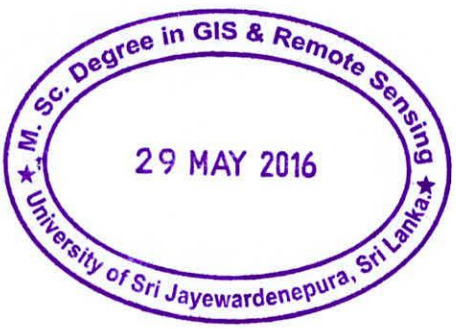
Managing water supply through a GIS-based monitoring and controlling system: A case Study within the Port Limits of Colombo

By

N.P.P.Malalasekara



Thesis Submitted to the Faculty of Graduate Studies University of Sri Jayewardenepura For the Partial Fulfillment of Mastre's of Science Degree in GIS and Remote Sensing on 20th March 2016

DECLARATION OF THE CANDIDATE

I do hereby declare that work described in this thesis was carried out by me under the supervision of Mr.Lasantha Nawarathna and Mr.H.M.P. Jayantha and report on this thesis has not been submitted in whole or in part to any University or any other institution for another Degree/Diploma.

Date 20/03/2016

N.P.P.Malalasekara
112/2, St.James Street,
Colombo 15

ACKNOWLADGEMENTS

I would like to offer my sincere gratitude to my two supervisors Mr Lasantha Nawarathna, Dean, Faculty of Humanities and Mr, H.M.Prabath Jayantha ,Visiting Teaching Faculty Member M.Sc. in GIS and Remote Sensing and Chief Manager (Logistics), Sri Lanka Ports Authority, Colombo for their guidance, encouragement and the fullest cooperation throughout the thesis with patience. Without their persistent help this thesis would not be completed in this manner.

I would like to thanks Prof. R.M.K. Rathnayake , Coordinator (MSc Programme) and academic and none academic staff of the Department of Geography for their kind assistance during this study.

I would like to offer my heartiest thanks to Miss. Nilusha Imashi kavirathne ,Senior Specialist – Economic Affairs, Sri Lanka Sustainable Energy Authority for the dedication and kind concession give me throughout the research study.

I offer my special thanks to Mr. Thushara Paranavithana, Deputy Chief Manager (Civil) and all staff members of the Civil Engineering Division and Survey Section of the Sri Lanka Ports Authority for their fullest cooperation given me in the field of data collection and comprehensive literature writing.

Finally I would like to thanks my family and all friends for their encouragement and support given me throughout the Msc progamme.

Chapter structure

Declaration of the candidate	i
Acknowledgements	iii
Chapter structure	iv-vii
List of tables	viii
List of figures	ix
Abstract	x-xi
Chapter one – Introduction	**1- 10**
1.1. Introduction	1 - 2
1.2. Problem of the study	2 - 3
1.3. Objectives	3
1.4. Significant of the study	4
1.5 Methodology	5 - 8
1.5.1 Study area	7
1.5.2 Data and Data collection	7-8
1.5.2.1 Primary data	7
1.5.2.2 Secondary Data	8
1.5.2.3 Data Analysis	8
1.6 Scope	9
1.7 Limitations of the study	9-10
1.8 Structure of the study	10

Chapter two - Literature Review **11 - 22**

2.1. Introduction 11

2.2. Water Transmission system 11

2.3. Components of the water distribution system 11

2.3.1. Physical Elements 11-12

2.3.2. Mechanical elements 12

2.3.3. Treatment elements 12

2.3.4. Control elements 12

2.4. Significant of a water management system 15

2.5. What is Geographic Information system (GIS) 16

2.6. Geographic Information systems for water utility 16-17

2.7. A GIS based decision support system (DSS) for water Distribution Network 17-18

2.8. Two-stage stochastic fractional programming) TSEP model 19-20

2.9. Implementing a Utility Geographic Information System for Water, Sewer, and Electric: 20-22

Chapter three – Methodology **23-49**

3.1. Introduction 23

3.2. Study Area 23

3.2.1. Rational of Selecting the Study Area 24

3.3. Spatial & Attribute of Data collection 25

3.3.1. Primary Data 25

3.3.2. Secondary Data 26

3.4. Data Layers 26

3.4.1. Port Boundary Map 26

3.4.2. Buildings 26
3.4.3. Water meters 26-27
3.4.4. Water lines 27-28
3.4.5. Valves 29
3.4.6. Water slump / Pump houses / Water Tanks 29
3.4.7. Water Towers 29-30
3.5. Develop a Comprehensive Spatial Database for Water Management System 31
3.5.1. The Geodatabase 32
3.5.2. Feature Dataset 33
3.5.3. Feature classes 34
3.5.3.1. Water meters 35
3.5.3.2. Water pipe lines 35
3.5.3.3. Buildings 35
3.5.3.4. Valve 35
3.5.3.5. Water Pumps / Water sumps / Water Tanks 36
3.6. Building Topologies 37-38
3.7. Creating Relationships 38
3.7.1. Relationship Building Table VS Meter table 39
3.7.2. Relationship Water tower Table VS Water Distribution Table 40
3.7.3. Relationship Water distribution VS hydrant table 41
3.7.4. Relationship Water distribution line table VS Valve table 41-42
3.7.5. Relationship Water distribution line VS Pump/ Tank table 42-43
3.7.6. Relationship Water distribution VS Lateral Table 43
3.7.7. Relationship Lateral Table VS Fittings Table 44
3.7.8. Relationship Lateral Table VS meters Table 45

3.7.9. Relationship water distribution line VS fittings Table 46

3.7.10. Relationship meter VS fittings Table 47

3.8. Creating Geometrics network 47

3.8.1. Utility Network Analyst toolbar 48

3.8.2. Understanding sources and sinks 48-49

3.9. Software and Tools used 49

Chapter four - Research, Analysis and Discussion **50-62**

4.1. Introduction 50

4.2.Model to improve water supply management 50-51

4.2.1. Assigned the Spatial tolerance, Edges and sources & sinks 51

4.2.2. Creating connectivity rules 52-54

4.2.3. Establishing Flow Directions 55

4.3. Network tracing and results discussion 56

4.3.1. Find connected 56-57

4.3.2. Find path 58

4.3.3. Trace downstream 58-59

4.3.4. Other traces operations and results 59

4.4. Statistics of distribution main 60

4.5. Creating a database for proper water distribution plan 61-62

Chapter five - Conclusions and Recommendations **63-66**

5.1 Conclusions 63-64

5.2 Recommendations 64

References 65-66

List of Tables

Distribution System Components categories	13
Spatial Data Layers and Attribute Data Sources	26
Collected Data Layers, Formats and the Sources	31
Collected attribute data and Formats of the Water Meters	34
Collected attribute data and Formats of Water pipe lines	35
Collected attribute data and Formats of Buildings	35
Collected attribute data and Formats of Valves	36
Collected attribute data and Formats of Water Pumps / Water sumps	36
Defined connectivity rules	53-54
Other trace operations and their results.	59-60

List of Figures

Methodology	6
Study area	7
Radial network Vs Looped network	14
Maintaining water utility data	17
Networks integrated with GIS data	18
Water distribution lines and meter locations	28
Water Tower at Kochchikade Area	30
Water Tower at Passenger Terminal Area	30
Entity diagrams of Meter table and Building table	39
Entity diagrams of water tower and distribution tables	40
Entity diagrams of water tower and hydrant tables	41
Entity diagrams of water Distribution and Valve table	42
Entity diagrams of water Distribution and pump / sump / tanks	42-43
Entity diagrams of water Distribution and laterals	43
Entity diagrams of laterals and fittings	44
Entity diagrams of lateral and meter	45
Entity diagrams of water distribution line and fittings	46
Entity diagrams of meter and fittings	47
Utility Network Analyst toolbar	48
Source and Sink	49
Flow direction	55
Trace results of find connected	57
Before trace operation of find connected	57
Trace results of find path	58
Trace result of downstream	59
Statistics of Distribution main	60
Interface of the relationships among network elements	62

Managing water supply through a GIS-based monitoring and controlling system:

A case Study within the Port Limits of Colombo

N.P.P.Malalasekara

Abstract

The thesis designs a GIS base monitoring and controlling system for water management within Port limits of Colombo. The system capability to operate geo- referenced data and results in different formats and it will be suitable for planning and operation of water management system. The question of "How to manage water system efficiently?" has to be answered for strategically using GIS geometric network analysis. Therefore, it should be systematic technology is required to implement water supply management and in order to meet the challenges in the water sector of ports limits. This thesis introduces a GIS based monitoring and controlling system in the field of the water management activities in ports limits in Colombo. Furthermore this thesis describes methodologies to develop a geospatial information system to identify water network to be used as a guide for manage and find leakage points and repairing points.

Geometric network can be used to model and analyze the infrastructures found in the real world like water utility network. It has a logical network and it is a collection of tables in the geodatabase. A geometric network is built within a feature data set in the Geodatabase. The feature classes in the feature dataset are used as the data sources for network junction and edges. When we define the connectivity rules it will play much topography in the geometric network. They show how resources flow through the geometric network. In this geometric network has used feature classes and they are buildings, water distribution lines, water main lines, water towers, water tanks, pump houses, water sump, water meters, hydrant and Road. The water utility system based on GIS presented in this thesis is an perfect tool for accomplishment the analysis and viewing the water utility system. It allows water system planners to work on the real system by involving to the water leak or repairing points. The system will become an essential tool for Civil Engineering Department of the Ports Authority. The data of water supply or water distribution systems are very complex to update and there is a lack of

linkage between spatial and non-spatial data. Therefore the design and implementation of a GIS based monitoring and controlling system for water system within Port limits is vital to minimize time for maintenance of water supply. As well it helps to efficient planning and preventive maintenance. This thesis promotes necessity of a WebGIS server to share a water system with relevant authorized officers.

Key words :GIS, Geo reference, Geodatabase, feature data set, feature class, webGIS

Chapter 01

Introduction

1.1 Introduction

One of the most important needs of the human beings is the water. The year 2005 marked the beginning of the "International Decade for Action: Water for Life" and renewed effort to achieve the Millennium Development Goal (MDG) to reduce by half the proportion of the world's population without sustainable access to safe drinking water and sanitation by 2015. It is estimated by World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) that 1.1 billion people lack access to improved water supplies .Therefore the water situation is very important for mangers that are responsible of distribution, operation and maintenance of water networks to build an effective and complete comprehensive management of water distribution networks system. Therefore, water supply authorities must develop technologies and strategies for detecting, providing, advance warning, and controlling water system. So effective systems can save time, cost, and minimize the mistakes in managing operation & maintenance systems in water distribution networks.

There has been tremendous progress in the use of computer-based control, both for pump efficiency (accompanied by energy efficient pumps) and for network management, especially dynamic pressure control. This provided the opportunity to introduce the water loss reduction programme(UN-International Conference, Zaragosa, Spain 3-5 October). The driver of change to develop these technologies was, of course, water scarcity and the water losses being too high in the utility.

It will assist operation & maintenance manager to take the best decision which saving time, effort, and cost. If there is a water leakage in water distribution systems is an important issue that is increasingly attracting attention from water industry. Water leakage not only results in the waste of good quality water resources, but also leads to a high risk of drinking water pollution.

There are three things to affecting for the water management system.

1. Water pipe line leaks
2. Water stealing from the main distribution line
3. No proper monitoring or control system.

It is noted that there is no proper procedure in water system of the Ports Authority, always water break downs or problems regarding water system should be identified. Engineering Divisions which Civil Engineering, Electrical Engineering, and Mechanical Engineering in Ports of Colombo are wondering about the specification of pump houses, Sewage Treatment Plant (STP), Lifts, building, roads, different features like water supply of each quarters and service connection of common services etc. because there is no proper GIS based system. GIS systems include software, hardware, modeling, database management and display the cases unified by geographical area (Gao et al., 2009). To run a distribution system efficiently for providing a reliable service, it is required to manage geographic information, which can help engineers to operate the system as per the requirement (Vader and Kulkarni, 2006).

1.2 Problem of the study

There should be a popper system to improve the water management system,effective detection, billing, advance warning, and control of water pipeline leakages. But still in sriLanaka, Traditional technologies are used in water management system and for passive detection of leakage are labor-intensive, time consuming, and of low reliabilities, thus they cannot meet the needs of large-scale distribution systems in many countries of the developing world, including regions with water scarcity, water losses (technical leakage and water theft) are very high, mostly exceeding 40% and often even exceeding 60%. To improve water supply and serve more consumers (preferably from low income areas, which often remain unnerved), the capacities of water supply systems must be increased (UN-water international conference – Zaragoza, Spain 3 – October)

In Sri Lanka, Geographic Information System (GIS) based water supply management system is still in experiment level. And today's water utilities are realizing the benefits of Geographic Information system technology for engineering, construction and operations purpose.Sri Lanka Ports Authority is managing all their utilities by

itself. Therefore, there are lots of problems with regard to the water utility Management. The details of the elements of the excising water system is keep in minds of people who attached to the water system. All utilities are located different places of ports limits and there is no centralized database on excising water system. There is no way to get details of roads, buildings, length of water supply lines, meters, valves, hydrants etc.

It is very difficult to trace the error position during break of the supply, power failure, breakdown of feeder or shutdown of the system because there is no GIS base water management system in the ports limits of Colombo. Hence, introducing a proper system for the managing of water supply has been a vital requirement of the civil Engineering at present. Therefore, new system has to proceed to determine the best water network system for the ports limits of Colombo.

1.3 Objectives

Main Objective

To introduce a model to improve water supply management through a GIS based monitoring and controlling system in the Port of Colombo.

Other objectives

1. Develop a Geospatial Information System to identify water network to be used as a guide for manage and find leakage points, repairing points.
2. Propose a proper distribution plan for operation of water distribution line, water networks pipes lines and water meters.

1.4 Significance of the Study

Better water Management system have become a serious need for the Ports limits of Colombo,due to the unavailability of systematic procedure .There is no water database. Hence, plans must be developed for water efficient use through better management at the ports limits. Applying GIS base monitoring and controlling system for water network can be raising efficiency and improvement of water networkmanagement.A water utility needs a geospatial platform and ArcGIS is the geospatial platform which we can use for better water management system. Then GIS base water management system provides easy access to maps and information on one click. As well this system can be used to store the water maters, valve, water lines, and fittings etc. locations. It can be store important data about the element or components of the water management system. GIS provide more accurate records of water infrastructure and mechanical way to maintain these records efficiency.

Ex: Installation date, rapier history, size, location, covering area, Types

Not only that but also GIs based monitoring system can be used to regarding maintenance of buildings like internal plastering, external plastering, painting, roads, pump houses.

It can be identifying their assets differently.

Ex: If we consider a Valve, wecan be identified it is a normal valve or hydrant valve.

Therefore Geographical Information System (GIS) technology plays an important role in efficient water management system. As well any alteration or change in the data to relate to water networks facility must be entered on the database for water network where they help the manger to manage water networks and have a good decision about water distribution of the Ports limits.

Traditionally, Sri Lanka Ports Authority managed their systems by paper maps. They relied on these paper maps for information about their assets and the location. The maps served the purpose in three major areas: existing location of the system infrastructure, engineering aspects of the utilities and customer connections, and the overall network of the system for analysis. (Environmental Systems Research Institute, ESRI, 2003).