

Establishment of missing stream link between the Markanda river and the Vedic Saraswati river in Haryana, India – geoelectrical resistivity approach

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A missing stream link between the Markanda river and the Vedic Saraswati river in the plains of northern Haryana has been established based on geoelectrical resistivity surveys. The study revealed extensive buried sand channels composed of coarse sand with gravel and fine sand. The average thickness of coarse sand with gravel aquifer horizon was about 90 m and has been identified at a depth between 10 and 100 m. The fine sand horizon was observed beyond a depth of about 45 m. These sand bodies are extended laterally for a distance of about 12 km in the northeast to southwest direction connecting the Markanda river and the Vedic Saraswati river. The transverse resistance values of these buried channels (7392–7585 Ωm^2 for coarse sand with gravel, and 384–2856 Ωm^2 for fine sand) indicate good groundwater potential. The age of these buried sand bodies belongs to the Late Harappan period, as evident from different archaeological sites found in and around the survey area. Thus, the present study reveals that once the Markanda basin was a part of the Vedic Saraswati river system, and one of the headwaters of the once celebrated Vedic Saraswati river can be identified as the present Markanda river.

Keywords: Aquifer, geoelectrical resistivity surveys, sand channels, stream link.

SEVERAL streams of northern India like the Dishradwati and the Saraswati rivers as mentioned in the ancient Sanskrit literature, have generated much interest among the scientific community in the country. This curiosity ultimately led to the delineation of many of the present streams, unveiling the cultural history of the region in the remote past. Former courses of once celebrated palaeochannels like the Drishadwati and the Saraswati have been traced out using satellite imageries^{1–3}. One such relic is the Saraswati Nadi, presently a small tributary of the Chautang river system located to the east of the Markanda river^{4,5} (Figure 1). An attempt has been made here to study the stream relationship between the Vedic Saraswati river (Saraswati Nadi) and the present Markanda

river by using resistivity method. The findings are supported by remote-sensing studies.

The Markanda river located in the foothills of the Siwalik hills and Gangetic plains of Haryana, is the most dominant ephemeral stream between the Yamuna and the Ghaggar river systems. The river originates from Nahan in Himachal Pradesh and flows through Siwalik hills before meeting the Ghaggar river in the plains of northern Haryana. On the other hand, the Saraswati Nadi also known as Saraswati river, Saraswati Nala or Sarsuti, is one of the tributaries of the Vedic Saraswati river system, present during 6000–3000 BC (refs 2, 6–9). Presently, the Saraswati Nadi is in a defunct state; it used to originate near Rampur Herian in Yamunanagar District and flow through the plains in Bilaspur, Mustafabad, Thanesar, Bibipur and Pehowa before joining the Ghaggar river near Rasauli in Kurukshetra District. The Saraswati river is considered sacred in Haryana, as is evident from the occurrence of several historical temples, pilgrimage and Hindu ritual sites, and relics of archaeological sites all along the river course, indicating a perennial river of the past⁵.

The Vedic Saraswati is considered as a holy river that existed during the Mahabharata period (6000–3000 BC) of the Indian civilization in northwestern India¹⁰. The river originated from Har-ki-Dum glacier in Garhwal Himalayas and debouched into the ancient Arabian Sea through the Rann of Kutch. Many relics of this river have been identified as palaeochannels based on remote-sensing techniques^{1,9,11–15}. At present, the river has been represented by the Ghaggar river and Saraswati Nadi/Saraswati river^{1,5,16–22}. Numerous archaeological sites found along the course of the Vedic Saraswati are from the Mature Harappan, Sothi Harappan, Late Harappan and Post Harappan periods²³.

The Survey of India (SOI) toposheets (1 : 50,000 scale) were used to extract the drainage network of the study area. Satellite image of IRS 1D LISS IV (date of acquisition: November 2003; scale: 1 : 250,000) has been used to delineate the old river courses and the present drainage network in the study area. The satellite data were digitally processed in Erdas Imagine 8.7 software using digital image processing techniques like geometric correction, band combinations and contrast enhancement for the identification of features. After demarcation of the palaeochannel course, sites for vertical electrical resistivity sounding (VES) were chosen along the suspected stream link sites. VES surveys were carried out following Wenner configuration with a maximum electrode spacing up to 1 km. These sites were selected at Lotni, Kothi Lotni, Malakpur, Thikri and Sarusti Khera near Pehowa, Haryana (Figure 1) in one direction (NE–SW) between the Markanda river and the Saraswati Nadi. The apparent resistivity field curves were interpreted using curve matching techniques. In the present work, two-layer master curves prepared by Mooney and Wetzel²⁴, and Orellana

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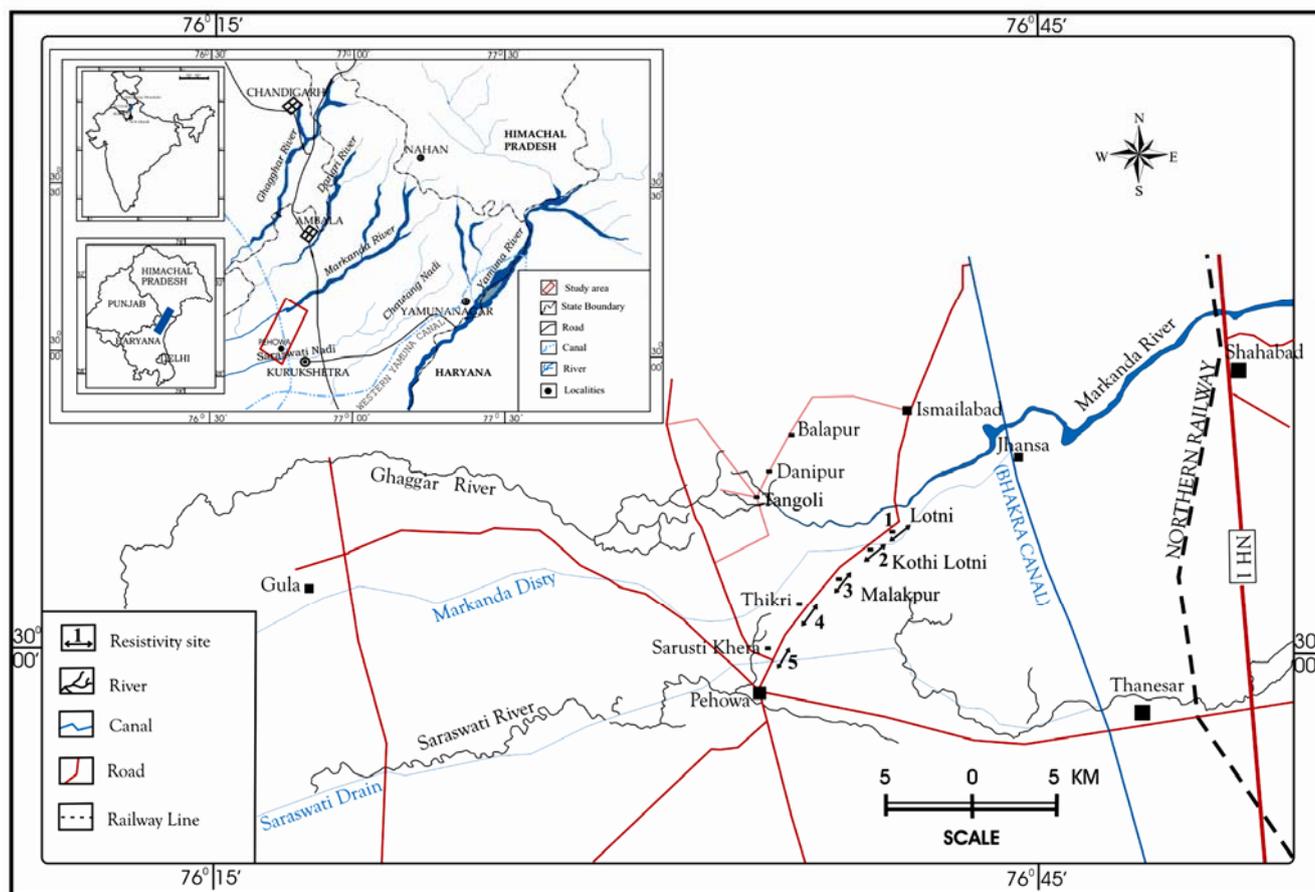


Figure 1. Map showing the study area. (Inset) The Markanda and surrounding river basins.

and Mooney²⁵ were used to interpret the field curves. The hydrogeological interpretations of these surveys were made on the basis of standard resistivity values of geologic formations under different hydrogeological conditions given by earlier workers²⁶⁻³⁷. The resistivity interpretation results were compared with the tubewell litholog data from Central Ground Water Board, Chandigarh and accordingly, the values were standardized for different geological materials. Further, resistivity log section of the study area was prepared to know the subsurface geological formations and possible subsurface stream link. Archaeological findings given by earlier workers of the area were referred for a possible historical link in terms of age in different places.

On the basis of visual interpretation on false colour composite (FCC) (2-3-4) image of IRS 1D LISS IV, palaeo-channel of Saraswati Nadi has been identified near the Pehowa region (Figure 2). The palaeo-channel is a former stream course along which water flows for a short distance during the rainy season, making the internal drainage. It appears as dark green in FCC because of its high moisture content. This palaeo-channel course passes via Thanesar, Thikri, Sarusti Khera and Pehowa from east to west direction. In the northern part of this course lies the dry

river bed of the Markanda, which is indicated by white colour in FCC. The observation points out that the region between the Markanda and the Saraswati Nadi is connected with a high moisture content surface displayed by dark green. This suggests that in the past, the Markanda river possibly joined the Saraswati river near Pehowa.

By following the initial remote sensing studies, the resistivity surveys were carried out in the following sites, near Pehowa (Kurukshetra, Haryana). The apparent resistivity field curves and their hydrogeological interpretations have been shown in Figure 3 a-e.

Site 1: Resistivity survey at this location revealed five different layers to a depth of about 90 m (Figure 3 a). The first layer has resistivity value of 62 Ωm and thickness of 1.5 m, and has been interpreted as surface clay. The second layer has resistivity value of 40 Ωm and thickness of 10.5 m, and has been interpreted as medium sand. The third layer has resistivity value of 110 Ωm and thickness of 38 m, and has been interpreted as medium sand with gravel. The fourth layer has thickness of 36 m and resistivity value of 27 Ωm, and interpreted as fine sand. The fifth layer has resistivity value of 25 Ωm, indicating fine sand with clay.

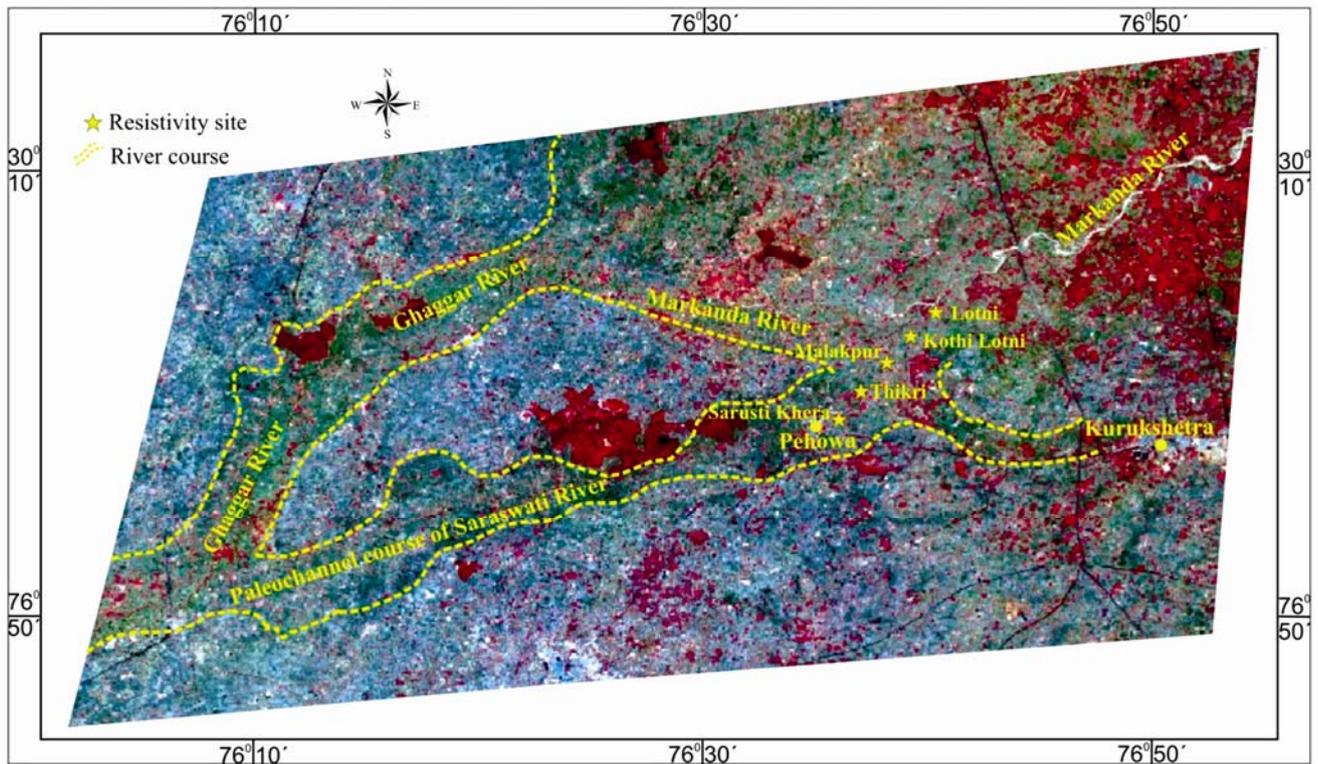


Figure 2. False colour composite of IRS 1D LISS IV image of lower portion of the Markanda river and palaeochannel course of the Vedic Saraswati in the northern Haryana plains.

Site 2: At this site, the field curve recognized four different layers to a depth of 100 m (Figure 3 b). The topmost layer shows resistivity of 100 Ωm and thickness of 2.2 m, and has been interpreted as surface clay. The next layer has a thickness of 11.2 m and resistivity of 30 Ωm , and has been interpreted as fine sand. The third layer shows higher value of 70 Ωm having a thickness of 87.5 m, and has been interpreted as medium sand. The fourth layer, thickness of which could not be ascertained, has resistivity value of 34 Ωm and has been interpreted as fine sand.

Site 3: The resistivity survey in this area revealed four different layers to a depth of 128 m (Figure 3 c). The top layer has resistivity value of 50 Ωm and thickness of about 1 m, and has been interpreted as artificial fill. The second layer shows high resistivity value of 125 Ωm and 5 m thickness, and has been interpreted as coarse sand with gravel. The third layer has resistivity of 40.8 Ωm and thickness of 122 m, and has been interpreted as medium sand. The fourth layer has low resistivity of 22.5 Ωm and has been interpreted as fine sand.

Site 4: The survey of this location revealed four subsurface layers of resistivity values between 36 and 180 Ωm (Figure 3 d). The topmost layer has thickness of 1.7 m and resistivity of 36 Ωm , and has been interpreted as artificial fill. The second layer has high resistivity of 180 Ωm and thickness of 27.2 m, and has been interpreted as coarse sand with gravel. The third layer has

resistivity value of 64 Ωm and thickness of 75 m, and has been identified as coarse sand. The fourth layer has low resistivity of 24 Ωm and its thickness could not be ascertained by the survey. This layer has been interpreted as fine sand.

Site 5: The resistivity survey at this location revealed three layers to a depth of 86 m (Figure 3 e). The topmost layer has resistivity of 13 Ωm and thickness of 2.8 m, and has been interpreted as artificial fill. The next layer shows high resistivity value of 91 Ωm with thickness of 84 m. This layer has been interpreted as coarse sand and gravel. The third layer shows resistivity of 34 Ωm . This layer has been interpreted as fine sand with kankar, and its thickness could not be ascertained by the survey.

To study the possible subsurface stream link between the Vedic Saraswati Nadi and the present Markanda river, the resistivity section along the area of suspect has been prepared (Figure 4). As evident from this section, subsurface geological materials are composed of an admixture of fine sand, medium sand and coarse sand with gravel. An aquifer layer consisting of coarse sand with gravel having resistivity value ranging from 40 to 184 Ωm with an average thickness of about 90 m was recognized at a depth between 10 and 100 m. This subsurface layer has lateral extension of about 12 km in NE–SW direction from Lotni to Sarusti Khera. Another aquifer horizon consisting of fine sand was observed beyond 148 m

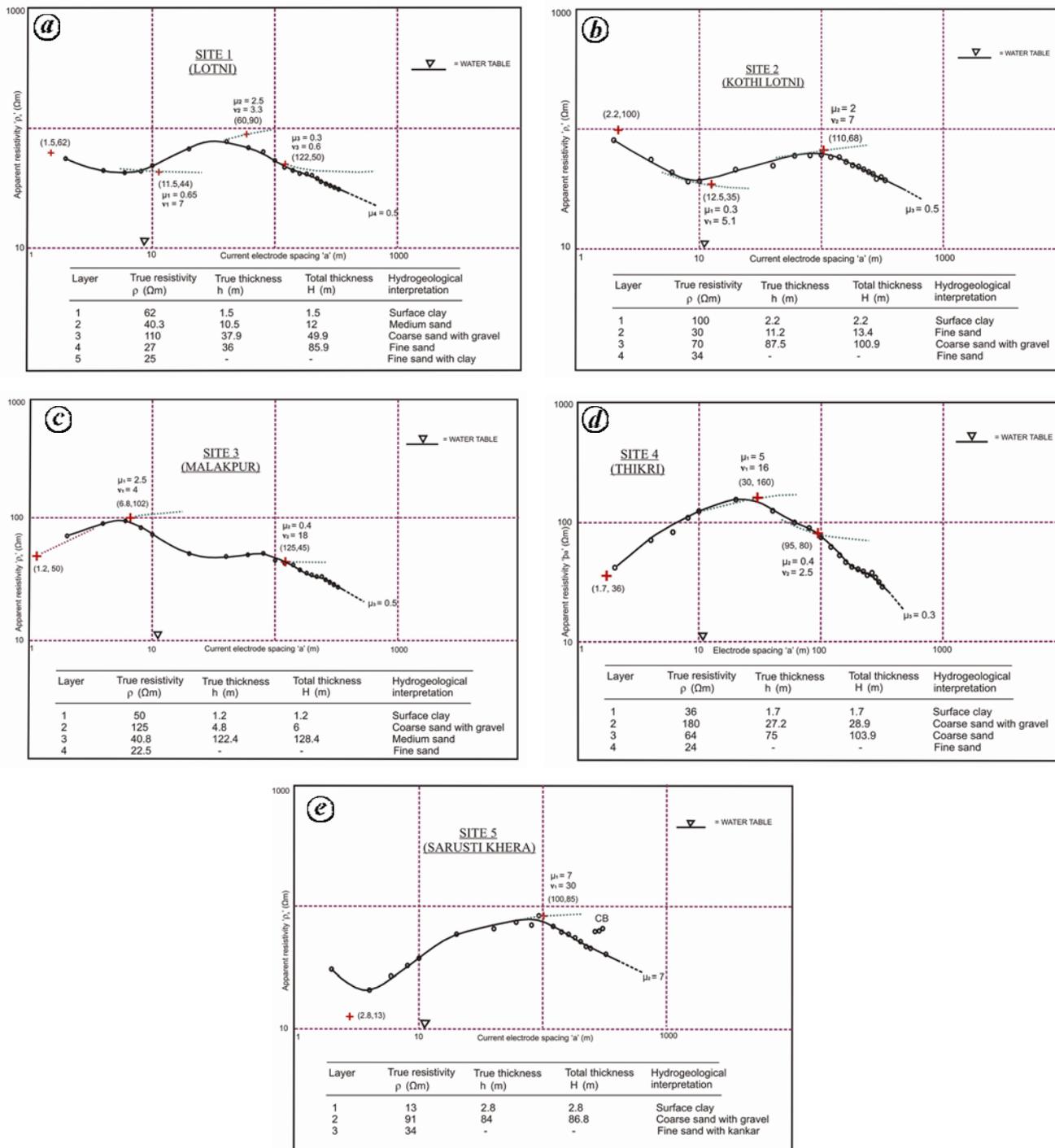


Figure 3. Interpretation of Wenner resistivity field curve with hydrogeological interpretation at Lotni region (a), Kothi Lotni region (b), Malakpur region (c), Thikri region (d) and Sarusti Khhera (e), Kurukshetra District, Haryana.

depth. This layer has low resistivity ranging from 23 to 34 Ω m. The thickness of this layer could not be ascertained by the survey. Another aquifer horizon which shows pinch and swell behaviour of medium sand having resistivity of 40 Ω m has been identified within the layer of coarse sand with gravel. This layer has been recognized at a depth between 6 and 184 m. Based on the dis-

tribution of these aquifer horizons, it appears that the lower course of the Markanda river is hydraulically connected with the palaeochannel of the Saraswati Nadi. The transverse resistance^{38,39} values of these buried channels are 7392–7585 Ω m² for coarse sand with gravel, and 384–2856 Ω m² for fine sand, indicating good groundwater prospect. Presence of these buried channels

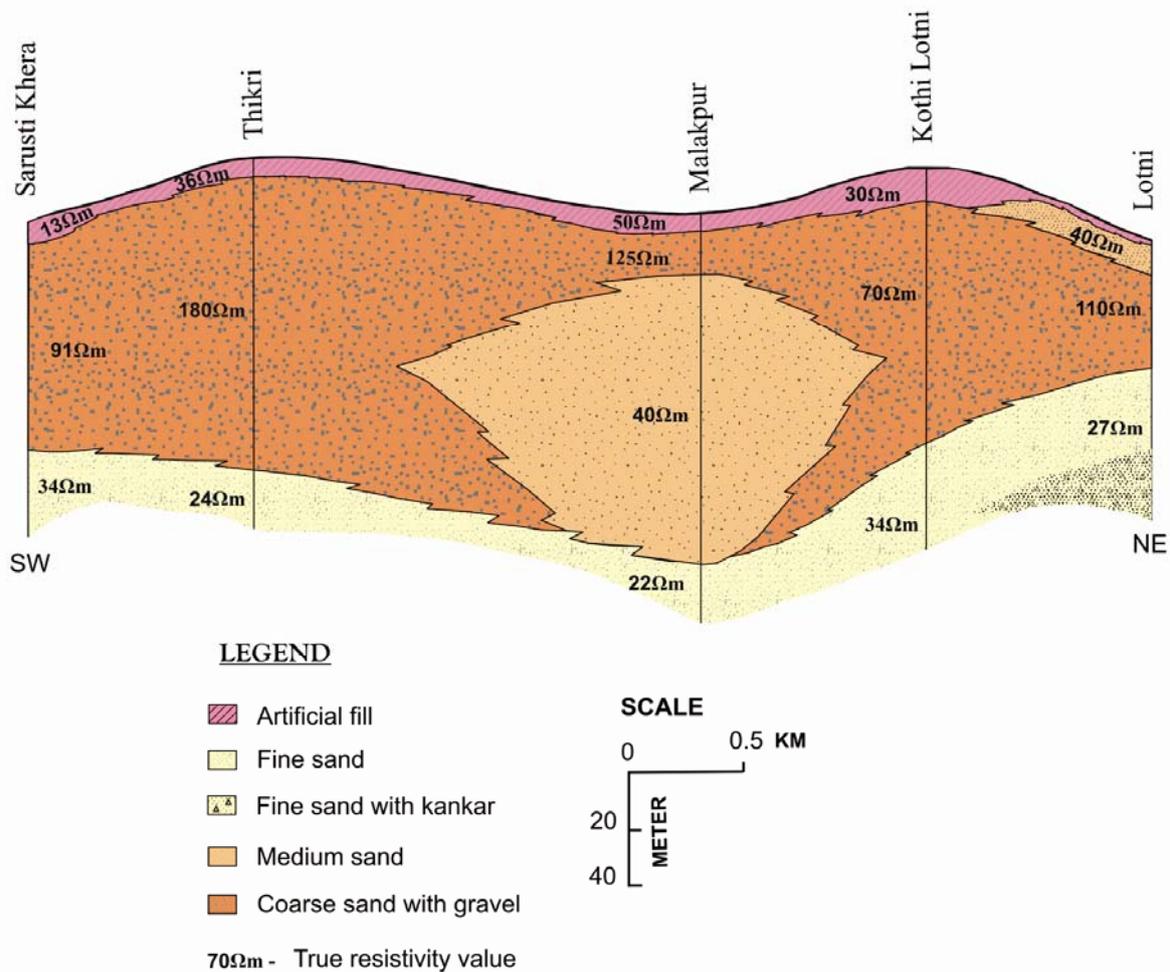


Figure 4. Resistivity log section between the Markanda river and Vedic Saraswati river.

suggests that the Markanda river has been a part of the Vedic Saraswati river system. Archaeological sites found in and around the Markanda and the Saraswati Nadi indicate that they belong to the same age (Late Harappan period)⁵. IRS 1D LISS IV image also shows surface indication of moisture content as palaeochannel in the region between the lower portion of the Markanda and the Saraswati Nadi (Figure 2). These buried sand bodies could be an answer to the missing stream links between the relic of the ancient Vedic Saraswati and the present Markanda river systems. Thus, the Markanda river could be identified as one of the headwaters of the once celebrated Saraswati river.

The following conclusions have been drawn based on the present study.

(i) Resistivity surveys in the Gangetic Plains around Pehowa region in Haryana, have revealed different subsurface geological formations composed of fine, medium and coarse sand with gravel.

(ii) Resistivity section between the lower part of the Markanda basin and the Saraswati Nadi around Pehowa

region indicates the presence of buried sand bodies connecting the two rivers.

(iii) These buried sand bodies are: (a) An aquifer horizon composed of coarse sand with gravel having resistivity of 40–184 Ω m found at the depth between 10 and 100 m. This layer has an average thickness of about 90 m and has lateral extension of about 12 km in the NE–SW direction (Lotni to Sarusti Khera). (b) Another aquifer horizon which connects the two river systems has been identified as fine sand. This aquifer horizon has low resistivity of 23–34 Ω m, and has been observed at a depth between 45 and 148 m.

(iv) Based on the distribution of these aquifer horizons, it appears that the lower course of the Markanda river is hydraulically connected with the palaeochannel of the Saraswati Nadi. The transverse resistance values of these buried channels are 7392–7585 Ω m² for coarse sand with gravel, and 384–2856 Ω m² for fine sand, indicating good groundwater prospect.

(v) The archaeological sites found in the study area belong to the same age (Late Harappan period), suggesting

that the buried sand bodies at different places have the same historical links in terms of age.

(vi) Thus, the study indicates that there is a stream link between the present Markanda river and the Vedic Saraswati system. The Markanda river was a part of the Vedic Saraswati system and that it can be identified as one of the headwaters of the once celebrated Vedic Saraswati river.

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