EVOLUTION AND DEVELOPMENT OF IRRIGATION ECO-SYSTEMS AND SOCIAL FORMATIONS IN ANCIENT SRI LANKA

by

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Introduction

The ancient irrigation systems of Sri Lanka are recognised as one of the man-made wonders of the ancient world, comparable to the pyramids of Egypt. Unlike the pyramids, however, these ancient irrigation systems had an utilitarian function.

These systems had a certain ecological stability because they were in harmony with the natural environment; but their economic productivity was low compared to the productivity of modern systems that are dependent on high energy inputs in the form of fertiliser, herbicides, pesticides, and tractive power. The ancient systems could be described as traditional irrigation eco-systems, which is the term used in this paper.

Associated with each type of irrigation eco-system there is a particular type of infrastructure, such as for example, river diversion, or storage in small, medium or large reservoirs. Each type of infrastructure may also correspond to a particular mode of production, and to a particular social formation. A 7 stage theory for the evolution and development of the infrastructure of the ancient irrigation systems has been presented earlier. (Mendis, 1984, 1985). The evolution and development of different social formations, and modes of production corresponding to these stages is discussed in the present paper.

Ancient Irrigation Systems

The ancient irrigation systems in Sri Lanka consist of river diversion schemes, and small, medium and large storage reservoirs. It has been shown that by far the large majority of the medium and large reservoirs and the large diversion channels, together formed interconnected irrigation systems spread over the dry zone of the island. (Brohier, 1937) These diversion-cum-storage schemes were trans-basin systems, conceived and executed on a scale comparable with any scheme in any part of the modern world. They were constructed over a long period of time, according to the historical record, from about the fifth century B.C. to at least the eleventh century A.D., after which there was a period of decline well before the arrival of the European colonizers.

The historical record is derived from such sources as the following, used in the University History of Ceylon: literary sources, foreign sources, epigraphic sources, numismatic sources, and archaeological sources. The earliest inscriptions or epigraphic sources belong to the third century B.C. The distribution of these inscriptions indicates that practically the whole island had been occupied by about the third or second century B.C. by a literate people. Of the literary sources, the earliest is 'the Dipavamsa which, compiled by unknown authors, was completed about the middle of the fourth century A.D.' (URC, 1959, 48) This work had recorded the oral tradition of the people that had come down from generation to generation down the ages. Of the authenticity of this work it has been said: "It could scarcely be called a work of art, but its historical value is great" (Ibid )

There are other chronicles that had been compiled at various times which are known to scholars, of which the best known is the Mahavamsa. The University History says: "It was not composed all at once for it exists in four recognizable sections. The first part which consists of the first thirty-seven chapters is commonly known as the Mahavamsa. The rest of the chronicles is usually referred to as the Chulavamsa". (URC, 1959, 49) The author of the first part known as the Mahavamsa, has been identi-

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fied as Mahavamsa, a monk who lived at the turn of the fifth century A.D. The author of the second part, the Chulavamsa, has been identified by Geiger as another monk named Dharanakiththi who lived in the twelfth century A.D. (Geiger, 1953.) The Mahavamsa and the Chulavamsa were compiled by monks, as they say at the end of each chapter "for the serene joy and emotion of the pious". The information about the ancient irrigation systems given in these chronicles is not of a technical nature, as may be expected on account of the religious identity of the authors, and not, for example, because technical readers are not to be identified with the "pious"). Moreover, the translations from the original Pali language in which these works were written, were done by oriental scholars like Wilhelm Geiger, who were themselves non-technical men. Nevertheless, these scholars have shown a remarkable appreciation of many technical features of the ancient irrigation works and this makes the task of the modern engineer who reads translations in search of original material concerning the ancient irrigation systems, easier than it may otherwise have been.

In regard to the inscriptions, the University History says that they "provide valuable confirmation of the record of the chronicles and sometimes even shed new light on them and correct the chronicles on some minor points as well. Besides, on some aspects of history, they fill gaps left by the chroniclers who were mainly interested in religion and in the main political changes .... They have the further advantage that they are contemporary records," (UHC, 1959, 66)

In British times, the ancient irrigation systems had been studied by many engineers and administrators on the field, of whom the engineer Harry Parker is perhaps the best known. According to Parker, and other authorities who came after him, the earliest reservoir, that can be identified with certainty today, is the present-day Basavakulema. This is the Abhaya wela of King Pandukabhaya built about 300 B.C.

Neither Parker nor any later scholars have investigated the antiquity of the large ancient channels in Sri Lanka. This is perhaps understandable because the storage reservoirs built in ancient times in Sri Lanka are an unique achievement not repeated in any other part of the ancient world, whereas diversion channels had been built in many other ancient civilizations. Nevertheless this lacuna has persisted to the present day, with the emphasis placed on storage reservoirs even in understanding and interpreting the evolution and development of the ancient irrigation systems, with some unfortunate results.

This emphasis on the storage reservoirs, especially the large reservoirs, is due in part to the recognition of the fact that these reservoirs could not have been built and used for irrigation in ancient Sri Lanka, without the horowwa (sluice) with its bisokotuwa (access tower), which about which Parker wrote:

"Since about the middle of the last century, open walls, called 'valve-towers' when they stand clear of the embankment and 'valve-pits' when they are in it, have been built at numerous reservoirs in Europe. Their duty is to hold the valves, and the lifting-gear for working them, by means of which the outward flow of the water is regulated or totally stopped. Such also was the function of the bisokotuwa of the Singhalese engineers: they were the first inventors of the valve-pit, more than 2100 years ago". (Parker, 1909, 379).

In contrast to this unequivocal tribute by a Colonial engineer who had had the rare privilege of working in this island for more than thirty years, and who had obviously made the most of the opportunities afforded him to study the ancient hydraulic civilization of Sri Lanka, there are others who have published their views based on generalisations made without any reference to the ancient irrigation systems of Sri Lanka. Typical is the following quotation from a publication titled "A History of Dams:

"Dams to create reservoirs were very rare and never large. The idea of storing water during the wet season for use during the dry was not a concept with which the ancients were familiar. Probably the need did not arise. So long as the required amount of irrigation could be obtained from diversion dams across rivers and wadis, people were not likely to experiment with other and more elaborate procedures. In other words, in antiquity, dam-building was widely practiced but only in a limited way. It was not until the Roman came on the scene that the size of dams was increased and complex uses were found". (Smith, 22).

More recently, Goldsmith has stated: (referring to the ancient reservoirs in Sri Lanka):

"Today, the majority of the tanks which so impressed Tennent have either totally or partially silted up. Nonetheless, numerous smaller tanks still survive (although many of these, too, are now partially silted up) and continue to provide the basis for irrigation agriculture in the dry zone of the island". (Goldsmith, 302)
One of those authors has apparently not even heard of the ancient irrigation works of Sri Lanka. The other has visited this country many times, but has collected some wrong information.

It is easy to say that Sri Lankan engineers must bear the responsibility for this type of mis-information that has spread around the world, because they have not found the time to put down in writing the facts that they surely know about our ancient irrigation systems, so that others have been able to pontificate on what they manifestly do not know, and thereby mislead so many others. However, in defence of the Sri Lankan engineers it should be stated that they themselves have been subject to various pressures, some subtle, some not so subtle, that may be collectively described as 'neo-colonial' methods of destroying our sovereignty. The Conclusion to this paper has been written especially on account of these subtle forces that are today all too prevalent in engineering in this country, with the hope that the powers-that-be will waken to the realisation that what has been described as one of the wonders of the ancient world, the ancient irrigation systems of Sri Lanka, is being taken away from us, in more subtle ways than were used to physically transfer the Parthenon marbles or the treasures of Tutankhamen to foreign museums.

Evolution and Development of Irrigation Systems in 7 Stages in Ancient Sri Lanka

The seven stage theory for the evolution and development of irrigation systems in ancient Sri Lanka is shown in Figure 1. This theory is different to that presented by Brohier in his Presidential Address in 1956 to this Institution, which was re-published by Needham (1971) as given in Figure 2. Brohier's sequence assumes that storage tanks or reservoirs were built earlier than diversion channels.

In the 7 stage sequence, it is argued that "water management in the dimension of space represented by diversion is an earlier stage than water management in the dimension of time represented by storage" (Mendis, 1985). The historical record in various parts of the world shows that river diversion irrigation systems date back to earliest antiquity. Moreover, storage and controlled issue of water for irrigation could not have been accomplished until the invention of the sluice. This event took place in ancient Sri Lanka about 2200 years ago, according to Parker as quoted above. Irrigated agriculture started several thousands of years earlier. Hence the 7 stage theory is based on a rational sequence of events that occurred in the history of agriculture, beginning with the rain-fed systems of the neolithic revolution and culminating with damming of perennial rivers.

Irrigation and Social Formations

Rain-fed agriculture

Purists may remark that the first stage in the 7 stage sequence, rain-fed agriculture, is strictly not an irrigation system. Nevertheless rain-fed agriculture was the first and earliest method of crop production which heralded the first revolution in human history, the Neolithic revolution, when man the hunter-gatherer first discovered the possibility of settled agriculture, and the domestication of animals.

Rain-fed agriculture is essentially a subsistence agriculture. In ancient Sri Lanka it took the form of shifting cultivation, called swidden agriculture. It still exists as 'chena cultivation' in the dry zone of Sri Lanka.

Rain-fed agriculture was first discovered in the late stone age. At that stage, man the hunter-gatherer, was wandering around in groups using stone tools and implements, and stone and bone weapons. With the beginnings of agriculture, the wandering groups could also begin to settle, no doubt where the natural eco-system provided the best environment. This was the beginning of the earliest settlements. It is conceivable that most of these earliest settlements were located near natural sources of water, such as lakes, or streams and rivers; but it is still a far cry from this stage to the use of these sources for irrigated agriculture.

In these earliest settlements mother right or matrilineal succession would have been recognised. As Engels (1977) said: "In all forms of the group family it is uncertain who the father of a child is, but it is certain who the mother is...... It is thus clear that, wherever group marriage exists, descent is traceable only on the maternal side; and thus the female line alone is recognised." (Engels, 42).

While rain-fed agriculture, alone was being practiced in the earliest settlements, the mode of production was what is described as primitive communal. There was collective ownership and control

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of the means of production, and presumably there was equal access to land for all. There is also evidence that there was equal distribution of the product of labour among the members of the primitive community. The social formation in this stage of development has therefore been described as the 'Original Affluent Society'.

Temporary or seasonal river diversion

The next stage in the sequence is the well-known stage of temporary or seasonal river diversion; the best known examples of which from other countries are the diversions in the river valleys of the Tigris-Euphrates, the Indus, the Nile, and the rivers in China. There is no reason to believe that a corresponding stage had not occurred in Sri Lanka in the pre-historic period. The University History indicates that much work has yet to be done by research-workers to uncover the yet unknown features of life during this very early period. (UMC, 74-81).

However, it is possible to draw some broad inferences of the social formations in this period when seasonal or temporary river diversion irrigation first began to be practised. The term 'oya' describes the non-perennial streams and rivers of the dry zone of Sri Lanka. During the southwest monsoon season these oyas run dry, but they tend to carry large volumes of water during the northeast monsoon season, when they regularly over-top their banks and flood the surrounding low-lying areas. This corresponds on a smaller scale, to the seasonal flooding of the great rivers mentioned above, the Nile, the Tigris-Euphrates, the Indus and the rivers of China. This seasonal or temporary river diversion in the dry zone of Sri Lanka would have been used in the microlithic age which followed the neolithic and this could well have taken place in three stages as follows:

1) flood or inundation irrigation on the banks,
2) development of contour channels on the banks to train the water for flood irrigation, and
3) development of diversion channel systems on the river banks, using basin, border and furrow irrigation.

At this stage, if it had not been discovered under rain-fed agriculture earlier, the use of draught power for land preparation would definitely have been discovered. This would have greatly improved the earlier method of land preparation using labour power alone, and would have represented the first supplementary energy input into agriculture.

The human settlements that began under rain-fed agriculture would have been consolidated with the development of river diversion, even seasonal or temporary. With this would have come the possibility of pairing off rather than group living, and with pairing the beginning of the family unit would have been seen. From this stage, the earlier primitive communal mode of production would have become transformed into stages into other modes. Stages in such a transformation would include the beginning of division of labour among men which could lead to class stratification, and the emergence of the concept of private ownership of the means of production, probably cattle in the first instance, and later, access to land.

Permanent river diversion

Temporary river diversion would have been practiced, just as rain-fed agriculture was certainly practiced, for thousands of years, from earliest antiquity. In terms of technological advancement, such diversion would have resulted in the development of channel systems on the riverbanks as mentioned above. The next technological jump would have been the establishment of permanent river diversion structures, and this would have required the introduction of some form of building blocks, and a method of holding them together. The possibility lies with stone block masonry rather than with brick masonry for obvious reasons of strength.

However, although there is ample evidence of the use of brick masonry in urban centres that grew in the river basin civilizations several thousands of years ago, there does not seem to be any real evidence of the development of stone masonry in South Asia. Rather, the generally accepted view is that dressed stone masonry is a technology transferred to India from ancient Persia around the fifth or fourth century B.C.

On the other hand, Parker was of the view that the horowwa (juice) was invented about the fourth century B.C. (Parker, 179); and these ancient horowwas were made with dressed stone slabs to form the culvert and part of the bisokotuwa or access-tower as well. It may be that Parker's estimate of the time of the invention of the horowwa is out by a century or two. This has to be verified by modern archaeologists using such recent techniques as carbon dating and thermo-luminescence that are now available.

It is also possible that permanent river diversion structures were first constructed in Sri Lanka in
brick masonry, and that these were later replaced by stone masonry. If so, traces of the ancient brick masonry may still be found in some of the stone masonry river diversion structures like the famous Tekken across the Aruvi-aru or Malaitu oya. It should also be noted that in regard to engineering aspects, the temporary or seasonal diversion structures were most often built on poor foundations, while the permanent structures were always built on good natural rock foundations.

Very soon after the first permanent diversion structures have been constructed in brick or stone masonry, the same technology would have been used to build weirs and spillways along the contour channels. Weirs would have been used to release irrigation water to the tracts of fields along the channel, the only method available before the invention of the sluice. Spillways at regular intervals along the channel would have been necessary because the runoff from one side of the contour channel was intercepted by the channel, and this could overload the channel and cause the bund to breach, during the monsoon season, unless adequate spillway was provided.

In passing it may be mentioned that there are some very large ancient river diversion channels still in a very good state of preservation, which have not been satisfactorily identified by historians, of which the two large channels on either bank of the main Mahaweli gange, taking off from the place known as Kalinga nuwara, is the best example. These may well be examples of permanent river diversion systems in the evolution and development of irrigation systems in ancient Sri Lanka, in the proto-historic or even pre-historic period.

Other major channels such as many of those described by Brohier (1937), and Nicholes (1959, 1960) also belong to this stage in the classification of irrigation systems, although they may have been constructed at a later date than the pre-historic and proto-historic periods when permanent river diversion structures are believed to have been first constructed. It is important to appreciate the fact that a later stage in the evolution and development of irrigation systems did not totally replace an earlier stage that preceded it. Each succeeding stage augmented the preceding stages. Hence, as time went by there were more types of irrigation systems being built and in use in different locations. After the invention of the horowwa, all types co-existed together. For example, chena or more correctly pan cultivation, the earliest stage in the sequence, has persisted down to the present day.

The social formations associated with permanent river diversion systems may best be described as a consolidation of the social formations developed under temporary river diversion systems. Village type settlements were strengthened, and fort type settlements that would later develop into towns and cities, began at this stage. The family became the normal social unit, and the beginnings of the State would have been seen when groups of families formed permanent settlements, that also began trade with each other.

At this stage, there was a rapid development of technology on account of the use of metals; but whereas in other parts of the world, the first metallic age was the bronze age, followed by the iron age, there is no evidence of a bronze age in Sri Lanka. The iron age seems to have followed the late stone age, or microlithic age. However, much work has to be done to collect and interpret the data relating to this period.

Also at this stage, pottery and the art of spinning and weaving had been well established. There is therefore the possibility of the division of labour along such functional lines during this period, and the consequent beginnings of class formations. With the consolidation of classes, albeit on the basis of a functional division of labour, some groups would have been able to take control of the means of production, and thereby appropriate the surplus produced by the other working groups. This again would have been a part of the process of state formation.

The group or class that took control of the permanent river diversion irrigation systems at this stage would have had effective control over the means of production, and hence of the State. The next vital stage in the evolution and development of irrigation systems, the invention of the horowwa with the bijokotuma, must have been due to one or more of these people, as described below.

A tremendous amount of research work has to be done to establish or demolish this type of theory based as it is on assumptions and interpretations. Engineers, as much as other scientists, must take a scientific interest in the subject, rather than be copied away by sentiment or unscientific hypothesis. In this context, the ancient sluice at Nadur Oya, and the ancient iron ore deposit at Seruwila have yet to be investigated and reported upon by engineers or scientists.
Invention of the horowwa (sluice) with bisokutawa (access tower)

The next important landmark in the evolution and development of irrigation systems in ancient Sri Lanka after the consolidation of permanent river diversion systems, is identified as the invention of the horowwa with its bisokutawa, which as already stated, was believed by Parker to have taken place in the fourth century B.C. A hypothesis for the manner in which this invention had taken place is as follows. (Mandis, 1985, 5).

"Flow of water along a long contour channel would cause incidental storage or ponding to occur at intersections with cross-drainage streams along its course. These small pondings in the dynamic channel systems rather than storage in ponds, would have been the germ of the next truly remarkable achievement, the management of water in the time dimension, or the invention of the storage reservoir for the control and issue of irrigation water over a full cropping season. However, this invention though undoubtedly born of necessity, was itself effectively dependent on the invention of the horowwa with its bisokutawa which is universally recognised as the key to the ancient irrigation systems of Sri Lanka.

Conveyance of water in contour channels, and discharge over weirs and spillways for a very long period of time, would have provided necessary and sufficient experience in hydrodynamics for the invention of the horowwa which led to the construction of storage reservoirs.

In Sri Lanka even today the truth of this assertion may be verified, in a manner of speaking, by observing the discharge over some of the ancient weirs along an ancient channel such as the Brahara channel. Figure 3 (adapted from Brohier 1945) showing the 'Ancient System of Irrigation and Distribution of Water' illustrates this point.

It is argued that observation of the discharge of water over a weir would sooner or later have given someone (perhaps one of the Kulaaes) the idea of enclosing the weir, in effect creating a culvert. The tendency of water to accumulate at drainage crossings that was mentioned previously, combined with this culvert, combined of course with the basic necessity to store water when it was available in excess for use when it was scarce, would have given the germ of the first storage reservoir with a controllable arrangement for issue of irrigation water.

Control was truly achieved when the culvert was joined with an access tower, the bisokutawa, which has been correctly described as 'the precursor of the modern valve-pit'. (Parker, 1900, 379)

After the invention of the horowwa, storage reservoirs were constructed. In general the same technology was necessary to build small, medium or large reservoirs in ancient Sri Lanka. Small village tanks formed one type of settlement and social formation, and medium and large reservoirs, other quite different types. These will now be discussed.

Small village tanks

There are about 18,000 small village tanks as they are now called, shown on the 1 mile to an inch topographical survey of the island. Of these, about 7000 are in working condition, while the remainder are described as abandoned. However, it has been estimated that up to 30,000 of these small tanks may have been constructed in ancient times, and the rest are still lying undiscovered. (FFHC Bulletin No. 1, 2).

Some of the most intensive development of these small tanks around which were established small village settlements, were in the ancient Rohana rata, in the south and southeast of the island. For example, some references in the Chulavamsa have been given by Geiger:

"In the first half of the twelfth century after the tripartition of the Kingdom Rohana was divided between the two brothers Kittisirinagha and Siri-wellaha. The former took possession of the south-western part of the province, called Dvasesahassaka-ratha, the latter of its north-eastern part, Athasa-sahassakhada. ....... We are inclined to infer from the names Dvasesahassaka-ratha and Athasa-sahassaka-desa which can be translated only as 'province of the twelve thousand [eight thousand] fields or settlements' that Rohana was intensively cultivated and of extraordinary prosperity in the 12th century, and that this cultivation was largely destroyed by Parakramabahu who restored many tanks and temples in this country after the war." (Geiger, 1960, 11, 12)

Here then is reference to the existence of a total of 20,000 tank village settlements in the southern Rohana rata alone, at the time of Parakramabahu (1153-86).

In more recent times, Leach (1959) has described these settlements based on small tanks as nuclear villages. He distinguished them from the centrally controlled large irrigation systems consisting of
inter-connected large reservoirs and channels which have been mapped and described by Brohier (1937), and identified by Nicholas (1960 etc.) and others.

The social formation associated with the small village tank settlement was essentially similar to that still existing in some of the most remote dry zone jungle villages today. Originally these isolated settlements there was a division of labour according to skills, so that each village, or perhaps in some cases, a small group of villages, had its own potters, blacksmiths, weavers, etc., who were manufacturers engaged in petty commodity production for the local market. This type of manufacture is characterised by small scale, high labour intensity, and the absence of elaborate market relations. The majority of the villagers were of course peasant farmers or cultivators, but in general everybody had some access to land and water for irrigated agriculture, even if it was only the first stage as described here, namely rain-fed agriculture, or home cultivation.

The small tank then was not a stage in the construction of reservoirs as alleged by Brohier and others, but the infra-structure of a definite type of human settlement that came into being after the invention of the horowa or salwawa. It should be described as a traditional irrigation eco-system.

Medium and large-scale reservoirs

It is found that what could be described as medium scale reservoirs had been constructed near large towns and cities in ancient times. Some examples are the Basavakulam and the Tissawawa near ancient Anuradhapura, and the Yodakandiya weva, the Tissa weva, and Yoda weva, near ancient Magama, capital of Rohana, (modern Tissa mahawela). (Manolis, 1985). Though these reservoirs would have been used for irrigation in ancient times as they are being used today, it seems that they were also meant to provide water for other domestic uses for the urban populations of these capital cities.

According to tradition which has also been enshrined in the written word in the ancient chronicles, a group of settlers led by a Principe Vijaya had arrived in the year 543 B.C. from northern India, landing at Mantota (modern Mannar) and moving up river along the ancient Kadambli Nadi (modern Aruvil aru or Malwatu oya) until they reached the site of the future capital Anuradhapura. This capital, then called Anuradhabaga had actually been set up much later, in about the fourth century B.C. and both, the Basavakulam and the Tissawawa have been found to date from about that period (Parker, 1909, 360, 364). The characteristic of the medium scale reservoirs therefore seems to be that, in spite of their larger scale than the isolated village tanks, they too were isolated and individual storage systems because they were meant to service urban centres. They therefore represent another type of traditional irrigation eco-system.

The urban centres had developed over the ages, on the banks of rivers, for example Anuradhabaga on the banks of the Malwatu oya, or Panduwswamreru on the banks of the Kularum oya. In the Indus valley, the great ancient cities, Harappa and Mohenjodaro are believed to have been established as far back as about 4000 B.C. In Sri Lanka there is no evidence about the setting up of urban centres in the pre-historic period. These urban centres would have been built from the surplus generated by the diversion irrigation systems originally, and the medium scale reservoirs that are located near them would have been built later, after the invention of the horowa, to supply the town or city with water, and also to provide water for some irrigation. That is why these medium scale reservoirs are isolated, although in the case of the Anuradhabapa city tanks, they were also later interconnected through the Kalawawa yoda ola.

The large-scale reservoirs, on the other hand, were never constructed as isolated or segregated systems in ancient times. Rather they were always interconnected to form part of a single system. The master plan for the design and construction of these storage reservoirs in ancient times has been described as follows.

*Each large reservoir when constructed; fitted into a system of inter-connected reservoirs and channels. These systems were built over very long periods running into centuries. In the course of time different systems were also inter-connected, so that what began as a separate system later became part of a more complex system, or just a sub-system. Each large reservoir when first constructed was located either:

1. at the head of an existing diversion channel system or sub-system, thereby submerging the diversion headworks that had existed earlier (sometimes for centuries), or

2. at the tail-end of a diversion channel system or sub-system; and in this case the channel was often a trans-basin diversion channel.

However, as a system grew by new inter-connections, the relative position of a large reservoir could change, so that it now appeared to be in the middle of a larger system of interconnected reservoirs and channels. This gives a clue to understand ho
the ancient systems were built over very long periods of time; and also for their identification today". (Mendis, 1984, 1985)

Extracts from 'A Concise History of Ceylon' by C.W. Nicholas and S. Panamaitana, (1951) showing the Ancient Irrigation System of Raja-rata, and the Inter-relation of Irrigation Works, are given in Figures 4 and 5 respectively. These two figures give a picture of the complexity of the ancient system of inter-connected large reservoirs and channels.

According to the 7 stage theory presented in this paper, very often a large reservoir was built only after the channel that connected it to the rest of the system had been constructed. No large reservoir was ever constructed in isolation from the rest of the system. This is in contrast to the construction of the Udawalawe reservoir in recent times, which seems to have been the result of confused thinking arising from the mistaken idea that large reservoirs should replace small village tanks, following Brohier's 4 stage theory concerning the development of irrigation systems. It is worth repeating again, what has been said before, that the so-called 'water management problems' at Udawalawe cannot be resolved until and unless the fundamental errors in the very conception of the scheme are first understood. (See Figure 6)

The social formations associated with the large storage reservoirs in ancient times may now be discussed. These large reservoirs were built in historic times, although some of the channels must have been constructed earlier, in the pre-historic or proto-historic periods. By the time large reservoirs were being built, the State had come into existence. Division of labour was established, and people were identified in terms of their vocations or occupations. For example, the Kulinna were the people who were responsible for the maintenance and operation of the large-scale irrigation systems.

After the introduction of Buddhism in the third century B.C, there is evidence of ownership of land and property by monasteries. Private ownership, at least in a restricted sense of having access to its use, had also become possible in regard to some irrigation systems. Apart from King and nobility, and the priesthood, there was also an administrative hierarchy, to manage and help consume the surplus produced by the working people. Wittfogel (1957) surmised that a hydraulic-society would only have existed on account of a centralised state run by a powerful bureaucracy, but Leach (1959) refuted that view.

**Chronology**

The evolution and development of irrigation systems in ancient Sri Lanka as presented in this paper, is a sequence of events beginning with rain-fed agriculture dating from the neolithic revolution in pre-history, passing through two stages of river diversion in the proto-historic period, and reaching a significant landmark with the invention of the horowve with its bisokotuwa in the earliest historic period, which made the construction of storage reservoirs with control arrangements for issue of irrigation water possible for the first time in any part of the world.

The question that remains to be discussed is the dates of these events.

Wanke (1980) quotes Steward (1949) to the effect that the neolithic revolution started independently in Mesopotamia circa 8000 B.C., in Egypt, c. 7000 B.C, in India c. 6700 B.C, and in China c. 5000 B.C.

There is evidence of the existence of Homo sapiens in Sri Lanka as far back as 35,000 B.C. It is safe to assume that the hunter-gatherer in pre-historic Sri Lanka discovered settled agriculture somewhere around 7000 B.C. to 6000 B.C. It is not possible, however, to distinguish the beginning of temporary or seasonal river diversion agriculture, from rain-fed agriculture.

Various hypotheses have been presented to account for the origin of domestication and agriculture in South-west Asia, many of them based on the twin assumptions of population increase and climatic change, but there is no finality about these theories. Less data is available about South-east Asia (including Sri Lanka) to put forward similar hypotheses, but it has been observed that "it is at least obvious that South-east Asia was an important core area for early domestication and agriculture". (Wanke, 1980, 302)

In these circumstances, and without the benefit of firm archaeological evidence, it may be suggested that seasonal river diversion for irrigated agriculture began in Sri Lanka in the pre-historic period, somewhere around 6000 B.C. This form of temporary irrigation system would have been practiced together with rain-fed agriculture, for more than 5000 years throughout the long pre-historic and proto-historic periods. If the tradition of the Yakkas and Nagas is to be accepted, they were the indigenous people who practiced these early forms of agriculture. (Fernando, 1982)

The next chronological landmark is the traditional
arrival of Vijaya in 543 B.C. He is said to have found the indigenous Kuveni, spinning beside a pond or lake. As stated above, this does not mean that there were storage reservoirs or tanks in that early age for irrigated agriculture. Man-made or natural ponds and lakes would well have formed part of the natural environment, but without the sluice or horowwa, their use for irrigated agriculture would have been severely limited. The existence of river diversion irrigation systems alone would have ensured the survival of Kuveni’s people.

The question which arises next is whether permanent river diversion structures existed in Sri Lanka before the arrival of Vijaya, or whether he brought the technology for these structures with him or whether it was developed locally after his arrival?

There are traditional stories or folklore about the construction of monumental structures in ancient, pre-historic times, by the Yakhas and the Nagas. An example is the tradition that the Sconbora wave, with its sluice built in stone-masonry, and set in a cell of a cut rock, was built in pre-historic times. If there is any truth in these traditions it means that iron-age tools and implements were used in ancient Sri Lanka before the advent of Vijaya, in 543 B.C. It also means that the other popular tradition that the art of stone masonry construction was a technology transferred from Persia to India, and then to Sri Lanka in historic times, or at least in the proto-historic period, has to be revised.

Nevertheless, it is quite within the bounds of possibility that permanent river diversion structures had been constructed in brick masonry, in the pre-historic period, thereby consolidating the developments achieved through seasonal or temporary river diversion irrigation systems over very long periods of time previously.

This means also that social formations in the pre-Vijayan period would have been capable of managing the common infrastructure of irrigation systems, and using the agricultural surplus obtained from it for the common good. Indeed the crucial step of organising the resources necessary to build the permanent diversion structures would not have been possible without such a social formation. This in turn would have been dependent on a division of labour into occupational and social classes, rather than on the earlier organisation of society based on kinship.

As Wence (1980, 413) has observed: "One of the major trends in the evolution of complex societies generally was the change from a kinship-based society to one based on divisions along occupational, social, and economic class lines."

As stated previously, if the permanent river diversion structures had been constructed first in brick masonry, and later rebuilt in stone-masonry, it should be possible to find some of the ancient bricks and to establish their age by modern methods for dating.

On the other hand, if the modern evidence shows that the permanent river diversion structures had been built in stone-masonry from the beginning, there may be support for the view that there was a transfer of technology with the coming of Vijaya, which resulted in the establishment of permanent structures in stone-masonry, thereby effecting an improvement in the irrigation systems available up to that time in Sri Lanka. Even so, the organisation of society such as it was before the coming of Vijaya, has to be studied with evidence provided by archaeologists and historians. Organised agriculture through temporary or seasonal river diversion could have produced a surplus that could have been used to support a non-agricultural part of the community of Yakhas and Nagas, although this may not have led to an advanced form of the State, before the arrival of Vijaya.

The oral traditions that were written down by the scribes of the Divavamsa and the Mahavamsa several hundreds of years later, unfortunately did not include information about social formations before the arrival of Vijaya.

The date of the invention of the horowwa with the Bisokotwa has been discussed already. Parker was of the view that it dates from about the fourth century B.C. Other theories advance the date to about the 2nd century B.C. or even later.

Once the difference in function of the small, medium and large reservoirs has been understood, the exact date for the invention of the horowwa is not of too great importance, and a date range of a few centuries is not too great for the time being. What is more important is an understanding of the necessity, and the circumstances which led to this unique invention by the ancients, in the pre-Christian era.

When Smith (1971) asserted that "the idea of storing water during the wet season for use during
the dry was not a concept with which the ancients were familiar", he only demonstrated that he was not familiar with conditions in some parts of the world, arising from which some of the ancients were able to invent the horowwa and thereby effectively store water "during the wet season for use during the dry", in Sri Lanka.

There is a similar lack of familiarity with social conditions in our part of the world today, as a result of which some foreign engineers sometimes come to wrong conclusions when faced with a problem that has to be understood in terms of both its technical or technological aspects, as well as the social or societal context in which it exists.

However, foreign social scientists have made useful contributions to an understanding of the way society was organised in time past through their careful study of the way some social organisations function in rural areas even today. For example Leach (1957) in his study of the dry zone village Pili-alleya, documented many of the traditional agricultural and irrigation practices followed by villagers in the dry zone. From this and other studies it has been possible to understand why so many as 30,000 small storage tanks had been built in the dry zone of Sri Lanka in ancient and medieval times, and the type of social formation that was associated with these so-called 'nuclear villages'.

Flannery (1972) has suggested that cultural complexity can be analysed in terms of systems theory, using for example the concepts of centralization and segregation. In these terms, the nuclear villages of the dry zone are political, economic and social sub-systems within a larger system, a classic example of segregation. They came into being and exist to this day, around the small village tank.

The interconnected large reservoirs and channels on the other hand represent centralization of state power as understood by Wittfogel (1957) and others. Leach (1959) correctly described this organisation of 'hydraulic society' in ancient Sri Lanka in his classic response to Wittfogel's incorrect generalisations about the nature of all ancient irrigation-based societies.

Nicholas (1960) and others have identified and dated many of the large reservoirs and channels that together form so many interconnected systems and sub-systems. According to the information so compiled, virtually all these large channels and reservoirs belong to the historic period, beginning about the fourth century B.C.

However, according to the theory of the evolution and development of irrigation systems presented here, some of these channels must date from an earlier period, going back to the pre-historic or proto-historic era. The large storage reservoirs however, date from the historic period, after the invention of the horowwa in the fourth century B.C. or later. Confirmation or disproving of this hypothesis will no doubt be available in the future, when modern dating techniques are applied to these ancient structures.

Conclusion

Today, vast sums of money are being spent on large-scale irrigation projects in many parts of the third world. Irrigation engineers and other technocrats in these third world countries are finding themselves bypassed by their counterparts from the rich countries who often ride rough-shod over our sensibilities when it comes to getting a toehold for themselves on an irrigation project in our own countries. The most recent example of this has been the Kanteleai tank breach.

The Kanteleai tank built by king Aggabodhi II (604-614, A.C.) had been 'restored' by the British in 1873. The man-made earth embankment had appeared to the British engineers, (as it had seemed to the Dutch before them) to be a natural hill formation, despite the fact that the face of this embankment was packed with "cola pane", neatly placed stone boulders, some of them partly rounded by centuries of wave-action, which were obviously not 'natural'. It should be remembered though that the Colonial engineers, could not have easily adjusted their minds to accept this fact, that they were seeing the remains of one of the wonders of the ancient world, an account of their self-proclaimed role as a chosen race on a 'civilising mission'. (Coomaswamy, 1971)

Be that as it may, the Kanteleai tank bund that had stood in such magnificent splendour for at least 13 centuries, breached on the night of April 19, 1985. The news of the disaster that resulted in the loss of many lives, was flashed around the world by the news media, always ready to make the most of any disaster or tragedy in the third world. No mention was made of the fact that this was an ancient reservoir built in the early seventh century. Instead, it was announced that the breach
was due to natural causes.

Shortly afterwards, the Institution of Engineers offered its services to the government to assist in whatever way possible. These services have not been called upon. Instead with much publicity, a foreign firm of consultants has been invited to advise the government. Their report has been submitted, and the news has been published that the breach resulted from failure of the ancient sluice due to natural causes.

This episode seems to highlight in a rather dramatic (and unusual) manner, a concept that has recently been spelled out, of 'irrigation as a social force'. Eggink and Ubels (1984, 149) have expressed it thus:

"In Wageningen the approach of irrigation as a social force started to develop in the mid-seventies as a result of discussions among students about the social political and economic aspects of irrigation-development in relation to the task and position of irrigation engineers. This debate emerged as a reaction to the strictly technocratic approach to irrigation in the courses at the department of Irrigation and Civil Engineering at the Agricultural University. Since 1975 a growing number of students have tackled the problem of how the social effects of irrigation-development in third world countries should be analysed..."

Although Eggink and Ubels were concerned with the importance of proper adjustment of an irrigation project (and especially the management-organisation) to the local social structure, they could well extend the scope of their research on irrigation as a social force in the modern context to such activities as so-called 'technical assistance' and 'foreign aid' in the area of irrigation development.

References

EVILOTV AND DEVELOPMENT OF IRRIGATION SYSTEMS IN ANCIENT SRI LANKA

Synopsis

1. Rain-fed Agriculture (Man-made and natural ponds and lakes)
2. River diversion from a flowing river (ganga, oya, ara, etc)
   Temporary or seasonal diversion structures made of sticks and stones etc. on poor foundations
   Diversion channels for flood irrigation on river banks
3. Development of permanent diversion structures
   Development of dressed-stone masonry, including wedge-shaped blocks, use of lime mortar etc. on good foundations
   Development of contour channels
4. Construction and operation of spillways and weirs
   along contour channels, using dressed stone masonry, natural rock outcrops, etc.
5. Invention of the horowwa (sluice) with bisokotuwa (access tower)
6. Construction of small, medium and large storage reservoirs
   across non-perennial oyes and aras, and in so-called dry valleys, using the horowwa with bisokotuwa for controlled issue of irrigation water, and the spillway for safe discharge of flood runoff.
7. Damming a perennial river
   There were two techniques for damming a river which had some flow, however, small, even in the driest season:
   1. Temporary river diversion through a sluice
   2. The twin-tank method

FIGURE 1
Brohier's Theory, quoted by Needham

"The process of evolution which is thought to have occurred may be described as follows:

First the farmers made numerous small tanks in the hills and foot-hills, near their fields or terraces to catch the run-off water which they baled out at leisure. Then numbers of small dams (bunds, benna) were built, often in series, on the upper reaches of tributaries of the greater rivers, thus retaining the annual or inundatory flow and discharging it as desired by small capails (ela) along the valley sides. As time went on larger dams were built submerging or rendering unnecessary the smaller ones. The next step was revolutionary: a weir (anicut, Tamil - tekkam) was built much higher up the main river (ganga, kya, Tamil - aru) to form the headworks for a long lateral water to join the annual monsoons supplies in the great reservoir. This method ambitious as well as scientific, had numerous advantages:

(a) it harnessed a greater volume of water than any local catchment area could yield,
(b) it put both monsoons as well as other rainfalls to full use,
(c) it secured a resource in drought periods as well as an even supply in normal years, and
(d) it lessened the silt accumulation problem because the feeder capails could be cleared periodically much more easily than the tanks."

(Needham et al., 1971, 368)
ANCIENT SYSTEM OF IRRIGATION AND DISTRIBUTION OF WATER

FIGURE 3

(26)
ANCIENT IRRIGATION SYSTEM OF RAJA-RATA

FIGURE 4
FIGURE 5 - DIAGRAM SHOWING THE INTER-RELATION OF IRRIGATION WORKS
FIGURE 6
WALawe BAsIN DEVELOPMENT
ANCEint DISPERsED SMALL-SCALE SYSTEM vs
MOdERN CENTRALISED LARGE-SCALE SYSTEM