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Disappearance of River Sarasvati in India - An Environmental Perspective, Lessons for the Future for Revival Management

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Abstract

Many rivers have disappeared from the ground surface of the planet earth in different periods of the history, some of them are codified and some have no records. Climate change is not a current phenomenon in the geological periods. Many civilizations had been destroyed, eliminated and abandoned at different phases. Climate had compelled the settlements to evacuate the cities, fortified locations and establishments. Largely, such events have happened due to scarcity of the water at the ground level, change of the courses of the river – that was the lifeline of the settlement, disappearance of the river because of the destruction of the source of the river. Himalayan rivers are largely glacier fed rivers or rain fed rivers. Only few depend on the perennial streams. The river Sarasvati was a glacier base river and was also depending on the rainfed. The glacier changed its location with glaciation and the river Sarasvati disappeared and caused many civilizations of ancient India to die. Cosmopolitan cities like Dholavira, Kalibangan, Rakhigarhi and couple of others were abandoned. Sarasvati sources have been dictated through ISRO satellite and researchers. Exploratory research with tri- approach model of geography is used in this river disappearance study with representation of source evidences. Many stepwells were constructed on the river Sarasvati bed to access water source in the medieval period. In this century the attempts have been made to recharge the river bed to reactivate the river flow, because of its holy status. Many researches have been conducted for the restoration of the river. One fact gets established that all Himalayan glacier fed rivers will die in this century due to climate change. Literature from the 3000 BCE have been taken into account for the study till the geological satellite findings in this century. Wide variety of researches were examined and evaluated with triangulation approaches; investigative methods used for the establishment of the findings from many sciences for this research. This is specific research from the environmental management perspective for revival of a disappeared river; the Sarsvati.

Keywords: River Sarasvati, Dead River, Disappeared River, River Revival, Climate Change

Introduction

Around 6000 B.C., the Sarasvati River, one of the most fascinating natural features on the Indian Subcontinent, began to flow spectacularly. Described in the Rig Veda as a powerful Himalayan River, it was known as Sapta-Sarasvati due to its six major tributaries (Bhadra et al., 2009). The river ran between the Indus in the west and the Ganges in the east, flowing through present-day Punjab, Haryana, western Rajasthan, and Gujarat, eventually draining into the Arabian Sea via the Gulf of Kutch. Near the confluence of its tributaries, the river expanded to such a vast extent that it resembled an ocean (Srivastava 2018). The river's abundant natural resources fostered thriving human settlements and supported agricultural livelihoods, as well as cultural and educational hubs. However, climatic shifts and tectonic activity in the Himalayan region caused the Sarasvati to dry up around 3000 B.C (Bharadwaj 1999). By the time the later portions of the Rig Veda were composed, the river's prominence had diminished, and its name was gradually replaced by Spata-Sindhu, referring to the Indus and its six tributaries. In the Yajurveda, the focus shifted to Panchanadya, a collective term for the five rivers in the region, and Panchadha, referring to the division of the river into five distributaries (Chatterjee et al., 2019). The Mahabharata's Aaranyak Parva describes the Sarasvati as a once-mighty river that lost its course near a location called Vinasana, on the desert's boundary. Its remnants were reduced to a chain of lakes surrounded by forests, reflecting the river's faded splendour yet serving as a reminder of its significant past (Chopra et al., 2006).

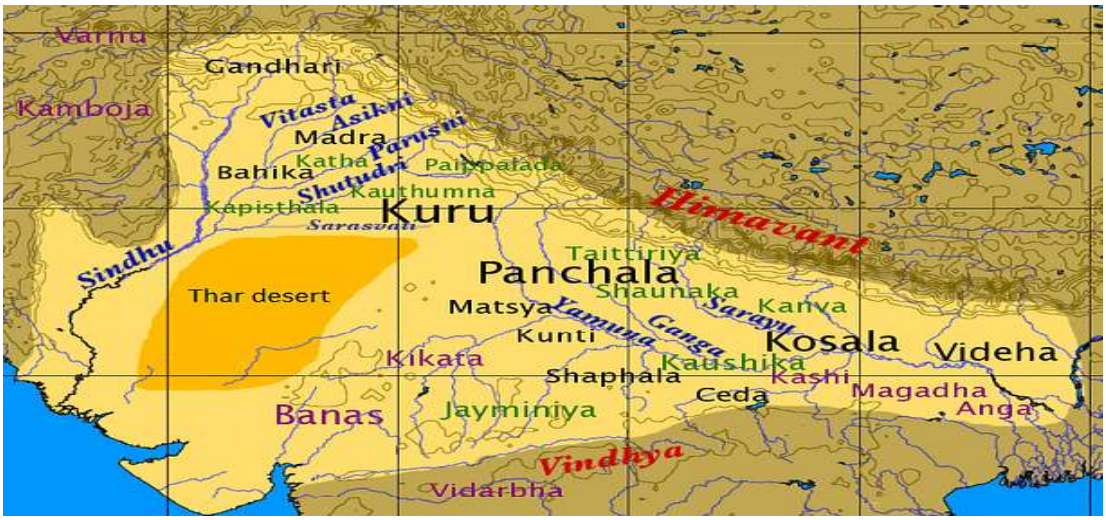

Fig. 1. Rig Vedic Mentioned Mahajanapadas and the Rivers (Sarasvati – the disappeared river)

The existence and eventual desiccation of the Sarasvati River, as referenced in the ancient texts, has long intrigued geologists, geographers, and archaeologists worldwide. This fascination began in 1874 when Oldham of the Geological Survey of India (GSI) published the first report on a 'lost river' in the Indian Desert. Oldham later expanded on these findings in a more detailed account in 1886, published in the Journal of the Asiatic Society of Bengal. Oldham's initial 1874 report discussed traces of a lost river in the Great Indian Desert (Thar Desert) (C.F. Oldham 1874). In a subsequent paper (1893), he proposed that the present-day Ghaggar River, which converges with the Sarasvati near Shatrana, represents the ancient Sarasvati River. According to him, this river, once fed by tributaries such as the Sarasvati and Markanda, flowed westward during the Vedic period but eventually lost its course in the sands of the desert near a place called Vinasana. The dry bed of the Ghaggar River is believed to mark the ancient Sarasvati's course (Hodell, et al., 2019).

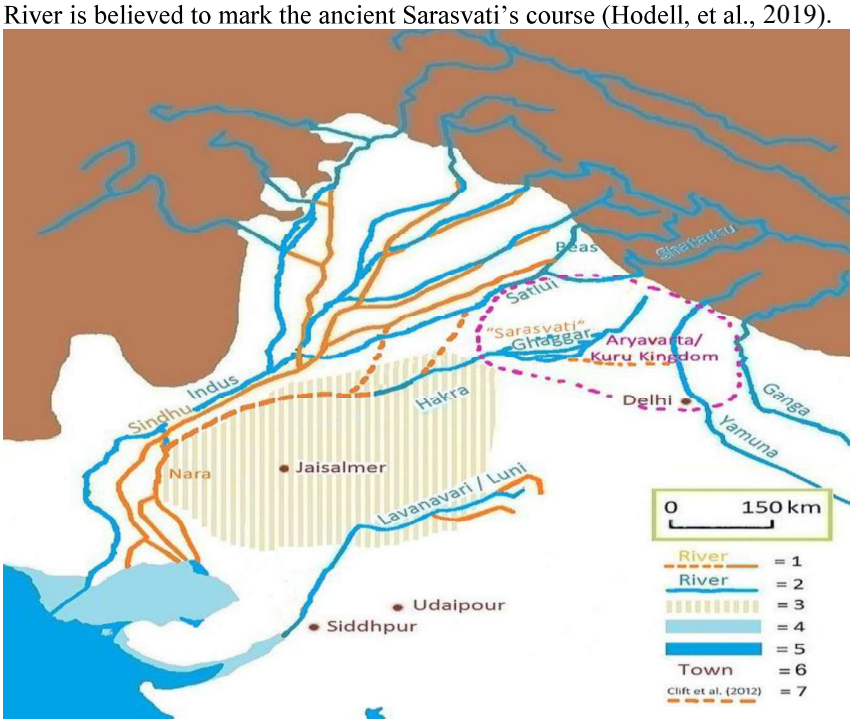

Fig. 2. River Hakra – Bed – (Sarasvati River Channel)

The Indian subcontinent was the scene of dramatic upheavals a few thousand years ago. The northern east region entered an arid phase, and erosion coupled with tectonic events played a great Havoc with river courses. One of them disappeared is the river Sarasvati. Recently the geographical and climatological studies have probed its evaluation and disappearance, while satellite imagery has traced the rivers buried courses and dried beds and isotope analysis have dated ancient water still stored under the Thar Desert of Rajasthan and the Rann of Kutch of Gujarat. Many of the pre Harappan and Harappan civilization sites perished without the water of the

river Sarasvati. Since Aurel Stein's expedition in the 1940's, hundreds of Harappan sites have been identified in the now dry Sarasvati basin.

Research Methodology Used

Such research is highly dependent on geographical methods of managing evidence with triangulatory approaches, linking the physical facts, secondary evidence and scientific surveys and excavations. In a larger context this research has used geographic exploration methods with substantial physical evidence and link based historical evidence of archaeological excavations at different phases in the last two centuries. Some evidence was satellite surveys by the ISRO. Physical evidence spanning over 500 years is used in this research paper.

Origin of the River Sarasvati from Himalaya Mountain Range

Dependencies: Civilization (Dholavira, Lothal Rakhigarhi)

Ancient India's knowledge text "Rigveda" defined the rivers Sarasvati as a lifeline of many human settlements, so this was called the holi river (Kinsley, 1998). The river is also described and explained as a powerful river with mighty flood (Wilke, 2011). In the late 19th century ADE numerous scholars of archaeology and history proposed and explored to identify the Sarasvati with the Ghaggar- Hakra river system, which flows through North- Western India and Eastern Pakistan, between the Yamuna and Sutlej, and ends in the Thar Desert region of Rajasthan and possibly in the Gujarat province in India. (Cleft, et al., 2012). ISRO satellite has observed that major Indus valley Civilization sites at Kalibangan (Rajasthan), Banawali and Rakhigarhi (Haryana), Dholavira and Lothal (Gujarat) lay along the course (Sankaran, 1999). The river dried up some 4000 years ago that is, 2000 BCE becoming an intermittent river, and the urban Harappan Civilization declined along with Dholavira, Lotha, Kalibangan, Rakhigarhi, Banawali in India (Singh, 2017).

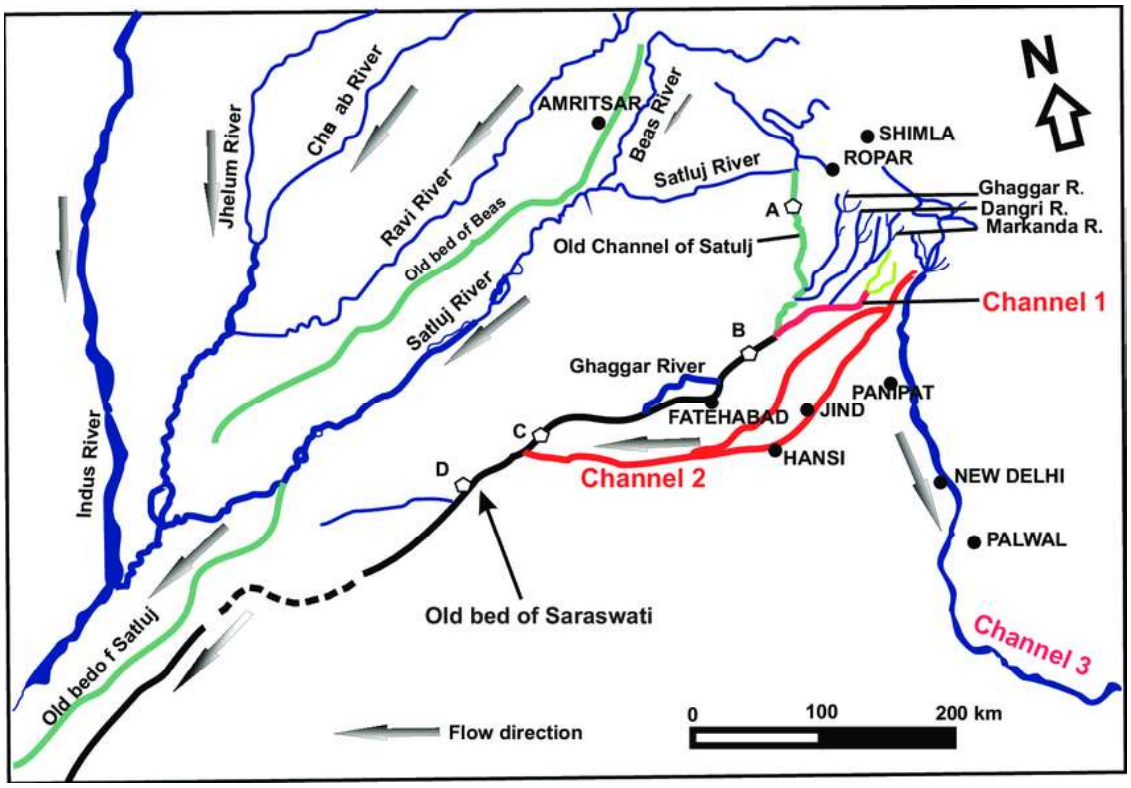

Fig. 3. Old Bed of River Sarasvati (Disappeared River)

The Sarasvati River decline system well establishes the river as a glacier fed drainage system, that drainage system dried due to the displacement or shifting of the glacier on the Himalaya Mountain ranges. Many rivers of India are of Himalayan origin from glaciers and some are rain fed with the impact of the climate change many rivers are subject to dry in the coming century. The first reference to the disappearance of the lower course of the Sarasvati is from the Brahmanas, a treatise, text that are composed in Vedic Sanskrit, but dating to a later date than the Veda Samhita's (Witzel, 2001). Post Vedic texts note that the historical river Sarasvati was a topographically tangible mythogeme, which was already reduced to a small, sorry trickle in the desert, by the time of composition of the Hindu epics (Ibid, 2011). The Ghaggar-Hakra river is a seasonal river in India and Pakistan that flows only in the monsoon season, but satellite images of the Indian Space Research Organisation

have confirmed that the major course of a river ran through the present day Ghaggar River (Valadiya, 2002). In the 2000 BCE, the monsoon diminished and the Ghaggar Hakra fluvial system dried up, affecting the Harappan Civilization. There is a general agreement among the researchers that the river courses in the Indus basin have frequently changed course; the sequences of these changes and their dating have been problematic (Schuldebreil et al. 2004). Many recent publications have shown that the Sutlej and Yamuna shifted course before Harappan times. According to a group of researchers, the Sarasvati River used to flow from the glaciated peaks of the Himalayas to the Arabian sea and an huge amount of water was flowing through this drainage network (Chaudhicietal. 2021) many Indus Valley Civilization sites and urban settlements are found on the banks of and in the proximity of the Ghaggar -Hakra fluvial system. Monsoon fed Ghaggar - Hakra in Harappan times (Stein, 1942). Number of archaeologists and geomorphologists have identified the Sarasvati River with the present day Ghaggar - Hakra Rivers, on the dried up part of it. Before Vedic times the river Sarasvati had already dried- up and became a small seasonal river. In the recent centuries a number of Scholars have identified the Sarasvati River with Ghaggar. Hakra river scholars like Christian Lassen (1800 to 1876), Max Muller (1823 to 1900), Marc Aurel Stein (1862 to 1943), C. F. Oldham and Jane Machintosh have identified the Sarasvati as the Ghaggar Hakra River. Michel Danion notes that the 1500 km long Sarasvati River fed was rediscovered in the 19th century. Most Indologists were convinced in the 19th Century that the river bed of the Ghaggar Hakra was the relic of the Sarasvati (Danino, 2010). Indologist Michel Danino places the composition of the Vedas therefore in the third Millennium BCE, a Millennium earlier than the conventional dates (Danino, 2010). Michel Danino notes that accepting the Rigveda accounts as a mighty river as a factual description, and dating the drying up late in the third Millennium are incompatible. Indus valley Civilization is sometimes called the Sarasvati culture, Sarasvati civilization, Indus Ghaggar-Hakra civilization, Indus Sarasvati civilization. The research and satellite imagery of the state Haryana of India has confirmed to have found the lost Sarasvati River when water was detected during the digging of the dry river bed at Yamunanagar (Nair & Daniel, 2015). Satellite photograph, surveys and researchers have confirmed that there was once a great River that rose in the Himalayas glaciers, entered the plains of Haryana, flowed through the Thar Desert of Rajasthan and Eastern Sindh running roughly parallel to the Indus River and then reached the sea in the Rann of Kutch in Gujarat state. The Marshy landscape of the Rann of Kutch is plentily due to the fact that it was once the estuary of the great river (Bhadra et al 2009). The government constituted Sarasvati Heritage Development Board (SHDB) had conducted a trial run to revive the river bed in Haryana.

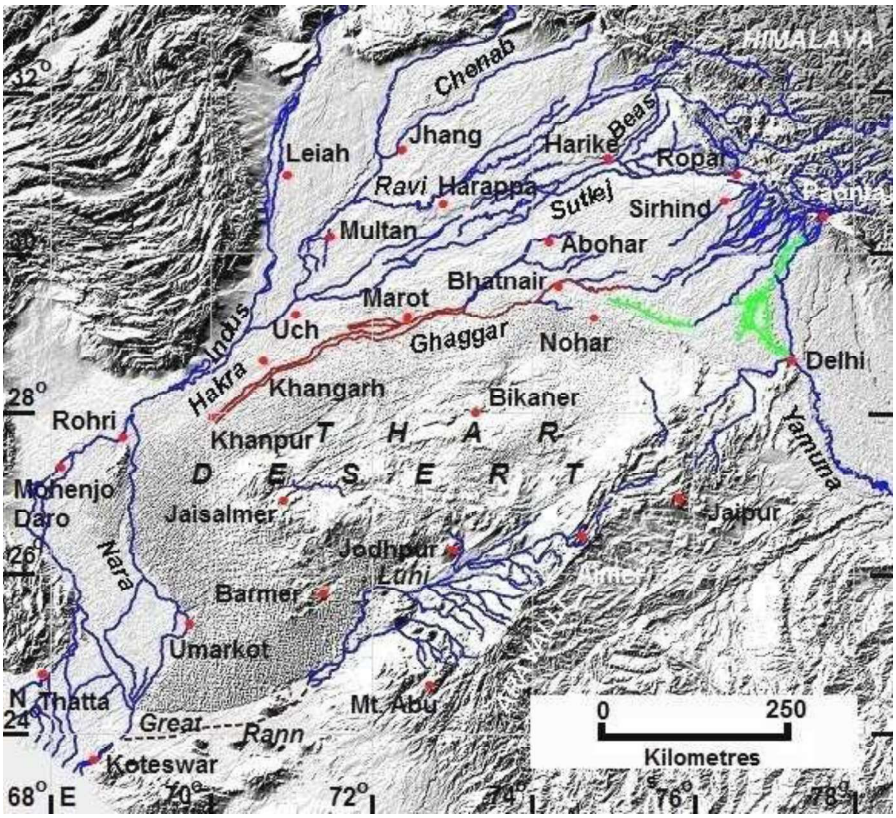

Fig. 4. The Ghaggar-Hakra valley (brownish red), the Nara and few other streams (blue), and some canals (green) from A.K. Johnston's 1873 map of North India which was geo-referenced for the purpose. Background image is a SRTM-1km DEM of the area.

Dholavira - Ancient Cosmopolitan City

In the Kutch district of Gujarat, the archaeological site of an ancient urban cosmopolitan city, Dholavira is located in Bhachau Taluk, at Khadirbet village also known locally as Kotada Timba. The ruins of a city of the Ancient Indus valley Civilization or Sarasvati River bed civilization dates back to 2600 BCE, located on the Tropic of Cancer. It is one of the five longest Harappan sites. Dholavira ruin site is located on Khadir Bet Island in the great Rann of Kutch in Gujarat. The site is spread over 120 acres as a quadrangular city lay between the seasonal streams Mansar in the north and Manhar in the south. This Ancient city was occupied from 3500 BCE till 1800 BCE. The ruins of the city were discovered in the 1960s by Archaeological Survey of India. The major Harappan sites discovered so far are Harappa, Mohenjo-daro, Ganeriwala, Rakhigarhi, Kalibangan, Rupnagar and Lothal.

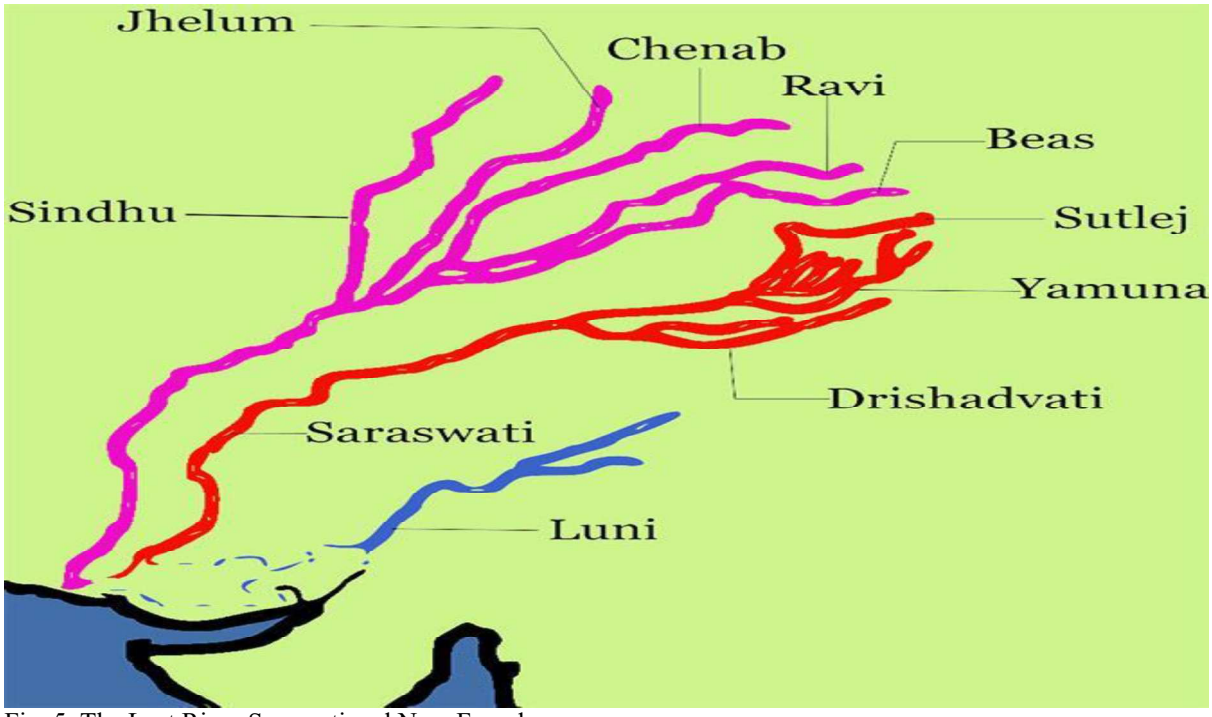

Fig. 5. The Lost River Sarasvati and Now Found

Dholavira depicts the scientific knowledge of water conservation, water reverse voice, step wells in the 3rd millennium BCE. The archaeological excavations during the stage III of the city, due to the drying up of the river drainage system of Sarasvati. Dholavira civilization was engaged in the global trade through river systems for inland navigation and sea to connect the Egyptian and Iraq (Mesopotamia) civilizations. The city had massive reservoirs, three of which are exposed (Mclntosh, 2008). Excavation at the site in 2014 began on a rectangular step well which measured 241 feet long, 96 feet wide, and 33 feet deep, making it three times bigger than the Great bath of Mohenjo Daro (Tewari 2014). It is also established that a coastal route existed linking Lothal and Dholavira to Sutkagen Dor on the Makran coast (Singh, 2008). It is possible that the settlement in Dholavira opted to construct a large number of reservoirs, the main stream drainage dried up (Sarasvati) and rivulets on the south and north of the Ancient Cosmopolitan City. Disappearance of the river Sarasvati caused out migration from the ancient city of Dholavira and finally dated to abandonment and decline. Dholavira has a foundry of coin making and Seal making, its own scripts and language massive civil Constructions and used the best architecture and defensive structure, that stands till today as remnants. Dholaviras trade links were global. Dolavira spoke an unknown language and their script has not yet been deciphered. Some inscriptions are also found on copper tablets, bronze implements and small objects made of Terracotta stones and faience. Research of IIT Kharagpur Indian Institute of Technology reveals that the decline of Harappan city Dholavira was caused by drying up of rivers like Sarasvati River and Meghalaya drought. These researchers have for the first time connected the decline of Harappan city Dholavira to the disappearance a Himalayan snow fed river which once flowed in the Rann of Kutch. They have also been able to connect the dots between the growth and decline of Dholavira, located in the Rann with this river which resembles the Himalayan River Sarasvati.

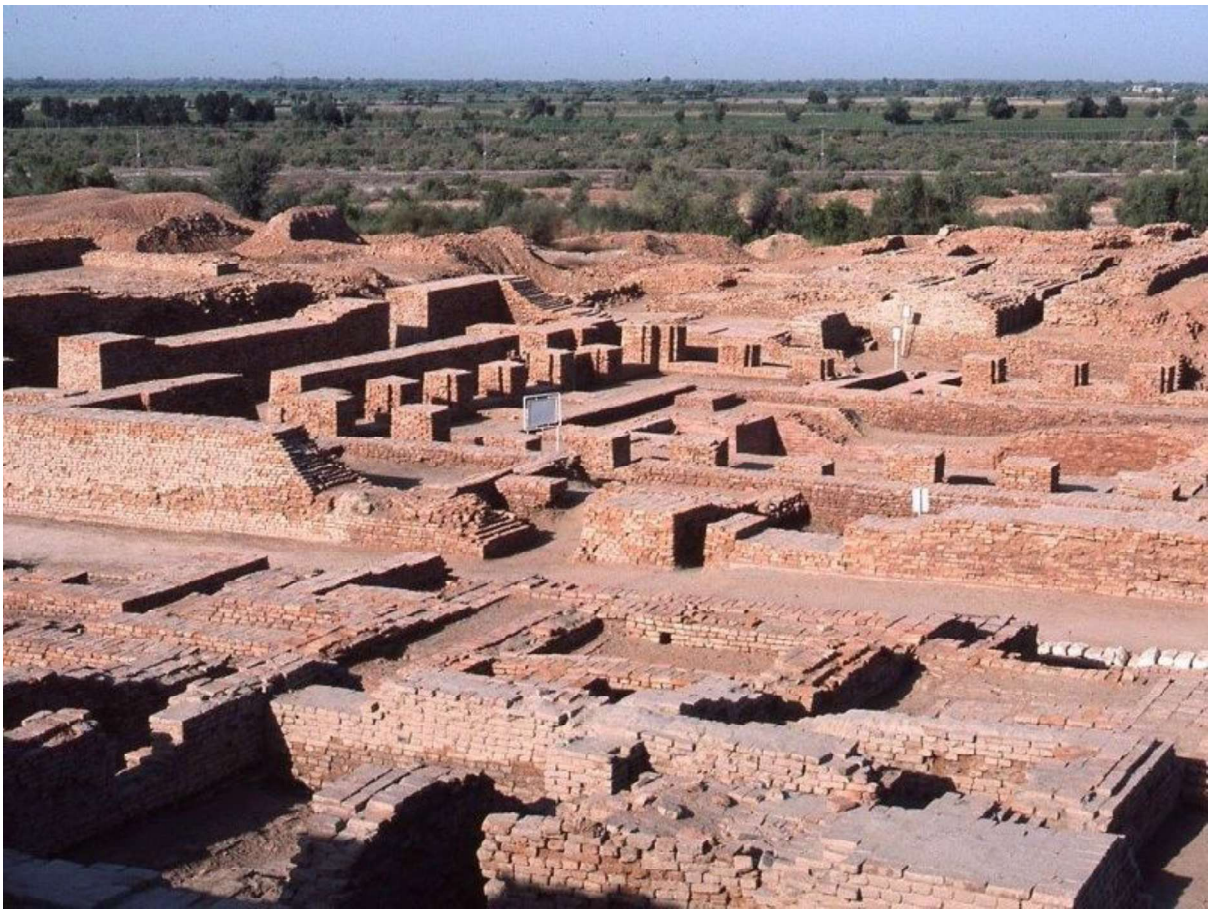

Fig. 6. Abandoned Cosmopolitan City Dholavira (Ancient City) Rann of Kutch, Gujarat

Lothal the Southernmost City of Indus Valley Civilization

The city of ancient civilization Lothal, located near Ahmedabad in the state of Gujarat. Construction of the city is believed to have begun around 2200 BCE (Kulke) 2004 according to the Archaeological Survey of India, Lothal had the world's earliest known dock, which connected the city to an ancient course of the Sabarmati River on the trade route. This ancient trade route stretched between Harappan cities in the Sindh (Pakistan) and the peninsula of Saurashtra where the surrounding Kutch desert of Gujarat today was part of the Arabian Sea (Leshnik,1968) the National Institute of oceanography in Goa had discovered foraminifera (Marine and see microfossils) and salt, gypsum crystals in the dock site of Dholavira clearly indicates that sea water once filled the structure and it was definitely a dock yard. Lothal was a significant trade Centre in ancient times. The city used to trade with west Asia and Africa. Lothal was an Ancient urban settlement with bricks and stone construction Lothal was linked to Dholavira in the waterways. River Sarasvati, the rivulet that connects Lothal was the rain fed or a Himalayan glaciation fed River system. Another angle of human urban settlements does link every possibility that the step wells in the medieval period were constructed on the river Sarasvati bed areas. The step wells do establish the possibility that the river Sarasvati used to depend on the water supply from the river Sarasvati. Lothal was providing access to the gulf of Khambhat through a river (Rao, 1985).

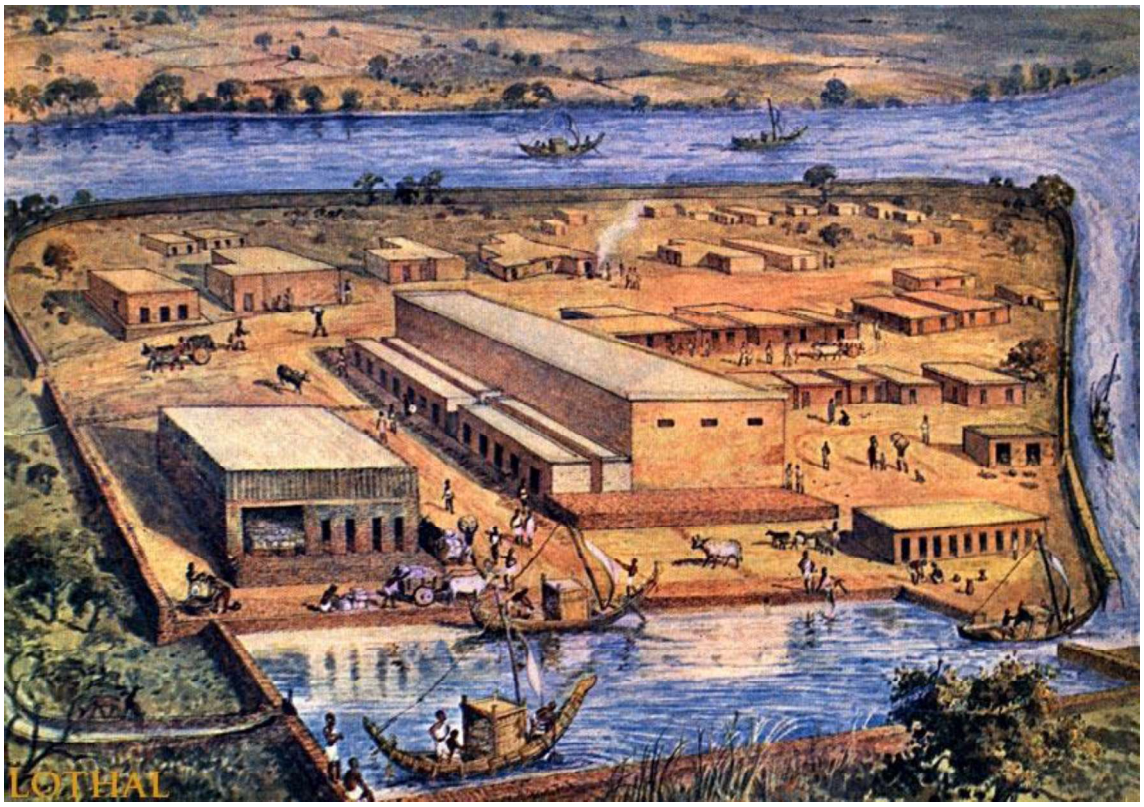

Fig. 7. Ancient Port City Lothal, Gujarat – Died with the disappearance of the River Sarasvati

The beads and gems of Lothal were in great demand in the west. River Sabarmati is a rainfed system with its origin from aravali Range in Rajasthan in the recent years. The river has also dried up. The river had tributaries of the river Sarasvati origin in an early Harappan age and prior to it Lothal port and Lothal dock started declining with shortage of river water and disappearance of the river Sarasvati. Another possibility is that the cause for the abandonment of the city may have been changes in the climate as well as Natural disasters, as suggested by the environmental magnetic records (Khadkikar et al. 2004). Lothal is based upon a mound that was a salt marsh invaded by a tide. Before the Arrival of Harappan people in 3000 BCE, Lothal was a small village next to the river providing access to the mainland from the gulf of Khambhat. The indigenous people maintain a prosperous economy attested by the archaeological excavation and the construction of Dholavira city where fire dried bricks line sand and mortar the indigenous people maintain a prosperous economy attested by the archaeological excavation. The construction of Dholavira city was made of fire dried bricks, lime sand and montan not by sun dried bricks as the bricks are still intact after 4000 years and still bound together with each other with a montan bond. Lothal dockyard and the font were scientifically designed with modern engineering skills and knowledge. Fresh water and drinking water are the lifeline of any Civilization with the disappearance of the river Sarasvati, the supply chain drainage of freshwater disappeared and the decline in phase of the ancient port city Lothal standard. Lothal is an epitome of a lost civilization depending on the Lost rivers Sarasvati.

Rakhigarhi - Ancient Urban City in Haryana

Rakhigarhi archaeological site is located in the Hisan district of Haryana state, about 150 km northwest of Delhi, located in the Ghaggar river plain (Wright, 2009). Rakhigarhi belongs to the Indus Valley civilization. It was among the largest settlements of the ancient civilization. Many sites in the vicinity are still awaiting excavation are Mitathal and Lohari Ragho. Rakhigarhi is located in the Ghaggar plain, some 27 km from the seasonal Ghaggar river. According to Jane Mclntosh, Rakhigarhi is located in the valley of the prehistory Drishadvati River (the real root of Vedic River Sarasvati) that originated in Shivalik Hills (Mclntosh, 2008). Rakhigarhi was spread over 750 acres encompassing a set of 7 mounds (Nath 2015). Rakhigarhi was the largest town and regional trade centre surrounded by the Ghaggar Hakra River system. There are many other important archaeological sites in this area, in the old river valley to the east of the Ghaggar plain among them are Kalibangan, Kunal, Baln, Bhirrana and Banawali (Nath, Ganga and law, 2014). Different archaeological findings confirm both early Rakhigarhi existence in the early and mature Harappan pages and include 4600 years old human skeleton, fortification and bricks.

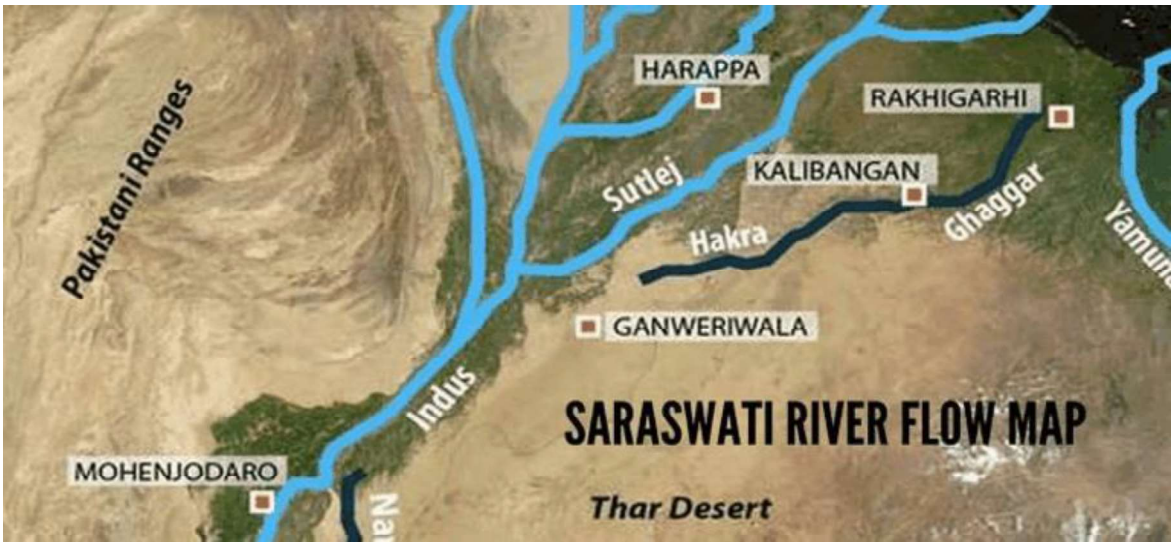

Fig. 8. River Sarasvati flow map (3000 BCE)

The city was a planned urban settlement with a massive granary, drainage system, cemetery and burial sites, planned city structures with nothing less than a modern urban city with the disappearance of the rivers Sarasvati and drying of the river bed. Rakhigarhi urban fortified city started declining. It was the largest Indus Valley Civilization after Mohenjo-Daro. In the nearby vicinity, contemporary to Rakhigarhi were Kunal and Bhirrana. The carbon dating of Bhirrana site revealed that it dated back to 7030 BCE i.e., 9000 years old. Kunal, pre Harappan Indus Valley Civilization settlement is located at a distance of 30 kms from Fatehabad city in Faridabad district of Haryana state. Birhana is also called as Birhana located in a small village in Fatehabad district of Haryana. Bhirrana dates back to 8th-7th millennium BCE. It is one of the many sites seen along the channels of the Ghaggar river i.e., Rigvedic Sarasvati river.

Fig. 9. Ancient Urban Settlement Rakhigarhi (Haryana) abandoned with the disappearance of the River Sarasvati

Topographical Variation of the Region using DEM

The physiographic characteristics of northwest India can be represented on a slope map, revealing a vast expanse of gently sloping terrain from the northeast to the southwest. This region has an elevation range from about 270 meters at the foothills of the Himalayas to the sea level along the Gujarat coast. Numerous streams originate from the southern slopes of the Siwalik Hills, flowing southwest and eventually merging with the Ghaggar River. Apart from the Himalayan foothills, much of northwest India consists of extensive alluvial deposits made up of clay, silt, and sand. The region experiences a hot and dry summer, a southwest monsoon

season, and a cool winter (Raghav 1999). The physiographic features of Rajasthan, Haryana, and Gujarat are detailed below.

Physiographic Divisions of Northwest India

Drilling data from Jaisalmer district in Rajasthan reveals fine to medium and coarse-grained sand and gravel deposits within paleochannels, which were shaped by ancient fluvial activity. Coarser sediments are typically found at depths of 40–125 meters in most tube wells. These channels are approximately 35 to 80 meters thick, with water levels ranging from 35 to 60 meters. In contrast, lithological data from areas close to paleochannels in Haryana show medium to coarse-grained sands, gravel, and pebbles at depths between 10 and 100 meters. Electrical resistivity soundings along the Ghaggar River indicate thick and extensive subsurface sand deposits in parts of northwestern Rajasthan, Haryana, and Punjab. The dimensions of these paleochannels suggest the presence of a large, long-standing fluvial system in this region.

Physiographic Divisions of Rajasthan

Rajasthan is divided into two natural regions. The northwestern part consists of sandy, arid land with scarce water resources, though it becomes more fertile and habitable as one moves eastward. The western part of Rajasthan is characterized by aeolian sands and alluvium deposits in the Thar Desert. In the southwestern region, the landscape includes several hillocks forming part of the Aravalli Mountain range (Gupta et al., 2001). The main physiographic features of Rajasthan include:

Western Sandy Plains
- Sandy Arid Plains (Marusthali)
- Semi-Arid Transitional Plains (Rajasthan Bagar)

Aravalli Range and Hilly Region
- Aravalli Range and Bhorat Plateau
- Northeastern Hilly Region

Eastern Plains
- Banas Basin
- Chappan Plains

Southeastern Rajasthan (Pathar or Harauti Plateau)
- Vindhyan Scarp land
- Deccan Lava Trap

Physiographic Divisions of Haryana

Haryana's landscape is divided into four major physiographic features which includes **Siwalik Hills** altitudes range from 900 to 2300 meters, and these hills serve as the source for rivers such as the Sarasvati, Ghaggar, Dangri, and Markanda. **Ghaggar-Yamuna Plains** area is split into two parts: the higher 'Bhangar' and the lower 'Khadar'. These alluvial plains consist of sand and calcareous gravel balls, locally known as 'Kankar'. **Semi-Desert Sandy Plain** Bordering Rajasthan region includes the districts of Sirsa, parts of Fatehabad, Hisar, Bhiwani, and Mahendragarh. **Aravalli Hills** is a dry region with an uneven and irregular landscape (Bhadra et al., 2006).

Physiographic Divisions of Gujarat

Gujarat's physiographic features are divided into several distinct regions: **Coastal Zone** located in the southern part of the state. **Kachchh Mainland** comprising the central part of the state, it consists of rocky terrain with hills in the north and coastal plains. **Banani Plains** characterized by fluviomarine sediments, this region features mudflats and soft pans. **The Two Ranns** then are The Great Rann in the north and the Little Rann in the east, both consisting of vast saline wastelands (Bhadra et al., 2009).

Drainage System of Northwest India

Several thousand years ago, the north western part of India was drained by a network of mighty rivers. However, these river systems have been largely disrupted, with many either destroyed or preserved only as remnants, forming the present-day drainage patterns. While the Himalayan rivers continue to nourish the Indo-Gangetic plains, southwest Haryana, southern Punjab, and western Rajasthan remain riverless. These regions are covered by a 10–30-meter-thick layer of younger riverine sediments, characterized by numerous channels that carry floodwaters only briefly. Many of these channels are now filled with sediments or buried under the sands of the Thar Desert (Raghav, 1999).

The presence of numerous archaeological sites along the palaeochannels of the Sarasvati basin highlights the strong connection between the Indus-Sarasvati (Harappan) civilization and the ancient Vedic Sarasvati River. The spatial arrangement of Early, Mature, and Late Harappan settlements in Haryana suggests a gradual

migration of populations from the southwest to the northeast, corresponding to the progressive drying of the Sarasvati River (Gaur et al., 2005).

Disappearance of River Sarasvati:

The Saraswati River system in the Vedic period includes the rivers Ghaggar, Markanda, Chautang, Sutlej and Yamuna. The diversion of the Sutlej and Yamuna is considered as the main cause of loss of River Saraswati by most of the researchers. The rivers Ghaggar, Markanda, Saraswati and the Chautang rise in the Siwalik Hills. Different scholars attempted to establish chronological sequence of events that contributed to the desiccation of Vedic Saraswati. Their compiled works are based on different aspects like climate, tectonism, drainage changes and cultural events which can be combined for the purpose of evaluating the changes in the drainage systems of northwestern India. In turn, it throws light on the events that have contributed to the decline and final loss of river Saraswati (Valdiya, 2000).

Late Quaternary tectonism in combination with the sudden increase in aridity related aeolian activity disrupted and obliterated the courses of the rivers of NW India mainly the Saraswati River. From the studies by the various eminent researchers for the past several years now it has been clear that the Yamuna as well as the Sutlej were tributaries of the Saraswati River. Around 3700 B.C tectonic disturbances in the area have caused the capture of upper catchment water of Saraswati by Yamuna and westward migration of Sutlej causing the drying up of the river (Oldham 1886).

Over a 3000-year long period since the Vedic times, the drainage pattern of many rivers had changed from that described in the earlier religious literatures. The decline of Saraswati appears to have commenced between 5000–3000 B.C. probably precipitated by a major tectonic event in the Siwalik Hills of Sirmur region. Geologic studies indicate destabilizing tectonic events in the entire Siwalik domain extending from Potwar in Pakistan to Assam in India resulting in massive landslides and avalanches. These disturbances, which continued intermittently, were all linked to uplift of the Himalayas. One of these events must have severed the glacier connection and cut off the supply of glacier melt-waters to this river. As a result, Saraswati became non-perennial and dependent on monsoon rains. All its majesty and splendour of the Vedic period dwindled with the loss of its tributaries and the river totally got lost around 3000 B.C. (Radhakrishna 1998).

Saraswati was totally lost when its water was captured by the Sutlej and the Yamuna. Thus, climatic changes and geotectonic movements have led to the migration and abandonment of several rivers and drainage systems. The cumulative effect of reactivation of Yamuna tears constriction of catchment area of Vedic Saraswati by emergence and migration of river Drishadvati. Views of some important authors have been highlighted here (Oldham 1886).

The researchers suggested the following causes for Saraswati migration and drainage desiccation in NW India. The following are the possible reasons for migration and loss of Saraswati River:

- Rise of Delhi-Haridwar ridge along the NE-SW lineaments.
- Rise of Aravalli hills bounded by lineaments on its west.
- 6. Stream piracy by the rivers like Yamuna and Beas.
- Climate change from wet to dry spell, as evidenced by geomorphological and stratigraphic records during the Quaternary period.
- Neo-tectonic changes in the Himalayan and Aravalli regions.
- Uplift of Himalayas and Siwaliks
- Uplift of Aravalli range resulting in northward shift of river Saraswati.
- River piracy of Saraswati and subordinate rivers by Yamuna, Satluj, and Ganga.
- Climatic changes from humid to desertic conditions.
- Changes in glaciation in Himalayas.
- Choking of rivers by enormous sand debris.

Settlements on River Saraswati:

Paleontological studies of Rajasthani lakes show that the climate was unsuitable for human survival prior to 8000 BC, that there was a high rainfall between 8000 and 7500 BC, a slight decrease in rainfall between 7500 and 3000 BC, and a brief dry spell between 3000 and 1000 BC. Based on these findings, we can conclude that the climate in the Saraswati bed would be suitable for human settlement after 7500 BC. The pre-Harappan features of Kalibangan, located in the Hanumangarh District of Rajasthan on the left bank of the Ghaggar River, include fortified houses made of mud bricks, pre-Harappan type pottery, and ploughed fields. The mature Harappan features, such as houses with baked bricks, terracotta, and a citadel on the west side of the houses, were dated between 5600BC and 2700BC based on radiological findings, indicating that the culture there was pre-Harappan. Just 10 kilometers from the Nohar railway station in Rajasthan's Hanumangarh District, the

excavation at Sothi displays pre-Harappan elements such as mud or brick homes, pottery, and village culture, as well as Harappan elements like terracotta, cartwheels, round cakes, and bangles. Radiological data indicates that the culture was active between 5600 BC and 2192 BC. The archeological site of Siswal, located in the Hissar region of Haryana, yielded blades and copper artifacts utilized in mature Harappan culture, as well as colored ceramics similar to those found in Kalibangan and mud-houses that revealed pre-Harappan culture (Nigam, R. 2012). On the bank of Saraswati in the Fatehabad district of Haryana, Banawali is another excavation site where pre-Harappan (sun-dried bricks, mud walls in homes, painted motifs) and mature Harappan (fortification towards the north, baked bricks) may be found. Located in the Kaithal District of Haryana, 2 km north of Balu Village, the excavation site Balu exhibits post-Harappan culture through the usage of mud and brick constructions, brick platforms, kilns, furnaces, beads, shell bangles, and copper artifacts. Rakhigarhi, situated in the Tehsil-Hansi district of Haryana on the banks of the Saraswati and Drishadvati rivers, exhibits a drainage system, circular pits, a fire chamber, arrowheads made of metal, copper bangles, toy carts, and steatite beads, all of which are examples of pre-Harappan objects; post-Harappan items include blades, terracotta, shell bangles, semi-precious stone beads, copper objects, animal figurines, toy cart frame, bone points, and steatite seals. Excavation site Kunal, found in Fatehabad district of Haryana, shows pre-Harappan culture which as per radiological data was dated back to 3016 BCE-2577 BCE. In this site, the pre-Harappan settlers dug up large pits over which wattle-and-daub huts were raised and they used agriculture and domestic animals, bone-tools, micro-blades of chalcedony, copper arrow-heads and fish-hooks; the mature Harappan settlers used moulded mud-bricks as in Kalibangan and Banawali, and dwelling pits; and the post-Harappan settlers constructed rectangular and square houses, terracotta, shell seals, crowns, armlets, bangles and necklace of silver, six gold beads. Bhirrana, which is located in Fatehabad district of Haryana. Other characteristics of the mature Harappan period included mud walls, baked bricks, steatite beads, pottery assemblages, city layout, and fortification. Ganeshwar is an excavation site in Rajasthan's Sikar District that has pre-Harappan artifacts from 3800 BC to 2000 BC (Nigam, R. 2012). The pre-Harappan period included chert tools for hunting and gathering, mud homes, and sun-dried bricks; mature Harappan men left behind copper metal works, fired clay pottery, city layout, drainage systems, and copper bangles. Among the most notable post-Harappan traits observed here were urban culture and the widespread use of copper items. Pre-Harappan dwellings consisting of wattle and daub were discovered at the Baror excavation site in Rajasthan's Sri Ganganagar District, indicating the early Harappan civilization there. Ploughed fields, blades, and pottery were unearthed from the excavation sites in North Gujarat, revealing a fully developed Harappan culture there all at once. Pottery, animal skeletons, steatite micro-beads, shell and semi-precious beads, terracotta items, and lumps of burnt clay—the primary items used by pre-Harappan man—were discovered during an excavation at Lotheshwar in Gujarat's Patan district. The remains of Early Harappan man's copper blades, mud homes, bowls, black-painted pots, and hand-made wheels were found at the Padri excavation in Gujarat's Bhavnagar District. There are excavation sites in the Mewar region of Rajasthan where artifacts from a time before the pre-Harappan period were found. These sites were mostly utilized for rudimentary farming and community life (Gaur, et al., 2005).

The Saraswati-Ghaggar Rivers were perennial in northern Rajasthan during the pre-Harappan and mature Harappan periods, and they have since reduced to a small stream, indicating that the river was receiving less water and gradually drying up. Archaeologists have discovered numerous excavation sites in the bed of the extinct Hakra-Saraswati-Ghaggar system and their extinct tributaries. Numerous protohistoric sites can be located along the route of the defunct Saraswati system, particularly between Hanumangarh in India and Bahawalpur in Pakistan. (Gaur, et al., 2005). Kalibangan, Sothi, Banawali, Rakhigarhi, Kunal, Bhirrana, Baror, Grawad, and Ganeshwar excavation sites were used to study pre-Harappan features. This suggests that human settlements may have existed in these locations between 4500 and 3000 BC. The presence of human settlements during the mature Harapan period in each of these regions demonstrated that human settlements existed from the early 3000 BC to the 1800 BC. Only post-Harappan artifacts were excavated in Balu since human settlement was restarted after 1800 BC and 1600 BC. Based on the findings, we can conclude that the transition from pit dwelling to ground dwelling took place around this time. Neolithic man bones were also found at this location, demonstrating that early humans survived between 7500 and 6000 BC. Based on radiological evidence, Martimer Wheeler claims that the Harappan society existed between 2350 and 1700 BC, rather than 3000 BC as Marshall claimed. However, in the Saraswati bed, human culture predates the Harappan culture. As a result, it is believed that the human culture in the Saraswati bed was very different from the Harappan society and more like the Vedic culture (Bhadra, et al., 2009).

Stepwells and Rivulets on the Rivers Sarasvati Source

River Sarasvati was the life line of many advanced urban settlements of the ancient period. After the disappearance of the river Sarasvati many civil engineering methods were used by the ancient Civilization to store the water and to connect drainages to have water supplies. Step wells are constructed in areas where water is scarce. There were many times constructed on trade routes to facilitate the needs of travellers. The well

digging and the construction of the step wells followed the Civil engineering principles of underground water streams and the community of well diggers in many regions in western India were well versed with the knowledge of existence of underground streams and also the techniques of well - digging. Some step wells are multi- storeyed and can be accessed by the pension wheel which is pulled by a bull to bring water to the first or second floor. The earliest evidence of step wells is found at Dholavira where the site also has water tanks or reservoirs with fights and steps. The earliest evidence of step wells has reference in Asokan pillar edict No. 7, the first rock cut step wells in India date from 200 to 400 ADE (Livingston, 2002) some of the prominent step wells are available in Patan, Junagarh, Gandhinagar and Ahmedabad. Many rivulets were constructed and dug by the inhabitants of ancient settlements, fortified urban townships in the acid zone, Rann of Kutch, desert and in the acid zone of the Rajasthan, Delhi and Haryana region. Some of the rivulets are natural in India but many are wide canals for the inland navigation voyage ships anchorage. Many rivulets were dug on the river Sarasvati to bring the water to the Harappan period ancient settlement Dholavira, Lothal, Rakhigarhi and other ancient settlements.

Rani Ki Vav Step Well in Patan

The queen's step well is locally known as Rani ki vav in Gujarati language, located in Patan district of Gujarat. This step well was constructed by queen Udayamati of Bhima in the 11th century ADE. Rani ki vav was constructed during the rule of Chalukya Dynasty, on the area of the Sarasvati River. This city was plundered and stacked by Qutb-ud-din Aybak and Allaudin Khilji the Islamic Delhi Sultanate in the 12th and 13 century ADE (Lal, 1950). The step well was commissioned in 1063 ADE and was completed after 20 years. The step well was later flooded by the Sarasvati River and silted over (Tomar and Faruqui, 2018). The step well is designed as an underground shrine or invented temple, this represents the sanctity of water. There are a large number of celestial beings (Apsaras) Rani ki vav, on the bank of Sarasvati River, was initially built and a memorial Rani ki vav is an expansion example of distinctive forms of subterranean water architecture of India. Subcontinent, the step well which is located on the river bed of Sarasvati. This step well was built to provide drinking water to the nearby village settlements in Patan Rani ki vav in a UNESCO World Heritage site due to its stone architecture. Step wells in India were the permanent water source in these arid lands, ensuring water availability during times of drought. In Indian beliefs it's Holy to get access to the river Sarasvati water. River Sarasvati is treated holy in the Hindu, Jai, and Buddhist faith. Apart from being a UNESCO World Heritage site, Rani ki vav has been declared a monument of national importance. The step well is 98 feet deep with 7 levels of stairs. There are more than 500 principal sculptures and over a thousand minor ones. This is a Marvel of civil engineering in bringing the dried river bed water to the surface (Mehta & Bhatt, 2014).

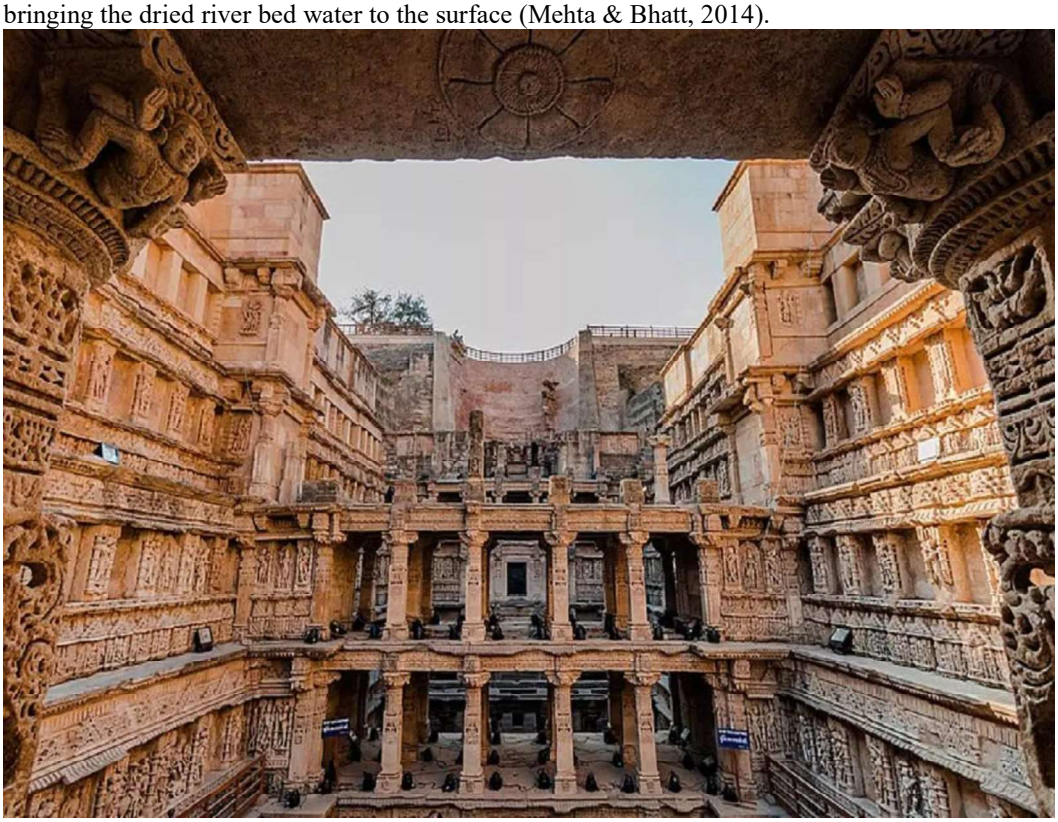

Fig. 10. Rani Ki Vab (Stepwell) on the River Sarasvati Bed, Patan District, Gujarat, India

Adalaj Step Well or Rudabai Stepwell, Gandhinagar

The step well is located in Adalaj near Gandhinagar. Step wells were once integral and highly essential to the semi-arid regions of Gujarat, as they provided water for drinking, washing, and bathing. These step wells were also venues for colourful festivals and sacred rituals. (Takerawa, 2002) step wells as stepped ponds, built between 5th and 19th centuries ADE, are common in western India. Gujarat state hosts more than120 such step wells in the past that were frequently used by travellers and caravans as stopovers along trade routes (Takerawa, 2002). Ancient and medieval step wells survived so long in Gujarat because of the builder's knowledge of the soil conditions and the earthquake proneness of the region (Livingston, 2002). There is every possibility that Adalaj stepwell is located on the ancient disappeared river Sarasvati bed. River Sabarmati was a later period river. Adalaj was well connected with Lothal trade city of the ancient world. The Adalaj stepwell or "Vav", is intricately carved and five stories deep. This was built in 1498 ADE. The stepwell was built in sandstone in the Solanki architectural style.

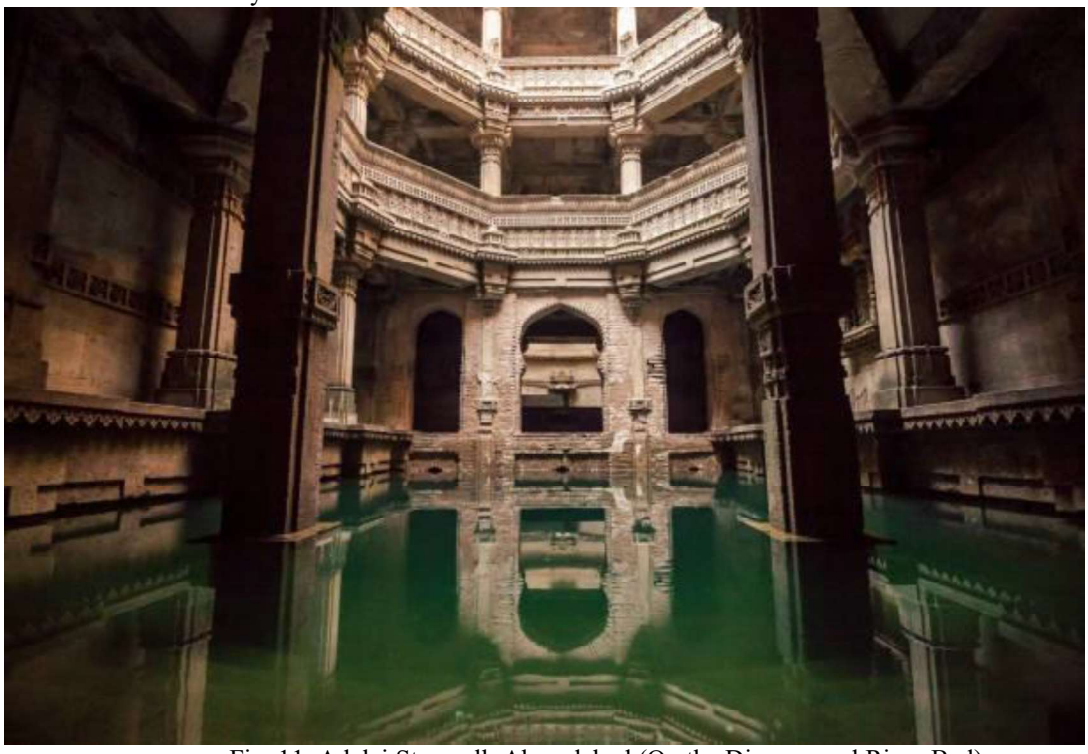

Fig. 11. Adalaj Stepwell, Ahmedabad (On the Disappeared River Bed)

Other Stepwells on the River Sarasvati Bed

Some of the noted step wells on the river Sarasvati bed are Mata Bhawani's stepwell, Dada Harir stepwell, Jethabhai's stepwell etc. in the Ahmedabad district of Gujarat. Mata Bhavani in Asarwa area of Ahmedabad was built in the 11th century ADE during Chalukya dynasty rule in Gujarat with the funding of overseas traders and maritime merchants. The stepwell was built much before the establishment of the modern city Ahmedabad. This multi-story stepwell has open pavilions positioned along the east-west axis (Tadgell, 1990) this stepwell has three stories and three pavilions. The diameter of the well is 4.8 meters (Jutta Jain, 1981). The stepwell is 46 meters long and 5.1 meter wide at its entrance.

Another stepwell on the river bed of Sarasvati is Dada Harir stepwell in Asarwa area of Ahmedabad district 15 kilometres off of the city Ahmedabad. Dada Harir stepwell was built in 1485 ADE (Gargette, 1879). The stepwell was built in sandstone in Solanki architecture style with five stories deep. The well has five levels. At the level of the ground it is 190 feet long and forty feet wide. In the vicinity there were several step wells, closed and not used. The river Sarasvati bed leaves the underground water source for use and in future to revive if possible, next to impossible.

Jethabhai stepwell was built in 180 ADE with four pavilions and one entrance pavilions in the Isanpur area of Ahmedabad district (Kumar, 2008). This stepwell was an ancient monument but was destroyed and rebuilt by the Islamic power by the old stepwell. Step wells in and around Ahmedabad and Gandhinagar districts are built on the disappeared river Sarasvati bed. This stepwell is restored by the archaeological survey of India.

Impossible Revival of the River Sarasvati

The revival of the ancient river Sarasvati, considered as the holy river of India, has been on the agenda of the state governments and the community at large. Reviving the river that has disappeared around 3500 BCE by

sabotaging many advanced civilizations sacred by more than one billion population of India's, Sarasvati is one among the trio of India's holy river Sarasavati disappeared due to tectonic disturbances, impacting its tributaries. The glacier source of the river shifted its location causing no water supply to the river course. At present the river bed is not dry, the step wells provide the vivid evidence. Claims have been made that the river is alive and flowing underground. The Sarasvati River system in the vedic period included rivers like Ghaggar, Hakra, Markanda, chantang and Yamuna. In 2018 proposal of the revival of Sarasvati River was considered by the ministry of environment forest and climate changes (MOEFCC) Expert Appraisal Committee (EAC) for river valley and hydroelectric project, in its meeting on May 27, 2019. Sarasvati River is a heritage project with additional benefits like, ground water recharge, flood control, fish farming and recreation / tourism. With reference to a MOU (Memorandum of Understanding) in 2022 between government of Haryana and Himachal Pradesh for construction of Adi Badri dam on the river somb in Himachal Pradesh. Along with its linkages with Sarasvati River. Storage in Adi Badri dam shall be primarily used for revival of river Sarasvati and development of Sarasvati heritages (PIB 2022). Also, Sarasvati heritages development board had been constituted by the government of Haryana for rejuvenating of Sarasvati River and development. Delineation and mapping of the paleo channels of Sarasvati River has been carried out by Indian space research organisation (ISRO). On the basis of revenue record alignment of Sarasvati River and its tributaries in about 200 kilometres stretch from Adi Badri, Haryana to Ghaggar, Punjab has been identified. The discovered river course has been validated by a variety of scientific data and investigation carried out by various survey agencies. In another research it has been identified that the glacier feeding the Sarasvati River was located on the Siwalik range of the Himalayas. In another mountain engineering theory, glaciers located on the Siwalik ranges of Himalaya are subject to frequency shifting. The Sarasvati River flowed through the plains of Haryana, passed through the thar - Cholistan desert of Rajasthan and eastern Sindh, running roughly parallel to the involve river and then reached the sea in the Rann of Kutch in Gujarat state (Bhadra et al. 2000) in 2016, Sarasvati Heritage Development Board (SHDB) conducted a trial run by filling the river bed with 100 Cusecs of water which was pumped into a dug-up channel near Yamunanagar. The Sarasvati River project seeks to build channels and dams along the route of the lost river (ZMB, 2016).

Conclusion and Recommendation:

The river Sarasvati can be brought back to life as a perennially flowing river by recharging the river bed though rain water harvesting, supplying water from other drainage sources, having dams at the required distances and creating reservoirs on the river beds and the river course. Rejuvenation of the river is possible at a huge cost and expenses with the marvels of water engineering. In fact, it is true to say that, it is impossible to revive the lost river to flow again. One prominent warning, with the climate changes the glacier fed rivers in future will dry like Sarasvati River. Most of the rivers flowing down the Himalayas are highly susceptible to climate change impacts. River Sarasvati may be brought back to a flowing stream like a river, but the tributaries and distributaries cannot be recharged. Rivulet, man-made and naturally linked with the river Sarasvati will remain dry. The river Sarasvati bed needs to be treated with poly layers to prevent water slippage, side wall construction demand turns into a mandatory feature to keep the water level constant in the total drainage process. The river will look like a flowing channel in its appearance. Such a recovery of the lost river as a revived one will attract greater attention for further research in developing new engineering concepts for other rivers susceptible to climate change and climate threats. A pessimistic view, the mountain glacier fed rivers will dry within a span of over a hundred years. The revival and restoration of the dead rivers need localized plans and engineering. No universal water engineering can be provided for all dried rivens to recover. Hydrology and irrigation engineering as traditional technology has to come out and redesign different strategies and engineering solutions for the drainage system. Satellite images and scanning systems have been proved fruitful in the context of the river Sarasvati. The river Sarasvati revival from a disappeared river to a live river will leave great lessons for mankind.

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