AN ANALYSIS OF SUSTAINABLE MANAGEMENT PRACTICES IN THE OLD CITY IN SRI LANKA: SPECIAL REFERNECE TO SIGIRIYA

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Abstract

This study aims at identifying historical sustainable management practices in the ancient city of Sigiriya and how the sustainable management practices are still sustained in the urban setting as well as to evaluate the prosper of the iron production in Sigiriya region. This study was carried out based on qualitative research approach and basically, the data collection was done based on field notes from observations, photographs, documents on Sri Lankan history, and legendary stories of people, interview transcripts and other wide verity of records which provided an insight to conduct a rigorous analysis on the sustainable management practices in the city of Sigiriya. Further, a detailed data collection was undertaken in places such as Sigiriya library, department of Achieves and the library in the department of Archaeology since this study is more about a place of an ancient construction. One of the notable sustainable management practices of the city of Sigiriya is prevention of soil erosion as much as possible. Various techniques were in place in minimizing the soil erosion including use of underground conduits with pasted clay, & when the channel was widespread, the width of the cover slab was reduced by a supporting cross wall that separated the channel into two equivalent slots and use of kinetic energy with boulders in bringing water to a downstream etc. It was also observed that the retention of maximum quantities of water throughout the year, adequate & fresh water supply, as a sustainable management practice in the city of Sigiriya. This practice was witnessed from methods such by constructing many pools and ponds at the summit of the rock & around the rock and use of three-layer structure in constructing pools to retain water thereby minimizing the absorption of water into soil etc.

Key Words – Sustainability City development, Sustainable development, sustainable management practices, Sigiriya.

1. Introduction

History of Sigiriya

Among the World Heritage properties, Sigiriya is one of the wonders of the world having ranked of 8 place in the world. Evidence of agriculture and iron production in Sigiriya area have been witnessed between 1,000 and 3000 BC (Rohan Wickramasinghe, 2009). This rock was ignored and invaluable by monks since the King was treated as a parricide. In this period king Dathusena denied possessing any wealth other than the water of an irrigation reservoir he had constructed (Rohan Wickramasinghe, 2009). In this era rulers were highly concerned about the preservation and protection of existing and potential water systems. In order to prove the fact that the preservation of water was a main priority of rulers witnessed by king Parakkramabuhu expressing his view emphasizing the following. "Not a single drop of water received from rain should be allowed to escape into the sea without being utilized for human well-being" (Trevor Turpin, 2006). Sigiriya was built by king Kasyapa during his ruling period from 477 CE to 495 CE. Sigiriya is situated in Malathe district close to Dambulla town. The palace of king Kasyapa was built on a natural rock having height of 660 ft.

Hydraulic System

The approach to the granite rock (the Lion Rock) is surrounded by inner and outer moats and formal water gardens and water is fed by underground and surface drainage systems from elevated tanks during the rainy season, to form water fountains and sources (Trevor Turpin, 2006). There is a 25m square pond created out of the rock for water storage on the top of the 200m high rock. The water gardens themselves were used for bathing by the various members of the King's court some of which are still functioning until today (Rohan Wickramasinghe, 2009, The Official Web Site of Sri Lanka Tourism Promotion Bureau, 2011). The Fountain Garden has two long ponds with stepped sides fed by shallow serpentine streams paved with marble. These serpentines are punctuated by fountains consisting of circular limestone plates with perforations. They are fed by underground water conduits and operate by gravity and pressure. Water for the town was stored in the Sigiriya Wewa (Trevor Turpin, 2006).

This creation is, at present, considered as a tremendous architecture. As per the ancient believes, Sigiriya was designed as a castle as well as a palace to protect against conquerors. The beauty of

Sigiriya represents from the uniqueness of its creations such as Lion Gate, Gardens, Mirror Wall, Walls, Frescoes and Moats. The Gardens comprise Water Gardens, Boulder Gardens and Terraced Gardens (Senakabandara, 1990). These gardens evidence that ancient people much consider the natural aspects of the environment when they built constructions. In addition, exclusive art creations were performed in side of the rock. It is recognized that people in present are able to view only eighteen frescoes. Further, people believe that these paintings indicate either Portraits or concubines of the king Kasyapa. The importance of World Heritage properties cannot be denied due to their priceless and irreplaceability.

These properties are essential for each nation and the humanity as whole (UNESCO, 2008a). Sigiriya was published as a world heritage site by UNESCO in 1982 under three selective criteria and operational guidelines by the world heritage convention. It is identified as a masterpiece of human creative genius, an exhibition and interchange of human values with a development of architecture and technology and bearing a unique testimony to cultural tradition (UNESCO Official Website, 1995-2011)

Sustainable Development in Cities

Archaeologists are still wonder how the development of the Sigiriya and its city have been built up while protecting the sustainability management practices. As a result, this World Heritage Site provides an edge over the other countries in attracting tourists (Sharmani Perera, Chandran, 2014). So Sirigiya not only denotes the culture of the country but also indicates a tool which improves the economic perspectives. It is also noted that sustainable management practices are well revealed in World Heritage properties and cities such as preservation of water and protection of biodiversity in constructing cities and eco-friendly practices etc (Lina Hiselius, 2016). The sustainable practices were developed thousand years back not recently. The sustainable development is the development that meets the needs of present generation without compromising the ability of future generation to meet their own needs and wants (World Commission on Environment and Development, 2005). It is highly evidenced that the Sigiriya and the city around it were adapted the sustainable management practices that prove from Water Gardens, Boulder Gardens and Terraced Gardens etc.

It is noted that this study is going to evaluate and analyse the sustainable management practices adopted by the old city of Sigiriya. The factor is these architectures are highly sophisticated and genius creations and the technology they used is incredible. Hence, it is vital role of everyone to look after the World Heritage city of Sigiriya. In doing so, everyone should try to preserve this city of outstanding universal value and must build up a platform which prevents the city being destroyed. At the same time, the future generation must be allowed to obtain benefits from this and enjoy the natural culture and heritage (Viau, 2009). Because this place protects the culture of the nation while boosting the economy through the tourism sector.

2. Literature Review

Hydraulic Technology in Sigiriya's Water Gardens

When studying about Sigiriya and its Hydraulic system plays major role since it provides the hidden concepts which cannot be understood even today contexts. However, when understanding the hydraulic System and Irrigation systems in Sigiriya, Little attention has been given (Cooray, 2012). However, the Bandaranayke (1990a:46-48,1993a:12-17) stated that, the Hydraulic technology in water gardens are

outputs of the micro level application of principles of the macro-hydraulics, which provide the concrete for the technological development for the civilization during the early and middle historical periods (3rd century BC-13th Century AC) (Cooray,2012). Moreover, He has identified that there was an interconnection of Macro- and Micro-Hydraulics and he identify two macro systems and two micro systems: respectively, Sigiri Mahavava, which has elevation more than water garden and the Sequence of moats fed directly from Sigiri Mahavava (Macro Systems) and the main water storage system of the water garden in western precinct, and water monitoring and control system from the rock summit up to the water garden (Micro systems) (Cooray, 2012). Moreover, Bandaranayke (1993a:24-26) holds that;

> 'The historical importance of the gardens at Sigiriya lies essentially in two factors one, their antiquity and degree of preservation and their ingenious combination on a grand scale, of at least three traditions of landscape gardening. Past and recent archaeological excavations have confirmed that the gardens substantially date from the 5th century. The clearest parallels to the water gardens at Sigiriya are to be found in the much more ancient geometrical gardens of Egypt or the 'paradise gardens' of ancient Persia, while Sigiriya's chronological successors are the well-preserved examples of the gardening and the geometrical gardens of the Renaissance Europe. Among the survivors of the ancient gardens of the world, Sigiriya is become prominent and are equally well preserved those of the Romans such as the private and public gardens of Pompeii and Herculaneum and the imperial gardens of Hadrian at Tivoli. The subsequent developments in the Asian water gardening tradition, that is represented at such early dates at Sigiriya, are found on a majestic scale about four or five centuries later at Angkor in Cambodia, and even much later in the exquisite gardens of the Mughals'.

The boulder gardens at Sigiriya, on the other hand, have eastern rather than western correspondence. The closest parallel to the Sigiriya gardens are the gardens of China, Korea and Japan. The third garden form at Sigiriya, the terraced gardens, are so basic and archetypal in character that parallel forms exist in many diverse cultures of the ancient world from the ziggurats of Mesopotamia and

'Hanging Gardens' of Babylon to the pre-historic ritual terraces and stepped stupas of Southeast Asia. They are often encountered in early Indian sites and are a conscious element in Chinese landscape gardening and architectural planning (Bandaranayke, 1993). Their most obvious correspondence, however, are with the terraced rice fields and other terraced hillside agricultural systems which are extensively found in Sri Lanka, as in most parts of tropical Asia. The diversity of parallels and correspondences, that we see in the gardens at Sigiriya serve, in the end, only to underline the uniqueness of this 5th century creation of Sri Lankan master builders. (Bandaranayke, 1993). As per the above evidences it can be assumed that there were ways by which the knowledge was being transferred among the countries as soft (through learning) & hard (through experiencing) elements. However, there was in technological hostage since the advance technology of building the city of

Sigiriya had not been transferred to the other cities like Anuradhapura, Polonnaruwa etc. So, it could be made an assumption that this city would have been operated as a closed city. Ellepola, 1990, has taken an attempt to predict the hydraulic technology in Sigiriya by giving the account on available field evidence and archaeological recodes relating to the Sigiriya by comparing them with the context of 5th century Sri Lankan hydraulic technology. Ellepola, 1990:183 states that;

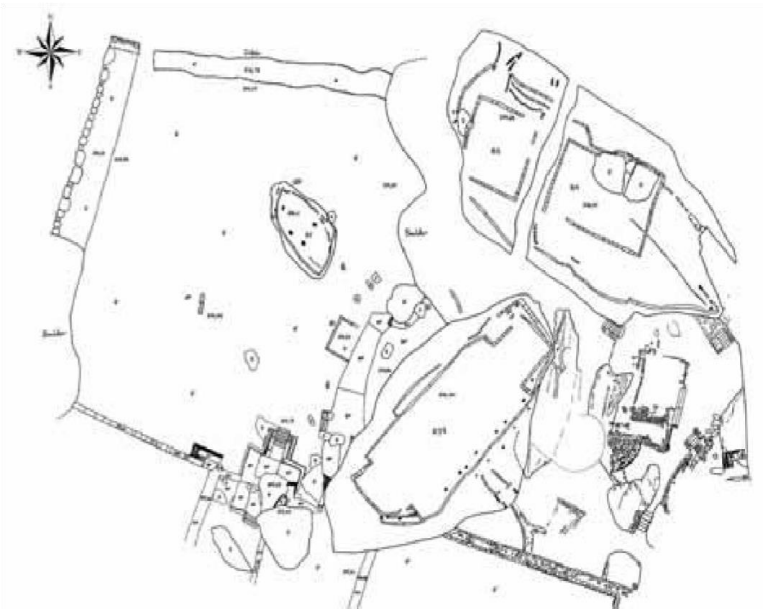
> 'The hydraulics of Sigiriya may be considered as a composition of many specialized systems that were engineered to serve the diverse needs of the citadel. Although these individual systems functioned differently, their component parts were intricately interrelated to form a single comprehensive network by means of numerous by-pass and loop connections. This facility permitted parts of the system to continue working while other sections remained closed, facilitating the processes of repair, maintenance or even water conservation. The water flowing through these different hydraulic systems within the citadel was passed out of the complex and collected into channels that finally emptied the water into the Sigiriya Oya. Downstream irrigation of the Sigiriya region was thus ensured with the water conserved from within the Sigiriya complex. The water distribution through the complex was caused by gravity action, which created a gently flow into the successively lower areas where the supply was required.'

City Planning and Architecture

The historical city planning Sri Lanka, the Sigiriya Provides exemplifies the great scale and vision of Sri Lanka (Cooray, 2012). As per the findings of Bandaranayke (1990b:26) the most important facts of the urban model of Sigiriya is, it was planned in accordance with mathematical requirements and its total design concepts. Since the gardens was made symmetrically, it implies the basis of eco planning concepts. The design of the Sigiriya expands to the outward from outer section of central east- west and north – south integrates at the Centre of the palace of the complex and the entrance from the eastern and western are directly align with the Centre of east-west axis (Bandaranayke,1990b). According to the field works done relating to the Sigiriya and historical evidence find through the studying the literature of Indian town planning, it can be concluded that the inner city, outer city and suburde are the ceremonial park with pavilions, and inner city and includes the markets and other buildings for public use and outer city for urban social study (Karunarthne, 1994).

In order to become a sustainable city, the city must be well planned as well as it should not harm to the environment, society and economy. As per the design plan of the Sigiriya, it shows that interrelation between the structure of the bolder and build element on the ground level (Sunnemark and Wik, 1997). They assume that when selecting the materials for building central palace, they have used the combination of bricks and timbers (Bandaranayke, 1990b) since it makes sure the prevention of the harms to the environment. There are three main tradition in landscape gardening: one is symmetrical and geometrically built water garden in central and south western areas; second one is asymmetric or

organic cave garden on eastern escarpment; last one is stepped or terrace garden at the base of central rock (Bandaranayke, 1993a). These identifications provide the evidence of proper managements system in ancient Sri Lanka, since, without an efficient manner to the build city, this type of symmetrical developments could not take place. However, we can build a conjunction that there was a sustainable management practices which was backed by some well-established accounting system. Moreover, without proper recording, communication system and resource planning system, it would not possible to being a witness for this kind of world sustainable heritage



The cut-marks on one of the boulder clusters indicating the structures upon them and their relationship to the remains at the base (courtesy: Sunnemark and Wik 1997)

Basics of developing urban quality development

Sigiriya & its city provides number of sustainable management practices and sustainable environment as well. Re-modification and reengineering of existing cities are outdated practices since they are only concerned about refrigeration of city by focusing on modern technology. According to study of Marting Lehmann, 2007, he identified the basics of developing urban quality development which is one of the dimensions of sustainable city development. He revealed that quality development of urban cities comes from networks constructed by social actors in terms of environment, social and cultural aspects. Which means he has tried to persuade that management practices will only be sustained and prosper, when there are many ambitious linkages among the system created by social actors. But focusing on our research, it is somewhat difficult to emphasis such kind of opinion since the ancients were believing that there was one dominant ruler so that there was not enough space to make independent social systems and the all systems were run by the king. So, it was not a network but it was a centralized city development.

Preservation of world heritage properties

It is requirement of the present that cities need to be developed to stay alive. But it is undeniable that every city requires new development to stay alive and cities need to be developed according to particulars and its current conditions. At the same time, it is pre-determined fact that strict laws and regulations should be adhered at the development process. An accurate monitoring system needs to be placed which ultimately results in development with the positive impacts on the sustainable use of world heritage cities. Further, it is not required that old cities should be developed in a modernized way. New development method needs be understood and implemented in order to preserve the outstanding universal values of world heritage cities. (UNESCO, 2008a)

Sometimes, preservation of world heritage properties will be implemented in a way that it is severely affected to the ancient cities. Following practices will highly be affected to the outstanding universal values of the ancient cities such as lack of sufficient regulatory framework, lack of sufficient impact analysis, insufficient corporation of stakeholders or integration of respective institutions and lack of management plan. (Tumer *et al*., 2011), (Angela Pons, Ana R. Pereira Road, Molly Turner, 2011) If the development of cities not taken place as expected will result in being destroyed of world heritage properties and badly impact on the on the uniqueness of cities.

Also, it is highly risk that the world heritage property will be delisted from the list that brings social, political and economic repercussions. (Tumer *et al*., 2011). Sigiriya and its cities were created using natural resources and protecting the nature of the environment. Developers of the ancient Sigiriya City were highly concerned about the sustainable management practices.

Increasingly the world is requiring to meet common standards in order to measure the sustainable contribution from wider range of organizations. These standards can be used as a tools of evaluating the sustainable cities development and identify how far it will be sustainable. In environmental context, the carbon emission needs to be considered to meet sustainable goals in term of environment. The best example is the study conducted by Nnamodi O. Madichie by grounding the Masdar City in Iran. Iran is a country which should be responsible directly or indirectly to depreciation of Olson Layer due to high level of oil production. So, the author was concerning about zero carbon foot print city development. “Masdar city remains the world’s acclaimed first zero carbon, zero west city fully powered by renewable energy and poised to attract leading international expertise, academics, commerce and residents” (Madichie, O 2011). But in this study sustainability has been weighted on the environmental consideration. But in our study, it is not only about sustainable city development in terms of environmental consideration but also it is wider than it. Now we are going to focus on what are the old management practices and how they have been survived by environment and how such practices have survived in the environment. However, there was no intention to restrict our study only to environmental

consideration but we want consider how the sustainable standards have been met by such management practices.

Stakeholders' concerns over world heritage properties

At the development of sustainable cities, the challenge is to balance the economic growth & development with sustainable development (Turffic Merzer, pp 136-141). In this scenario, we need to know how to overcome technology advancement and the changing behavior of people. The balance can be maintained if stakeholders think smart way not just work hard (Majdalani, et al, 2006). Sustainable cities are carbon free, more energy efficient than existing cities and more rely on the renewable energy sources (Choucri and North, 1993).

Challenges to sustainable development

According to the study carried out in city Allahabad, India point out that one of the big challenges in a sustainable city is to manage natural water. Water is one of the crucial natural resource of any nation since it is capable of being enough to effect to people's life every day. At the same time, it will directly impact on diversion, transport, storage, and recycling (Kumar et al., 2005). It is highly vital of managing and implementing better water systems to ensure the adequacy of the supply at the present and the future. Also, regulators should take steps to ensure the quality of supply (Saumya Singh, A.B. Samaddar, R.K. Srivastava, 2010). In ancient cities for an instance Sigiriya, it is appreciated to state the management and implementation of well water system. Because they have managed this with a less technology advancement. It is also important to note that water management practices followed by Sigiriya which is evidenced by around the Sigiriya area.

Further, a research study conducted in Allhabad pointed out that it is undeniable the importance of existence of a sustainable waste management system in a sustainable city. This aspect was mainly considered since old cities were concerned environment factors as the basis for the development. Ancient waste management systems need to be developed in order to come with new systems. Nowadays, every nation takes this as serious issue since the environment is getting polluted day by day at the cost of human life. New sustainable waste management systems should comprise of institutional, financial and technical aspects (S. Saxena, R.K. Srivastava, A.B. Samaddar, 2010).

Further, studies can be undertaken in relation to the Sigiriya area such as management accounting practices/ cost accounting used in managing costs and the sustainability of the international trading in Sigiriya region. There are evidence to prove that the international trading activities had taken place in the city of Sigiriya such as international coins and trading piece of goods from excavation.

3. Methodology

Overview

This study reports on historical sustainable management practices of the old city Sigiriya, designed to enhance the important of historical sustainability management practices and measure the quality between modern sustainability practices and those sustainability practices in such old city in terms of water management, land management, urban management and artworks. We mainly used secondary sources of data and observations in order to collect relevant data about sustainability practices in Sigiriya.

Research Approach

A qualitative research approach was applied for this study to identify the sustainable management practices in terms of its archaeological planning, engineering, artwork, land management and conservation of resources which helped to outline the techniques and practices that ancient people used to manage resources in an urban context to sustain for a long time. This needs to evaluate number of research findings and literature about the history of Sigiriya. In this approach the researcher "centers on the attempt to achieve a sense of the meaning that others give to their own situations" (Smith, 2005, p. 12).

The data collection from this study consists of field notes from observations, photographs, historical documents, and legendary stories of people, interview transcripts and other wide verity of records which help researcher to conduct a rigorous analysis on the subject. Three processes are blended throughout the study: collection, coding, and analysis of data (Glaser & Strauss, 1967): This approach strengthen the flexibility which is vital to the qualitative researcher who can change a line of inquiry and move in new directions, as more information and a better understanding of what are relevant data are acquired (Blumer, 1999).

Research Design and Procedures

A rigorous literature review has carried out about the history of the Sigiriya as an ancient city which was able to survive for a long time, to identify the sustainable management practices in terms of its archaeological planning, engineering, artwork, land management and conservation of resources. Key findings are backed by field studies, photographs, notes and famous literature on Sigiriya citadel.

Sigiriya premises and other places where valuable information regarding Sigiriya such as Sigiriya Library and Archeological Department is kept were visited because this study is about a place of an ancient construction. These visits helped to recognize people who aware about the history of Sigiriya and its Management Practices where exists even today.

Interviews with people around the Sigiriya area and with officials in respective authorities are conducted during this study. Interviews were started as unstructured questions; occasional questions were asked for clarifications and necessary follow-up interviews were conducted during the study. The interviews were informal and open-ended, and carried out in a conversational style.

It was vital that ongoing data analysis was taken place throughout the study. All of the documented interviews, literature reviews, photographs and field notes were organized around different topics and themes found in this study. These findings and new data were analyzed by the researcher in order to enhance the quality of the study.

4. Findings and Discussion

4.1 Findings

Being one of the major archeological sites, Sigiriya is a unique combination of 5th century urban planning, architecture, engineering, hydraulics, and garden landscape. It is an arrangement of national beauty of surrounding and technology developed by the 5th century dominant builders. Starting from its border historic origins, Sigiriya region was become one of the major centers of iron production in Sri Lanka especially between 1st & 4th century A.D. Sigiriya is very famous due to operation of its hydraulic system which has been developed in order to retain and sustain water available in Sigiriya area. When it comes to Sigiriya, the term hydraulic potential is an essential part. The "hydraulic potential" can be defined as; "the ability to stock water in the higher level, with respect to the ground level and it is formed the gravitational energy by water in the particular region. The hydraulic potential depends on the rainfall, soil condition topography, water sources, and elevation of a particular region. Water management system operated at the Sigiriya complex is such finding which shows the proficiencies of our ancestors in blending technology within natural setting. Scholars who have studied this system have segregated Sigiriya complex into different zones like palace complex, rock summit, water garden 3, water garden 2 and water garden 1. Each of the areas stated above shows sustainable practices including maximum water retention and minimizing soil erosion with the use of exceptional technology.

The water management system of Sigiriya comprised of many specialized systems that facilitated to meet diverse needs of people living in Sigiriya area. Even if these systems operated differently, their components have been liked with each other to function effectively. This has been effectively used by ancient people to work parts of system while other sections remained unchanged and this gained benefits such as smoothing the process of repairs, preservation and even for water conservation. The water flowing through these different hydraulic systems within the Citadel was passed out of the complex and collected into channels that finally discharged the water into the Sigiriya Oya. The one of the purposes of the development of hydraulic system was to ensure the retention of water within the Sigiriya Complex. Specially, the downstream irrigation of the region was thus ensured with the water conserved

within the Sigiriya complex. The sustainable management practices used in old city Sigiriya are discussed below;

4.1.1 Prevention of Soil Erosion

Water distribution of the complex was heavily designed with the use of gravity action which ensures the supply of water to lower level uninterruptedly. The horizontal distribution of the water was primarily directed through underground conduits. Therefore, the sub-surface of the Sigiriya zone may well be imagined as a maze of water lines. Specially, in the Sigiriya zone water distribution has been operated through underground conduits. But cross-sectional dimensions very according to the volume of water they conducted. The typical conduit had its base and sides constructed in stone work, and was covered with a stone slab. When the channel was wide, the width of the cover slab was minimized by a supporting cross wall that divided the channel into two equivalent slots. The entire channel was surrounded in a "puddle" of filled clay which acted as a waterproofing on the outside. This has been done with the purpose of eradicating the soil erosion. This can be interpreted as a sustainable management practice used by the Sigiriya zone. These conduits are still operated at the Sigiriya zone and sutaining for thousand years.

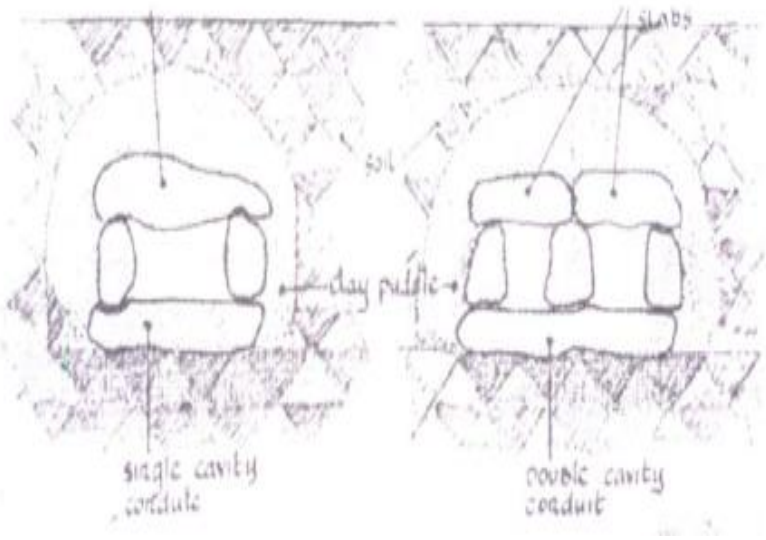


Fig 4.1 Horizontal Water Distribution Conduits, Ancient Ceylon, 1990

In addition to above, some of evidence are still available to prove that the Sigiriya complex and its water system have been constructed in minimizing soil erosion. This is witnessed by the ponds located at the rock summit and from their run-off. When water is flowing from high elevation to a lower elevation the kinetic energy of the flow depends on the slop of the surface. Higher the kinetic energy higher the quantity of soil particles travelling along with the flow & this rises the soil erosion. Soil erosion is the movement of the higher layer of soil, a form of soil deprivation. This natural process is affected by various activities including water, glaciers, wind, plant and humans. This problem has been tackled by constructing boulders to decrease the elevation and further by making these boulders perpendicular to surface water flow. Moreover, the architectures of Sigiriya knew that the effects might come from the sessional changes in monsoon rains. In order to avoid and overcome adverse impacts many measures had been in place in Sigiriya including unique topography and drainage system was created to accommodate a considerable numbers of water run-off. It could also be noted that an effective water management system has to ensure that prevention of soil erosion due to natural free flow of water run-off on the exterior of the side.

Fig 4. 2 Bolder of the Sigiriya Summit

The water management system operated at the Sigiriya complex has been constructed with the purpose of mitigating the soil erosion as much as possible. Even this technology can be used at the present context to construct ponds with purpose of eliminating soil erosion.

Fig 4. 3 - A run - off of the Sigiriya summit

At the present the world is moving towards the green world, where people have to pay more attention on the environmental aspects. This perspective was effectively considered in the old city of Sigiriya. When analyzing the structure of the water system, it is revealed properly.

4.1.2 Retention of adequate Water quantity on a constant level

In deciding water management system in dry zone, the major problem encountered is the availability of water in adequate quantities. To overcome this problem & collect rain water as much as possible many water retaining ponds have been constructed in Sigiriya complex stating from rock summit to innermost. The royal palace located on the top of the rock has its independent ponds of which the largest being 27M in length and 22M in width is situated at the middle of the summit. This covers total of 594 $Sqm^{2.}$ Other ponds are smaller and situated at the northern & southern end of the summit. Drinking water requirements of the occupants of the palace as well as its surrounding water gardens are considered to be fulfilled by these ponds. It is observed that a strong wind is available which would have been used as a natural purification method. This gives fresh water to occupants of the palace.

The excess water of the rock summit has been directed towards the ponds which are located around the rock and then water garden. The higher reaches of the same slope undoubtedly acted as a natural soak away, absorbing and retaining the free run-off, only to release water into a controlled hydraulic system within the water garden area. The chain of garden pools lying immediately below the Boulder garden area were easily sprinkled with a water supply from the Sigiriya Wewa. It could also be noted that there existed an underground conduit linking the Sigiriya Wewa to the pools. This underground conduit had been used to supply water to the ponds in addition to the supply of water from the surface run-off thereby leading to retain maximum quantity of water in all ponds. **(**Ellapola C. Ancient Ceylon No. 11 Vol. 5 Dep. Archaeology Colombo 1990).

Fig 4.4 Reservoir at summit

Surface water flowing from terrace garden is directed towards some ponds situated at the edge of the boulder garden. One pond is of particular important due to its harmony blend of natural setting with human involvement. This is situated close to a rock which forms two side of the pond. Other six side were made out of stone walls making its total size and the pond is referred to as the octangle pond. Rectangle ponds lying in both side of the approach paths belongs to the zone. These ponds also fade

upon Sigiriya Wewa and the waters headers formed enable the felt down springs of Sigiriya to operate. The edges of these ponds are broken further generally in three levels. The bottom level is for water retention and the second level was to minimize the erosion embankment during the over flow. The third level was to avoid water destruction during human activities such as walking. The technology used in the retention of water at the Sigiriya Complex provides a greater inspiration to present water management system.

Fig 4.5 - A rectangular pond, Terrance garden

There are 4 large ponds at the central of Sigiriya area apart from adding the esthetic beauty to the landscape, these ponds may have functioned as the bathing pools as well. The Sigiriya Wewa has supplied pools with required clean water through concealed conduits ensuring constant and clean water supply even during dry sessions. All the ponds situated at the garden have been interconnected with each other and this made up single hydraulic system within the ponds leading to a constant and clean water in all ponds throughout the year. In order to achieve water purification, several outlets (a mechanism by which water is moved) were used with the sluice keeping constant. Therefore, based on the extent of water purification required in the pool, the degree of water change would have varied, by monitoring the sluice gate at the outlet and balancing the inflow at the supply point. Providing clean water is one of the sustainable goals that every nation should try to achieve. Constructers of the Sigiriya have exactly considered about the clean water requirement of the occupant of the Sigiriya Complex.

Fig 4.6 - Water inlet, ancient Ceylon, 1990

Further, the continuous water supply into the pools is ensured from the Sigiriya Wewa and with the automatic execution of the conduits the pools are able to maintain constant level of water and the storage will never become empty as long as the conduit supplies water.

Inside western entrance is a garden is very different in character from others. This garden is consisting of shallow reflecting pools requiring small volume of water. The intention is to form an esthetic view appearing even during the dry sessions. Flow of these ponds were made of pebble and polished marbles. These would have served as cooling devices and prevented in absorbing water to the soil directly. The excess rain water run-off and the final outflow from the water garden is passed in to major water discharge conduits from the upper water garden area. The inner mote acts as the final discharge of all water system. The technology involved in discharging water is highly sophisticated and the method controls the water flow velocity to reduce soil erosion.

Fig 4.7 - A pond with spread out marble & pebbles

4.1.3 Significance of the Ancient Metallurgy and Iron Smelting in Sigiriya for a Sustainable Urban Setting

Metal has been one of the important technological and economic resources in every historical societies and even today. That is why many studies about patterns of ancient settlements prove the characteristics of societies were connected to resources that they possess. Solangaarachchi (2011, p. 30) claims that 'even before the metallurgical properties of metals were discovered some iron ores were used by the ancients in Sri Lanka such as goethite ($Fe_2O_3.H_2O$), limonite ($2Fe_4O_3.3H_2O$) and hematite (Fe_2O_3)'. According to ancient chronicles like Mahavansa, Thupavansa and Pujavaliya, ancient ancestors had the technology to explore, process and make gold, iron, copper and bronze based products. Also, this has provided the background for the settlements around Sigiriya. Evidences exist even today to prove that the Sigiriya has consumed ancient metallurgical technology to build and maintain its presence in the history as one of the precise citadels and an urban setting.

Archeological explorations and excavations carried out in various parts within and around the Sigiriya area has estimated the earliest known date for iron smelting as 10^{th} century BC base on C_{14} carbon dating (Deraniyagala, S. 1990, *Ancient Ceylon No 12,* Department of Archaeology, Colombo).

A prominent study (Hadfield 1912) revealed that the iron masters in Sigiriya era had known the art of 'quenching' to strengthen steel. Some artifacts found from Sigiriya were made from pure iron. Also, the Hadfield's study focused on fact that hardening or cementing, the method of carbonizing wrought iron and the quenching technology were used to produce hard cutting edges. As per Hadfield's findings, traditional iron and steel production in Sigiriya was of a very high standard which was latterly reflected in urban development, hydro engineering and craftsmanship of Sigiriya Citadel.

Systematic archeological investigations of this subject were beginning in 1980 by the Postgraduate Institute of Archeology (PGIAR) in collaboration with Swedish Board of National Antiquities in Sigiriya-Dambulla region. Department of Archeology was conducted its investigations and unearthed evidences of ancient metallurgical industry including iron smelting furnaces and iron slag mounds from different sites around Sigiriya area, Dehigaha-Ala Kanda near Alakolavava village. This site was identified in 1988 and excavated in 1990 and 1991. Alakolavava is located 8.5 Km south-east of the Sigiriya rock and the ancient iron smelting site was hidden in deep jungle covering an area of nearly 3750 m^2 revealing the large-scale iron smelting using advanced bloomery process. Large furnaces were used to smelt separate iron from ore and smelted iron were used for the various purposes of the people around Sigiriya such as making tools for cultivation, irrigation, constructions and also for making weapons for wars. Therefore, the boom of the iron industry contributed to the emergence of the Sigiriya as a suitable place for urbanization.

The approximate volume of iron production was estimated from the amount of slag remaining on the site. However most of the slags were remain buried under soil layers. According to rough calculations of Department of Archeology, more than 10,000 tons of iron had been produced at the Alakolavava site. A total of 35 iron production sites including about 5 of similar magnitude have been found around the Sigiriya area.

The study region with iron production sites.

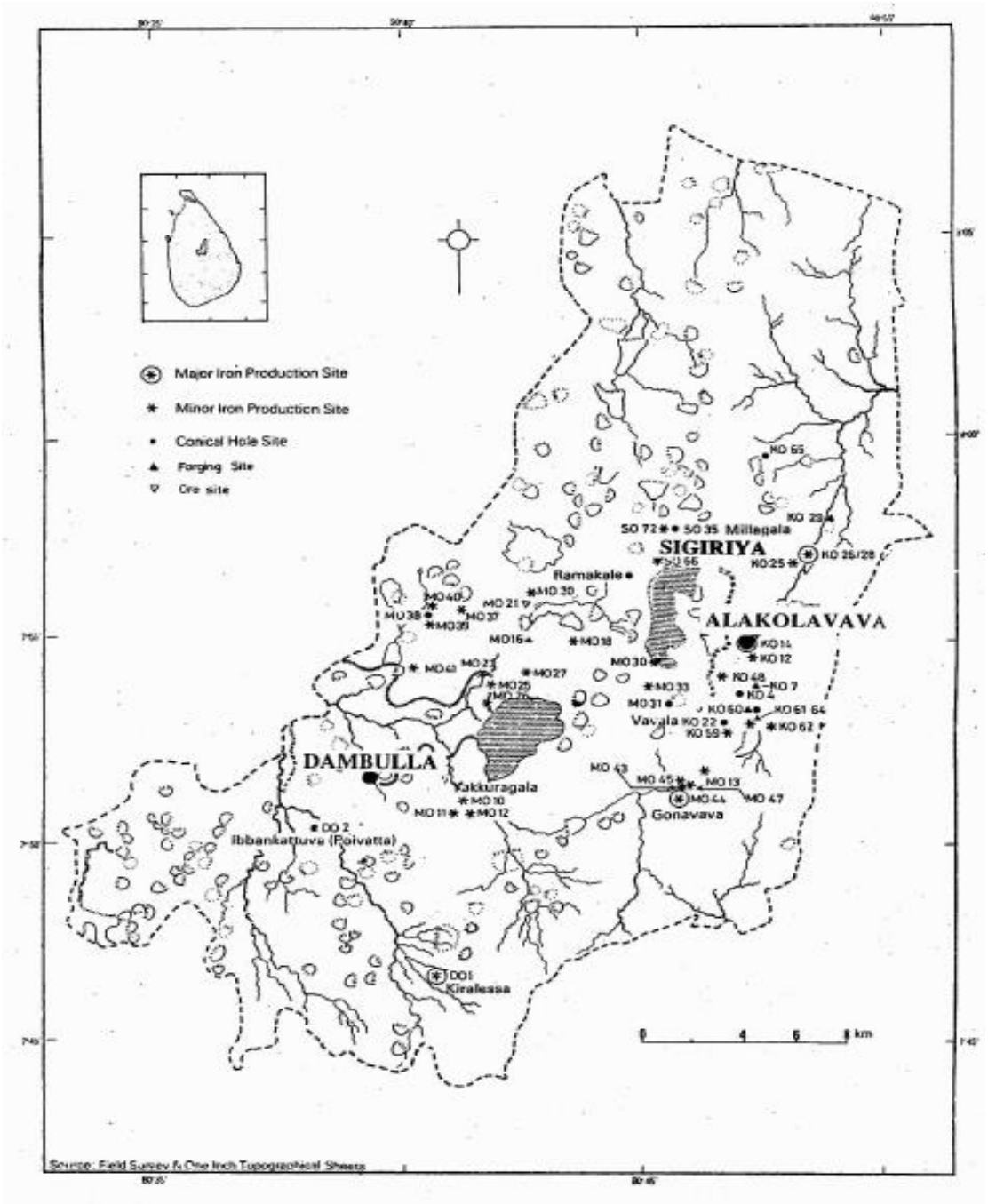


Fig 4.8 - The locations of iron production in Sri Lanka

Source: Field Survey & One Inch Topographical Sheets (Solangaarachchi, R 2011, 'History of Metallurgy & Ancient Iron Smelting', *Vidurava Journal,* vol. 19, no. 1, pp.32.)

Excavations in Alakolavava site was able to discover several furnaces which were used in iron production. These furnaces were made by carving bedrock into an oval shaped pit. Front walls were made up by clay which can reserve the temperature within the furnace to melt iron from ore. Draught was used to raise the temperature for smelting process induced by a high chimney and provision for an air blast blown in by bellows through a tuyere.

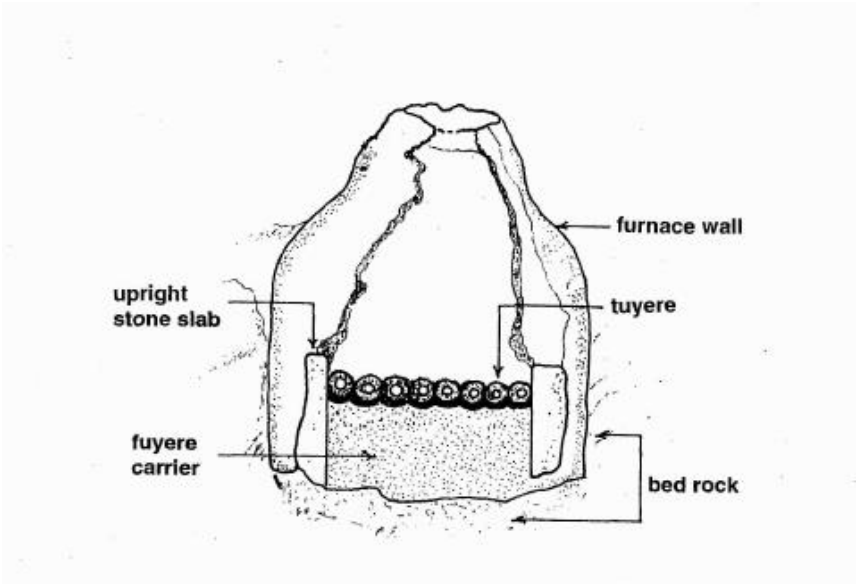


Fig 4.9 - A furnace

Drawing of a structure of a well-preserved furnace founded from Alakolavava site (Solangaarachchi, R 2011, 'History of Metallurgy & Ancient Iron Smelting', *Vidurava Journal*, vol. 19, no. 1, and pp.32).

It is very important to be mentioned the fact that contrast to Alakolavava, the researchers believe that the smelters in Smanalavava used the monsoon winds that lashed across the region at a velocity of nearly 70 Km per hour from April to August as a natural draught for the furnaces.

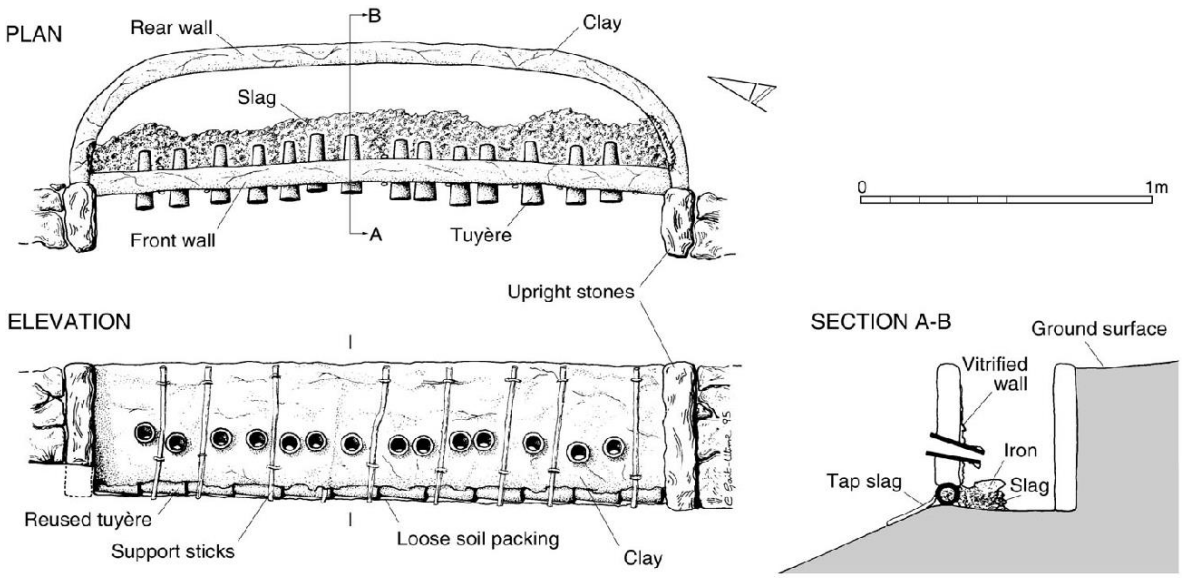


Fig 4. 10 –The structure of a furnace

Drawing of a structure of a well-preserved furnace founded from Samanalavava site
(Solangaarachchi, R 2011, 'History of Metallurgy & Ancient Iron Smelting', *Vidurava Journal,* vol. 19, no. 1, and pp.32.)

Ancient Metallurgy Industry in Sigiriya area as a Sustainable Management Practice

When looking at the technology and the raw materials of the production process, the ancient people has used environmentally friendly way to make the iron from ore. Contrast from today coal and petroleum fueled factories, the ancient craftsmen have used wood as fuel for the process and wind as for the inducer of the temperature. This is one of the fundamentals in sustainable practices towards a greener environment. Also, these excavated sites are examples for the fact that the Sigiriya Citadel always tried to sustain independently from other administrative areas in the ancient Sri Lanka as a closed citadel with minimum interactions with outsiders. The iron smelting industry helped the citadel as a sustainable urban practice to make the metal-based products within the city.

According to the C_{14} dates[28] the Factory in Alakolavava was in operation from about the 2nd century BC to 4th century AD. The pottery types found around the site provide clue of that the iron production was carried out in well-organized manner prior to the 5th century AD Kashyapian period which was the main construction phrase of the Sigiriya city. However, the excavations in some other sites including Ibbankatuwa in the Dambulla area and Aligala prehistoric cave within the citadel of Sigiriya have provided strong evidences that the iron industry was in operation even after the Kashyapian phase. Sigiriya as a citadel and as an urban setting was flourished with water irrigation systems, agriculture, building technology and art which are fundamentals for a sustainable urban setting, was mainly backed by the technology, resources and workmanship possessed by people in that era. Unless the iron industry was not in there to serve the engineers, there would not be massive walls made up with granite or a place on the summit of the Sigiriya.

Ancient Cast System as Sustainable Management Practice in Sigiriya

When study about sustainable urban management practices used in Sigiriya era, it must be drawing the attention to the community and socio-economic system existed based on the cast system in ancient Sri Lanka. The cast system was mainly derived from the occupation of the citizens. As a result of that, the knowledge, technology, craftsmanship and artworks were preserved and handed over from generation to generation according to their occupations. The society was divided from higher level casts who participated in the administration of the city to lower casts who were engaged in lower level occupations. This is similar to the concepts of authority levels, organizational structure and

administrative units in modern developed management teachings. Similarly, ancient societies occupied this community grouping system based on the relative power to maintain the socio-economic system of the day.

4.2 Discussion

This section discusses the key findings of the study and highlights the consistencies and inconsistencies of the findings with the existing literature on this subject. It was revealed that there were not any inconsistencies with the existing literatures since lacking sources of previous publication in relation to this type of study in Sri Lankan context. This study examined the sustainable management practices of old City of Sri Lanka – special reference to Sigiriya.

However, this area is new to the management field, we intended to make a link between cultural history and management field (which includes accounting, administration, environmental concern, etc). It was found that pure accounting will not survive in the today's business world since now the pure accounting has been marginalizing within the organizational context. In order to survive accounting as a subject, it has to be linked with other subjects. One major development in accounting is using historically sustainable accounting techniques into today routines.

Throughout this report, high level of emphasis was given on the water (hydraulic system) management system and other sub systems around water system in Sigiriya Citadel because it is one of major survivors of the Kashyapa era. In this, it was found that, the ancient engineers have given more concerns over the environmental protection and physical and sustainability. However, the development of sustainable and eco-friendly systems is one perspective of research; other is found the way by which those developments were sustainably managed. This report could be able to provide answers for those questions about on extent to which information had been obtained through the research.

Moreover, this report has been uncovered new potential areas for future researchers in field such as ancient management accounting techniques. In this study, it could be shown that how the iron production has been carried out in a historical context. Even though those production activities were carried out by using primitive technology, those who were engaging the iron production could be able to manage it sustainably.

As per our findings other than those discussed above, it can be said that there was some knowledge transfer system among the countries in the world. That was evidenced by the coins and small BARTER tools found from Sigiriya premises. Those coins and tools were sharing the characteristic of coins used in Rome and India *(During the civilization of Mohendajaro and Harappa).*

5. Conclusion

The requirement of the research paper is to identify historical sustainable management practices in the ancient city of Sigiriya and how the sustainable management practices are still sustained in the urban setting. The water management system operated at the Sigiriya complex has been constructed with the purpose of mitigating the soil erosion as much as possible. It was also observed that the retention of maximum quantities of water throughout the year for adequate & fresh water supply. Even this technology can be used at the present context to construct ponds with purpose of eliminating soil erosion.

The Hydraulic technology in water gardens are outputs of the micro level application of principles of the macro-hydraulics, which provide the concrete for the technological development for the civilization during the early and middle historical periods (3rd century BC-13th Century AC) (Cooray,2012). Evidenced that the iron production in Sigiriya region was much prosper in the past and methods deployed in obtaining iron with a less carbon (environment friendly iron production) can be appreciated even in the present. Archaeologists are still wonder how the development of the Sigiriya and its city have been built up while protecting the sustainability management practices. It is requirement of the present that cities need to be developed to stay alive. But it is undeniable that every city requires new development to stay alive and cities need to be developed according to particulars and its current conditions.

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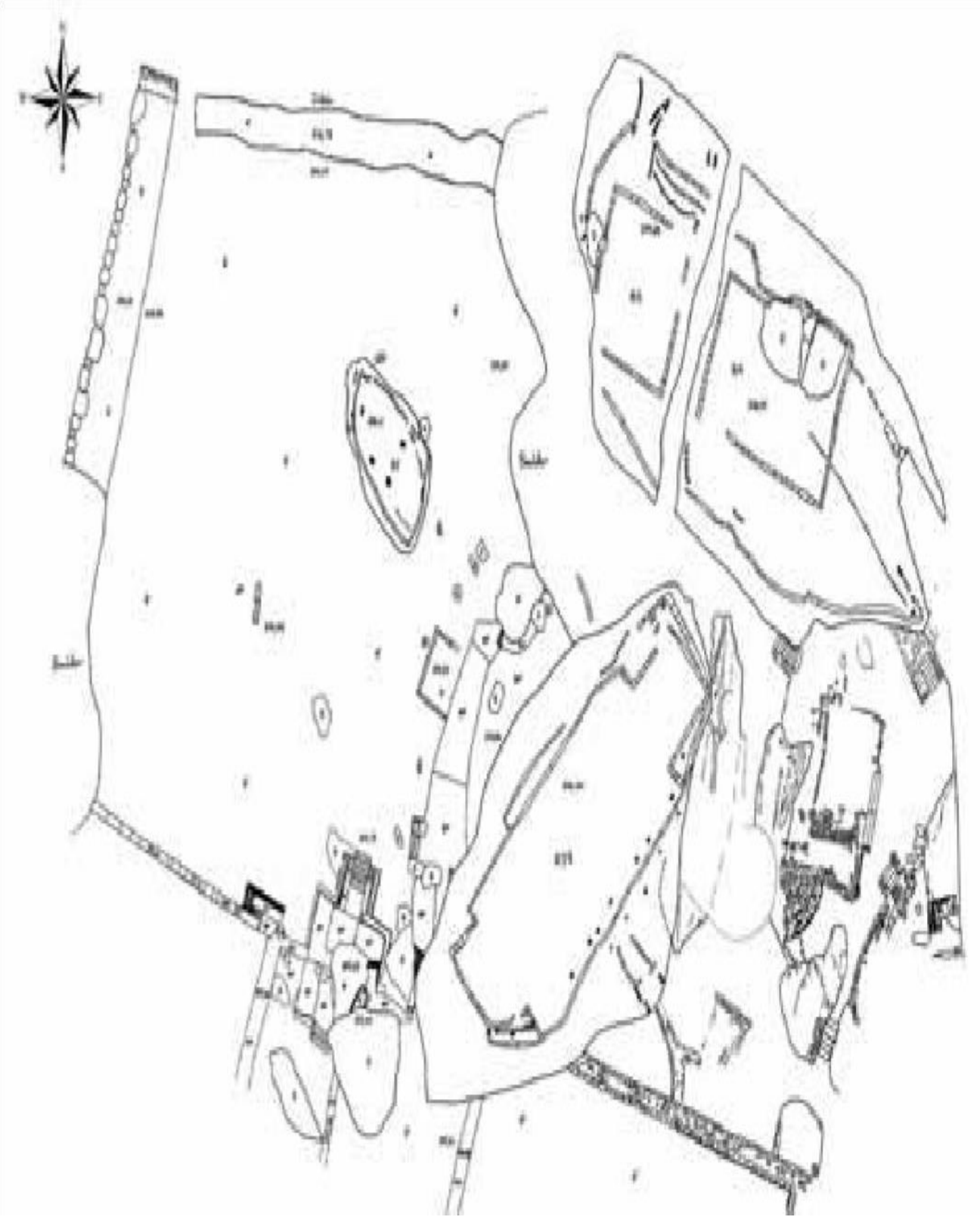
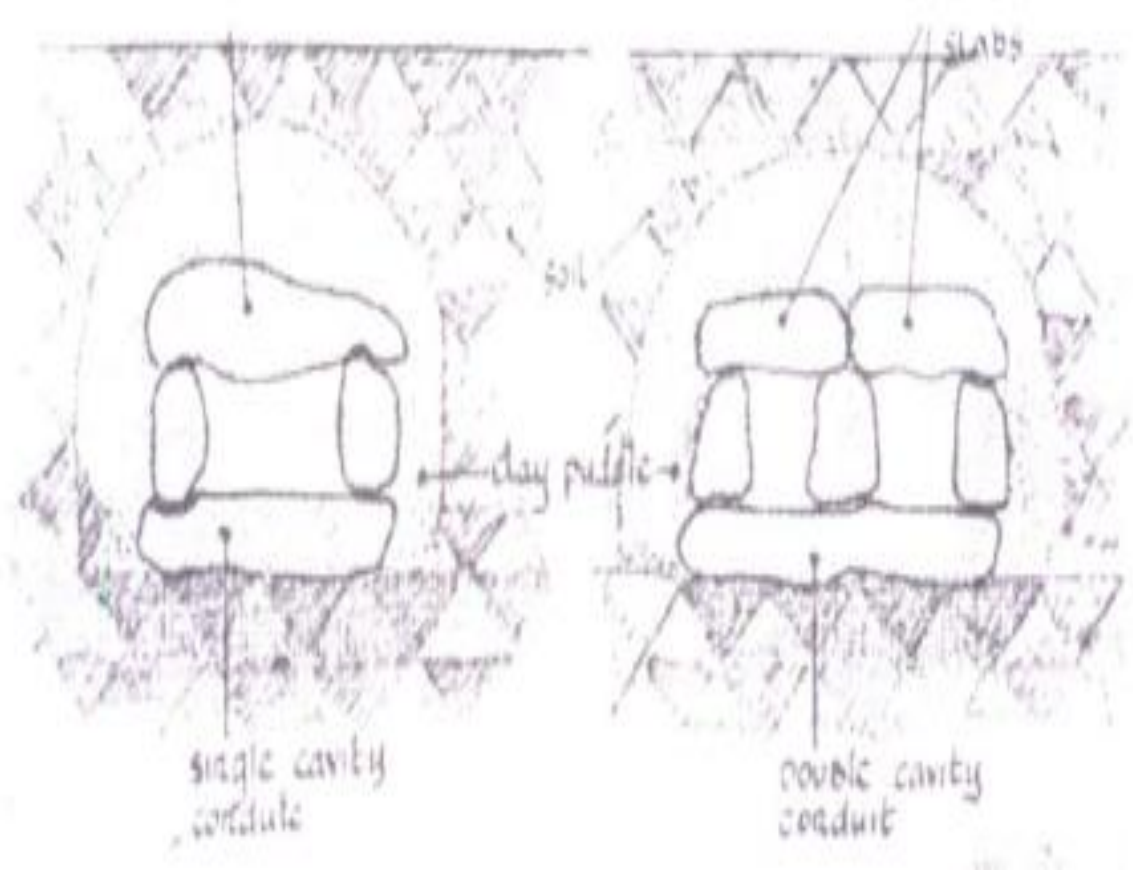
Appendix 01



A drawing of the Sigiriya Complex

Appendix 02



Single Cavity Conduit and double cavity conduit

A boulder to bring down water

Appendix 03

A water Run Off

A Water Inlet