ECONOMIC EVALUATION OF INSTITUTIONAL LEVEL RAINWATER HARVESTING

M.M.M. Aheeyar
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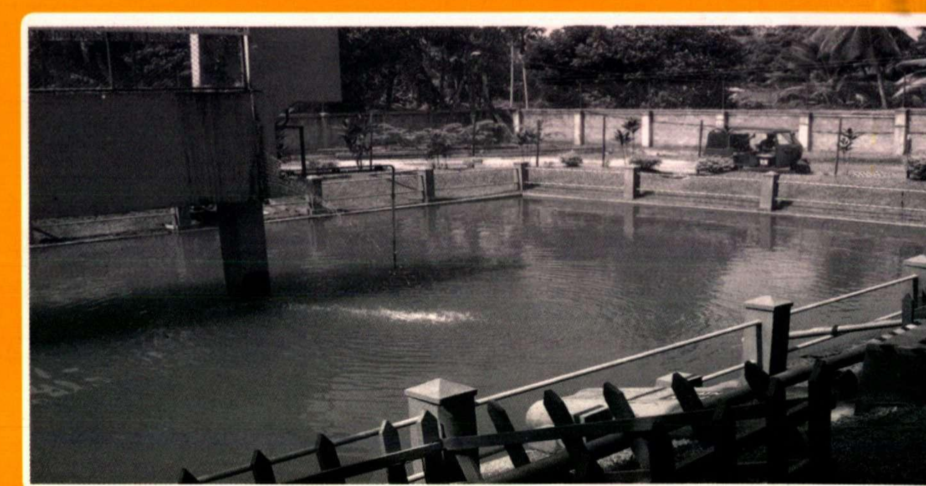

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FOREWORD

As the competition for water has been increasing between agricultural, industrial and service sectors with population increase, water allocated to the agricultural sector may become limited. Therefore alternative water supply options like rainwater harvesting could play an important role in improving water supply. The promotion of rainwater harvesting in the industrial and service sectors could effectively reduce the competition for water with agriculture sector.

Sri Lanka has a long history associated with rainwater harvesting for domestic and agricultural uses. The network of ancient tank system and the associated structures clearly illustrate the water heritage of the country. But, rainwater harvesting for large scale industrial and service sectors in a systematic manner is a relatively new concept for the country.

Rainwater is a valuable resource gifted by nature. The harvesting of this resource without any special treatment is a useful option to meet the water demand for washing, cleaning, toilet flushing, industrial cooling, vehicle washing and landscaping. Use of rainwater would reduce the water bills, and save purified water needed for drinking and protect the environment. In many parts of the world including developed countries, rainwater is one of the main means of supplying household water needs.

The case studies discussed in this report provide considerable insight on this subject which would be useful for policy makers, development planners and plan implementers. As it has been mentioned in this report, further research on this subject is necessary to evaluate environmental benefits of rainwater harvesting to conduct extended cost benefit analysis.

Lalith Kantha Jayasekara
Director

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EXECUTIVE SUMMARY

The share of water requirement for industrial and service sector has been growing over the years with the ongoing phase of economic development. However, due to current higher rate of water tariff system adopted for industrial and service sector by the National Water Supply and Drainage Board (NWSDB) and the uncertainty in 24 hours water supply, industrial and service sectors are highly dependent on groundwater resources to meet their water demand, though unlimited tapping of groundwater has serious negative environmental consequences. Therefore, introduction and promotion of alternative low cost and environmentally sound water supply options has gained importance.

Harvesting of rainwater from roof and surface catchments was seen as one of the feasible alternatives to bridge the gap in water availability and accessibility in the industrial and services sectors. A large number of day to day activities undertaken in the industrial sector can be performed using harvested rainwater. Available literature indicates that, over 90 percent of industrial water requirements do not need treated quality water and are able to meet from sources like rainwater harvesting.

Although fulfilling the growing water demand in industrial and service sector is a challenging task, the potential possibility of harvesting rainwater has not reached momentum. There are few private and public institutions in Sri Lanka that have incorporated rainwater harvesting facilities in their building premises. The performances of these projects are not scientifically studied, though it is imperative to draw lessons from them and promote the concept and its application throughout the country.

The major objective of this report is to discuss the experiences of rainwater harvesting and the outcomes of the economic appraisal of institutional level rainwater harvesting projects implemented in three locations namely David Peiris Motor Company (DPMC) at Madapatha; Millennium IT Campus (MITC) at Malambe and Brandix Casual Wear Pvt. Ltd at Seeduwa.

DPMC has developed two independent RWH systems at factory complexes I and IV. The harvested water is being used for sanitation, hygiene requirements, cleaning of floors and gardening after a series of cleaning process to bring that water to potable quality though it is basically used for non-potable water needs. About 51% of water requirement of the complex I and 100% of water requirement of complex IV, (except drinking water needs) are met by the rainwater harvesting project.

Rainwater harvesting project at Brandix Casual Wear (Pvt.) Ltd was able to meet about 15 percent of total water requirement from RWH project. The harvested water has been used for toilet flushing and gardening. Water requirement for toilet flushing at MITC is supplied by rainwater harvesting projects for about 10.5 months per year. The project has provided a saving of about 30 percent of daily water requirement which otherwise had to be obtained from NWSDB.

The economic assessment of the selected projects are showing positive results in terms of internal rate of return and net present value except the Brandix project at Seeduwa.

The pay back periods of the investment of the success stories are 7-15 years. The amount of investment made for the construction of storage tanks and the costs involved for water treatment process and the scale of operation of the rainwater harvesting make the difference in the results of the economic analysis. The low cost technology adopted at MITC has given better results among the cases considered in this study. If the benefits of the inundation and environmental benefits gained by groundwater recharge are included in the economic analysis, the BCR could provide much higher figure.

The experiences in rainwater harvesting at institutional level shows that rainwater harvesting projects implemented has greatly reduced the risk and uncertainty in the production process that may arise due to scarcity of water and also help to reduce the cost of production. However, extended dry periods that might occur in some years may hinder the water harvesting. The major problems in implementing rainwater harvesting are higher initial investment, need of large surface area for water storage and lack of awareness on the potential and prospects of rainwater harvesting and the extended benefits in the long-run.

The report concludes that, low construction cost and efficient operation of RWH systems are critical to achieve the economic efficiency. It is recommended to incorporate RWH design at early stages of planning in order to minimize the cost of construction. Systematic interventions are vital to educate and create awareness and capacity on the RWH technology and its management among the public which are vital to advocate and influence the relevant sectors.

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LIST OF ABBREVIATIONS

BCR	-	Benefit- cost ratio
CSR	-	Corporate Social Responsibility
CWSSP	-	Community Water Supply and Sanitation Project
DPMC	-	David Peiris Motor Company
HDPE	-	High Density Poly Ethylene
IRR	-	Internal Rate of Return
LEEDS	-	Leadership in Energy and Environmental Design
LRWHF	-	Lanka Rainwater Harvesting Forum
MITC	-	Millennium Information Technology Campus
NGO	-	Non Governmental Organization
NPV	-	Net Present Value
NWSDB	-	National Water Supply and Drainage Board
O&M	-	Operation and Maintenance
RWH	-	Rainwater Harvesting

CHAPTER ONE

Introduction

1.1 Background

The government of Sri Lanka has set a goal to provide safe drinking water to all citizens by year 2015. Although Sri Lanka receives an average annual rainfall of 2400mm, wide spatial and temporal variations restrict adequate water distribution. Dry Zone receives over 70% rainfalls during the period October-December. The provision of safe drinking water adequately while maintaining the present water allocation to other water-use sectors has become a challenging task with growing population, drying up of water resources, pollution of existing water sources. Urban development is already putting considerable strains on existing water resources which are struggling to keep pace with steadily rising demands. As development projects take place we have more buildings, expanded tar/concrete paved roads, bigger villages and cities. The housing units in Colombo and Gampaha Divisional Secretariat divisions alone have been increased by 30% during past 10 years (Wijesekara, 2008). This phenomenon makes groundwater recharge more difficult thus depleting groundwater levels while there is an increased competition for remaining available water.

On the other hand providing treated pipe borne water is becoming expensive considering the high level of investments and Operation and Maintenance (O&M) costs. Industrial and service sectors in Sri Lanka are mostly dependent on treated water supply provided by the National Water Supply and Drainage Board (NWSDB) and the water pumped from groundwater and rivers for their water needs. The current water tariff system in the country provides water at low cost for low use domestic consumers (starting from Rs. 3 per cubic meter of water) and higher rate for commercial and industrial water users allowing the cross subsidization benefiting domestic consumers. Water tariff of NWSDB for commercial and industrial uses is Rs.65 and 53 per m^3 of water respectively plus monthly service charge in the range of Rs. 25 to 100,000 depending on the quantity of water consumed in a month. The current water supply option of NWSDB incur tremendous cost to industrial and service sectors and also causes utmost pressure to natural environment. Due to the high rate of water tariff for commercial sectors and the uncertainty of 24 hours supply, most of the private institutions and industries try to meet their water requirement from groundwater sources creating pressure on the finite resource. Table 1 indicates that although number of industries in the country has been increasing over the years, the use of water from NWSDB is decreasing. Due to the current high tariff structure and the risk involved in obtaining reliable water supply throughout the day for commercial activities, the industrial and commercial sector users have shifted the water supply option towards alternative water sources such as groundwater. However tapping groundwater without any control has serious negative implications on environment. On the other hand the water supply from NWSDB is not guaranteed and in the some he areas supply is restricted to few hours per day. Therefore, it has become an important task to explore low-cost alternative and simple water supply options, which could be managed easily at the institutional/local level.

People of Sri Lanka have centuries old wisdom of harvesting rainfall for domestic needs and agricultural uses. The sophisticated rainwater reservoir system on the top of the rock in Sigiriya fortress complex built in the 5th century is one of the evidences for the wisdom of rainwater harvesting (RWH). Collection of rainwater for domestic use was practiced in government quarters during 1950's and 1960's in ground pits to bridge the water scarcity for 2-3 months. However, this practice was gradually abandoned with the introduction of pipe borne water and tube wells (Ariyabandu, 1999). Traditionally rainwater was collected for domestic use from tree trunks using banana or coconut leaf or arecanut (*Areca catechu)* sheath as gutters, open tank roof water harvesting using bamboo or polythene gutters, use of natural rock cavities and use of domestic containers and barrels and open air collection (Ibid).

In the recent past, there was a revival of rainwater harvesting via institutionalization of the practice with government and NGO interventions. More research has been conducted and technologies have been developed. World Bank funded community water supply and sanitation project (CWSSP) introduced Rain Water Harvesting (RWH) as one of the options of drinking water supply in the two districts; Badulla and Matara. Since then, government and non-governmental organizations promoted this technology throughout the country for domestic needs at various levels of success. It was an innovative project aimed to establish an alternative system of water supply and sanitation delivery in rural Sri Lanka. The project was implemented based on the needs and aspirations of the people through community initiation (Aheeyar, 2001). The project mainly used following technologies to achieve domestic water security at household level. The technologies used included graving water supply systems, shallow dug wells, hand pumps/boreholes and pumped pipe systems. However, these conventional technologies were not suitable to supply safe water for the community living in up hill settlements and some dry zone areas. In hilly areas, groundwater table is very deep and most of the springs and wells dry out quickly during the dry season. Some places in dry zone of Sri Lanka also have water problem for domestic use, particularly those areas in which groundwater sources are not reliable throughout the year. The available water also has disadvantages of sanitary, hardness and high concentration of other elements. Therefore, a technology for rainwater harvesting was proposed by the project and successfully implemented in the up hills and dry zone of Sri Lanka with community participation and contribution.

Urban development Authority Act No. 41 of 1978 was amended as act No.36 of 2007 to include the provision of RWH in the urban settlements and other buildings. Accordingly all development plans should be prepared in keeping with National Rainwater Policy and Strategies and need to incorporate necessary measures for RWH in the drainage site and roof. Therefore, there is a need to conserve water through harvesting of rainfall at homesteads, industries and work places.

Table 1.1: Industries Obtaining Water from NWSDB Schemes

Province	Parameter	Year					
		1999	2003	2004	2005	2006	2007
Western	No. of industries	831	1224	1354	566	578	350
	Consumption (mcm)	3.1	3.20	2.9	1.9	1.3	1.1
Southern	No. of industries	-	166	176	89	93	97
	Consumption (mcm)	0	0.17	0.2	0.1	0.1	0.1
Sabaragamuwa	No. of industries	30	67	74	77	98	95
	Consumption (mcm)	0.01	0.02	0.0	0.0	0.0	0.0
Central	No. of industries	-	118	112	102	90	83
	Consumption (mcm)	0	0.05	0.0	0.0	0.0	0.0
Uva	No. of industries	30	44	45	2	2	-
	Consumption (mcm)	0.04	0.03	0.0	0.0	0.0	-
Eastern	No. of industries	-	35	36	34	34	31
	Consumption (mcm)	0	0.22	0.3	0.2	0.2	0.2
North Western	No. of industries	168	98	103	67	71	163
	Consumption (mcm)	0.06	0.08	0.1	0.0	0.0	0.0
North Central	No. of industries	-	40	40	5	6	3
	Consumption (mcm)	0.06	0.08	0.1	0.0	0.0	0.0
Northern	No. of industries	-	1	2	2	2	2
	Consumption (mcm)	0	-	0.0	0.0	0.0	0.0
Total	No. of industries	1,059	1797	1942	994	974	824
	Consumption (mcm)	3.27	3.85	3.6	2.2	1.6	1.4

Source: Central Bank of Sri Lanka (2008)

The large numbers of day to day activities undertaken in the commercial sectors can be performed using harvested rainfall such as water closet (WC) and urinal flushing, washing and cleaning, and for industrial cooling requirements. There is no specific need for this to be potable quality of water. Findings of a research conducted in UK shows that 63% of daily water use in the office buildings goes to WC and urinal flushing, while canteen use is only 8% (Roebuck, 2008).

The rainwater harvesting technology consists of three main components;

i. Rainwater catchment (Roof or suitable ground surface)
ii. Conveyance system- Gutter system including down pipes or other needed deliver pipelines
iii. Storage tank-Rainwater cistern

In addition to the main components, the technology required accessory components such as filters to ensure the collection of clean water for storage. If the storage tank is constructed on the ground or underground, a water extraction device (water pump) is needed. The main components and accessory components are to ensure collection and storage of rainwater scientifically for the use of potable water needs. Prevention of mixing with other particles such as animals/birds droppings and leaf particles should be avoided to ensure collection of clean water. Therefore precautionary measures are taken to avoid collection of rainwater from roof catchments from the rain during first 30-45 minutes after longer dry periods using first flush device and filter the water to avoid entry of external particles if the water is for potable quality needs.

1.2 Research Problem

Although water need has become a central issue to industries and service sectors which consume substantial quantities of water for processing, washing, cooling purposes and sanitary needs, the potential of harvesting of rainwater has not gained proper attention. Only few commercial ventures and public buildings have incorporated rainwater harvesting in their building premises, but with a large investment. For example David Peiris Motor Company (DPMC) has invested Rs. 13.1 million for rainwater harvesting project since 2005 in their factory premises. Similarly various other public and private sector institutions have made investment for RWH to meet their part of water requirements and also in line with their Corporate Social Responsibility (CSR) to save the environment. The performance of these projects, usefulness of harvested rainwater, economic return to the investment made and the problems and constraints of theses projects are not scientifically studied to date. Therefore it is important to study the performance of the current institutional level RWH facilities in the country with special focus on economic perspectives. The findings of this study are useful to advocate and influence the industrial and commercial sector for the implementation of RWH in their building premises. The outcome is valuable for the country in terms of economic and environmental context and leading way to sustainable development.

1.3 Objectives of the Study

The major objective of the study is to conduct an economic appraisal for institutional level rainwater harvesting projects implemented in selected areas. The specific objectives of the study are;

1. To assess the suitability of rainwater harvesting as an alternative option for industrial/commercial sector and the public institutions
2. To find out the return to the investment made for rainwater harvesting projects (IRR, cost-benefit ratio and payback period etc.)
3. To document the experiences gained in rainwater harvesting in the study locations (strengths, weaknesses and lessons learned)
4. To make recommendations to promote rainwater harvesting at institutional level
5. Advocate and influence the relevant stakeholders on the lessons of experiences

1.4 Study Sites

The following sites were selected for the detail study considering the service and industrial sectors, differences in locations and most importantly willingness of the private sector institutions to share the information and experiences.

1. Rainwater harvesting project at the factory premises of David Peiris Motor Company (DPMC) –Private sector Industrial use located in Piliyandala, Colombo District
2. Rainwater utilization facility at Brandix Casual Wear (pvt) Ltd, Seeduwa Site -Private sector Industrial use located in Seeduwa, Gampaha District
3. Rainwater Harvesting facility at Millennium IT campus- A privately owned, service sector located in Malambe, Colombo District

1.5 Study Methodology

The study is mainly based on the secondary data maintained by the selected projects and the qualitative information collected through rapid methods such as key informant interviews and focus group discussions. The collected data was analyzed using descriptive methods and project appraisal techniques such as cost-benefit analysis (CBA), Net present value (NPV), Internal rate of return (IRR) and pay back period.

NPV is an indicator of how much value an investment adds to the firm. NPV is used in capital budgeting to analyze the profitability of an investment or project. NPV compares the value of a Rupee today to the value of that same Rupee in the future, taking inflation and returns into account. If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the project should probably be rejected because cash flows will also be negative.

IRR of on an investment is the annualized effective compounded return rate that can be earned on the invested capital. IRR indicates the financial attractiveness / viability of capital intensive projects or investments.

NPV, IRR, BCR and pay back period are calculated as follows.

$$NPV = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

$$BCR = \sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t} / \sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}$$

B_t	=	Benefit in year t
C_t	=	Cost in year t
t	=	1,2,3, ... n
n	=	life time of the Rainwater harvesting system in years
i	=	opportunity cost of capital/ rate of interest
IRR	=	Interest rate at which NPV become zero
Pay back period	=	Number of years need to recover the investment cost of rainwater harvesting system by its net return

Sensitivity analysis of the investments was also carried out in two different scenarios.

I. 10% percent increase in total cost
II. 10% percent decrease in total benefits

CHAPTER TWO

Institutional Level Rainwater Harvesting: Some Experiences

2.1 Experience of RWH in Sri Lanka

Rainwater collected from rooftop and surface run off is being utilized in Sri Lanka for domestic use, agricultural activities and industrial uses. CWSSP is the main project involved in the construction of household level RWH tanks primarily for household water needs. There are three types of domestic tanks widely used in Sri Lanka for RWH.

i. Underground brick dome tank
ii. Above ground Ferro cement tank
iii. Ferro cement partial underground tank

Runoff tanks also have been constructed primarily in dry zone parts of Sri Lanka for agricultural purposes. There are two types of Run off tanks in Sri Lanka.

i. Unlined Runoff ponds *(Pathaha)*
ii. Lined Runoff tanks (*Pokuna*)

The detail of runoff tanks constructed in Sri Lanka for agricultural purposes is given in Table 2.1. Rainwater for commercial or industrial use is being implemented in some locations in order to reduce the cost of water for commercial and industrial sectors, and to reduce the risk of water supply and preserve the environment. The list of RWH systems constructed for industrial/ commercial use is given in Table 2.2.

Rainwater Harvesting at Sabaragamuwa Provincial Council New Building

A new six storied building complex for Sabaragamuwa provincial council was constructed in the year 2002/2003. Roof water harvesting was planned at the designing of the building utilizing the roof areas of 19m x 44m and 30m x 39m size. Two rainwater tanks with the capacity of $22m^3$ (3.3mx5mx1.2m) each at the 6^{th} floor and an underground well (sump tank) with the capacity of $60m^3$ were constructed. Zinc-aluminum metal sheets roof was used to collect rainwater (Gunathilaka, and Panagoda, 2004).

Sabaragamuwa provincial office has a workforce of 400 and daily visitors of around 200. RWH is considered as one of the feasible options for the new building in terms of financial and ecological perspectives. Selected labourers were given training on management of roof catchment, cistern and other components and periodical maintenance of the tanks.

Total water available from roof catchments is 8.4 million liters per year and the project is expected to harvest 4.2 million liters per year. It was estimated that proper functioning of the RWH system would provide a monthly saving of about Rs. 10,000 for the institution from monthly water bill at the water tariff prevailed at that time. The awareness programme and capacity building was provided by Lanka Rainwater

Harvesting Forum (LRWHF) and technical support was given by the University of Moratuwa and ICTAD (ibid). However, the rainwater harvesting in the complex is not practiced despite this massive investment and the high potential mainly due to lack of awareness and negligence of the officials in the location.

MAS Intimate Thurulie- Thulhiriya

MAS Intimate Thurulie is a casual wear factory located in the North Western province of Sri Lanka. It is an eco-friendly plant constructed in 2008. The main eco-friendly aspects are, firstly the plant consume 40% less energy due to installation of energy efficient lighting, utilization of solar power and evaporative cooling system. Secondly the plant consume 50% less water compared to similar size of plant through rainwater harvesting and using dual flush toilets and low flow water fixtures.

Rainwater that falls on the roof catchment is collected and channeled through gutters to the overhead storage tanks. The roof catchment is made with Zinc/ Aluminum sheet, which is most suitable for RWH. The total roof area is 4056 m^2. The stored water is used by gravity for toilet flushing. There are five rainwater tanks with a total capacity of 150 m^3. Rainwater stored is expected to cover ninety percent of flushing needs considering average rainfall pattern of the area.

A large surface pond is available within the site as a component of landscaping, which collects overflow water of rainwater storage tanks and the surface runoff. The pond replenishes the groundwater table. Overflow from pond feeds the Ma-Oya River. The water requirements of the plant are drinking and sanitation needs for about 800 workforces for around 22days per month, cooling system operation, cleaning of the plant and gardening. All the water needs are met by pumping water from Ma-Oya and purified to approved standard within the factory premises except for toilets flushing needs.

David Peiris Motor Company (DPMC)-Madapatha

DPMC constructed a 500 m^3 capacity rainwater tank in 2003 and a 275 m^3 capacity supplementary tank in 2005 at factory complex I (Three wheeler assembling plant). With the experience gained in RWH, the company constructed another large scale 4000m^3 capacity tank at factory complex iv (two wheeler assembling plant) in year 2006 (Dias, 2004). The system has been designed to collect rainwater that falls on the factory and office buildings' roofs and rainwater that falls on the ground (surface runoff water) which is directed to the collection tanks through a channel network. The collected water is purified through various methods, such as aeration by high pressure jet, flocculation, settling in sedimentation tank, filtering in rapid gravity sand filter, use of activated carbon filter, disinfections by adding Sodium Hypo- chloride solution, filtering the water in micron filter and use of UV Sterilizing method.

Millennium IT Campus- Malambe

Recently constructed Millennium IT campus (MITC) has rainwater harvesting facilities to meet the part of water demand for toilet flushing and landscaping. Water demand for current occupation of 300pax for toilet flushing and landscaping is $22m^3$/day and $88m^3$/day. About $5,525m^2$ of roof area and three storage tanks are used to collect the rainfall for toilet flushing and $1,450m^3$ surface runoff tank is used to collect surface runoff for part of the landscaping water requirement (Kuruppu, 2007).

Brandix Casual Wear- Seeduwa

A new rainwater harvesting system was designed at Brandix Casual wear factory under their Green building project. The project consisted of two components namely; collection and storage of roof water for toilet flushing and landscaping and diverting roof water for groundwater recharge through twelve bore well type percolation pits. The entire system was aimed to reduce at least 40% of potable water drawn from groundwater aquifer and recharge the subsurface reservoir.

A number of other institutions in the country are practicing rainwater harvesting for various non potable water needs. In addition quite a number of agencies have prepared proposals to develop rainwater harvesting facility to achieve water security, part of CSR and to receive international manufacturing standards such as ISO 14000 and LEEDS certificate.

Table 2.1: Runoff Tanks used for Agriculture (by 2008)

District	Number of Units	Year
Puttalam	238	2007
Hambantota	329	2000-2008
Kurunegala	135	2000-2001,2004
Anuradhapura	128	1998-2002,2003
Moneragala	533	2001-2007

Source: Data maintained by LRWHF and Authors' survey data

Table 2.2: Industrial/Commercial/Institutional Use of Harvested Rainwater (by 2008)

District	Location
Colombo	Millennium IT campus, Malambe
	David Peiris Motor Company, Piliyandala
Gampaha	Brandix Casual wear Factory, Seeduwa
	Damro PVT Ltd, Nittambuwa
Rathnapura	The Sabaragamuwa Provincial Council, Ratnapura
Kegalle	MAS Intimate Thurulie, MAS Fabric park, Thulhiriya
Kalutara	CKT Apparel- Mihila (Hydramani Group), Agalawatta

Source: Authors survey data and LRWHF

2.2 Experiences of Rainwater harvesting in Industrial and Service Sectors in Other Countries

Rainwater harvesting is one of the popular options in supplying safe drinking water in different parts of the world. Rural water supply system plan implemented in Thailand has constructed nearly 9.0 million rainwater harvesting jars to provide water security for drinking purposes. Rainwater harvesting has become the main source of water supply in countries such as Maldives, Caribbean Islands, Papua New Geniua, Hawaii and Latin America. RWH is very popular in Gibraltar, Bermuda and other Islands where groundwater is contaminated by salt water intrusions and runoff in streams is minimal. Rainwater has been harvested and stored for various needs of industrial and service sectors in different countries. These countries have formulated new policies or amended the existing policies to promote rainwater harvesting at households, public and commercial buildings.

Germany: German cities amended their drainage by laws, to stop high-cost drainage into the municipal storm sewer system, and to return more rainwater to the natural cycle. It thus complies with the requirements of the revised water laws which have the intention of having less rainwater from a property after construction than before construction. For that reason, the rainwater draining into the municipal storm sewers is subject to an annual lump-sum charge per square meter of sealed surface, payable by the occupants. It is therefore an obvious benefit to collect precipitation, to percolate it and to avoid paying this fee. A grant of US$ 600-1200 per household is available in Germany along with further subsidy of US$ 3 per m^2 of roof area draining to any tank linked to seepage well. On the basis of this subsidy, saving in water charges (US$ 0.56/m^3) and an annual rainwater drainage fee waiver of US$ 1.30 per m^2, the pay back period for investment in a tank seepage well system constructed at a new house was estimated to be 12 years (Wessels, 1994). Even without the subsidy and constructing a system at an existing house, the investment would be recouped in 19 years. Costs and the return period on investment would be greatly reduced if households contribute some of the labour requirement themselves (Gould, 1999).

Rainwater harvesting facilities have been used for the industrial cooling process in the new Hüttinger industrial building in Freiburg, Germany since 2006 (König, Klaus W., et-al., 2008). Large scale rainwater harvesting is widely practice in Germany in vehicle service stations and bus companies to clean the vehicles. In Berlin, rainwater draining from 5000m^2 roof area is collected and stored in 900m^3 capacity series of tanks at Sony center. The harvested water is used to feed automatic sprinkler system, toilet flushing and fire fighting system for the office tower of German Federal Railway (Water 21, 2003).

Severe drought conditions prevailed in Germany during 1992 and 1993 which curtailed the supply of potable water for Marbach tennis club for irrigation. It was very difficult to meet the irrigation requirement of the tennis court and had to seek alternative water sources locally to fulfill the needs. One of the easiest ways was to collect the rainwater drained from the club house roof top to irrigate the courts. However the collection from the roof was not sufficient to meet the demand. Then, the rainwater drainage system which belonged to adjacent municipal and indoor swimming pool was connected to the rainwater storage tank (Water 21, 2003).

India: Some of the Municipal Corporations in India have already introduced bylaws to make roof water harvesting as mandatory for buildings having roof area larger than specified norms. Through an ordinance titled Tamil Nadu Municipal Laws ordinance, 2003, dated July 19, 2003, the government of Tamil Nadu has made rainwater harvesting mandatory for all the buildings, both public and private, in the state. Since June 2001, the Ministry of Urban affairs and Poverty Alleviation has made rainwater harvesting mandatory in all new buildings with a roof area of more than 100 sq m and in all plots with an area of more than 1000 sq m that are being developed in New Delhi. Rainwater harvesting has been made mandatory in all new buildings with an area of 1000 m^2 or more in Uttar Pradesh, while it is mandatory for all the new buildings with an area of 300 m^2 in Hyderabad (Andra Pradesh), India.

The roof top water harvesting is of special importance in case of institutional buildings in India, which have large roof area and space for installation of groundwater recharge structures. One such example is the rainwater harvesting structures installed in the building of Ministry of Water Resources, New Delhi, which has a roof area of 3110m^2. It was able to collect a recharge of 3000m^3 during the rainy season of year 2000 (Sharma and Smakhtin, 2006).

Korea: The first institutional community rainwater harvesting facilities in Korea were installed in the four stadiums used for the soccer World Cup 2007 under the new regulations in the "Water Law". Rainwater was collected from the roof and stored in a tank, after treatment. The rainwater has been used for toilet flushing, gardening or cleaning purposes. A 200 m^3 concrete rainwater tank is installed at the new dormitory constructed in Seoul National University and the rainwater had been used for toilet flush and landscaping to one of the buildings (Mooyoung Han, 2008).

A Roof water harvesting project has been incorporated at 'Star City"- a major real estate development project with more than 1,300 apartment units in Gwangjin-gu, a district in eastern section of Seoul, Korea. The basic design idea for the Star City rainwater harvesting system was to collect up to first 100 mm of rainwater that falls on the complex and to use the collected rainwater for gardening and public toilets. All together the rainwater harvesting system can store 3,000 m^3 of water in three separate tanks with a total floor area of 1,500 m^2. The construction cost for the rainwater harvesting system was approximately US$ 450,000. Based on the half year operation of the system, it was expected the water conservation to be approximately 40,000 m^3 per year, which is about 67% of the annual amount of rainfall over the Star City complex. Considering the average cost of supplying one cubic meter of tap water in Korea is about seven U.S. dollars, the saving is significant to the city, while the residents will save about US$ 80,000 per year in reduced payment for water. This cost saving will increase as the price of water increases future along with the rising cost of energy. Considering the expected water saving during the operation, the cost of the project is predicted to be recovered in less than eight years.

Japan: More than 60 municipalities in Japan have subsidized the installation of rainwater tanks. It has been estimated that four member families living in Tokyo needs average of 0.2m^3 of water per day for flushing toilets and watering garden.

A number of interesting demonstration projects has been developed in Japan to illustrate the potential of rainwater harvesting. At the main Sumo wrestling stadium in the Kokugikan, the rainwater runoff from the 8400m^2 roof areas is diverted into a 1000m^3 underground tank for the use of toilet flushing and the cooling system of the building. About 750 private and public buildings in Tokyo (Source: http://rainwaterharvesting.org/international/tokyo.htm) have already introduced rainwater collection and utilization systems. Rainwater utilization is now flourishing at both the public and private levels. According to one estimate, the collection of total rainwater runoff from the Tokyo area reveals that this is greater than the total water consumption of the metropolis which could theoretically become self-sufficient in water (Gould, 1999).

Australia: Although the East coast of Australia gets lots of wet weather, the long-term sustainability of water is not secure especially in heavily populated cities such as Sydney. Therefore the Government of Australia has started rainwater harvesting in the top of major state buildings such as the Parliament House, State Library and Sydney Hospital. These hold 60,000 litres each, but the water is fed into St James Lake, which is an old unused railway tunnel under the city. About 1km long, 10m wide and 5m deep, it's expected to hold over 17 million litres of water, that will in time be pressed into service for the city's gardens and toilets, instead of using vital drinking water (Rainwater Digest, August 2009). The total estimated budget of the project is Aus$110,000. This is one of 72 storm water harvesting, groundwater and recycling projects costing the state around Aus $40 million.

China: Since 2006, Beijing has constructed over 1,200 rainwater collection projects, with a capacity of 45 million m^3. These were set up by at businesses, parks and communities to collect and recycle rainwater, which can be used to wash toilets and cars, as well as for landscaping. According to statistics from Beijing Water Authority, first 8 months of 2009, 24.5 million m^3 of rainwater, had been stored in Beijing (http://www.probeinternational.org/beijing-water/rainwater-collection-projects-gather-245-million-cubic-meters-rainwater-beijing).

CHAPTER THREE

Institutional Level Rainwater Harvesting in Sri Lanka: Description of Case Study Sites

3.1 Rainwater Harvesting at David Peiris Motor Company – Madapatha, Piliyandala

David Peiris Motor Company (DPMC) commenced a two wheeler and three wheeler assembling plant (complex 1) at Jampuraliya, Madapatha, Piliyandala, 30 km south of Colombo in 1994. Water requirement of the plant was met by two dug wells and a tube well installed within the premises. However, the groundwater condition was not conducive to draw water throughout the year; especially it was a problem during dry seasons. The company had to depend on water bowsers of National Water Supply and Drainage Board (NWSDB) to fill the gap in the water demand at a higher cost though the supply was unreliable. The company experienced a considerable risk in achieving the production targets due to scarcity of water during some parts of the year.

Due to overwhelming demand for two wheelers and three wheelers, there was a huge need to expand the facility. However, scarcity of water was one of the primary constraints in the expansion process. Therefore the management of the company decided to implement a rainwater harvesting project to meet the part of water demand and to manage the risk involved in the disruption of operations. The major aim of the project was to meet the water needs of employees for bathing and sanitation, and floor cleaning and gardening. The project was also a part of the company's environment friendly practices under its CSR.

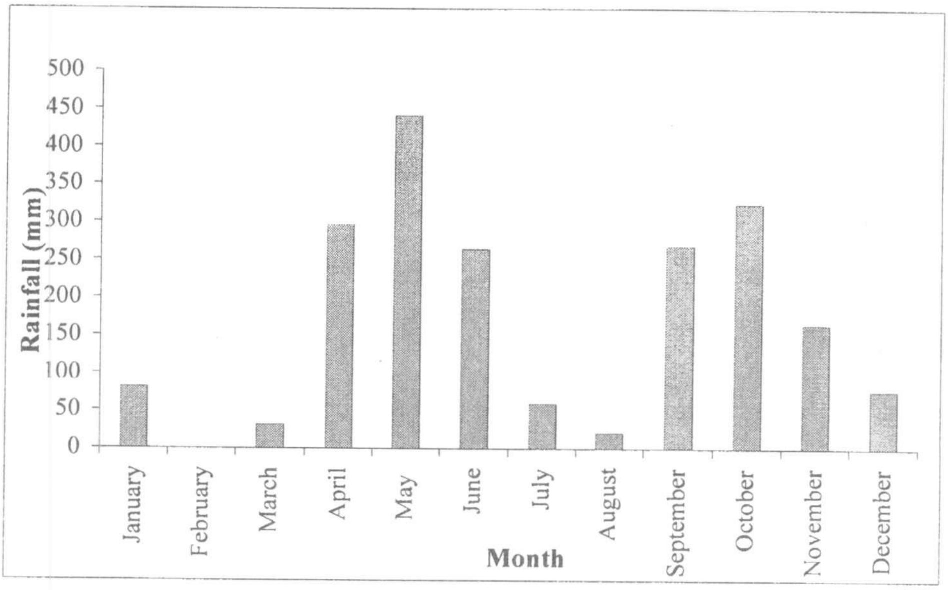
First phase of rainwater harvesting project at the site was completed in 2003, which consisted of $500m^3$ capacity storage tank. In 2005, another supplementary storage tank ($275m^3$) was constructed to meet the growing water demand in the expanded assembling plant. The project was designed to collect every drop of rainwater collected from roof catchments and paved ground surface through the well connected roof gutter system to underground drainage system.

The company built a new assembling plant (complex IV) for two-wheelers at Shylathalaramaya Road, Madapatha in 2006 where it was planned to meet all water requirements except drinking water needs through rainwater harvesting. The plant has a water collection tank with a capacity of $4000m^3$. An abandoned quarry has been developed as the water collection tank.

3.1.1 Rainfall pattern in the area

As Madapatha is located in the wet zone, the area received rainfall throughout the year. However, the amount of rainfall received during December to March and July/August is comparatively less (Figure 3.1).

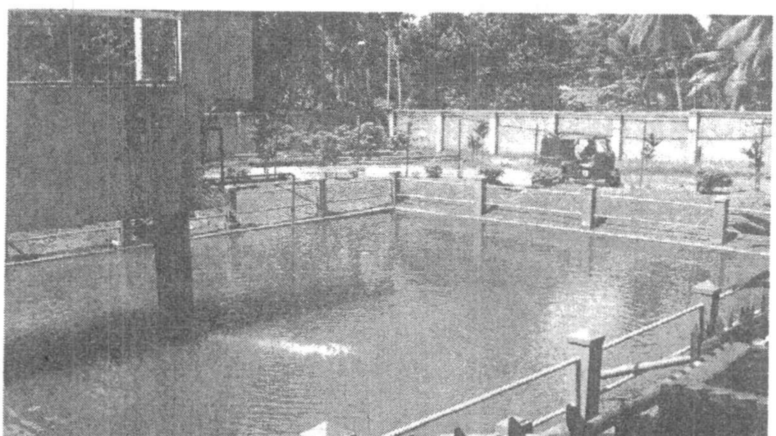
Figure 3.1: Monthly Rainfall at Complex-I (2007)



Source: David Peiris Motor Company (Official communication, 2009)

Rainwater is collected from both roof catchments of the factory and office buildings and ground surface and delivered to open air collection ponds (Figure 3.2) through properly designed drainage lines. The roof area available for rainwater harvesting at complex-I is 5,800 m^2 and total ground area is 21,000 m^2. The collected water is treated through a series of process namely aeration by high pressure jet, flocculation, settling in a sedimentation tank, use of rapid gravity sand filter, activated carbon filter and micron filter, disinfection by sodium hypo-dichloride solution and UV sterilizing. The chemical and biological tests of the treated water quality show the higher standard than potable water quality standards.

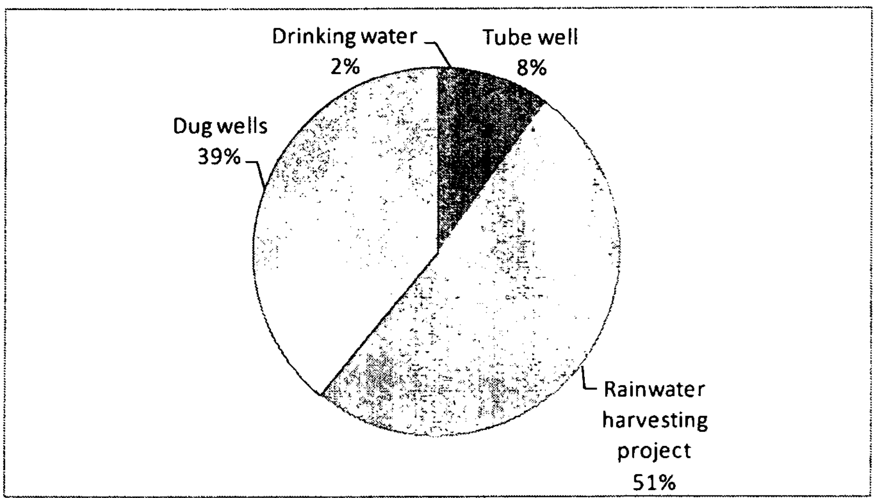
Figure 3.2: Rainwater Collection Pond at Complex-I of the DPMC



3.1.2 Water Demand and Supply

Current water demand is met by rainwater harvesting, two dug wells and a tube well and bottled water purchased from the market. The degree of use of different water sources for various water requirements in year 2007 at Complex one of the factory is illustrated in figure 3.3. Over 50% of annual water requirements at complex one is met by rainwater harvesting which has greatly helped to reduce the risk element in factory operations and minimize the pressure on groundwater in the area. The total water requirement at Complex IV except. drinking water. is met by rainwater harvesting. The average daily water demand for sanitation, hygienic requirements, cleaning of floors and gardening is about $20m^3$. If the average number of working days per month is 25 days, the monthly water demand is $500m^3$ excluding drinking water needs.

Figure 3.3: Water Consumption from Different Water Sources-Complex-I, DPMC



Source: Dias, 2004

3.1.3 Worker Perceptions on Rainwater

The workers were reluctant to use the harvested rainwater for bathing since part of the collected water is form ground surface. Therefore the company had to do much in changing the attitudes and behaviours of the workforce to familiarize with the rainwater. The company has adopted very thorough treatment process as indicated earlier than the actual requirement for cleaning and sanitation. The executive officers and other top management officials also used the treated rainwater for bathing at the initial stages aiming to change the attitudes of the workforce. This has been very successful in changing the worker perception on the quality of harvested rainwater. At present the workforce is primarily dependent on rainwater for their sanitary requirements.

3.2 Brandix Casual Wear (Pvt) Ltd, Seeduwa

The Brandix Casual Wear (Pvt) Ltd located at Seeduwa, north of Colombo, was another site selected for the detailed study. The 30 year old factory was re-designed to become world's first apparel green manufacturing facility to be rated platinum under the Leadership in Energy and Environmental Design (LEEDS), Green Building Rating System of the US Green Building Council (USGBC). The 130,000 square-foot Brandix Eco-center received LEEDS award in 2008 considering its achievement in 46 percent low energy consumption, Zero solid waste to landfill, 58 percent reduction in water consumption and 80 percent reduction in Carbon emissions. The plant also clinched a gold award at the National Cleaner Production Award 2008 in recognition of its eco-friendly production practices.

According to the company management, eco-friendly manufacturing not only helped to achieve quality environment and fulfill corporate social responsibility, but also assisted to cut costs and improve efficiency.

Before the commencement of eco-friendly manufacturing in 2008, water requirement for the industry was primarily met by tube wells installed within the premises. However, they had experienced water scarcity during the dry months and were forced to purchase water from NWSDB supplied by bowsers while creating enormous pressure on groundwater. The past records show that, the purchase of water per day during dry months is around 20,000-25,000 liters per day, though it is unreliable in terms of timeliness of supply.

Under the Green building project, following two types of rainwater harvesting and utilizing techniques were implemented aiming at reducing at least 40% potable water drawn from groundwater.

1. Artificial re-charge of groundwater:
The technique of artificial re-charge of groundwater was designed to augment groundwater aquifer through bore well type percolation pits constructed at the tube well feeding zone. This was accomplished by connecting outlet pipe from rooftop to the percolation pits. The past experiences show that artificial re-charge has helped to enhance the sustainable groundwater yield conservation and storage of excess roof runoff water for future requirements and improve the quality of existing groundwater through dilution.

The benefits of the re charge well have been experienced not only by company , but also the neighbourhoods of the factory premises through increase in groundwater level in the domestic dug wells. In the past, the company had to purchase water from NWSDB bowsers during dry seasons due to drying up of tube wells, but this was not the case after the installation of artificial re-charge wells.

2. Rainwater harvesting from roof catchment and storage in underground storage tank for reuse:
The area of the roof catchment is 2240m^2. The water collected from roof gutters is diverted to collection tank. The company decided to construct an underground

storage tank instead of over ground or open air tank in order to maintain the greenish area within limited space available for the factory to meet the LEEDS standard (Figure 3.5). Based on rainfall pattern in the area (Figure 3.6), available land space and the site conditions, 115m^3 capacity storage tank was built to collect and store the rainwater harvested. The project proposal estimated an annual rainwater collection of 10,500m^3 with these facilities.

Rainwater collected in the roof catchment is channeled through a silt pit and a wire mesh prior to entering the storage tank in order to remove sand and other debris. The collected water is being used for toilet flushing and landscape requirements after a series of filtering and disinfection system. Activated Carbon filter, Sand filters and Chlorine disinfection are used in the water treatment process despite the water is used for non potable needs.

Figure 3.4: Groundwater Recharge Pit at Brandix Seeduwa Plant

Figure 3.5: Underground Rainwater Storage Tank with Greenish Ground Cover

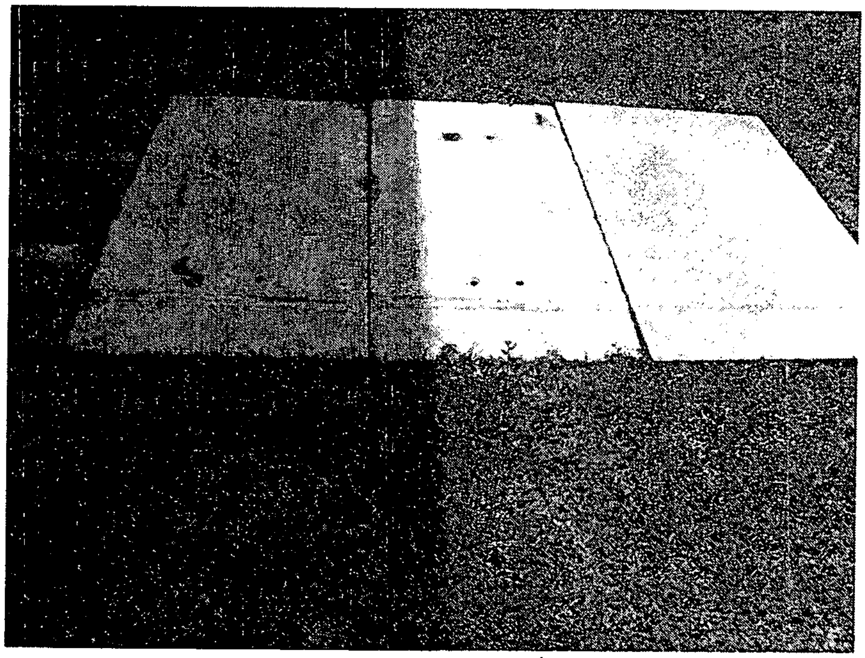
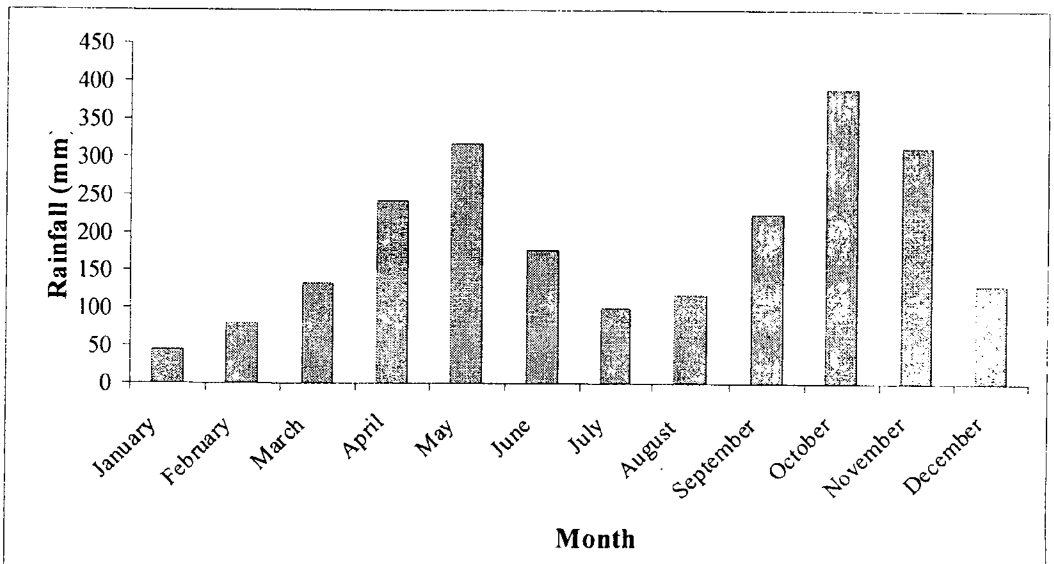


Figure 3.6: Average Monthly Rainfall (1960-1990), Katunayake



Source: Rerecords maintained by Brandix (Official communication, 2009)

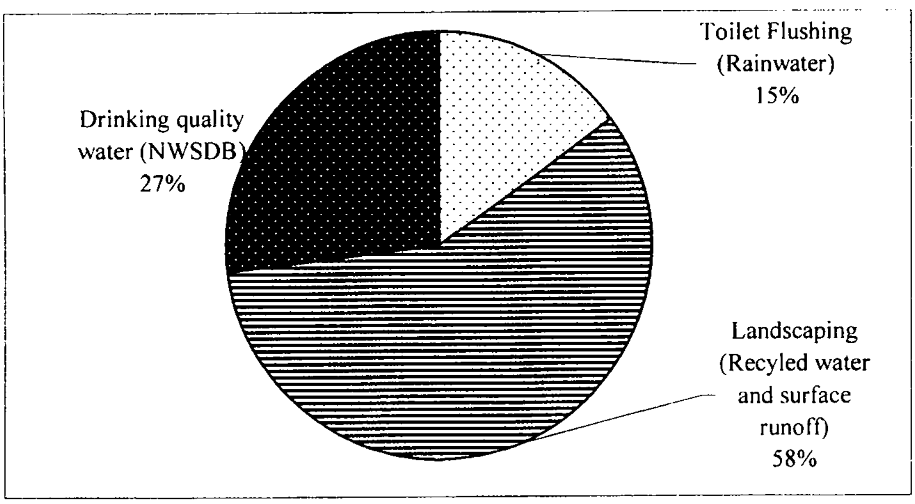
3.3 Millennium IT Campus (MITC), Malambe

MITC is a state of art information technology training institute located at 16 km North of Colombo. The campus has 12,000 m^2 developed facility in a 6.5 ha sloping land site. The current occupation in the campus is around 300 pax. The present water demand for drinking, wash basins, showers and swimming pool is totally met by NWSDB pipe water supply. The majority of water need for toilet flushing is designed to meet by rainwater harvesting through 5,525m^2 of roof of three major buildings and storing in three ponds with a volume of 2,315m^3. Water for landscaping is being obtained by recycling of waste water and stored surface runoff water. The current water demand composition at the site is illustrated in Figure 3.7.

The demand composition and supply options indicate that millennium IT Campus has been designed to meet 75% of its water demand through rainwater harvesting and recycling of black and grey water of the campus to a quality suitable for landscaping.

Storage ponds are constructed using High Density Poly Ethylene (HDPE) foils and are finished with cement block work. Rainwater collected is filtered through a sand filter and chlorinated to improve the quality though it is solely used for toilet flushing and gardening. Toilets have dual pipe system in order to incorporate back up water supply from NWSDB.

Figure 3.7: Water Demand Composition at Millennium IT Campus



Source: Kuruppu (2005)

Figure 3.8: Rainwater Storage Tank at Malambe IT Campus

CHAPTER FOUR

Economic Analysis

4.1 Estimation of Project Costs and Benefits

With respect to institutional rainwater harvesting systems, the issues of return to investment and economic feasibility are crucial, especially in the context of commercial and private sector involvement. The main question is that, do the benefits associated with the rainwater harvesting projects justify the investment? However, it should be noted that comparing the cost-benefit of rainwater harvesting system on equal basis with other feasible alternative water supply options usually has an inadvertent negative bias. For instance, in standard economic analysis of pipe born water supply project development through damming a river, usually ignores the cost of downstream effects and other externalities such as ecological services provided by the river, and therefore, the final project cost is underestimated.

Cost Component:

1. Capital cost of rainwater harvesting systems (cost of sump, plumbing system, booster pump or normal water pump, and treatment system)
2. Cost of operation and maintenance of rainwater harvesting system including treatment cost (if any)

Benefits:

1. Value of water savings equal to NSWDB water tariff rate or cost of bowser water supply by NWSDB depending on the availability

4.2 Assumptions

1. The roof material used in the building design (Zinc-Aluminum sheets) is satisfactory for the rainwater harvesting
2. Life cycle of the rainwater harvesting system is 30 years
3. A separate plumbing (dual pipe system) is needed to convey rainwater from the storage tanks to toilet/ sanitary systems within the building
4. The discount rate was taken as 7% as it is equal to average international borrowing rate
5. Construction cost of rainwater harvesting system was converted to value of 2008 using GDP deflators
6. The extended environmental benefits of rainwater harvesting such as benefit of flood risk reduction and the reduced pressure on groundwater resources and related environmental benefits were omitted in the analysis due to lack of data

4.3 Case Study 1: Brandix

Rainwater Use

No. of working days/month	= 25
No. of working days/year	= 300
Average daily rainwater use	= 13.5 m^3 (15% of total water requirement)
Total annual rainwater use	= 13.5 x 25 days x 12 months = 4050 m^3

Cost items:

i. Capital investment (construction of tank, plumbing and other accessories)		=Rs.2,764,905
ii. Maintenance cost per annum		=Rs. 6,000
iii. Water treatment cost (chemical and electrical)		=Rs.11.75/m^3

Benefits

Reduction in monthly water supply fixed service charge		=Rs. 2,500
Annual saving of water supply service charge		=Rs. 30,000
Annual saving from water usage tariff	=Rs.53 x 4050	=Rs.214,650
Total saving due to rainwater use	=Rs.30,000 + =Rs.244,650	Rs.214,650

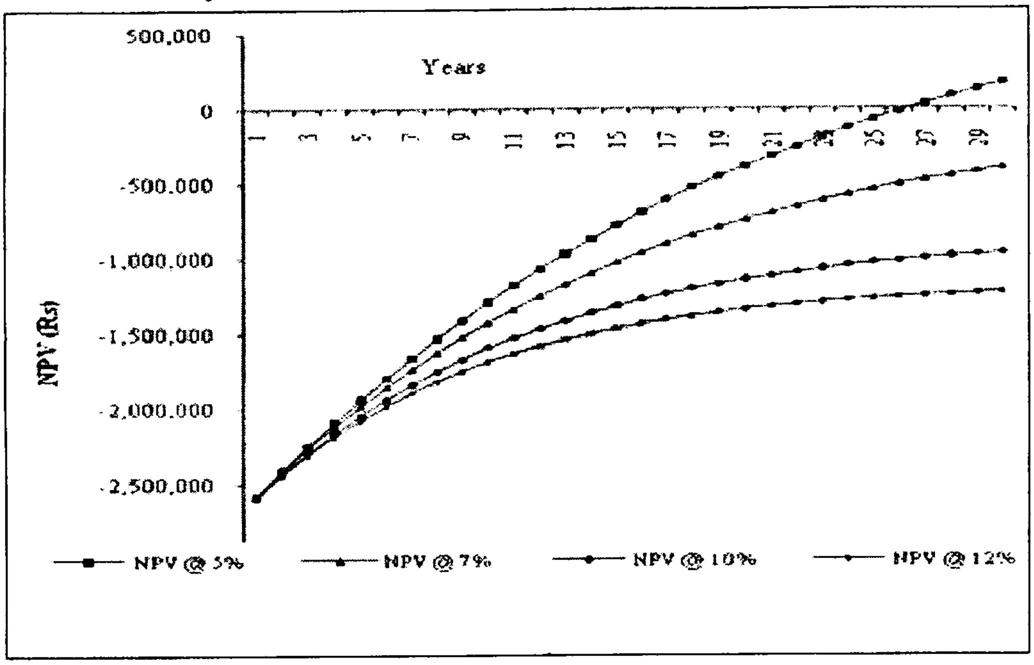
The findings on NPV, IRR and benefit-cost ratio at the interest rates of 5, 7 and 10 percent are given in table 4.1.below:

Table 4.1: Results of the Economic Analysis- Brandix Rainwater Harvesting Project

Items	Interest rate		
	5%	7%	10%
Net present value	172,490	-394,010	-963,950
IRR		6%	
Benefit-cost ratio	1.05	0.89	0.71
Pay back period (years)	27	33	46

The results show that the project is not economically viable at the present scale except when calculated with 5% interest rate. The main reasons for the non viability of the rainwater harvesting system at Brandix is the higher investment cost incurred for constructing the storage system and other related accessories for a small size of storage system (115m^3). However it should be noted that the investment made in the rainwater harvesting storage tank and the treatment system are simultaneously used for wastewater storage and treatment as well. It is difficult to separate the cost and benefit component of waste water treatment and usage from rainwater harvesting cost-benefit analysis. Therefore the actual benefit of the total investment is much higher than the estimated figures in this analysis made solely for rainwater harvesting.

Figure 4.1: NPV under Different Interest Rates- Brandix Rainwater Harvesting Project



4.4 Case Study 2: Millennium IT

Rainwater Use

I	Current average daily water requirement	= 72 m^3
II	Average rainwater use per day	= 22 m^3
III	Rainwater use per annum	= 24 days * 10.5 months * 22 m^3
		= 5544 m^3

Cost Items:

I Capital investment cost in 2000 = Rs. 620, 000
(Tank construction, plumbing, filter system and booster pumps)
Total investment cost at 2008 prices = Rs. 1,408,423
Capital cost at year 2008 = C_t

$$C_t = {PI_t}/{PI_p} \times C_p$$

Plt = price index of the time construction cost is converted to current value
PI_p = price index of the time of construction
Cp = construction cost

II	General Maintenance cost	=Rs. 6, 000/year
III	Operational cost (Electricity)	=Rs.13.8* 8 hrs/ day* 24 days/ month *10.5 months
		=Rs. 27,821 per year
IV	Booster Pump repair cost	=Rs. 2,000 (once in 5 years)
V	Restoration of Filter media	=Rs. 60,000 (once in 8 years)

Benefits:

Reduction in water tariff (per annum) = Rs.53 * 5544 m^3

= Rs.293, 832

Reduction is monthly NWSDB service charge = 0

(from 1000-2000 m^3 use no difference in Monthly service charge)

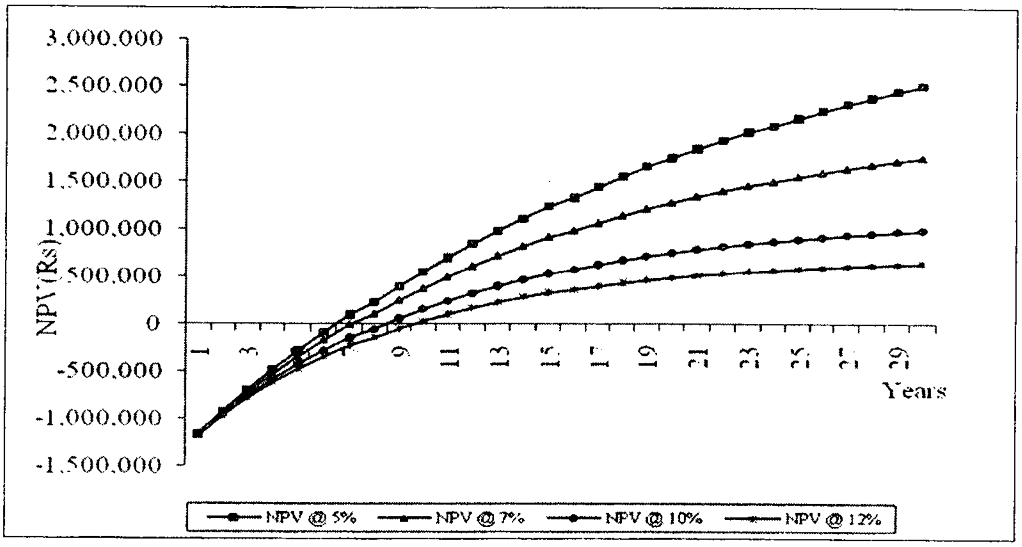
Economic analysis of the project shows the following results (table 4.2):

Table 4.2: Results of the Economic Analysis- Rainwater Harvesting at Millennium IT

Items	Interest rate		
	5%	7%	10%
Net present value (Rs.) (NPV)	2,501,965	1,748,584	991,692
Internal rate of return (IRR)	18%		
Benefit-cost ratio	2.24	1.92	1.56
Pay back period (years)	7	7	9

The project has a potential of providing a financial benefit of Rs.1.7 million in 30 years at 7% interest rate. The pay back period of the investment is 7 years.

Figure 4.2: NPV under Different Interest Rates- Rainwater Harvesting at Millennium IT



The results of the sensitivity analysis of the project in two different scenarios indicate that (Table 4.3), BCR and NPV decrease with the increasing discount rate, but yet project remains viable at all discount rates under both scenarios. The analysis also shows that reduction in NPV and BCR are much higher when the expected benefits are reduced by 10% than expected cost increase.

Table 4.3: Sensitivity analysis of NPV and BCR – Millennium IT Campus

Description	Scenario – 1 10% increase in cost	Scenario – II 10% decrease in benefit
NPV		
5% discount rate	2284849	2024098
7% discount rate	1549949	1366370
10% discount rate	810048	704527
12% discount rate	470620	401074
IRR	16%	
BCR		
5% discount rate	2.02	1.99
7% discount rate	1.74	1.71
10% discount rate	1.41	1.39
12% discount rate	1.25	1.23

4.5 Case Study 3: David Peiris Motor Company

Rainwater Use:

Average daily rainwater use = 20 m^3

Average number of working days per month = 25

It was assumed, that rainwater was available during a period of ten months

Average annual rainwater use = 20 * 25 * 10 = 5000 m^3

Cost estimation:

1. Construction cost
   - Construction cost of main rainwater collection tank and plumbing system in 2003 =Rs. 4.7 million
   - Cost of water treatment system (test net, UV filter) =Rs.0.3 million
   - Construction cost of supplementary tank and plumbing in 2005 =Rs.4.2 million
   - Total investment cost at 2008 prices =Rs.15.06 million
2. Operation and maintenance cost (O&M)
   - Water treatment cost (chemical and electricity) =Rs.12.5/ m^3
   - Water treatment cost per annum =Rs. 12.5 * 5000 m^3 =62, 500
   - Other maintenance cost (Monitoring, repairing, laboratory) =Rs.6000/annum
   - Total O&M cost =Rs.68,500/annum

Benefit estimates:

If there is no rainwater, the alternative operation for the site is supply of water through NWSDB bowsers.

The cost of water bowser = Rs.2634/ bowser (7.5 m^3)

Cost of unit of water = Rs.351.22/ m^3

The price for unit value of rainwater = Rs.351.22/ m^3

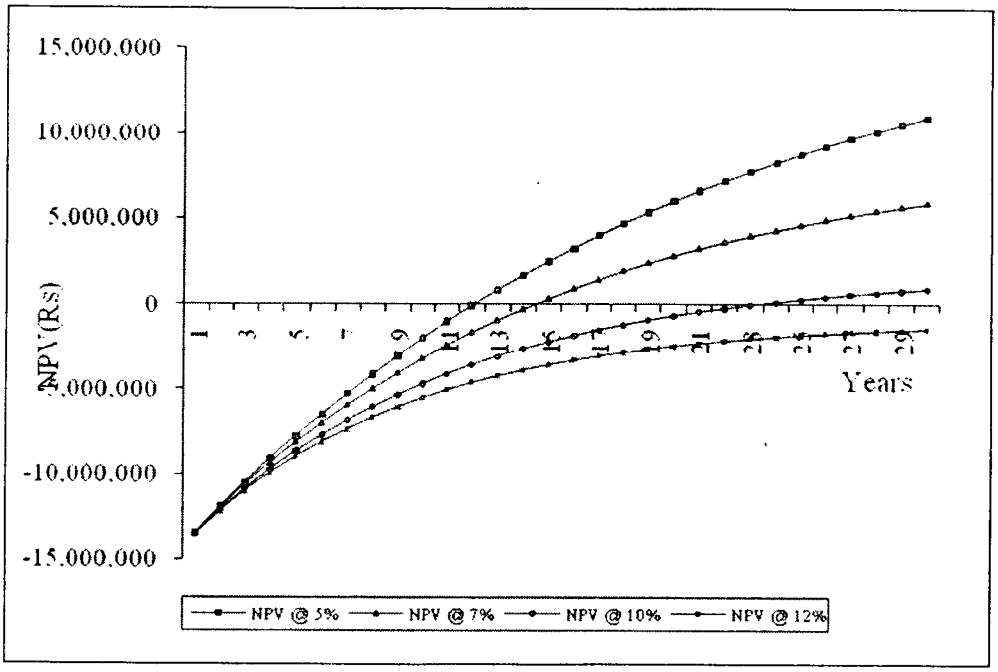
The price for annual value of rainwater = Rs.351.22 X 5000 m^3 = Rs.1,756,100

The findings of the economic evaluation of the rainwater harvesting facility at complex -1 of David Peiris Mortar Company are given below in Table 4.4.

Table 4.4: Results of the Economic Analysis- Rainwater Harvesting at the DPMC

Economic evaluation	Interest rate		
	5%	7%	10%
Net present value (Rs.) (NPV)	10,879,568	5,875,873	841,802
Internal rate of return (IRR)	11%		
Cost-benefit ratio	1.67	1.37	1.05
Pay back period (years)	12	15	24

Figure 4.3: NPV under Different Interest Rates- Rainwater Harvesting at DPMC



The results of the sensitivity analysis of the project under different scenarios are discussed in table 4.5. The findings indicate the viability of the project at less than 7% discount rates.

Table 4.5: Sensitively Analysis – Rainwater Harvesting at DPMC

Description	Scenario – 1 10% increase in cost	Scenario – II 10% decrease in benefit
NPV		
5% discount rate	9267717	8179760
7% discount rate	4284332	3696745
10% discount rate	-729305	-813485
IRR	9%	
BCR		
5% discount rate	1.52	1.51
7% discount rate	1.24	1.23
10% discount rate	0.96	0.95

4.6 Advantages Experienced in Rainwater Harvesting

1. Risk and uncertainty in the production process through public water supply have been reduced especially in dry periods
2. Reduction in water tariff or in cost of water extraction from alternative water source
3. Pressure on groundwater resources has been reduced
4. Control of flash flood by reducing the run off
5. Groundwater recharge has helped to increase water levels in the wells and also in the quality of water

4.7 Constrains Experienced in Rainwater Harvesting

1. Requirement of higher initial investment
2. Requirement of large surface area for water storage
3. Extended dry periods hinders the water harvesting and consequently the production process
4. Change of attitude and behaviours need special efforts to familiarize the rainwater use

CHAPTER FIVE

Conclusions and Recommendations

5.1 Concluding Remarks

In the hydrological perspective, RWH is one of the feasible strategies to mitigate the growing water crisis. It is a good prospect for industries and public and private sector institutions as they have large roof areas to collect rainwater. In addition, industrial and commercial complexes have large impervious surface areas which also can be used for water harvesting as demonstrated in DPMC case study. The all case studies clearly illustrate the potential of RWH to serve as an alternative water source, protect surface water quality, reduce the pressure on public water supply and groundwater resource and reduce the risk of flooding. Rainwater has been successful in augmenting groundwater by artificial recharge. The case study of Brandix Casual wear Pvt. Ltd shows the success achieved in re-charging groundwater table. This is a very easy way to improve the quantity and quality of the groundwater resource.

The inputs to the economic analysis for the three case study designs differed significantly with respect to two investments: (1) Strength and quality of the construction made for storage tanks; and (2) the costs associated with the rainwater quality management. Results of the two case studies out of three examined in this report readily show a positive economic results and the investment made is recoverable within 7 and 15 years at 7% interest rate with the IRR of 18% and 11% at Millennium IT and DPMC respectively. The DPMC has made a long lasting fairly high investment in the construction of RWH facility considering the water scarcity in the area in order to minimize the risk and uncertainty in their operations. The investment in the treatment plant is also high, which is more than the potable water quality standards. The DPMC has almost achieved self sufficiency in water need at complex IV, through RWH except for drinking requirements. This is indeed an enormous achievement and an eye opener to show the potential of RWH.

Rainwater is an equally valuable water source to serve the purposes of washing, cleaning, toilet flushing, industrial cooling, vehicle washing and landscaping without additional treatment cost as practiced in 'MAS Intimate Thurulie'. The benefits of reduction in flash flood and controlling of storm water are manifold such as reduction in inundation of road system and public places and consequent damages to shops and houses. The cost of inundation of roads includes traffic congestions and damages to health and sanitary system. If the benefits of the inundation and environmental benefits gained by groundwater recharge are included in the economic analysis, the BCR could provide a much higher figure.

Low construction cost and effective operation of RWH systems are critical for achieving economic efficiency. The construction technology adopted in the Millennium IT campus is a good case to learn more on minimizing cost of construction while maintaining the quality. It is also important to select the most appropriate treatment system with low cost technology in order to increase economic viability. Sophisticated treatment facilities not only increase the initial investment, but also cost of periodic maintenance. The minimization of construction cost can be achieved easily by incorporating RWH design at the early stage of planning process. Designing the roof with good quality roofing materials like Zink-Aluminum corrugated sheets has the ability to collect good quality water. Periodic maintenance of roofs and gutter systems also ensures better quality water which needs minimum level of treatment. Designing the storage tank in higher elevation or in the roof top to deliver the water on gravity force, has proven to reduce the cost of booster pumps and operational costs.

The failed rainwater harvesting case at Sabaragmuwa provincial council main building clearly illustrates the importance of suitable institutional arrangements in establishing and maintaining rainwater harvesting systems in public and commercial buildings. Public awareness and education on the importance and the benefits of rainwater harvesting and the potential role of RWH in minimizing the risk and uncertainties of alternative water supplies can play a key role in promoting this technology. As the CSR and the greener production processes are getting priority these days, rainwater harvesting concept can be easily promoted at institutional level through advocacy and influencing of the relevant sectors.

5.2 Recommendations

1. The government agencies engaged in the drinking water supply and groundwater resources management should come up with a plan to provide the water users an incentive package to promote rainwater harvesting at institutional level.

2. RWH should be promoted for public and commercial buildings through appropriate legal framework, proper incentive mechanism and suitable institutional arrangements. The government should enforce necessary bylaws in this aspect.

3. The government should play a key role in promoting RWH at institutional level developing rainwater harvesting facilities in all new buildings. Special attention is needed to incorporate the rainwater harvesting facility in new mega city projects. Initial action is necessary to develop the unutilized rainwater harvesting facilities at the new building of the Sabaragamuwa Provincial Council as a model demonstration site of institutional rainwater harvesting for non potable water needs considering the public money already invested in the project.

4. Low cost appropriate technologies should be developed for large scale rainwater harvesting in order to increase economic efficiency.

5. Regulation should be in place to control unlimited tapping of groundwater and the policy of 'groundwater is free for all without any limit' should be changed, not only to preserve environment but also to motivate users to shift towards RWH.

6. Education and awareness building are essential to advocate and influence the people towards RWH.

7. Measures should be taken to introduce the concept of RWH as a part of CSR among private sector organizations.

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