IDENTIFICATION OF A METHODOLOGY FOR REDUCTION OF NON REVNUE WATER & IMPROVEMENT OF PIPE BORNE WATER SERVICE IN COLOMBO CITY

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Abstract

Colombo City being located in the wet zone of Sri Lanka cannot be considered a water-stressed area. However there is an ever-increasing demand for drinking water supply, due to the increase in population and the rapid development of the area. Colombo City receives 66mgd of treated water but the records could account for revenue only 30.48mgd and 8mgd as free thus showing a gross Unaccounted For Water (UFW) percentage of 42. Colombo City also recorded one of the highest percentages of Non Revenue Water (54%) in the region mainly due to the deteriorated distribution system and associated problems. Most of the pipelines in the distribution system are encrusted and experience frequent leakages which resulted in low pressure zones. This situation created consumer dissatisfaction and development restriction in the city. In this thesis the author discusses the benefits of NRW reduction the selection of appropriate methodology for water loss management and shows how such benefits can be achieved by applying the developed methodologies to a pilot area of the city.

The Author obtained knowledge of various methods by reviewing of case studies and research papers from various countries seminars and donor agencies. An analysis of the Colombo City Water Distribution System showed that 67.6% of pipes comprised with more than 60 years old, encrusted CI pipes and the major factors contributing to NRW are leakages, illegal consumption free water supply and administration losses such as estimated bills water meter errors, human errors etc.

Under the pilot scale study, initially the main causes of NRW were identified and more attention was paid to the most significant causes. After studying various strategies "part to whole method" was selected as more appropriate to reduce NRW in the pilot area. Accordingly small areas or road stretches were isolated and causes that create NRW were reduced. Implementation of this exercise to cover the entire pilot area helped to reduce NRW by a considerable quantity.

In addition to the above pilot scale study further studies were made via IWA water loss management concepts distribution management decentralization and integrated water loss management concepts, economical water loss management with or without smaller diameter deteriorated pipe replacement and improved hydraulics in large pipes preventive maintenance of distribution system and finally target setting for achievement of millennium development goals etc.

After implementation of this exercise on water loss management, it shows that fixing of responsibility with proper directions and commitment interest with awareness of all staff members top to bottom is important to ensure positive results and to provide reliable and customer satisfactory service.

The aim of the research was to develop appropriate method with strategic framework for water loss management. The method adopted for water loss management is different from country to country city to city and place to place depending on factors such as the condition of infrastructure maintenance practices resource availability and institutional frame work etc. The short and long term strategies developed for water loss management for Colombo City could be applied to similar cities in developing countries.

Declaration

I certify that this dissertation does not incorporate without acknowledgement any material previously submitted for Degree or Diploma in any university and to the best of my knowledge and belief it does not contain any material previously published or written or orally communicated by another person except where due reference is made in the text.

Signature of the candidate

To the best of my knowledge the above particulars are correct

UOM Verified Signature

Prof. (Mrs.) N. Ratnayake

Acknowledgement

I am thankful to The University of Moratuwa for providing me with the training and education required for my post graduate studies. I gained a valuable knowledge under a devoted staff and access to facilities available at the University of Moratuwa. It has provided me an insight to Environmental Engineering and Management. Further I use this opportunity to convey my deepest thanks to Vice Chancellor, Prof. K.M.A.K. Ranasinghe and Dean of the Faculty of Engineering, Prof A.K.W. Jayawardane and Head of the Department of Civil Engineering, Prof. W.P.S. Dias for providing me this great opportunity to follow this course to obtain this achievement.

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S. S. Devaraja

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Abbreviations

AE - Area Engineer

AWWA - American Water Works Association

BS - British Standards

CARL - Current Annual Real Losses

CC - Colombo City

CI - Cast Iron

CMC	- Colombo Municipal Council
CV	- Circulation Valve
DMA	- District Metering Area
EAA	- Engineering Assistants
ELI	- Economical Leak Index
GIS	- Global Information System
HDPE	- High Density Poly Ethylene
IBNET	-International Benchmarking Network
ILI	- Infrastructure Leak Index
IWA	- International Water Association
JICA	- Japan International Cooperation Agency
km	- Kilo meters
l/sec	- Liters / second
m^3	- Cubic Meter
MDGs	- Millennium Development Goals
mgd	- Million Gallon per Day
MIS	- Management Information System
Mm^3	- Million Meter Cubes
MNF	- Minimum Night Flow
NNF	- Net Night Flow
NRW	- Non Revenue Water
NWS&DB	- National Water Supply & Drainage Board
OIC	- Officer In Charge
OPD	- Operation and Development
PVC	- Poly Vinyl chloride
SLS	- Sri Lankan Standards
SV	- Sluice Valve
TG	- Tenement Garden
UARL	- Unavoidable Annual Real Losses
UFW	- Unaccounted For Water
UN	- United Nation
UNESCO	- United Nations Educational, Scientific and Cultural Organization
UNICEF	- United Nations Children's Fund
WHO	- World Health Organization

1 Chapter One: Introduction

1.1. Background

Fresh Water is no longer a freely available resource in the planet due to population growth, economic development, rapid urbanization, large-scale industrialization, deforestation and global warming. The scarcity of water for human and ecosystem uses and the deteriorating water quality leads to "water stress" and intense socio-political pressures. Many parts of the planet are already under severe water stress. Even though two third of the earth surface is covered with water, only 2.5% of the water is available as fresh water as shown in fig 1.1. Yet the water resources have not only remained constant but have increasingly been polluted by the growing population. The rate of abstraction of freshwater has grown rapidly in tandem with human population growth. It is estimated that global water withdrawals will increase by 35% between 1995 and 2020. As a result, per capita water availability is steadily declining.

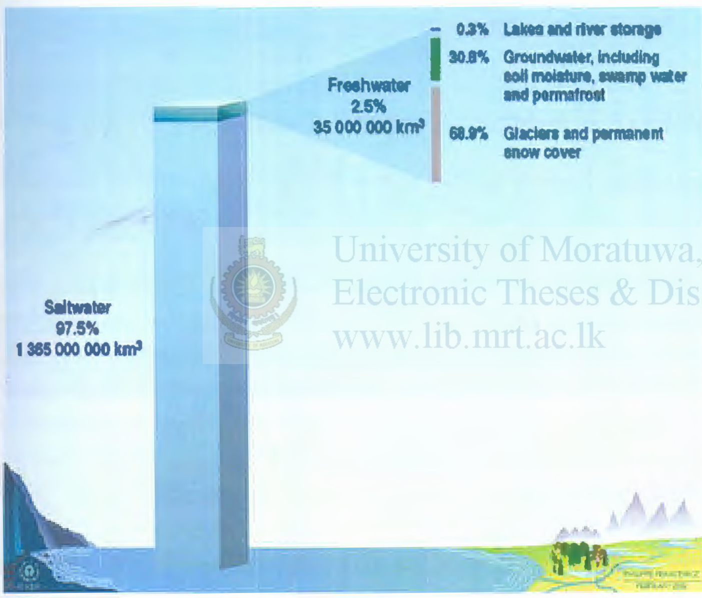


Figure 1-1: Total Global Saltwater & Freshwater Estimates

Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999

The water scarcity situation will get worse in the world's urban areas where over 50% of the world's population lived. Between 2000 and 2030, it is projected that there will be an increase of urban population of 2.12 billion, with over 95% of this increase expected to be in low-income countries ((UN-HABITAT's State of the World's Cities Report 2006/7). Parallel with this growth in population, the demand for drinking water has been increasing rapidly in urban areas of developing countries.

The WHO report of global annual assessment of sustainable and drinking water 2008 shows spreading of resent demarcation of water stress situation which shown in figure 1.2. Accordingly current situation is not favorable that most part of the world suffered without access to drinking water and this will continue to be worst in next the millennium. Hence it is important to pay more attention to avoid such situation for betterment of the society.

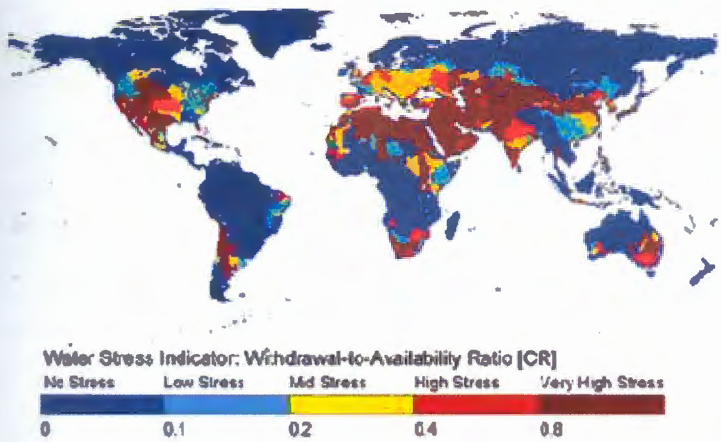


Figure 1-2: Water Stress Indicator (Withdrawal to Available Ratio)

Source - WHO report of UN water global annual assessment of sanitation and drinking water 2008.

In the year 2006, 0.9 billion people of the world population were without access to safe drinking water supply. From 1990 to 2006 approximately 1.56 billion people gained access to improved water facilities. Accordingly 87% of world population used drinking water from an improved sources as compared to 77% in the year 1990. Situation will be further improved with the activities of 2008 international year of sanitation in near future. WHO report "UN water global annual assessment of sanitation and drinking water 2008" demarcate global water coverage areas shown in figure 1.3 which shows most of the countries access to 75% safe drinking water but due to water scarcity majority of African counties still suffer with shortage of drinking water.

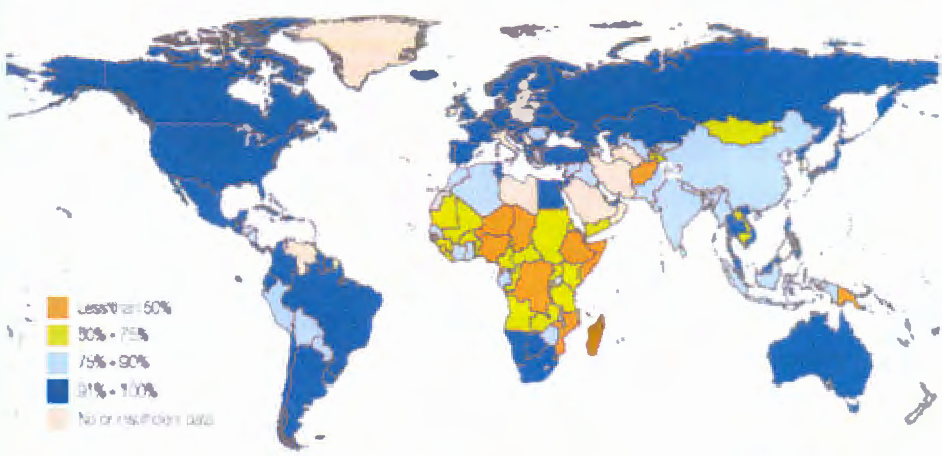


Figure 1-3: Safe drinking Water Coverage 2006

Source: UN water global annual assessment of sanitation and drinking water 2008

In 2002, 82% of the Asia and Pacific region had gained access to improved water supplies and the increase of approximately 758 million people since 1990. In Sri Lanka access to improved water supplies in urban are 90% and rural 72% and island wide 78%. The Millennium Development Goal (MGD) target for improved safe drinking water supply is to have Rural 90% and urban 100% of the population in Sri Lanka by the year 2015. (Millennium-Project 2005) source "Asia water watch 2015- WHO"

It is a major challenge to cater for the new demand due to rapid urbanization and population increase in order to achieve millennium development goal objectives. New raw water sources and more treatment facilities are needed. Further to this, many of the water supply schemes have poor infrastructure or treatment limitations to provide more water. These situations are compounded by water losses occurring from pipe distribution system and making it increasingly difficult to satisfy the growing demand. Water distribution losses (Non Revenue Water) in the networks of developing countries are around more than 50% (Bill Kingdom 2006). In developing countries water sector policy makers and professionals need to have a shift in the way they manage water resources in urban areas, instead of focusing on only increase of treatment capacities, there is a need to apply water demand management.

Water losses in distribution system (33% NRW) where National Water Supply & Drainage Board maintain the schemes in Sri Lanka are at reasonable level among South Asian countries. Non Revenue Water (NRW 53%) in Colombo City has one of the highest recorded in the region. Colombo City is, one of the oldest distribution systems in Sri Lanka. By reviewing the distribution system originally it had good system but periodical rehabilitation has not taken place and only day to day maintenance existed. Due to this passive management system, the following deficiencies are created at present as tabulated in Figure 1.4

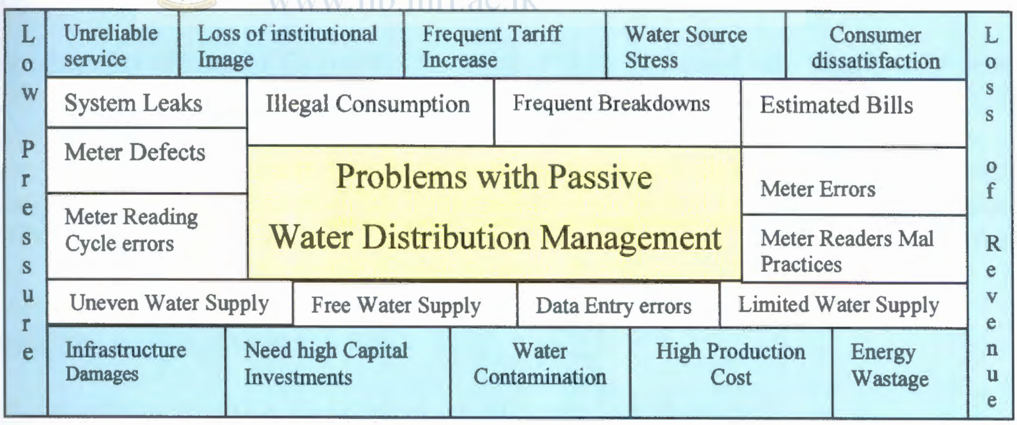


Figure 1-4: Problems with Conventional Water Distribution Management

Reduction of NRW had been given less attention in early days in the water supply sector in Sri Lanka due to freely available water and less pollution. However nowadays, the reduction of NRW has become a very important factor due to two main reasons, such as high production cost and drinking water source scarcity. Simultaneously much attention has been given to provide reliable service and consumer satisfaction. With these concepts passive distribution system has changed to active management system with more attention has been paid for distribution management with investment on rehabilitation to achieve following as tabulated in Figure 1.5

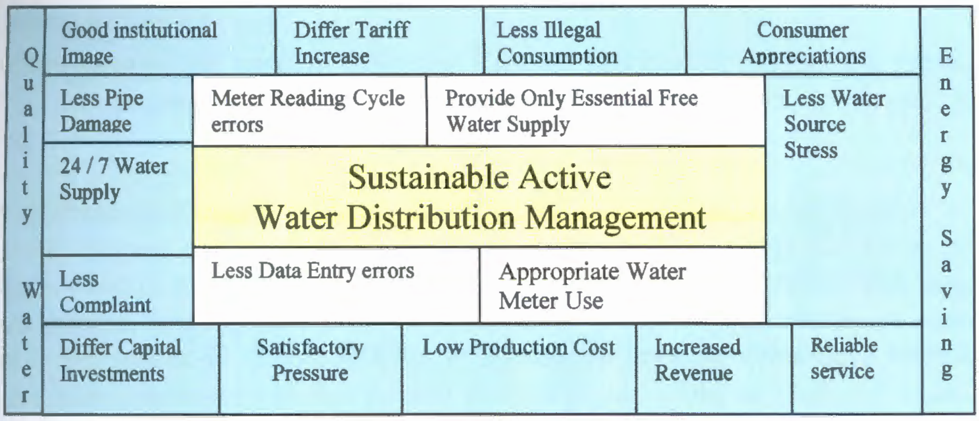


Figure 1-5: Characteristics of Sustainable Active Water Distribution Management

Therefore the water loss management can provide sustainable access to safe drinking water and achieve the MDGs (Target 10 of goal 7) of ensuring environmental sustainability

Therefore water loss management is one of the main strategies to improve accessibility and reliability of water supply for the majority of residents in developing countries.

In Sri Lanka, water stress situation has not been experienced but other associated environmental problems are common due to rapid urbanization, deforestation and population increase. In general, water is difficult to purify, expensive to transport and impossible to substitute, hence it is important to discuss about the effective distribution of drinking water in a pipe borne water supply system minimum wastage.

Water supply system in Colombo City is more than 100 years old. There were several projects, which increased the quantity of water supplied to the city during the last few decades. However, there was no planned rehabilitation of distribution system other than many minor improvements that have been implemented depending on the situation. Colombo Municipal Council (CMC) maintained distribution system up to the year 2001 while head works, maintenance of transmission mains, and all commercial activities were carried out by National Water Supply & Drainage Board (NWS&DB). The contract with CMC was terminated and maintenance of entire distribution system was taken over by NWSDB in Feb 2001.

1.2. Previous Studies Done by the University of Moratuwa

In 1997 October Eng H.J.V.C. Chandrasekara had studied and submitted thesis for his Masters Engineering (Environmental Engineering and Management) namely "Management of Unaccounted For Water in Greater Colombo Water Supply System". In this report the author studied and analyzed in depth the problem of Unaccounted For Water (UFW) in Greater Colombo distribution system. Further studies involved impact of water meters including performance comparison between turbine meters and volumetric meters, several NRW reduction pilot scale studies etc. Author further studied the impact of throttling of Stand Post and its impact to NRW reduction.

1.3. Problem Identification

At present most of the areas in Colombo City are reported as having low pressures and most of the inhabitants of the Colombo City are suffering with unreliable and poor service.

Many of these problems have been identified for a long time. A fair number of studies have been carried out to find the causes and remedial measures for these problems. However, most of the studies have not progressed beyond the identification stage due to various reasons. Leakage is the major contributory factor for the water loss followed by illegal consumption. In Colombo City no significant improvements have been achieved in water losses management during past years and this could be seen as a result of lack of necessary resources and incorrect approaches. The other major reason could be the use of methodologies and techniques currently used in developed countries without critically looking at the local situation. It is therefore vital to develop a method suitable to local conditions by following an appropriate approach to formulate a sustainable water loss reduction strategy.

1.4. Objectives of Study

The broad objective of the study is identification of a methodology for reduction of distribution water losses and improvement of pipe borne water service in Colombo City.

Specific Objective

Following specific objectives have been identified to achieve these goals

- To evaluate the Colombo City water supply distribution management system and rearrange the same with appropriate strategy to handle NRW
- To evaluate and characterize the water loss in the distribution system
- To develop long term and short term strategies for the reduction of water losses in the distribution system to suit local conditions.
- Study, design and implement a NRW reduction method as a pilot project which will provide a better service to the consumers in the Colombo City.

1.5. Description of Study Area

1.5.1. Background of Colombo City Water Supply :

Colombo City is the commercial capital of Sri Lanka with approximately 642,000 inhabitants. It is expanded daily by nearly 400,000 floating population. According to the Colombo Municipal Council data the City covers an area of 37 sq. Km. consisting of over 120,000 numbers of dwellings including 65000 underserved settlements. However most of the inhabitants of Colombo City have basic needs of water supply and sanitations facilities at least as common services. Presently Colombo City receives a pipe borne water supply of 66mgd, out of which 54% is recoded as NRW including 11% is used to provide free water supply to maintain common services to improve sanitation conditions in the underserved settlements. Figure 1.6 shows the main road net work of Colombo city. Most of the pipe lines are along this road all over the area.

Figure 1-6 : Map of Colombo City

1.5.2. Water Sources

The pipe borne water supply to Colombo City, commenced in 1886 with the impounded reservoir in Labugama (Situated at eastern part of Colombo district 30 km away from Colombo City) as shown in figure 1-7 and a 20 inch diameter CI transmission main up to Maligakanda reservoir (located at high elevation in the center of city). Further the transmission capacity was increased later in 1905 by laying another 20 inch diameter CI pipeline to Eliehouse reservoir, in the northern part of the city and in 1917 with 30 inch diameter pipeline to Maligakanda. In 1958, Kalatuwawa reservoir (Close to Labugama) was commissioned, and the water was conveyed to Colombo with another 30 inch pipeline leading to Maligakanda, while a 33 inch pipeline leading to Dehiwala reservoir, is supplying to the southern part of Colombo. At present, the combined supply of Labugama and Kalatuwawa is 25 million gallons per day (mgd).

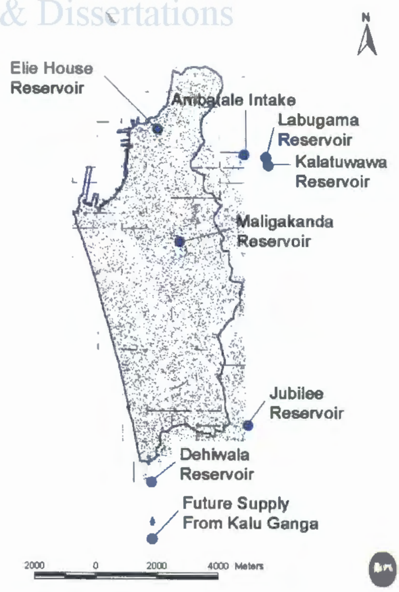
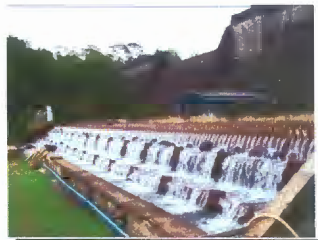


Figure 1-7: Key Map of Water Intake and Storage Reservoirs

Labugama Treatment Plant

Ambalate Treatment plant



Kalatuwawa Treatment Plant

Figure 1-8: Water Treatment Plants feed to Colombo City

Ambatale treatment plant, which extracts water from Kelani River, was commissioned in 1958, with a capacity of 27 MGD. Subsequently, the plant was expanded with another two 40mgd in 1966 & 1994 and 10mgd in 2004. (Source - Colombo City master plan development study report NWS&DB) Presently, the supply from Ambatale is 113mgd, Labugama 9.42mgd and Kalatuwawa 18.11mgd with a total production of 140.54mgd. Out of the total production of these three Treatment plants Colombo City receives 66 mgd which is relatively of high quantity, compared to Colombo City actual consumption.

1.5.3. Water Distribution in Colombo City

The distribution network within Colombo City area has not been properly developed during the period after its initial construction. This has been expanded and strengthened on several occasions subsequently; it has not been rehabilitated according to a proper plan. In the recent past, the distribution network has been strengthened in 1986 under the assistance of the 3rd World Bank Project. As a result of these expansions and strengthening done from time to time, different types of pipes of different age presently exist in the distribution network. In September 2009 the distribution system comprises 835km pipe network with 118,199 water connections (NWS&DB MIS). The distribution network map has been digitized and a distribution model has been developed for larger diameters pipes.

1.5.4. Present Service Status

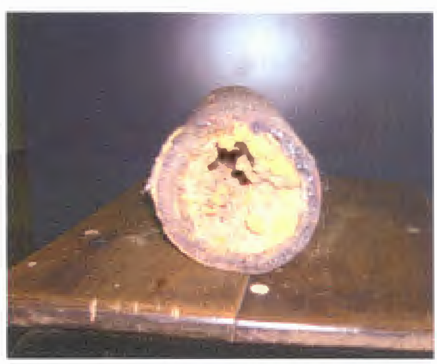


Figure 1-9: Status of smaller diameter pipes in Colombo distribution system

Colombo City distribution system comprises more than 70 years old Cast Iron pipes. Due to the deterioration, frequent pipe bursts, underground leaks are common in the system. Scaling is another deficiency of this system as shown in figure 1-9. Scales will reduce actual internal diameter and the associated theoretical calculations produce inaccurate results. Further, due to these reasons most of the inhabitants of the Colombo City suffer with unreliable and poor service.

2 Chapter Two: Theoretical Framework and Literature Review

2.1. Water Loss Management

The intention of all institutions in water management is trying to distribute entire water production to the consumers with minimum water loss to collect maximum amount of revenue and maximum utilization of water. Operation and maintenance of reliable water supply through appropriate management techniques is vital to support all aspects, especially in urban population, due to polluted ground water situations. Due to the geographical situation, infrastructure developments, different climatic conditions, cultural behaviours and natural conditions, many countries have to maintain reliable water service with limited water resources. Infrastructure development and the population concentration mainly depend on availability of reliable water service. One of the major constraints affecting the reliability of a sustainable water supply is water loss. Figure 2-1 shows the possible means of water losses in a water supply scheme.

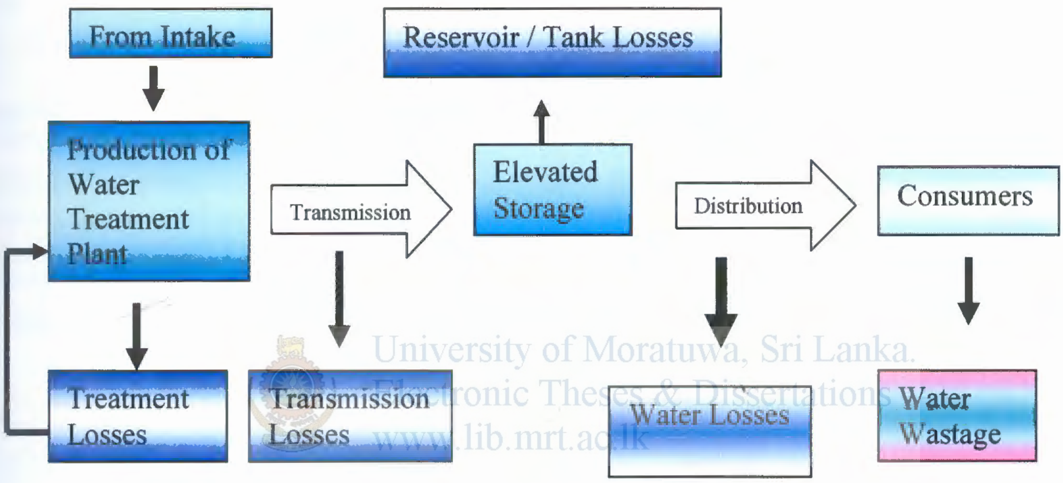


Figure 2-1: Means of Water Losses in Water Distribution Processes

The amount of water losses in water distribution systems depend on the characteristic of the pipe network, water utility's operational practice, the level of technology and the expertise applied to controlling the same. The volume of losses and causes for each loss are not similar for all water supply schemes. It is situational and the strategies for controlling therefore differ from scheme to scheme. Hence, it has been revealed that the examination of relative significance of each of the components and attending to the key areas by using proper technology is vital to obtain positive results.

2.1.1. Definition of NRW & UFW

There are many terms that are used to reflect water losses, the most commonly used being Non Revenue Water (NRW) and Unaccounted For Water (UFW). Leakage is one of the main contributory factors in a Water Supply Scheme.

The NRW define as the quantity of water that does not earn revenue to the organization, expressed as a percentage of the net production. The major causes for NRW are water leakage, illegal consumption, administrative losses, legitimate free water uses such as un-metered supplies to the tenement gardens, fire fighting, stand post supplies, etc. Percentage of NRW can be expressed as,

$$NRW = \left(\frac{Q_{\sup ply} - Q_{Consume}}{Q_{Supply}} \right) \times 100$$

UFW in a water supply system represents the difference between "net production" (the volume of water delivered into a network) and "consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not). This is usually expressed as a percentage from the net production. The major causes for UFW are water leakage, illegal consumption and administrative losses, etc. Percentage of UFW can be expressed as,

$$UFW = \left(\frac{Q_{\sup ply} - Q_{Consume} - Q_{Legitimate\ Unmetered\ Consumption}}{Q_{Supply}} \right) \times 100$$

Compared to the above, these two terms describe the status of the water supply scheme. If UFW & NRW are high it may directly indicate high leakages existing in the distribution system. Leakage of water is a waste of resources while losing revenue. Common features of poor water loss management are shown in figure 2.2. Accordingly it clearly shows that if UFW is very high, performance of the water scheme is in a low level of operational condition. Therefore it is not favourable for the utility as well as to the consumers.

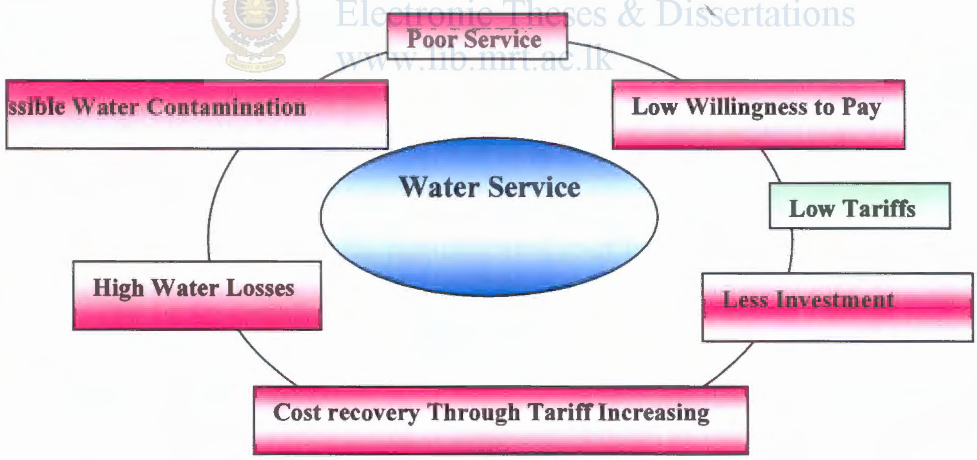


Figure 2-2: Features of Poor Water Loss Management Scheme

Further considering the predicted scarcity of drinking water in the next millennium and development and improvement infrastructure of the cities, it is important to minimize the water leakages in distribution systems.

2.1.2. NRW in Developed Countries

Most of the developed counties in the world have managed with quite satisfactorily low levels of water loss in the process of water distribution. Salient features of the low NRW are the high degree of private sector participation, using concession and lease contracts and the existence of basin agencies that levy fees on utilities in order to finance environmental investments.

However, water loss management is a dynamic equilibrium process, which depends on amount of resources pumped into the system. Water losses in Italy being 29%, is high compared to France (26%), England (19%), Germany (7%), The Netherlands (6%), and Singapore (4%) and Japan (8%). Most of these countries paid more attention and invested massive amount of resources to maintain these levels. (IWA Publications - Water Loss Control 2008 by By Julian Thornton, Reinhard Sturm, George Kunkel , Losses in Water Distribution Networks 2006 & Data requirements for integrated urban water management By Tim D. Fletcher, Ana Deletic)

In Singapore and Tokyo galvanized iron and Poly Vinyl chloride (PVC) service connections have been replaced with stainless steel service connections and NRW levels has been remained very low due to the success of this approach. Singapore, Tokyo, and other cities also have programs for replacing asbestos cement pipes in distribution systems, as pipe breaks have increased very often. (A.O. Lambert 2005)

Benchmarking is one of the successful features in Dutch water sector water companies (first introduced in 1997) which has inspired similar efforts in other European countries. Benchmarking NRW is useful, as it enables utilities to compare themselves with others, and their performance during different period (IBNET). The leakage component can be measured in some other ways, as water loss per kilometer of distribution and as water loss per connection, but this assumes that NRW does not have a high contribution of apparent losses. (A.O. Lambert 2000)

Asset Management is another successful feature developed in developed countries. This was mainly initiated in Australia and New Zealand and later followed by other developed countries as a concept to maintain distribution system in order to achieve reliable uninterrupted water supply with the reduction of NRW. Accordingly the establishment of Water Asset Management philosophies, information, systems and performance measures are required to be in sequence to establish financially sustainable programme for the reduction of NRW. Water Asset Management plan includes preparation of a summary of asset conditions, a condition statue and risk management analysis of assets, preparation of optimized maintenance programme which will include a recommended approach and recommended annual expenditures of any programme for NRW reductions. (Rob Blakemore , 2007)

2.1.3. NRW in Developing Countries

In early days of the world, water was freely available but with the population growth and industrial development, safe water became a scarce commodity. Due to the scarcity, available fresh water has to be properly managed and it is one of the major challenges facing many water utilities in most of these countries due to lack of resources including expert knowledge. But most of the water utilities in developing countries recorded high NRW, some recorded as more than 60% (Asia Water Watch 2015). High level of NRW implies huge amount of water being lost through distribution system as leaks. Recent management of most of the utilities in developing countries just maintains systems to provide water. Main attention is been paid to collect revenue. Expenditure is being balanced with tariff increase without paying attention to active leakage controlling programmes.

The World Bank database on water utility performance, "The International Benchmarking Network for water and sanitation utilities (IBNET)" includes data from more than 900 utilities in 44 developing countries. The average figure for NRW levels in developing countries is around 35%. But most of the developing countries do not have proper records of NRW because of lack of flow meters both domestic and bulk and proper continuous monitoring system. Figure 2-3 shows the mean NRW in large cities in Asia, which clearly illustrates the situation of developed countries compared to developing countries

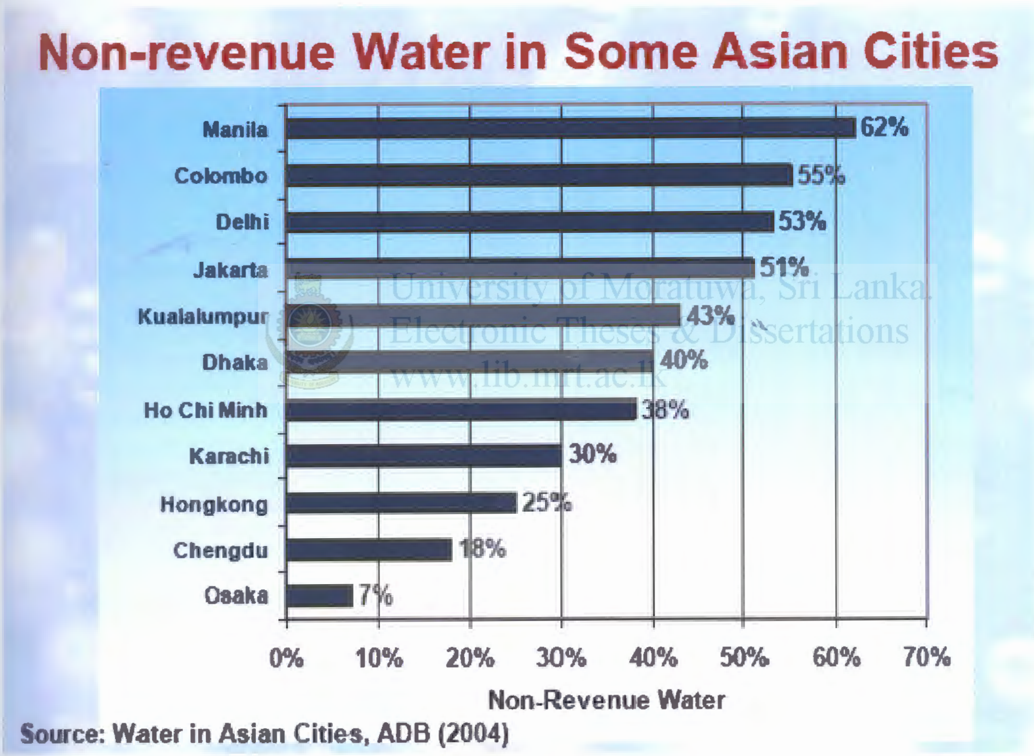


Figure 2-3: Mean NRW in Some Cities in Asia

It is necessary to pay more attention to reduce non revenue water in these countries because treated water is costly to produce due to the cost of chemicals, energy, administration, high capital and maintenance etc. To maintain sustainable service these costs need to be recovered through water sale. If the utility has high figures of NRW, due to the inefficiency of the institution, the consumer ends up with increased water tariff. This is a big burden especially in developing countries as the majority of the consumers are poor and as a result the service becomes unaffordable. Due to this majority of consumers either use water illegally or are forced to use alternatives such as common stand post or contaminated water sources like open wells, water streams etc. Hence the main objective of healthy nation cannot be achieved through these kinds of inefficient services.

Figure 2-4 shows the mean UFW in large cities in Africa, Asia, Latin America and North America, which clearly illustrates the situation of developed region compared to developing regions.

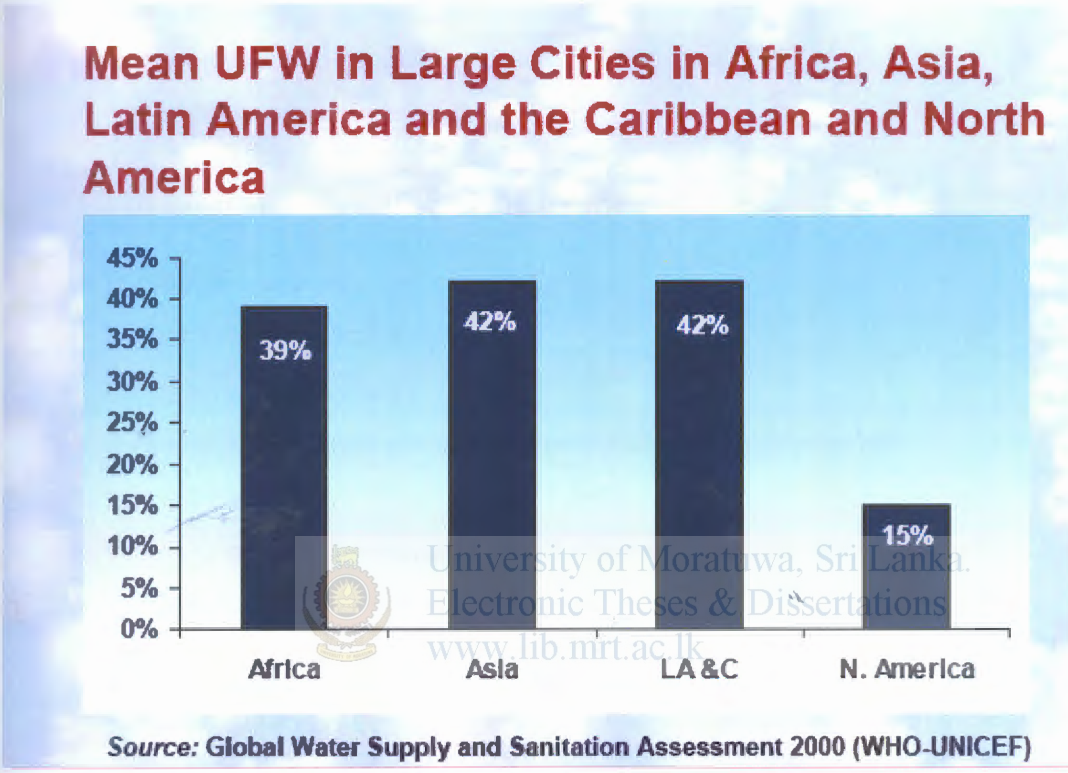


Figure 2-4: Mean UFW in Large Cities in Developing Countries in Global Water Supply

2.2. Causes for Water Losses

Major causes for water losses are treatment losses, leaks in pipe lines (transmission mains, distribution system, and service lines), illegal water consumptions, administrative losses and free water supply. These causes are mainly divided into two groups namely

- Apparent losses (Non Physical)
- Real losses (Physical)

2.2.1. Apparent Losses (Non Physical Losses)

This is not really wastage or losing of water, but is recorded as NRW because it does not bring any revenue to the water authority. Components of Apparent Losses are:

2.2.1.1. Illegal connections and usage such as

- Unauthorized individual connections
- Meter by passes
- Disconnected and illegally reconnected premises
- Unbilled consumption

2.2.1.2. Administrative errors, that could be attributed to

- Estimated readings
- Defective meters and meter errors
- Un metered connections
- Deficiencies in meter reading and computerized billing system

2.2.1.3. Legitimate Free water supply

This consists of Tenement Garden supplies, Fire demands, Service requirements, Bowser supply, emergency temporally supply etc. Tenement Gardens in Colombo City are getting 11% of water quantity free of charge per day (approximately 8mgd). (This amount has been assessed based on a pilot study done by NRW section of NWS&DB with Norwegian Consultants - 2002)

Due to the social problems it is very difficult to reduce this quantity of water to convert into the billing system by providing individual connections. Some such social problems are.

- No proper drainage systems in the Tenement Gardens
- Lack of space to obtain individual water facilities
- Low pressure in the area to provide new connections
- Common Sanitary facilities
- Objections of community

2.2.2. Real Losses (Physical Losses)

This is the water that is physically lost after production, in the water distribution process between the treatment plant and the end user, without being used in the distribution system. Real losses may be attributed to causes such as,

- Treatment losses
- Leakage and overflows from reservoirs
- Leakage from transmission mains and distribution systems (Pipe network)
- Leakages from consumer connections and service lines. before the consumer meter

2.2.2.1. Treatment Losses

Treatment losses could be minimized, but cannot be eliminated as it needs for process of the Treatment Plant. However this water could be re-circulated to minimize intake pumping. Water losses occur mainly due to treatment process requirement such as filter back washing etc.

2.2.2.2. Leakage of Overflows from Reservoir

In a small water supply scheme this is the main contributory factor for the UFW. This can be completely controlled by fixing ball float valve. Nowadays many automatic electronic apparatus are developed to control overflows.

2.2.2.3 Leaks in Pipe Network

This is the main contributory factor for the NRW and UFW in most of the water supply schemes. This also cannot be completely eliminated but it is possible to minimize to a certain extent. Leaks will occur due to the following:

- Age of the distribution net work
- Soil condition
- Pipe material
- Quality of water
- Overflows and wastage of water in multi storied flats
- Increasing leakage due to frequent scraping of smaller diameter CI lines
- Inadequate cover to pipeline
- Inactive CI lines in the distribution system
- Heave moving loads

In addition to the above water leakage in pipe network will be further depend on

- Lack of preventive and corrective maintenance

- Speed of leaks repairs
- Availability of maps, reliability of details and process of updating
- Availability of leak repair materials and related resources.
- Quality of material used and workmanship
- Standards of design
- Status of distribution valves

2.2.2.3.1. Leakages in Transmission System

Transmission mains generally consist of 2 – 3% of volume water leakage mainly from sluice valve gland and pipe joints. This kind of losses could be eliminated by implementing of proper preventive maintenance programme.

2.2.2.3.2. Leakages in Distribution System

Leakage from distribution systems is frequently found to be the single largest component of NRW. Factors contributing to this are as follows:

- Extensive network of small diameter pipes with unnecessary pipe lines
- Large number of pipe joints
- Numerous house connections, bundle pipes and ferrules
- Inadequate ground cover given to house connections
- Less attention paid to system design, materials, installation & inspection
- Missing of preventive maintenance of valves and fittings etc
- Usual pipe burst / Leaks due to vehicle loading
- Pipe damages due to development work

2.2.2.3.3. Leakage from Service Lines

- Wastage in consumer premises due to lack of maintenance, e.g. dripping taps, overflowing tanks and toilet cisterns, etc
- Poor workmanship at ferule connections
- Poor quality materials

2.3. Water Loss Reduction Techniques

2.3.1. Water Audit

To have a better understanding of the water loss in a water supply area, it is essential to carry out basic assessment. IWA (A.O Lambert 2005) has developed a chart showing how the quantity of water flows into and out of distribution system, which is widely used in audit. Analyzing the data, gives a clear representation about water losses in the system as detailed in figure 2-5 below.

System Input Volume (corrected for known errors)	Authorized consumption	Billed Authorized Consumption	Billed metered consumption (Including exported water)	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non Revenue Water (NRW)
			Unbilled Unmetered Consumption	
	Water loss	Apparent Losses	Unauthorized Consumption	
			Customer meter inaccuracies	
		Real Losses	Leakage on transmission and /or distribution mains	
			Leakage over flows	
			Leakage on service connections up to point of customer metering	

Figure 2-5: IWA Standard International Water Audit (balance and terminology) (A.O. Lambert 2005)

The concept of the water audit is to account or balance all the water which is brought into the distribution system and subsequently consumer usage or loss. The water audit informs how much of each type of water loss occurs and how much it is accounted to the water utility. The key concept around this method is that no water is "unaccounted for". All water supplied is accounted for in the components listed by using either measured or estimated quantities. A quantity and cost is placed on each component in order to assess its financial impact to the water utility (AWWA 2006).

Under the context of the drinking water scarcity, a water audit is an important step towards maximum utilization of water for the benefits of people. It is linked with key areas such as a leak detection plan or any other corrective plans which can save the utility a significant amount of money and time.

2.3.2. Meter Management

Proper meter management is one of the important aspects for prevention of water losses in the management of water supply scheme, as the entire exercise is depended on the accuracy of meters. Every water meter type has its own characteristics and limitations according to the manufactures specifications such as low flow limits, upper flow limits, life time, accuracy and water quality etc.

Meters not only provide information on water usage but also help to determine potential losses in the system. Water usage as recorded through meters is the basis for water user charges, the main revenue of the utility. Basically a meter management programme will cover four main aspects. These are outlined below:

2.3.2.1. Meter Selection

The selection of water meter is a very important activity when concerning of water audit. It purely depends on capacity and requirement of utility organization because high accuracy meters are costly. The meter must accommodate the expected range of flows, and the lowest anticipated flow should fit within the normal accuracy of the meter. The incorrect matching of a particular water meter performance with the demand characteristics of a consumer can result in the loss of revenue to a water utility.

2.3.2.2. Meter Installation

Installation of meter should be according to the manufacturers' specification otherwise due to the turbulent flow it will give incorrect result which leads to loss of revenue to utility organization. Different installation procedures are required for different meters. It must be ensured that straight pipe lengths, suitability for vertical, horizontal and inclined installations and meter head or error installation requirements are adhered too. Seals should be installed on the meter to reduce tampering and legal action should be taken when tampering does occur. The meter should be easily accessible for service, inspection, and reading even if meter reading is via remote sensing equipment.

2.3.2.3. Meter Testing and Maintenance

Residential meters should be checked, and calibrated as required every five to ten years depending on the lifetime. Priority should be those with high or abnormally low readings. Testing and maintenance of the meters will depend on the quality and quantity of the water distributed. If adverse conditions, such as high minerals or large flows are encountered, meters will require more frequent attention.

2.3.2.4. Meter Replacement

Meter replacement should be carried out when the cumulative revenue lost due to meter inaccuracy exceeds the amount it costs to replace the meter. Cumulative revenue loss depends on change in accuracy over the service life of a meter. Factors such as water quality and specific meter characteristics contribute to the degradation and loss of accuracy of the water meter over time in service.

Figure 2.6 explains the relationship between potential losses of revenue with the cost to replace the water meter. The amount where cost and value of lost revenue are equivalent indicates the optimum point for meter replacement.

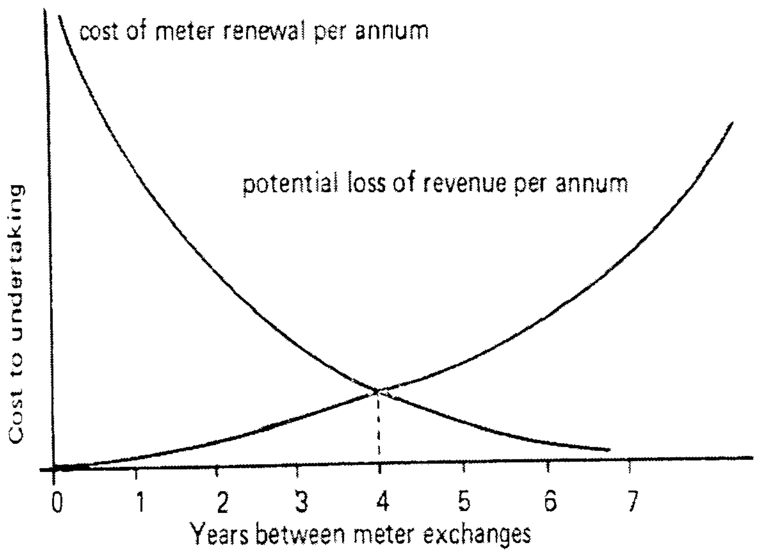


Figure 2-6: Economics of Meter Exchanges (Source: Coe, 1978)

2.3.2.5. Type of Meter Usage in Water Distribution

There are two types of meters use in the water distribution systems namely production or bulk meters and consumer meters.

2.3.2.5.1. Production or Bulk Meter

Accuracy of bulk meters is very important to verify actual quantity of water flow into the distribution systems. For precise water loss calculation it needs to fix high accurate production meters which give information on production capacities, quantity of water losses, acceptable revenue and requirement of periodical rehabilitation with the improvements.

Production and bulk meters can be checked-calibrated by temporarily installing a recently calibrated check meter adjacent to the permanently installed production meter on each major production main. Insertions meter (a clamp-on ultrasonic meter or electromagnetic meter) can be used for this task with minimal site work and without interrupting the flow in the pipeline. An alternative approach that is effective where the metered production main delivers water directly to the service reservoir supplying the distribution system, is to measure the rate of filling of the reservoir over a specified time period with all reservoir outlet valves closed and checked for water-tight closure. Before undertaking the test, the water tightness of reservoir has to be checked to obtain accurate results. However checking of accuracy of bulk meter is important and this process has to be repeated once in two years to take remedial actions accordingly if error exists.

2.3.2.5.2 Consumer Meter

Consumer meters are used to determine consumer consumption for the preparation of bills. Their sizes are generally 15mm or 20mm. however there are usually large numbers of them in the distribution system. Major deficiencies of domestic meters include under-record consumption at low flows. Nowadays high accuracy low flow readable meters are developed but they are very expensive compared to the normal meters.

Common causes of meter defects are, it become defective within short period or meter tampering, may break from excessive network pressure, air flow, silt, sand and due to high turbidity. Meters may under-register consumption if water pressure is unusually low or over-register because of air. Meter defects are a major cause of apparent losses.

2.3.3. District Meter Areas (DMAs) (Zonal Metering)

In order to study the water losses in a distribution system, the distribution area is initially divided into isolated zones or DMAs and suitable logging facilitated Bulk meters are fixed to compare flow into the system and billed quantities. In this system it is essential to ensure that all flows pass through flow meters located at the zonal boundary in order to obtain accurate zonal data. This may possibly require the closure of some boundary valves to isolate each DMA and minimize meter requirements.

In this process by fixing logger, it is very easy to identify zonal behaviours and characteristics such as flows into a zone, Minimum Night Flow (MNF), peak hour consumption, daily inflow fluctuation etc. By analyzing MNF, it could estimate the leakage quantity of the zone. Where unusual MNF exists DMA is further divided into sub divisions by installing waste meters or section valves to facilitate step testing which is the next step to identify heavy leak areas. Leak locating and repair activities are then performed in the area to reduce MNF. Further district and waste metering options were combined the policy is referred to as combined metering.

DMA meters are monitored at regular intervals; the flows measured are being used to determine consumption patterns and levels, as well as to quantify leakage and wastage. If unexplainable, increases in supply occur, further investigations to locate any leaks should be undertaken. Such investigations could be possible with sounding technique or entail step testing at night (where leakage is the major flow component) whereby flows into the zone or sub-zones are monitored by the DMA meter while successively closing valves to progressively reduce the area served through the meter. Sections of the pipe network showing unusually high consumptions can then be identified for detailed inspection by specialized leak detection teams using equipment such as electronic leak detectors or leak noise correlators etc., to systematically survey the zone to locate leaks.

The effectiveness of DMA mainly depends according to the size of the zone. Smaller zones have a higher initial capital cost and higher operating costs, but will permit identification of smaller leaks and will maintain leakage at lower overall levels. Determination of the size of DMA zones is of crucial importance. In extensive zonal metering systems, zones, 1500 - 5000 properties may be used depending on nature of work and availability of resources.

2.3.4. Pressure Management

Leakage reduction by pressure control is probably the simplest, most widely used and popular way of reducing leakage within the distribution system. However in Colombo city this method is hardly used to control leakages due to low pressure. In this method it is not allowed to increase system pressure with the demand fluctuation. So during night time pressure will be controlled by pressure sustain valves. With this method system does not experience any excessive pressures and level of leakage is minimum even if visible or invisible leaks exist as shown in figure 2-7.

There are other ways of pressure reduction systems available such as reducing pumping capacities by using series of pumps which will start on demand (special pumps are set to cater for night demand), Variable Speed pumps, installing break pressure tanks or, more commonly, using pressure reducing valves. Pressure control provides no information on the level of leakage or the location of leaks, but it can be implemented in conjunction with any of the other control options.

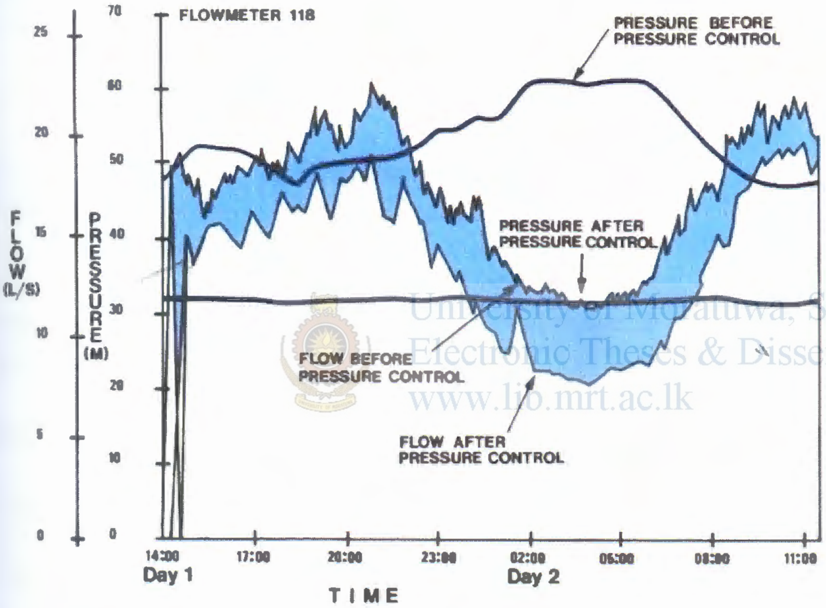


Figure 2-7: Water Saving due to Pressure Management

Source - Leakage from Distribution Systems (WHO guild line)

2.3.5. Leakage Monitoring and Control Methods

It is not economical to water tight all the components of a water supply scheme. All the design codes allow certain amounts of leakage to occur with satisfactory acceptance testing. There is, however an economic limit to the loss of water that should be tolerated.

There are mainly two policies available for leakage control namely active policy and passive policy. Due to situation of the scheme and availability of resources, these policies can be applied to control the leakages.

In passive policy only reported leaks will be repaired and a planned programme is not implemented for control leakages. For active policy there are three different methods of leakage control practice, which exist to suit local conditions.

Two active methods are direct detection of leakage and pressure control which is widely used in developed countries as explain in 2.3.4. Each method requires a different level of staff input, resources and equipment. Consequently each method has a different cost associated with it. However, each method will also maintain leakage at a different level and depending upon the costs of supplying water and the characteristics of the system, different leakage control policies will be appropriate in different situations.

2.3.5.1. Passive Leakage Control

This gives least effort as no attempt is made to detect leaks, and generally repairs are only done on leaks which are reported as a result of either water flowing on the ground surface or of consumer complaints. This method of leakage control will normally only be cost-effective in areas where water is freely available and require less treatment.

2.3.5.2. Active Direct Leakage Control

There is no single method which is appropriate everywhere to control leaks in the distribution system. The selection of the most appropriate method or several methods is taken into account to suit the local circumstances of the system under consideration. However, the benefits of leakage control are mainly socioeconomic. Therefore, the factors to consider are primarily the level of leakage within the system and hence the cost of that leakage, and the cost and effectiveness of each of the methods of control.

Active Leakage Direct Control Methods

- **Routine or Regular Sounding**

In this method of control, leaks are located by deploying teams of technically sound personnel who systematically work their way around the system sounding all meters, stopcocks, hydrants, valves, and other convenient water fittings, listening for the characteristic noise of leaking water.

By using this method even small underground invisible leaks can be detected quickly by well trained inspection staff. To effectively undertake a program of regular sounding, a large number of trained staff is required. Suitable trained and experienced individuals are often not available to start such a program as sounding expertise can only be acquired gradually with extensive practical experience and also sounding process is limited to silent environment because instruments will detect water flowing noise. Hence in the field it can be executed during night where no vehicle movement exists. Presently Japanese companies have been developing such instruments where it is possible to detect leaks in day time environment too.

- **Step Testing**

This is the most effective system which could be implemented to identify leaks in the distribution system. This method is used to identify heavy leakage areas and pin point leaks through detectors or by visual inspection during night. Isolation DMA or waste district, section valves and boundary valves are installed to isolate small sections of pipe lines. The flow is recorded after closing the boundary valves during MNF condition. Subsequently the night flow of the respective section is obtained by closing the section valves one by one with reasonable time interval and records the time and flow reading at the bulk flow meter to calculate flow reduction. This will give an idea about night flow at the particular section and level of leakage.

2.3.6. Deteriorated Smaller Pipe Line Replacement

Replacement of deteriorated smaller diameter pipes in distribution system is one of the service improvement methods where repairs are not economically viable. Scaling and hardly seen lining is another deficiency in the distribution network. Most of the ferrule connection leaks (dripping) exist in these lines due to frequent scraping to reduce low pressures in the system. It is possible to identify pipe replacement areas within low pressure zones too. These areas are critical and needs urgent rehabilitation to improve water facilities.

Most of the house connections in distribution system are provided from smaller diameter pipes. Therefore with smaller diameter pipe replacement can be eliminated leaks, illegal tapping and low pressure zones. Direct benefits are reduced NRW, save water and increase water connection capacity, increase revenue, reduce maintenance cost, improve hygienic condition of the people, reduce road damages due to less water leak and improvement of development due to improved water supply. Presently in most of the developing countries deteriorated pipes are replaced with High Density Polyethylene Pipe (HDPE) to reduce water losses. Cambodia, India, Malaysia use this strategy to reduce water losses. After replacing smaller diameter pipes, it is necessary to implement an active leakage control policy to sustain the system.

2.3.7. Rehabilitation of Distribution Network

Network rehabilitation, became fashionable during the last two decades as a solution for increasing leakage levels in most parts of the world. Mainly it was understood as capital expenditure intensive replacement of distribution mains. There are two types of rehabilitation in distribution systems: namely, pipe replacement and relining with suitable material, depending on available technology and funds. Normally, pipe replacement is suitable for smaller diameter pipes with house connections because of the high cost to provide uninterrupted service. Further it eliminates service leaks, unmetered connections and illegal connections too. Relining is suitable for large diameter pipes without house connections, depending on outer core condition.

Unfortunately, replacement of assets is always the most expensive exercise. Thus options have to be studied how limited funds can be utilized in a more cost effective way. Generally, total distribution mains replacement programmes are not economically justifiable. Selective rehabilitation by replacement of the worst affected sections in combination with alternatives such as introducing suitable liner ("slip-lining") for less affected parts and the immediate introduction of an active leakage control policy is probably the only possible way to proceed.

2.3.8. Part to Whole System

At present most of the Asia pacific countries implement this method to control water losses in distribution systems. This is started with smaller number of water connections, for e.g.: 500 to 1000 or road wise and cleared all the possible means of water losses and continue this exercise for entire distribution system. In this method, distribution system is converted or modified to from one feeder and fixed meter to measure supply quantity then and there the water losses are calculated. If the water loss exists, investigate reasons and eliminate all possible means of loss to finally tally with the supply quantity. This exercise will be continued until the entire distribution system is covered. With the improvement of water supply and increase of revenue, funds generated can be invested to replace identified deteriorated pipes to achieve sustainability of the system.

2.3.9. Asset Management and Ownership Concept

After reducing water looses, it is necessary to introduce water loss management system to maintain sustainability. Asset Management is another successful feature developed in many countries to maintain distribution system in order to achieve reliable uninterrupted water supply. Accordingly the responsibility of maintenance belongs to operational staff and ownership of the asset goes to Asset Management Department. In Water Asset Management, the preventive maintenance is one of the key elements implemented annually. This involves minimizing of breakdown in the system and all spare parts or assets are replaced after their useful lifetime or with the assessment.

At Present in some countries ownership concept is delegated to lower level of the staff as watchdogs to look after smaller part of the distribution system. Accordingly every employer in the water supply scheme has responsibility of distribution system. Powers have been delegated to investigate and report all the short coming in the system in the respective areas such as illegal consumptions, leakage and meter reader's corruptions etc.

2.3.10. Incentive Based Management

This is very popular among employees but hardly see any plan activity implementation in Colombo city based on incentive management. Implementation of zonal concept and DMA with systematic approach with incentive base management is very much successful compared to other high tech systems.

2.4. Performance Measures for Water Loss and Leakage

Water loss from a distribution system is a direct measure of how well a system is performing and being maintained. The measurement of efficiency of the system would be at a point in time or over a long period. High and increasing water losses are an indicator of ineffective planning and construction, and of low operational maintenance activities (Lambert 2000).

The IWA's task force on water losses recommended a standard international terminology for calculation of real and apparent losses from the water audit and performance indicators (PIs) to enable comparisons between different water distribution systems worldwide. These are discussed below.

2.4.1. Measuring and Evaluating the Water Loss and Leakages

There are several methods available to evaluate water losses and leakages in water distribution networks. Each method has its own limitations. The most popular methods are the total quantity method (water audit) and minimum night flow method.

In the total quantity method, (A.O. Lambert 2005) the quantity of water loss is determined by calculating the difference between the total amount of water delivered to the network and the summation of the water quantities consumed by customers. This method gives the total NRW rather than the amount of leakage. The minimum night flow rate method assumes that the minimum flow rate that occurs during late night hours (1 am to 3 am) will represent the rate of leakage upon reducing legitimate night flow (actual consumption at night). This method can be improved by calculating the net minimum flow, which is the difference between the total night flow and the legitimate night flow. Further, quantity of leakage, which gives net minimum night flow rate multiplying by appropriate factor (called T factor corresponding to minimum and maximum pressure) to correct pressure fluctuation during day and night. This method cannot be applied to intermittent supply systems.

After measuring the water loss, a technical audit can be carried out for the water distribution network using a number of indicators to express the level of water losses. For evaluating the technical condition of the water distribution network the following indicators are recommended by A.O Lambert 2005 – IWA water loss task force , the Infrastructure Leakage Index (ILI) and the Economic Leakage Index (ELI). These are determined from the unavoidable real losses and current real losses and the various costs required to carry out a water loss reduction programme.

2.4.2. Current Annual Real Losses (CARL)

The CARL is the total loss from the system as calculated using water audit excluding the apparent losses and authorized consumption. These are physical water losses from the system, up to the point of measurement of customer use. It is expressed in m^3/day. It is given by the formula:

CARL = 'System Input' – (Authorized consumption + Apparent losses)

Where:

System input - is the volume input to that part of the water supply system to which the water audit calculation relates, allowing for known errors.
Authorized consumption - is the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so.

Apparent losses - are unauthorized consumption and all types of metering inaccuracies.

Where it is difficult to get reliable data on the real losses, it can be estimated that the CARL are equal to the NRW as normally the apparent losses take up a smaller percentage of the total losses.

2.4.3. Unavoidable Annual Real Losses (UARL)

The concept of UARL is based on the fact that leakage cannot be eliminated but possible to reduce. Even a new distribution system without water use appears some level of leakage, although it may be relatively small. UARL represents base on distribution length a theoretical reference value representing the technical low limit of leakage that could be achieved for the given system based on the following assumptions:

- The system is in top physical condition and is well-maintained;
- All reported leaks are repaired quickly and effectively;
- Active leakage control is practiced to reduce losses from unreported leaks.

The standard form of the equation is as follows:

UARL = (18 Lm + 0.80 Nc + 25 Lp) P --------------- equation 2.1

Where: UARL = Unavoidable Annual Real Losses (liters/day)

Lm = Length of mains (km)

Nc = Number of service connections

P = Average operating pressure at average zone point (m)

Lp = Length of service pipe (underground) from street edge to customer meters (km)

The basic equation is based on an average length of pipe from the water main up to the customer meter of 10 m. The term (Lp) is therefore only used in cases where the customer meter is located in excess of 10 m from the water main (McKenzie et al 2002).

In some countries where the customer meter is located at the street edge, the equation can therefore be simplified as follows:

UARL = (18Lm +0.80 Nc) P ------------------------------ equation 2.2

2.4.4. Infrastructure Leakage Index (ILI)

The ILI is the ratio of the CARL to the UARL. It is a ratio which gives us how well the real losses are being managed (maintained, repaired, and rehabilitated) at the current operating pressures. It is given by the formula:

ILI = CARL/ UARL ------------------------- equation 2.3

As an example, an ILI close to 1.0 represents that the operational management of the highest standard. The higher value of the ILI, poorer the performance of the system. Continuous monitoring of the ILI gives as an indication of direction of improvement. As an example, an ILI of 1.5 means the real losses are supposedly 1.5 times the lowest technically achievable real losses at the current average pressures.

ILI is a good indicator of how a distribution system is performing as opposed to current methods of expressing water loss in terms of percentage of system input as is done in many developed and developing countries. According to Liemberger and McKenzie (2000), it was found that this significantly underestimates the true extent of the leakage problem in developing countries and tends to penalize systems with lower consumption. This can be clearly seen from examples on studies carried out in Vietnam, Indonesia and Sri Lanka. The ILI turned out to be:

- Vietnam: 42% (ILI = 79)
- Indonesia: 40% (ILI = 31)
- Sri Lanka: 46% (ILI = 39)

It can be seen, the losses do not reflect the huge difference in leakage performance between the Vietnam system and the remaining two systems.

Liemberger (2000) suggested a simple look-up table based on the ILI to help address this issue. This allows a first simple assessment using liters per connection per day in combination with the approximate average pressure. This is presented in Table 2.1

Table 2-1 : Relationship between leakages and Average System Pressures & ILI in developed and developing countries -Liemberger and McKenzie (2000)

Technical Performance Category		ILI	Liters/connection/day (when the system is pressurized) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed countries	A	1 – 2		< 50	< 75	< 100	<125
	B	2 – 4		50 - 100	75 - 100	100 - 200	125 - 250
	C	4 – 8		100 - 200	150 - 300	200 - 400	250 - 500
	D	> 8		> 200	> 300	> 400	> 500
Developing countries	A	1 – 4	<50	< 100	< 150	< 200	< 250
	B	4 – 8	50 – 100	100 - 200	150 - 300	200 - 400	250 - 500
	C	8 – 16	100 - 200	200 - 400	300 - 600	400 - 800	500 - 1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

From table 2.1, different ILI ranges have been provided for developing and developed countries (Liemberger and McKenzie -2000). The proposed table attempts to classify the leakage levels within the water utilities into four categories based on the ILI value as follows:

- Category A: Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost effective improvement;
- Category B: Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance;
- Category C: Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts;
- Category D: Horrendously inefficient use of resources; leakage reduction programmes imperative and given high priority.

Since the vast majority of water utilities in the developing world will have ILI values exceeding the upper limit of 16, reducing real losses to below 16 will be the starting point. As soon as the utilities starts to introduce active leakage control, carry out flow and pressure measurements, and improve overall data quality the bandwidth of the ILI will dramatically be reduced. Often leakage reduction will also lead to an improved supply situation and pressure increases that will make the calculation of the UARL formula more accurate (Limburger and McKenzie 2005).

2.4.5. Theoretical Analysis of Water Leaks in Distribution System

In a closed conduit pipe line, the leakage is mainly proportionate to the pressure in the pipeline. Leakage increases with the pressure, and vice versa. Therefore percentage of leakage could be reduced by controlling unnecessary pressure in the distribution system.

Relationships between pressure and rates of flow from existing leaks

The leakage rate L (volume/unit time) also depends upon the orifice area (A), according to the equation: $L = V \times A = C_d A \times (2gP)^{0.5}$

Where:

V is the velocity of water through the orifice in m/s

C_d is a discharge coefficient: a dimensionless factor of less than 1

g is the gravitational constant in m/s^2

P is the pressure in meters head

The most appropriate general equations to use for simple analysis and prediction of pressure: leakage relationships are,

L varies with P^N and $L_1/L_o = (P1/P0)^N$

Where: L_1, L_0 are leakage levels corresponding to pressures of P_1 and P_0 and N is a coefficient for given system

From the above considerations, most of the studies reviewed that the exponent N in the above relationship could vary between 0.50 and 2.50, depending upon the types of leak presence. These relationships are shown in figure 2.8

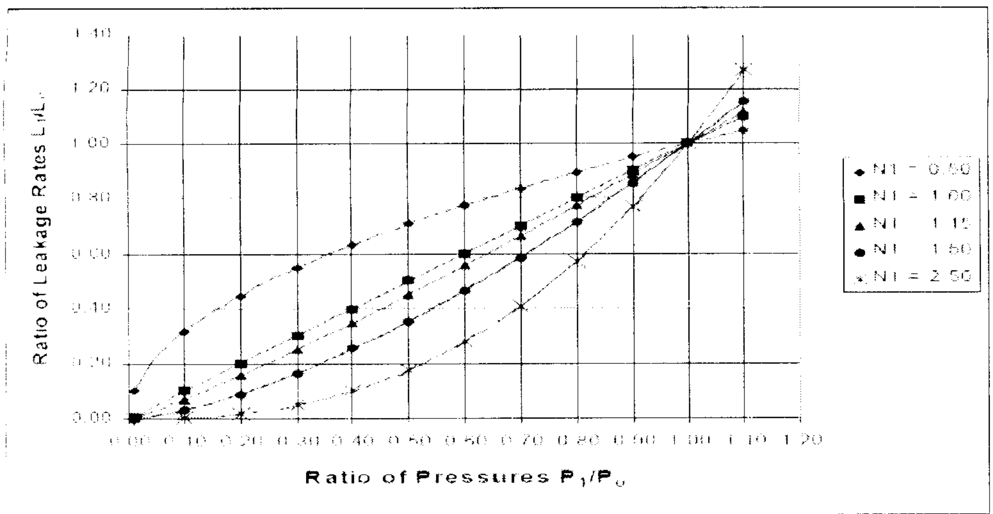


Figure 2-8 : Relationship between pressure and leakage rate for different "N" values.

(Source Farley and Trow, 2003)

Using the relationship in figure 2.8 reductions in pressure from 70 meters to 40 meters can halve leakage levels. Doubling pressure will increase leakage by three times and halving pressure will decrease leakage by two thirds.

If the excess pressure in a system can be reduced, then so too can the leakage, which, in turn, will save money and conserve water. This is the basic philosophy governing pressure management in potable water distribution systems and is often the most effective and cost efficient form of water loss management that can be applied to a particular system (McKenzie 2002).

2.4.6. Quantification of Leakage

The approach of leakage estimation is the measurement of Minimum Night Flow rate that is required. During the night domestic consumption is minimum or negligible and only few commercial uses exist. Therefore following equation could be used to derive the estimated level of leakage at night:

$$U = S - (m + a \times n)$$

Where: U = night leakage flow rate (Net Night Flow, NNF)

S = Minimum Night Flow (MNF)

m = industrial and commercial consumers night flow rate

a = average domestic night flow rate per property (waste)

n = number of properties supplied

From the experiments, night leakage flow rate can be converted into the total daily leakage quantity by multiplying 18 hours instead of 24 hours, as the pressure at night is higher than that of during the day. In other words, it is assumed that 24 hours at the average leakage flow rate is equivalent to 18 hours of flow at the night leakage flow rate.

2.4.7. Benefits of Reduction of Leakage

In distribution systems where it is not possible to supply sufficient water to satisfy the existing demand, leakage control measures can be used to reduce leaks, thus enabling a larger proportion of the demand to be satisfied. The economic benefits of leakage control are represented by the resulting increase in net revenue and minimizing damages to the other infrastructure such as, road structures and other services.

2.4.8. Economical Analysis of Leak Repairs

If the demand is already fully satisfactory, the leakage control to reduce system losses will reduce operational costs, and defer further capital expenditure to construct new water supply projects. However there is a limitation for economical cost savings of leakage controls. Therefore implementing leakage controls could be justified only when the resulting economic benefits are greater than the costs of implementing such measures together with capital cost for new water supply schemes and water scarcity etc. This exercise is complicated as it is analysis based on the discounted net present value of future source and distribution works with the period of deferring.

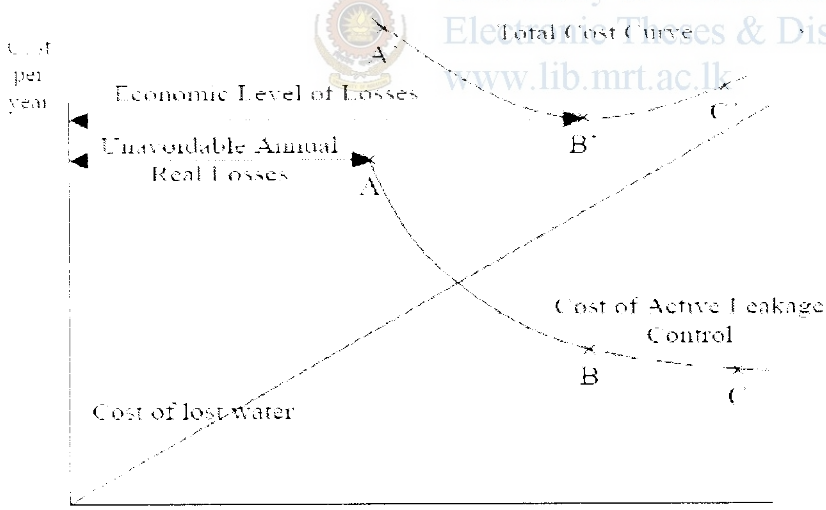


Figure 2-9 : Relationship between UARL and ELL (Lambert 1999)

Above chart explains the concept and presents a simplified economic approach to determine an appropriate intensity of active leakage control for dealing with unreported leaks and bursts. As the intensity of active leakage control increases (C > B > A), causing the annual cost of leakage control (Y-axis) to increase, the average real losses (X-axis) reduce asymptotically towards some base level, and the annual cost of the lost water decreases as the average volume of real losses falls. The economic level of losses occurs when the total cost curve (A'>B'>C'), which is the sum of the cost of lost water and the cost of active leakage control, is at a minimum (Point B' in figure 2.9). With simplifying assumptions that:

- *Infrastructure is in good condition;*
- Point A represents the technical 'state of the art' for intensive active leakage control;
- All detectable leaks and bursts are identified and repaired rapidly and effectively.

Then the real losses for point A correspond to UARL. Actual or economic levels of real losses should always lie at, or to the right of, point A. The ILI – the ratio of actual or economic real losses to UARL - should always exceed 1.0. (Source Lambert et al 1999) It is clear that economical leakage control is financially viable to some extent. When the leakage is small, the cost of control is very high and vice-versa. Therefore after the optimal point it is not economical by further reduction of the same.

2.5. Present Development in NRW Management in the World

2.5.1. Water Loss Reduction Strategies

Many strategies exist on how to deal with water loss and different types of approaches have been tried in different parts of the world with success. Due to inappropriate, conventional practices or high tech approaches with lack of expertise or resources in many cases, the problem has resulted in failure and the waste of valuable resources when trying to deal with water losses.

The IWA Task Forces on PIs (Alegre 2000) and water losses (Lambert and Himer 2000) have recently produced an international "best practice" standard. These best practices are intended to promote a more standardized international approach to the definition, assessment, monitoring and management of NRW and water losses.

2.5.2. Water Loss Strategy Development

In order to succeed in the programme, it has to be operated in a strategic way; Most of the programmes may fail due to ignoring the role of development of the deployment of strategies. Hence the main issues to developing a strategy for prevention of water loss is to gain a better understanding of the reasons for water loss and the factors which influence its components (Real and Apparent losses). Then appropriate techniques and procedures can be developed and order of priority selected, based on key areas that suit available resources.

To understand the causes of water losses it is necessary to review past records and evaluate the current situation. To evaluate current situation it is necessary to develop a strategy to ask some questions about the network characteristics and the operating practices. Then use the available data to suggest appropriate solutions, which are used to formulate the strategy. A generalized process for water loss management is presented in figure 2.10

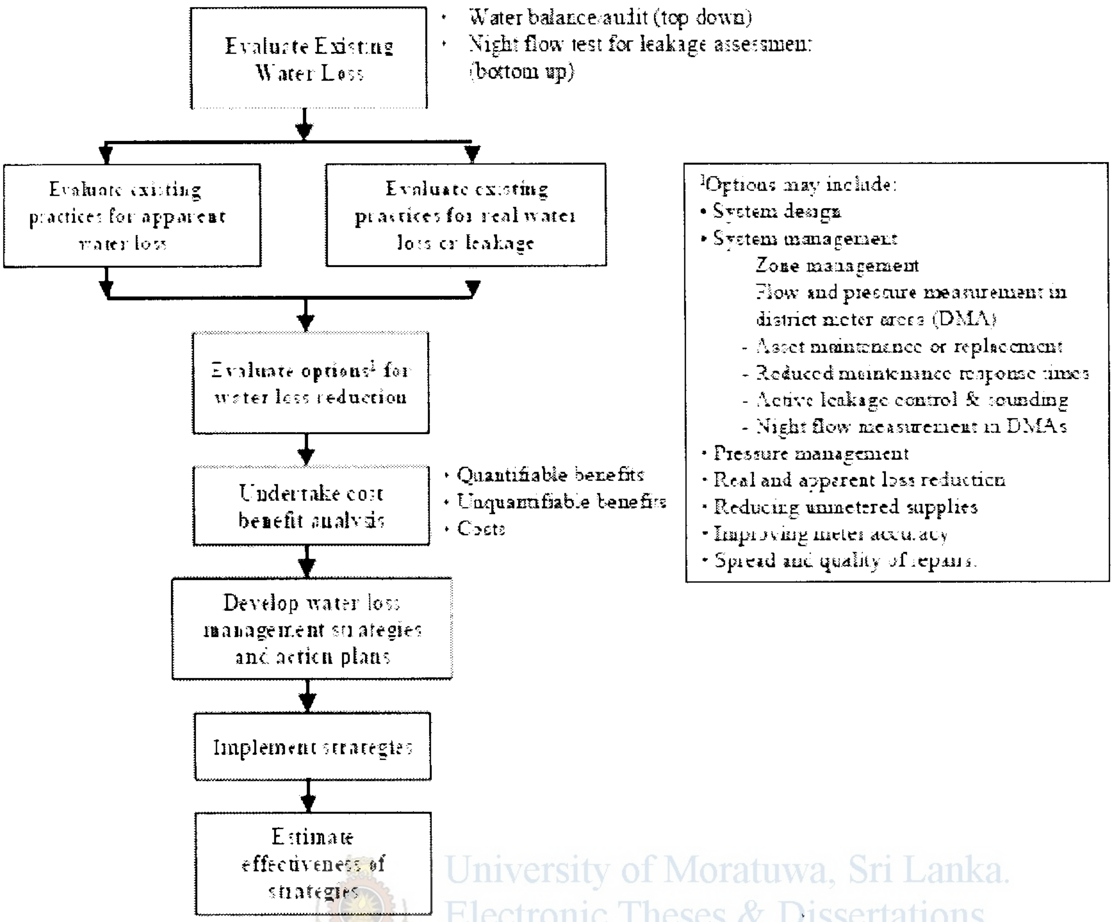


Figure 2-10: Water loss management process (Source: Water loss management implementation guide line 2004 - IWA publication)

2.5.3. Water Loss Interventions

Each, water distribution system has different types and degree of water losses. One cannot be expected to find common solutions; unique solution must be found by adopting appropriate approaches with available resources.

Interventions For Real Losses

The intervention methods for losses depend on factors which contribute to the real losses such as pressure, corrosion, poor material or workmanship and lack of preventive maintenance. The type of interventions chosen will also be influenced by the local conditions and attitudes of people.

Real losses have four basic intervention methods. As the system ages, there is a tendency for a natural rate of rise of real losses through new leaks and bursts, some of which will not be reported to the utility (Lambert 2002). This tendency is controlled and managed by a combination of the four primary intervention methods of real losses management as shown in figure 2-11 such as

- Pipeline and assets management
- Pressure management
- Speed and quality of repairs
- Active leakage control to locate unreported leaks

The number of new leaks arising each year is influenced primarily by a long term pipeline management. Sometimes one leak is responsible for the failure of the whole distribution system. Pressure management can influence the frequency of new leaks, the flow rates of all other leaks and new pipe bursts. The average duration of the leaks is limited by the speed and quality of repairs and the active leakage control strategy controls how long unreported leaks exist, before they are located. The extent to which each of these four activities is carried out as mention in figure 2-11, will determine whether the volume of annual real losses increases, decreases or remains unchanged.

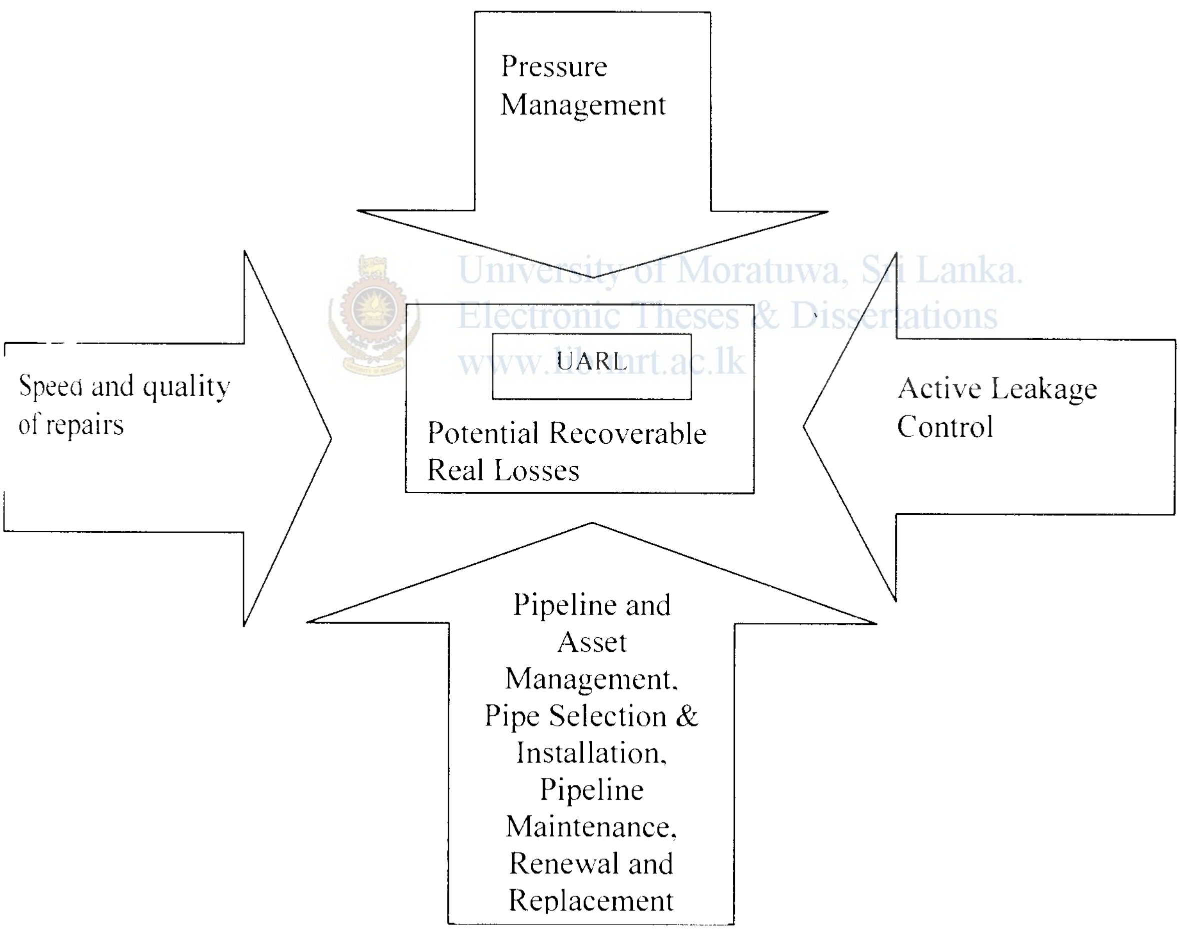


Figure 2-11 - Four basic methods of managing real losses (Source – Lambert 2002)

Interventions for Apparent Losses

The intervention for apparent loss focuses on the management of unauthorized consumptions including all technical and administration inaccuracies associated with customer metering. Four components of an apparent loss management system can be defined as shown in fig 2.12.

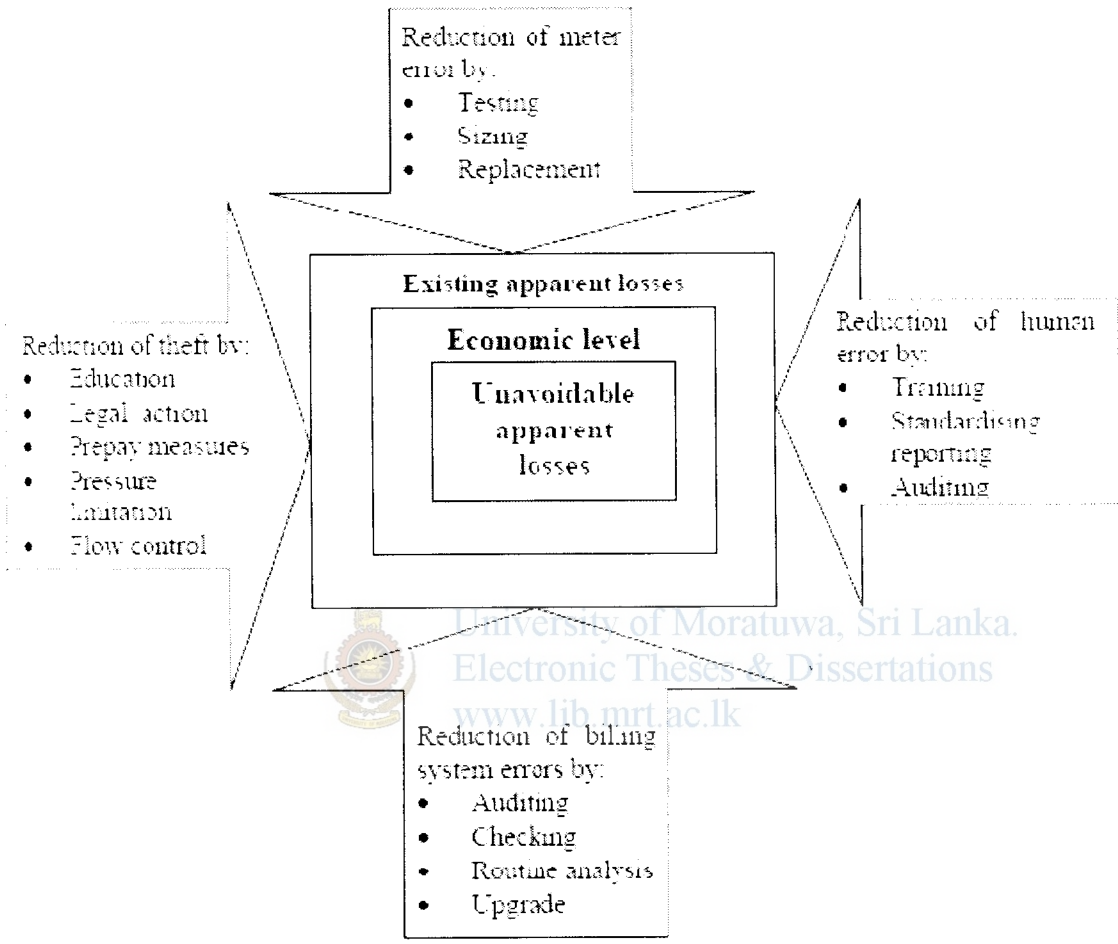


Figure 2-12: Four basic methods of managing apparent losses (Source Thomton 2002)

2.6. Case Studies

Presently NRW management is one of the high priority activities in the world in water utilities in many governments because of water scarcity and limitation on new water sources because there is water stream pollution due to industrialization. IWA has recommended a set of standard approaches, which is one of the useful aspects of management water loss available in the world today. In their recommendation Pressure Management is one of the main concepts, followed by meter management; leakage detections and controls. These interventions are being successfully used in the water utilities in the world to achieve success.

2.6.1. Case Studies in Developed Countries

Several case studies were reviewed such as Geneva Water, South Africa Experience, Water Supply System in Budapest, Water Supply System Vienna & Singapore Water system

2.6.1.1. Case Study in Geneva Water

Geneva Water which is a public utility situated in the capital city of Switzerland was concerned about the method of NRW calculation and the high amount of NRW compared to other European water utilities. They produce 70 Mm^3 of drinking water per year for approximately 450,000 customers.

In 2006 March, Geneva Water has established NRW calculation procedure with the guidance of IWA. Later it realized that previous estimates were under-evaluated and that there was improvement of the whole process of water production and distribution. It helped to understand causes for water loss and action was taken accordingly.

An in depth evaluation of the Water Balance for Geneva, has carried out when the previous calculation reached a Non Revenue Water percentage exceeding 10% , highlighted that the situation was not acceptable and many improvements where necessary and possible as shown in figure 2-14. This work allowed for a knowledge of all the components of the water balance and wide spread information of the staff involved. Necessary improvements concern both the reliability of the Water Balance figures and the reduction of losses. Water audit for Geneva water 2004 is shown figure 2-13.

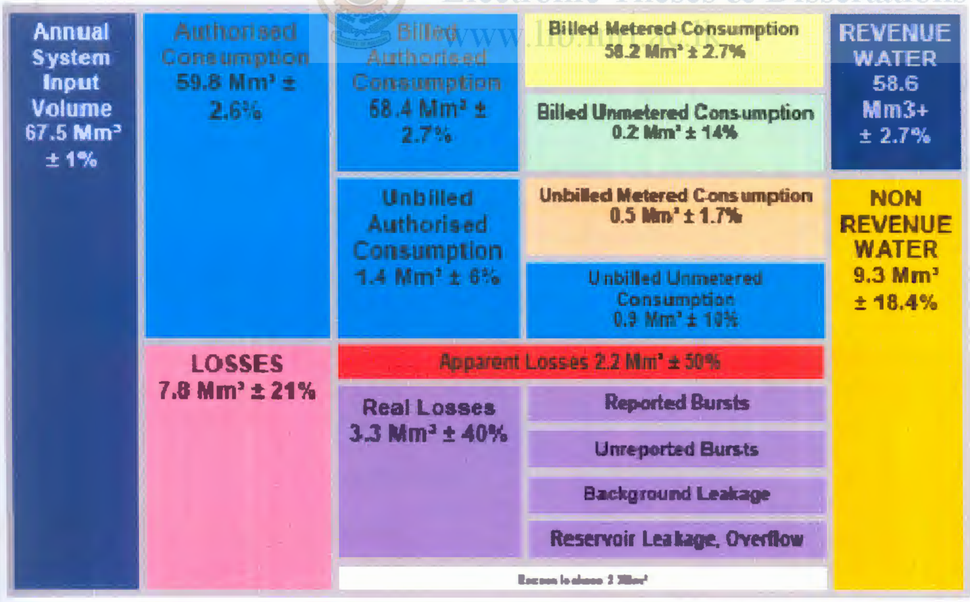


Figure 2-13 IWA's water balance results for Geneva – Year 2004- (H. Guibentif 2006)

Year	Non Revenue Water	
	Previous Estimation of Water Loss	Water Loss of IWA Methodology
2002	9.3%	
2003	9.6%	
2004	*10.5%*	*13.3%*
2005		14.0%
2006		13.7%

Figure 2-14 : Evaluation of the Non Revenue Water (% of Production) (H. Guibentif 2006)

As the first steps of implementation of the action plan allowed to reduce easily, some of operational losses, and the next step will fix the necessary targets for the two main points of optimization of the consumer meters renewal programme (important financial losses) and pressure management (important reduction of bursts are expected.)

Improvement of the reliability of figures

- Calibration of flow meters
- Customer meter sampling and checking the accuracy
- Proposition of an improved method for integration of consumption data (Annual index)

Identification and reduction of the losses

- Optimization of the customer meter renewal programme
- Calculation of Infrastructure Leak Index (ILI) indicator to focus pertinent actions
- Identification and implementation of sectors for reducing average pressure in the network

The main lesson learned from this project

- Correctly identified the failures and high priorities to cure it
- Incurred resources with appropriate methodology to suit the situation
- Concern about the situation top to bottom and correct directions

2.6.1.2. South Africa Experience

Leakage reduction is rapidly becoming a major issue throughout South Africa due to limited water resources (McKenzie 2002). It helps to meet growing water demands and improve living standards as well as the government's commitment to supply drinking water to all South Africans. Leakage has been identified as major deficiency which exceeds revenue water in many parts of the country.

In order to reduce leakage levels from water distribution system, pressure management is identified as one of the most efficient and cost effective measures used in South Africa. The concept of pressure management was first introduced in 1995 to South Africa by a private consultant with series of courses, presentations and various pilot projects all over the country. With the knowledge acquired of pressure management, Johannesburg is the first major project that started in 1998 in South Africa. With the positive result, 100 of modern pressure management equipment were installed throughout South Africa and more than 80% were successfully operated.

2.6.1.3. Water Supply System Budapest

40 km lengths of pipes were rehabilitated using suitable liner to prevent water losses in a project of the Budapest water supply scheme (Stuart Trow 2005) The suitable liner systems used were selected for each line by evaluating degree of deterioration, operational experiences, and quantitative risk management in the water supply network. It was reviewed through investigation and evaluation process that over 70 years old Cast Iron pipes were in excellent condition and only needed to be sealed water tight by an interactive compound as the former liners were already absent.

2.6.1.4. Water Supply System Vienna

System pressures were increased by minimizing water losses through introducing liners in critical pipe lengths in the distribution system as shown in figure 2-15 (U Rabmer – Koller 2006)

Pipe before rehabilitation / pipe with impregnated textile tube / rehabilitated pipe

Figure 2-15 : Deteriorated Pipe Rehabilitation with Inner Liner

(Source – U Rabmer – Koller 2006)

This method involves cleaning process; with liner selection is depended on degree of incrustations, pipe material and discharge method of the loosened deposits. In some cases it needs high pressure water jetting with up to 120 bars. During this rehabilitation temporary bypass was provided to provide uninterrupted water supply.

CCTV inspections have done in different stages of the rehabilitations such as

- Prior to rehabilitation to evaluate prevailing situation
- Immediate after the cleaning to confirm cleaned surface

The conventional replacement of pipes by excavation is very expensive, causes damages to infrastructures, time consuming, No available road space due to service line congestions and extremely disruptive to public. Nowadays in the developed world No-dig projects are implemented widely to overcome this deficiency. In this project it was proved that relative short construction time and minimum infrastructure disturbance are the main advantage of this method.

2.6.1.5. Case Study in Singapore

Population of Singapore is around 2.8 million and the country incurred huge amount of money to import water from Malaysia. Hence it was a mandatory requirement to take steps to reduce water losses through distribution system. In 1989 it was reported that losses were 10.6%, and with the implementation of following strategies it was reduced to 6% in 1994. (Asian water supplies reaching the urban poor – Arthur C McIntosh 2003)

- Metering of production and consumption is 100%
- Used durable high accurate meter by adopting endurance and flow test during tendering stage and Production meters are calibrated every month
- Meter replacement policy was introduced and domestic meters are replaced every 7 years and industrial meter for every 4 years
- Volume of fire water used is estimated or measured and fire department is billed
- Commercial system is highly reliable
- Controls are in place to prevent meter tampering
- Billing complaints are dealt with promptly
- High and low consumption patterns are investigated
- The entire distribution system is surveyed for leaks every year
- Water district can be fully isolated to monitor for leaks.
- Distribution pipes are cement lined to reduce corrosion and replaced if the number of breaks exceeds three per km per year.
- House connections are made of stainless steel.
- Certified plumbers do in house repairs and installations.

2.6.2. Case Studies in Developing Countries

Several case studies were reviewed in developing countries such as Sandakan, Sabah, Malaysia, Case study in Phnom Penh water supply authority, Cambodia and Case study in Manila Water in the Philippines

2.6.2.1. Case Study in Sandakan, Sabah, Malaysia

Background

Sandakan is a city in the Malaysian state of Sabah situated in the north east of Borneo Island. It has a population of approximately 450,000 and reported over 60% NRW towards end of 1990's. In 1997 a NRW reduction contract was awarded to a private company and their objective was to design and implement DMAs and reduce physical losses by 25% (Richard Pilcher 2005)

Total length of pipe net work is 600km including transmission and distribution system and has approximately 36,000 service connections. With the detail studies Consultancy Company had identified the following were responsible for the water losses in the

Sandakan Water Supply Scheme

- Poor materials and infrastructure;
- Operational practice due to water shortage;
- Damage to fittings by people stealing water;
- Low pressure areas
- Intermittent supplies
- Frequent pipe bursts due to Asbestos pipes
- leaks occurring on service pipes
- Theft of water and increase in leakage due to the tampering of pipes and fittings

Water Loss Reduction Activities

After assessing and identifying the reasons for water losses in Sandakan, a strategy was developed to reduce water loss with the discussion of officers concerned. After implementing several important stages to water loss management activities, it was realized that there is no standard approach and, as in Sandakan, it had to be tailor made to suit the local conditions. The target to be completed by August 2005, was to reduce real losses by 5,500 Ml/annum (15 Ml/day) this would result in a level of NRW of 30% thus achieving the target set by the Malaysian Federal Government. In practical terms the rationing of water would be greatly reduced and there would be an increase in revenue as each cubic meter of water that can be saved can be sold.

In many water distribution systems, losses can be reduced to an acceptable level by the introduction of an active leakage control programme i.e. proactively 'finding and fixing' leaks but, in Sandakan, parts of the infrastructure were in such poor condition that some pipes were in need of replacement. Thus, the problem of water loss had to be tackled from two directions – leak location and repair and selective pipe replacement.

The strategy included the following activities:

- Updating the existing records system;
- Construction and verification of a hydraulic model;
- Establishment of 31 existing DMAs;
- Develop and implement DMAs to cover 75% of the system;
- Increase manpower in the leakage detection and rectification section;
- Specify and procure leakage equipment;
- Identify scope for pressure management;
- Reduction of physical losses by 15 Ml/day;
- Identification of mains that required replacement

Impacts

During the course of the project approximately 2,100 leaks were located and repaired. At the end of June 2005, physical losses had been reduced by almost 17.5 Ml/day against the target of 15 Ml/day. 11 Ml/day had been saved through active leakage control and 6.5 Ml/day by replacement of mains. The reduction of NRW (in Ml/ day) is shown in figure 2.16 for the period 2000 to 2005

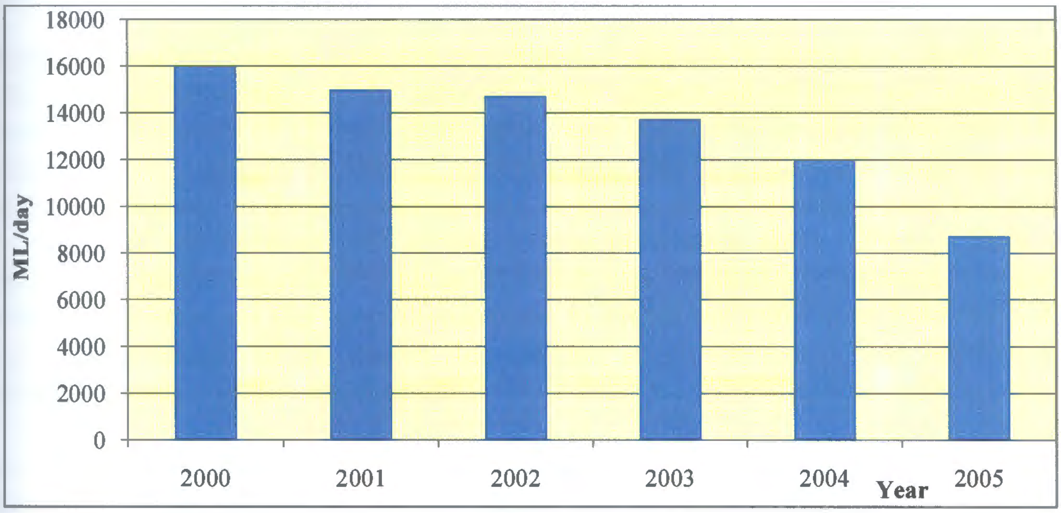


Figure 2-16 : NRW reduction in Sandakan (Richard Pilcher 2005)

2.6.2.2. Reducing leakage in Jakarta, Indonesia

Background

Jakarta is one of the most highly populated cities in Asian region of around 12 million inhabitants. Before 1997 water service to inhabitants of Jakarta was not fulfilled and 46% NRW was reported of which over 75% was real losses (Source: Dewi Rogers 2005). Hence the management of the water authority decided to privatize the network in two separate concessions towards the end of 1990's. The water distribution system speared over 3000 km comprised pipes varying in diameter from 25 mm to 1200 mm. The operating pressures rarely exceeded 15 meters and usually were less than 10 meters and low pressure areas and frequent pipe bursts were common to the system. Due to absence of maintenance and map updating, the available information was very limited. . Furthermore, old networks were not always abandoned when a newer network was constructed. Most of the by roads are having concrete surface, hence leaks hardly ever became visible. Before 1997, real losses were controlled by using traditional methods as no proper active leak control programme was implemented.

Water Loss Reduction Activities

The DMA approach used in Jakarta was to permanently divide the network into a number of sectors, supplied by a few key mains. This was done so as to immediately identify the presence of leaks and also to locate them more easily. Consequently, this enabled the leakage teams to maintain the leakage at its minimum level by always working in the highest priority sectors. The main objective of a permanent control system is to continuously quantify the current leakage level and identify immediately the presence of a new leak. It is vital therefore that the boundaries of the sectors are tight. One way to ensure this is to use natural boundaries. It is also necessary to understand the existing hydraulic operation of the network.

A hydraulic mathematical model was developed for Jakarta to accurately identify errors in the historical knowledge of the network and to understand its hydraulic operation. It contained all the pipes of 125 mm diameter or lager and had an accurate allocation of the consumption. It was fully calibrated by comparing the calculated pressures and flows with those measured in the field during field tests. The model was then used to optimize the division of the network into sectors termed permanent areas (DMAs). Each was supplied by a maximum of 3 key pipes on which was installed a permanent flow meter. Valves were closed on the other connections to create the permanent boundary. As a result for application of the model, the number of closed valves was reduced to a minimum. Source - McKenzie et al, 2002

The objective of a permanent leakage control system was not just to reduce the leakage but to enable a low leakage level to be maintained in the future. The approach developed for Jakarta proved highly successful in locating the leaks. However it soon became apparent that no sooner had a big leak been eliminated that another broke out. Figure 2-17 presents the variation of the leakage level in one permanent area over an 18 month period. The reason was pressure.

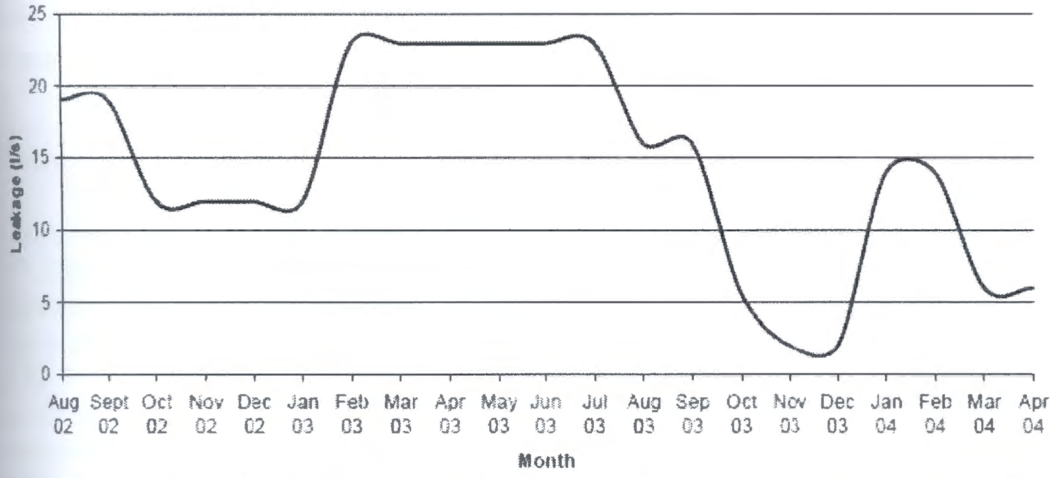


Figure 2-17 : Variation in leakage level over time (Source: McKenzie et al, 2002)

A trial was undertaken in a pilot area of around 20 km. A high quality PRV of the same diameter as the inlet pipe was installed so as to minimize the head loss at peak flows. The results were very positive and showed that not only was the PRV capable of maintaining a constant downstream pressure, but that by lowering further the pressure, it was possible to reduce significantly the leakage. An electronic control unit acting on the PRV's pilot was installed to automatically lower the outlet pressure from 20:00 to 05:00 hrs.

Impacts

The application of a step by step approach proved very successful in the network of Jakarta. In the first permanent area analyzed, the leakage level was reduced by over 60 l/s just by eliminating the large leaks.

The installation of a pressure reducing valve with the application of an electronic controller, made it possible to lower the night leakage by a further 50%. The Jakarta results are significant for the following reasons:

- It is possible to reduce leakage with modern pressure reducing valves
- Low pressure is a consequence of the high leakage level;
- Pressure control is essential to reduce new leaks;
- Significant gains can be achieved by reducing the night pressure even when the existing operating pressures are very low;

2.6.2.3. Case Study in Manila Water in the Philippines

In 1997 NRW in Manila water was reported as 63 % and water authorizer were concerned to develop method to reduce to a reasonable level (Virgilio C. Rivera 2005). Due to in house activities it was not possible to provide reliable service to Manila inhabitants. Due to high demand and poor service, the water authority decided to invest capital to rehabilitate the water supply scheme. Under the rehabilitation programme US$ 368 million was invested for rehabilitation of the system which included 1,440 kilometers of pipe replacement and other rehabilitation activities.

Water Loss Reduction Activities

The project succeeded and NRW was reduced from 63% in 1997 to 30% in 2006. Under this project old Asbestos cement pipes, galvanized iron and cast iron were replaced. Primary water lines were replaced to eliminate further losses, starting in the areas with high occurrences of leaks and pipes bursts. The pipe replacement works was completed in 2004 and proceeded to establish DMA. Manila water currently has 507 DMAs which are monitored as NRW zones. To establish DMAs major pipe lines were laid and deteriorated pipes line were replaced with isolation control valves to make the area easier to manage and monitor. Pipe rehabilitation was carried out by defective and inaccurate meter replacements, installing pressure reducing valves for monitory purpose to adjust water pressure and prevent pipe bursts, and disconnection of all abandoned service lines and mains. In addition to rehabilitation, a hydraulic model was developed.

Impact

- With all these initiatives Manila Water was able to reduce NRW from 63% in 1994 to 30% in 2006.
- Water recovered from previous leaks and system inefficiencies was translated to water delivered to more customers.
- The billed volume of water has increased 938 million liters per day to 2,100 million liters per day.
- Number of water connections has increased from 325,000 in 1997 to 803,000 out of which 148,000 is low income sector.
- By using hydraulic model, any deviations of the distribution system can be easily identified and corrective action taken accordingly.

2.6.2.3 Case Study in Phnom Penh Water Supply Authority Cambodia

Situation in Cambodia is similar to or worse than other Asian countries due to civil war. In 1993 NRW was reported as 72% in Phnom Penh (Ek Sonn Chan 2007) . Due to the civil war most of the inhabitants had taken unauthorized connections due to the impression that water should be available free of charge. In 1994 under the Technical cooperation of Japan International Cooperation Agency (JICA) a programme was implemented to reduce NRW, which is more field oriented rather than high tech applications.

Water loss reduction activities

- Attitude was changed and all the illegal connections were converted to legal connections.
- Zones were established by replacing or rehabilitation of value and water tight test was carried out.
- The entire zones modified to feed one inlet point to facilitate DMAs and monitoring of night flows and step testing.
- Defective meters were replaced with high quality meters
- Active leak detection programmes were introduced and more leak repair gangs employed.
- Saved water revenue was reinvested to replace deteriorated asbestos cement pipes and smaller diameter lines with Polyethylene (PE) pipes.
- Various kinds of incentive schemes were introduced to achiev this success

Table 2-2 : Improvement in 2006 compared with 1993 in Cambodia

1993	Indicator	2006
22	Staff/1000 Connection	4
65000	Water production m3/d	235000
25%	Service coverage	90%
10hr/d	Service hours	24hrs
0.2 bars	Water pressure	2.5 bars
26880	No of connections	147000
72%	NRW	8%
48%	Collection rate	99.7%
150%	Running cost/revenue	22%
Subsidized	Financial status	Independent

To be successful, however, the studies show that good preparatory work with team work is required. The starting point is to develop a strategy based on a sound baseline assessment of the sources and magnitudes of the NRW. Such a strategy needs to consider both the short and long terms (for example, the achievement of short-term reductions versus how to maintain lower levels of NRW over the long term). It is during strategy development that opportunities for teaming with the knowledgeable sector can be identified. Once those opportunities are known, policy makers must create an incentive framework that will encourage the parties to deliver reductions in the most cost-effective and appropriate manner.

2.7. Typical Problems in NRW Management in Developing Countries

Problems have been identified with a fair number of studies done in with local and foreign experts to find the causes and remedial measures. However, most of the studies have not preceded beyond the identification stages due to various reasons such as

- Lack of resources
- Non availability of drawings of distribution system
- Lack of updated maps
- Poor asset management and maintenance
- Poor prioritization of available resource
- Less bulk meters to calculate water loss
- No DMA to monitor distribution system faults
- Attitudes of staff and consumers
- Political interferences
- Poor coordination among utility organizations and lack of centralized data base

3 Chapter Three: Research Methodology

After reviewing the literature an excellent foundation and background was created to develop a methodology by analyzing available data to achieve research objectives as stated in the introductory chapter.

3.1. Study approach

The study approach of water loss management in Colombo City includes

3.1.1 Literature Review

After review of various concepts of water loss management that were carried out in developing and developed countries, theoretical back ground and current practices for the reduction of NRW, and learning from the 'best practices' carried out in these countries to manage water losses were useful to formulate appropriate method to develop water loss management strategies for the Colombo City.

3.1.2 Estimation of Water Loss Using the Standard IWA Water Audit (balance) Method

Water losses in Colombo City is analyzed in respect to annual water production and consumption by using IWA format which helps to determine the water loss on component by component basis (billed, unbilled, metered, un metered). This gave an indicator to the causes of water losses and enabled a characterization to be made of the factors having an impact on the water losses; leakages, bursts, water meters, ages of pipes and other local conditions.

3.1.3 Calculation of Performance Indicators

Key performance indicators were calculated after assessment of water losses of the distribution system by the UARL and ILI. This was done both at the city level, pilot areas and the selected branches as a pilot scale. A comparison was done between them which were termed as satisfied (lower ILI) and critical zones with higher values of the ILI. This was to determine the underlying factors which cause the significant differences. A critical review of the applicability of the performance indicators in developing countries was also made.

3.1.4 Determination of the ELI

The ELI was determined by estimations of water lost through leakage under a period of analysis of 5 years. This gave a fair indication of required capital investment of water loss management rather than the special reason.

3.1.5 Review of Existing Network

A current network practice in the Colombo distribution management system was reviewed to identify short comings to exit such a huge water loss, of both the physical and operational characteristics, and developed sustain management concept to handle water losses.

3.1.6 UFW Reduction Management

With the review of Colombo City maintenance management it was realized that all the responsibilities and operations are concentrated to one key location. This is identified as the key point of failure which results a worst NRW situation in the city and detailed analysis with disadvantages are discussed in chapter 4.6.1.1. After reviewing of the situations it was decided to decentralize the authorities and responsibilities to handle water wastage in more appropriate way. With the decentralizing of authority and responsibility to the middle management level of Colombo city OIC office and respective zone officers handled all the maintenance activities in Colombo City. However due to prevailing high water losses it is difficult to handle planed programme by the maintenance staff due to the heavy day to day work load.

Hence special team will be assigned to handle UFW in each zone or DMA under the responsibility of the zone officers. The function of such team is to cover all possible UFW reduction covering 500 connections in one stretch and to continue the process in the entire DMA within target period (Three years) to clear all the possible water losses. But this is a slow process and needs concentration and increase resources to accelerate the process. This exercise is continued until the supply quantity and consumption was very close or ILI was close to 1 in the particular fragment. The process is continued to cover entire area until ILI gets close to one. All the training and limited necessary equipment will be provided under the Japanese International Technical Cooperation programme. This method widely used in East Asian region and has obtained positive results to empowered infrastructure development.

To match supply and consumption or ILI close to 1, it needs to identify causes for water losses. By conducting House to House survey with field test and observations etc was able to identify apparent losses and some of the real losses. Majority of real losses were detected by conducting step testing to locate invisible or hidden leakages followed by sounding technique in critical areas.

3.1.7 Development of Short and Long Term Strategies for Colombo City

With the analysis of performance indicators and water loss in the distribution system, pilot scale programme was carried out to identify the appropriate methodology to suit local conditions to reduce water losses. Subsequently a right mix of long and short term strategies for water loss management for entire Colombo city was developed.

3.1.8 Development of the Strategic Approach for Water Loss Management

The strategic approach was proposed after looking at what type of methodologies and techniques were applicable to the Colombo city and what were the constraints and limitations of applying these methodologies and techniques in pilot studies. The study methodology is summarized in Figure 3.1

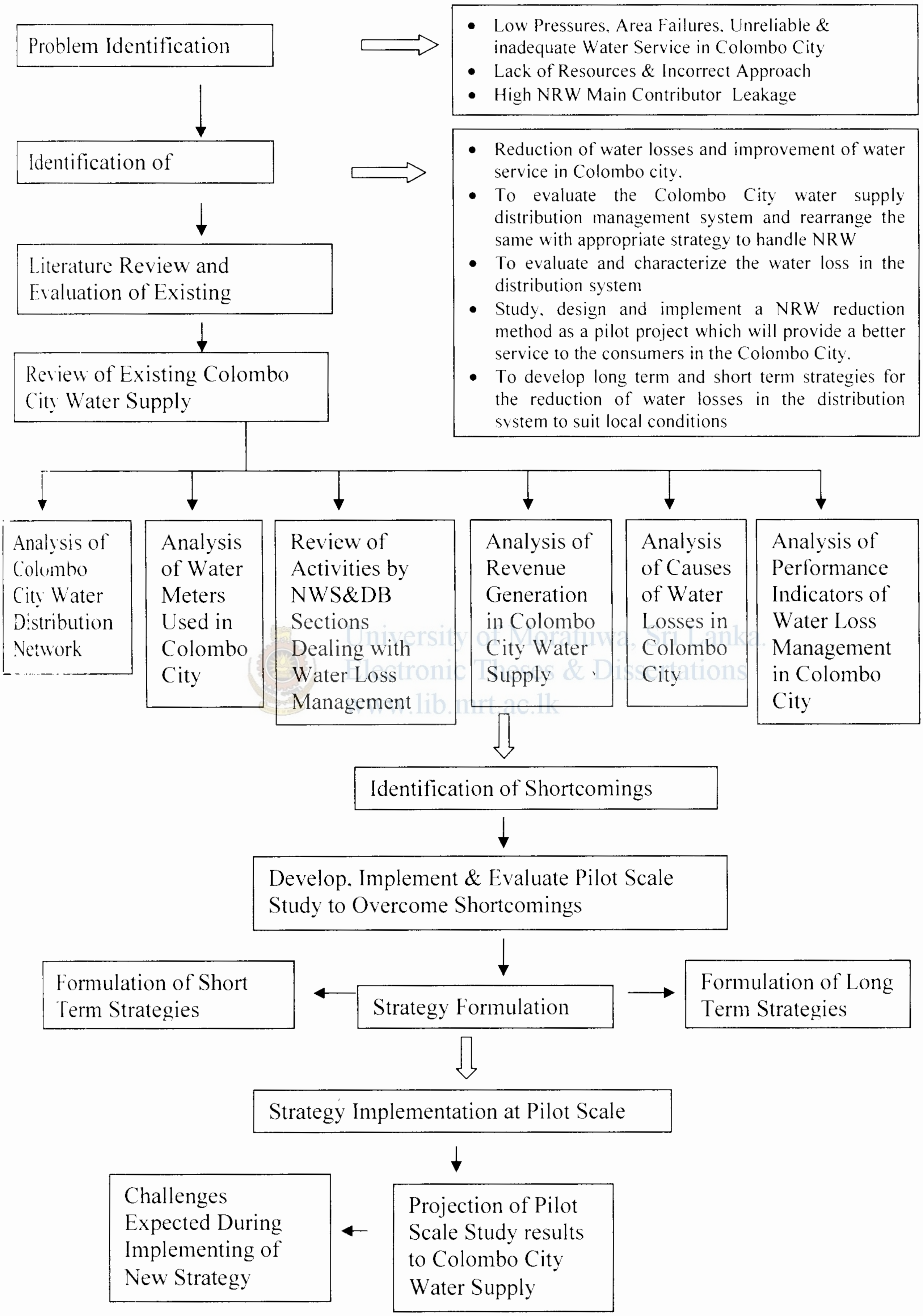


Figure 3-1 **Flow Chart of Research Methodology**

3.2. Method for Data Assembly

3.2.1. Type and Method of Data Collation

Information Required	Core source
Colombo City Population Details	Colombo Municipal Council.
Water Production Consumption Details	NRW Section of NWS&DB
Water Supply Standards & Policy Institutional Arrangements, Financing and Disbursements,	WHO & SLS, Western Central Region of NWS&DB
Digital Drawings and Pipe Lengths	Mapping Division of NWS&DB
Consumption Data	Commercial Division of NWS&DB
Number of Service Connections, Customer Meter Location,	Manager (CC) Office . NWS&DB
Frequency of Bursts, Leakages and Repair Programme, Average Pressures	OPD Section, Western Central of NWS&DB
Data of Millennium Development Goals in Sri Lanka	Asia Water Watch 2015
Current Practices (staffing structure, staff numbers and skills), equipment and techniques	Western Central Region of NWS&DB
Cost Data (production cost, distribution cost and repairs cost)	Western Central of NWS&DB & Production Section

3.2.2. Desktop Studies

The first part of this research was focused on a detailed literature review on existing water loss management methodologies and techniques in developing and developed countries. Indicators used to assess distribution system performance were also reviewed. The desktop study involved the analysis of reports, policy documents and procedures, DMA design with zone isolation, identification of bulk meter and valve positions etc. The desktop study was also used to see how the different divisions have interacted with each other in achieving their set goals on reducing water losses.

By using digital distribution map, Colombo city is divided into 22 zones with each zone comprising of 5000 water connections which can be easily looked after by one officer with two gangs. The zone officer is responsible to implement all the day to day maintenance work and list of duties were prepared after discussion with maintenance staff which is attached in Annex I.

Widely used strategy development is based on current practices reported in the world and most of the planning of water losses involved in modeling and its verification. In this research modeling based studies was not done due to unknown distribution system characteristics.

3.2.3. Role of Operational Staff

Discussions were held with operational staff on distribution system features and practices with the objective of getting their views on water loss, on failures to address problems associated with water loss, causes and effects and how to address these problems to be solved. Monthly progress review meeting is been held with all relevant operation staff to monitor the progress.

3.2.4. Pilot Scale Studies

To identify the methodology to reduce NRW, a pilot project was implemented in southern part of Colombo city with natural boundaries. Because of natural boundaries, the area was easily isolated and four meters were installed to measure inflows. This area comprised of 8873 water connections. Studies commenced with assessment of initial NRW.

According to literature review, there are several methods available to reduce water losses in distribution systems. However most of the methods are not favorable to the local situations. Therefore pilot scale studies were initiated at very basic level with house to house survey to find out causes for water losses. This strategy was to conduct with trained technical staff to identify illegal connections, service leaks by using equipments, meter accuracy with scaled one liter bottle, defective meter replacement, finding reasons for estimated bills and their solutions, identifying appropriate method to get meter readings from house closed premises, etc.

Further, leak survey was planned to identify visible leaks by the same studies groups. In addition to the day time leakages most of the leaks are visualized during night and at the same time pipe leakages at culvert crossings were examined by special teams with instruments.

Night leak survey was implemented and step testing was carried out section-wise to identify heavy leakage areas. Pilot zone consists of 75 roads and initially several roads were planned for step testing. Due to the condition of existing valves, difficulties in obtaining road cutting permission and limited resources, the studies were limited to one road sector with step testing to complete this study.

3.2.5. Field Observations

The field observations were carried out between July 2007 and September 2009 and documented through photographs to clarify and support some of the statements in this thesis.

During the pilot project studies, it was observed that during most of the time low pressure areas were reported due to heavy leakage. After repairing these leaks water pressures increased gradually after long period. Though the average consumption is less than $20m^3$/month/consumer, the minimum night flow appeared around 114 l/sec between 4.30 to 5.30 hrs which was also a comparatively high flow. At the beginning of the study, percentage of estimated water bill consumers were 8% and it was reduced to 3% by the end of the study period. On every road, about 2 to 3 illegal consumers were caught and some of the multistory flats had bypasses too. Half way of survey, it was noted that number of illegal detection was gradually reducing due to passing of illegal connection detection message to the adjoining community. Further meter tampering incidences and unbilled, un-metered connections were also detected. There were house-closed situations which had prevented the meter readers from obtaining normal meter readings where huge quantity of water had consumed but estimated as little amount.

In the distribution system most of the valves were not in operational condition and pipe lines were heavily scaled. Due to the defective valves, leak repair is carried out without interruption of water and contamination and heavy water wastages are dominant.

3.3. Methods of Data Analysis

The raw data was analyzed to reflect the progress of the pilot studies and appropriately developed methodology was adopted to achieve the research objectives. The analysis was mostly of a quantitative nature with the use of excel spreadsheets to calculate performance indicators such as UARL, ILI and ELL for the city as a whole and for the pilot project. In addition to the above indicators, service level, System pressures and consumer complaints was analyzed.

Based on the information collected, an estimation of water savings with economical environment and their impact on achieving Millennium Development Goal, water supply coverage targets for Colombo city in particular were analyzed.

4 Chapter four: Observation and Data Analysis

This chapter deal with analysis of the data collected from Colombo City water distribution system and mainly from the pilot project studies. Details of the distribution system included composition of distribution network, DMAs, status of pipes, system pressure distribution and quantification of water inflows, revenue generation analysis, consumer complaints analysis and impact of illegal consumption, free water supply etc. According to the present management system, three sections are dealing with water loss management to achieve different scope in different scales. But none of these sections handle active water loss management programme to achieve set targets due to lack of resources and only manages day to day activities for survival and the result was degradation of the service. Without the rehabilitation of distribution system or proper water management, increase of production would not be a good solution approach, because a water leakage in non peak demand interval will be increased.

The maintenance of distribution network and water balance is dealt by the Colombo City Operational and Development (OPD) section and all commercial and consumer related activities are handled by Colombo City office. In addition to these sections NRW management division is responsible for prevention of illegal consumption and reducing free water supply. At present only NRW & UFW are calculated to assess how the distribution system is currently performing and no UARL, ILI and ELL calculations are practiced.

Furthermore, short and long term strategies are formulated to address this water loss for Colombo city and subsequently, a strategic framework is developed to manage water loss activities with the discussion of operational staff. The challenges that could be encountered in implementing the strategies are also discussed in the monthly meetings. Finally, a review of MDGs progress in Sri Lanka towards improving accessibility to improved water supply is done and quantitative recommendations made on how to improve accessibility with targeted expansion of the water distribution system through water loss reduction.

4.1 Analysis of Colombo City Water Distribution System

Colombo City receives water from three treatment plants operating with two impounding reservoirs 50 km away from east of the town and Kelani river, 13 km away from Colombo City. Considering cost reduction of water transmission, two reservoirs are located within the city and two reservoirs are located close to the city to four areas of city; north, central, east and south. But some of the transmission lines are interconnected to the distribution system without proper studies as short term measures to eliminate low pressure areas and now there is no data about such locations. Due to this fact entire distribution system in the city is interconnected. There are no separate feeding systems to each area from reservoir. Hence it is very difficult to isolate areas even for the leak repairs or urgent maintenance work.

4.1.1 Water Pipes and Accessories

The pipe network consists of approximately 24.3 km of transmission mains and about 810.6 km of distribution mains. Most of the pipes in the network comprise of Cast Iron pipes that are more than 70 years old as explained in the introduction. The oldest known age of pipes in the network is more than 120 years. Table 4-1 shows the various ages of the pipes in Colombo city.

Table 4-1 : Pipe ages of transmission and distribution mains in Colombo city (JICA NRW Reduction Project Report 2006)

Pipe type	>30 years	30 -60 years	60 - 80 years	80 - 110years	110>	Total
Transmission mains (km)	12	2.1	0	4.7	17.4	24
Distribution mains (km)	302	112	42	230	112	810
Totals (km)	314	114.1	42	234.7	129.4	834
Percentage of total	37.6	13.7	5.0	28.2	15.5	100

An analysis of Table 4-1 shows that 45% of the pipe network is over 80 years old and about 15% of the pipes were over 100 years old. The breakdown shown in the table above does not include the length of service connections. The entire network is digitized and available in the form of Auto Cad map link to Geographical Information System (GIS). But no proper mechanism is adopted to verify or update the details in the drawing. Further analysis of Cast Iron pipes sizes with age is useful to take decision for pipe rehabilitation in the future.

According to the September 2009 Management Information System of National Water Supply of Sri Lanka (MIS) reports, there are 118199 service connections including bulk connections, 176 wayside stand post and 4036 common outlets in Tenement Gardens. Length of service connections is estimate as approximately 1500 km.

The network consists of different kinds and age group pipes as mixture of Cast Iron (CI) , Ductile Iron (DI), Galvanized iron (GI), Un-plasticized Poly Vinyl Chloride (UPVC), and Steel pipes (S). All new pipe extensions are mainly in UPVC. Table 4-2 and Figure 4-1 shows the different proportions of each pipe material makes up in the Colombo city distribution system. Accordingly most of the pipe lines in Colombo city distribution are the CI pipes i.e. 67.6%. (NWSDB – Mapping Division)

Table 4-2 : Pipe Line Composition of Colombo City Distribution System

Pipe Material	Length	Percentage
Cast Iron	564,159	67.6
Ductile Iron	32,778	3.9
Asbestos Cement	1,107	0.1
Galvanize Iron	188	0.0
Poly Vinyl Chloride (PVC)	22,7422	27.2
Steel	9,193	1.1
Total	834,847 m	

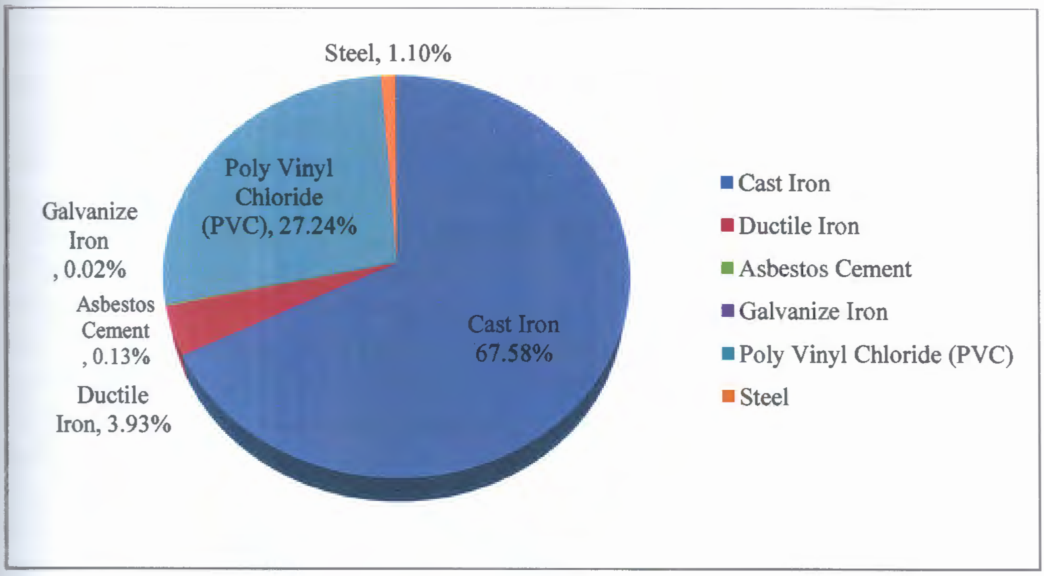


Figure 4-1 : Pipe Material Composition by Percentage

With the analysis of distribution system in Colombo city, it was realized that large amount of leaks, frequent burst, high UFW and low pressure in most part of Colombo city. With the comprehensive studies it was reviewed that urgent pipe replacement needed, at least smaller diameter Cast Iron pipes, in northern part of the city where high UFW is reported. In this area, water distributed with high losses through valve operation in specific time intervals. Hence it was decided to replace 120km of smaller diameter (less than 6") deteriorated CI pipes in stages. In stage I, funding was finalized to replace 56 km of pipes which belongs to two zones which will help to reduce leaks, illegal connections, unbilled connections and all kind of estimation bills, etc.

Figure 4-2 shows some of the problems currently being faced in the distribution system of leaking and corroded pipes.

Figure 4-2 : Leaking Cast Iron pipe and Scaled Cast Iron pipe

In Colombo City, distribution consists of 4,876 Sluice valves but most of the valves are buried and not in operational status. There are also 3530 fire hydrants spreads in the distribution system (Mapping data – NWS&DB). Fire hydrants in Colombo City act as an air and scour releasing points in the distribution system in addition to catering for the fire demands. However these valves need periodical operations to meet system requirements which are not currently functioning due to lack of resources. In addition to the fire hydrants there are 101 scour valves and 132 air valves recently introduced to the distribution system. All pipe lines and utilities are digitized and linked to GIS. But some of the unknown valves are mapped under the flag of suspicion. At present there is no preventive maintenance programme but arrangements has been made to commence such programme from year 2010 onwards with the reorganization of Colombo City distribution management.

4.1.2 System Pressures

Most of the reservoirs that feed Colombo City is situated around 30 – 25 meters above Mean Sea Level. Hence during the day time, no significant pressure fluctuation exists in the distribution system. Therefore no pressure management system is currently functioning in the Colombo City other than periodical valve operations to feed low pressure areas. The average pressure in the network is below 10 meters. In the Colombo City South pilot area the night pressure of the entire zone was increased to14m from 8m at the commencement of the study. Obtained pressures in the distribution system during the study period are tabulated in Table 4-3.

Table 4-3 : System Pressures in the Four Areas

Branch	North of City	East of City	West of City	South of City
Pressure range	0.5 m – 18 m	3 m – 12 m	0.5 m – 10 m	4 m – 16 m

4.1.3 Bulk and Domestic Water Management

In water loss management, accuracy of entire operation mainly depends on readings of bulk and domestic meters. As a policy most of the water authorities have installed high accurate meters for the bulk readings and less accurate meters for domestic meters because of the meter cost. In Colombo City too highly accurate Ultrasonic meters are installed to measure inflows, but for measuring bulk consumptions, turbine type meters are still being used which provides less accuracy. However most of the income is generated from such bulk consumers. It is clearly shown in Table 4-4 & figure 4 -3 that 82% of the income generated by the less than 12% of commercial connections. Presently one unit (one m^3) of production cost to NWSDB is Rs 37/= while tariff for domestic consumers progressively vary from Rs 1.25/= to 120/= per m^3 depending on consumption and for the commercial and shipping it is Rs 65/= and Rs 400/= per m3 respectively. Hence it is clear that the cross subsidy and sustainability of the scheme is wholly depending on bulk consumers. Hence more attention and close monitoring should be paid to the high consume commercial and domestic consumers with fixing of high accuracy meters. Its Current Tariff Structure use in NWS&DB is in Annex 2.

Table 4-4 : Impact of Average Monthly Consumption with Income Generation in Different Categories of Consumers NWS&D – MIS)

Type of Consumers	No of Connections	Consumption m^3	Revenue SLRs	Consumption per Unit	% of Income	% of Connections
Bulk	1994	1638632	96983365	822	23.2	1.7
Commercial	11975	319007	248322506	27	59.5	10.1
Gov. Institutional	628	48028	2973232	76	0.7	0.5
Domestic	84698	1634107	62354317	19	14.9	71.3
Tenement Garden	19277	252920	5485189	13	1.3	16.2
School	148	24311	482604	164	0.1	0.1
Condominium	129	57570	868012	446	0.2	0.1

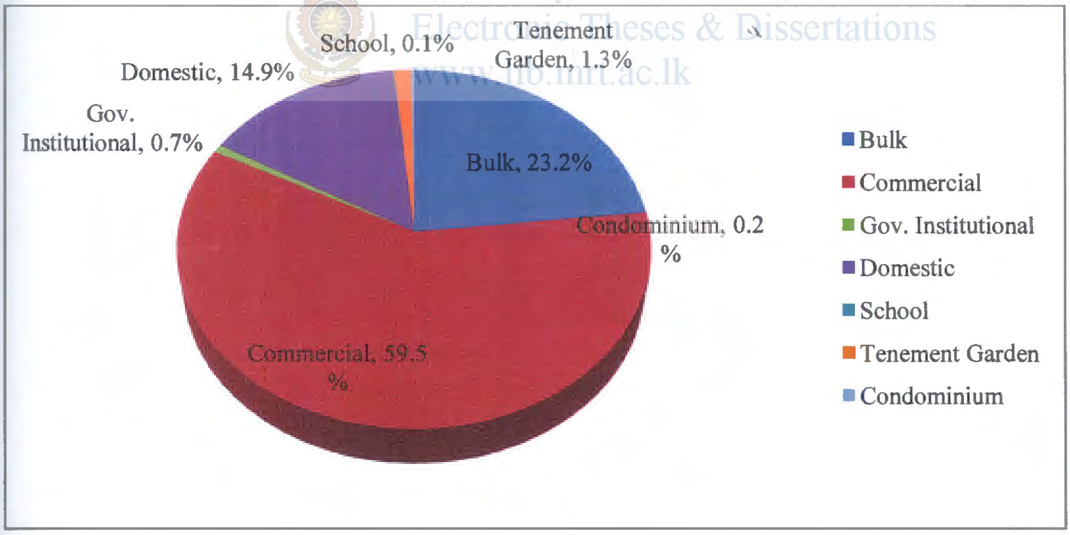


Figure 4-3: % of Revenue in Colombo City in Each Category of Consumption in month of 2009 May

The key connection categories contributing to the revenue are shown in figures 4-3, 4-4 & 4-5. With the increase of revenue, more funds could available for the system rehabilitation work to operate more efficiently.

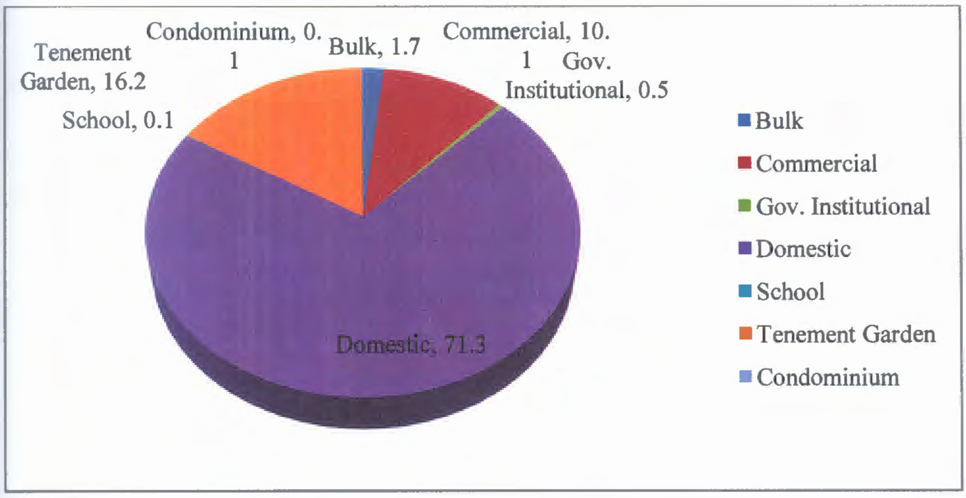


Figure 4-4 : % of Connections in Colombo City in Each Category in month of 2009 May

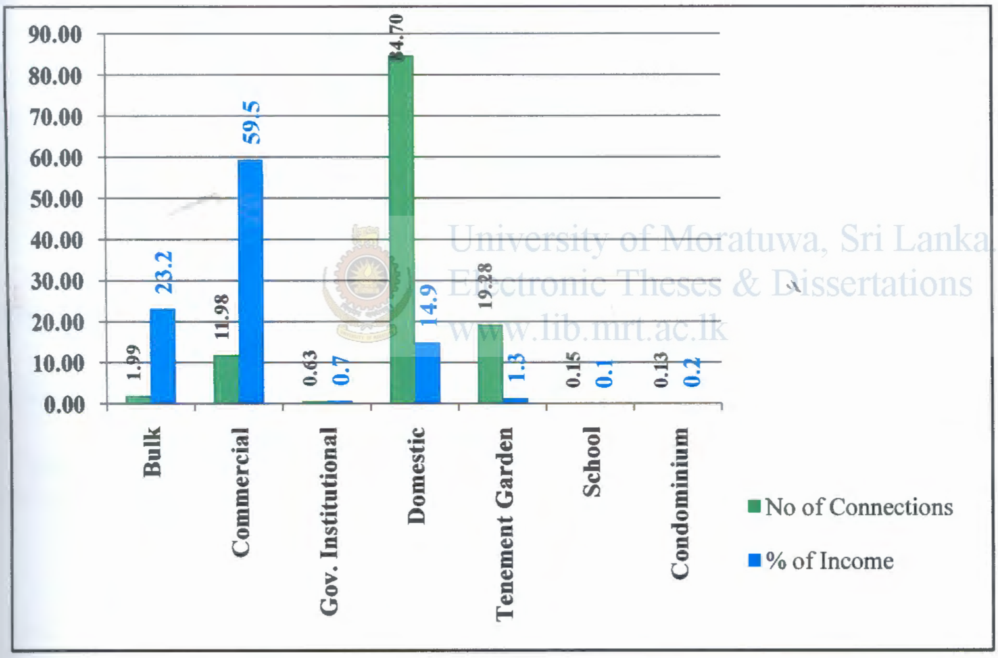


Figure 4-5 : % No of Connections Vs % of Income in Each Category in Colombo City in Month of 2009 May

4.1.4 Statistics and Status of Domestic Meters

In 1982 water tariff was introduced to measure domestic consumption by using turbine type water meters. Nowadays it is replaced with volumetric type meters due to their better accuracy. In May 2009 Colombo City distribution system consisted of 118199 individual connections and 97% of them were metered. In some cases, these meters are not suited for special situations such as withstanding water with air, silt & sand, debris etc., as a result , more than 2% of meters (year 2008) become defective and considerable amount of funds are needed to replace the same annually. Yearly progress of reduction of estimated bills and defective meters are tabulated in Table 4-5 and figure 4 -6.

Table 4-5 : % of Estimated Bills and Defective Meters in Colombo City (NWS&DB - MIS)

	Year 2006	Year 2007	Year 2008
Estimation Bill %	16	15	6
Defective Meter %	4	4	2

Figure 4-6 : Reducing of Estimated Bill and Defective Meter Percentages in Colombo City

According to the present available water meter specifications, it clearly says that these water meters are only suitable for use with clear water and without impurities or air. Due to the high leak repair rate and low pressure, it is very difficult to maintain such requirements favorable for present water meters. Therefore when such situations occur, it is needed to purchase suitable water meters to withstand said conditions for long life usage.

Figure 4-7 : Meter to Withstand Air

By browsing through internet for the suitable water meter to suit the above conditions, a meter type is found available that works with fluid oscillation technology and capable to measure quantity of water though air is present and can withstand for the heavy turbidity situations as shown in figure 4 -7.

The main drawback is the cost. It costs 3 times more than the normal volumetric type meter. But its life span is 3 times more and accuracy is high. When compared with defective meter replacement cost it is more economical to install such a meter in special situations.

4.1.4.1. The Main Problems Identified in Domestic Metering in Colombo City,

- Frequent Meter defects
- Absence of a meter replacement policy
- Availability of variety of meters in the system due to tender procedure
- Meters used are not suitable to the system requirements in special events such as air, debris an sand etc in water

The major problem being faced with meter management is meter blockages and defective meters. Meter blockages are mainly occurred as shown in figure 4 – 8 due to clogging by sand, debris in the water or deposition of excess solvent cement or physical tampering; do not record any water flow. In the end of year 2007 Colombo city recorded 4% defective meters which was reduced to 2% at the end of the year 2008 by implementing a special meter replacement programme. Normally defective meters contribute to a considerable amount of NRW as once consumers get aware about their defective meters, they use water freely and result in high wastage and pay less amount of monthly bill. However it is difficult to quantify the amount because once defective meter is replaced consumer usage become normal.

Figure 4-8 : Water Meter Blocked Incidents due to Sand and Solvent Cement

Meter replacement is carried out only when a meter is damaged, stolen, defective or faulty. At present there is no meter replacement policy in the board in respect to meter life span.

It was noted that due to the system deficiencies such as water containing air, sand and silt, water meters become frequently defective. Nowadays meters are available to overcome such situations that function with different working principle. Therefore development of meter selection policy and testing procedure including endurance test will help to reduce rate of defective meter replacement.

4.1.4.2. Impact of Domestic Water Meters on NRW

Accuracy of water meter for average flow with age

Volumetric meters are sensitive to the water quality and under-read with the age. To determine reliability and impact on NRW from domestic water meters, a sample was tested in pilot project by using scaled 1.5 litter bottle. Later faulty meters were tested at meter testing workshop for the better analysis with the age of the meter and results were tabulated in Table 4-6.

Table 4-6 : Analysis of Water Meter Performance in Pilot Studies in Wellawatta

No of Meters		Accuracy				
		100%	100 – 90%	90- 80%	80– 70%	Less than 70%
100	Normal Flow	78	12	4	3	3
	Low Flow	23	14	12	17	34
	Trickling	Nil	Nil	8	23	69

It shows that present used-meters have considerable impact for the NRW in Colombo City. Mainly it does not record with dripping and droplets.

Impact due to recorded minimum flow rates

According to the specifications minimum recordable flow is 15 liters per hour which does not record water drop lets. This too has considerable impact, but high accurate meters are not economical to replace domestic consumer meters when compared to consumption. However adopting following good practices help to minimize the losses;

Before providing new connections check the quality of workmanship. To improve workmanship, arrangement is made to maintain registered list of private plumbers and train them periodically. This list is then provided to new connection consumers to employ such plumbers for their internal plumbing.
Insist to use good quality materials for internal pipe laying (Insist on SLS or BS standards for pipes and fittings)

4.2. Review of Activities for Sections Dealing with Water Loss Management

Responsibility of water loss management presently deals with three different sections to prevent further deterioration of service conditions in Colombo City. These sections have different roles and responsibilities as follows. However no active NRW reduction activities are performed due to lack of resources.

Manager (Operation and Development) deal with maintenance of distribution system and flow control with leak repairs etc,

Manager (Colombo City) attend to all commercial activities and consumer complaints

NRW section deals with the reduction of water wastage of common outlets, prevention of illegal consumption, policy formulation, NRW reduction pilot scale studies and invisible leak detection with instruments etc. But due to lack of resources priority has been given to day-to-day activities hence no arrangements have been organized to monitoring of night flows or active leak reduction programmes.

4.2.1. Management Structure & Effectiveness

Main problem of this management structure is less collective-activities between the sections and all their efforts seem to be fragmented without considering common goals of water loss management. Quality materials for maintenance work with excellent management system helps to reduce water loss by some extent with four principles of water loss management as expressed by section 2.5.3. But to reduce water losses by considerable amount, it needs to modify the distribution network to facilitate proper monitoring and identify causes in small sections with one or very few feeding point.

4.2.2. Inputs of Information Technology

All the commercial information is computerized and each consumer has an individual customer database. Hence data can be reviewed either for entire area or individually. In Colombo city monthly meter readings are taken in 4 cycles (four batches) and issued with a monthly spot bill to the customer. Commercial division of Head office is responsible for generating the relevant MIS reports submitted to the board of directors. With the assistance of computerized billing system it is capable to furnish such data in reasonable time.

Table 4-7 : Collection Ratios 2004 to 2008 (NWS&DB – Western Central Region)

Year	2004	2005	2006	2007	2008
Billed Amount	45783	73012	72908	89151	81040
Collection	43163	81379	73717	75990	85937
Collection Efficiency (%)	94%	111%	101%	85%	106%

Table 4-7 explain yearly billing performance and it was observed that the utility has collected reasonable amount of its billed amounts. Disconnection notice and disconnection programme is the main reason of improving collection efficiency in the utility and it has a separate unit to organize such programmes.

4.3. Performance Indicators for Colombo City Water Supply

The performance indicators for the Colombo City distribution system were calculated both at the city and pilot zone level. NRW, ILI, UARL and ELL were determined in order to analyze the system performance.

National Water Supply & Drainage Board monitored the main performance indicators for the management of drinking water sector goals tabulated in Table 4-8.

Table 4-8 : Performance Indicators for the Colombo City Water Distribution System

Yearly Performance Indicators	2005	2006	2007	2008
Water quality at treatment as sample	99%	99%	99%	100%
Metering ratio		82%	98%	98%
Water service coverage by area	100%	100%	100%	100%
Hours of supply	18	18	20	20
Staff per 1,000 connections	4.2	4.0	3.7	3.5
Operation and maintenance cost coverage collection	Cost recovery	Cost recovery	Cost recovery	Cost recovery
Debt age in collection	3.1	3.6	2.99	3.23

4.3.1. Water Demand and Supply

Colombo City is the commercial city of the Sri Lanka. There are three categories of population as residents. Colombo Municipal Council accommodates a normal-resident of 320,000 underserved settlement residents of 325000 and another floating population of 400000. (CMC) Accordingly theoretical water demand is

Assumes the following design parameters (NWS&DB D2 manual)

Normal residence for per capita consumption	120 liters / day
Floating population for per capita consumption	45 liters / day
Under served settlement per capita consumption	60 liters / day

Theoretical water demand is around

$$(180 \text{ x } 320000 + 45 \text{ x } 400000 + 60 \text{ x } 325000) / 1000 = 95100 \text{ m}^3/\text{day}$$
$$= 21.13 \text{ mgd}$$

Actual consumption is

Billed consumption	19 mgd
Free water supply estimated as	11 mgd
Total consumption	30 mgd

But the supply quantity to the city is 66 mgd which is double the actual consumption. Hence the water wastage is clearly notable and urgent rehabilitation is required for the entire Colombo City distribution system

Estimation of Free water Supply in Tenement Garden (TG)

Most of the TG situated in low land areas in Colombo city comprise of 5712 Tenement Gardens having 64274 housing units. Details of Tenement Gardens are tabulated in Table 4 – 9

Table 4-9 : Summary of Tenement Garden Details in Colombo City (NWS&DB - NR.W Section)

City No	Nos.				
	TG	Houses	Bath Taps	Toilet Taps	Stand Posts
Colombo 02	152	3639	208	82	272
Colombo 03	47	662	33	13	53
Colombo 04	8	91	7	4	7
Colombo 05	72	4660	30	20	49
Colombo 06	66	3121	55	48	57
Colombo 07	21	749	14	15	18
Colombo 08	79	4938	59	50	71
Colombo 09	152	5102	129	95	181
Colombo 10	249	8260	287	131	357
Colombo 11	9	158	10	7	8
Colombo 12	177	3936	151	69	214
Colombo 13	250	7196	188	104	266
Colombo 14	156	8359	141	123	176
Colombo 15	133	13401	81	92	61
Total	1571	64272	1393	853	1790

A study was carried out by fixing of water meter to the sample of free water supply out lets in tenement gardens in Colombo City and monthly reading was obtained for a period of 3 months and the activity was repeated to cover the entire city area of Colombo 1 to 15 by using 100 water meters and results which are tabulated in Table 4 - 9

However, for the calculation of average consumption for each type of outlet, a weighted average consumption is used. The number of common outlets metered in the each town is used as the weighting parameter. This approach was used to have a well balanced and representative figure for common outlet usages. Further meters were not installed places where voluntarily caretakers could not find.

Table 4-10 : Summary of Pilot Scale Study to Analysis Common Outlet Consumption in Colombo 1 to 15

City Area	Common Out let								
	Stand Post			Toilet Tap			Bath Tap		
	Nos	Average Usage	Overall (weighted) Average	Nos	Average Usage	Overall(weighted) Average	Nos	Average Usage	Overall (weighted) Average
Colombo 1	-	-	-	-	-	-	-	-	-
Colombo 2	39	2.96	2.98	16	1.2	1.46	55	3.39	3.13
Colombo 3	31	2.55		6	1		27	2.95	
Colombo 4	-	-		-	-		-	-	
Colombo 5	03	8.10		-	-		03	6.68	
Colombo 6	40	2.91		48	1.88		55	2.77	
Colombo 7	-	-		-	-		-	-	
Colombo 8	04	4.93		-	-		-	-	
Colombo 9	03	6.19		-	-		03	3.44	
Colombo 10	80	2.83		6	1.16		33	2.75	
Colombo 11	-	-		-	-		-	-	
Colombo 12	-	-		3	.53		2	0.85	
Colombo 13	04	1.85		-	-		-	-	
Colombo 14	02	4.58		-	-		1	5.24	
Colombo 15	06	2.66		8	.29		6	5.50	

Table 4-11 : Summary of Pilot Scale Study for Analysis of Common Outlet Consumption in Colombo City

Type	No of outlets	Average Consumption m^3/day	Total m^3/day
Stand Post	1790	2.98	5334
Toilet Tap	853	1.46	1245
Bath Tap	1393	3.13	4360
Total	4036		10939

It was noted that after fixing of water meters to the free water outlet, consumption was reduced than the expected estimation. The main reason is that the consumers had the idea that after obtaining of consumption data, if it is high there is a possibility of removing the same due to high wastage. So they obtained water very carefully from such metered outlets without any wastage.

Hence the exercise did not show the real picture at all. Therefore it cannot be seen the wastage from common out lets and its impact to the NRW. With the real values of common out lets, it is close to the theoretical calculations which means 2/3 of water supplied was been wasted from Colombo distribution system. Please refer page 60 to compare with following.

Therefore actual consumption would be about

Billed consumption 19 mgd
Free water supply 2.43 mgd (10939 m^3/day)
Total consumption 21.43 mgd

4.3.2. NRW in Colombo City and Water Balance

By reviewing of NRW in Colombo City, it was noted that the gradual increase had no significant difference between the figures over the past 5 year's period. Increasing water demand met with increasing supply quantity as conventional method of finding solution to low pressure zones. When the loss management is taken into account, this is not the best practice because this will result not only in wastes of water but also cause damage to the infrastructure due to leakages.

Table 4-12 : Non Revenue Water in Colombo City from 2000 to 2008

	Year								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
NRW %	53.74	54.49	51.95	52.25	53.04	51.25	51.79	53.95	53.68

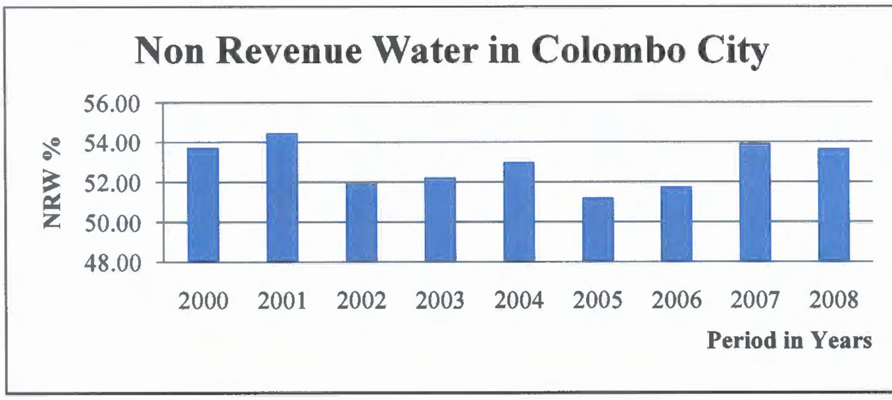


Figure 4-9 : Non Revenue Water in Colombo City from 2000 to 2008

The above NRW figures are based on the system input volume and the billed authorized consumption over the period of 2000 to 2008 and expressed as a percentage. Accordingly it was noted that NRW percentage fluctuating 51.5 to 54 during this period. After introducing water from Kaluganga new water treatment plant in year 2007, NRW percentages were slightly increased. The major contributory factors for the high amount of NRW are system leakages, followed by free water supply, illegal consumption and administrative losses.

Frequent studies carried out by the consultants and experience in the operational staff and the NRW section, the composition of NRW in Colombo City is expressed as in Figure 4-10

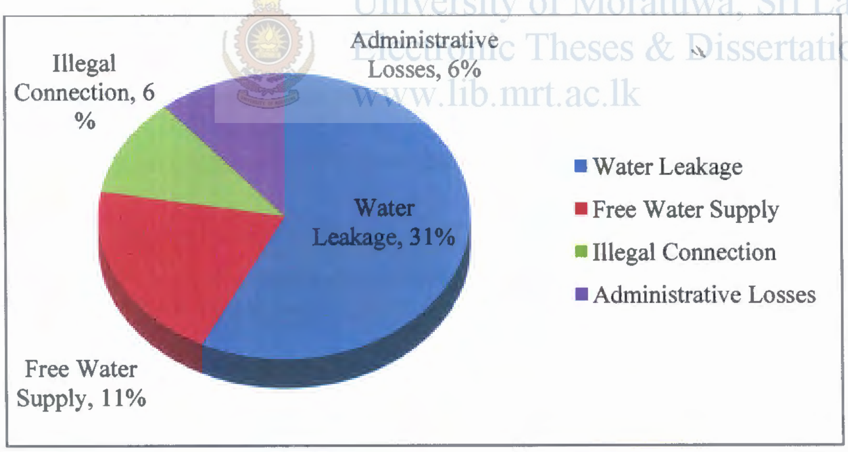


Figure 4-10 : Composition of Non Revenue Water in Colombo City

Water Balance

Practicing of the IWA format for water balance analysis is the first step in getting started with a water loss reduction programme. Knowing the various components of consumption and losses will give an idea of where the losses are occurring and at what magnitude. This will help to identify key resulted areas with priority order to give more weight age to reduce water losses. Reduction of real losses is very important as it leads weightage to wastage of water as well as money. Hence the calculations help to estimate value of leakages and design appropriate leakage management programme.

The components of the water balance for Colombo City distribution system in 2008 (Water volumes in m^3/ year) are illustrated in figure 4-11.

<table>
<tr><td rowspan="4">System Input Volume
106,842,600

100%
(+/- 3%)</td><td rowspan="2">Authorized consumption
61,606,032

58%
(+/- 4%)</td><td>Billed Authorized Consumption
49, 380,000
46% (+/- 4%)</td><td>Revenue Water
49,380,000

46% (+/- 4%)</td></tr>
<tr><td>Unbilled Authorized Consumption
12,226,032
11% (+/-5%)</td><td rowspan="3">Non – Revenue Water (NRW)
57,462,600
54% (+/- 4%)</td></tr>
<tr><td rowspan="2">Water Losses
45, 236,568

42%
(+/- 5%)</td><td>Apparent Losses
12, 821,112
12% (+/- 2.4%)</td></tr>
<tr><td>Real Losses
32,415,456
30% (+/- 5%)</td></tr>
</table>

Figure 4-11 : Water Balance Colombo City in Year 2008

The approach to estimation of different components is elaborated below:

(i) The system's input was obtained from progress report of Non Revenue Water division of National Water Supply & Drainage Board. The total production was reported as 106,842,600 m^3/ year in the year 2008.

(ii) Authorized consumption was extracted from the computerized billing system from the commercial Section of NWS&DB. Unbilled authorized consumption is extracted from the records of NRW section. Estimates for unbilled unmetered consumption such as the system requirements of hydrant flashing and fire services etc cannot be accurately obtained. In addition that it is not the real consumption of the outlets in TGs.

(iii) The NRW section estimates apparent losses to be approximately 12.8 Mm^3/ year. It was 28.3% of water loss which includes 14.3% of the unauthorized consumption from illegal connections and legal connections, with by-passes etc and balance includes impact of estimated bills, meter errors, computerized system defects, billing adjustments and meter reader mal practices etc.

(iv) This leaves physical losses of approximately 32.4 Mm^3/ year which are 71.7% of the total water losses. The real losses were calculated by subtracting the average annual metered/ unmetered consumption from the average annual flows and deducting the estimated apparent losses of 28.3%. Colombo city estimates that the accuracy of this data is approximately +/- 4%.

4.3.3. Unavoidable Real Losses

The UARL and ILI for Colombo city water distribution systems were calculated in order to assess the operational performance of the distribution system and to gauge how well the water loss reduction programmes put in place and working. It also enables us to make international comparisons with other utilities. The calculations are done based on the theory outlined in section 2.3.3 and 2.3.4.

In Colombo City length of most of the connections are less than 10 m. Hence equation 2.3 of page 2.3.3 can be used to calculate UARL

UARL = (18 Lm + 80 . 0 Nc) x P from equation No 2.2

The parameters are:

UARL (liter/connection/yr)
Lm = Length of mains (km) = 834
P = Average operating pressure when system is pressurized = 10 meters
Nc = No of house connections 118,010

UARL = (18 x 834 + 0.80 x 118,010) 10 x 365
4.0 x 10^8 Liter / year = 0.4 Mm^3/year

Table 4-13 : presents summarizes of system data and presents the UARL, CARL and ILI in Colombo City.

Input Description	Actual Data	Units
Length of Mains (Transmission + Distribution) (Lm)	834	km
Length of Mains (Service) Lp	1500	km
Number of Service Connections (Nc)	118010	Number
Density of Service Connections (per km of mains) (Nc/Lm)	146	Per km
Average operating pressure when system pressurized (P)	10	meters
Population served by the supply system	880000	Number
Current Annual Real loss (CARL)	32.4	(Mm^3/yr)
UARL	0.4	(Mm^3/yr)
ILI	81	

The pressure in the distribution system varies from 0.5m to 18m. However, for the calculation of the UARL, the weighted average pressure of the distribution system was used in Colombo 1 to 15 individual 24 hrs average pressures were obtained and a weighted average for all is calculated. The number of service connections in each town is used as the weighting parameter. This approach was used, to have a well balanced and representative figure for pressures in the distribution system.

From Figure 4-11, the CARL is approximately 32.4 Mm^3/ year. This is approximately 30% of the system input. This is significantly high compared to corresponding CARL in cities of developed countries refer chapter II page 21. With the system input of 106.8 Mm^3/ year and NRW of approximately 57.4 Mm^3 in 2008, the UARL is approximately 0.44%.

It was noted that the average system pressures varies from 0.5 to 18m in the Colombo city. This ILI index is only indicates the average picture of the entire distribution system. In order to assess the breaches, it needs to calculate the ILI for each branch to get the correct picture.

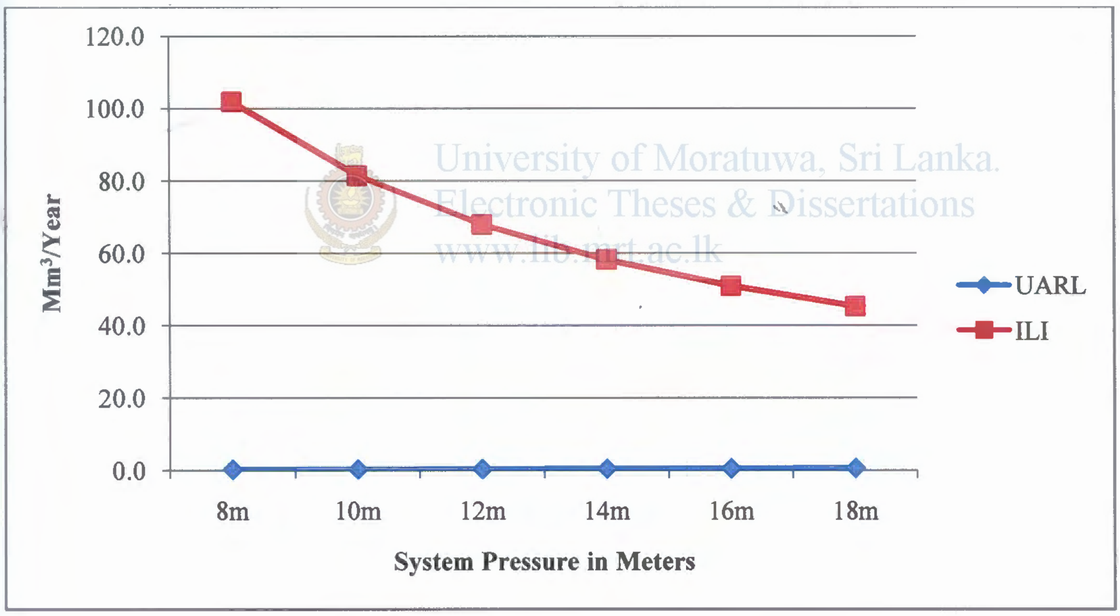


Figure 4-12 : Relationship between ILI Vs Distribution Pressure Variation in the Colombo City

The ILI was calculated from equation 2.3 in section 2.3.4. Colombo City ILI was estimated to be 81 at the average pressure of 10m. This is very high compared to the same for the cities in developed countries. The ILI is an indicator for the status of the distribution system and how well the utility is managing its real losses according to the IWA; it is quite evident that the Colombo city distribution system is performing poorly in this aspect.

Figure 4 -12 indicates changing pressure from .5m to 18m (In Colombo City day to night and area to area pressure change) respective value of UARL and ILI is derived by using equation 2.3 & 2.4.

These results of the ILI show a wide variation in the condition of the infrastructure in Colombo City's water distribution system and therefore simply calculating the ILI for the whole water distribution system would not show the actual condition of infrastructure in particular zones. This indicates that without rehabilitation of distribution system and proving its soundness it is not economical by simply increasing input quantity into the distribution. It proves that if the pressure is sustained up to the designed level during operation, system leaks will be less and it implies that the infrastructure is in good condition. However, figure 4.12 show that Colombo City cannot sustain high pressure without infrastructure rehabilitation.

To get better knowledge and analysis of conditions of infrastructure and leakage in areas or in different branches, UARL and ILI values should also be computed for areas or branches.

Details of ILI index of the developed world

Many countries in developed world, practice bench marking concept to evaluate for decision making on when and where to improve infrastructure. ILI is one of the best tools for such decision making. Figure 4.13 to 4.15 show some graphical information of three different countries. It clearly shows the number of water supply schemes above mean ILI value which needs improvements.

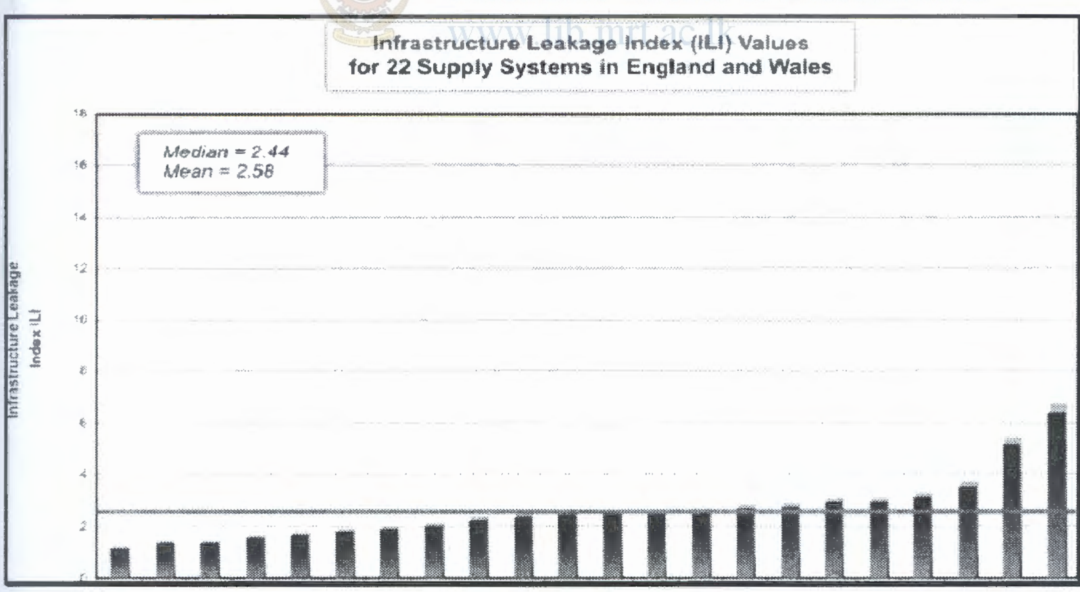


Figure 4-13: ILI result for 22 systems from England and Wales

Source February 2004 paper by David Howarth, Environment Agency)

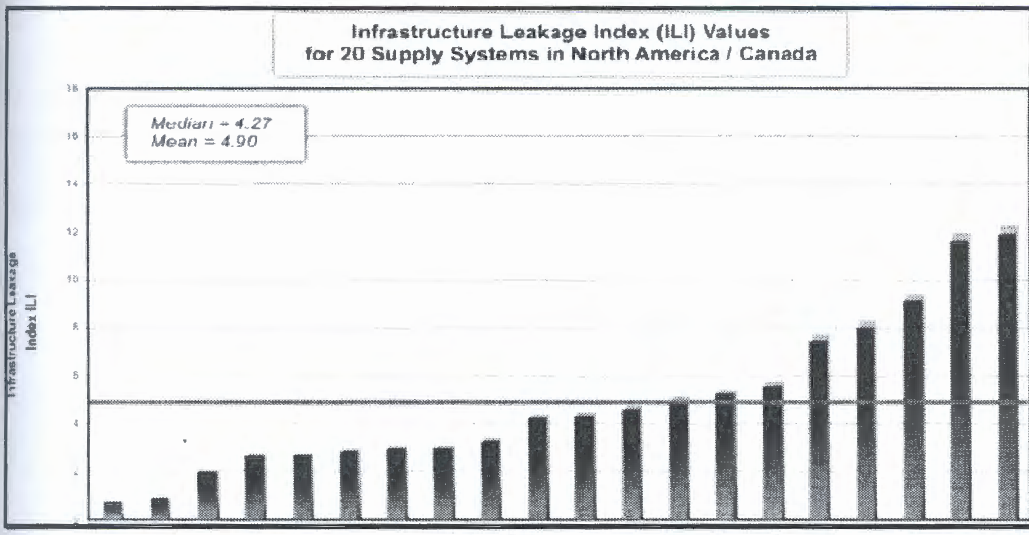


Figure 4-14 : ILI results for 20 systems from the USA and Canada

(Source – June 2004 Presentation by Tim Waldron and Allan Lambert)

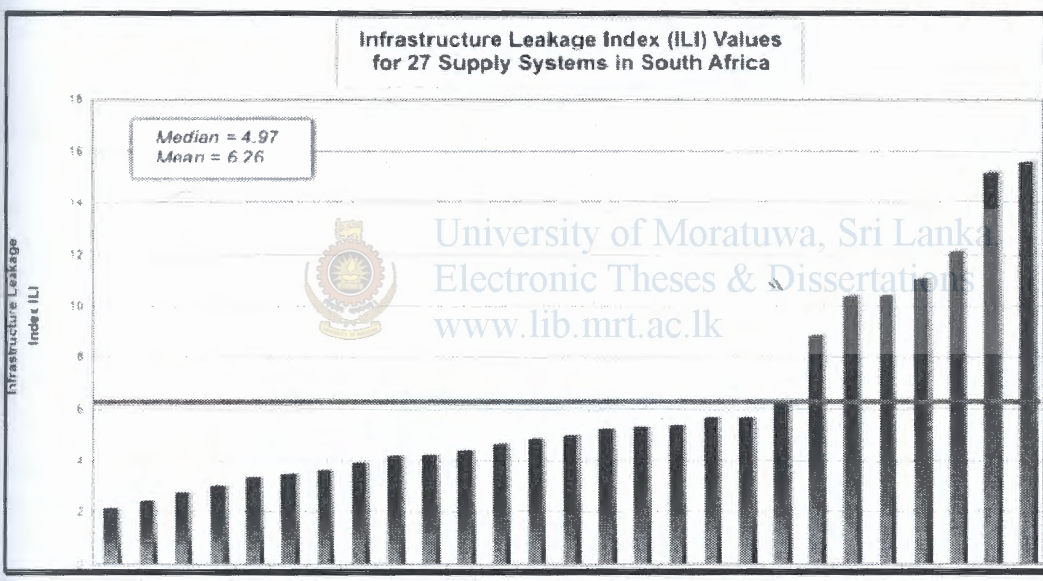


Figure 4-15 : ILI results for 27 Systems from South Africa

(Source - The South African Water Research Commission)

4.3.4. Economic Level of Leakage (ELL)

ELL is one of the indicators used to evaluate feasibility of the investment in water loss management projects. According to the calculations of the relationship between active leakage control costs and the cost of lost water considered, for the determination of the ELL, the total water production of approximately 106.8Mm^3 for the year 2008 and the real loss of 32.4Mm^3 were used. These data was obtained from the MIS report of the NWS&DB for Colombo City.

According to the graph which was drawn using the different level of costs with saved water provides information of investment needs and the type of technology to be used to control leakages. Case studies have shown that a combination of activities, rather than one single activity will be needed to reduce the leakage to a target level.

The activities assessed were:

- Provide more resources with training facilities
- Zones establishment and monitoring
- Employment of Leak Repair contractors
- Increased efficiency of leakage surveys with new equipment and technology
- Mains and service pipe rehabilitation and replacement;
- Impact on defective meter replacement
- Impact on illegal connections
- Impact on unmetered connections

At present no active leakage programme is implemented in the Colombo City water distribution management system. But after implementation of zoning concept with proposed JICA technical cooperation project with modern equipment and training, active leakage works will be implemented in all zones in the Colombo City. According to the JICA project, reduction is targeted from 53% to 25% which will be achieved in 4 years time period.

4.3.5. Colombo City Revenue Analysis

When comparing the 2008 revenue of Colombo City with the other distribution areas in the same region, it has been revealed that still it can generate more revenue per m^3 than other distribution systems. But due to the huge water losses, revenue per m^3 was reduced by considerable amount. Further to that the water supply to the consumer per month is 68 m^3 while the recorded consumption is $23m^3$ which is quite high compared to other areas. This clearly shows that the huge quantity of water that is wasted without utilization by the consumers compared to other distribution areas in the same region namely Western Central is tabulated in Table 4 -13. Hence investment for improvements to the distribution system in Colombo City is more feasible, considering future developments.

Table 4-14 : Analysis of Western Central Region, Revenue Vs consumption in month of 2008 December including Colombo City.

Section	No of Connections	Quantity			Supply per Connection m^3	Consume per Connection m^3	Sold Vs Revenue Rate Rs	Revenue per Unit Supply Rs
		Supply 000 m^3	Sold 000 m^3	Revenue SLRs				
Priority	2308	3023	3011	132569	1310	1305	44.02	43.85
CB I	44223		909	25096		21	27.61	
CB II	30622		669	19563		22	29.24	
CB III	33347		919	30282		28	32.95	
Colombo City	108192	7374	2497	74941	68	23	30.01	10.16
Kelaniya	44792		861	19512		19	22.66	
Biyagama	29745		545	10624		18	19.49	
Ja-Ela	10564		175	3592		17	20.53	
TNC	85101	2323	1581	33728	27	19	21.33	14.52
Dehiwala	45572		1047	29324		23	28.01	
Moratuwa	35366		698	14245		20	20.41	
TSC	80938	2837	1745	43569	35	22	24.97	15.36
Kotte	38964		867	23878		22	27.54	
Kolonnawa	39344		815	13926		21	17.09	
Battaramulla	38883		801	16121		21	20.13	
TEC - N	117191	3120	2483	53925	27	21	21.72	17.28
Maharagama	22843		478	11460		21	23.97	
Homagama	7860		164	3576		21	21.80	
Pannipitiya	17214		325	5480		19	16.86	
Piliyandala	13894		262	4722		19	18.02	
Avissawella	4280		99	2591		23	26.17	
Mattegoda	12102		222	3506		18	15.79	
TEC - S	78193	1715	1550	31335	22	20	20.22	18.27

4.3.6. Activities to Maintain Leakage at Different Levels in Colombo City

Under the economical analysis two different scenarios were considered for cost benefit analysis.

- NRW reduction by Active leakage control programme
- NRW reduction with pipe replacement with active leakage control programme.

These two methods were carried out in different pilot scale studies in local and international levels

In Avissawella water supply scheme which was reported as 56% NRW in year 2000, the highest in Sri Lanka was reduced to 7% in year 2006 with deteriorated AC pipe replacement and implementing active leakage reduction programme with monitoring of minimum night flow.

In general an international experience up to 25% NRW reduction is possible with active leakage control programmes. JICA NRW studies in 2005

With the economical analysis based on the present leakage level of 32% with resources and plan for main activities with resources to obtain different levels of leakage control is tabulated in Table 4 – 15.

By using different leak levels and resource requirements, capital investment was worked out and tabulated in Table 4 -16. To workout economical analysis, it was considered loan installment and the depreciation as tabulated in Table 4 -16. The final graph was obtained from the three tables which are resources requirement, Required Capital Investment and finally Annual Capital Investment Cost which includes annual loan installment plus depreciation cost.

For cost calculation unit cost is different according to the leakage level. The reduction of leakage level from 31% to 15% could be done at a particular slab of unit cost and further leakage reduction below 15% which need sophisticated equipment with highly paid technique has to be carried at a higher slab of unit cost. Therefore unit cost in Table 4-15, is divided into two categories for cost calculations respect to the leakage level.

To calculate annual installment, it was assumed 6% annual interest with 30 years installment period, i.e. current bank rates. For calculation of depreciation it was assumed 1.67% annual depreciation for the distribution system and 20% for the instruments which is current practice in NWS&DB of Sri Lanka.

Table 4-15 : Activities to Maintain Leakage at Different Levels in Colombo City with Active Leak Reduction Programme

Activities of the ALC	Leakage level					Unit cost (m Rs)	Leakage Level		Unit cost (m Rs)
	31%	30%	25%	20%	15%		10%	5%	
Staff (No.)	380	410	425	464	491	0.025	525	600	.04
Equipment (No.)	2	5	10	25	48	2	60	75	6
DMA establishment (No.)	4	8	8	24	24	5	48	72	8
Training (No.)	50	60	70	150	200	0.25	200	250	0.5
Leak detection vehicles (No.)	0	4	8	20	24	0.055	48	72	0.055
Leakage repair (No.)	5,800	7,000	10,000	12,000	15,000	0.025	20000	25000	0.025

Table 4-16 : Capital Investment Needs for the Different Levels of Leakage Control

Activities of the Active Leakage Control	Leakage levels						
	31%	30%	25%	20%	15%	10%	5%
	Capital Investment in Million Rs.						
Staff costs	10	10	11	12	12	21	24
Equipment	4	10	20	50	96	360	450
DMA establishment	20	40	40	120	120	384	576
Training	12.5	15	17.5	37.5	50	100	125
Leak detection & vehicles	0	0.22	0.44	1.1	1.32	2.64	3.96
Leakage repair	69.6	84	120	144	330	500	625
Total	116	159	209	364	610	1,368	1,804

Table 4-17 : Loan Installment for Capital Investment for the Different Levels of Leakage Control

Activities of the Active Leakage Control	Leakage levels						
	31%	30%	25%	20%	15%	10%	5%
	Loan Installment for Capital Investment						
Staff costs	10	10	11	12	12	21	24
Equipment	0.8	2	4	10	19.2	72	90
DMA establishment	1	3	3	8	8	25	38
Training	13	15	18	38	50	100	125
Leak detection vehicles	0.0	0.2	0.4	1.1	1.3	2.6	4.0
Leakage repair	70	84	120	144	330	500	625
Total	93.72	114.11	155.21	212.12	420.72	720.98	905.98

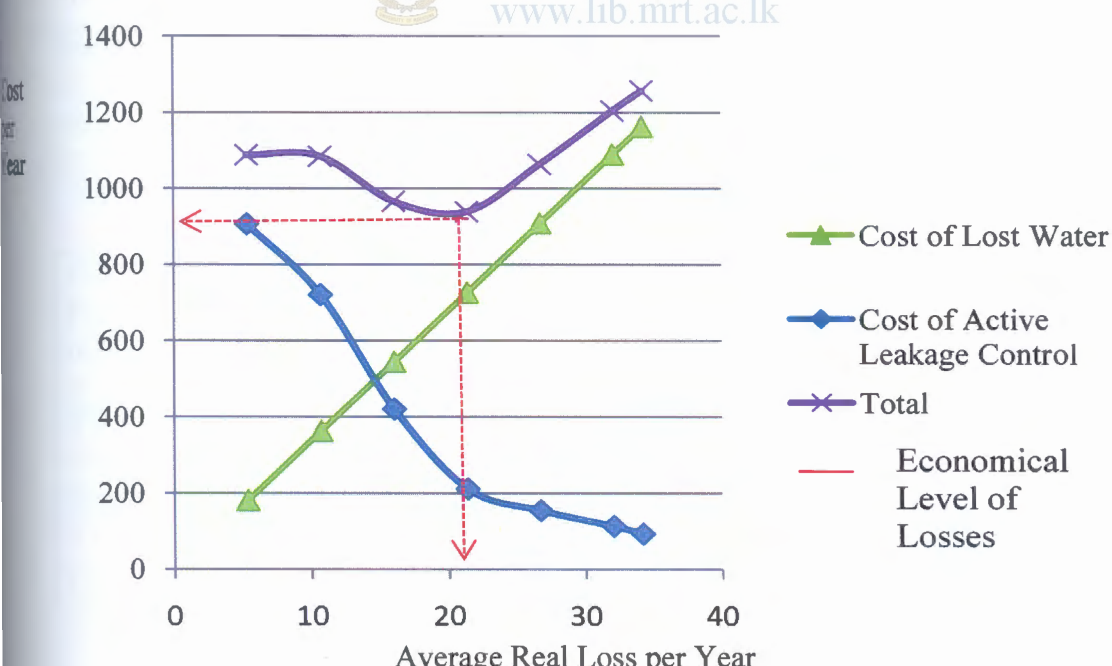


Figure 4-16 : Ecumenical Analysis of Leakage Control in Colombo City without Pipe Replacement

Table 4-18 : Active Leak Detection with Pipe replacement

Activities of the Active Leak Control	Leakage levels							Unit cost (Rs)
	31%	30%	25%	20%	15%	10%	5%	
Staff (No.)	380	410	425	464	410	410	410	25,000
Equipment (No.)	2	5	10	25	24	24	48	800,000
DMA establishment (No.)	4	8	8	24	24	48	72	5,000,000
Training (No.)	50	60	70	150	200	200	200	250,000
Leak detection vehicles (No.)	0	4	8	20	24	24	24	55,000
Leakage repair (No.)	5800	6000	6000	5000	4000	3000	2500	25,000
Deteriorated Pipe replacement (km)	0	10	40	80	120	180	320	10,000,000

Deteriorated Pipe replacement cost Rs M		100	400	800	1,200	1,800	3,200
Pipe depreciation cost Rs M		1.67	6.68	13.36	20.04	30.06	53.44
Pipe cost per Year Rs M		7.2	28.8	57.6	86.4	129.6	230.4

Table 4-19 : Capital Investment Needs for the Different Levels of Leakage Control

Quantity of activities of the ALC	Leakage levels						
	31%	30%	25%	20%	15%	10%	5%
	Loan Installment for Capital Investment						
Staff costs	10	10	11	12	10	10	10
Equipment	0.32	0.8	1.6	4	3.84	3.84	7.68
DMA establishment	1	3	3	8	8	16	24
Training	13	15	18	38	50	50	50
Leak detection vehicles	0.0	0.2	0.4	1.1	1.3	1.3	1.3
Leakage repair	70	72	72	60	48	36	30
Deteriorated Pipe replacement (km)	0	9	35	71	106	160	284
Total	93	110	140	193	228	277	407

Quantity of water to be saved	34.176	32.04	26.7	21.36	16.02	10.68	5.34
Cost per m3 of water	34	34	34	34	34	34	34
Cost of water save	1162	1089	908	726	545	363	182
Active Leak detection cost	79.75	93.62	121.80	155.33	179.05	226.61	400.00
Total	1241.73	1182.98	1029.60	881.57	723.73	589.73	581.56

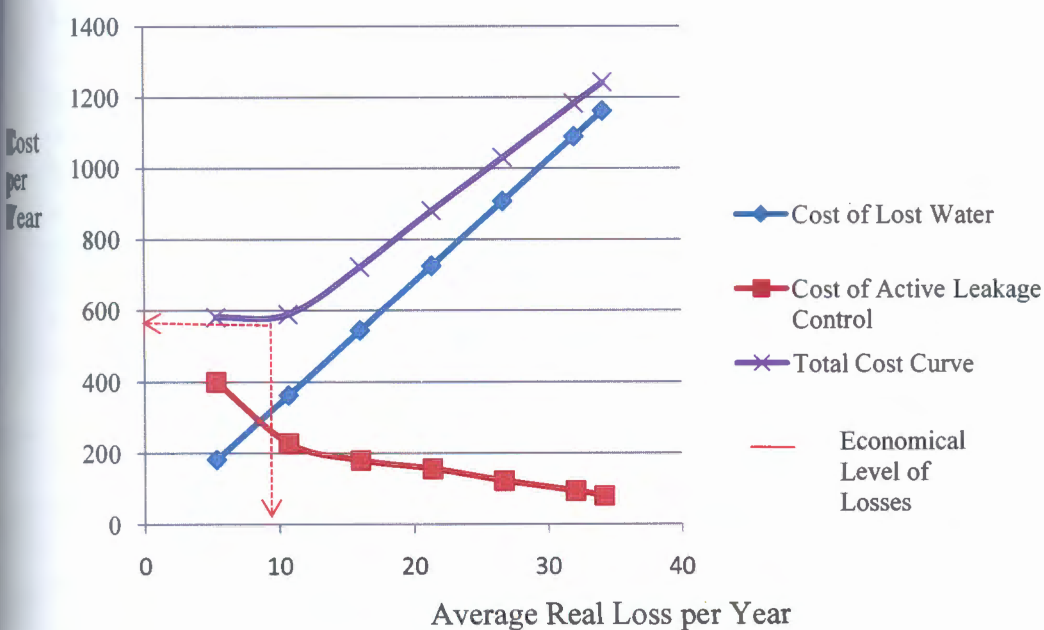


Figure 4-17 : Economical Analysis of Leakage Control in Colombo City with Pipe Replacement

It is difficult to isolate the total amount spent on water loss reduction activities (staff costs, contractors, bulk meters, leakage repairs and other miscellaneous expenses) for Colombo City in 2008 with other associated expenditure. Therefore the average cost of such items was considered for calculations.

By reviewing the graphs, it was clearly observed that only active leakage control is very costly compared to an active leak control with deteriorated replacement in a weak distribution system. In certain extent it is economical with the revenue but operation cost will be very high.

In Colombo city average leak repair per km is about 7 (Colombo City leak repair data base) without implementation of active leakage programme. Hence funding to maintain a weak system is not economically viable without rehabilitation in long run.

4.4. Major Factors Contributing to NRW in Colombo City

Colombo city is one of the oldest water supply schemes in Sri Lanka. It provided satisfactory service in its early period where as it presently provides a marginal service due to no major regular rehabilitation programme implemented for the distribution system, but quality of water has been increased with the new treatment plants. As mentioned earlier, 53% of NRW in Colombo City contributes to four major factors. By reviewing our studies, leakage is the main reason, followed by illegal connections, free water supply and meter errors with administration errors.

4.4.1. High Amount of Leakage

In Colombo City, 32% of NRW is due to leakage. At present, the area reports frequent pipe leaks that are difficult to scope up with existing staff. Leak repair cost is very high and most of the smaller diameter pipes were scaled due to the age of the pipes. Main reasons for the high amount of leakages are heavy dynamic loads, pipe line damages due to excavation for other utility service requirements and further deterioration of CI pipe lines.

Figure 4-18 : Scaled Pipe in Colombo city

The number of water leaks contributes to high water losses in Colombo City. The number of leakages has been steadily rising over the past three years with approximately 7 leakages occurring per kilometer in 2008. Table 4-15 gives the total number of leakages from 2006 to 2008.

Table 4-20 : Leakages and frequency of pipe bursts per kilometer

Year	Main Leaks	Length of network	Frequency of pipe bursts (per km)
2006	4780	800	5.9
2007	5808	805	7.0
2008	6156	810	7.4

Compared to the figure with other developed countries it is very high

From figures available in Manager (Operation and Development) section of the NWS&DB, it was noted that time to attend to a main leak in Colombo City is less than 6 hrs or as soon as it is reported.

4.4.1.1. Age of the Distribution System

Any system tends to deteriorate with the age. To provide sustainable service it needs to have preventive maintenance programme with regular rehabilitation. In Colombo City, no such system existed for the last decade, due to lack of resources and associated tender procedures.

4.4.1.2. Scraping Without Lining

At present most of the CI pipes in the distribution system having encrustation create low pressure zones. Some occasions the actual diameter is reduced to lesser inches. There is hardly any lining to be seen inside the Cast Iron pipes and most of the connection leaks (dripping) exist in these lines due to frequent scraping, carried out to reduce low pressures in the system.

4.4.1.3. Unnecessary Pipelines

Due to increase of pipe joints of unwanted pipes in the system, possibility of leaks are high. Colombo distribution system has unnecessary pipe lines in the distribution with few connections which should be disconnected by transferring the connections to the newly laid pipe lines.

4.4.1.4. Bundle Service Pipes

This is common to the old distribution systems. This increases number of joints and leaking possibility is very high. Normally these service pipes were laid at shallow depths and have higher possibility of damages. Further if the workman ship is poor, dripping is a common outcome. Hence it is important to replace bundle pipe with common lines.

Figure 4-19 : Bundle pipes in Colombo City

4.4.1.5. Active Leak Detection Programme

As mentioned earlier there is no programme implemented at present due to lack of resources. But one positive step has been taken to employ contractors to repair leaks. Therefore they work with minimum resources and help to reduce visible leaks. However searching of leaks at night has recently been started by employing maintenance night gangs after mid night when pressure slightly increases due to less consumption.

4.4.1.6. Absence of Preventive Maintenance Programme

Preventive maintenance programme helps to reduce operational deficiencies such as valve operations in the distribution system. Leak repairs were carried out in Colombo City without closing valves as most of the valves are defective. So it is not possible to close valves either when pipe burst occur or while repairing. This tends to high leakage. Therefore to reduce NRW, preventive maintenance programme is essential.

4.4.2. Illegal Connections and Water Theft

Illegal consumption has considerable contribution to the Non revenue water in Colombo City. Special teams have investigated such places by implementing special planned programme in addition to day to day complaints. To encourage such teams, attractive incentive scheme is practiced. There are four types of common illegal activities in Colombo City such as, complete illegal, by-passes, illegal re-connection the disconnected places and meter tampering. The last five years Progress of illegal consumption is tabulated in following Table 4 -19

Table 4-21 : Economical Analysis of Last Five Years Illegal Detection in Colombo City

Description		Year			
		2005	2006	2007	2008
No of Places inspected		2,384	4,044	9,108	21,682
No of Illegal Detected	Complete	609	998	1,992	2,033
	By Passes	88	23	460	363
	Disconnected Reconnect	242	617	817	570
Total		939	1,638	3,269	2,966
% of illegal detected over inspection		39%	41%	36%	14%
Total No of Connections in Colombo City		104,867	109,843	112,315	116,176
% of Illegal Connections detected		0.9	1.5	2.9	2.6
Cost of Detection in Rs Million		7.2	9.6	12	14.4
Revenue to Board in Rs Million		44.4	61.6	69.6	80.1

By reviewing of above data it is clear that the investment still signify to employ more gang to control illegal consumption in Colombo City. Initially with available resources only complaints were handled and nearly 40% of the complaints were successfully detected as illegal connections and with the increased of more gangs, complaints with suspected premises were checked. After further increases of staff, more premises were checked with plan programmes in addition to the normal complains, detection percentage was reduced but income is been increased by considerable amount when compared with the investment as clearly shown by figure - 4 -20.

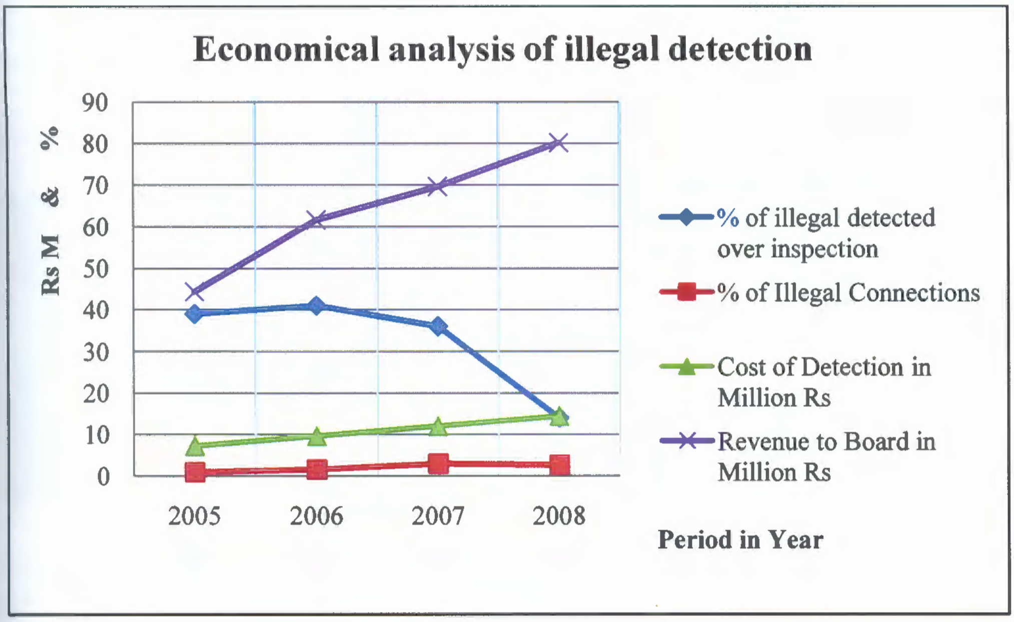


Figure 4-20 : Economical analysis of illegal detection in Colombo City

4.4.3. Free Water Supply

Free water supply contributes to 11% of NRW in Colombo City, mainly due to stand post in Tenement Gardens and marginal contribution due to fire demand and system flushing.

4.4.3.1. Tenement Garden Consumption

Figure 4-21 : Tenement Garden demarcated Colombo city map

There are about 60000 low income families living in Tenement Garden demarcated in green colour dotes in Colombo City map as shown in figure 4 – 21. Presently 100% pipe born water coverage is available with common facilities to these TG. However the sanitary situation is not fully satisfactory inside the TG with common facilities and water wastage is comparatively high. Hence a programme has been launched from year 2000 to provide individual house connections at concessionary rate with installments and disconnect the common outlets in Tenement Gardens in the Colombo City to improve living standards of the residents and minimize the water wastage through common outlets. This programme involves community mobilization, providing house connection and disconnects unnecessary stand post in the Tenement Garden.

Before starting this programme residents of the Tenement Garden in Colombo city were using water from common outlets and problems were observed as illustrated in figure 4-22. The wastage of water as shown, which is a common phenomenon, helps development of low pressures in the distribution system in Colombo City.

Figure 4-22 : Illustrates Low living standards and Water wastage Hygienic Problems in Colombo City Tenement gardens

Water Contamination & Creation of Low Pressure Zones

Due to the low pressures in some Tenement Gardens, water is collected in the ground level pits and consumed. This tends to huge wastage and more possibility of contamination as shown in figure 4-23.

Figure 4-23 : Temporary Collecting pits in Tenement Garden due to low pressure

Initially there were 4,350 common out lets in 1,600 Tenement Gardens at the commencement of the project and this was reduced considerably and thereby reduced water wastage through common outs.

Under this programme at present 18,355 individual connections were given by the disconnecting of 1,465 common out lets in 565 gardens. Annual Progress of this programme is tabulated in Table 4-23. Balance Tenement Gardens to be covered with common outlets to be disconnected in future are tabulated in Table 4 - 22.

After reviewing the present data it shows that the individual water consumers in Tenement gardens with normal supply consumed 14 m3 per month which helps to improve their hygienic conditions.

Table 4-22 : Present Status of common out lets as at year 2007

Tenement Gardens to be completed		1,035
Common outlets	Bath Tap	255
	Toilet Tap	1,525
	Stand Post	1,130

Table 4-23 : Progress of Connections Provided to Tenement Gardens

Year	No of Connection Provided	Disconnected No of Common outlets
2000	2395	159
2001	3229	195
2002	3440	347
2003	1424	206
2004	2230	132
2005	2239	150
2006	2005	105
2007	1393	171
2008	594	130
2009	611	219
Total	19560	1814

Constrains to the Programme

- Low pressure in distribution systems in the area
- No proper drainage facilities available in the Tenement Garden
- No proper access
- No space to obtain individual connections
- No spaces to have a bath tap
- No space to individual septic tank
- Mainly most of the Tenement Garden are situated in low land area
- Low affordability
- Reluctant to work with Government officers
- Low literacy level
- Protest against disconnection of common outlets

4.4.3.2. Fire Demand

There are 3530 fire hydrant valves available in the Colombo City distribution system. These hydrants mainly act to fulfill fire demand, as scour valve to flushing distribution system and as air valve to release entrapped air in the distribution system.

4.4.3.3. Bowser Supply

Bowser supply service is mainly focused to the low pressure zone that is getting fewer water supplies from the distribution system. In addition to that, festivals and high demand occasions are covered.

4.4.4. Administrative Errors

The administration errors include estimation of bills, meter errors, human errors, etc in water loss management. Some of them are easily eliminated with little attention and the others are much costly which cannot be completely eliminated easily.

4.4.4.1. Estimated Bills

Issuing an estimated bill always has either a negative or positive impact to the UFW. Estimated bills occur when the meter reader cannot read the meter due to various reasons such as defective meter, meter dial being not clear due to moisture, house or gate closed, meter buried, untraceable meter location, etc. These kinds of errors are possible to be minimized with some attention and by using previously discussed appropriate techniques.

4.4.4.2. Meter Errors

This contributes an average of 4% to the NRW. This cannot be completely eliminated, but with high cost it can be minimized. To minimize defective meter it is important to use high quality meters but accuracy depends on quantity of usage.

4.4.4.3. Meter Readers' Malpractices and Data Entry Errors

This too contributes high amount of NRW and it is difficult to quantify. However with high attention and introducing fines with disciplinary actions, this can be considerably minimized.

4.5. Pilot Scale Studies

To identify the appropriate methodology, pilot scale studies were carried out by adopting different appropriate strategies on trial and error basis. This Study includes identification and finding remedial measures with assessment of impact to NRW due to illegal connections, defective meters, un metered connections, house closed , meter under reading, meter reading audit, service leaks, road leaks, night visible leaks , Tenement grader out lets, etc.

Pressure control an internationally accepted method described in 2.3.4 was not technically feasible to reduce water loss due to prevailing low pressure situation. Hence studies were commenced by adopting part to whole method of water loss management as explained in 2.3.8.. Along with the field study of the distribution system of pilot area, a list of consumers was obtained with available details. It included batch vise data road by road. Initially, road vise house to house survey was carried out to the identification of all possible means for NRW and provided remedial actions accordingly and simultaneously. Format was developed to carryout survey is in Annex III.

This study was carried out by two teams. Each team comprises of an officer, pipe fitter and two labourers. All required materials are provided by National Water Supply and Drainage Board regional store and expenditure born by the board.

During the initial stage of this study, all the study teams were well aware with the survey and further staff members in area office were also made aware including meter readers to avoid any unpleasant instances. Officers of these gangs always discussed problems with meter readers and their support was obtained resolving the problems especially in house closed situations.

In addition to the above survey pipe line drain crossings and culvert crossings were searched for the leaks and six invisible major leaks with water draining to drainage system were identified. After repairing these leaks significant improvement was created in the pilot zone with increasing pressures and reducing complaints.

Under this studies work carried out are discussed in the following sections.

4.5.1. Analysis of Distribution System

The pipe network consists of approximately 5.3 km of transmission mains and 36.1 km of distribution mains. Distribution network in this area consists of 31 km of CI and 5.2 km of PVC pipes. Most of CI pipes are more than 50 years old.

There are 8770 service connections, 160 common outlets in Tenement Gardens. Length of service connections is estimate as approximately 41 km and pipe composition as tabulated in Table 4 -24 and represented in graphical form in figure 4-24.

Table 4-24 : Length and % of Pipe composition in Pilot Project

Pipe Material	Length	Percentage
Cast Iron	35766	85.41
Ductile Iron	509	3.26
Poly Vinyl Chloride (PVC)	5276	31.47
	Total	41551m

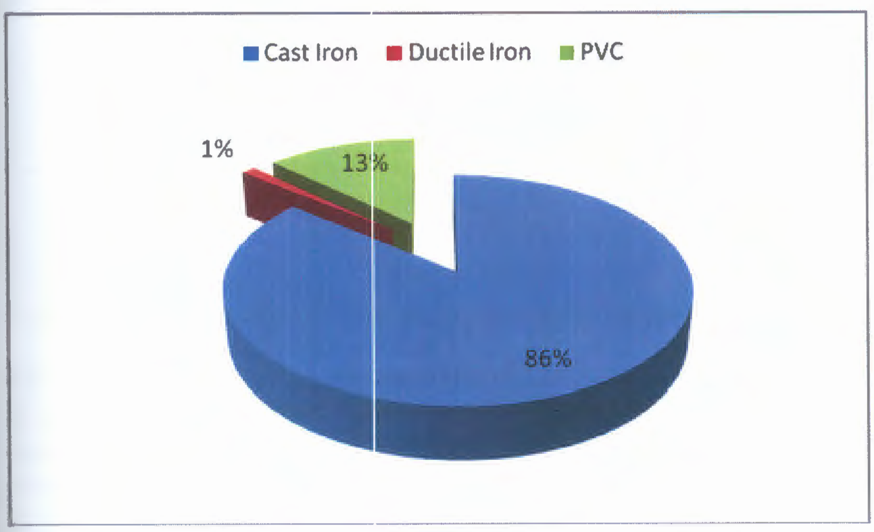


Figure 4-24 : Pipe material type by percentage

4.5.2. NRW in Pilot Zone and Water Balance

Table 4-25 : NRW variation in Pilot area from year January 2009 to September 2009

Year , Month	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09
Consume m^3 per day	8630.8	7989.1	7862.3	7774.4	7961.4	6777.4	7148.4	7061.5	7351.9	7806.7	8154.2	7294.6
Supply m^3 per day	16249	15552	15200.0	14700	14141	11746	12184	12274	11928.7	12750.0	13207.7	11836.4
NRW %	46.9	48.6	48.3	47.1	43.7	42.3	41.3	42.5	38.4	38.8	38.3	38.4

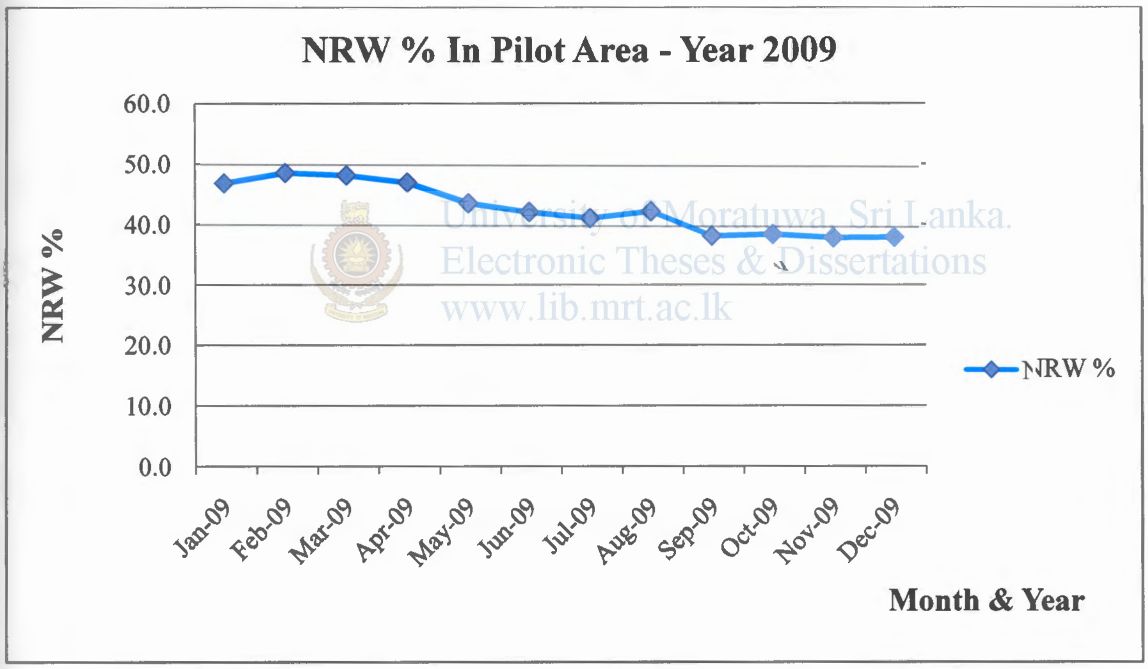


Figure 4-25 : Progress of NRW reduction in Colombo City pilot zone

NRW percentage in pilot area is gradually reduced with the progress of studies as shown in Table 4 -25 and figure 4- 25. To tabulate this table, monthly consumption data were obtained from computerized billing system of NWS&DB and flow measurements were obtain from NRW section of NWS&DB. Due to the close monitoring and commitment, all four causes were addressed simultaneously and contributed to the progress. During this period NRW was reduced approximately by 10% and low pressure areas in Wellawatta town were eliminated and improved the water facilities. This helps to further development of the city water supply and clear the pending and outstanding connection list.

Table 4-26: Illustrated in the components of the water balance in pilot zone in 2009 (Water volumes in m^3/ year) considering 09 month period

<table>
<tr><td rowspan="4">System Input Volume
4,959,003
m^3/year

100%
(+/- 3%)</td><td rowspan="2">Authorized consumption
2,889,887
m^3/year
58.3%
(+/- 4%)</td><td>Billed Authorized Consumption
2,742,287
55.5% (+/- 4%)</td><td>Revenue Water
2,742,287
55.5% (+/- 4%)</td></tr>
<tr><td>Unbilled Authorized Consumption
147,600
2.8% (+/- 4%)</td><td rowspan="3">Non – Revenue Water (NRW)
2069116
44.5% (+/- 4%)</td></tr>
<tr><td rowspan="2">Water Losses
2,069,116
m^3/year

41.7%
(+/- 5%)</td><td>Apparent Losses
778,563
15.7% (+/- 4%)</td></tr>
<tr><td>Real Losses
1,289,341
26% (+ 5%)</td></tr>
</table>

4.5.3. Unavoidable Real Losses

The UARL and ILI for Colombo City water distribution system were calculated in order to assess the operational performance of the distribution system and to gauge how well the water loss reduction programmes put in place are working. It also enables us to make international comparisons with other utilities. The calculations are done based on the theory outlined in section 2.3.3 and 2.3.4

From equation 2.2,

UARL = (18 x Lm + 80.0 x Nc) x P

The parameters are:

UARL (liter/connections/yr)

Lm = Length of mains (km) = 41.5

Lp = Length of service pipe can be neglected due to connection length less than 10m in Colombo city

P = Average operating pressure when system is pressurized = 10 meters

Nc = No of house connections 8873

UARL = (18 x 41.5 + 0.80 x 8873) 10 x 365

2.8×10^{7} Liter / year = 0.028 Mm^3/year

Table 4 – 26a Presents summary of system data and presents the UARL, CARL and ILI.

Input Description	Unit	Actual Data	Units
Length of Mains (Transmission + Distribution) (Lm)	Km	41.5	km
Length of Mains (Service) Lp	Km	88	km
Number of Service Connections (Nc)	No.	8873	Number
Density of Service Connections (per km of mains) (Nc/Lm)	/ Km	213	Per km
Percentage of time system is pressurised during year (T)	%	100	%
Average operating pressure when system pressurized (P)		10	meters
Population served by the supply system	Population	53238	Number
Current Annual Real Loss, refer Table 4-26 same as Real Loss		1.28	(Mm^3/yr)
UARL		0.028	(Mm^3/yr)
ILI		46.04	

From Table 4 -26b, present value of ILI 46.04 is too high compared to appropriate values. After continuing this exercise to cover whole area ILI is still high. It implies that leak repair and maintenance of scheme is not sufficient to reduce water losses and the system needs a complete rehabilitation according to the Table 2-1.

4.5.4. Leakage Control

Night flow of the inflow is comparatively high hence more attention was paid to control water leakage by adopting the following,

- **House to House Leakage Survey**

By house to house survey, several service leaks and road leaks were detected. After repairing of these leaks, prevailing number of water complaints got reduced in the pilot area and the complaints received to Colombo City office is tabulated in table 4.5.4

- **Survey of Culvert Crossing**

To find out water leakages due to settlements at culvert crossings by using open drain maps in the area. To carry out the survey five teams were employed with instruments and they were able to trace 6 major invisible leaks. After repairing of these leaks, pressure was gradually improved to reasonable level. Figure 4 -26 shows culvert crossing inspection to search leakages and detection of such leaks. Due to these leaks Harmars place and Dharmarama Mawatha in Colombo 6 area did not get water during the day time and during the night they had to collect water using underground tanks.

Figure 4-26 Culvert Crossing Leak Investigation in two roads

- **Step Testing**

Step testing was carried out section-by-section and road-by-road to find out invisible leaks and minimize night flow due to leakage.

With this study it was planned to carryout step testing in four roads, however due to the delay to obtain road cutting permission and limited resources, it was limited to one road.

Pamankada Lane, Wellawatta

After reviewing pipe lines and utilities in the road, initially all the valves were numbered, S1 to S8 as Step valves and CV1 as to prevent circulation in the distribution system.

Test was carried out during midnight by recording the Minimum Night Flow because of minimum consumption. Before commencement of the test CV1 valve was closed to prevent circulation. Then bulk meter reading were recorded in 10 minutes intervals in the following steps. After obtaining initial bulk meter reading, SV1 valve was closed for 10 minutes. Closing valve in 10 minutes intervals up to SV8 valve was followed. Results of the subsequence closing valve are in table 4 -27

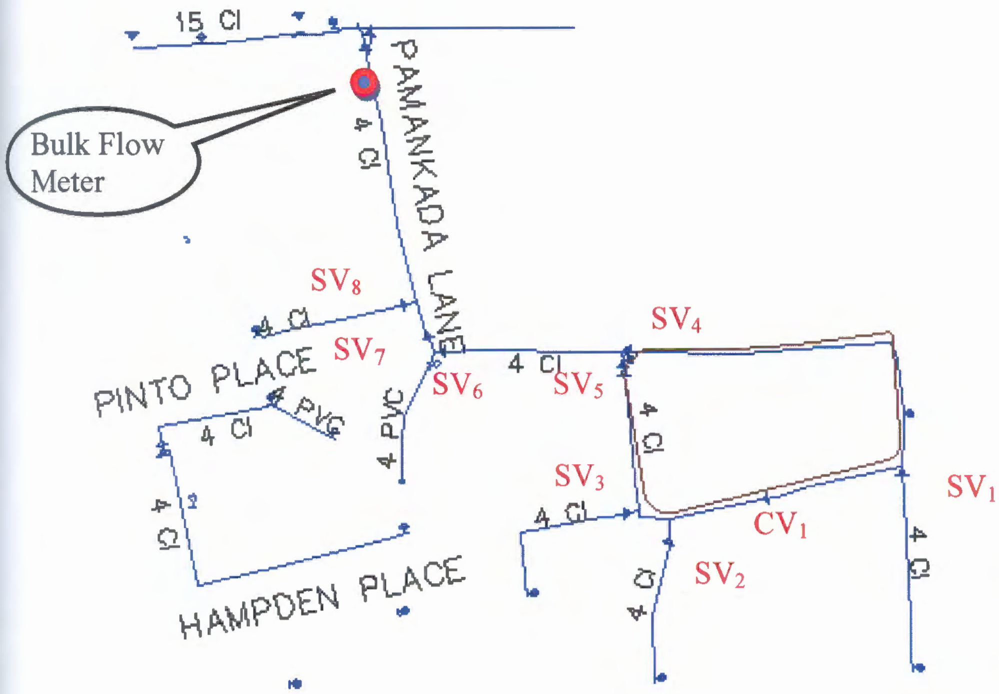


Table 4-27 : Sequence of Valve Closed in Step testing in Pamankada Road

	SV1	SV2	SV3	SV4	SV5	SV6	SV7	SV8	Flow Rate l/sec
Valve Position	Open	Open	Open	Open	Open	Open	Open	Open	4.66
	Closed	Open	Open	Open	Open	Open	Open	Open	4.40
	Closed	Closed	Open	Open	Open	Open	Open	Open	4.26
	Closed	Closed	Closed	Open	Open	Open	Open	Open	4.02
	Closed	Closed	Closed	Closed	Open	Open	Open	Open	2.28
	Closed	Closed	Closed	Closed	Closed	Open	Open	Open	2.19
	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open	1.75
	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Open	1.42
	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	1.08

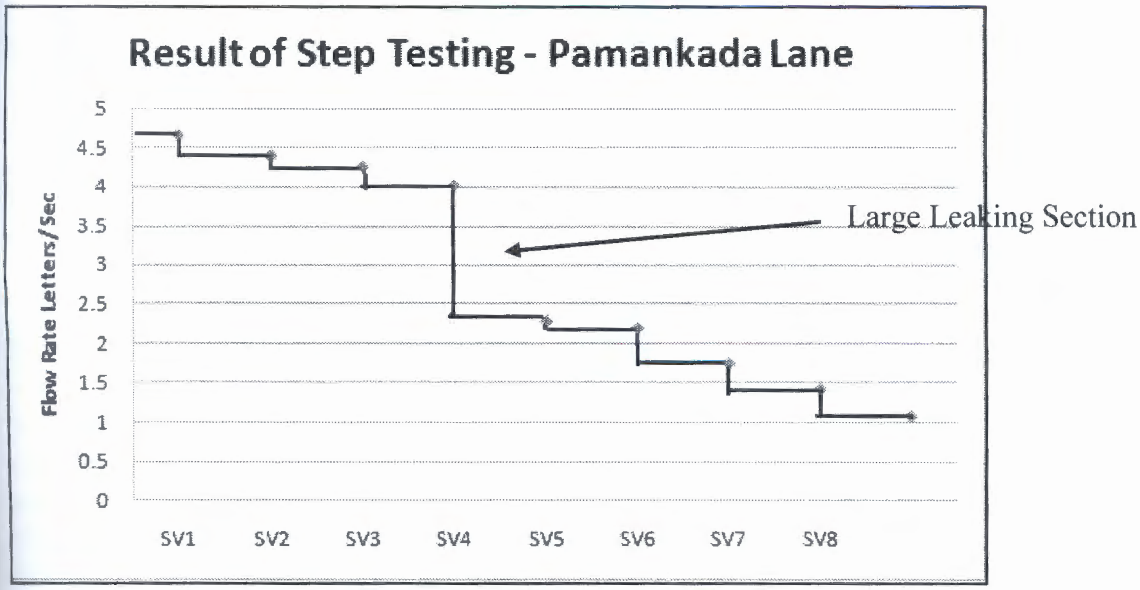


Figure 4-27 : Results of Step Testing

Result of the test is like a step. It is called step testing. However during the test, was detected that main leak at the sections between SV4 and SV1 and repair was done. With further studies it revealed that the night flows in the small section was very high and leak detection carried out with equipment could not detect any leaks other than small visible leaks. After repairing the visible leaks, monthly consumption did not tally with the monthly bulk meter water supply. Hence further investigation has carried out and one bypass at the condominium flat was found.

4.5.5. Reduce Free Water Supply

There are 66 Tenement Gardens with 57 Stand Posts, 55 Bath Taps and 48 Toilet Taps available in the pilot zone as free water outlets. After metering of the common out lets, it was assessed that free water supply average to 410m3 /day which is 2.8 % of NRW in pilot area NRW.

During this study period 23 common out lets were removed and 109 individual house connections were given to reduce free water supply and improve the hygienic conditions of the tenements

Another mode of free water supply is fire hydrant water usage which is hardly measured due to non available measuring means. Hydrants are not often used and no regular programme to washout or release air periodically. During our operation hydrants were not used. Hence this usage is not considered in our calculation.

4.5.6. Reduce Illegal Consumptions

Initially there were a significant number of illegal water users detected in the pilot zone; later, once the message of illegal connection detection was passed to the others who also had illegal connections, forcing them to remove such before checking. As a result, supply conditions were improved with increased revenue to the utility and reduce apparent losses.

From 2008 January to September 39 illegal connections were detected out of 1,675 places inspected and eight in line boosts were detected. It was noted that the majority out of these illegal consumers are largely consumers mainly the owners of the apartments who had by passes from the normal line. With the progress of house to house survey, most of the low pressure areas become normal due to removing illegal connections prior to checking.

4.5.7. Reduce Administration Losses

While implementing the house to house survey, all possible administrative losses were addressed. The recorded meter readings in the water bills were compared with actual and all the defective meters were replaced. The estimated bills due to house closed was addressed by the water meter being shifted to readable location or providing option to forward meter reading to the relevant office.

Due to various reasons there were 56 unmetered connections which were identified out of 1,675 premises surveyed. These were long outstanding, but action was taken to fix meter and proceed to normal billing system.

Before commencing the house to house survey, all the meter readers and respective zone officers were made aware of it. Hence considerable disparities could not be found miss match with actual meter readings. Hence pilot zone NRW reduction contributed to the above effect.

However two incidents were reported with meter tampering where meter readings were tallied but with the experience of the teams, they suspected under reading of meter compared to the number of residents in the houses. So after dismantling of the meters they found that the meters were tampered by making an additional hole as shown in figure 4 -28 and fines were imposed according to NWS&DB rules and regulation.

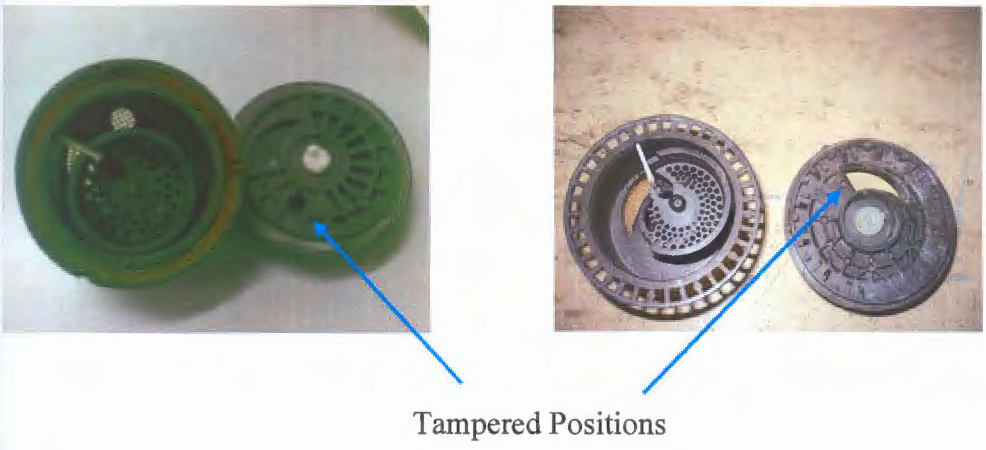


Figure 4-28 : Illegal Water Meter Tampering

4.5.8. Results of Pilot Studies

4.5.8.1. Result of House to House Survey

It was a slow process to implement water loss management study because all the causes had to be identified and rectified to obtain positive results. With my study it could only complete only 1/3 of connections. Results were tabulated in Table 4 -28

Table 4-28 : Result of House to House Survey

Description	Result
No of Consumers	8,873
No of Places Inspected	1,675
Major Leaks Repairs	06
Road Leaks	482
Service Leak Repairs	19
Fixing of meters to Un meter connections	56
Defective Meter Replacement	58
Illegal Detection	39
Gate Closed Arrested	81

4.5.8.2. Impact of Pilot Scale Study

After one and half years of studies, low pressure area was converted to a normal situation reducing NRW a considerable amount (refer figure 4-25) without pipe replacement. Initially, staff of the area was congested with consumer complaints and the staff could not get any support from them. With the studies in progress, one by one low pressure roads became normal and consumer complaints were reduced. In the pilot zone per connection consumption was increased by 24m^3 per month to 28m^3 per month.

With the studies it was found that the best methodology as road by road or small area water balancing is more appropriate to reduce NRW in Colombo City which is a very slow process but effective. By adopting more resource this can be achieved in several years.

In addition, the study exposed that the appropriate methodology with close monitoring, commitment and prompt action with awareness at all level of staff always help to reduce NRW within economical level in any worst situations. Refer Pamankada lane step testing and water balance page No 101.

With the analysis of distribution system in pilot zone it was identified that most of the pipelines on either side of WA Silva Mawatha were corroded and scaled. Hence arrangement has been made to replace the same within this year. Total length of CI replacement is 5 km.

4.5.8.3. Analysis of Billed Quantity

While implementation of active NRW programme, billed quantity in the respective Area Engineers region ie CC (South) has been gradually increased compared to other regions in Colombo city and are tabulated in table 4 -29. In June 2009, there was a slight decrease in billed quantity in all four areas due to rearrangement of bill cycle to 30 days per month. Sometimes monthly bill length exceeded 30 day due to administrative reasons and declaration of a work to rule trade union action by Meter readers during this period. In 2009 September and October billed quantity was gradually normalized in all four areas. However in the pilot zone area the increase was significantly higher than the normalized values as clearly shown in figure 4 -29. .

Table 4-29 : Analysis of Quantity of Billed in 4 Areas in Colombo City

Year 2008	Area Engineer Office – Quantity of Billed in 000' m^3			
Month	CC (North)	CC (West)	CC (East)	CC (South)
2008 Dec	589	587	599	737
2009 Jan	713	657	650	843
2009 Feb	649	740	677	785
2009 March	682	666	607	754
2009 April	694	572	659	772
2009 May	565	509	572	773
2009 Jane	499	494	539	697
2009 August	520	496	578	703
2009 September	515	519	589	720
2009 October	581	527	567	741

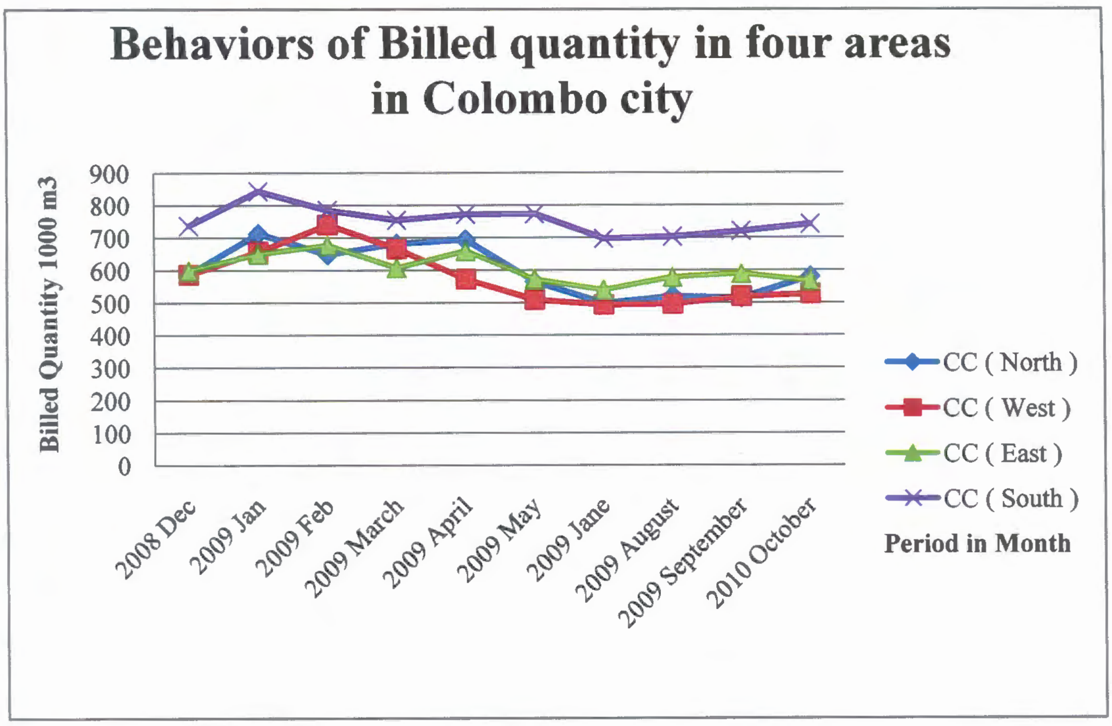


Figure 4-29 : Behaviors of Billed quantity in four areas in Colombo city

4.5.8.4. Analysis of Consumer Complaints

It was noted that after implementation of pilot studies the consumer complaints in Colombo 6 area (Pilot Study Area) was reduced. Summary of NWS&DB consumer complaint register with respect to water leaks, area failed, low pressures, No water are presented in Table 4 -26 to 4 – 29 and Graphical from in figure 4- 26 to 4 -29. Data of Colombo 6 area plotted in "*Italic letters*" for easy identification.

Table 4-30 : Water Leaks Complaints

	2009						
	January	February	March	April	May	June	July
Colombo 1	0	1	1	3	2	4	2
Colombo 2	11	18	5	18	13	22	23
Colombo 3	13	14	13	29	14	17	15
Colombo 4	11	9	11	11	19	15	12
Colombo 5	65	37	48	71	76	55	50
Colombo 6	***45***	***55***	***62***	***47***	***44***	***41***	***35***
Colombo 7	27	15	19	17	20	26	22
Colombo 8	35	25	35	33	29	39	42
Colombo 9	41	21	12	9	20	27	31
Colombo 10	47	23	36	36	24	47	69
Colombo 11	17	3	7	7	6	7	18
Colombo 12	33	21	22	10	18	23	26
Colombo 13	37	19	38	45	23	44	41
Colombo 14	57	40	65	34	41	63	59
Colombo 15	101	61	67	37	39	91	68

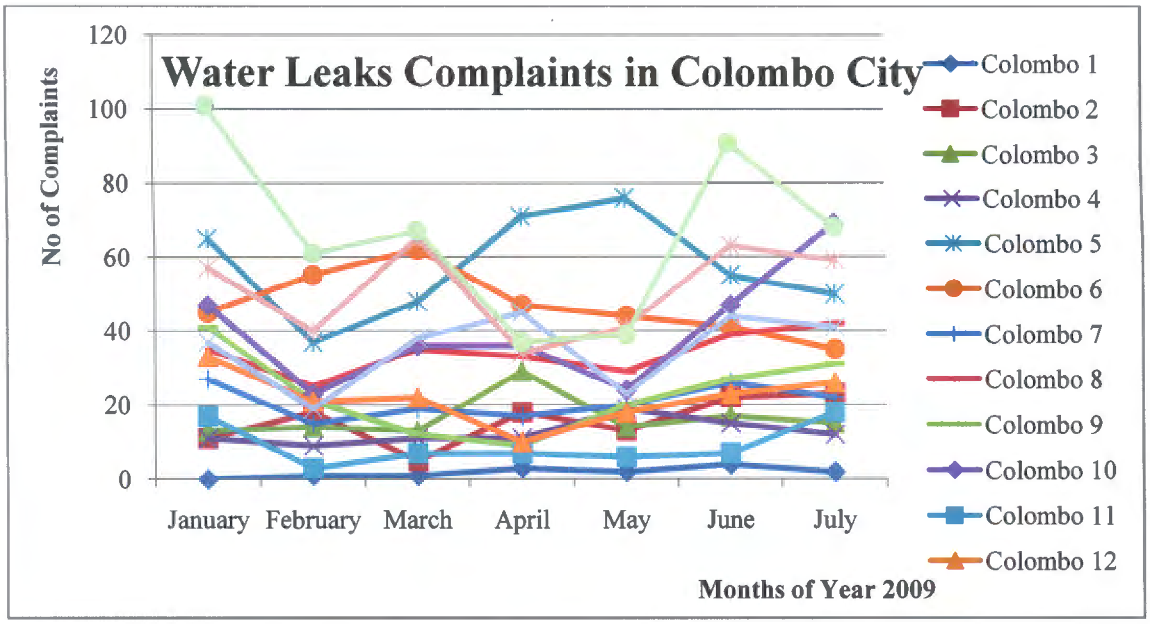


Figure 4-30 : Water Leak Complaints in Colombo City

Table 4-31 : No of Area Failed Reported

Postal Code	2009						
	January	February	March	April	May	June	July
Colombo 1	0	1	0	0	0	0	0
Colombo 2	2	0	2	0	2	0	0
Colombo 3	4	1	8	2	1	0	0
Colombo 4	1	0	3	1	0	0	0
Colombo 5	0	3	12	2	0	2	1
Colombo 6	***6***	***2***	***4***	***2***	***0***	***0***	***0***
Colombo 7	9	4	0	0	1	1	0
Colombo 8	0	0	2	0	4	0	2
Colombo 9	2	0	0	0	5	0	0
Colombo 10	0	0	1	3	7	0	3
Colombo 11	0	1	1	0	0	0	0
Colombo 12	6	7	1	1	4	0	1
Colombo 13	2	1	0	2	5	0	1
Colombo 14	11	1	0	1	1	1	1
Colombo 15	1	0	1	0	1	0	0

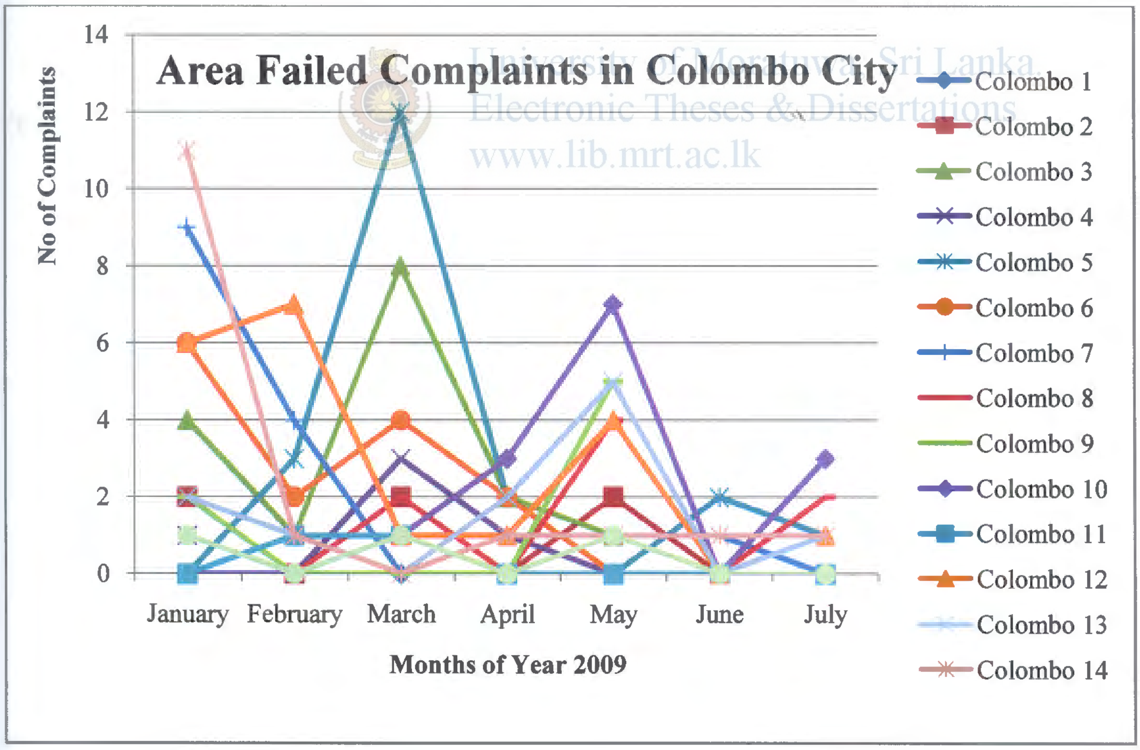


Figure 4-31 : Comparison of Area that Failed in Colombo city

Table 4-32 : No of Reported Low Pressures in Colombo City during year 2009

Postal Code	2009						
	January	February	March	April	May	June	July
Colombo 1						1	
Colombo 2	7	1	3	3	1	2	1
Colombo 3	12	17	14	6	6	3	5
Colombo 4	2	0	1	0	0	0	0
Colombo 5	6	3	10	3	4		
Colombo 6	***2***	***2***	***4***	***1***	***2***	***3***	***1***
Colombo 7	11	5	8	0	4	4	2
Colombo 8	3	7	6	7	11	0	0
Colombo 9	4	2	1	2	15	2	0
Colombo 10	8	8	15	4	15	3	10
Colombo 11	4	0	3	1	0	1	2
Colombo 12	9	2	9	5	3	3	2
Colombo 13	2	7	3	3	7	3	5
Colombo 14	8	3	4	4	1	2	1
Colombo 15	7	6		1	2	3	2

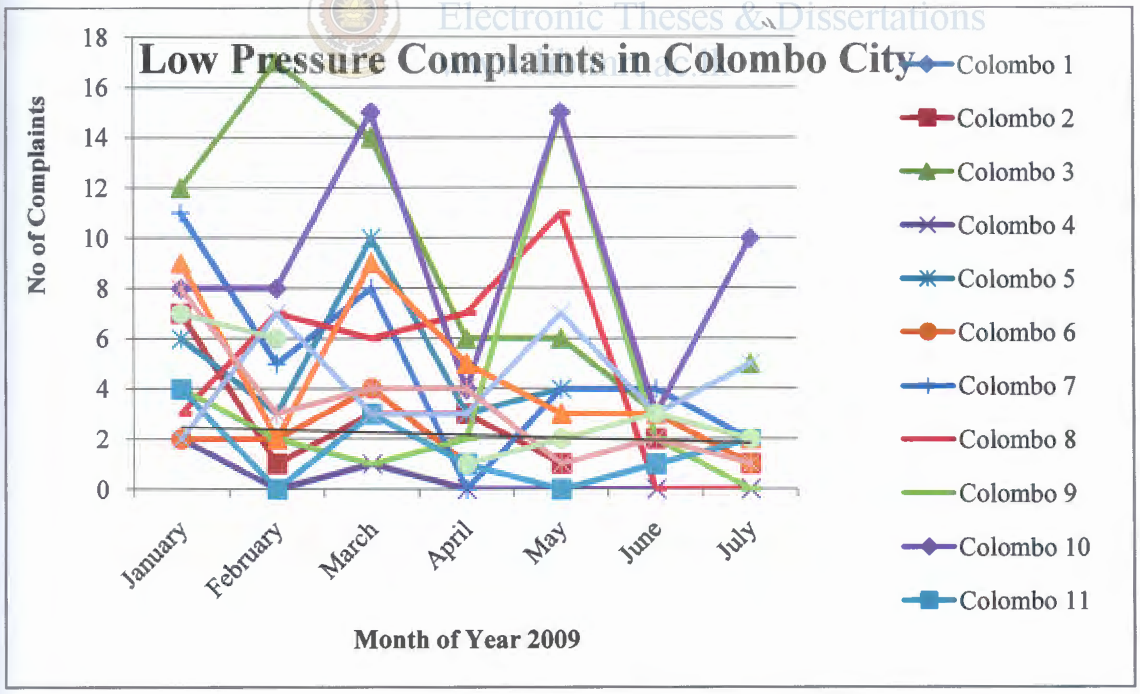


Figure 4-32 : Analysis of Reported Low Pressure in Colombo City

Table 4-33 : Reported No Water Complaints

Postal Code	2009						
	January	February	March	April	May	June	July
Colombo 1			2	1		2	1
Colombo 2	10	16	7	9	4	4	8
Colombo 3	16	14	25	17	30	15	9
Colombo 4	3	6	8	1	4	4	3
Colombo 5	25	20	30	19	20	19	12
Colombo 6	***25***	***14***	***21***	***8***	***6***	***12***	***8***
Colombo 7	19	15	16	13	14	19	6
Colombo 8	7	17	15	12	13	8	6
Colombo 9	9	5	6	6	12	10	4
Colombo 10	27	24	25	23	26	28	29
Colombo 11	3	2	3		1	1	2
Colombo 12	13	11	13	15	13	14	6
Colombo 13	12	5	10	11	4	12	14
Colombo 14	13	17	14	10	9	19	8
Colombo 15	10	8	11	6	9	9	5

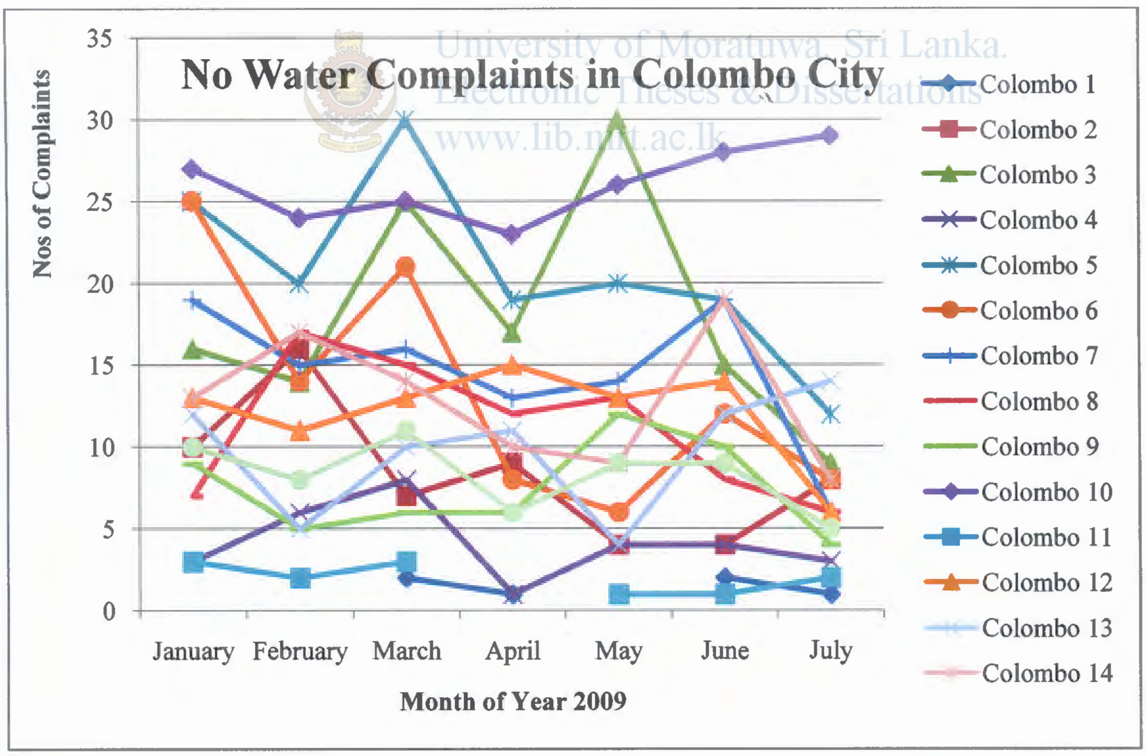


Figure 4-33 : Reported No Water Complaints

4.5.8.5. Pressure Distribution Over Pilot Area

In November 2009, obtained system pressures in several points spread in distribution area in final observation and graphs are as follows,

With the analysis it was noted that all the pressures in the system has been increased by 2m with previous reading and at 4 to 4.30 achieve minimum night flow with maintaining maximum pressure around 14m all over the distribution system. Relevant pressure reading obtained are indifferent intervals are attached in Annexes. This means either leaks are even or there are less leaks in the distribution system. While compared to early stage of studies day time pressures are very low and most of the consumers did not receive water. With our studies at present, day time pressures have been increased and consumers have sufficient quantity of water. This was emphasized by the reduction of consumer complaints too.

4.6. Strategy Formulation for Water Loss Management

Activities of operation & maintenance division help to maintain water losses at the same level in the Colombo City water supply system. In order to reduce NRW to an acceptable level, it needs to implement a planned programme with more resources. Based on the field study and data analysis, it was able to identify key resulted areas with priority order of activities to formulate the strategies required, both in the short and long term. Network management and leakage control need to be integrated if water losses are to be reduced and provision of water services improved.

4.6.1. Short Term Strategy

The short term strategy is aimed at carrying out tasks and activities which will bring some immediate impact on water losses with low cost to the utility. The first step deals with determining why and where the loss is occurring. Only when these are understood, meaningful steps will be made towards water loss reduction. Therefore, the following have been identified as short term strategies.

- Management rearrangement
- Water Audit and Creation of DMAs or water supply districts
- Set Target Levels for Water Losses on a year by year basis
- Re-train staff in improved and latest methods of water loss management
- Continue and intensify house to house survey and leak detection programmes
- Improve Repair Techniques and Workmanship
- Meter Replacement programme with a metering policy
- Meter Reader Rotation Programme
- Minimize illegal connections
- Continuous monitoring in Zones; Intensified bulk and domestic metering
- Continuous monitoring with assessing and managing apparent losses

4.6.1.1. Management Rearranges

Earlier Colombo City had two separate sections to look after the commercial and maintenance activities. Colombo city had been divided into three Area Engineers offices to handle commercial activities including minor repairs and consumer complaints etc and all the operational & development activities are separately handled by the office at Maligakanda as shown in Figure in 4 – 34. For the O&M works, responsibilities have not been decentralized to the OIC level/zonal officers' level and no zonal management system is practiced at the Colombo City. Due to this set up, following setbacks have been arisen,

- Actual work time gets limited due to vehicle congestion
- EAA are not assigned with proper and dedicated responsibility to look after overall maintenance activities in a particular zone
- Delay in attending to consumer complaints
- Inconvenience for consumer to travel to Maligakanda from other areas
- Delay in organizing leak repair work
- Failure to pay attention to the illegal activities of the consumers

Hence four basic principles explained in section 2.5.2; figure 2.11 to reduce real losses are not properly practiced in the above situation. Delayed leak repairs result in increased real losses and present situation is not constructive to expedite speed of leak repair with the central point operation. Further the quality of leak repair too has not been guaranteed due to above reasons.

Early Management System in Colombo City Water Distribution

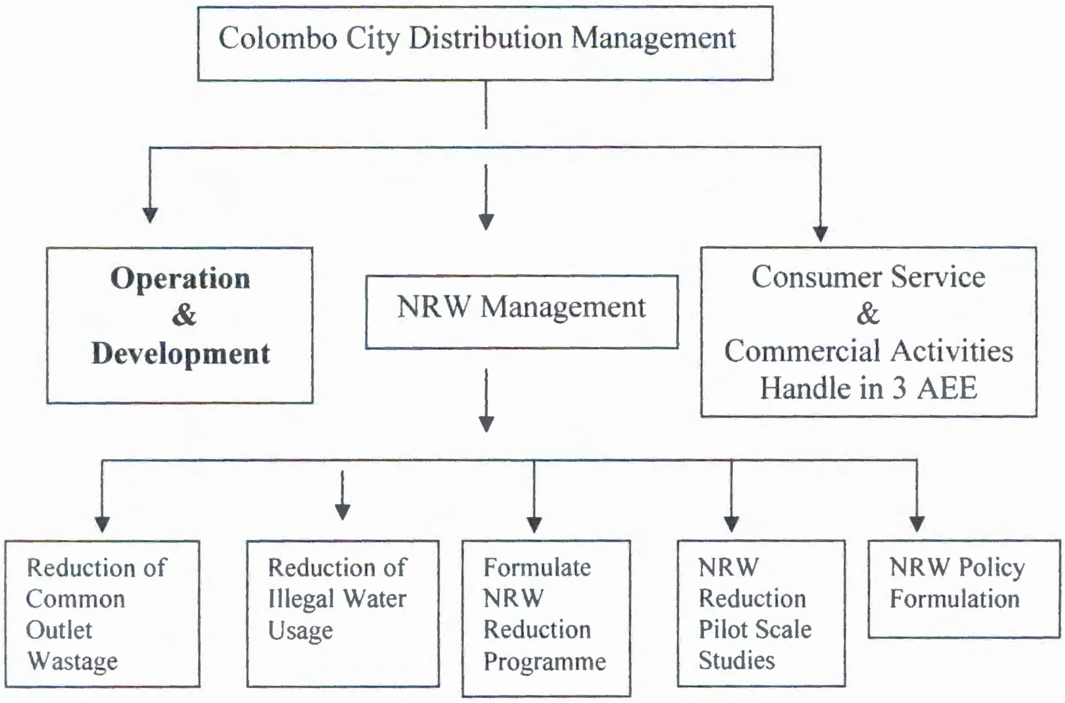
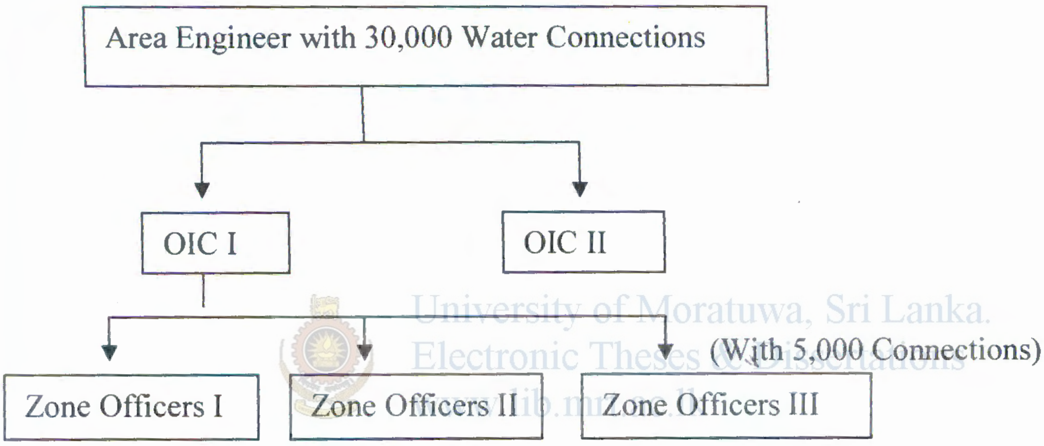


Figure 4-34 : Early Management System in Colombo City Water Distribution

To overcome the above deficiencies in Colombo City management, the system is rearranged according to decentralization principles with sufficient resources to pay more attention to carryout maintenance of such a deteriorated system.

Colombo City has nearly 116000 No of water connections by December 2008 and for effective management, following guild lines are used,

- Connections for AE office is limited to a maximum of 30,000
- Connections for EA zone is limited to 5,000
- Natural boundaries are used to demarcate zones wherever possible
- Zone officer is responsible for maintenance and commercial activities within zone



The entire Colombo City is divided into 4 Area Engineering regions namely Colombo City North, Colombo City South, Colombo City East and Colombo City West and each AE consists with two OICC, thus having a total of eight OIC divisions namely Mattakkuliya, Kotahena, Maligakanda, Borrella, Timbirigasyaya, Pamankada, Slave Island and Hulfsdorf to handle all the maintenance and commercial activities including UFW. OIC divisions will further be reduced to Engineering Assistants zones that comprise of approximately 5000 connections each, referred to as DMAs where decentralized authority and responsibility will be given to EAA. With the implementation of this programme, it is possible to closely monitor the activities and take prompt actions to reduce the expected NRW by 3% during the 1st year and by 1% in the following consecutive years up to a period of 5 years. Refer Propose Zonal Map

Advantages of the zone proposal

- Easy attention for consumer grievances
- Saving of water by attending for leak repair with minimal leak time
- Improvement of level of service
- Close monitoring of Meter readings, its auditing

- Effective reduction of estimated bills
- More attention on every consumer and their illegal activities
- More new connection with the improvement
- Easy identification of responsible officer
- Availability of reliable information system

The above mentioned deficiencies could be rectified up to an acceptable level by adopting integrated water loss management system shown in **figure 4 – 35** and the implementation of following strategies.

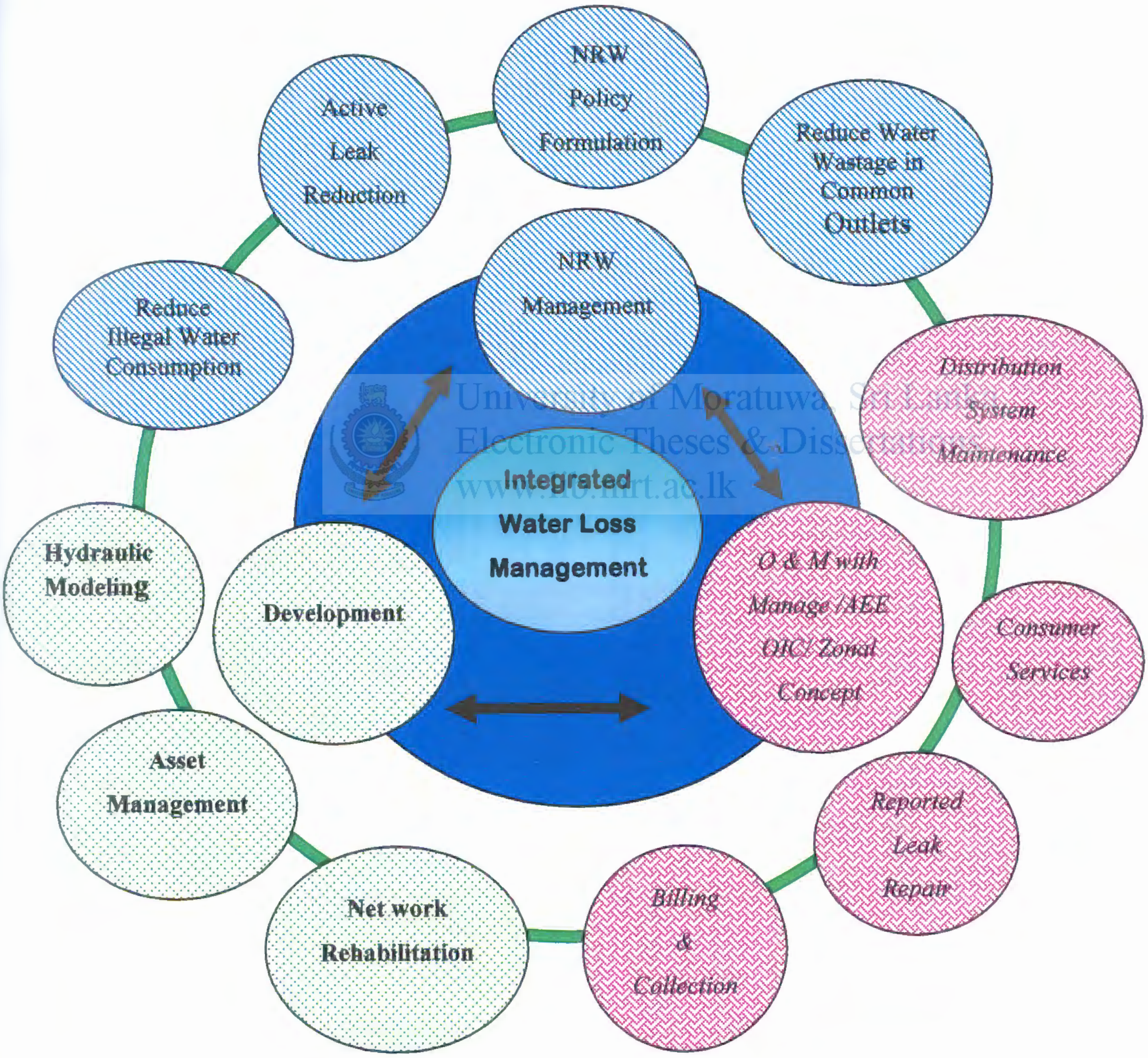


Figure 4-35 : Proposed Colombo City Distribution Management System

4.6.1.2. Water Audit

Colombo city has never carried out a full scale water audit; therefore this is the first step. In addition to the water balance, the audit essentially includes an appraisal of the system. But they have some understanding about the factors responsible for the water loss. However water audit will help the staff for better understanding of water loss and distribution system performances.

A comprehensive water audit will uncover any costly inefficiency in the water distribution system that results in money being literally poured down the drain.

The water balance will follow and will involve measurement of distribution input and water consumed. All components of the water balance should be quantified over the same designated period. Section 2.2.1 describes the water audit in detail. When the components of the water balance are established, the leakage level should be estimated and the ILI and ELL determined more accurately.

4.6.1.3. Continue and Intensify House to House Survey and Leak Detection Programmes

By introducing zonal management system to reduce NRW, Colombo city was divided into 22 zones with resources to carry out the maintenance works. But concentration for long term consumer works is not feasible with day to day maintenance work activities. Therefore NRW section will have to intensify house to house survey and leak detection in the zones and with the leak repairs, the distribution plans should be updated and mapping of losses should be introduced by the zone officers.

As the distribution system is divided into 22 zones; a target number of pipe length in kilo meters will have to be surveyed and leaks detected in each zone on both transmission and distribution mains. As an example, with a total of 810km of mains, approximately 285 km of mains in the entire distribution system can be surveyed and detected per year, translating to 1 – 1.5 km in each zone per month. With the employment of fully trained 15 number of leak detection gangs, it is possible to achieve this target in 3 years.

New methods will have to be tried to improve leak detection performance with pilot study experience. Considering that the Colombo city water supply system is having low pressure supply system. Step testing should be carried out during the night and with the minimum night flow for small isolated areas or possible distribution branches.

The steps are as follows:

a) Rearrange zone to have one or minimum feeding points and fix bulk meters
b) The test area is isolated by closing the boundary valves in the zone or district of interest;
c) Carry out valve proving test

d) Identify night consume premises that obtained night consumption or Stop taps on customers' service connections are closed;

e) Recorded night flow is responsible for the water leakage, hence closing valve in sequence responsible branch or part can be identified.

f) Leak detection equipment is used to locate the leak points.

4.6.1.4. Meter Reader Rotation

Under this zonal arrangement meter readers will be assigned to zone officers, and limited 1800 connections to each reader, with rotational system. This connection area will be called a District Metering Area or waste district system, with three meter reading cycles and readers being rotated every 4 months time as shown in figure. 4.6.1.5

A	A	A	C	C	C	B	B	B	A	A	A
B	B	B	A	A	A	C	C	C	B	B	B
C	C	C	B	B	B	A	A	A	C	C	C

1st month 2nd month 3rd month 4th month

Figure 4-36 : Propose Meter Reader Rotation in Colombo City Water Distribution

4.6.1.5. Improve Repair Techniques, Materials and Workmanship

In Colombo City most of the pipes are in a deteriorated stage, but pipe bursts are not so often seen due to low pressure. Most of the water leakages occurred due to external factors such as settlements, heavy moving loads, frequent de-scaling, illegal connections, poor workmanship etc. Currently, high night flow and high supply rate per connection show that there is a need for distribution system rehabilitation in dealing with leakage management.

The following should be carried out:

- The right type of repair material should be specified ;
- Leakage prone material such as AC, and CI should be replaced with appropriate pipe materials
- Propaganda to encourage to report leaks;
- Time taken to attend to a leak repair should be shortened

- Leak repair time should be shortened by providing proper equipments
- Workmen should be improved

4.6.1.6. Re-train Staff in Improved and Latest Methods of Water Loss Management

Water loss management, especially the leakage management is a much specialized area and it is important that all staff involved be re-trained in leakage technology and equipment usage. The training programmes among others should include:

- Practical demonstrations and experiences in the use of a wide variety of equipment the utility possesses such as sounding probes and flow meters,
- Setup of DMAs
- Analysis of data using distribution system by distribution design software.

4.6.1.7. Assess and Manage Apparent Losses

Most of the water loss management practices are paid more attention to reduce physical losses, rather than reduce apparent losses due to small contribution to NRW. But sometime most of the revenue losses will occur due to the apparent losses. With the progressive tariff adjustment of one unit, it will bring to the lower slab in tariff structure and change the bill by decreased high amount. Therefore cross checking with close monitoring or by using improved apparatus are essential to have a good income to the utility. For Colombo City, apparent loss is approximately 12 -15% of system input, so it is quite a considerable amount. 12 -15% of NRW contributes illegal consumption (water theft), meter accuracies, estimated bills, meter readers mal practices such as under readings etc.

House to house survey to carryout to wipe out all possible means of apparent losses

- Disconnected premises should be investigated to ensure that there is no further water use. If these places still use water, action is to be taken as illegal water usage
- To identify registered & unregistered consumers if unregistered or unmetered connection is found, action to be taken according to the procedures.
- Illegal connections or by passes, once identified should be converted to legal connections and regularized according to the procedure
- Identification of all tampered meters and action to be taken according to the procedures
- Seal all unsealed meters
- Identification of house closed estimated bill premises and implement method to be adopted to obtain meter readings by shifting meter to readable location or

mutual understanding with consumer to display or inform meter reading at schedule data.

- Identification and replacement of all defective meters
- Identified reason for estimate and implement meter rectification programme
- To reduce meter error, use one liter bottle to identified and replaced faulty meter at less for nominal flow

In addition to the house to house survey following step to be taken to reduce apparent losses,

- The utility should offer concessionary rate for inside premises leak detection services to customers.
- Introduce hand held data recorders with bill printing machine and staff to be trained in the proper use of hand held data storage units used to record meter readings;
- The Geographic Information System (GIS) should be used to establish a link between customer accounts, actual properties and/or buildings and meters;
- Connection traces should be used to future identification connection reference
- The publication of penalties and fines for illegal use should be promoted
- Continuous monitoring to be held with proper indication with benchmarking to encourage among waste districts

4.6.2. Long Term Strategy for Colombo City

In the long term, the utility will have to implement the following programmes in order to achieve significant gains in water loss reduction. Under the capital intensive programmes as an initial step, 56km of deteriorated smaller diameter less than 6" CI pipe will be replaced in Fort and Kotahena area which is the worst area among Colombo City. Secondary 80 km of same diameter range of CI pipe has been identified to be replaced in Colombo north and Salve Island area. In addition to the above replacement, the following are to be implemented to achieve reduction of NRW and sustainability of water loss management. Priority order of the works to be implemented reduces NRW and caters for new demand in Colombo City.

- Smaller diameter Pipe replacement
- Hydraulic improvements inside larger diameter pipes
- Establishment of DMAs with minimum feeding points
- Leakage management and control
- Network analysis with verification of field data

4.6.2.1. Smaller diameter Pipe replacement

As explained earlier replacement of smaller diameter pipes helps to reduce most of the physical losses and apparent losses in a water supply scheme. With the replacement of pipes all the house connections should be reconnected to the newly laid pipes. However, most of the house connections are provided from smaller diameter pipes hence all legalized connections can be easily traced after reconnecting and all illegal connections to be legalized according to the regularization procedures.

In addition to the illegal connections most of the hidden leaks and wet patches will be eliminated with the pipe replacement. Also frequent repairs cause inconvenient to the customers and allow mud particles to enter in to the system which will cause water meter defects and germs will cause problems to the public health. However frequent repairing of leaks is costly and it is more economical to replace pipe lines with valves and fire hydrants in order to improve the supply to customers and cater for future demand.

4.6.2.2. Hydraulic Characteristic Improvements in Large Diameter Pipes

Colombo city has approximately 60% of its pipe network which are older than 70 years. Other than smaller diameter pipes, if outer cast is good enough improving inner surface by relining will help to improve hydraulic characteristics. This is essential to be implemented because Colombo system is gravity-feeding with low pressure. Improvement of pipe inner surface will reduce friction losses that will help to manage the system properly. As per topography of Colombo City, reservoirs are located at highest points namely Maligakanda and Eli House that are capable to feed any point of existing network in Colombo City, if the pipes are in a better condition. Therefore an improvement in hydraulic characteristics is essential to improve Colombo City distribution system.

4.6.2.3. Water Meter Management

Meter management has to be improved and a meter policy put in place. The policy should include the followings

- Specify the procurement and testing procedures, installation procedures, type and classes of meters to be installed at domestic and commercial customer's premises to avoid purchase of poor quality meters;
- All meters to be installed with disconnecting devices
- All the meters to be sealed with stainless steel with unique sealer to avoid meter tampering
- Ensure that meter installed on customer premises match the details on the customer accounts in the billing data base and the GIS;

- Frequently investigate cases of extremely low or abnormally high consumption on customer accounts
- Specify a replacement date for meters reaching their working lifespan and define criteria for testing and replacement of water meters
- Ensure that calibration of bulk meters is carried out every three years.

4.6.2.4. Establishment of DMAs

Colombo City is to be initially divided into 22 zones, each comprising of 5000 water connections and zone offices appointed to look after all maintenance activities. Later these areas should be metered to measure inflows and calculate NRW. Each zone should be further divided into two sub zones to establishment of DMAs which will have 2000 - 3000 connections with one feeding point, at least only for the study period. Minimum night flow measurements should be monitored and step testing will be carried out. Further to that each and every branch should be monitored by installing pipe piece with chamber, facilitating to install external clip-on type flow meter. This arrangement can be used with even scaled pipes to measure flows for the study purposes. The average length of pipe network in each water supply zone is approximately 30 – 40 km with the entire Colombo City having 810 km in 22 zones).

Studies have shown that DMA design for leak detection responses require at least 30 Km of pipe network to provide for 24 hour response for leak identification by a single leak detection team (Brothers 2004). Accordingly by employing two teams per zone, Colombo City management restructuring process will be within the excepted norms for leak detection and repair exercises. Further establishing zone or DMAs with maximum length of 30 – 40 Km of pipe network also will be followed.

Zones in Colombo City are employed with two teams and a leak contractor, enabling one team to handle task of leakage where active leak detection is carried out on full time basis and the other team handles all the maintenance works including service leaks and visible leaks repairs.

4.6.2.5. Leakage Management and Control

Main strategy of the establishment of DMAs facilitates to control water loss in a small confined area, which is capable to handle in an effective manner. It is quite easy to monitor. Even a small deviation is observed and corrective action can be taken accordingly. DMAs help mainly to control leakage in distribution system by monitoring night flows. It is easy to workout step testing and identify heavily leaking areas and even to pinpoint leaks by using equipments to reduce leakage. It also helps to identify deteriorated pipe to be replaced and expedite leak repairs, finally achieving overall leakage control. With the monitoring of small area, it helps to minimize the average leak repair time between the occurrence of a leak and its elimination. Utility has introduced toll free four digits telephone number to receive information about leaks to expedite leak repair work to control leakage.

4.7. Challenges Faced During Implementing of New Strategy

The challenges in implementing the proposed strategy are not only financial constraints of the utility but also obtaining necessary resources within schedule time and the level of expectation with the prevailing procedures etc. High resistance to the proposal was observed during initial planning stage, demanding more resources to drop the proposal saying it is not technically feasible. This is because of the reluctance to change the attitude of people.
During the planning and implemented period many challenges were encountered, which are:

I) To convey concept to the different lays of management

This is the most difficult part of the process and concept was initially explained through several presentations. Later with the several discussions with operational staff and the key personnel, proposal was finalized and sent to the board approval. After obtaining board approval funds were allocated in stages with the progress of procurement. Further discussions led to rearrange the entire system to suit the new restructure.

High management of the Western Central region of the board was fully aware and committed to restructuring of Combo City water distribution management. Hence it was easy to implement this strategy in a useful manner. However, conveying this concept to middle management and lower level of the staff was a slow process. Initially key persons were identified within the existing staff as OICC and fortnight meetings were held for monitoring and keeping informed of the progress. The main strategy of the Colombo City distribution management includes paying more attention with decentralization authorities and responsibilities to implement appropriate programme for effective water loss reduction.

II) Constrained in Distribution System

Distribution in Colombo City was of systematic design but due to poor strengthening and rehabilitation, the system went out dated and deteriorated. Demand was catered by laying new pipe lines in an ad-hoc ways by connecting between low and high pressure areas. Due to this, the system had further deteriorated and resulted in leaving several pipe lines on the same road resulting in several feeding points to the area. Due to this fact the present system cannot be isolated even for leak repairs or any other improvement. Leaks were repaired under pressure; hence huge amount of water was wasted and in became time consuming work.

To overcome this situation a policy was introduced where pipelines in a road in main cities shall consists of maximum of two rider mains with minimum diameter of 100mm or maximum of 150mm on either side of the road, depending on width of it and as feeder and trunk mains due to necessity. With the proposed pipe replacement all inactive and unwanted pipe line to be disconnected in the system. New policy is easy to accommodate in prevailing distribution model in Colombo City.

It was observed that with the pipe replacing or strengthening with new lines it has resulted in increased NRW. This is because when new system is connected to the old system it caused reduced friction and increased pressure which resulted in more leakages. With this experience identification of pipe replacement the following strategy was used

- Pipe replacement confined to isolated area with one or few feeding pipes.
- DMA to be formed with easy monitoring
- All the inflows and out flows will be metered
- All old pipe lines to be disconnected with transferring connections
- All the defective valve to be replaced and maintained well
- Confirm leak proof in main lines other than over 150mm by adopting step testing

III) Attitudes of People

Changing attitudes is one of the main constrains in water loss management. Most of them foresee problem rather than to implement effective appropriate work. The leader with appropriate plans can change people's attitudes and direct them to work positive thinking. In these restructuring plans, management introduced lower level managers with authorities and responsibility for the effective water loss management system. They have better chance to approach lower level staff rather than middle level managers. Therefore they can change attitudes of skilled and unskilled workers and focus to effective water loss management.

The selection of leader or OIC is one of the major constrains in the system. Initially senior people were selected from existing staff. But this is not the appropriate selection for effective water loss management. According to the experience of pilot studies more attention with appropriate programme can achieve its objectives. Therefore it needs to provide appropriate training with effective monitoring system and with indicators required to evaluate performance of such officers to encourage water loss management process to achieve objectives.

IV) Skills and Capacity Building for New Technology in Water Loss Management

Water loss management is not individually effective. It needs contribution from all the staff members. Each of the members has collective role rather than has own duties. Hence it is very important to discuss strategies with all members and further improvement for the proposed management system and be aware about it. For the moment most of the employed in Colombo City distribution system has less experience and knowledge about new concepts of water loss management. Hence they need to be trained in modern appropriate methods of water loss management.

It is important to build capacity in local staff for the water loss management programmes to be successful, by designing appropriate training programmes and conducting field training for leak detection and location techniques. The matter was discussed with Japanese International Cooperation Agency (JICA), under the technical cooperation programme. They offered such training with capacity building with expertise and modern equipments. Under this programme, 2 zones out of 22 zones consists of 5000 connections were selected. They choose to implement part to whole method that is a comprehensive programme, implemented in sets of 500 connections in small areas to cover entire 5000 connections. It is planning to train several teams from NRW section and they will be posted to other zones to implement the same programme in an effective manner.

V) Resources

One of the main constrains for the water loss management is resources. After the exposed high water losses in Colombo City by the Auditor General report (2005) and the COPE report a great deal of attention was paid and several projects are being formulated within short period.

VI) Correctness of the Various Performance Indicators

In the world various kind of performance indicators are used to evaluate performance and make benchmarking to evaluate water utilities. UARL and ILI are such main indicators in the world.
For the Colombo city, such calculation is possible to be made, but for the Area Engineers, OICC and zones it is not possible for the moment due to non availability of inflow meters. But there are more indicators which are easily monitored until such facility to measure inflows are provided. Such indicators are System Pressures, Sold Quantity, Revenue Fluctuations, Consumer Complaints, Collection Efficiency, Ratio of Revenue/Expenditure etc.

4.8. Achievement of the Millennium Development Goals (MDGs)

In Colombo City MDGs were achieved well ahead by providing common facilities to the underserved settlements free of charges, in addition to the individual connections. But further improvements are needed to upgrade the life of these settlements in Colombo City. An interim solution programme has been launched to disconnect common out lets and provide individual connections at a concessionary rate with installments. Long term strategies are being implemented by the government to relocate such population with permanent structures with better facilities.

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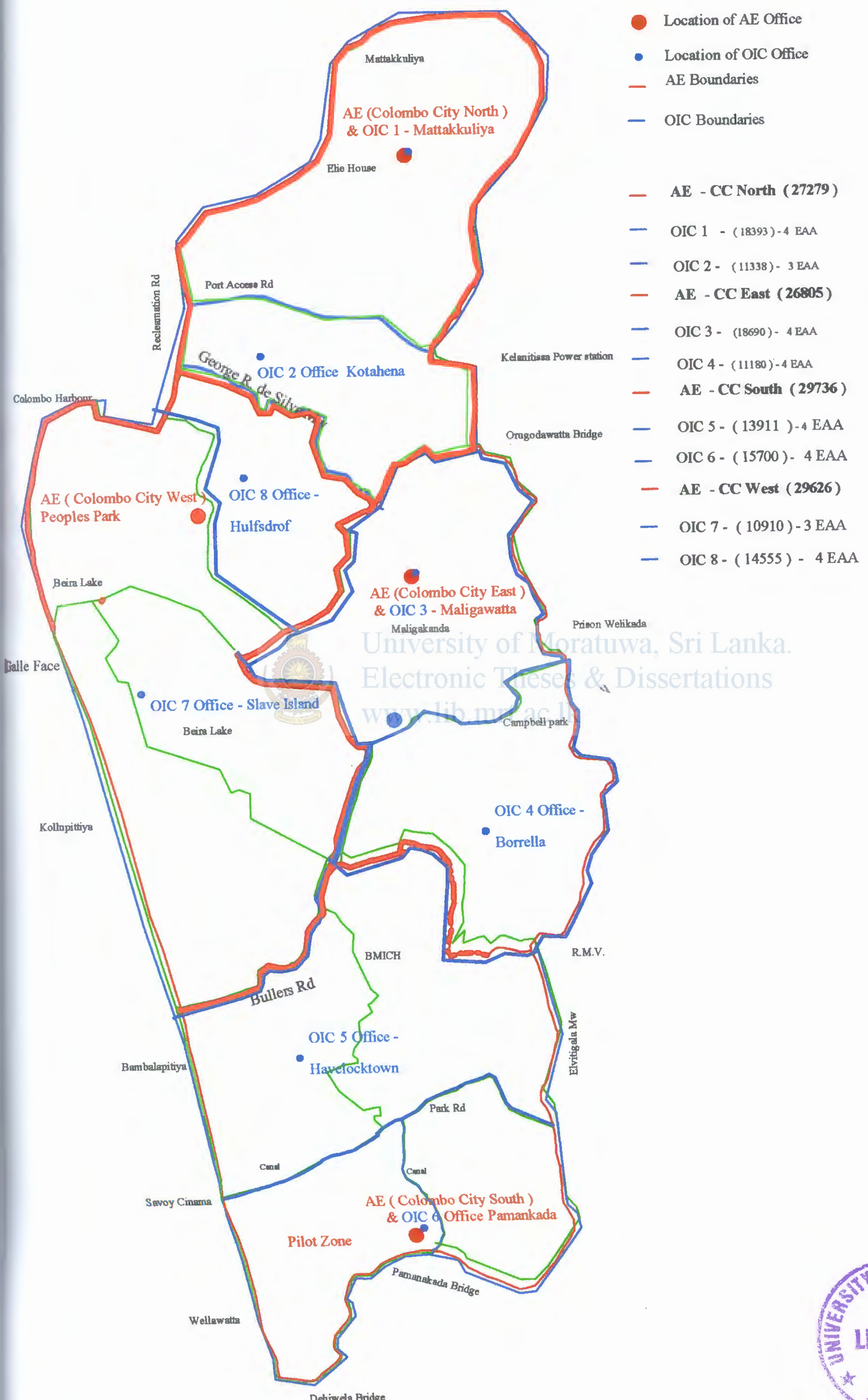
Annex - I

Propose Restructure for Management of Colombo City



Annex II

ජාතික ජලසම්පාදන හා ජලාපවහන මණ්ඩලය
National Water Supply & Drainage Board
தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை

ජල ගාස්තු සංශෝධනය
நீர் சேவைக் கட்டண திருத்தம்
Revision of water tariff

ගරුවත් පාරිභෝගිකය,
ජාතික ජලසම්පාදන හා ජලාපවහන මණ්ඩලය විසින් 2009. 02.15 දින සිට ක්‍රියාත්මක වන පරිදි ජල ගාස්තු සංශෝධනය කර තිබේ. (මෙය අංක 1588/26 දරණ 2009.02.13 දිනැති ගැසට් පත්‍රය මගින් ප්‍රකාශයට පත්කර ඇත). සංශෝධිත ගාස්තු පහත සදහන් කර ඇත.

அன்பான பாவனையாளர்களுக்கு,
தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபையினால் 2009. 02.15 திகதி முதல் அமுலாகும் வகையில் நீர் கட்டண திருத்தம் செய்யப்பட்டுள்ளது. (இது இல1588/26 கொண்ட 2009.02.13 ம் திகதி வர்த்தமான பத்திரிகை மூலம் அறிவிக்கப்பட்டுள்ளது.) திருத்தம் செய்யப்பட்ட கட்டண விபரம் பின்வருமாறு.

Dear Consumer,
The National Water Supply and Drainage Board has revised the water tariff with effect from 2009. 02.15 (this revision was gazetted in Gazette Notification no 1588/26 dated 2009.02.13). Revised charges are given below.

ගෘහස්ථ සමෘද්ධිලාභී ජල පාරිභෝගිකයන් සඳහා ගාස්තු
சமுர்த்தி பெறும் வீட்டு நீர்ப் பாவனையாளர்களுக்கான கட்டணம்
Charges for Domestic Samurdhi Consumers

ඔබගේ සමෘද්ධිලාභී කාඩ්පත සහ අදාල ප්‍රාදේශිය ලේකම් විසින් සහතික කරන ලද එහි පිටපතක් අදාල කළමණාකරු/ දිස්ත්‍රික් ඉංජිනේරු / ප්‍රාදේශිය ඉංජිනේරු / වාණිජ නිලධාරි වෙත ඉදිරිපත් කර සහනදායි ජල සැපයුම් ගාස්තු ලබා ගන්න. ඔබගේ සමෘද්ධිලාභී අනන්‍යතාවය සෑම වසරක් ආරම්භයේදීම එසේ තහවුරු කරගත යුතුය.

உமது சமுர்த்தி அட்டையை குறித்த பிரதேச செயலாளரினால் உறுதிப்படுத்தி பிரதியொன்று முகாமையாளர் / மாவட்ட பொறியியலாளர் / பிரதேச பொறியியலாளர் / வணிக அதிகாரியிடம் சமர்ப்பித்து சலுகை அடிப்படையிலான நீர் வழங்கல் கட்டணத்தைப் பெற்றுக் கொள்ளவும். நீர் சமுர்த்தி பெறுபவர் என்பதை ஒவ்வொரு வருட ஆரம்பத்திலும் உறுதிப்படுத்திக் கொள்ளப்படல் வேண்டும்.

Your Samurdhi Card along with a copy certified by the relevant Divisional Secretary may be presented to the relevant Manager / District Manager / Area Engineer / Commercial Officer to get concessionary water tariff. Please verify your status as a Samurdhi Recipient at the beginning of every year.

ප්‍රභේදය வர்க்கம் Category		බිල්පතෙහි ප්‍රභේද අංකය நீர் சிட்டையின் வர்க்க இலக்கம் Category Number in the Bill
ගෘහ வீட்டுப் பாவனை Domestic		20 24

මාසික පරිභෝජන ඒකක සංඛ්‍යාව மாதாந்த பாவனை அலகுகளின் எண்ணிக்கை Consumption units per month	ඒකකයක් සඳහා පරිභරණ ගාස්තුව රු. அலகொன்றிற்கான பாவனைக் கட்டணம் Usage Charge Rs./unit	සේවා ගාස්තුව රු. சேவைக் கட்டணம் ரூபா Service Charge Rs.
00 - 05	1.25	50.00
06 - 10	1.50	50.00
11 - 15	3.00	50.00
16 - 20	30.00	80.00
21- 25	50.00	100.00
26 - 30	75.00	200.00
31 - 40	90.00	400.00
41 - 50	105.00	650.00
51 - 75	110.00	1000.00
>75	120.00	1600.00

මාසිකව ඒකක 15 ක් හෝ ඊට අඩුවෙන් පරිභෝජනය කරන පාරිභෝගිකයින්ට මාසික මුළු පරිභරණ ගාස්තුව හෝ රුපියල් 20.00 ක් යන දෙකින් අඩුමුදල වට්ටමක් ලෙස දෙනු ලැබේ.

மாதாந்தம் அலகு 15 அல்லது அதற்கு குறைவாக பாவனை செய்கின்ற பாவனையாளர்களுக்கு மாதாந்த முழுமையான நீர் பாவனைக் கட்டணம் அல்லது ரூபா.20.00 என்ற இரண்டிலும் குறைந்த தொகை கழிவாக வழங்கப்படும்.

A discount of Rs.20.00 or the total monthly usage charge, whichever is lower will be granted for consumers whose monthly consumption is 15 units or less.

ගෘහස්ථ සමෘද්ධිලාභී නොවන ජල පාරිභෝගිකයන් සඳහා ගාස්තු
சமுர்த்தி பெறுபவரல்லாத வீட்டு நீர்ப் பாவனையாளர்களுக்கான கட்டணம்
Charges for Domestic non – Samurdhi Consumers

ප්‍රභේදය வர்க்கம் Category	බිල්පතෙහි ප්‍රභේද අංකය நீர்ச் சிட்டையின் வர்க்க இலக்கம் Category Number in the Bill
ගෘහ வீட்டுப் பாவனை Domestic	10,13
රජයේ නිවාස அரச வாசஸ்தலம் Government Quarters	11,14
සහාධිපත්‍ය නිවාස ඒකක தன்னாதிக்க வீட்டு அலகு Condominium Housing Units	18

මාසික පරිභෝජන ඒකක සංඛ්‍යාව மாதாந்த பாவனை அலகுகளின் எண்ணிக்கை Consumption Units Per Month	ඒකකයක් සඳහා පරිභරණ ගාස්තුව රු. அலகொன்றிற்கான பாவனைக் கட்டணம் ரூபா Usage Charge Rs./Unit	සේවා ගාස්තුව රු. சேவைக் கட்டணம் ரூபா Service Charge Rs.
00 - 05	3.00	50.00
06 - 10	7.00	65.00
11 - 15	15.00	70.00
16 - 20	30.00	80.00
21- 25	50.00	100.00
26 - 30	75.00	200.00
31 - 40	90.00	400.00
41 - 50	105.00	650.00
51 - 75	110.00	1000.00
>75	120.00	1600.00

මාසිකව ඒකක 15 ක් හෝ ඊට අඩුවෙන් පරිභෝජනය කරන පාරිභෝගිකයින්ට මාසික මුළු පරිභරණ ගාස්තුව හෝ රුපියල් 20.00 ක් යන දෙකින් අඩුමුදල වට්ටමක් ලෙස දෙනු ලැබේ.

மாதாந்தம் அலகு 15 அல்லது அதற்கு குறைவாக பாவனை செய்கின்ற பாவனையாளர்களுக்கு மாதாந்த முழுமையான நீர் பாவனைக் கட்டணம் அல்லது ரூபா.20.00 என்ற இரண்டிலும் குறைந்த தொகை கழிவாக வழங்கப்படும்.

A discount of Rs.20.00 or the total monthly usage charge, whichever is lower will be granted for consumers whose monthly consumption is 15 units or less.

බවුසර් මගින් සැපයෙන ජලය / பவுசர் மூலம் நீர் வழங்கல் / Bowser Supply:

බවුසර් මගින් සැපයෙන ජලය සඳහා ඒකකයට ගාස්තුව රු. 65.00 බැගිනි.
ප්‍රවාහන සහ පරිපාලනය ඇතුළුව සිදු වන අනෙකුත් පොදු කාර්ය වියදම් පිරිවැය මෙයට අයත් නොවන අතර ඒවා නියම මිල ප්‍රමාණයන් අනුව වෙනම අයකරනු ලැබේ.

பவுசர் மூலம் விநியோகிக்கப்படும் நீருக்கு ஓர் அலகுக்கான கட்டணம் ரூபா.65.00 ஆகும்.
இக் கட்டணத்தில் போக்குவரத்து செலவினம் மற்றும் சமைக்கு செலவாகும் ஏனைய செலவினங்கள் உள்ளடக்கப்படவில்லை. இவை காரணமாக ஏற்படும் மேலதிக செலவினங்கள் பாவனையாளர்களிடமிருந்து கோரப்படும்.

Tariff for supply of water through Bowsers shall be at the rate of Rs.65.00 per unit. This charge excludes costs incurred for transport and other overheads, which would be recovered on the basis of actuals.

ජාතික ජලසම්පාදන හා ජලාපවහන මණ්ඩලය
National Water Supply & Drainage Board
தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை

ජල ගාස්තු සංශෝධනය
நீர் சேவைக் கட்டண திருத்தம்
Revision of water tariff

රිභෝගිකය,
සම්පාදන හා ජලාපවහන මණ්ඩලය විසින් 2009. 02.15 දින සිට ක්‍රියාත්මක වන පරිදි ජල ගාස්තු සංශෝධනය කර තිබේ. (මෙය අංක 1588/26 දරණ
දිනැති ගැසට් පත්‍රය මගින් ප්‍රකාශයට පත්කර ඇත). සංශෝධිත ගාස්තු පහත සදහන් කර ඇත.

பாவனையாளர்களுக்கு,
வழங்கல் வடிகாலமைப்புச் சபையினால் 2009. 02.15 திகதி முதல் அமுலாகும் வகையில் நீர் கட்டண
செய்யப்பட்டுள்ளது. (இது இல1588/26 கொண்ட 2009.02.13 ம் திகதி வர்த்தமான பத்திரிகை மூலம்
ட்டுள்ளது.) திருத்தம் செய்யப்பட்ட கட்டண விபரம் பின்வருமாறு.

sumer,
onal Water Supply and Drainage Board has revised the water tariff with effect from 2009. 02.15 (this revision was gazetted in
Notification no 1588/26 dated 2009.02.13). Revised charges are given below.

ry	බිල්පතෙහි ප්‍රභේද අංකය நீர் சிட்டையின் வர்க்க இலக்கம் Category Number in the Bill
කණු සහ උද්‍යාන කරාම க்கம்பம் மற்றும் பூந்தோட்ட நீர் osts and Garden Taps	51, 52, 53

මාසික පරිභෝජන ඒකක සංඛ්‍යාව மாதாந்த பாவனை அலகுகளின் எண்ணிக்கை Consumption units per month	ඒකකයක් සඳහා පරිහරණ ගාස්තුව රු. அலகொன்றிற்கான பாவனைக் கட்டணம் ரூபா Usage Charge Rs./unit	සේවා ගාස්තුව රු. சேவைக் கட்டணம் ரூபா Service Charge Rs.
00 - 25	10.00	250.00
26 50	10.00	500.00
51 100	10.00	1000.00
101 200	10.00	1600.00
>200	10.00	2500.00

්දය க்கம் tegory	බිල්පතෙහි ප්‍රභේද අංකය நீர் சிட்டையின் வர்க்க இலக்கம் Category Number in the Bill
යේ පාසැල් සහ රජයේ අනුග්‍රාහක පාසැල් பாடசாலைகள், அரச அனுசரனை பாடசாலைகள் vt. Schools and Govt. Assisted Schools	12,15
යේ අනුමත පුණ්‍යායතන සහ ආගමික ස්ථාන அனுசரனை பெற்ற சமய தரும நிறுவனங்கள் ligious and govt. approved charitable stitutions	81

මාසික පරිභෝජන ඒකක සංඛ්‍යාව மாதாந்த பாவனை அலகுகளின் எண்ணிக்கை Consumption units per month	ඒකකයක් සඳහා පරිහරණ ගාස්තුව රු. அலகொன்றிற்கான பாவனைக் கட்டணம் ரூபா Usage Charge Rs./unit	සේවා ගාස්තුව රු. சேவைக் கட்டணம் ரூபா Service Charge Rs.
00 - 05	6.00	50.00
06 - 10	6.00	65.00
11 - 15	6.00	70.00
16 - 20	6.00	80.00
21- 25	6.00	100.00
26 - 30	6.00	200.00
31 - 40	6.00	400.00
41 - 50	16.00	650.00
51 - 75	16.00	1000.00
>75	16.00	1600.00

ජාතික ජලසම්පාදන හා ජලාපවහන මණ්ඩලය
National Water Supply & Drainage Board
தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை

ජල ගාස්තු සංශෝධනය
நீர் சேவைக் கட்டண திருத்தம்
Revision of water tariff

හිතවත් පාරිභෝගිකය,
ජාතික ජලසම්පාදන හා ජලාපවහන මණ්ඩලය විසින් 2009. 02.15 දින සිට ක්‍රියාත්මක වන පරිදි ජල ගාස්තු සංශෝධනය කර තිබේ. (මෙය අංක 1588/26 දරණ 2009.02.13 දිනැති ගැසට් පත්‍රය මගින් ප්‍රකාශයට පත්කර ඇත). සංශෝධිත ගාස්තු පහත සඳහන් කර ඇත.

அன்பான பாவனையாளர்களுக்கு,
தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபையினால் 2009. 02.15 திகதி முதல் அமுலாகும் வகையில் நீர் கட்டண திருத்தம் செய்யப்பட்டுள்ளது. (இது இல1588/26 கொண்ட 2009.02.13 ம் திகதி வர்த்தமான பத்திரிகை மூலம் அறிவிக்கப்பட்டுள்ளது.) திருத்தம் செய்யப்பட்ட கட்டண விபரம் பின்வருமாறு.

Dear Consumer,
The National Water Supply and Drainage Board has revised the water tariff with effect from 2009. 02.15 (this revision was gazetted in Gazette Notification no 1588/26 dated 2009.02.13). Revised charges are given below.

ප්‍රභේදය வர்க்கம் Category	බිල්පතෙහි ප්‍රභේද අංකය நீர் சிட்டையின் வர்க்க இலக்கம் Category Number in the Bill
පොදු ජල කණු සහ උද්‍යාන. කරාම பொது நீர்க்கம்பம் மற்றும் பூந்தோட்ட நீர் குழாய் Stand Posts and Garden Taps	51, 52, 53

මාසික පරිභෝජන ඒකක සංඛ්‍යාව மாதாந்த பாவனை அலகுகளின் எண்ணிக்கை Consumption units per month	ඒකකයක් සඳහා පරිහරණ ගාස්තුව රු. அலகொன்றிற்கான பாவனைக் கட்டணம் ரூபா Usage Charge Rs./unit	සේවා ගාස්තුව රු. சேவைக் கட்டணம் ரூபா Service Charge Rs.
00 - 25	10.00	250.00
26 50	10.00	500.00
51 100	10.00	1000.00
101 200	10.00	1600.00
>200	10.00	2500.00

ප්‍රභේදය வர்க்கம் Category	බිල්පතෙහි ප්‍රභේද අංකය நீர் சிட்டையின் வர்க்க இலக்கம் Category Number in the Bill
රජයේ පාසැල් සහ රජයේ අනුග්‍රාහක පාසැල් அரச பாடசாலைகள், அரச அனுசரனை பாடசாலைகள் Govt. Schools and Govt. Assisted Schools	12,15
රජයේ අනුමත පුණ්‍යායතන සහ ආගමික ස්ථාන அரச அனுசரனை பெற்ற சமய தரும நிறுவனங்கள் Religious and govt. approved charitable institutions	81

මාසික පරිභෝජන ඒකක සංඛ්‍යාව மாதாந்த பாவனை அலகுகளின் எண்ணிக்கை Consumption units per month	ඒකකයක් සඳහා පරිහරණ ගාස්තුව රු. அலகொன்றிற்கான பாவனைக் கட்டணம் ரூபா Usage Charge Rs./unit	සේවා ගාස්තුව රු. சேவைக் கட்டணம் ரூபா Service Charge Rs.
00 - 05	6.00	50.00
06 - 10	6.00	65.00
11 - 15	6.00	70.00
16 - 20	6.00	80.00
21- 25	6.00	100.00
26 - 30	6.00	200.00
31 - 40	6.00	400.00
41 - 50	16.00	650.00
51 - 75	16.00	1000.00
>75	16.00	1600.00

Annex - III

HOUSE TO HOUSE SURVEY - NRW PILOT STUDY

General Details

Tick here if completely illegal connection	
Tick here if legal but un-billed connection	

Name			
Address			
Account No		No of Users	

Service Details

Service Status	Disconnected		If Disconnected	Illegal Usage	
	Normal			Do not use	
Conn. Status	No Leak		Dripping		Leaking	

Meter Details

Meter Size			Reading				
Working		Defective		Burried		Un-metered	

Billing Details

Normal bill		Last reading		Is Category Correct	Yes / No
Estimated bill		Date		If Not Correct Category	

Remarks:

Officer's Name : Signature: Date of inspection

HOUSE TO HOUSE SURVEY - NRW PILOT STUDY

General Details

Tick here if completely illegal connection	
Tick here if legal but un-billed connection	

Name			
Address			
Account No		No of Users	

Service Details

Service Status	Disconnected		If Disconnected	Illegal Usage	
	Normal			Do not use	
Conn. Status	No Leak		Dripping		Leaking	

Meter Details

Meter Size			Reading				
Working		Defective		Burried		Un-metered	

Billing Details

Normal bill		Last reading		Is Category Correct	Yes / No
Estimated bill		Date		If Not Correct Category	

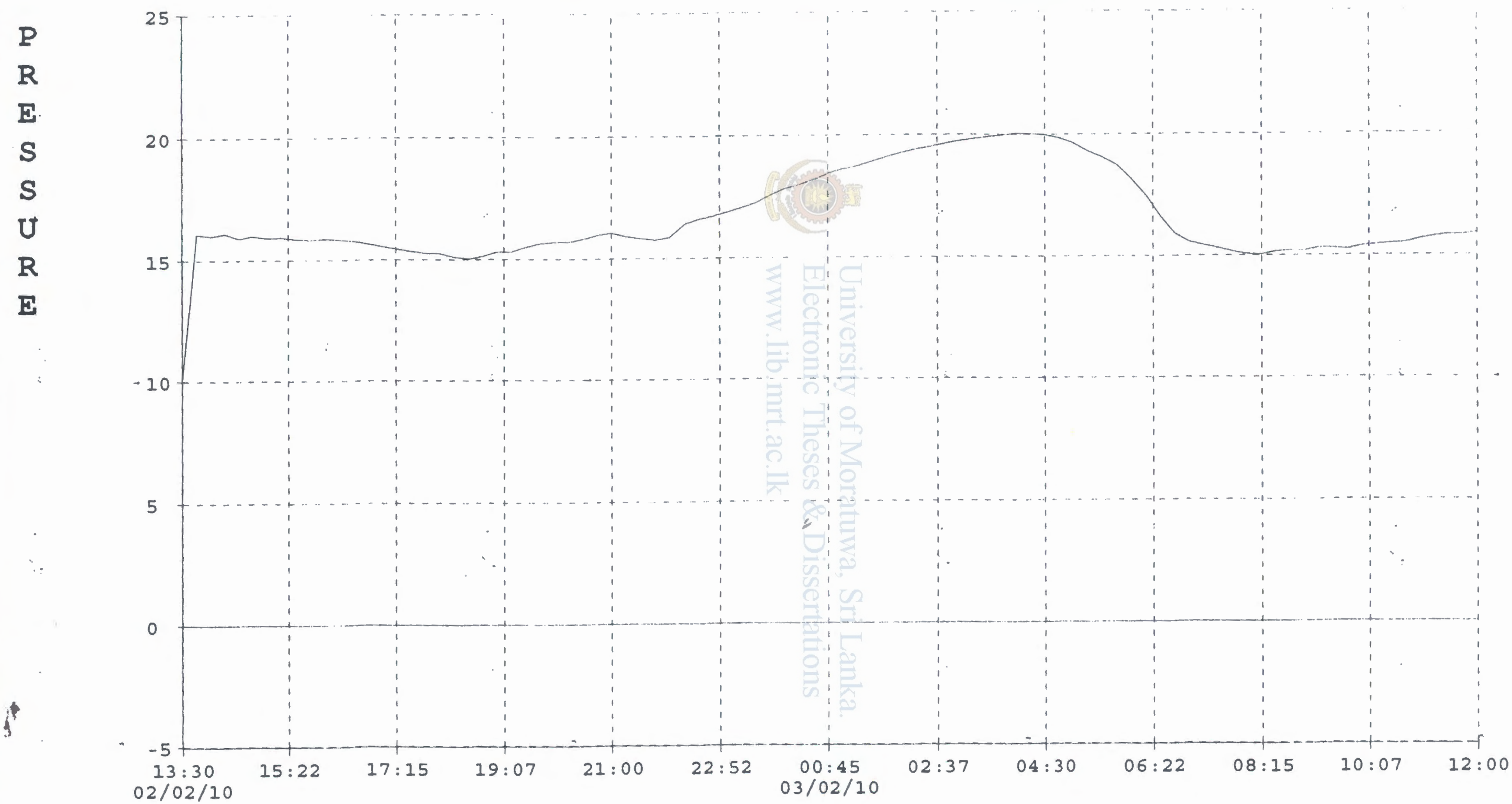
Remarks:

Officer's Name : Signature: Date of inspection

Annex - IV

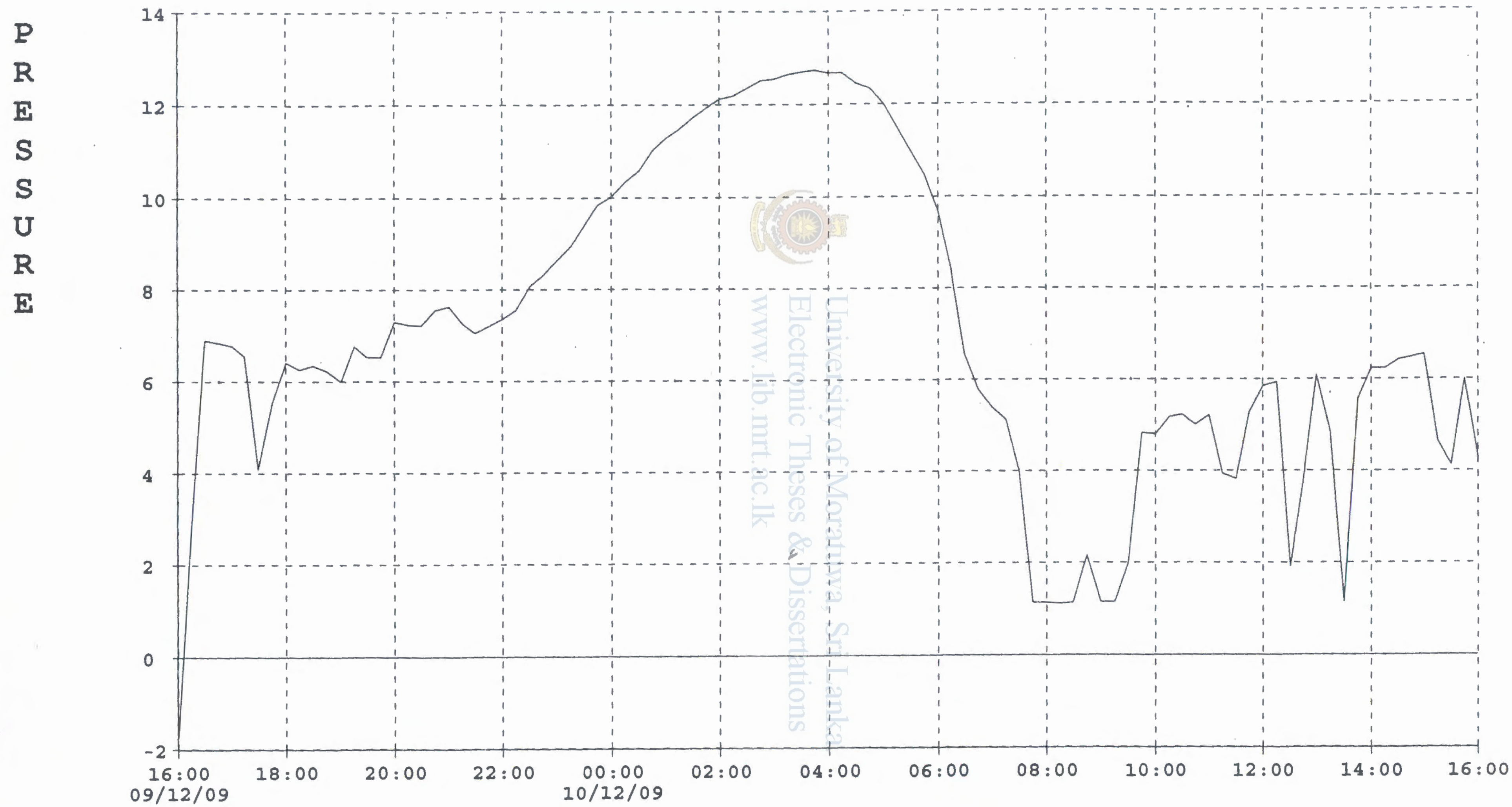
Key Map of Pilot Study Area

KIRULAPANA BRIDGE 500DIA,



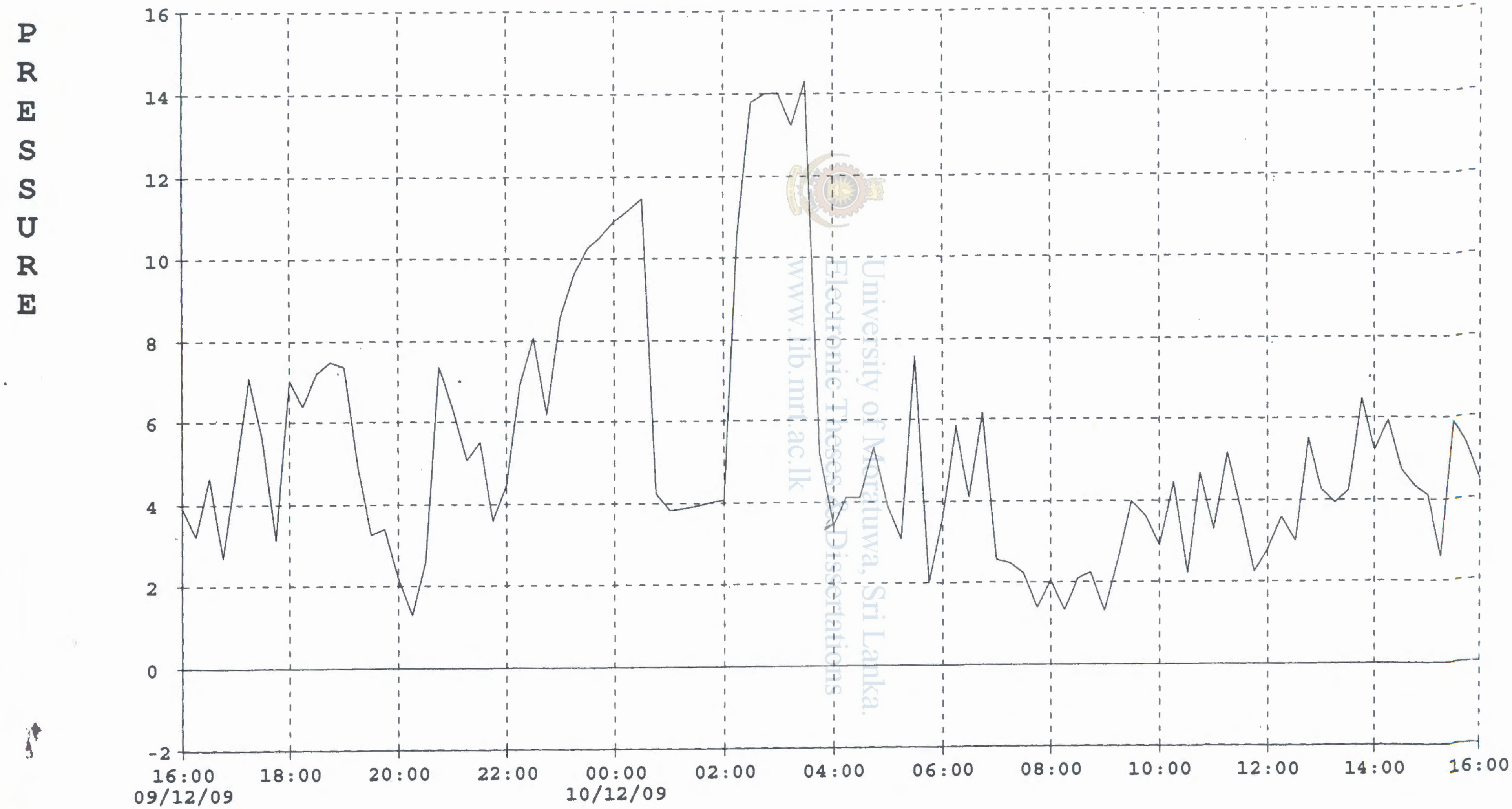
Site	Channel	Units	Min	Max	Vol
RULAPANA BRIDGE	15.0 minute pressure		10.16	20.03	n/a

PRESSURE MEASUREMENTS



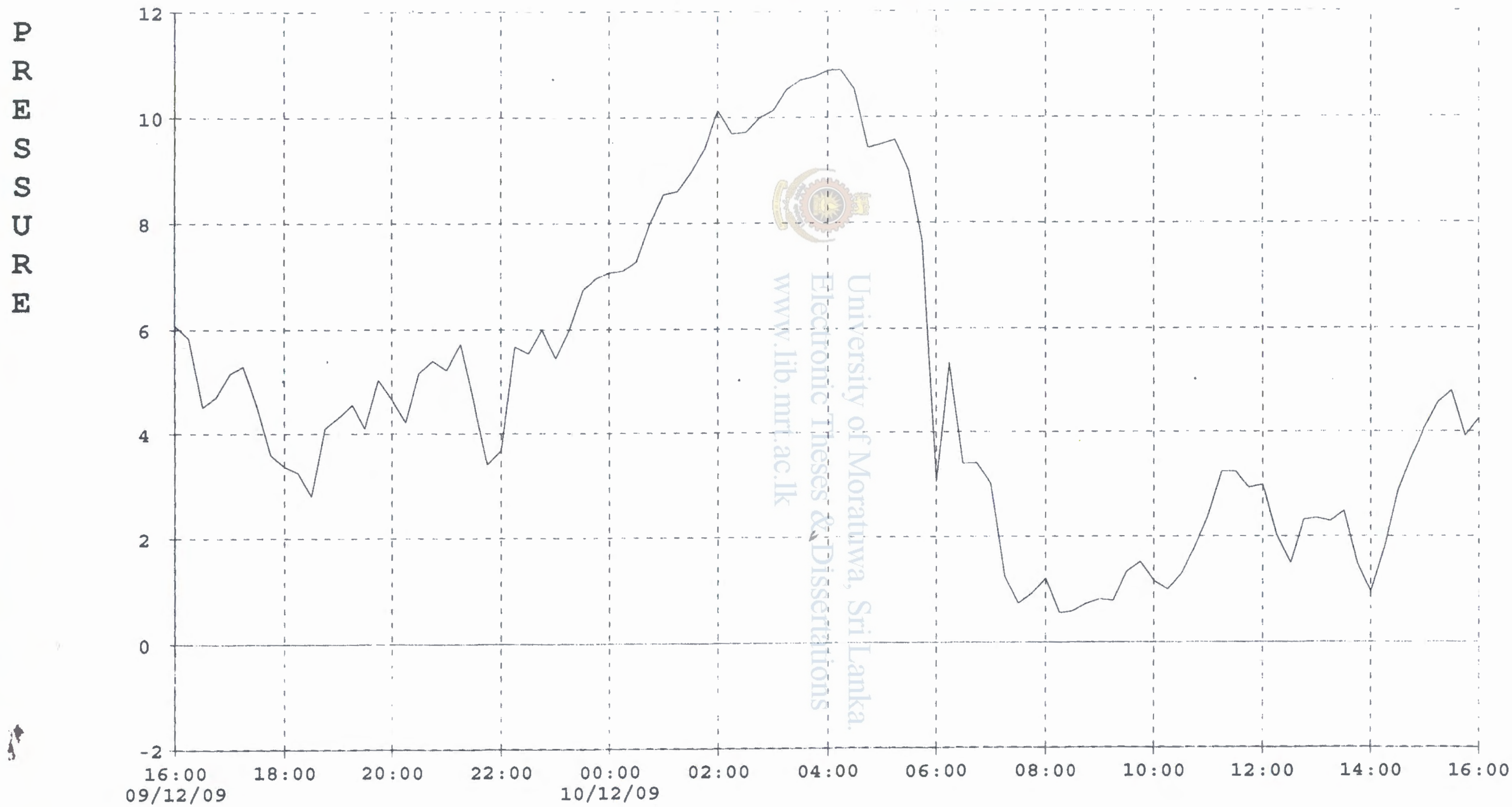
Site	Channel	Units	Min	Max	Vol
CC CB3	15.0 minute pressure		-1.73	12.74	n/a

PRESSURE MEASUREMENTS



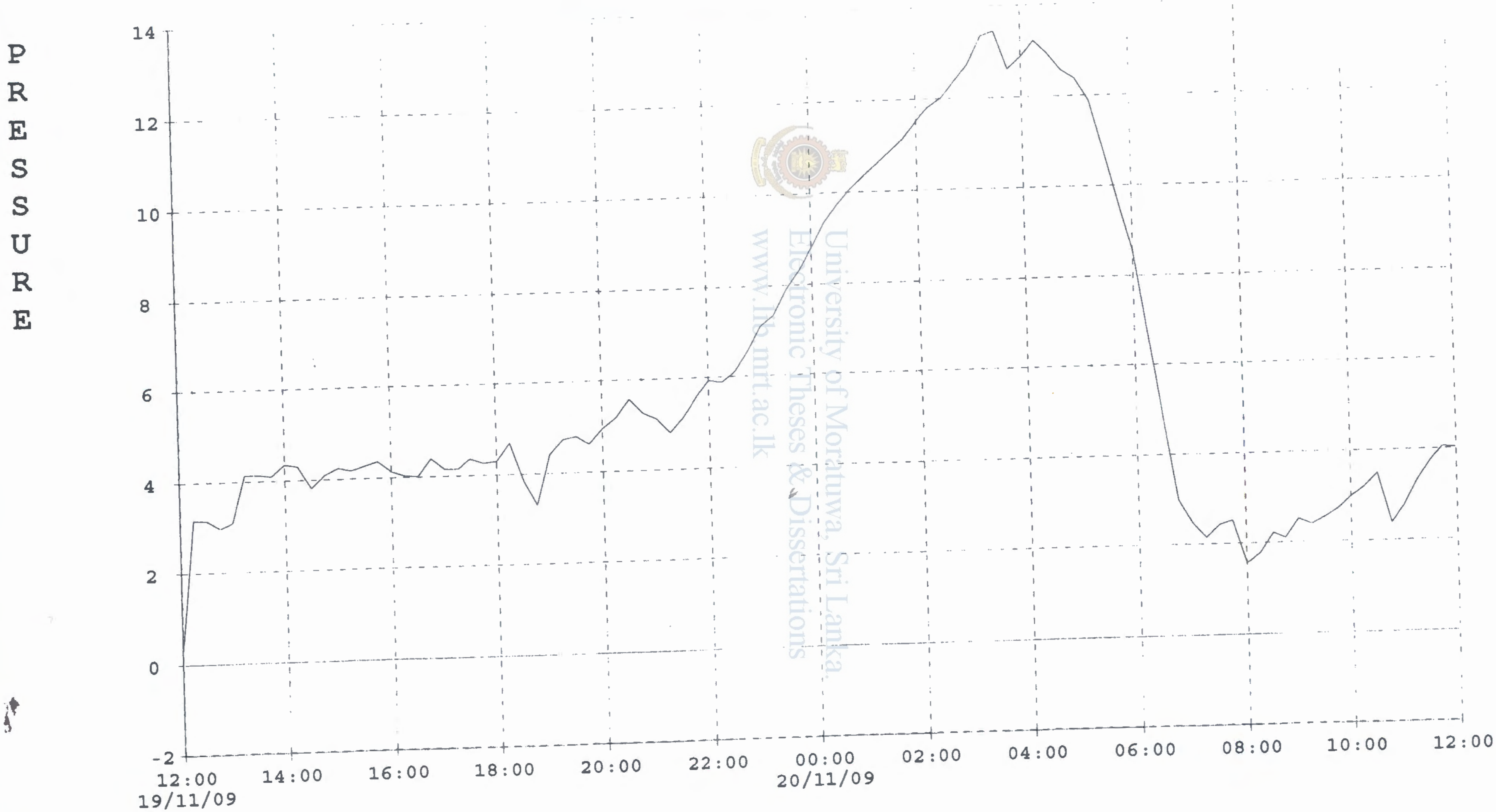
Site	Channel	Units	Min	Max	Vol
CC CB3	15.0 minute pressure		1.29	14.31	n/a

PRESSURE MEASUREMENTS



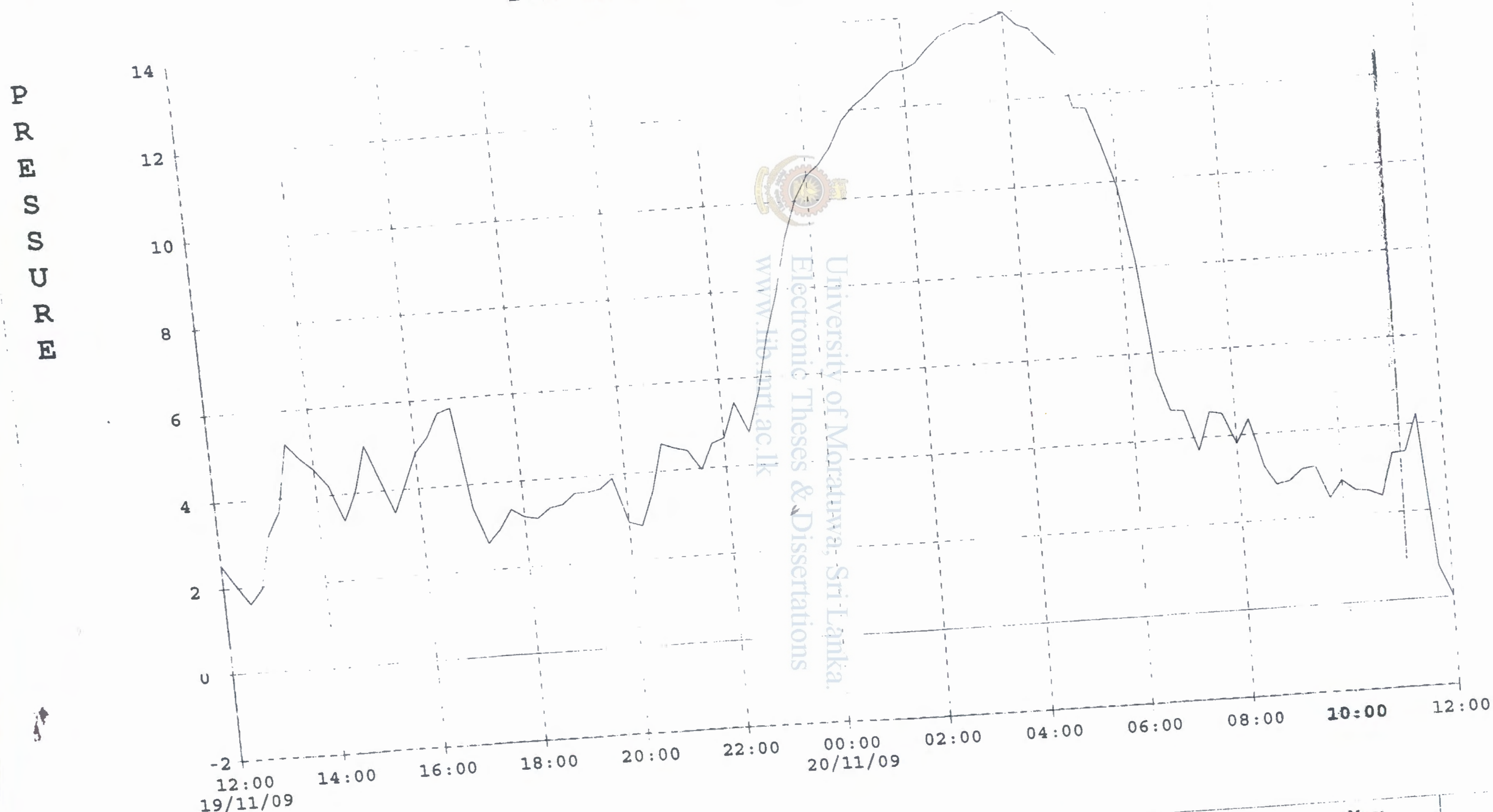
Site	Channel	Units	Min	Max	Vol
?B3	15.0 minute pressure		0.55	10.90	n/a

PRESSURE MEASUREMENTS



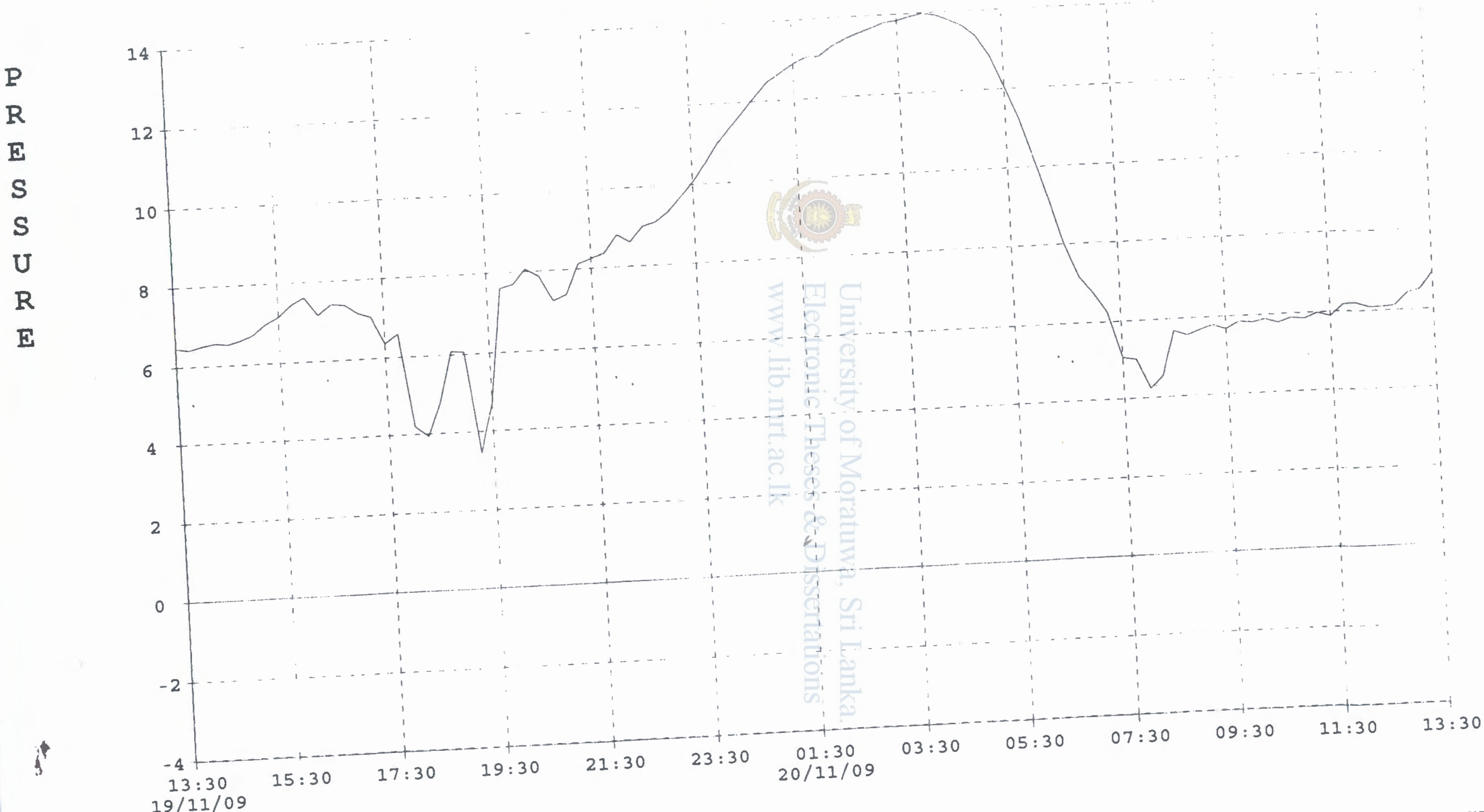
Site	Channel	Units	Min	Max	Vol
CCB3 P2	15.0 minute pressure		0.32	13.45	n/a

PRESSURE MEASUREMENTS



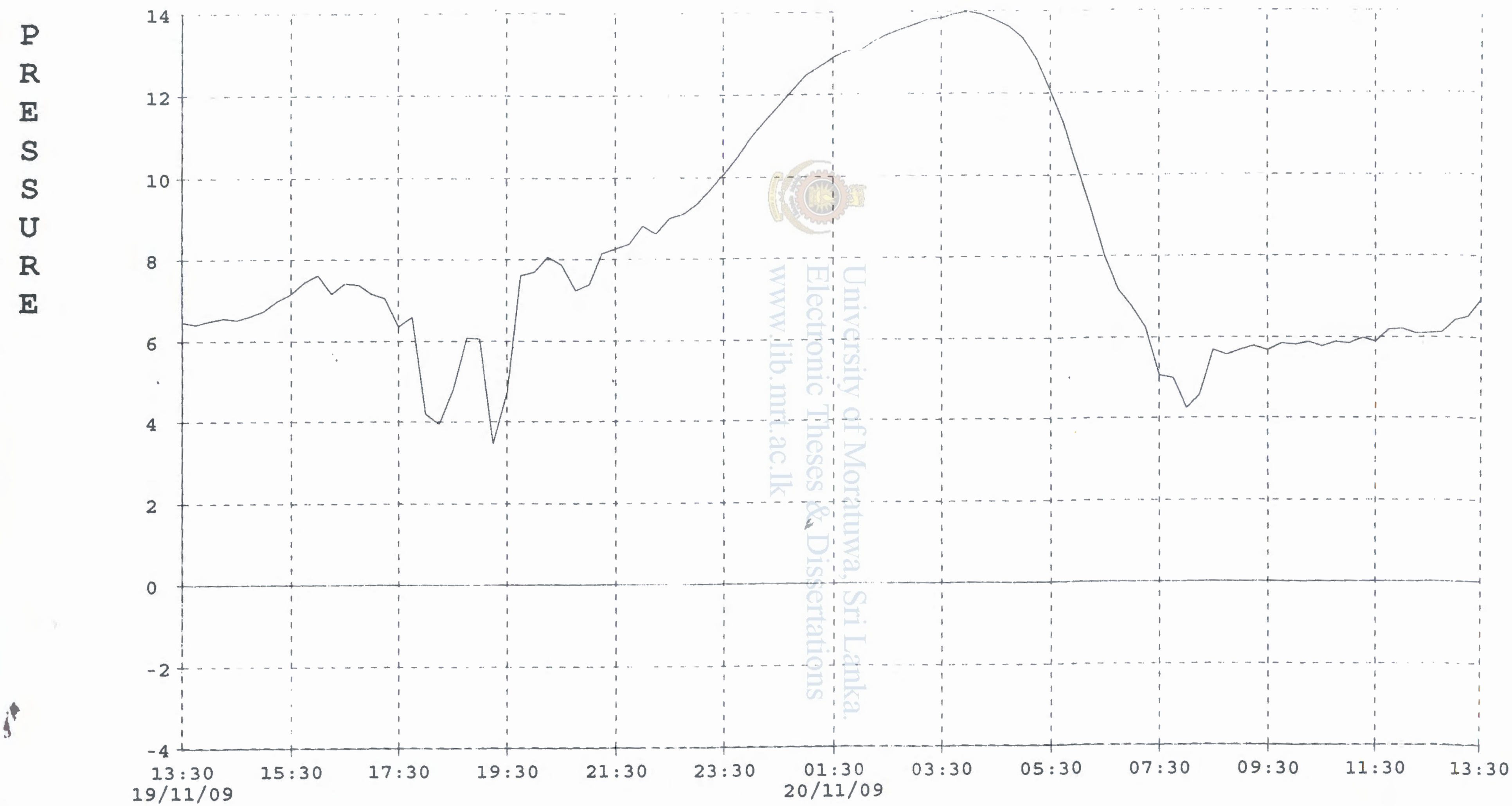
Site	Channel	Units	Min	Max	Vol
CCCB3 P1	15.0 minute pressure		0.01	13.99	n/a

PRESSURE MEASUREMENTS



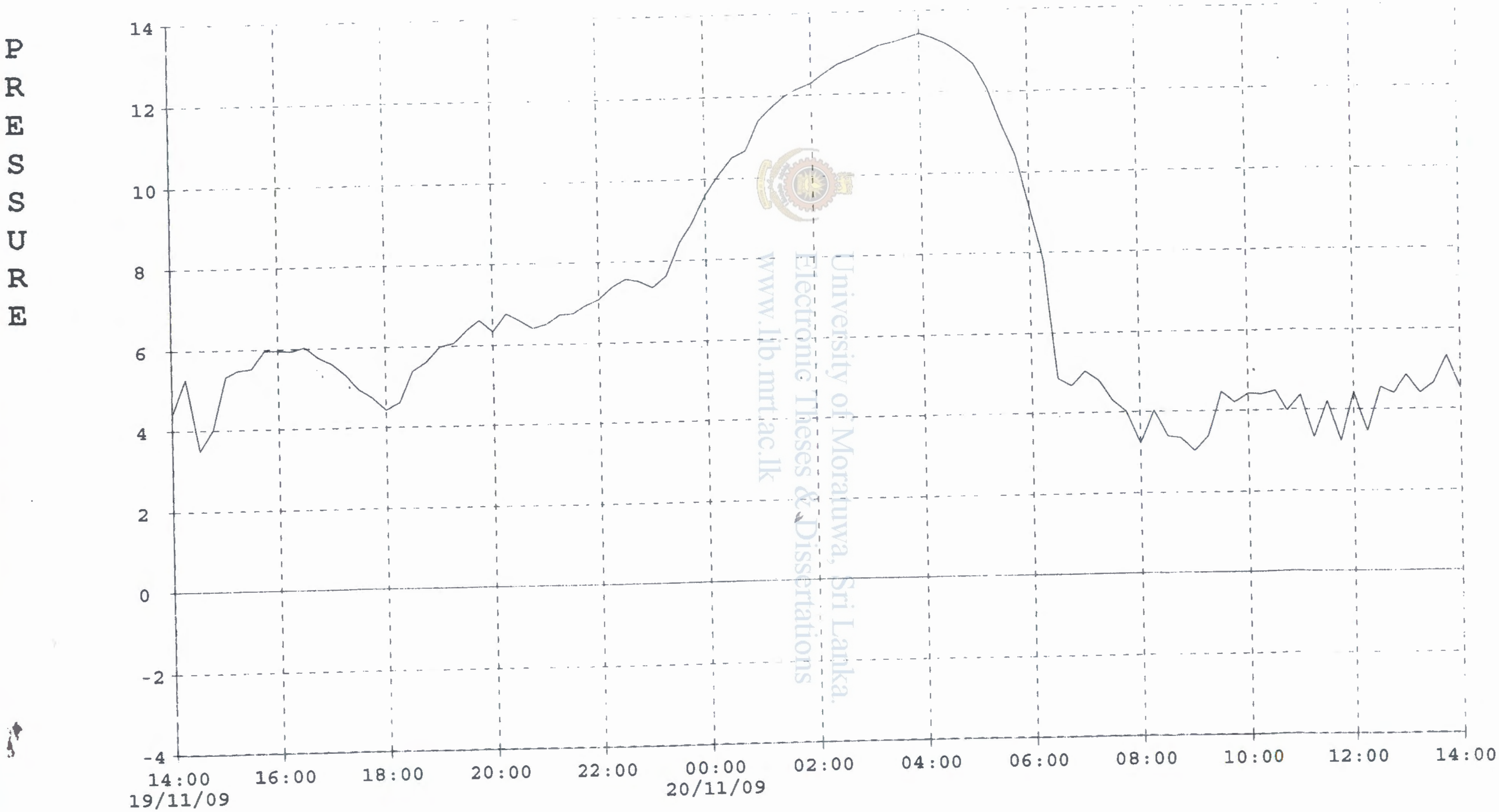
Site	Channel	Units	Min	Max	Vol
...3 P4	15.0 mi⋯te pressure		3.46	13.99	n/a

PRESSURE MEASUREMENTS



Site	Channel	Units	Min	Max	Vol
?CB3 P3	15.0 minute pressure		3.46	13.99	n/a

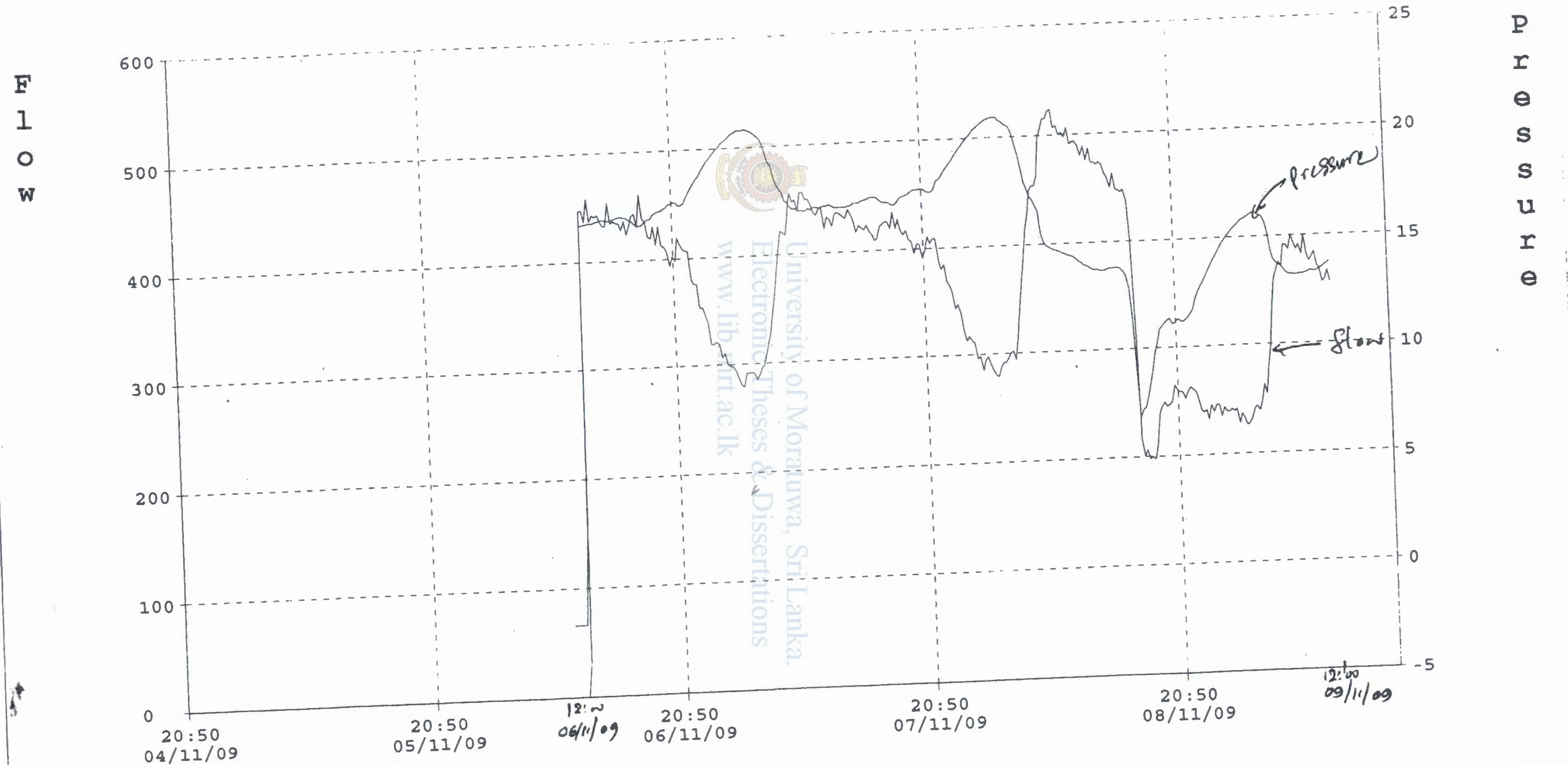
PRESSURE MEASUREMENTS



Site	Channel	Units	Min	Max	Vol
CCB3 P5	15.0 minute pressure		3.02	13.45	n/a

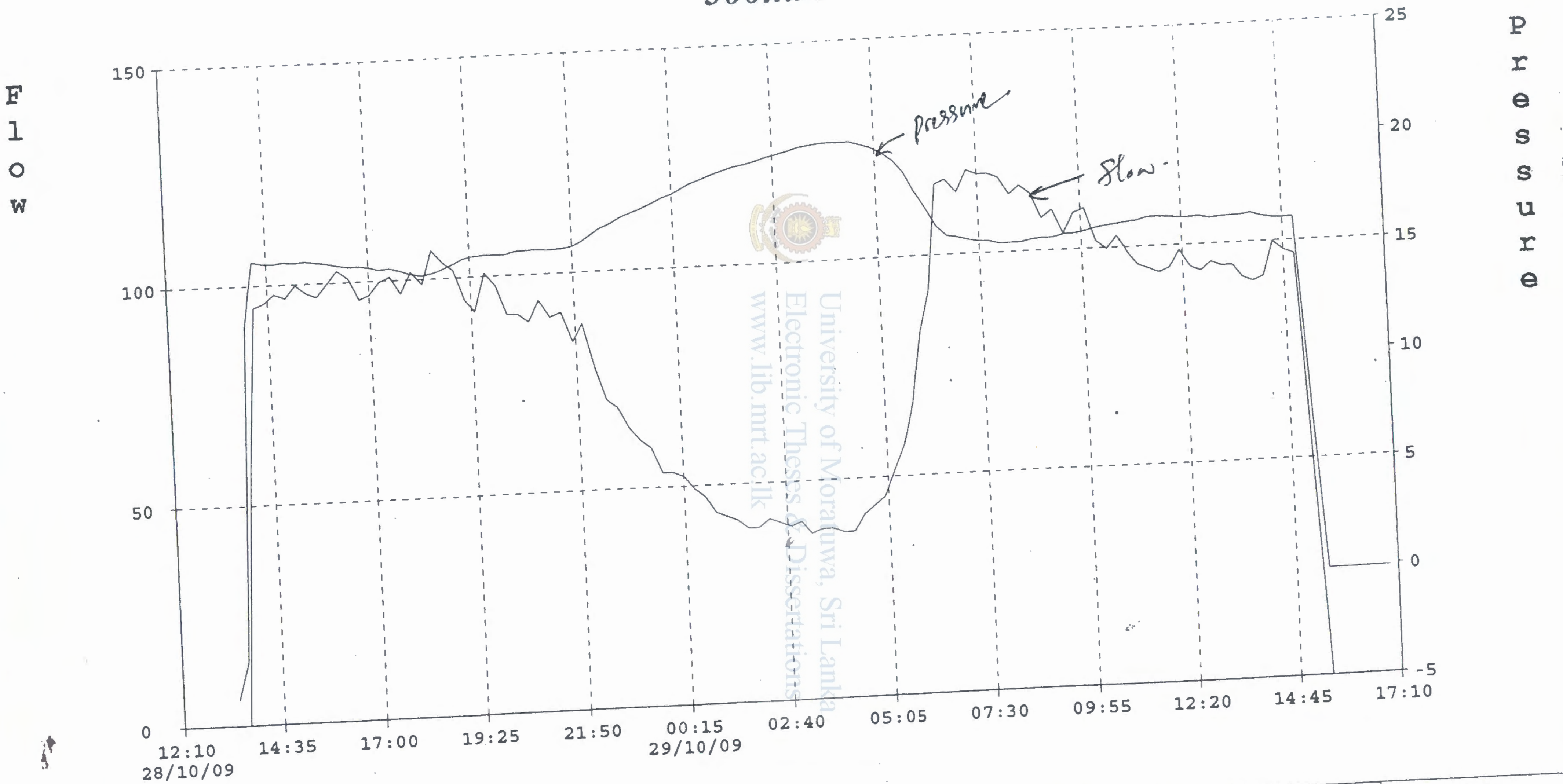
Pamankada Bridge

760mm



Site	Channel	Units	Min	Max	Vol
COLNRW PAMANKADA BRIDGE	15.0 minute flow		0.00	524.09	96495
COLNRW PAMANKADA BRIDGE	15.0 minute pressure	Metres	-1.70	20.92	n/a

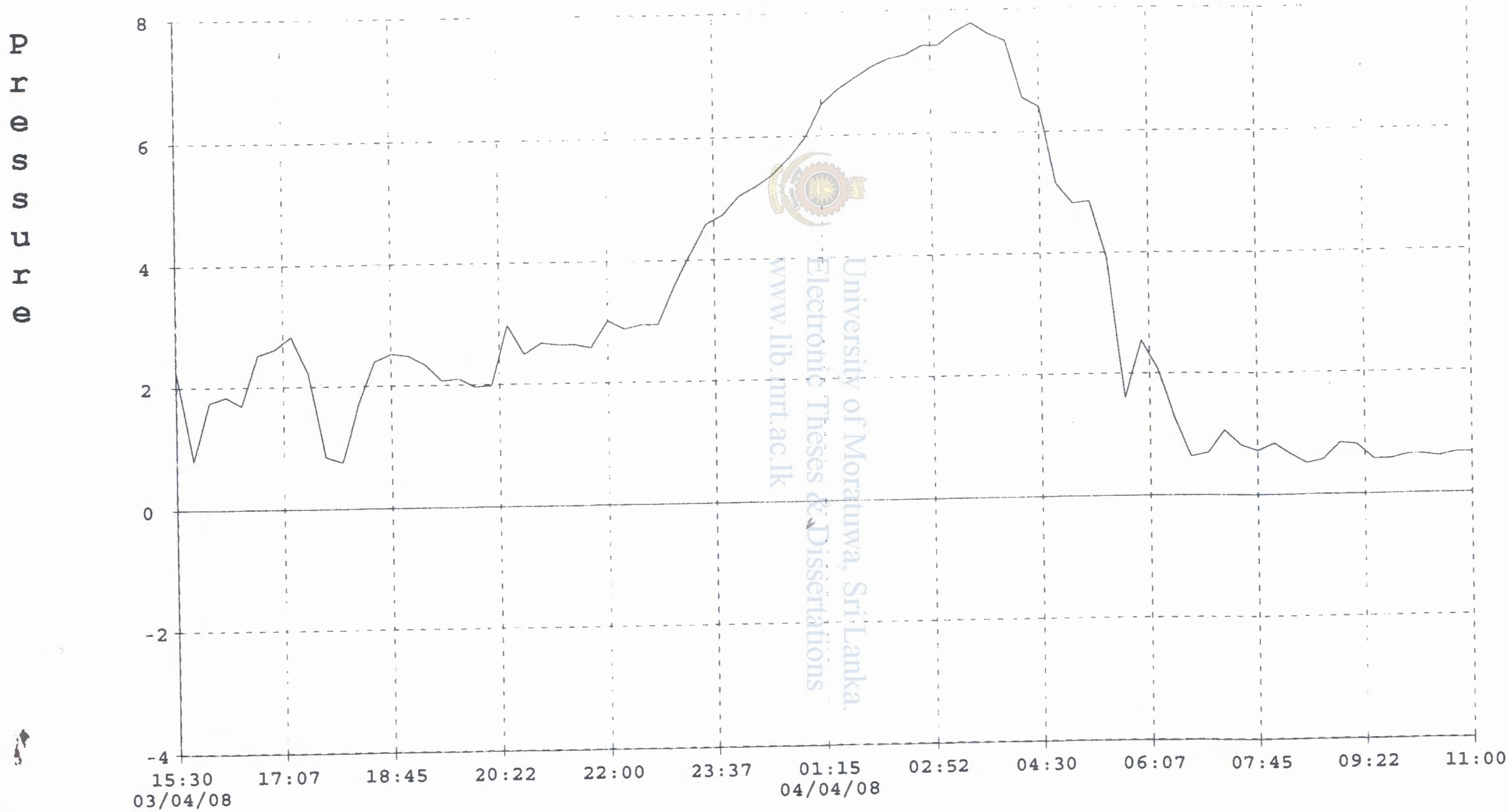
500mm



Site	Channel	Units	Min	Max	Vol
COLNRW KIRALOPANA BRIDGE	15.0 minute flow		0.00	119.12	7664
COLNRW KIRALOPANA BRIDGE	15.0 minute pressure	Metres	-3.79	20.37	n/a

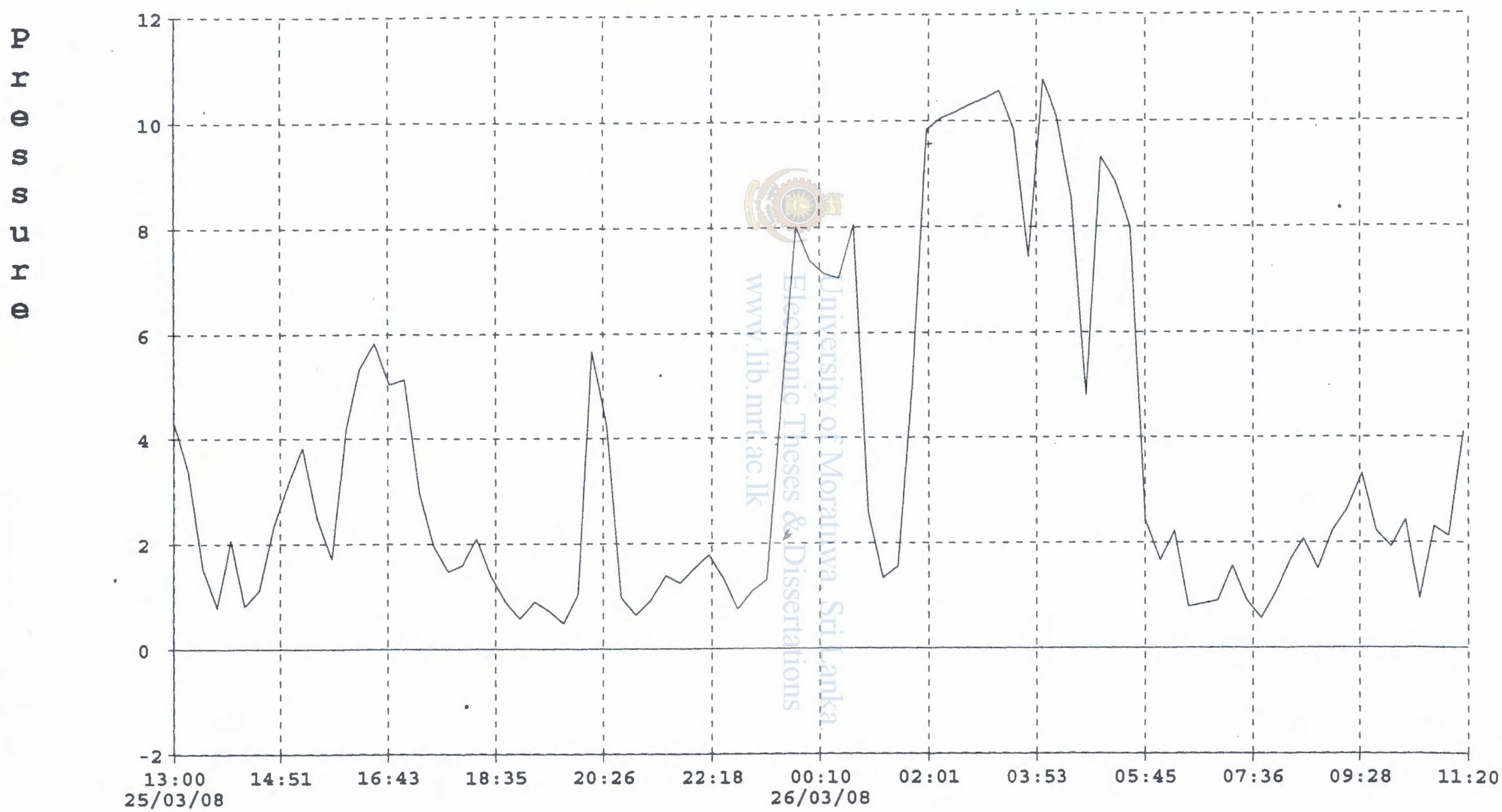
7285 m³/d

At No.52, Mayura Place Col-06.



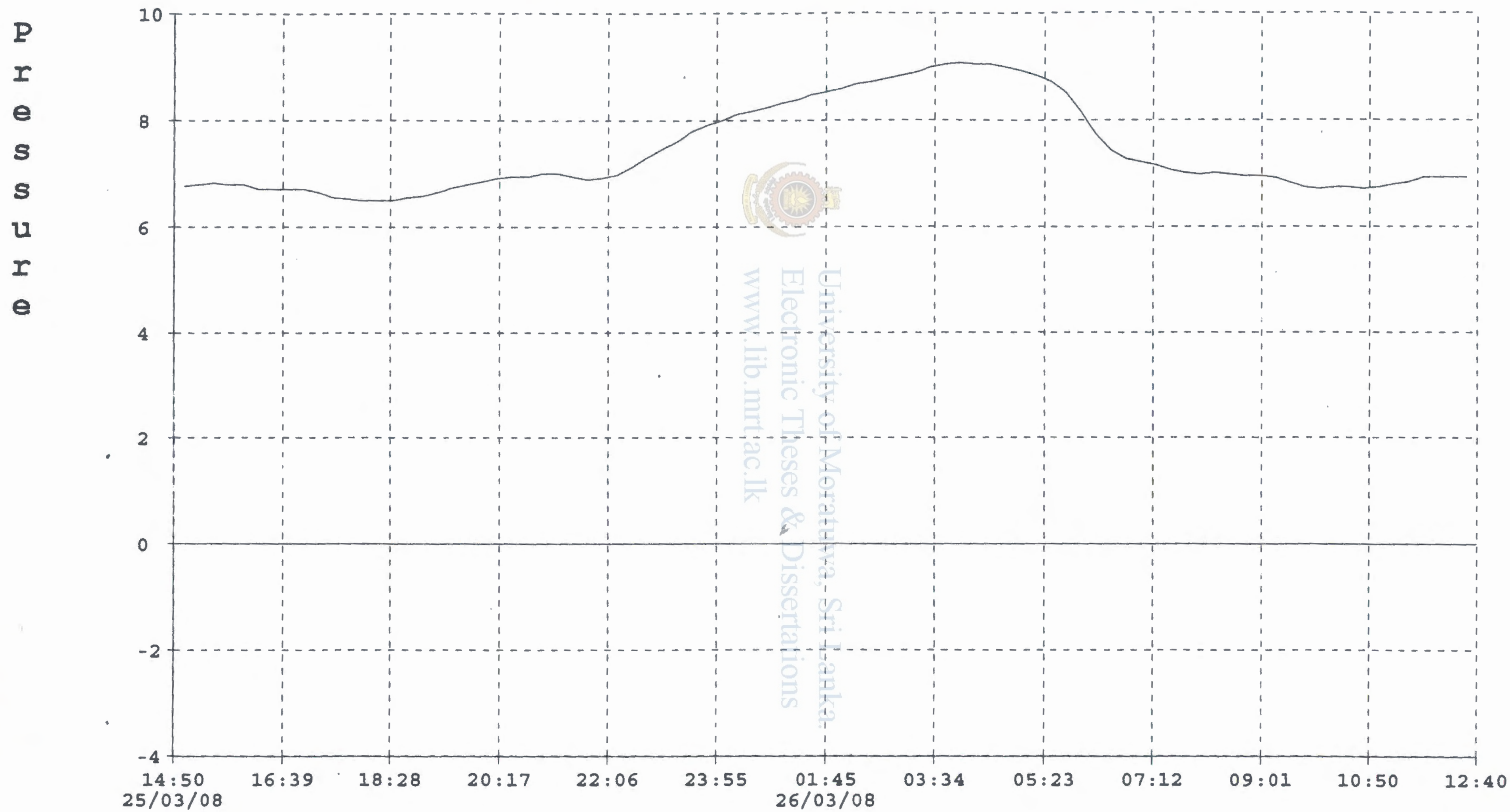
Site	Channel	Units	Min	Max	Vol
CCT11 P5	15.0 minute pressure		0.52	7.79	n/a

At No.191/4, Galle Road, Col-6.



Site	Channel	Units	Min	Max	Vol
CCB3 P9	15.0 minute pressure	Meters	0.48	10.78	n/a

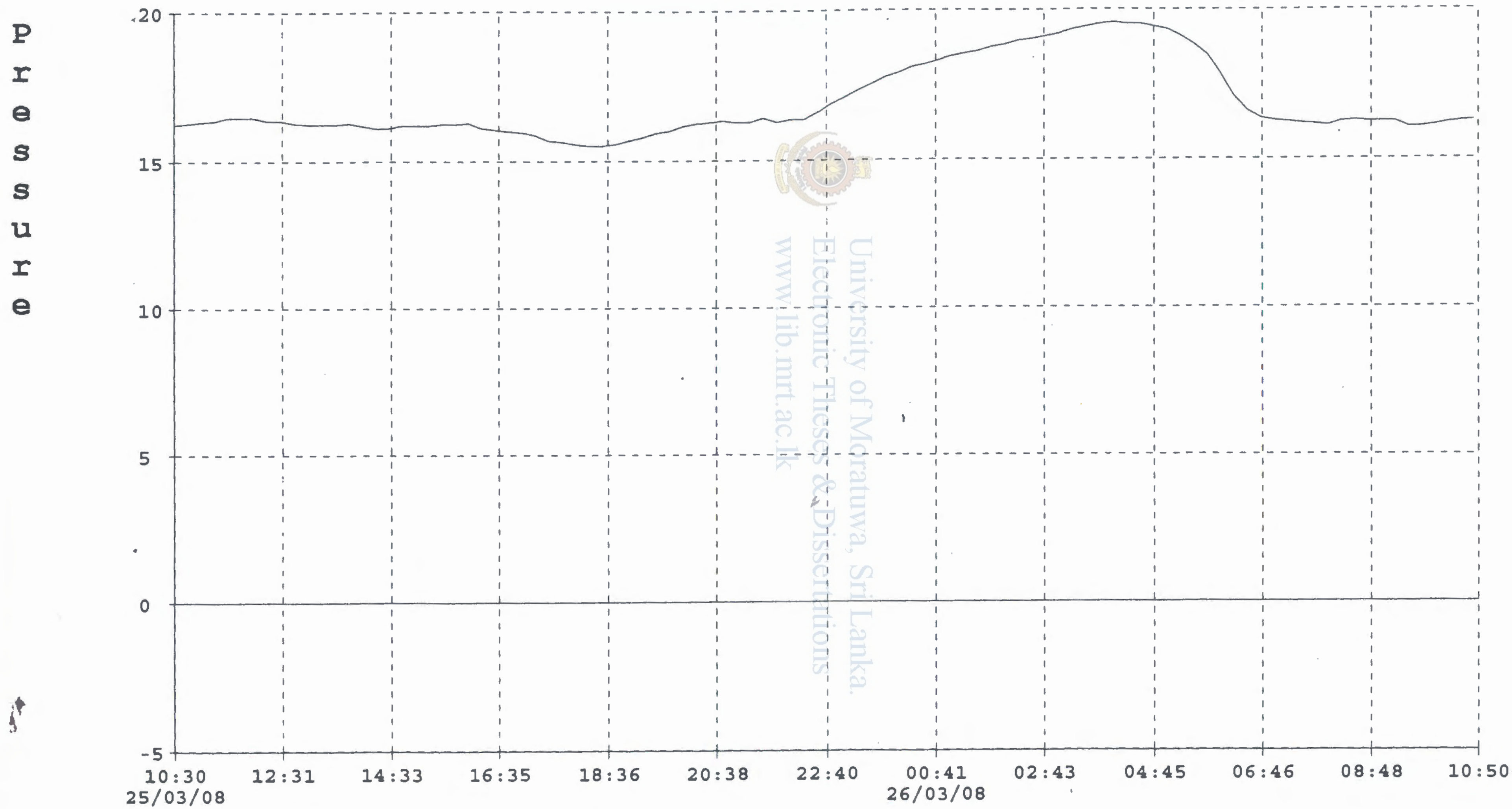
At Havelock Road Bridge (Royal Institute)



Site	Channel	Units	Min	Max	Vol
3 P12	15.0 minute pressure	Meters	6.50	9.07	n/a

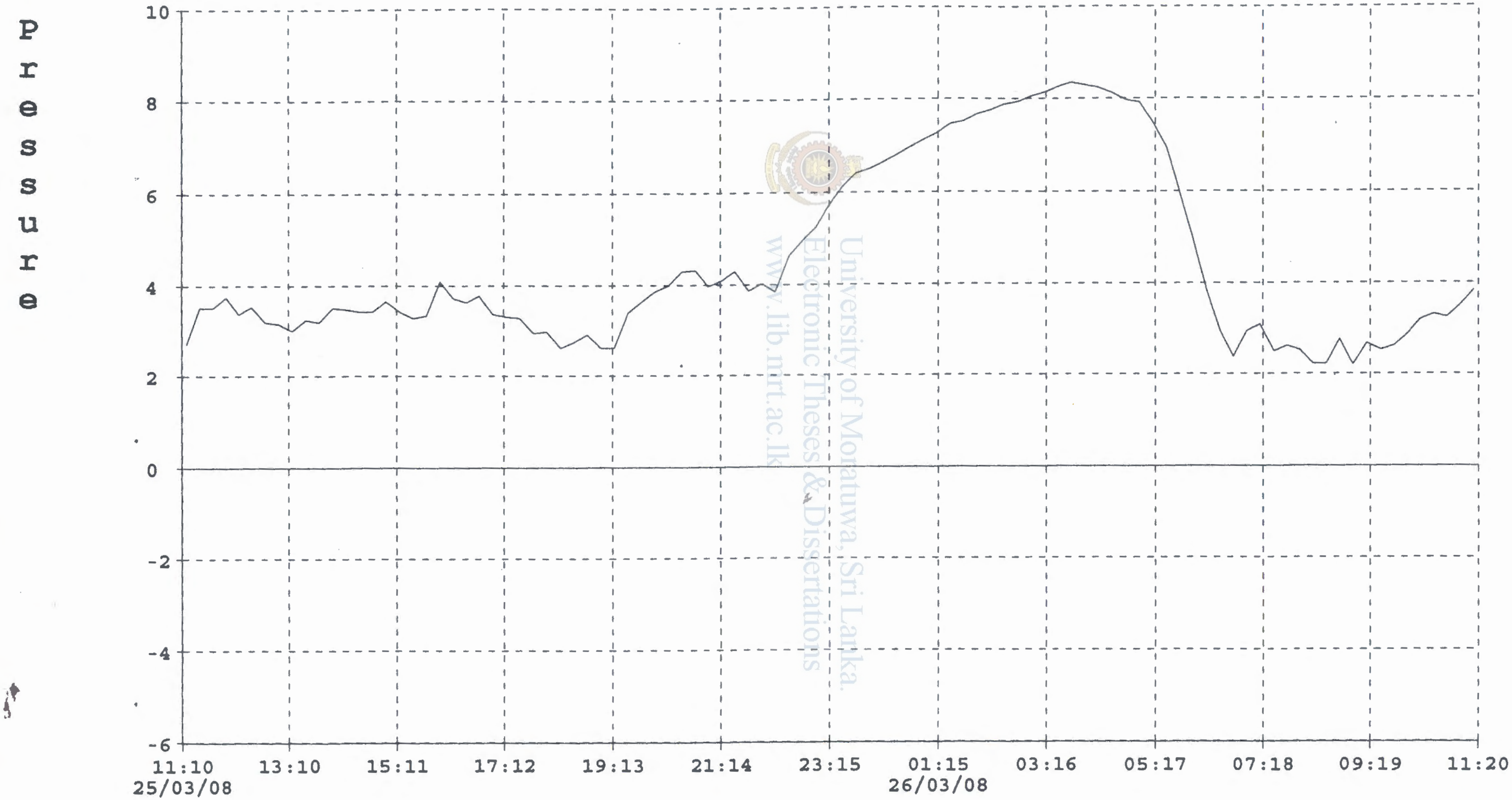
Colombo City Supply.

At Pamankada Bridge Crossing.



Site	Channel	Units	Min	Max	Vol
B3 P-1	15.0 minute pressure	meters.	15.52	19.56	n/a

At No. 194, W. A. DEsilva Mw, Col -6.

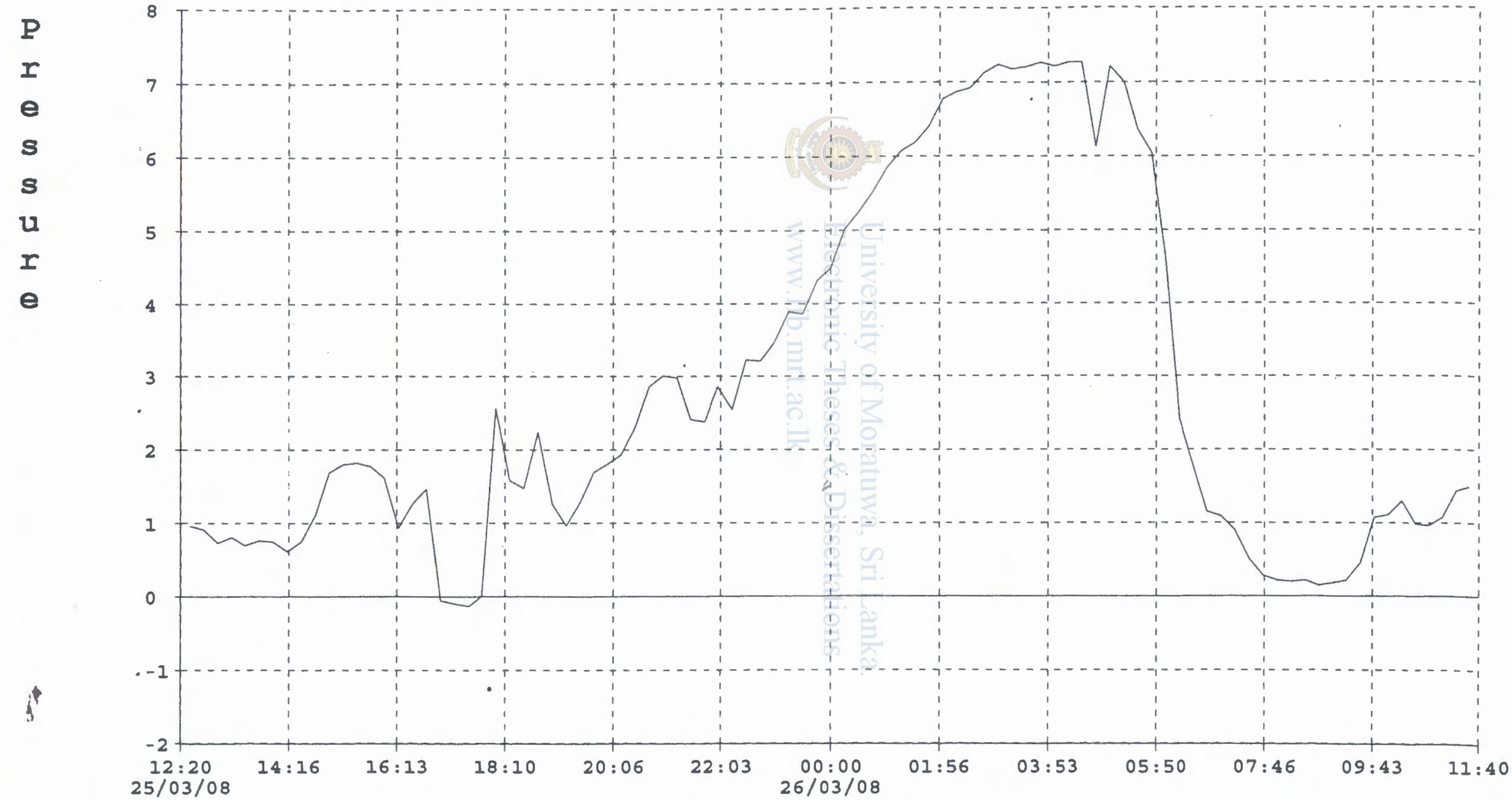


Site	Channel	Units	Min	Max	Vol
"CCB3 P4	15.0 minute pressure	METERS	2.20	8.36	n/a

Colombo City Supply.

Annex - XXIII

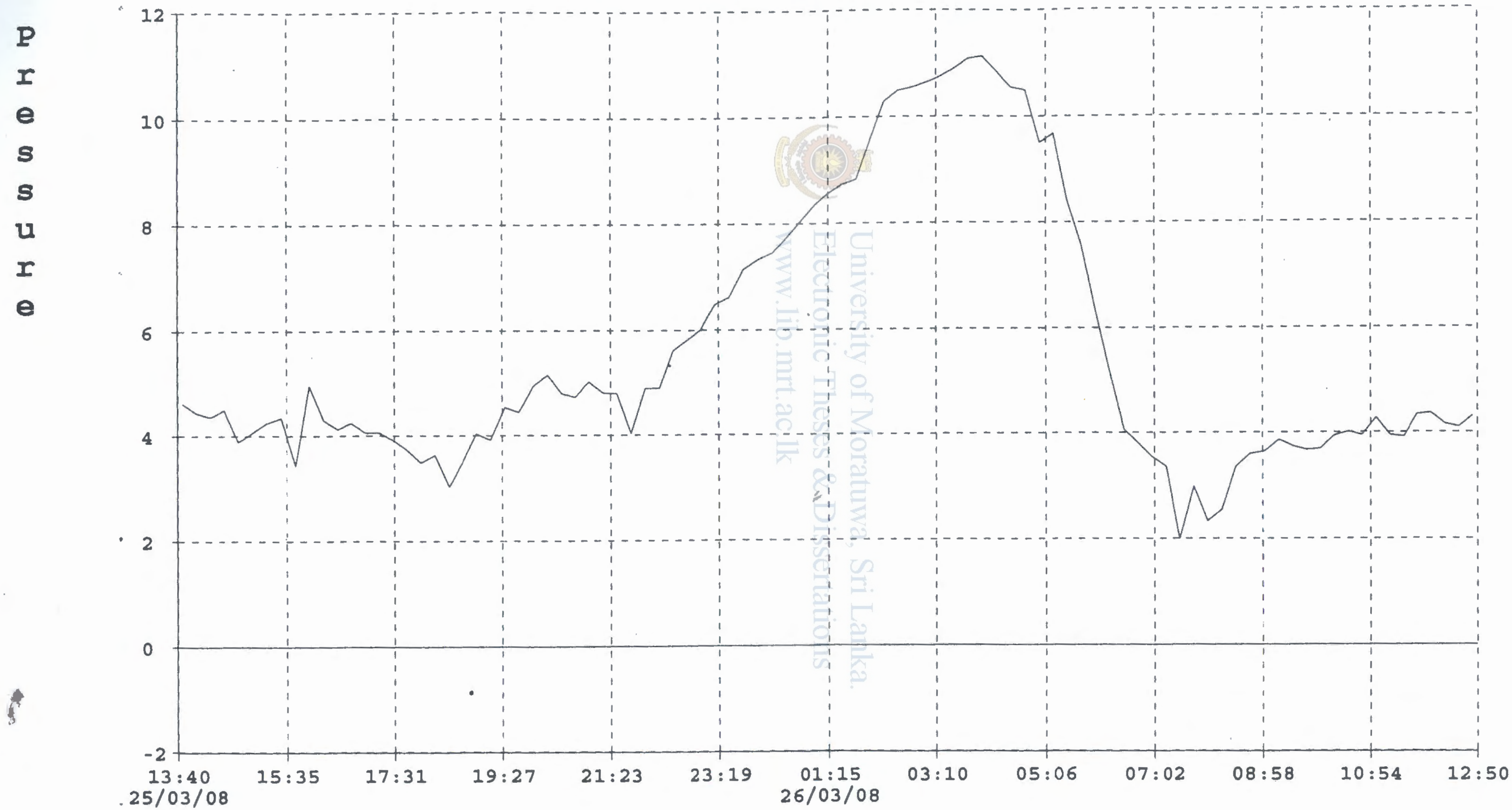
At No.5, Gregory Place, Col-6.



Site	Channel	Units	Min	Max	Vol
CB3 P8	15.0 minute pressure	Meters	-0.13	7.27	n/a

Colombo City Supply.

At No.47/18, Anula Road, Col-6.



Site	Channel	Units	Min	Max	Vol
CCCB3 P10	15.0 minute pressure	Meters.	1.99	11.13	n/a