PALEOCHANNEL INVESTIGATIONS AND GEO-HYDROLOGICAL SIGNIFICANCE OF SARASWATI RIVER OF MAINLAND GUJARAT, INDIA: USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

Paleochannels are remnants of stream channels cut in older sediments and filled by younger overlying sediments representing the distribution of valley systems as these existed at given geological time in the past. Reconstruction of paleodrainage network in Mainland Gujarat using remote sensing techniques has a societal relevance as the information is utilized as groundwater prospective zones and suitable sites for artificial recharge. Alluvial plain of Gujarat is a unique geomorphic province that constitutes hundreds of meters thick alluvial sediment making the region fertile and hospitable to many historic cultures of Gujarat. In the present study, we used IRS-LISS-III images for extracting information on geomorphology, vegetation cover and lineaments. The study carried out between Siddhpur in the East to the Little Rann of Kachchh (LRK) to the West forming West sloping narrow E–W stretching belt. Available groundwater, rainfall, irrigation practice, crop pattern, agriculture and soil data of last 15 years are superimposed with the Remote Sensing data gives a better understandings of potential Palaeochannels and aquifer zones. In spite of good rainfall in the area, the surface water tanks do not store adequate amount of water for irrigation purpose due to sandy and loamy soil type. It indicates good percolation power of the soil; where the rainwater when flows on very gentle ground with highly permeable soil cover, spars vegetation and scanty drainage systems, they constitute short-lived reservoirs and can readily recharge ground water. Hence, it is stated based of the palaeochannel study that in the alluvial terrain they could be a potential source of groundwater, irrigation and recharge structures and finally a good thrust area for economic growth.

Key Words: Paleochannels, Saraswati River, IRS (Indian Remote Sensing), Groundwater recharge, Alluvial plain

INTRODUCTION

Alluvial plain of Gujarat constitutes thick alluvium making it fertile and hospitable to historic cultures of Gujarat that witnesses a favorable paleoclimatic condition. The water and temperature largely govern climate, for its geographic and anthropogenic processes. Geological origin of this landscape implies that it is generated due to prolonged alluvial action in Quaternary period. Since the area is geotectonically a graben of early Tertiary period, it provides a room for large scale alluvial deposition through major river systems from the Aravallis, viz. Banas, Saraswati, Rupen, Sabarmati, Mahi, Vatrak and Hathmati. Saraswati, Banas and Rupen rivers vanish into the northern alluvial plain of Gujarat, which earlier used to meet the Gulf of Kachchh through LRK. A volume of work produced for climatic episodes of Quaternary period in this part of Gujarat alluvial plain. Thick deposits of Quaternary sediments formed between Saraswati and Mahi rivers to the north and Narmada and Tapi in the south. Scanty rainfall,
arid to semi-arid climate for past 1 ka has led the region with dearth of surface water and riverbed load and river lineament with less dissection and flow. It created lateral shifting of rivers due to the occasional flash floods and erratic heavy rains. Such geological and climatic perturbations gave rise to numbers of palaeochannels in the region. No systematic work for shifting of river systems using effective tools like remote sensing has been attempted in this region. Hence, the authors have tried to explore the paleochannels using remote sensing as a quantitative and geographic tool and have also tried to correlate it with the existing groundwater and irrigation data for the better understanding of past surface drainage flows.

The River Saraswati originates from the Aravalli hills in the north and flowing WSW crossing almost entire Gujarat alluvial plain transversely with very low gradient to the Westward (Fig. 1 and Fig. 2). The lower order streams mostly flow across the Precambrian rocks of Aravalli system while higher order streams are passing through the thick alluvial aprons forming two apparent fluvial regimes through its entire course. The segment of study falls in the district of Patan with its seven administrative territories. Patan is situated between 20°41’ to 23°55’ north Latitudes and 71°31 to 72° 0 East Longitude (Fig. 1). The district encompasses nearly 0.566 million hectare of land, out of which 0.0113 million hectare goes in urban area while 0.555 hectare in rural area showing almost negligible urbanization and that the larger population depends on agriculture. Saraswati, Khari, Pushpavati, Roopen and Banas are major rivers and almost 1303 lakes in the district. According the state soil data, it is medium black with 7 pH with neutral organic carbon and nitrogen. Mean annual rain fall ranges between 400 to 700 mm. Millet seed, cotton, castor and sesame are main Kharif crops that has been grown over an area of 0.186202 million hectares.

**METHODOLOGY**

The present study includes investigations of Saraswati River palaeochannels with reference to the present day water bodies, soil type, tectonics, vegetation cover, crop pattern and demography of the area. For the identification of present and past channel flows we used satellite data (LISS-III) of the region under investigation. Field surveys have been carried out for soil identification, sampling, investigation of vegetation cover and crop pattern. The existing rainfall and crop data along with the data of agriculture practice have also been used to draw
conclusion. Survey of India topographic maps are used for field studies as well as making maps using standard GIS software.

**Geology and geomorphology of study area**

The study area lies between Siddhpur in the East to the LRK to the West forming narrow E-W belt with very low gradient (Fig. 2). To the West of villages Sami and Harij, the River Saraswati almost vanishes and not traced actively further except some paleochannels or dense vegetation cover. During good monsoon, large quantity of water inundates the area, stagnates to make several pools, and does not flow to a specific direction due to low regional gradient, but they recharge the groundwater hence the track of paleo-river channel appears be fertile. The Gujarat alluvial plain is tectonically bounded by two major faults known as West Cambay Basin Margin Fault (WCBMFS) and East Cambay Basin Margin Fault (ECBMF) (Fig. 2). It was a large graben shaped depression in the pre-tertiary time and received sediments during Tertiary period in a closed gulf environment, which subsequently filled up by the major river systems originating from Aravalli terrain during quaternary period and formed alluvial plains.

The featureless terrain of the study area rarely exposes their sediments in the form of river cliffs wherever incisions are prominent. The authors have found such incisions at a few places where ~ 4m of quaternary strata were exposed (Fig. 3). The basement is made up of hard pedogenized surface with calcretes. It is overlain by one meter of hard compact soil with large calcretes, which is again overlain by 1.5 meter of light brown, loosely compact soil with nodular calcretes (Fig. 3). The top one-meter apron is loose, fine-grained aeolian sand indicting the dry phase.

![Geomorphic features like alluvial deposits, Precambrian rocky uplands of Aravalli Craton, fluvial systems, terraces, ravines and gully, stabilized dunes, Little Rann of Kachchh and marginal faults (WCMF(F1) and ECMF(F2))](image1)

**Fig. 2 :** Geomorphic map of a part of Gujarat alluvial plain showing various geomorphic features

![Note: the pedogenized basement horizon looks much stabilized](image2)

**Fig. 3 :** (a) Litho-log of Gujarat alluvial plain found at Manpur village of the Saraswati basin. (b) An incision of ~4 m of the basin indicates a hard calcretized layer at the bottom while the loose Aeolian sands (~1.5m) represented by the pigeon holes.
Data generation and usage

Using primary data in the GIS software, scientific and statistical analysis have been made. Various geo-spatial layers like Taluka – sub-territories and village boundaries, water bodies etc. are superimposed on IRS-P6, LISS-III data with the help of ENVI, ERDAS IMAGINE - 9.1 and Arc GIS - 9.3 GIS software (Fig. 4). Further, farm fields have varieties of crop patterns, and varieties of practices for water usage viz. tank irrigation, canal irrigation or groundwater irrigation. The soil cover and types could also be identified; the water tanks have either natural gradients or could have anthropogenic cause of their formation. Documentation of the features associated with abandoned fluvial landforms, their association with regional lineaments; abrupt termination of drainages, defunct channels, anastomosed channels, lake sediments and their outcrops are also attempted in the field as they helped in marking the palaeochannel network of the ancient river systems associated with Saraswati river (Fig. 5).

RESULTS AND DISCUSSION

The North Gujarat plains comprise thick and dominantly alluvial sediments that provide climate and fluvial history of late Quaternary period in Western India. We investigated various landforms viz. alluvial plains, sand dunes, saline flats and discontinuous water bodies during present study in the vicinity of Patan district. The stratigraphic successions exposed as cliff sections along major streams of the Rivers like the Luni, the Banas, the Saraswati, the Pushpavati, and the Khari reveals alluvial sediments comprising pedological layers and calcitized basement. Present study is confined to the limited drainage network of the River Saraswati where the authors have noticed cliff sections of 4m high containing clay, silt, sand and pedogenized calcrites (Fig. 3). The major river course is nearly 1.5 to 2 km wide as reported in the field and satellite image near the vicinity of Patan district. The Banas and Saraswati rivers remain dry for the greater part of the year. They follow broad and shallow channels and flow within their own sandy and gravelly deposits. The river beds in the middle part are almost a kilometer wide and covered with sand whereas in the lower part of the course, the channel narrows down and gradually gets disjointed, and becomes fragmentary. The river meets the Little Rann in a very insignificant manner, hardly showing any distributaries network (Fig. 2). Further, the satellite data, historical literature study also give clues that the area had a good river channel network along which many archeological sites are found. Nearly two hundred lakes are found along the broad network which is presently located around the towns and villages like Balisana, Borsan, Babasana, Unjha, Unava, Balad, Biliya, Kahoda, Dasaj, Hansapur, Borsan, Sankhari, Balisani, Matpur, Bhemosan, Dabhi, Uneba etc (Fig. 4). Abundance of lakes and water bodies are segregated along the palaeochannels of Saraswati River hence, it is said that lakes and water bodies are significant indications of palaeo-drainage basins. The climatic factors like heavy rainfall, flash floods, and heavy bed-loads are inferred for fluctuating course of the River Saraswati, however minor tectonic events might have changed the regional slope direction to modify the hydrological condition of the area.

To reconstruct the palaeodrainage network, the authors have identified in the satellite imageries the peculiar geomorphic features like sparse vegetation cover, surface water bodies like ponds and lakes and linear tracts of vegetation. The palaeochannels of Saraswati River are located around several villages mentioned earlier in the text. These are generally buried and defunct river paths of ancient times; they get abandoned due to active sedimentation. They are visible in near to infrared refractory indices that seem to be located along the highly dense, linear vegetation belts and water bodies that are the most prominent markers of paleo-water flows (Fig. 6). Palaeodrainage network and paleo-flows through applying and observing various other features and elements like highly vegetated regions, their channel like shapes, presence of fluvial sediments, low depression areas, moderately thick soil cover indicate the presence of groundwater and moisture content in the upper soil cover. In the case of the Vedic Saraswati river migration and shifting was attributed to neotectonic activities in the
Western India. It has also been observed that the course of Vedic Saraswati was shifted further due northwestern margins. Most of the Palaeochannels are observed as inter-linked with each other in erratic manner (Fig. 7). Further, they are demarcated by an unusual and patterned framework of water bodies indicates water stagnation where there used to be flood plains with finer sediments; the sandy paleo-courses of the rivers look like abandoned liner and crescent shaped features surrounded by thick vegetations (Fig. 5 to Fig. 7).

Note: drainages trending WSW in blue color and paleochannels in light colors; sky blue colored spots represents the Lakes and red color is reflecting the density of vegetation along and the tracks of Paleochannels

Fig. 4: IRS-LISS III digital mosaic of Patan taluka in the North Gujarat alluvial plain

Fig. 5: A field photo of paleochannel show sand bodies surrounded by vegetations
Fig. 6: IRS-LISS III data taken in 2000 and 2012. Difference in vegetation cover is distinguished, but paleochannel areas are coming out in both the imageries by light color.

Fig. 7: A paleochannel map of Saraswati river showing paleo paths in dashed yellow lines while the river Saraswati vanishes in the alluvial plain.

The Gujarat alluvial plain is the best ground for Quaternary climatic study along its river courses at significant incisions. However the sediment cores are also raised from some limited locations like Nal lake\textsuperscript{13} and the influence of sea water from the LRK and Gulf of Cambay are also identified in late Quaternary to early Holocene time.\textsuperscript{13} The rivers like present day Saraswati, Banas and Rupen are spreading their courses with braided network as they meet to the Rann, but in last several hundred years (~500 years) of dry weather in the region has not provided a good hydro-dynamic regimes.\textsuperscript{14} The surface run-off in these river courses has been decreased as a result; the rivers have not carved the alluvial landscape quite significantly making the ground almost flat and featureless with gradient of only 0.16 ft/km. Tyagi et al\textsuperscript{15} established the history of Rann sediments during 5.5 – 1.4 ka with marine and continental – mostly Himalayan river influence, while tectonic influence and landscape change in the Western India in last 200 years have been confirmed.\textsuperscript{16-20} The region dominantly contains surface sand bodies i.e. the core of the river course are displayed as non-vegetated and lighter in color, while the palaeo river channels, where the
sands are generally buried under the alluvial deposits have good vegetation cover because the sand bodies are good aquifer zones, which provide the surface vegetation the water; while the overlying alluvial sediments are good source of nutrients, therefore they seem to be in a linear fashion and mostly parallel to sub parallel to the present day river courses. The crop pattern suggests that the Kharif crops like Millet seeds, castor, grains etc. are being grown, instead of Rabi crops indicating chief dependency of rain only instead of other irrigation means. Irrigation practice dominated by open dug-well and bore-well type, rather than canal or tank irrigation suggesting large dependency of ground water.

CONCLUSION
In spite of good rainfall in the area, the surface water is not been stored for the irrigation purpose, only because the type of soil is unfavorable. High percentage of loamy soil indicates good percolation power, hence the rain water when flows through the very gentle slope they immediately form small reservoirs mostly short lived and will readily recharge ground water. Eastern bank of the river contains archeological structures with the rain and surface water harvesting structures like step-wells (vavs), recharge wells and kunds – water pools suggesting frequent flash floods in last ~1000years. Splendid vav structures of 12th Century AD in the area suggest the scientific knowledge of slope, water way system, water harvesting, and architecture was available with ancient people.

RECCOMONDATIONS
It is recommended after the present study that all aquifer zones can be recharged using check dams, recharge wells etc. to restore the groundwater for irrigation purpose. Since ground water is recharged by mainly natural catchment flows, while discharge for irrigation overpass resulting in high salinity. For every village falling in this critical zone, recharge wells could be prepared to regain the ground water during rains. The areas falling on palaeochannels of Saraswati can possibly take 2-3 crops in a year using ground water source throughout the year if the outcomes of this study are implemented. The study of palaeochannels of the river systems and its correlation with ground water, crop pattern and soil characters are subsequently lead one to construct a viable model, which can be useful for the similar region of India or any semi-arid part of the world. A further extension of the present study is the construction of sustainable model wherein controls of many natural and anthropogenic factors have been well defined and understood for better yield of a prime source of life, the water.

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