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IRRIGATION TECHNOLOGY IN THE LOWER INDUS VALLEY: A PEEP INTO THE PAST*

The Sukkur Barrage, with its growing progeny of younger barrages on the Indus, is to be viewed as almost the culmination of the technological process which was initiated by the Indus Man in pre-historic times. In the context of this paper, *irrigation technology* may be defined as a man made effort to use Indus waters for purpose of agriculture.

The First Stage of Constructing Tiny Embankments

The process of irrigation is essentially a technological process, be the technology so used a simple or a more complicated one. 'Natural' irrigation in the sense of absolutely automatic irrigation is, indeed, a misnomer. The Indus waters naturally flowing in the Indus itself, could never have brought about any cultivation. It was only when the waters flooded out of it that agriculture became possible. At the early stage of uncontrolled periodic floods of the Indus, the pre-historic man began to learn and employ simple technique of holding the naturally spreading flood waters, in his small fields for sowing the seed. At that stage, he must have used his hands, pieces of wood, stones and straw, to improvise tiny embankments of earth and alluvium. With this repeated periodic practice for thousands of years, the technology of 'simple holding embankment' was born.

The Second Stage of Channellizing Water

The Indus itself was too powerful and frightening for the pre-historic man. Its natural off-shoots and their sub-streams were comparatively smaller in size with which he became gradually familiar. Simultaneously, he had emerged from the 'Stone Age' and entered the 'Bronze Age', and had learnt to make tools which could be employed for digging. Being so

*A Paper read at the Golden Jubilee Seminar and Conference of the Sukkur Barrage, held at Sukkur, Sind, Pakistan, on 30 March 1982.

equipped, he succeeded in diverting and bringing waters from the seasonal streams to his fields by excavating small channels.

It would be reasonable to presume that the Indus man who developed the great civilization with Moenjodaro as its metropolis, had mastered the technology of channellization. There are different theories about Moenjodaro's rise and fall as a great Urban Centre, but the more plausible ones cannot be dissociated from the Indus. Its perennial waters undoubtedly contributed to its prosperity as a centre of high agricultural production, resulting as much from the fertility of the soil of the region as from the network of some well stabilized perennial streams and inundation channels and smaller man-made irrigational canals. However, the frequently changing courses of the Indus and, therefore, also of its main branches and sub-branches, could hardly give birth to the technology of channellization which must have developed under a condition of prolonged stability of the perennial streams and the inundation channels.

To explain this, some digression may not be entirely out of place here. It is to be recognized that all through the ages, agriculture in Sind has been a function of *the changing courses of the Indus* which may be grouped, in terms of their geographical distribution, into three systems: the Western System, the Eastern System and the Middle System. The Western System approximately coincided with the present course of the Indus while the Eastern System was represented by the Hakra-Nara (known as 'Eastern Nara' beginning with the official record of the 19th century). In between these two—and running mainly through the central parts of the present Khairpur, Nawabshah and the Sanghar districts, and then some deflecting westward through the Hyderabad and the Thatta districts and others south-eastward through the Tharparkar district—lay the courses of the Middle System represented by the abandoned beds of Lohano, Goongro, Phito, Puran, Ren and the later Guni and Phulali. All the three systems have had a common upper deltaic apex in the westerly bend of the Indus in the Rohri-Sukkur section though the Eastern System represented by the Ghaghar—Wahinda-Hakra-Nara course often remained independent. The continuity between the northern Ghaghar-Wahinda-Hakra courses in the Bahawalpur Division and the Southern Hakra-Nara course in Sind is well established by the intermediary beds of Reni and Gorhelo in the Ubauro-Mirpur Mathelo tract of the present Rohri Division (district Sukkur).

Development of the metropolis of Moenjodaro and spread of the Indus Civilization would postulate the availability of perennial Indus

waters and the stability of its main course, because the irrigational use of its waters through the technology of channellization would have been possible only if the then western distributory of the Indus had remained stabilized for a long period. Except the course of the Hakra-Nara which is known to have remained stabilized for longest period in history, no other stream has so far been identified as a stable stream over a long period.

It is to be suggested that the other one was the Aral off-shoot of the Indus, which was responsible for sustaining the fertility and prosperity of the Moenjodaro region. With the Aral branching off westward from the upper deltaic apex and the waters of the Indus being distributed equitably into the main middle stream and the two arms at the apex—i.e. between the Kote-Dijian/Nara branches of the eastern system and the Aral of the western system—it kept the courses in the three systems balanced and stable. This equilibrium would appear to have lasted for a considerably long time. For, if the generally held view is to be accepted that Alexander with his army sailed along the main course of the Indus and that he had touched Sehwan, it may be assumed that it was some time earlier than 3rd/4th century B.C. that the main middle stream of the river deflected at its deltaic apex, leaving the mouth of the distributory of Aral silted and dry. With this change, while the lower course of the Aral from Sehwan southward was fed with the inundation waters of the main middle course of the river, the upper course of the Aral between the deltaic apex and Sehwan was abandoned and gradually obliterated, thus ruining the irrigation system of Moenjodaro and causing its decline. From Sehwan southward, the well cut course of the Aral is visible to this day, because of its well stabilized alignment. Writing in 1840, Dr. Kennedy thought that "It is an artificial canal dug in some long forgotten age by some patriot sovereign or some wise generation[1]". It is, however, obvious from its size and alignment that it was never an excavated canal; it was a natural channel of the Indus from times immemorial. The first recorded reference to it is already thirteen centuries old. It is mentioned by its present name of 'Aral' in *Fathnama* (alias *Chachnama*), and the reference indicates that during the first decades of the 8th century A.D., or about 1290 years ago, the annual inundation waters of the Indus flowed into Aral on the northern side of the city of Sehwan[2]. Thus, if Aral has survived for the last thirteen centuries despite the annual floods of the Indus, its antiquity some 2800 prior to 8th century A.D., i.e. during the Moenjodaro era, cannot be doubted. Also Aral's antiquity would seem to be confirmed philologi-

cally by its very name Aral which is not derived from any other language. The name is undoubtedly of an ancient origin[3].

The Third Stage of Lift Technology

The agricultural prosperity of the Moenjodaro region was most probably achieved as a result of the development and extensive use of the channellization technology based on the perennial waters of the well stabilized Aral/Proto-Aral branch of the Indus. If the Aral was flowing on a high ridge like the mother Indus, irrigation by natural gravitational flow in some areas might have been possible but it could not have covered the whole region. It is to be presumed that possibly the Indus man at an advanced stage conceived the idea of lifting water from the somewhat deeper cut inundation channels.

This was the stage when he discovered the technology of the wheel, a solid wheel first which was used by him in his bullock-cart. Necessity was the mother of invention. The ingenuity of the Indus man enabled him to lift water for irrigation by applying the wheel technology. His 'Water Wheel' has not survived, and obviously a wooden wheel could not have survived; even the Solid Wheel has survived as a toy in the baked clay form. If the invention of the solid bullock-cart wheel is conceded on the evidence of the toy wheel, the next step in the invention of Water Wheel cannot be ruled out. Considering the elaborate nomenclature employed for the present types of the irrigation wheel used in Sind, the most ancient word would appear to be its very name *Urlo* or *Hurlo*, the former pronunciation being more popular in the northern Sind, i.e. nearer to the Moenjodaro region, and the latter in the lower Sind. In case its ancient name has survived in the present form of *Urlo/Hurlo*, wherein the suffix 'o' means 'of', *Urlo* could originally mean *'of Aral'*, i.e. the irrigation *water wheel belonging to 'Aral'*, the one which was first developed in the Moenjodaro region as part of the Aral irrigation system. Thus, a sort of 'Indus Water Wheel' could have emerged as the most significant achievement in the lift irrigation technology during the Moenjodaro era.

The basic structure of the age-old *Urlo/Hurlo* may be briefly described here. It consists of two wheels: the *Taj/Chhatr/Chakar*, i.e. the upper 'Spoked Wheel' which is pulled by the bullock and revolves around in a horizontal plane, and the *Bhāndi/Bhāndo/Dhīngo* or the lower 'Lift Wheel' which is set into motion by the spokes of the *Taj/Chhatr/Chakar* but revolves in a different plane (at right angles to the *Taj/Chhatr* plane) and lifts water by means of baked earthen jars roped around it. Obviously, the mechanism is based on the principle of gear, the spokes of the *Chhatr*

operating as gear against the *pharahiyūn* (singl. *pharahi*) or beams of the 'Lift Wheel' (*Bh ndī/Bhāndō/Dhīngō*).

The Fourth Stage of Barraging

Though no chronology, as such, can be specified for the successive stages of development in the Indus irrigation technology, the idea of blocking and barraging a stream in order to raise the level of water for channellizing it out into the fields might have dawned much later in time. The process could have begun with the loose stone/straw/wood blockades of the small man-made channels, but blocking of the bigger inundation channels was yet a Herculian task for the Indus man. Progress in this aspect of technology might have been made during the post-Moenjodaro eras with the discovery and use of iron tools. The first recorded evidence of the barraging technology comes from the Arab-Islamic period of Sind History from the 8th through 10th century when considerable progress was made in irrigation and agriculture. This was because firm orders were issued by the Caliph to promote agriculture. When the military contingents in Sind applied for leave to return to their homes in Syria and Iraq after having served in Sind for about four years, Caliph Sulaiman (715-720 A.D.) denied this request and issued a firm order which said: "Stay on there, cultivate, till the land, and be prosperous".[4]

Progress in agriculture during this period is also attested by the varied terminology, and the continuous use till today of some key Arabic words either in their original or Sindhized form, such as *Hārī Mujerī* (the tiller and the employer), *Kāsah* (a measure of grain equivalent to 16 seers), *Jarīb* (cultivable area of about half of an acre), *phurdo* (*alfurdat* = bridge) etc. etc. It was during this period that expertise was developed to barrage bigger channels. An important reference to this effect is available in the contemporary record. During the reign of the Abbasid Caliph al-Mu'tasim Billāh (833-842 A.D.), 'Imrān b. Mūsā who succeeded to the governorship of Sind on the death of his father (Mūsā) in 221 A.H./836 A.D., got *"constructed a barrage which was called the 'Barrage of the Med."*[5] Obviously this barrage was constructed some time between 836 and 842 A.D., and that it was constructed approximately in the area of the present Rohri-Sukkur section of the Indus, on the "Aror River" (*Nahr al-Rūr*), since 'Imrān had encamped on the bank of this stream. The verb which has been used in the Arabic text for 'building the barrage' is *Sakara*, and the noun used for 'barrage' is *SAKR*. There can be no doubt that the name of the city of 'Sukkur' is reminiscent of the name of that first barrage in history which was built on the 'Aror River' (a natural off-shoot of the Indus).[6] History repeated itself when

modern advanced technology was used to construct the Sukkur Barrage in 1932. That its name should be none else than 'Sukkur Barrage' accords well with the rhythm of history.

Further Progress in Lift Technology

The use of the simple 'Water Wheel', *Urlo* or *Hurlo* which was invented first, was gradually extended all over the country during the post-Moenjodaro eras. By the dawn of history, the Achamenian period of Sind history, this 'Indus Water Wheel' *Urlo* or *Hurlo* was already a marvel of lift irrigation technology in the lower Indus valley. The possible export of this irrigation technology from Sind to Persia during this period or the subsequent Sassanid period (when there was political alliance between Sind and Persia) and its use there beginning from the 6th century B.C., cannot be ruled out. But from the point of its origin, it would be a misnomer to call it "Persian Wheel". Its varying types, structural forms in relation to the different functions, its elaborate indigenous terminology, the pairing between the bullock and the wheel with reference to the load and the pulling period, and the social basis of its operation would indicate that by its origin and history, the irrigation wheel belongs essentially to the Lower Indus Valley of Sind.

An advanced development in its structure took place probably during the Arab-Muslim period when, as already pointed out, special emphasis was placed on promoting agriculture. It came to be realised that in order to bring a larger area under cultivation on a single unit wheel, it was necessary to lift more quantity of water. Accordingly, an advanced type of irrigation wheel was developed. It was based on the principle of securing more revolutions of the 'Lift Wheel' in one single round taken by the pulling animal. To achieve this, a smaller third wheel with spokes (*Chakri*) was added and also the spokes of the upper (*Taj/Chhatr* wheel/ *Chakar*) were redesigned each with an externally bulging curve, and hence called the *qubbās* (domes). With this pairing of the two spoked wheels, the gear force and the frequency were augmented, thus increasing the revolutions of the third 'Lift Wheel' per each pulling round. Due to the additional load, camel or pair of bullocks (instead of one bullock) was used for pulling. This new machine was named as *Nā'ūrah* but became more widely known as *Nār*, a name which has continued to this day. Three significant terms *Nā'ūrah/Nār*, *Taj/Chhatr* and *qubbās* (domed spokes) indicate that the new type of Irrigation Wheel was invented some time during the Arab period (9th/11th century A.D.) of Sind history.

A brief mention may be made here of the varied types of 'Sindhian Wheel', representing a unique development and a complex configuration

by itself, of which no comparable example is to be found in any other part of the world.

In their long history of development, all the varying types were orientated to two basic requirements, (*a*) the capacity to lift more water, and (*b*) the depth from which water was to be lifted. The capacity to lift water was increased by two methods: firstly, by bulging the girth of the 'Lift Wheel' so that more of the baked jars of larger capacity could be roped around it; and secondly, by increasing the number of its revolutions per one round of the pulling animal.

(*a*) *Orientation to the Lift Capacity.*

The following type of the *Urlo/Hurlo* and the *Nar/Aitru* orientated to the quantity of water to be lifted were developed:

1. The *Bārho* or the *Twelve Number Urlo/Hurlo*, probably the original proto-type, with its *Chhatr* (Spoked Wheel) having in all 12 *arā* or spokes, and its *Bhandi/Bhando/Dhingo* also having 12 *pharhiyūn*.

2. The *Chod'ho* or the *Fourteen Number Urlo/Hurlo*, with the addition of two more spokes in the Spoked Wheel and two more *pharhiyūn* in the 'Lift Wheel'.

Also the two types of the *Nār*, later called *Aitru*, both having three wheels to secure more revolutions were developed.

3. The *Ararrho* or the *'Eighteen Number' Nār/Aitu*, with 18 qubbās/spokes/*pharhiyūn* in the three wheels respectively.

4. The *Chovīho* or the *'Twenty-four Number' Nār/Aitu*, representing an increase of 6 more units with a total of 24 qubbās/spokes/*pharhiyūn* in the three wheels respectively.

(*b*) *Orientation to the Depth of Water*

5. The *Bā'irr-badho Urlo/Hurlo*, wherein the *mālha* (the jar carrying stair) is tightly bound to the 'Lift Wheel' because the water level is high enough to submerge the lower portion of the 'Lift Wheel'.

6. The *Chhārhū Urlo/Hurlo*, wherein the jar-stair is somewhat longer in order to reach the water level, a little lower below.

7. The *Trangin* or the *Lāngrrio Urlo/Hurlo*, wherein the jar-stair is much longer to hang below the Lift Wheel in order to reach the water at deeper levels.

8. The *Beharr* (plu. *Beharrūn*), a vertical pair of the *Urlo/Hurlo* units, one above the other, to draw water particularly from the deeper *dhorās* left by the receding waters of the Indus in the inundated *Kachā* tract alongside its main course.

The Social Basis of Operation

The 'Sindhian Wheel', since its very inception, has been a social phenomenon both in terms of avocation and operation. It is worked in mutual partnership between the owner of the land (*mālik*), the entrepreneur (*mujerī*), and the worker (hārī = tiller). It is manufactured and operated as a result of the combined labour of the carpenter, the potter and the cobbler. For about 4 months (June-Sept.) its premises serve as living quarters for guest visitors, a place of entertainment for the village folk, and as a rendezvous for dear friends. The water channel feeding the wheel units situated on it, is to be excavated and cleaned on the basis of voluntary community effort known as *wangār* or *ābat*. Also all the wheel units situated on the same channel share its waters on a community basis, the governing principle being equitable distribution of water based on the age-old 'turn system' known as *'Wārō* and *Sānghārō.'*

In case the quantity of water available in the channel gets reduced, say by about half of the original full level, the *Waro* (the normal group-wise turn) system is to be introduced. The channel is blocked in half way between its upper and lower sections, allowing the wheels situated on the upper section to operate for one full day; the blocking is then removed to enable the wheels situated on the lower section to operate the next day while the upper section wheels remain closed on that day. But, if the quantity of water is just marginal, the *Sānghārō* (the restricted sing-unit turn) system is put into effect, whereby each wheel operates for an hour or two while all others stand by for their own individual turn.

The opening of the Sukkur Barrage in 1932 brought an end to the fascinating era of the picturesque Sindhian Wheel, but it had its own important place in the history of irrigation technology.

NOTES

1. *Narrative of Campaign of Army of the Indus in Sind* by Paign Kennedy (1840), quoted by H. T. Sorely in the *Gazetteer of Sind*, p. 451.
2. *Fat'hnama* (alias *Chachnama*), Persian Text, ed. N. A. Baloch, Institute of Islamic History, Culture and Civilization, Islamic University, Islamabad, 1982, p. 88.

محمد بن قاسم بر دروازۂ ریگستان فرود آمد از اکچه بجهت حرب جائی دیگر نبود و آب بر شکل غلبه کرده بود و از طرف شمال جوئی سند در ارل روان شد . (ص ۸۸)

3. The only other meaning in which the word *aral* has been used in classical Sindhi is in an adjective form meaning "a strong intractable young horse".

4. Tabari, *Tarikh*, Leiden, Vol. II, p. 1275.

5. al-Balādhuri, *Futuh al-Buldan*, ed. De Goeje, Brill, 1886, p. 445.

وَسَكَرَ سَكْرًا يُعْرَفُ بِسَكْرَا الميدو عَسكر عمران عالى نهر الرور .

(ص ٤٤٥)

6. The skill to dyke and dam bigger channels which developed during the 9th century A.D., continued to be used subsequently. References to one such dyke, *Dyke of Aror* (*Arorr-ji-Bandh*), abound in Sindhi lore and literature. According to one tradition, it was constructed some time during the 5th century A.H./12th century A.D. and, as a result, the mouth of an easterly branch of the Indus (which folklore would identify with Hakra-Nara) was blocked up and its waters were diverted into the main course of the Indus. The event, which occurred by about the turn of the 13th century, was a significant one so that it echoed subsequently in folk-lore, and also indirectly in historical writings. The prosperity of the territories of the ruling Soomra Dynasty (1050-1365 A.D.), which then depended upon the waters of the Eastern System (the Hakra-Nara and the Puran branches), was ruined because of this change (artificial or natural) in the configuration of courses at the upper deltaic apex of the Indus in the Aror—Sukkur section. The following verse referring to *Arorr-ji-Bandh* has been preserved for posterity and is widely known all over the country to this day.

hāk wahando Hakrro bhagī bandh Arorr
bih machhi ain lorr, Sammey vīndā sūkhirrī.

The Dyke of Arorr is to break and the Hakra will flow again
Bih, fish and *Lorre* (will again abound in the Soomra lands and)
will go as a gift to the ruling Sammas.