comprises of well graded sand with D_{50} of the bed material 0.74 mm. The bank material on right bank at proposed location consisted more than 70% of silt and clay. D_{50} of the bank material varied from 0.026 mm to 0.049 mm. The right bank was composed of hard soil, very firm and not easily erodible in normal circumstances.

SUSPENDED SEDIMENT

Suspended sediment concentration analysis during monsoon as well as in lean period is very much necessary to decide the drawal levels at intake from the point of minimizing sediment entry into the raw water system. It will also decide necessity of desilting arrangement and likely volume of sediment to be handled.
Sediment concentration data of river Narmada at Hoshangabad gauging site were available for the period of 1986-2001. The ten daily averages of suspended sediment concentration of coarse, medium and five sediment and corresponding discharges during flood period i.e. July-September were analysed. Maximum sediment concentration of 9072 ppm prevailed for about 10 days in August 1993. The average total sediment concentration during flood varied from 219 ppm to 1318 ppm. Also the total sediment concentration of 1000 to 1100 ppm had occurred almost every year for a period of about 10 days. It was also noticed that out of total sediment, more than 90% was fine and remaining was coarse and medium. However during lean season i.e. non-monsoon period sediment concentration was very low and varied from 29 to 40 ppm.

SITE INSPECTION

To get familiarize with the site conditions or to know the ground truths, it is also necessary for the designers to carry out site inspection before finalizing the design. With this view site inspection was carried out in the month of February. The Narmada river reach from 4 km upstream to 2 km downstream of proposed intake location was inspected through boat. It was noticed that deep channel of river was along right bank from about 2 km upstream to 2 km downstream of proposed location. Within the reach under study, the river flow is between well defined & firm high banks. The distance between both the banks varies from 350 to 450 m Even during the high floods river discharge is contained within banks. Only the peak floods of the order of 30,000 m^3/s or more have witnessed over bank flows in the river. Local enquiry from the village people revealed that water depth available at proposed intake location remained at least 3 to 4 m even during the lean season.

INTAKE LOCATION AND ITS HYDRAULIC DESIGN

For trouble free perform ance of intake, its location plays a very im portant role. Once the location is f inalized, inputs such as lowe st minimum water level, deepest river bed level, discharge to be drawn, sediment concentration etc. are necessary for evolving efficient design from operation and maintenance considerations. For deciding the foundation level of the intake when located in the river, the maximum discharge and its corresponding water level, maximum discharge intensity, grain size distribution of bed m aterial etc. a re required. From the consideration of drag forces and local scour, it is desirable that the shape of the intake should be like a bridge pier with round ease and cut waters. If conditions are favorable, intake could be provided at relatively higher level since it is not subjected to scour.

For deciding the sill level of the opening of the intake, a realistic assessment of minimum water level is necessary. The sill level of the opening shoul d therefore be such that it is sufficiently below the lowest minimum water level satisfying the criteria of submergence. Concentration of sediment near the bed is more. For minimizing the sediment entry into the intake, the sill level of the opening should be provided wi th openings at different levels depending upon variation in water level with the arrangement to close bottom openings. Also the water way of intake opening should be such that at minimum water level the velocities at opening / entry should be preferably below 0.2 m^3/s for drawl of required discharge. Based on the site inspection, analysis of river cross-section, river discharge-water level data and satellite imageries it was inferred that the proposed location of intake well at Hirani was suitable from point of stability of river channel and flow depth available at m inimum water level. Intake could be located either in the deep channel or on the high bank.

LOCATING INTAKE WELL ON HIGH BANK

The deep channel at proposed location was very near to right bank i.e. about 60 m and also the bank was very firm and steep. Therefore, an open intake on high bank was considered with the following provisions as shown in fig.5:

1. A fore bay / approach channel cum silt trap to minimize siltation problem at intake. The bed level of silt trap could be about 3 to 4 m below minimum water level of R.L.283.50 m.
2. A low level flexible weir with crest about 0.5 to 1.0 m above river bed level at the entry of fore bay to prevent bed load entry into the intake.
3. Pump-sump of appropriate dimensions.
4. Arrangement of multi-level openings with gates for drawl of water selectively from different levels.
5. Bed and bank protection works for a reach of 50 m upstream to 30 m downstream over suitable synthetic filter.
6. Provision of slurry pump for removal of deposited sediment from fore bay / pump-sump.

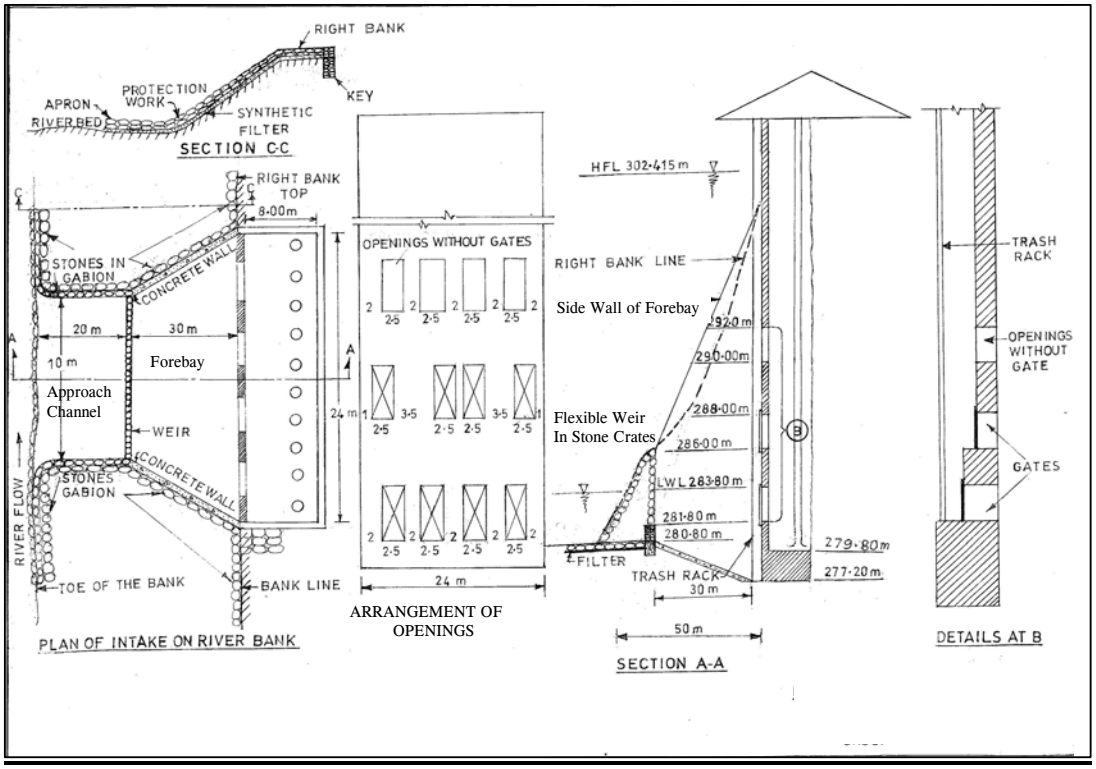

Fig. 5 : Schematic of Intake provided on high Bank

LOCATING INAKE WELL IN DEEP CHANNEL

The deep channel of river Narmada is very close to right bank at proposed location at village Hirani. Intake can also be provided in the deep channel with adequate arrangement for Vertical Turbine pumps for pumping the discharge of 3.94 m^3/s. Minimum water level of R.L. 283.50 m with flow depth of 3 to 3.5 m was available at intake site. Such intake would need following provisions:

a) Multiple level openings with gates to draw water selectively from different levels and suitable trash-track and stop-log arrangements.

b) Approach bridge for operation / maintenance and installation of pumps.

c) Depth of foundation at about 32 m below the existing river bed level i.e. up to R.L. 248.00 m from scour considerations and grip length.

d) Slurry pumps for removal of sediment deposited in intake well.

e) Bed and bank protection measure over synthetic filter.

The schematic diagram of such intake structure is shown in fig.6.

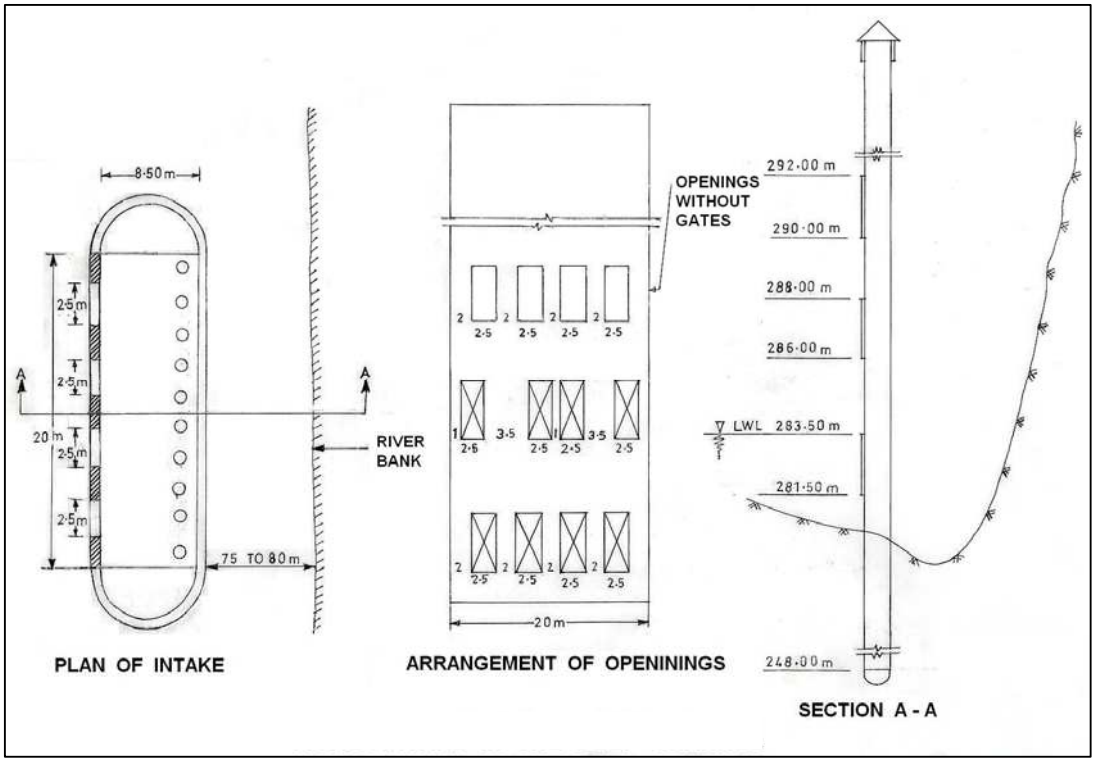

Fig.6 : Schematic of Intake provided in deep channel

CONCLUSIONS

- The proposed location seems to be most suitable from the point of availability of required water depth even during the lean season owing to an elevated rock out-crop in the downstream.

- In the present situation, the intake could be provided either in the river or on the bank. Considering that the deep channel is close to rightbank and more number of pumps are required to handle 3.93 m^3/s discharge, it is felt that an intake on the bank would be a better option.

- The multiple level openings need to be operated carefully during monsoon. The low level openings should be closed during flood period and water should be drawn from gates at higher elevation. During non-monsoon period water could be drawn from low-level openings.

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