Design of Sustainable Water Supply for Hindalco-Muri Works in Subarnarekha Riverbed Aquifer, Ranchi District, Jharkhand

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Abstract: Hindalco Industries Ltd Muri works Alumina plant requires water of about 500 m^3/hr after expansion at Muri, Ranchi District, Jharkhand. No deep-seated fractures could be seen in the area. Detailed groundwater exploration has been carried out through a number of Vertical Electrical Sounding (VES) in the Subarnarekha River upstream of Uraongarahanala confluence to select a suitable site for water sourcing. Hindalco has drilled six test bore wells in the riverbed to confirm thickness of the alluvial stratum determined through the geophysical investigations. The geo-technical investigations indicated that the alluvium has a maximum thickness of 4.6 m with an average thickness of 3.5 m. The alluvium comprises medium to coarse sand with gravels, clayey sand/sandy clay with mica flakes in the riverbed. Standing water level in the six bore wells during March 2005 was close to the ground level and during monsoon period the entire reach experiences flows with 1 m water column. The permeability of the riverbed alluvium varied from 60-80 m/day. Based on the above geo-technical results and geophysical data sets an intake system from the river bed (infiltration gallery) with a Jack well and a caisson on the right bank has been recommended in the Subarnarekha river at Biseria village.

The infiltration gallery may be expected to yield about 12,000 m^3/day under the prevalent river flow regime condition. During high river stage more water could be drawn from the intake system. Construction of infiltration gallery with 1 m diameter perforated intake pipes of 131 m length connected to a Jack well is underway at the site in Biseria village by Hindalco-Muri works, Muri, Ranchi district in Jharkhand and it is expected to yield about 12,000 m^3/day form the Subarnarekha river bed aquifer. Water budget for meeting the above requirement has been estimated from a groundwater flow model study.

INTRODUCTION

The Hindalco Muri works is situated in the Inter-stream region of Uraongarahanala and Sillinala in Subarnarekha river basin (Fig. 1). The Muri works is functioning since 1945 and presently it is envisaged to expand the Alumina plant capacity to five times. The water requirement has to be met from groundwater sources. HINDALCO Muri works has requested NGRI to carry out geophysical investigations for identification of suitable sites for water sourcing in the area. Chotanagpur Granite Gneissic Complex occupies the area. These rocks are found to be poorly permeable. The potential river alluvium along Subarnarekha locally offers good scope for relatively large supplies of groundwater.

Groundwater prospects map of Ranchi district indicates that the Chotanagpur Granite Gneissic Complex in Uraongarahnala and Sillinala interstream region, Subarnarekha sub-basin is having a poor permeability supported by steep gradient of groundwater levels (NRSA, 2005). Significantly none of the lineaments are extending into the alluvial fans around Uraongarahanala or Subarnarekha River. Thus groundwater exploitation through drilling of wells close to the lineaments may not yield sufficient quantity of water required for the industry. As regards groundwater potential in the inter-stream region of Uraongarahanala and Sillinala, the plateau weathered shallow granite gneiss is very poor, which is evident from large number of dug wells with shallow depths and used for limited irrigation and domestic purposes.

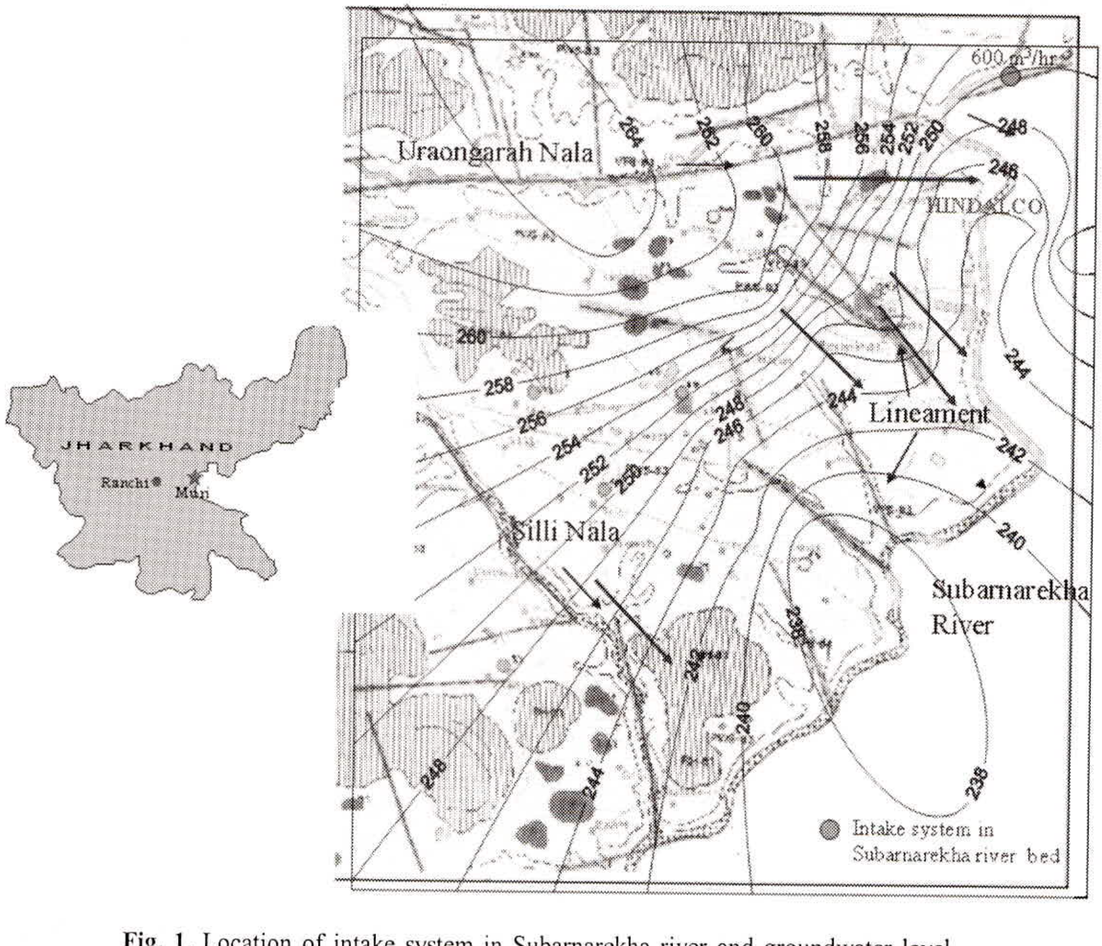

Fig. 1. Location of intake system in Subarnarekha river and groundwater level contours in m (amsl) – June 2004.

Geophysical Investigations

Vertical Electrical Soundings (VES) of 23 nos. have been carried out in the inter-stream region indicating that depth to bedrock is quite shallow (Fig. 2). In general, the interpreted resistivity sections indicated thin topsoil, weathered rock, and followed by a fracture zone, which is underlain by a hard massive granite gneissic basement rock. Absence of fracture zone could be a significant hydrogeological feature near the Uraongarhanala (Gurunadha Rao et al., 2006a). Valley fill deposits have formed on basement rocks along the streams (Fig. 3). Most of VES indicated a shallow thickness of overburden (max 20 m). As per the NRSA recommendation and results of detailed field investigations it is suggested that the area is not suitable for drilling of high yielding wells in the granitic gneissic terrain. No deep-seated fractures could be seen in the area (NRSA, 2005).

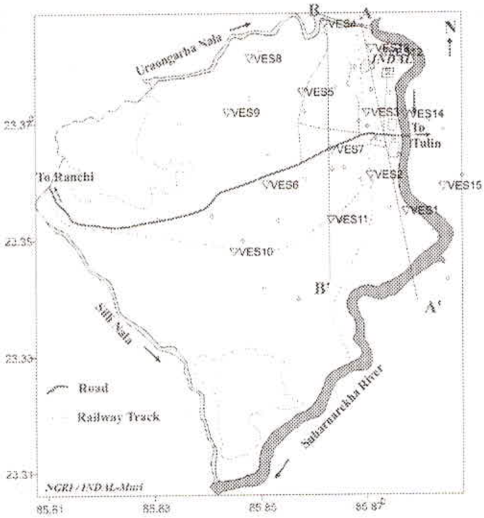

Fig. 2. Locations of VES in Uraongarhanala and Sillinala Interstream region.

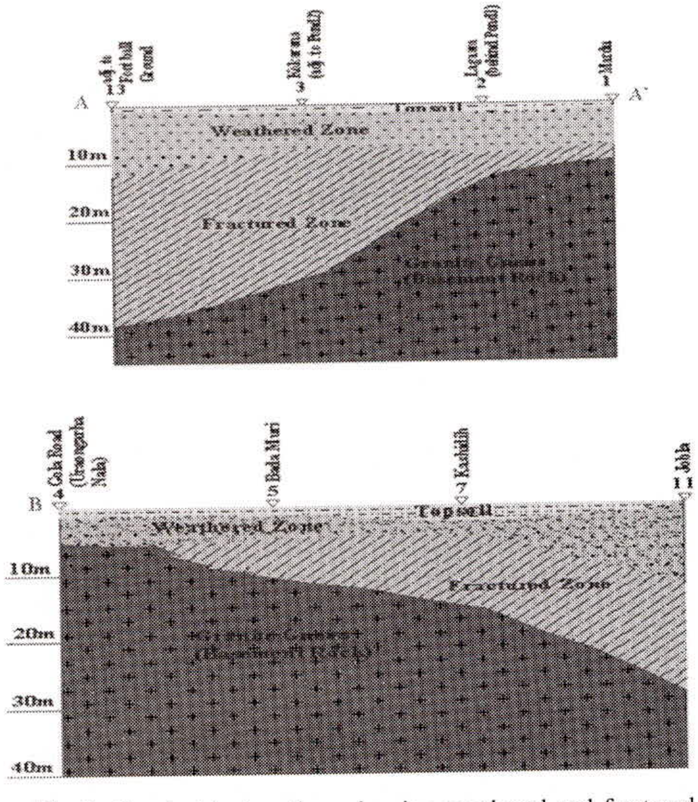

Fig. 3. Geoelectrical sections showing weathered and fractured formations along AA′ and BB′.

Subarnarekha Riverbed

The information has led to explore possibility of searching sites for installing infiltration/collector wells along the lineaments in the Uraongarahanala and Subarnarekha River. Ten VES soundings have been carried out on Uraongarahanala and Subarnarekha riverbed. VES results in the Upstream of Hindalco-Muri works on Subarnarekha river in Bisariya and Kotam villages indicated that weathered zone has > 15 m thickness, which could be even > 20 m in the Bisariya village about 500 m from Subarnarekha river. It has been suggested that the hydrogeological features are favourable for construction of a large diameter (~ 8 m) collector well in the riverbed.

Reconnaissance hydrogeological surveys carried in the Subarnarekha river bed of about 600 m upstream of Uraongarhanala confluence with Subarnarekha river indicated favourable hydrogeological features such as larger width of river flow on the gravel and sand-covered river bed (Gurunadha Rao et al., 2006b). Detailed geophysical investigations in the area close to the lineament cutting Subarnarekha river have revealed the occurrence of 6-7 m thickness of riverbed alluvium at Biseria village (Figs. 4 and 5). Further geotechnical investigations through drilling of six bore wells at the proposed site were carried out to confirm the interpreted depth of alluvial formations estimated from geophysical investigations (Fig. 6).

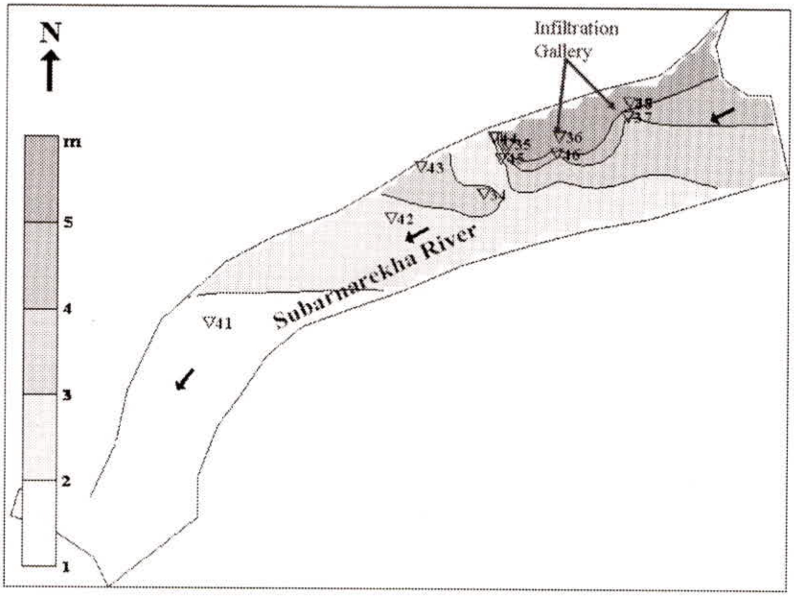

Fig. 4. Estimated thickness of River Alluvium (sand) in Subarnarekha river at the proposed site (Biseria village).

Geotechnical Investigations

Slim hole drilling has found that maximum thickness of 4.5 m river alluvium is met in the borehole BH-02. In view of maximum thickness of river alluvium and its nearness to right bank, the borehole BH-02 site has been selected as intake well site. A few representative samples from the boreholes have

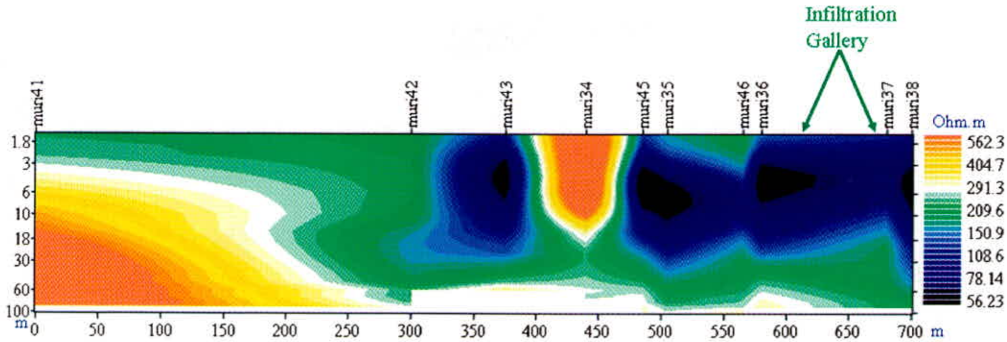

Fig. 5. Vertical cross-section of resistivity around infiltration gallery in Subarnarekha river bed (Biseria village).

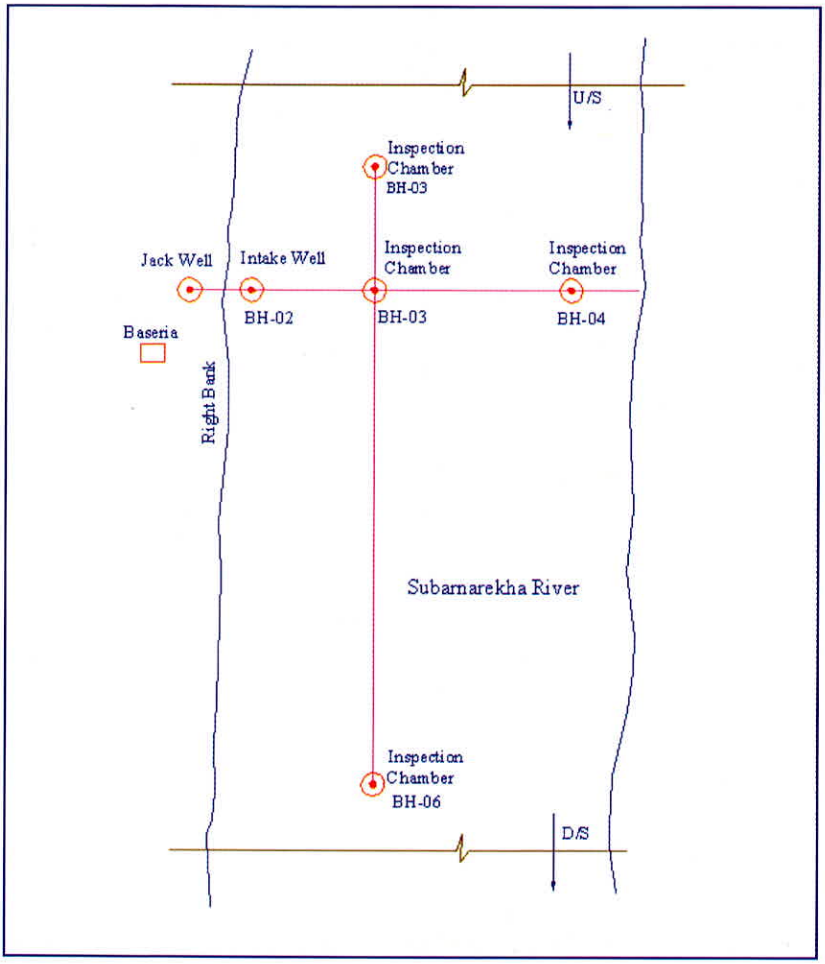

Fig. 6. Boreholes drilled in Subarnarekha river bed confirming thickness of river alluvium.

been subjected to grain size analysis. Range of gravel, sand and silt content were found to vary widely from 1% to 20%, 77% to 100% and 1% to 12% respectively. The alluvial strata can be described as fine to coarse sand with some gravel and little silt. In the absence of any data on aquifer parameters, it is very conservatively assumed that the entire thickness of alluvial aquifer in Subarnarekha riverbed may possess a transmissivity of at least 100 m^2/day. Stratum I was basically riverbed/bank comprising medium to coarse sand with gravels, clayey sand/sandy clay with mica flakes. Grain size analysis on samples of this stratum exhibited the following percentages of gravel, sand and silt.

Gravel	-	1% to 20%
Sand	-	77% to 100%
Silt	-	1% to 12%

Scour depth of 1 m is calculated by considering a peak discharge of 590 cumecs in Subarnarekha river at Tulin Bridge recorded in July, 1991 and 1.25 times the normal scour depth has been considered.

Standing water level measured in six bore wells drilled in the river bed has been found close to the bed level during March 2005 and the entire reach will be carrying water with height > 1 m during monsoon period. Estimated permeability of riverbed alluvium varied from 60-80 m/day from sieve analysis. In view of the above geotechnical results and geophysical data sets an intake system of infiltration gallery from the river bed with intake well and a jack well with caisson on the right bank has been proposed at Biseria village. The well is likely to yield 500 m^3/hr under normal river flow conditions. Further it was estimated from a preliminary groundwater flow model study of the river bed aquifer system, about 95% of groundwater withdrawal from the infiltration gallery will be replenished by base flows alone in the river. The proposed site in Biseria village, about 3 km upstream of Hindalco-Muri Works Alumina Plant, is the nearest location for design of an infiltration gallery for tapping Subarnarekha river bed aquifer.

Radial Collector Well

Groundwater wells located adjacent to a body of surface water (river, lake) may, over time, withdraw enough water from the flow system to reverse flow gradients and induce water from the surface source. Wells are commonly placed in close proximity to riverbanks and lakes to take advantage of this induced infiltration thereby maximizing the water-supply potential of the area. There are many advantages besides a greater supply volume: possible improved water quality over a surface source, gained filtration from the alluvial deposits. The well produces a mix of surface water and ground water but is definitely meant to capitalize on the potential for induced infiltration from the Subarnarekha river.

Basic factors affecting the design of withdrawal systems:

- Permeability of the aquifer
- Hydraulic gradient from the source to the installation
- Vertical permeability of the river bed
  Limiting infiltration rate of the river bed:
- Vertical permeability of the river bed may be so low that dewatering would occur under part of the river causing the line source to move farther away from the unit.

- Silt, deposited over a period of time, might reduce the infiltration rate. No long-term studies have been made.
- It is thought that high velocities every spring would scour the river bed and limit clogging effects, if present, to short periods of low-velocity flow.

Water Availability for the Intake System

As discussed earlier, in view of the above results of geotechnical investigations and geophysical data sets, an intake system from the river bed (infiltration gallery) and a jack well with caisson on the right bank has been suggested at Biseria village. The well is likely to yield about 500 m^3/hr under normal groundwater conditions. Further it was estimated from a preliminary groundwater flow model study of the river bed aquifer system, about 95% of groundwater withdrawal from the infiltration gallery will be replenished by base flows in the river alone.

The proposed infiltration gallery may yield about 500 m^3/hr considering lateral valley slope flow (Q_1) of 1600 m^3/day and under flow (Q_2) from upstream of 500 m^3/day. Contributions from base flows and direct runoff (Q_3) during greater part of the year are controlled by releases from the upstream hydroelectric project authorities. The minimum surface water flow recorded was 9000 m^3/hr (July) and maximum being 35,000 m^3/hr (September) during monsoon. The proposed intake system does not require exceeding 5% of the minimum surface water flows during summer months. Conservatively one may assume about 5% of the flow as direct recharge (10,000 m^3/d). Other components include contribution from rainfall (Q_4), salvaging evaporation and evapotranspiration losses (Q_5) of 800 m^3/day. Dewatering of alluvial aquifer by pumpage (Q_6) by taking the specific yield of the loose materials of coarse textured aquifer formation in the river bed to be 0.3, the area of aquifer dewatered to an average depth of 2 m and with an area of 0.4 sq. km (2 km reach and 200 wide) works about 240,000 m^3. The bulk of this quantity would account for the withdrawals and aquifer depletion in about 60 days during April to June and not considering other sources of recharge during this period. The daily yield by the depletion would be 240000 m^3/60 = 4000 m^3/d. The depletion would be restricted to the river bed, which in this case may not happen due to sustained controlled releases from upstream hydroelectric power station even during summer months. The depletion would be made good of releases and the bank storage (Q_7) component would also supplement. Thus it could be evident that estimated available groundwater from river bed aquifer and its environs total to 16,600 m^3/d. Considering available contributions to the groundwater recharge of huge quantity with 60% dependable flow, daily demand of 12,000 m^3/d from the proposed intake system of infiltration gallery at rate of 500 m^3/hr can adequately be met from various flows occurring in the river bed in the particular river reach alone during lean period without affecting groundwater table in the surroundings (Gurunadha Rao et al., 2006b).

Intake System of Infiltration Gallery in Subarnarekha River

Water requirement estimated for Muri expansion project is about 500 m^3/hr. Considering a daily withdrawal for 20 hrs, the designed discharge from infiltration gallery should be about 600 m^3/hr. Hydrological studies accompanied by geophysical studies and slim hole drilling in the river bed have identified a 50 m stretch of Subarnarekha river bed with large groundwater potential in the river alluvium with thickness of river alluvium limited to 3 to 4.5 m. Main advantage of the river reach, apart from occurrence of potential river alluvium, is sustained flow of surface water throughout the year from controlled releases from upstream hydroelectric project. In view of greater possibility of interaction of surface water and groundwater, the site offers a sustainable groundwater resource by appropriate design of a suitable intake system of infiltration gallery (Gurunadha Rao, 2006c).

An infiltration gallery is a groundwater withdrawal system consisting of a lengthy perforated pipe (intake pipe) laid with a very gentle slope below a riverbed and connected to a intake well and jack well, which is located on the bank. R.C.C. pipes with perforations are laid in trenches of 4-5 m below the lowest water table in the most permeable part of aquifer and back-filled with gravel of size suitable for aquifer materials and perforations in the intake pipes. An intake well for discharge of water from the intake pipe and settlement of fine particles and inspection chambers at required intervals have to be provided. Quantity of inflow into the intake pipe will depend on hydraulic conductivity of aquifer materials. It was recommended to drill six slim holes in the Subarnarekha riverbed to determine geometry of most potential river alluvium. The proposed site for infiltration gallery lies in Subarnarekha riverbed close to Right Bank at the borehole BH-02 (Fig. 6). Sources of water for meeting the enhanced requirements of the alumina plant of Hindalco shall consist of two infiltration galleries perpendicular to each other with intake sections of perforated pipes, four inspection chambers and an intake well and a jack well connected to the intake well by a blank pipe (Fig. 7). Profiles of the gallery and intake system up to the jack well as well as elevations and dimensions of perforated pipes, intake well, inspection chambers and jack well are also shown in the figure. Total length of perforated pipes in the intake system is 131 m (INRIMT, 2005). Two numbers of 40 HP Horizontal Centrifugal pumps shall be installed in the jack well to deliver required quantity 600 m^3/hr of water. The pumps will be operated on a schedule of 20 hours of pumping with a rest period for allowing recovery of four hours. A third pump will serve as a standby.

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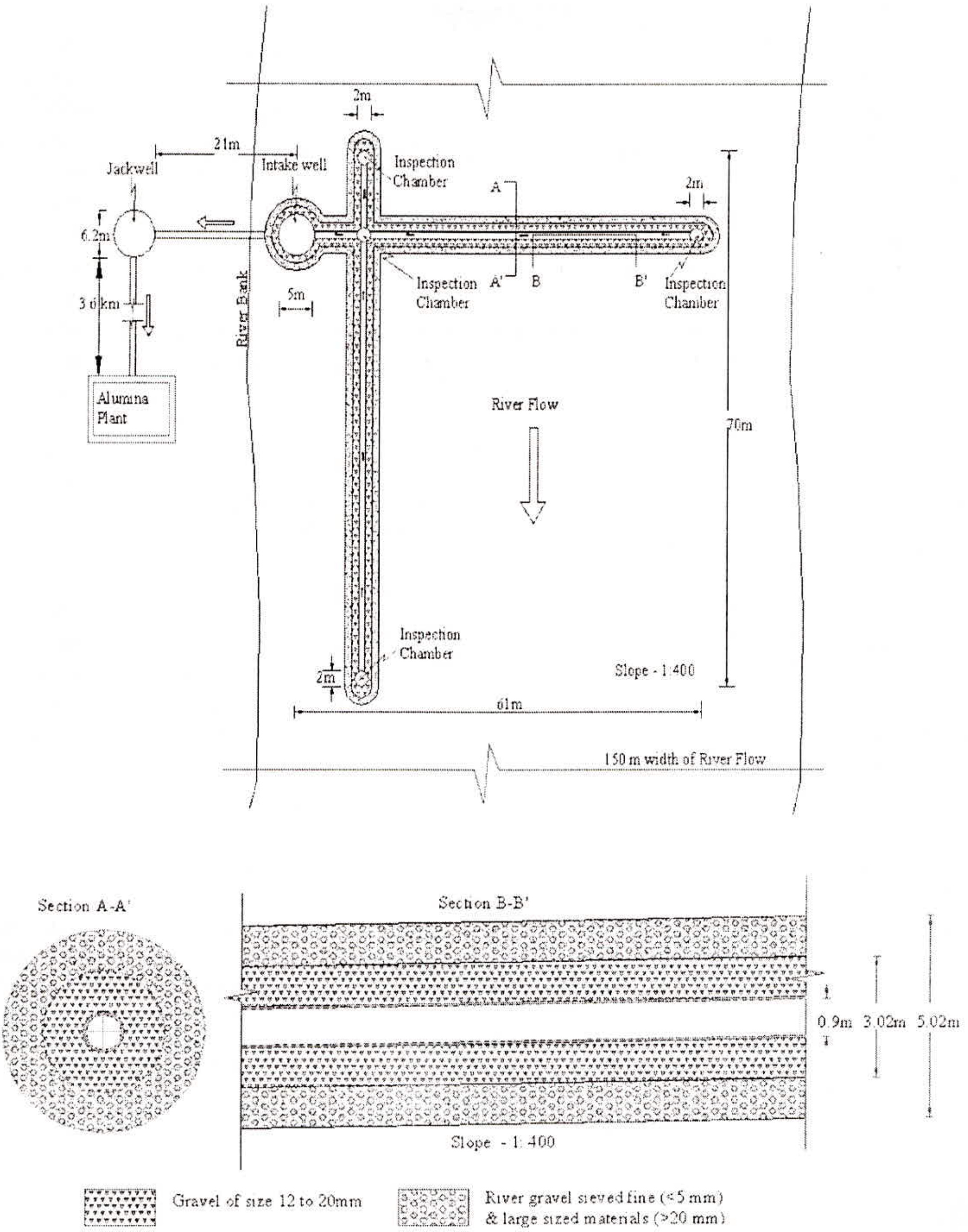

Fig. 7. Layout of intake system of infiltration gallery in Subarnarekha river in Biseria village for Hindalco.

CONCLUSIONS

Thickness and extent of alluvium is inadequate for sustaining large scale withdrawals through tube wells and collector wells. It is feasible to construct an infiltration gallery drawing partly upon river flows by induced infiltration. An infiltration gallery with appropriate length of intake system of perforated pipes of appropriate length may be placed around 3-4 m depth in the river bed. The infiltration gallery may be expected to yield about 12,000 m^3/day under prevalent river flow regime. More water can be drawn from the proposed intake system during high river stage. Construction has been underway for the infiltration gallery with 1 m diameter perforated intake pipes of appropriate length connected to a jack well through an infiltration well to obtain an yield of 12,000m^3/day. The diameter of the jack well could be 5 m. The perforated pipe has been provided with inspection at the terminal point and intersection point between two perforated sections. Efforts are made to avoid sand mining in the area as these operations may have an effect of decreasing the groundwater potential in area.

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