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The Lost River Saraswati: A Blessing for Drought Proofing in Arid Environment of Western Rajasthan, India

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ABSTRACT: There is deep belief that discovery of palaeo-courses of vedic Saraswati can be a blessing for the Great Thar Desert in arid lands of western Rajasthan. Evidences in support of existence of palaeo-drainage include mythological, early literary writings, archaeological findings, remote sensing studies, geomorphic and other features, fluvial deposits, geophysical studies, occurrence of fresh groundwater pockets and isotope studies etc. The river was lost during prehistoric times due to neo-tectonic and aeolian activities causing river piracy and its disorganization. The river has recharged potential aquifers like Quaternary alluvium, Palana, Nagaur and Lathi Sandstones containing waters of 7000 to 9500 years old. However, occurrence of freshwater potential aquifers feasible for construction of thousands and lacs of tube wells is a misconception since the palaeo-channels are buried under a mantle of aeolian cover and presently having no connections with the Himalayan waters. Also, fresh groundwater resources in the palaeo-floodplains during earlier times might have turned in to saline/brackish belts/pockets owing to present day aridity. Demarcation of buried channels in field is a difficult but possible task and has gained paramount importance for implementing mega artificial recharge projects. Precise delineation of palaeo-channels needs to investigate in a long term project mode with integrated multidisciplinary approach incorporating science of hydrogeology, geophysics, geochemistry, sedimentology, mineralogy, paleontology and so on. Non-committed waters from northwest India especially those flowing to neighboring country during monsoon and efficient use of Indira Gandhi Nahar Pariyojana water may be source of surface water for recharge. Deep groundwater levels and permeable geo-formations make the scenario conducive for large scale artificial recharge to groundwater through palaeo-channels. About 71,000 MCM of water can be gradually artificially recharged, which may be retrieved at any point of time and space through wells and tube wells and thereby perennial availability of water irrespective of deficit rains i.e."Drought Proofing" of permanent nature in arid lands of western Rajasthan.

Keywords: Arid, Aquifers, Artificial Recharge, Drought Proofing, Geo-Formations, Palaeo-Channel, Saraswati River, Quaternary.

INTRODUCTION

Mythological river Saraswati is mentioned as a prominent perennial river in Vedas, Mahabharta and other epic literature and is believed to have lost during prehistoric times. There is deep belief that discovery of palaeo-courses of Saraswati can be a boon to the Thar Desert. However, there are wide differences in opinion regarding its existence, flow path, groundwater potential, field demarcation and their utility in terms of artificial recharge to groundwater and therefore requires further debate and discussions. Effective implementation of concept in field can obviously develop Drought Proofing Scenario that too in arid environment of Thar desert and thereby overall socio-economy of deserters.

EVIDENCES OF PALAEO-DRAINAGE

Mythological Evidences

Written in Rigveda are some of the hymns (75 shlokas spread over ten Mandals) composed by old scholars (>8000 years ago) in glory of historical mythological river Saraswati existed during Vedic period and later on lost in the desert of Rajasthan (CGWB Atlas, 1999). A few hymns are also there in Yajurveda and Atharva-Veda. Saraswati is described as one of the seven rivers of Sapta Sindhus, which originated from Himalayan Mountains and flowed right up to the sea. The Saraswati is believed to be the eastern most of these mythological rivers flowing in southwestward direction. Earlier in the Barhmina literature and Manusmriti there is mention about Saraswati. The place of appearance of Saraswati was called Plaksa Prasvavana and that of its disappearance Vinasana perhaps indicating initiation of disappearance of river since Vedic times. Mahabharata gives a clear geographical account of a number of pilgrimage sites located along its course. By the time of Mahabharata, discharge of water in the river becomes very low and as a result the river vanished in desert sands at a place Vinasana. Location of Kurushetra is mentioned lying south of Saraswati and north of Drishadvati, a tributary to Saraswati. In Bhagwat Puran also there is mention of river Saraswati and Drishadvati as major tributary of Saraswati. It is also mentioned that the river disappeared near present town of Sirsa in Haryana. Saraswati River is widely quoted in Vaman Purana and other Puranic literature like Srimad Bhagawat Purana, Skandha Purana, Markandeya Purana and Vayu Purana etc.

Archaeological Findings

Most of the archaeological sites of the-then civilization are located on the Saraswati river basin. There are four Harappan and pre-Harappan sites in Punjab, Rajasthan and Uttar Pradesh. These sites are located at Ropar, Nihang Khan, Bara and Sirsa valley. Harappan culture flourished in the western part of Punjab around 2500 B.C. Thar desert is among thickly populated deserts of the world pointing towards existence of old civilization in the area. It is believed that the Harappans entered through the Indus Valley into Kalibangan valley (NW Rajasthan) on the left bank of Ghaggar (erstwhile Saraswati) and spread to Punjab along the Saraswati River. Carbon dating of the material at Kalibangan suggests that Harappan culture flourished around 2500 B.C. in India and existed for 1000 years. So the present day geomorphologic set up did not exist till 1500 B.C. and the Indus, the Sutlej and the Beas followed independent courses to the sea. Evidences from archaeological remains in Pilibanga, Kalibanga and Rangmahal in Ghaggar river basin area in Western Rajasthan indicate existence of a highly developed civilization during past. It is a well-known fact that ancient civilizations developed along perennial rivers, as is the case of Indus valley civilization. The archaeological findings also indicate that a major river originating primarily from the same source as the present Satluj flowed through northern Rajasthan and also through Bahawalpur and Sindh in Pakistan. The source area of the river was southeast of the present course of Satluj and Indus, in 3rd and 2nd millennium B.C. Some investigators working on ancient literature also suggests that Saraswati flowed along the present course of Luni river in Rajasthan and shifted westwards progressively. Similar archeological sites are found in some places in Haryana, Punjab and Gujarat. These sites are believed to be of Pre-Harrapan and Harrapan age. Recent archaeological findings have indicated that Harrapan civilization was post Vedic and script of Harrapan seals has been deciphered, which is Vedic Sanskrit. It is now inferred that collapse of Harrappan civilization was largely due to loss of water resources of which the drying up of Saraswati River was a major cause. Existence of major cities and religious locations along inferred palaeo-channels is also pointer towards existence of river Saraswati.

Evidences from Remote Sensing and GIS

Remote sensing study carried out by various agencies reveals signatures of palaeo-channels in the form of curvilinear and meandering courses. Yash Pal *et al.* found that the course of the river Saraswati in the States of Punjab, Haryana and Rajasthan is clearly highlighted in the LANDSAT imagery by the vegetation cover thriving on the rich residual loamy soil along its earlier course. Digital enhancement studies of IRS-1C data (1995), combined with RADAR imagery from European Remote Sensing Satellites ERS 1/2, identified subsurface features and recognized the palaeo-channels beneath the sands of the Thar Desert. Study of NRSA, based on satellite derived data has revealed no palaeo-channel link between the Indus and the Saraswati, confirming that the two were independent rivers; also, the three palaeo-channels, south of Ambala, seen to swing westwards to join the ancient bed of the Ghaggar, are inferred to be the tributaries of Saraswati/Ghaggar, and one among them, probably Drishtavati. Digital enhancement techniques using high resolution LISS-III data of IRS-1C satellite, identified two palaeo-channels trending NE-SW in Jaisalmer district of Rajasthan, which are presumed to be the lost river Saraswati. In a study, NRSA used IRS-P3 Wide Field Sensor (WiFS) data covering the Indus river system to study the palaeo-drainage in northwestern India. The image elements such as tone, colour, texture, pattern, association of WiFS and SIR-C/X-SAR images helped to derive information on current as well as palaeo-drainage. WiFS image reveals very faint trace of the river Saraswati/Ghaggar while in the SIR-C/X-SAR image; the connectivity of the palaeo-channel could be easily established due to the presence of dark irregular shaped features associated with wetness. A part of the river Saraswati till now exists as Ghaggar in Haryana, the rest of it has disappeared in the fringes of the Marusthali. Ghosh (1964) reconstructed, through aerial photographs several former stream courses in Luni-Jawai plains. Ghosh *et al.* (1979) identified some mega palaeo-channels in northern and western parts of the desert suggesting that a major Himalayan stream, the Saraswati, formerly used to flow through desert, the dry bed is now left along the northern margin of the desert. Bakliwal and Grover (1988) identified several stages of migration of river Saraswati. Yash Pal *et al.* (1980) of Space Application Center (ISRO), Ahmedabad studied landsat MSS imageries using visual interpretation and traced the course of lost Saraswati, which flowed westward through Rajasthan. Sood and Sahai (1983) studied multi-date and multi-spectral landsat (MSS) imageries and topographical maps for the Saraswati and Luni basin and arrived at divergent conclusion from the work of Ghosh *et al.* (1980) regarding course of Saraswati river and cause of its migration.

Hydrogeological/Geophysical Evidences in Ghotaru-Longewala—Kishangarh Area: A Case Study Area in NW Jaisalmer District

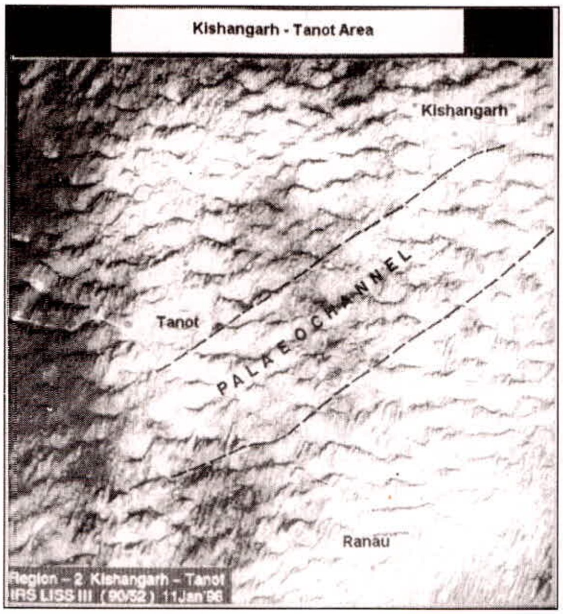
Central Ground water Board (CGWB) and Rajasthan Ground Water Department (RGWD) through their observation stations found linear pattern in NE-SW direction having a fresher quality of groundwater compared to the adjoining areas indicating presence of freshwater along internal courses of Palaeo-channels. Geophysical survey indicated presence of comparatively coarser sediments at shallow depths at some places in Tanot—Longewala area.

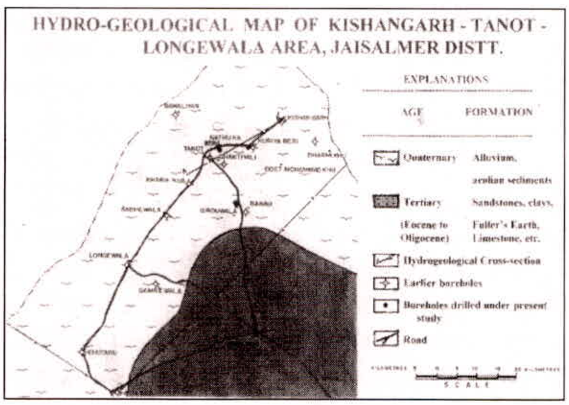
Surface Resistivity Survey

Electrical resistivity surveys in the area were interpreted in terms of 4 main litho-units. First layer comprising of fine blown sand corresponds to a general resistivity range of 135–3000 ohm-m. Lower range of resistivity indicates that the sounding spot is flat land with fine sand as the surface soil layer while higher range corresponds to sounding spot as elevated land with thick blown sand as surface soil layer. The second layer is represented by a general resistivity range of 550–2550 ohm-m, which corresponds to fine to medium grained and at places coarse-grained sand. A general resistivity range of 10 ohm-m to 100 ohm-m represents the third layer comprising of clay. The lower range of resistivity indicates presence of highly conductive clays at the depth of investigation. The higher range of resistivity in this layer indicates clay mixed with sand. In Ranau—Tanot section fourth layer comprising clays and shale was interpreted (layer resistivity from 1 to 36 ohm-m). CGWB has also carried out spot resistivity soundings at 31 favorable locations i.e. inter-dunal areas, where the ground level was almost flat. The standardization of interpretation of resistivity survey data was done with the existing boreholes in the area. It was found that the formation resistivity in the range of 15 to 25 ohm-m represents fine to medium grained sand containing freshwater. The zone lying immediately above the water table has a resistivity value in the range of 70 to 80 ohm-m representing the moisture conditions. The resistivity below 10 ohm-m was interpreted to be clay /silt containing poor quality of groundwater. Dry sands in upper layers indicated very high resistivities. Based on above interpretations, layers with resistivity range 15 to 25 ohm-m and showing considerable thickness were suggested for exploratory drilling. In general, it was interpreted that there is a general deterioration of groundwater quality with depth.

Exploratory Drilling—Fluvial Sediments

Exploratory drilling was undertaken in the area based on the remote sensing studies, field studies and geophysical surveys by various organizations. Geophysical well logging of the boreholes was done for identification of water bearing zones and interpreting water quality. Depth of drilling varied from 120 to 200 m. Depth of wells constructed varied from 70 m to 136 m. Medium to fine sand, silt, kankar, gravel etc. encountered at different depths at Ranau, Longewala, Nihal Khan Ki Dhani and Ghotaru. Thickness of coarser well-sorted sediments zones varies from 6 to 22 m at depth zones of 25 to 125 m indicating existence of old buried channels in the area along Ranau-Nihal Khan Ki Dhani-Ghotaru. Electrical logs of the bore holes also points to the existence of clean sands attributed to water action in depth range of 42 to 63 m and going down up to about 100m. Depth to water level in the boreholes drilled varies from 31.7 m at Nathu Ka Bera to 64.85 m at Ranau 4 Kms on Ramgarh road site. Discharge of well ranges from 60 to 650 litres per minutes (lpm). The Electrical Conductance (EC) of groundwater encountered in the drilling varies from 1210 to 9500 micromhos/Cm. at 25°C. The study reveals freshwater zone in a linear pattern i.e. Ranau-Dharmi Khu area surrounded by comparatively saline water. In freshwater areas also, there is deterioration of groundwater quality with depth. Presence of thin zones of well sorted medium and coarse sand (uniformity coefficient generally <3) indicates long traveled river deposits and therefore positive indication of existence of paleo-channels.





Geophysical Well Logging

Interpretation of electric and gamma ray logs of all the boreholes have revealed poor lithological contrast within the saturated alluvium. The formation resistivity progressively decreases with depth. The geo-electrical sounding course of the study area is also of 'Q' and 'K' type indicating decrease in formation resistivity values. The surface layer is characterized by aeolian sands ranging in thickness from 35 m to 65 m with resistivity value of >50 Ωm marking the unsaturated horizon. The underlying zone 'B' with a resistivity range of 20–50 Ωm represents partially saturated alluvium. This zone extends to a depth of 50 to 65 m containing flushed arenaceous sediments and is encountered only along Kishangarh-Bawar section. In other zone 'A' is directly followed by zone 'C' with a resistivity range to 10 to 20 Ωm. The 'SP' character of this zone suggests sharp change in the lower part (80–100 m) indicating an increase in salt content and change in depositional environment. The lower part of zone 'C' is relatively more compact and poorly flushed. However, predominantly this zone contains flushed to semi-flushed sediments and the formation water quality is generally potable. The lowermost zone 'D' has a resistivity value of <10 Ωm and is represented by unflushed semi-compact sediments, predominantly argillaceous. The formation water quality of this zone is poor. Wherever this zone is tapped (as at Nihal Khan ki Dhani, Longewala IInd; Gaje Singh Ka Tar and Karthai) the formation water quality is poor. The zone 'D' is not tapped in the northern part of the area (Ghantiali, Kuriya Beri, Kishangarn and Ranau) and therefore the formation water quality is potable. The top of zone 'D' represents the saline water interface. The formation water quality above this zone is having EC value of < 3000 micro mhos/cm and the water quality deteriorates with depth.

Chemical Quality

Chemical quality of groundwater varies largely from fresh to saline. EC varies from 1210 to 42,200 m.mhos/cm in the region. During exploratory drilling fresh groundwater was encountered at Ranau, Ranau 4.6 Km on Tanot road, Longewala, Kuria Beri, Ghotaru and Ranau 4 Kms on Ramgarh road. Coarse gravel formation was encountered at Nihal Khan Ki Dhani but the water quality is highly saline (EC 9500 micromhos/cm). However, exploratory wells and already existing wells indicate presence of freshwater in a linear NE-SW pattern surrounded by comparatively saline water on either side. In general, even in freshwater areas, there is a deterioration of groundwater quality with increase in depth. Deterioration in groundwater quality usually starts beyond depth of 100 m.

Isotope Studies

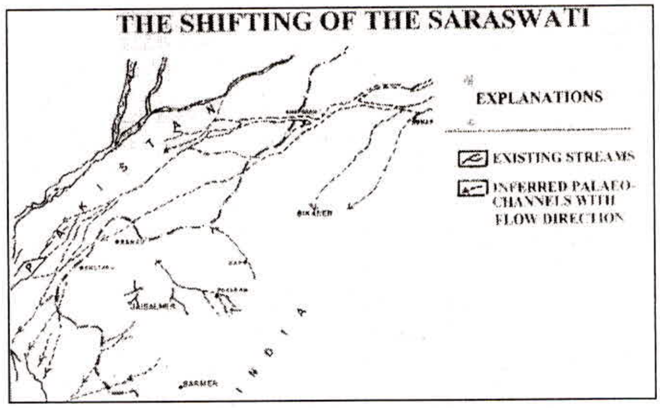
Groundwater samples from the exploratory wells were analyzed for isotope studies by the Bhabha Atomic Research Centre (BARC), which show negligible tritium contents indicating absence of modern recharge. Sample from Kuria Beri shows higher Tritium value indicating components of recent recharge. Owing to the complex problem of defining Tritium concentration at the time of groundwater recharge, most studies make only a qualitative estimate of groundwater age. Carbon 14 analysis needs to be done for age determination. During the earlier studies conducted by the BARC, Mumbai in the area, water samples from the existing dug wells were collected and analyzed for Tritium isotope. Water from these wells represents the uppermost-saturated zone. In general, dug wells as well as tube wells water have low (<1.0 Tr) Tritium values indicating absence of modern recharge. However, a few dug wells i.e. Dharmi Khu, Gajesingh Ka Tar and Ranau do show some component of recent recharge be due to local geographical terrain conditions of recharge. Water samples from few more exploratory wells were analysed by the BARC, Mumbai indicating Tritium contents varying from 0.4 to 1.2 TU inferring absence of modern recharge.

Goemorphic and Hydrogeological Features

There are remarkable similarities in geomorphic and hydrogeological features in the entire earth crust of western Rajasthan. All these features are aligned in NE-SW direction afterwards turning to NW-SE direction. The alignment of Aravalli Hill Range and Hill Ranges those in Pakistan, flow path of Luni River, water table contours follow the same pattern. Groundwater potential zones like Nagaur-Palana Sandstones, Lathi formations, Bhadka potential area etc. are aligned in the same pattern. Present ephemeral streamlets are also following the same pattern of flow direction. Incident of such remarkable similarities cannot be a mere coincidence. It may be concluded that the Ghaggar/Saraswati River was also following the same path through Thar Desert during geological past developing potential aquifers like Lathi Basin. Some of the tributaries might have supported the Vedic Saraswati during the humid phase of the Quaternary period. Fluvial deposits of Saraswati might be the source and supplier of vast quantum of sand for desert and dune formation during recent arid climatic conditions.

MIGRATORY PALAEO-DRAINAGE—CAUSES OF DRYING UP

It is believed by most workers that there was gradual migration of drainage courses due to neotectonism and climatic changes i.e. onset of aridity, which ultimately resulted the old river courses to get buried under aeolian sand cover. R.D. Oldham (1986), Geological Survey of India pointed out great change in drainage pattern of rivers of Punjab and western Rajasthan and suggested that there was a possible connection of other rivers of the region like Satluj and Yamuna to Saraswati. He was of the view that diversion of Saraswati water to Satluj and Yamuna (river piracy) was the reason for drying up of Saraswati. Satluj, which later changed its course and became a tributary of Indus, contributed bulk of the water to the ancient Saraswati. Tectonic disturbance in Haridwar—Delhi ridge zone and reactivation of Cambay grabon are given major causes of migration. River piracy by Yamuna has finally caused Saraswati to dry up and get buried in sands of desert. Apart from this, climate variation like intermittent humidity—aridity and sea level changes etc. also contributed to shifting of Saraswati River.



PALAEOCHENNELS AND GROUND WATER RESOURCE POTENTIAL

The mighty river Saraswati was a migratory drainage system recharging major parts of the Thar Desert. Freshwater zones were developed along its flow path especially in the depositional basins of Lathi, Nagaur-Palana depressions, Tanot-Ranau-Kishangarh area, Bhadka well field area etc. Isotope studies reveal that groundwater is of older age (Holocene) and present recharge to groundwater may be taken as negligible (arid environment i.e. low rains and high evaporation) and deep water levels. This gives inference that mighty Saraswati River has recharged the aquifers during ancient times. However, occurrence of high potentiality freshwater aquifers feasible for construction of thousands and lacs of tube wells is a misconception since the palaeo-channels are buried under thick mantle of aeolian cover and presently having no connections with the Himalayan waters. Humid palaeo-climatic conditions during the Quaternary period also suggest recharge to groundwater through certain drainage system forming subsurface freshwater horizons. However, present day aridity might have turned the fresh groundwater resources in to saline/ brackish quality.

ARTIFICIAL RECHARGE THROUGH PRESENT AND PALAEO-CHANNELS

Present as well as palaeo-channels of river systems are very good carriers of water, which in turn can be fruitfully utilized for recharge to groundwater. However, delineation and demarcation of buried palaeo-channels in field is a difficult and elaborated but possible task. Precise delineation of palaeo-channels needs to investigate in a project mode with integrated multi-disciplinary approach incorporating science of hydrology, hydrogeology, geophysics, geochemistry, sedimentology-mineralogy, paleontology and so on. Non-committed waters from northwest India especially those flowing to neighboring country during monsoon and efficient use of Indira Gandhi Nahar Pariyojana water may be source of surface water for recharge through present river drainage like Luni and especially palaeo-channels. This will cause revival of buried channels and spread of water and hence rapid recharge to groundwater through porous and permeable soils and aquifers. Deep groundwater levels and permeable geo-formations make the scenario conducive for large scale artificial recharge to groundwater through palaeo-channels.

DROUGHT PROOFING MANAGEMENT

It is estimated that 71,000 MCM of water can be gradually artificially recharged (CGWB report, 2001), which may be retrieved at any point of time and space through wells and tube wells and thereby perennial availability of water irrespective of deficit rains i.e. "Drought Proofing" of permanent nature and thus improving socio-economic conditions and desert eco-system in the arid western Rajasthan

CONCLUSIONS

Studies reveal existence of river Saraswati developing potential aquifer systems including Alluvial, Lathi, Plana and Nagaur Sandstone. Palaeo-channels of lost Saraswati needs to be precisely demarcated in field integrating various domain of science. However, it's a misconception that thousands of tube wells of freshwater quality may be constructed along the Palaeo-channels. The palaeo-drainage network may be of great significance for their revival and large scale artificial recharge to groundwater and thereby sustainable availability of water for safe drinking/ industrial purposes and agriculture growth for food security i.e. "Drought Proofing" scenario having positive impact on socio-economic fabric and desert environment in arid lands of western Rajasthan.

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