Analysis of the spatial variation of drinking water availability in Nilwala River basin using Geographic Information Systems

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G. H. Dumindya Prabali Royal

ABSTRACT

Water is the one of most important of all natural resources. It is vital for all living organisms and major ecosystems, as well as human health, food production and economic development. Difficult to purify, expensive to transport and impossible to substitute, water is essential to life. Drinking water is not an infinite resource. There is a limited amount which cannot be increased, yet it is constantly under threat from overuse and pollution. In the past 100 years the world’s population tripled, but water use increased six fold. Rivers and lakes are stretched to their limits – many of them dried up or polluted with the differing in chemical composition. With ground water taking up an average 1400years to be replaced, aquifers are being drained far faster than their natural rate of recharge. It already affects every continent and around 2.8 billion people around the world at least one month out of every year. More than 1.2 billion people lack access to clean drinking water.

This study presents a GIS methodology to perform a preliminary selection of suitable drinking water areas and what are causes relating water availability, integrating multicriteria. It is more important matter to decision making process in the future development activities. GIS is the skillful tool for the suitability analysis. Most of research not applying GIS to theses researches. Therefore this study is the fulfillment of GIS application in the water research field.
Chapter 1
Introduction

1.1 Introduction
Water is essential for life. The safety and accessibility of drinking-water are major concerns throughout the world. The amount of fresh water on earth is limited, and its quality is under constant pressure. Preserving the quality of fresh water is important for the drinking-water supply, food production and recreational water use. Health risks may arise from consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards. Improving access to safe drinking-water can result in tangible improvements to health. Water is a vital natural resource for people all around the world. There is an increasing awareness that our freshwater resources are limited and need to be protected both in terms of quantity and quality. This water challenge affects not only the water community, but also decision-makers and every human being.

Water is a multi-purpose natural resource and has been the foundation of life and human civilizations. Water contributes to the diversity of the biological and physical environment of the world as well as to the diversity of the human culture. Access to adequate water for all is recognized as a universal basic human need. The natural availability of water in an area is governed by hydrological factors. However, people throughout history have continued to alter the natural patterns of spatial availability of water for their benefit. As People Action International (PAI, 1997) states, water is the source of life and development on earth. Life is tied to water, air and food, while food is tied to water. Water is a regional resource, but water shortage is becoming a global issue due to increasing population, economic growth and climate change. Development of new sources of water beside its efficient use, together with conservation measures, should be an important component of any country’s national water plan.

Today, a quarter of the world’s population is affected by physical water scarcity – mainly in northern Africa, the Middle East, and in parts of India, Pakistan and
China. This means that there is not enough water for all uses, whether agricultural, industrial or domestic. Defining thresholds for stress in terms of available water per capita is more complex, however, entailing assumptions about water use and its efficiency. Nevertheless, it has been proposed that when annual per capita renewable freshwater availability is less than 1,700 cubic meters, countries begin to experience periodic or regular water stress. Below 1,000 cubic meters, water scarcity begins to hamper economic development and human health and well-being (WWAP 2009).

Diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking-water provide significant benefits to health. According to a PAI (1999) estimate, there were 31 countries with a total population of 458 million which faced water stress in 1995. More seriously over 2.8 billion people in 48 countries will face water stress by 2025, based on United Nations medium population projections. Of these 48 countries, 40 are in the Middle East and North Africa. Hinrichsen (1999) predicts that population increase alone will push all of the Middle East into water scarcity over the next two decades.

Figure No 1.1 Water Stress Indicators (WSI) in major basins
Gleick (2000) indicates that there are five major drivers demanding a huge expansion of water resources in the 20th century: population growth, industrial development, expansion of irrigated agriculture, massive urbanization and rising standards of living. According to the Gleick world population has grown from 1600 million to more than 6000 million over the last century. Land under irrigation increased from around 50 million hectares to over 267 million hectares. All these factors have led to more than six-fold increase in freshwater withdrawals, from 580x10^9 m^3/y estimated for 1900 to 3700x10^9 m^3/y in 2000.

From the above discussion and a comprehensive analysis of the literature, it may be concluded that the world is already facing severe water-related problems. These may be identified as follows:

- 20% of the world’s population or more than 1 billion people lack access to safe drinking water, (Simonovic, 2000). Figure 1.1 shows the population without access to safe drinking water.

- 50% of the world’s population or more than 3 billion people lack access to sanitation, (Cosgrove, 2000).

- About 80% of all illnesses and more than one third of all deaths in developing countries are related to water. It is estimated that worldwide, around 7 million die yearly from diseases linked to water. Every eight seconds a child dies from a water-related illness that is about 4 million a year, (UNEP, 1999 and Serageldin, 1999).

- Half of the world’s rivers and lakes are seriously polluted. Pollution of the waterways and surrounding river basins has created millions of environmental refugees, (Serageldin, 1999).

- Nearly half a billion people in 31 countries face water shortage problems, a figure that is anticipated to rise to nearly two-thirds of the world population by 2025. The worst areas comprise the entire Mediterranean region, including parts of southern Europe, North Africa and Middle East,
Northwest and south India, Mongolia, northern China, most of Sub-Sahara Africa and major regions in North and South America, especially the western United States. They will face severe water shortages in the coming years. Europe as a whole also faces severe problems, because half of its lakes have already atrophied, (Cosgrove, 2000 and Serageldin, 1999).

- Aquifers are being extracted at an extraordinary rate - 10% of the world’s agricultural food production depends on using extracted groundwater. As a result, groundwater tables fall by up to several metres a year - with the risk of collapse of agricultural systems based on groundwater irrigation in the north China plain, the USA high plains and some major regions depending on aquifers in India, Mexico, Yemen and elsewhere, (Serageldin, 2000).

- Some of the world’s biggest cities, including Beijing, Buenos Aires, Dhaka, Lima and Mexico City, depend heavily on groundwater for their water supply. The current overuse is not sustainable, because it takes many years to fill aquifers. Groundwater from aquifers under or close to Mexico City, for example, provides it with more than 3.2 million m3 per day, but already water shortage occurs in many parts of the capital. A related effect is that Mexico City has sunk more than 10 m over the past 70 years. Bangkok, similarly depleting its aquifer for drinking and sanitation, is also slowly sinking. Most of the world’s megacities are located on coast lines, where aquifer depletion leads to saltwater intrusion and the contamination of freshwater, (UNEP, 2000 and Cosgrove, 2000).

- Diverting water for irrigation in Central Asia has caused devastating effects. A notorious case is the Aral Sea. This has shrunk to a fraction of its original size and badly degraded in water quality. The latter has caused hundreds of thousands of people to suffer from anaemia and other diseases due to the consumption of water saturated with salts and other chemicals coming from the cotton fields, (Serageldin, 2000).
Transmission of water itself causes severe problems. The supply system of large European cities, for example, can lose up to 80% of the water transported because of pipe damage; with some Mexican cities losing up to 60% through leakage from their old supply systems, (Dossier, 1997). Countries like Bangladesh, the Philippines and Thailand experience water losses of 50%. In Middle East countries like Jordan, Yemen and others with rising water scarcity, more than 40% of the available water cannot be traced, (Chaturvedi, 2000).

Figure No 1.2 Population without access to safe drinking water, (Gleick, 1998)


Worldwide, over one billion people lack access to an adequate water supply; more than twice as many lack basic sanitation (WHO/UNICEF, 2006). Unsafe water, inadequate sanitation, and insufficient hygiene account for an estimated 9.1 percent of the global burden of disease and 6.3 percent of all deaths, according to the World Health Organization (Prüss-Üstün et al., 2008). This burden is disproportionately borne by children in developing countries, with water-related factors causing more than 20 percent of deaths of people under age 14. Nearly half of all people in developing countries have infections or diseases associated with inadequate water supply and sanitation (Bartram et al., 2005).
The effects of water shortages and water pollution have been felt in both industrialized and developing countries, and it will be necessary to transcend international and political boundaries to meet the world’s water needs in a sustainable manner that will conserve and preserve this common resource. In the last few decades, national and international organizations from both the public and private sectors have come together to tackle global issues in water and sanitation.

In recent years, water issues have been the focus of increasing international concern and debate. From 26 to 31 January 1992, the UN system sponsored the International Conference on Water and the Environment (ICWE) in Dublin, Ireland. The ICWE called for innovative approaches to the assessment, development and management of freshwater resources. In addition, the ICWE provided policy guidance for the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. UNCED highlighted the need for water sector reforms throughout the world.

In 1993, the World Bank issued a comprehensive policy paper defining its new objectives for the water sector. FAO recently established an International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD). Likewise, the UNDP, WHO, UNICEF, WMO, Unesco and UNEP are all coordinating or participating in special programmes related to water resources.

Other international, national and local organizations are becoming more active in water issues. The 1990 Montreal meeting, "NGOs Working Together", focused attention on drinking-water supply and sanitation. The Canadian International Development Agency, the French Ministry of Cooperation and Development, the German Agency for Technical Cooperation (GTZ), the United Kingdom's Overseas Development Administration and the United States Agency for International Development (USAID) have recently developed water resource strategies for foreign assistance.
The message highlighted by all these efforts is that water is an increasingly scarce and valuable resource. Of principal concern is our failure to recognize and accept that there is a finite supply of water. The consensus is that the growing water scarcity and misuse of freshwater pose serious threats to sustainable development.

In this situation most of the countries in the world consider about the water management strategy. According to that situation many NGOs generate regarding water resources. Some of those are identify as follows; The Blue Planet Project, Blue Planet Run, End Water Poverty, European Water Association, Global Water, International Private Water Association, International Water Association, International Water Resources Association, Water Advocates, Water Aid, Water for People, Water Life Foundation, World Water Council ect.

Most of these NGOs purposes are based upon the belief that the lack of access to safe drinking water is the primary cause of hunger, disease and poverty throughout the developing world. In addition to that Global Water Resources Policy objectives follows; “Planning is viewed as a means to address the need for water volumetrically, to protect water quality and to regulate conflicts about water access and quality; particularly to prevent possible political or military conflict. In nations of all classes, conflicts between urban and agricultural uses are expected to intensify, creating policy making challenges of increasing complexity”. UN–Water is the mechanism coordinating the actions of the United Nations (UN) system aimed at implementing the agenda set by the Millennium Declaration and the World Summit on Sustainable Development (WSSD) in all aspects related to freshwater. At the (WSSD) in Johannesburg in 2002, the international community acknowledged the importance of the water scarcity challenge by adopting the short-term target of developing “integrated water resources management and water efficiency plans by 2005, with support to developing countries, through actions at all levels.”

Considering about the Sri Lanka situation of water resources Rainfall in Sri Lanka is of multiple origins with monsoonal, convectional and depressional rainfall types
accounting for a major share of the annual rainfall. The mean annual rainfall is 1861 mm, which is approximately equivalent to a rainfall volume of 120 BCM (billion cubic meters) of rain water over the land area. Twenty out of the 103 rivers in Sri Lanka are classified as wet zone rivers, which carry about half of the annual surface runoff. Annual runoff is estimated to be around 35% of the annual rainfall. However, there are considerable variations of the individual values across rivers. Building numerous reservoirs and diverting water to the dry zone compensated this unequal distribution. There are 80 dams which qualify under the major dams category as defined by the International Commission of Large Dams. The groundwater resources are considered to be lesser compared to surface water resources. Seven main types of groundwater aquifers have been identified. The estimated groundwater potential is 7,800 MCM per annum. Both the quantity and quality issues limit the use of groundwater. It is widely used for domestic, small scale irrigation, industrial and other uses. The Government of Sri Lanka has assigned the top most priority for the provision of safe drinking water in achieving sustainable economic and social development. Sri Lanka too is committed to the United Nations (UN) Millennium declaration of halving by 2015, the percentage of people with no access to safe drinking water or lacking the means to obtain it. Drinking water is one of basic needs of the human for their sustaining life, but availability of drinking water is made critical problems to people worldwide. Sri Lanka considered as a water rich country, but people living in some regions of this country are facing problems related to the drinking water.

Since Sri Lanka is an island the ultimate source for groundwater recharge is rain. The infiltration or recharge rate varies from place to place and depends on the surface terrain. The infiltration or recharge is low in the hard rock terrain, which represents 80% of the Island’s land surface. As a result, groundwater potential is low in these hard rock areas. On the other hand, infiltration as well as groundwater potential is relatively high in the sedimentary terrain areas of the country. It has been observed that there is a noticeable change in the rainfall experienced in the country over the last two decades, which has been attributed to global climate change. This variation affects the overall recharge of the groundwater system (map
number 1.1). one of the UNEP report, “Freshwater under treat South Asia” introduce the Sri Lanka as follows. “Sri Lanka, water has been central to its evolution as a nation. A hydraulic civilization dating from the sixth-century B.C. was based on an advanced system of irrigation. Water was treated with great respect and value, with water usage being regulated by edicts issued by its kings, as well as customary rights and obligations determined by the community.”


1.2 Climatic Zones in Sri Lanka

On the basis of rainfall and topography, Sri Lanka can be divided into three climatic zones (Walker, 1962). The mean annual rainfall ranges between 900 mm to 6,000 mm, with an island wide average of about 1,900 mm, which is about two and a half times more than the world annual mean of 750 mm. The three zones are referred to as Wet, Intermediate, and Dry and the later covers the major portion of the country with a mean annual rainfall of 1,450 mm. Understanding the spatial variation of rainfall together with other factors provides an indication of the potential recharge to the groundwater system. The rainfall pattern is influenced by the monsoon winds of the Indian Ocean and Bay of Bengal and is marked by four seasons. First is from mid-May to October, when winds originate in the southwest, bringing moisture from the Indian Ocean. When these winds encounter the slopes of the Central Highlands, they unload heavy rains on the mountain slopes and the southwestern sector of the island. Some of the windward slopes receive up to 2,500 mm of rain per month, but the leeward slopes in the east and northeast receive little rain. The second season occurs in October and November, the inter-monsoonal months. During this season, periodic squalls occur and sometimes tropical cyclones bring overcast skies and rains to the southwest, northeast, and eastern parts of the island. During the third season, December to March, monsoon winds come from the northeast, bringing moisture from the Bay of Bengal. The northeastern slopes of the mountains may be inundated with up to 1,250 mm of rain during these months. Another inter monsoonal period occurs from March until mid-May, with light, variable winds and evening Thundershowers. Sri Lanka maintains a network of 400
rain gauges of which around 30 are automated. The Departments responsible for meteorology, irrigation, and agriculture manage the rain gauge network. A portion of the rain infiltrates into the ground forming and recharging groundwater bearing formations known as aquifers. Water from the surface water bodies also percolates down into the ground and contributes to groundwater recharge. This phenomenon is part of the hydrologic cycle.

Figure No 1.3 Rainfall Change in Sri Lanka during the Period 1950 to 2000

1.3 Safe Drinking Water
Water suitable for drinking from any source whether it is from dug well, tube well, rain water or pipe borne water (protected and/or treated) is considered as safe drinking water. Before 1980, only 50% of the urban population and 56% of those in the rural areas had access to safe drinking water. Between 1990 and 2002, access to safe drinking water has increased from 91% to 99% in urban areas and from 62% to 72% in rural areas.
1.3.1 Salinity in river water

With the lowering of the riverbed tidal water tends to flow into the country along the course of the Nilwala River. The seas around Sri Lanka are micro-tidal by world standards. The tidal range is within 75 cm at spring tide and 25 cm at neap tide (Panaboke., 1996). The coastal line of Sri Lanka is therefore subject to semi-diurnal tides of two nearly equal high waters, and two nearly equal lowers each lunar day.

Polwathumodera River which flows very close to the Nilwala shows that tidal water had intruded over 8 KM from the delta towards to interior. It was also found the salinity level at different points of the river were varying due to the differences of density of saline and fresh water (density of fresh water = 1.0000 g/cm$^3$ and saline water density= 1.0027 g/cm$^3$). The Map no:1.2 illustrated the salinity distribution in Nilwala basin.

![Map of Nilwala basin showing salinity distribution](image)

**Figure No 1.4 Saline water intrusions in Nilwala River**

Nilwala River is the only source of drinking water in the Matara district. The first water pumping station along the Nilwala river was constructed at Nadugala which is
8Km away from the delta (sea). But due to sea water intrusion occurred to the Nadugala pumping station, new pumping station was stabilized at Malimboda which is located 16 Km from sea. Again in year 2000 this was shifted to Kadduwa two kilometers further. Thus, the distance no is 18 Km from the sea. Most recently this pumping station was shifted to Balakawa, over 19 Km away from the sea. All this moves were triggered by the salinity intrusion of the river.

The watershed is located in the wet zone of Sri Lanka and the upper part of the catchment is covered with rainforest. The mean annual rainfall of the upper basin is above 3000 mm while the lower areas receive about 1900 mm. The average monthly rainfall exceeds 200 mm during the March–June and August–December periods, but in other months it is about 150 mm (Elkaduwa et al, 1998).

1.4 Research problem

Nilwala river basin where is lying in the southern part of the country is selected as the study area. Quality degradation of water is one of the burning problems associated with the Nilwala river. Therefore, the study was carried out to determine the factors that affect the water quality in Nilwala river basin, Matara, Sri Lanka, as this is one of the major water sources for drinking and cultivation in Southern Sri Lanka.

The people who are living in the River basin are facing various issues relating to the drinking water including scarcity of drinking water, periodical variations, inconvenience of approach to safe drinking water sources and affect to the quality of the drinking water. The problems related to the drinking water can be found and they are resulted by the various reasons in this research area. The coastal line of Sri Lanka is semi-diurnal tides of two nearly equal high waters, and two nearly equal lowers each lunar day. According to that sea water intrusion occurred to pumping station also.

As well as this problem has spatial variation. In this situation, using of GIS and remote sensing as an information technologies and its analytical capability for
decision making optimization, we can find spatial variation easily and find the solution for such questions. It can be used to reduce future socio-economic and environmental problems related to the Nilwala river basin.

1.4.1 Main Objective
Analyze the spatial variation of drinking water availability in Nilwala River basin using Geographic Information Systems.

1.4.2 Specific Objectives
- To identify spatial variation of Ground water salinity in Nilwala River basin.
- To measure the water scarcity of drinking water in Nilwala River basin.
- Application of Multi criteria analysis on drinking water availability.

1.5 Significance of the study
In this study can be identified the nature of the drinking water availability and their spatial distribution. According to that can be clarified the effective factors relating drinking water problems. The river is the largest in Southern province of Sri Lanka covering the distance of 72 km. Nearly 90 per cent of the area covered by the catchment of Nilwala River belongs to the Matera District. Therefore It is very important that study the drinking water availability in Nilwala river basin.

Nilwala River is the only source of drinking water in the Matara district. The first water pumping station along the Nilwala River was constructed at Nadugala which is 8Km away from the delta (sea). But due to sea water intrusion occurred to the Nadugala pumping station, new pumping station was stabilized at Malimboda which is located 16 Km from sea. Again in 2000 this was shifted to Kadduwa two kilometers further. Thus, the distance no is 18 Km from the sea (. Most recently this pumping station was shifted to Balakawa, over 19 Km away from the sea. All this moves were triggered by the salinity intrusion of the river. In this study can identify how the behavior and distribution of salinity intrusion in Nilwala river basin is? Identify spatial variation of salinity and scarcity of ground water table in Nilwala River basin. Increase community awareness of safe drinking water area through this
research. In order to this research developed the GIS database on Nilwala river basin.

1.6 Limitations

Some problems have to face in this research as changes. Some institutional data in has not issued to this research because of these data considered as the confidential data. It is one of major problems and it made the limitation to my research and one inconveniences that I have faced. In this research we haven’t collect data all around the Nilwala river basin. There for I have to limit the research according to exciting data. Some maps that important to my research unavailable and some institutional data that was not updating regularly, those made inconveniences for the research as limitation.
Chapter
Literature Review

2.1 Introduction to River Basin Hydrology

Hydrology is a branch of earth science which deals with the occurrence distribution and the disposal of water on the earth. The scope of this study is very broad and it is an interdisciplinary science. Ground water hydrology, Hydro meteorology, Chemical hydrology and Statistical hydrology etc. are the other subjects that related to the hydrology. Some definitions for the Hydrology can be define as below.

"Hydrology is the science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth" (Wisler and Brakster, 1949).

"The study of the water of the Earth: their occurrence, circulation and distribution, their chemical and physical properties and their reaction with the environment, including their relation to living things" (McGraw-Hill Science & Technology Encyclopedia:).

The branch of science concerned with the properties of the earth’s water, and especially its movement in relation to land” (Oxford dictionary).

The river basin Hydrology is one of most important features of the hydrology and it consists with the studies of processes in the river basins.

2.2 Teams used in River Basin Hydrology

2.2.1 River Basin

It is important to study about the river basin and its features before studying about the river basin hydrology. The river basin simply define as an area where the collected and disposal of the water from tributaries and flow in to the sea or an interior lake. A river basin has its own clearly defined boundary.
"river basin bounded by its drainage divided and subject to surface and the sub surface drainage under gravity to the ocean or to a lake" (R.G.More, 1969)

"The area of land drained by a river and its branches" (http://dictionary.reference.com).

"The entire geographical area drained by a river and its tributaries; an area characterized by all runoff being conveyed to the same outlet" (http://www.wordwebonline.com)

A river basin is the portion of land drained by a river and its tributaries. It encompasses the entire land surface dissected and drained by many streams and creeks that flow downhill into one another, and eventually into one river. The final destination is an estuary or an ocean. (ee enr state nc.us, 2009)

2.2.2 Watershed

Watershed is one of important component of a river basin. The watershed is the place where the rain water flowing in to the river basin and it can be simply defined as an area of high ground. Terms are used to describe a watershed are, catchment area, catchment basin, drainage area, Drainage Basin, river basin and water basin.

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. A watershed describes an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake or an ocean.

Not only does water run into the streams and rivers from the surface of a watershed, but water also filters through the soil, and some of this water eventually drains into the same streams and rivers. Larger watersheds contain many smaller watersheds. It all depends on the outflow point; all of the land that drains water to the outflow point is the watershed for that outflow location.

"A watershed is a basin-like landform defined by highpoints and ridgelines that descend into lower elevations and stream valleys." (watershedatlas, 2008)
2.2.3 Main Sources of Watershed

- **Precipitation**: The greatest factor controlling stream flow, by far, is the amount of precipitation that falls in the watershed as rain or snow.

- **Infiltration**: When rain falls on dry ground, some of the water soaks in, or infiltrates the soil. Some water that infiltrates will remain in the shallow soil layer, where it will gradually move downhill.

The amount of water that will soak in over time depends on several characteristics of the watershed:

- **Soil characteristics**: Soils absorbing less water results in more runoff overland into streams.

- **Soil saturation**: Like a wet sponge, soil already saturated from previous rainfall can't absorb much more, thus more rainfall will become surface runoff.

- **Land cover**: Some land covers have a great impact on infiltration and rainfall runoff.
- **Slope of the land**: Water falling on steeply-sloped land runs off more quickly than water falling on flat land.

- **Evaporation**: Water from rainfall returns to the atmosphere largely through evaporation. The amount of evaporation depends on temperature, solar radiation, wind, atmospheric pressure, and other factors.

- **Transpiration**: The root systems of plants absorb water from the surrounding soil in various amounts. Vegetation slows runoff and allows water to seep into the ground.

**2.2.4 Delineation of Watershed**

Principle tool for watershed delineation is drainage divide, water divide, divide, ridgeline, watershed divide. Watershed divide is the line that separates neighboring watersheds. Rainfall on one side of a divide will drain into one watershed; precipitation on the other side will collect in a different watershed. In hilly areas the divide lines along ridgeline and may be in the form of a single range of hills or mountains.

*Figure No 2.2 delineation of watershed*

**2.2.5 Divided Type**

- Continental Divide: A divide in which waters on each side flow to different oceans

- Major drainage divide: Waters on each side of the divide never meet, but do flow into the same ocean

- Minor drainage divide: Waters part, but eventually rejoin at a river confluence
2.2.6 Factors to be considered in delineating a watershed

- Hydro network
- Physical and cultural landform
- Geomorphology of the area
- Distribution of Tanks, paddy and other water bearing features

2.2.7 Runoff

Runoff will come from rainfall. However, not all rainfall will produce runoff because storage from soils can absorb light showers; Soil retains a degree of moisture after a rainfall. This residual water moisture affects the soil's infiltration capacity. During the next rainfall event, the infiltration capacity will cause the soil to be saturated at a different rate. The higher the level of antecedent soil moisture, the more quickly the soil becomes saturated. Once the soil is saturated, runoff occurs. High amounts of rainfall and low potential evaporation are needed to generate any surface runoff (Wikipedia, 2008).

2.2.8 Flow Rate

The flow rate is the quantity of water flowing past a point at a given time. Typical units used for flow rate are cubic meters per second (m³/s), liters per second (l/s).

2.3 Water Scarcity

Water scarcity is either the lack of enough water (quantity) or lack of access to safe water (quality). It is dividing as follows:

Physical scarcity: is defined around the low availability of water per capita.
Economic scarcity: is related to lack of infrastructure for reliable supply.

2.4 Water Availability

Water is the most widespread substance on earth. It covers more than 70% of the world’s surface. It forms oceans, seas, lakes, rivers and the underground water. In a solid state, it exists as ice and snow cover in polar and alpine regions. A certain amount of water is contained in the air as water vapour, water droplets and ice
crystals, as well as in the biosphere. Huge amounts of water are present in the composition of the different minerals in the earth's crust.

2.5 Freshwater Distribution

Freshwater is distributed very unevenly over the world. Fewer than 10 countries possess 60% of the world's available freshwater supply: Brazil, Russia, China, Canada, Indonesia, U.S., India, Columbia and the Democratic Republic of Congo. And even in those countries, the availability varies greatly (WBCSD 2009). Only 80% of the world's population are served by renewable and accessible water; a fifth of the world population relies on ancient aquifers (aquifers that are not renewed any more presently), inter basin transfers or on desalinized seawater (WWAP 2009).

![Figure No 2.1 Water Stress Indicators (WSI) in major basins](image)

Water Scarcity Index: The above maps show the exploitation of water resources on the world. The darker the colour, the more water is exploited and the higher is the water stress in that area. Source: REKACEWICZ (2009)

The earth is the only one planate which existing the water in the solar system and it is called as the blue planet. 70.9% of earth surface is covered by the water. The
majority found as the oceanic water. It is 96.5% of the global water budget. At the rate of 1.7% be included in ground water and the glaciers icecaps as Antarctica and Greenland. A small fraction has included other large water bodies. The fresh water is only 2.5% of the global water budget and therefore 98.8% considered as the ground water and ice. Less than 0.3% of all freshwater is in rivers, lakes and the atmosphere. The smaller amount like 0.003% is suited to fulfill the biological needs. The global water distribution shows an inequality. Some countries are water rich and others are water poor countries and they are suffering terrible problems relating to the scarcity of water, including inability to access of safe drinking water in water poor countries. The international water management institute (IWMI) mapped out the countries by scarcity of water in the world.

![Diagram of global water distribution]

2.4 The Global Water Distribution

Source: Rathnayake, M. “Water Resources Conservation”

According to The World Health Organization,(WHO) 1.6million children under the age of five years have killed by unsafe water and lack of basic sanitation in every year, and over 1.1 billion people do not use water from improved sources.

2.6 Water Quality

Conner (1998) states that during the water cycle, water quality may take many aspects. Over this repetitive cycle, a single water molecule may assume various states, returning to the basic hydrologic pathway as new chemical compounds are
mixed with various solid and liquid substances. Hence, water is often qualified as: pure, natural, salt, fresh, polluted, drinking, spring, mineral, bottled, tap, filtered, rain, raw, spa, distilled, etc.

2.6.1 Pure water
Pure water contains water molecules only (H₂O - two parts hydrogen and one part oxygen), with no suspended or dissolved material. Away from that, its composition depends on where it comes from, and how it is processed and handled. Pure water does not exist in nature due to its solvent action; it dissolves at least a portion of everything it contacts.

2.6.2 Natural water
Natural water contains different minerals and gases. The quantities of these depend on the source of water and especially on the terrain through which it flows. Therefore the quality of water varies substantially from area to area. In some cases, the quality of water in a given area can alter even on a day to day basis.

2.6.3 Salt water
Salt water, which covers about 70% of the earth surface (oceans and seas) is so called as it contains a certain amount of dissolved salts (about 35000 ppm), (Conner, 1998). Saltwater is not suitable for drinking, because it dehydrates, that is salt drains water from human bodies. In order to drink saltwater, it needs to undergo desalination.

2.6.4 Freshwater
Fresh water is water with a dissolved salt concentration of less than 1%. There are two types of freshwater reservoirs: surface water (water collected as rain and snow runoff and groundwater seepage, collected in reservoirs, lakes and rivers) and groundwater (water contained in underground aquifers that reach the surface through springs, deep wells or artesian wells).
2.6.5 Polluted water

Fresh water is drinkable if it is not polluted. Polluted water contains harmful bacteriological and/or chemical substances such as bacteria, toxics, nitrates, heavy metals, hydrocarbons, pesticides, etc.

The bacteriological contamination of water is the main problem in developing nations. It is necessary to make appropriate tests to determine if water is bacteriologically safe for human consumption. Also, control procedures are needed, involving chlorination and filtration or boiling. Water pollution is a new problem approaching crisis levels in many parts of the world. Polluted water is a major cause of death and disease in the developing world. According to Love (1999) an estimated 80% of all diseases and over third of deaths in developing countries are caused by the consumption of contaminated water. Water-related diseases cause a 10% reduction in overall production effect.

2.6.6 Drinking water

Drinking water comes from municipal water systems, wells or springs. It is often treated to remove bacteria and other pathogens and pesticides. In general, water for drinking and cooking should be healthy – free of harmful bacteriological and chemical components. In addition, drinking water should be clear, colourless and have no unpleasant taste or odour.

2.7 Water regarding research in the world

The United National Organization (UNO) introduced a water supply and sanitation decade (1980 – 1990) and it had been a turning point in the world. “At the beginning of the water for life decade, 1.1 billion people did not have access to an improved source of drinking water and 84% of the population without access to an improved source of drinking water lives in rural areas (www.who.int)”. The UNO introduce targets that represent various fields to achieve in 2015 and named it as millennium development goals. It is included a target relating to the drinking water as to ensure the sustainable access of safe drinking water for the people who have not possibility to it. The World Health Organization,(WHO) and United Nations
International Children’s Fund UNICEF are the monitoring organization of this goal. These steps which taken by the international community shows that the supply of drinking water is vital necessity.

Water is essential for all socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users, and excessive pressure on the environment. The increasing stress on freshwater resources brought about by ever rising demand and profligate use, as well as by growing pollution worldwide, is of serious concern. Imbalances between availability and demand, the degradation of groundwater and surface water quality, intersectoral competition, interregional and international conflicts, all bring water issues to the fore. Therefore most of the countries are paid the attention on their unrepeatable water resources. They are doing the researches and finding the solutions for the existing problems.

The Pacific Institute tells that “Water is one of our most critical resources – even more important than oil. Water sustains agriculture and, thus, our food chain. Vast quantities of water are used to make the silicon chips that help power our computers and cell phones. Electric power plants depend heavily on water, and account for a staggering 39 percent of freshwater withdrawals in the United States. It could be said our economy runs on water.” (http://www.pacinst.org/). When considering the literature of the water regarding research define as various conditions that is why International, National, Organizational, regional and personal researches exist since many years.

In order to that many researches are done by UNEP. Among those research “protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources” is most valuable one. As well as International Water Management Institute (IWMI) also many reports were published for support sustainable increases in the
productivity of the irrigated agriculture within the overall context of the water basin. It is explained that Water scarcity can be defined either in terms of the existing and potential supply of water, or in terms of the present and future demands or needs for water, or both. World Health Organization’s world water day report tells like this. “Water is one of the earth's most precious and threatened resources Health is one of each person's most precious resources We need to protect and enhance them both Water for Health”

“By 2025, one-third of the population of the developing world will face severe water shortages (Seckler et al. 1998). Yet, even in many water scarce regions, large amounts of water annually flood out to the sea. Some of this floodwater is committed flow to flush salt and other harmful products out of the system and to maintain the ecological aspects of estuaries and coastal areas (Molden 1997). The problem is that the sporadic, spatial distribution of precipitation rarely coincides with demand. Whether the demand is for natural processes or human needs, the only way water supply can match demand is through storage” (Andrew. K et sl,2000) 39 research report indicated like that.

Safe water, suitable for human consumption is a scarce and a limited resource which is under threat of pollution, contamination and waste. This ever dwindling resource is indispensable for sustenance of life on the planet and in particular the well being of humans. Safe drinking water is considered a key factor contributing towards overall economic and social development of a country. Accordingly access to safe drinking water is considered as an inalienable right of the people Water suitable for drinking from any source whether it is from dug well, tube well, rain water or pipe borne water (*protected and/or treated*) is considered as safe drinking water. Before 1980, only 50% of the urban population and 56% of those in the rural areas had access to safe drinking water. Between 1990 and 2002, access to safe drinking water has increased from 91% to 99% in urban areas and from 62% to 72% in rural areas (National policy on drinking water,2009).
One of the major drivers in development is water as it is required for all life activities including consumption and other life activities for living beings, farming, fisheries, industries etc. The quantity and quality of water are equally important. According to the National Water Use Master Plan which is still under preparation, the estimated water demand for the Northern Province for 2025 is 4.6 mcm/day of which 3.3 mcm/day will be required for the urban population. The paper describes the availability and potential of both surface and ground water resources in the districts of the Northern Province. (Hemanthi, R, 2012) “An assessment of water quality and pollution in Puranawella Fishery Harbour Sri Lanka” research finds the Spatial and seasonal variations of physico-chemical parameters and phytoplankton abundances were examined together with bacteriological analyses. (Niroshana.et al, 2013)

Sri Lanka being a small island of 65,610 square kilometers and a population of 20 million receive fairly adequate rainfall. Water sources are being replenished by the rain except in dry season and unexpected droughts. Island is divided in to two zones; southwest part as wet zone and northwest and southeast as dry zone. Annual rainfall is 2540 mm to over 5080 mm in south west of the Island (Wet Zone). It is less than 1250 mm in the Northwest and south east of the Island (Dry zone).

Generally there are two rainy seasons per year: Southwest Monsoon- May to August and Northeast Monsoon - November to February. Agriculture in the north and east suffers badly during the South-west Monsoon. June, July and August are almost totally rainless throughout the Dry Zone. There is scarcity for water in the dry zone during this dry period. In addition to agriculture water is required to maintain the wildlife during these dry periods. Annual renewable water resource is 52,800 million m3. Total Renewable Water Resource (TRWR) per capita is 2531 m3 for the year 2009 (Source: Aquastat FAO). Data on surface vs. ground water is not readily available. From the available water 11,310 million m3 is withdrawn for agriculture. Municipal withdraw 805 million m3 and industries withdraw 831 million m3 during the year 2005 (Source: Aquastat FAO). Total water withdrawal per capita 638.8 m3 for the year 2005 (Source: Aquastat FAO). Status of wastewater
as a part of overall water budget is very minimal and data on this is not readily available.

Approximately 1500 ground water based water supply schemes produces 6 million cubic meters per year. In addition about 23000 tube wells are also available throughout the country. The overall water budget for the year 2012 for water supply is Rs. 24 billion and Rs. 5 billion for wastewater disposal (Source: National Water Supply and Drainage Board).

Rainfall forecasting for flood prediction in the Nilwala basin is one of the research regarding Nilwala river basin. It was done develop a flood prediction tool for the Nilwala river basin. (Uditha.R, et.al, 2010)

Another research of Nilwala river basin Development of acid sulphate soils was observed in some paddy fields of Nilwala flood protection area in Matara district. Fernando. G.W.A.R, et al, 2009) Rapid sand mining in the Nilwala river bed and river bank have caused serious problems to various sectors of natural and anthropogenic environments. That research study aimed to identify corrective and behavior of the environmental impacts in Nilwala river basin due to river sand mining.(Piyadasa.R.U.K, et al, 2011)

If there are many water regarding researches done by International, national, organizational and personal levels, no one do the GIS based analysis of drinking water availability in Nilwala river basin. Therefore this research very important that is why drinking water is most popular theme in future and Nilwala River is the main hydrological feature in Matara district. As well as Geographic information system is the key to better decision-making. It is better to day-to-day operations or long-term planning, is related to its geography.
Chapter 3
Methodology

3.1 Methodology
The methodology of this research is divided into three main parts according to figure. They are,

- Data collecting methods
- Data analyzing methods
- Methods of output present

3.2 Study Area
Nilwala River at the south of Sri Lanka is the main source of irrigation, drinking and industrial water supply for people living in and around the coastal town of Matara. The river starts from the hill country in Deniyaya and Rakwana and runs through Deniyaya town, Morawaka, Akuressa and reaches the city of Matara where it joins the Indian Ocean at Thotamuna. The catchment consists of 971 km² land area, with approximately 30 km² floodplain. The Nilwala River is nourished by number of tributaries which bring a large volume of water to the main stream. They are;

- Hulandawa ganga
- Siyabalagoda oya
- Digili oya
- Kirama oya
- Badulla oya

In the GERSAR (Groupement d'Etudes et de Realisations des societes d'Amenagement Regional) project in 1980, to eliminate the flooding in downstream areas of Nilwala River (Matara, Nawimana and Tudawa), a system of flood protection bunds and by-pass was proposed. However the GERSAR flood protection proposals have not being completely implemented. Only the flood bunds have being constructed as planned but the bypass channel with a design flow of 550 m³/s has not being constructed. Because of not having a proper flood management system, the downstream area of the Nilwala River is often affected by floods and
cause large damages during monsoon seasons. As well as it also affected to the water availability in the region.

The Nilwala River Basin falls mainly within the wet Zone of Southern Province in Sri Lanka and originates from the Sinharage highland Natural forest (Map no 3.1). The river is the largest in Southern province of Sri Lanka covering the distance of 72 km. Nearly 90 per cent of the area covered by the catchment of Nilwala River belongs to the Matera District. Study area falls within the WL2 agro ecological region. Annual rainfall of the selected area is between 1875mm - 2500mm, mean temperature is 25°C and Relative Humidity is 75% - 80%. The Catchments area represent approximately 971.0 km² and its falling within the latitude and longitude between the 5°55' & 6°13' and 80°25' & 80°38'. From a hydraulic point of view, the course of Nilwala River consists of two very different parts. The upper stream part has a steep longitudinal slope, where the river bed is rocky, and the rate of flow fairly high. The valley is clearly marked and the floods do not cause any considerable inundation. The southern lowlands of the basin extending inland up to about 12km from the coastline were subject to serve flooding in the southwest monsoon rains and with conventional and cyclone activities. Approximately 70 per cent of the Nilwala river basin is used to grow paddy, tea, coconut, cinnamon, citronella and rubber. Paddy area covers approximately 18000ha, including 9000 ha in the lower part of the basin subjected to seasonal flooding. Wet land called ‘Kirelakele Marsh’ is located near the Indian sea outfall of the Nilwala River.

3.2.1 Geology and Hydrogeology of the area

Geological information available for the region shows that the flood plain of the river basin has been under sea during lower Miocene period when lagoonal and estuarine deposits settled on the shallow sea bed (Cooray., 1983). In the study area, Precambrian metamorphic hard rocks are major rock under laying and along river flood plain and lower coastal areas show quaternary sedimentary deposits. But in all places basement consists of Precambrian rocks of the so-called Highland Complex and consists of granite silimants with-biotite gneiss. Topsoil mainly consists of sandy clay. The isolated lateritic hills found in the flood plain are of the same
geology as the inland land mass. The top unconfined alluvium aquifer is distributed in the Nilwala River basin and on the coast (Panabokkeand, Perera, 2005). Water-bearing sand in the top section is more often fine while lower sections usually have coarse sand with small portions of gravel.

In general, the aquifer consists of calcified sand, in case of the Nilwala River basin of sandstone. Recharge of the aquifer takes place mainly from rainfall in the Northern region of the catchment area. The top quaternary sandy aquifer and the surface soils of the coastal margin of Matara area are most permeable. The hydrogeological conditions are very favorable for saltwater intrusion; therefore, along the coastal belt, alluvial and coastal sand deposits are dominating and forming higher-yielding local aquifers.

3.2.2 Physical features of the Nilwala River Basin

A river has three stages according to the Devis, they are young stage, mature stage and old stage. The river Nilwala is flowing in the 1st stage from the Gongala to the interior 5km with 80m per 1km gradient with ratio of 12.5:1 and it is an intensive degree. The Nilwala is flowing in the 2nd stage after 5km from its origin to the Bopegoda and its gradient is 5m per 1km with ratio of 200:1. Below the 30m elevation of this basin recognizes as the 3rd stage and its gradient is 0.3m per 1km and ratio of 3000:1. Above statistics showed that the river is flowing with steep longitudinal slope and an intensive degree in the first stage as the upper part of the stream. The second and third stages have less longitudinal slope and it lying from the coastal line in Bopegoda.

According to the Cooray, quaternary sedimentary deposits cover the Precambrian metamorphic hard rock dominantly in this river basin and basement consists of Precambrian rock of the so-called Highland Complex. (Piyadasa R.U.K) Topsoil mainly consists of sandy clay, as well as isolated lateritic hills lying in the flood plain and inland wetland like Kirala Kele can be found on the flood plain. The top unconfined alluvium aquifer is distributed in the Nilwala river basin and on the coast (Panabokke C.R, Perera A.P.G.R.L,2005, Piyadasa R.U.K).
The river bed of the Nilwala River is below that mean sea level approximately 2.19m and it spreads to the area of Akuressa. It severely influenced to the salinity level rising in the river because the saline water enter and up rush through the river banks by tidal waves. It causes to reduce the water quality of the water quality of the water sources of the study area.

3.2.3 Distribution of human activities and Land use patterns in Nilwala River Basin

Nilwala river basin is one of highly populated river basin and many human activities can be found here. Most of people depend by the agriculture, and paddy fields got the majority of the land use patterns and it exceeds 8000ha. Market gardening, farming pastoral and fishery are other primary economical activities found in this river basin. Tea rubber and coconut plantations distribute in the river basin as financial crops and mostly rubber and tea plantations are distributing in upper part of the basin. Coconut plantation can be considered as an important land use pattern in the bellow part of the basin. Forest land like Anil Kanda, Panil Kanda, Dediyagala, Kotapola, and Viharakele are other important land cover pattern in this basin and the forest department statistics showed that 80% of the basin is covered by forests before in last century, but this forest cover is reduced due to various reasons.

Clay mining and sand mining are other type of human activities which remain in this basin and these two factors effect to the water quality of water sources. Human settlements and road networks are other land use patterns and basically it can be divided in to two parts as urban and the rural land use patterns because urban areas like Matara municipal council area and other rural areas are situated in this river basin.
**Legend**

<table>
<thead>
<tr>
<th>Nilwala river basin</th>
</tr>
</thead>
</table>

**Elevation Value**

- **High:** 917.84
- **Low:** 0

Fig No: 3.1 Study Area
3.3 The Research Sample

The research sample can be defined as whole area of the Nilwala river basin. This river basin covers approximately 1000 km$^2$ land area and it represents the whole of the Matara District where the one of highly populated districts. In addition to that Galle, Hambantota and Rathnapura districts also represent the relatively small fractions in to the Nilwala river basin. Divisional Secretariat Divisions relevant to the basin of those districts can identify as follows;

Ratnapura district represent the 02 DSDs and those are Embilipitiya, Kolonna korale tawalama Galle district represent the 03 DSDs and those are Neluwa, Nagoda, Yakkalamulla. Matara District represent the whole relevant DSDs and those are Kotapola, Pasgoda, Mulatiyana, Akuressa, Malimboda, Kamburupitiya, Hakmana, Dikwella, Tihagoda, Weligama, Matara, Devinuwara, Pitabeddara, Welipitiya, finally Hambantota district represent the 04 DSDs and those are Katuwana, Weeraketiya, Beliatta, Okewela. In this research sample randomly were collected salinity and pH data in relevant areas.

Malimboda and Pitabeddara DSDs are situated in the flood plain of the Nilwala river basin and it is over flowed by most flood incidents occurring in this basin. It is a one of causes to the decrease of water quality of the water because most of wells are overflowed by floods. On the other hand when there is a dry period, the saline water enters to the wells by ground water recharges. All of these factors pointed out in this research sample area.

Some parts of Akuressa and Katuwana DSDs have water scarcity problems because of it there are no water supplying projects to distribute drinking water and it is affected the elevation problems to the natural water resources distribute areas. In order to that can identify disparities of drinking water availability have in all of the basin area.
3.3.1 Situation Analyses
The existing issues of drinking water and its impacts on human environment in the study area will be studied under the situation analyses. Spatial distribution of issues of drinking water is studied to identify the effective factors for drinking water availability in Nilwala river basin. Vector and raster layers are used to analyze the existing situation with GI/RS techniques.

- 1:50000 digital data
- 1:10000 digital data
- Google Earth

Spatial distribution of drinking water salinity, scarcity and their impacts on human environment and land use are analyzed by using above data and information of the study area. The negative impacts of the water salinity are identified by the reported complains from the public in study area to National Water Supply and Drainage Board.

Existing situation of the study area is analyzed by Using above methodology with the Geographic Information System and the Remote Sensing techniques to identify the basic criteria of Nilwala River basin.

3.3.2 Determinations of efficient criteria and factors
The basic criteria which identified by the situation analysis is completed with the reference data and information. After completing, those criteria are finalized by the consultation of the expert team who selected from social and environmental areas.

3.3.3 Collections of Data
According to the criteria which identified through the expert team, decide the data and information which are needed to be analyzed. The following data and information is collected base on the criteria. These data were collected from various institutes in Sri Lanka.
Table 3.1 Collected Data Layers, Scales, Formats and the Sources

<table>
<thead>
<tr>
<th>Layer and Scale</th>
<th>Format Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 m Interval Contours</td>
<td>DGN and Geodatabase</td>
<td>Survey Department</td>
</tr>
<tr>
<td>Spot Heights</td>
<td>DGN and Geodatabase</td>
<td>Survey Department</td>
</tr>
<tr>
<td>Streams and Rivers 1:50,000</td>
<td>Geodatabase</td>
<td>Survey Department</td>
</tr>
<tr>
<td>Land Use 1:50,000</td>
<td>Coverage</td>
<td>Survey Department</td>
</tr>
<tr>
<td>Roads 1:50,000</td>
<td>Coverage</td>
<td>Survey Department</td>
</tr>
<tr>
<td>District, DSD</td>
<td>Shape files and Coverage</td>
<td>Survey Department</td>
</tr>
<tr>
<td>Rainfall Data (30 Years)</td>
<td>CSV - Attributes</td>
<td>Meteorology Department</td>
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<tr>
<td>River Basins 1: 250000</td>
<td>Shape files</td>
<td>Irrigation Department</td>
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<tr>
<td>Forest Reservation 1: 50,000</td>
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<td>Shape files</td>
<td>Geological Survey &amp; Mining Bureau</td>
</tr>
<tr>
<td>pH data</td>
<td>CSV - Attributes</td>
<td>National Water Supply &amp; Drainage Board</td>
</tr>
<tr>
<td>Salinity data</td>
<td>CSV - Attributes</td>
<td>National Water Supply &amp; Drainage Board</td>
</tr>
</tbody>
</table>

3.4 pH data

The term pH comes from the French, pouvoir or hydrogen power. Soil reaction is an indication of the acidity or basicity of soil and is measured in pH units. The scale ranges from 0 -14 with pH 7 as the neutral point. At pH 7 Hydrogen ion concentration \([H^+]\) equals the hydroxyl ion concentration. From pH 7 – 0 the soil is increasingly more acidic; from pH 7 – 14 the soil is increasingly more alkaline (basic) (GUPTA 1999)

3.4.1 Importance of Soil pH

The soil pH is easily determined and provides clues about other soil properties. The soil pH greatly affects the solubility of minerals. Strongly acidic soils (pH 4-5) usually have high toxic concentrations of soluble aluminum and manganese. Most minerals are more soluble in acidic soils than in neutral or slightly basic solutions.
The soil pH also influences plant growth by the pH effect on activity of beneficial microorganisms. Most nitrogen-fixing legume bacteria are not very active in strongly acidic soil. Fungi usually tolerate acidity better than do other microbes.

On mineral soils most agriculture crops do best in slightly acidic soils (pH 6.5) on organic soils about pH 5.5. non leachate soils or those high in calcium may have pH values to 8.5 with increased exchangeable sodium, soil may reach values of pH 10, plants on soils of pH greater than about 9 usually have reduce growth of even die. Some plants are tolerant of high salt or high pH values (GUPTA, 1999). So this is more important factor to availability of drinking water in the Nilwala river basin.

The pH of a solution is the negative common logarithm of the hydrogen ion activity: pH = -log (H+) in dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration. The pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. An increased carbon dioxide concentration will therefore lower pH, whereas a decrease will cause it to rise. Temperature will also affect the equilibria and the pH. In pure water, a decrease in pH of about 0.45 occurs as the temperature is raised by 25 °C. In water with a buffering capacity imparted by bicarbonate, carbonate, and hydroxyl ions, this temperature effect is modified. The pH of most raw water lies within the range 6.5–8.5.

3.4.2 pH Relationship with water-quality parameters
The pH is of major importance in determining the corrosivity of water. In general the lower the pH is the higher the level of corrosion. However, pH is only one of a variety of factors affecting corrosion.

3.5 Electrical Conductivity (EC)
In drinking water, the salty taste produced by chloride depends upon the concentration of the chloride ion. Water containing 250 mg/L of chloride may have
a detectable salty taste if the chloride came from sodium chloride. The recommended maximum level of chloride in U.S. drinking water is 250 mg/L.

Some sources of Chloride Ions:
- River streambeds with salt-containing minerals
- Runoff from salted roads
- Mixing of seawater with freshwater
- The Use of Water softeners
- Irrigation water returned to streams
- Chlorinated drinking water

Salinity is the total of all non-carbonate salts dissolved in water, usually expressed in parts per thousand (1 ppt = 1000 mg/L). Unlike chloride (Cl\(^{-}\)) concentration, salinity is a measure of the **total** salt concentration, comprised mostly of Na\(^{+}\) and Cl\(^{-}\) ions. Even though there are smaller quantities of other ions in seawater (e.g., K\(^{+}\), Mg\(^{2+}\), or SO\(_4\)\(^{2-}\)), sodium and chloride ions represent about 91% of all seawater ions. Salinity is an important measurement in seawater or in estuaries where freshwater from rivers and streams mixes with salty ocean water. The salinity level in seawater is fairly constant, at about 35 ppt (35,000 mg/L), while brackish estuaries may have salinity levels between 1 and 10 ppt. Since most anions in seawater or brackish water are chloride ions, salinity can be determined from chloride concentration. The following formula is used:

\[
\text{Salinity (ppt)} = 0.0018066 \times \text{Cl}^{-}\ (\text{mg/L})
\]

A Chloride Ion-Selective Electrode can be used to determine the chloride concentration, which is converted to a salinity value using the above formula. Salinity can also be measured in freshwater. Compared to seawater or brackish water, freshwater has much lower levels of "salt ions" such as Na\(^{+}\) and Cl\(^{-}\); in fact, these ions are often lower in concentration than hard-water ions such calcium (Ca\(^{2+}\)) and bicarbonate (HCO\(_3^-\)). Because salinity readings in freshwater will be significantly lower than in seawater or brackish water, readings are often expressed in mg/L instead of ppt (1 ppt = 1000 mg/L).
Salinity is also of interest in bodies of water where seawater mixes with fresh water, since aquatic organisms have varying abilities to survive and thrive at different salinity levels. Saltwater organisms survive in salinity levels up to 40 ppt, yet many freshwater organisms cannot live in salinity levels above 1 ppt.

3.6 Multi criteria analysis method of GIS

GIS is a software and hardware system that is designed to capture, manage, manipulate, analyze, model and display spatially-referenced data to solve complex planning and management problems, especially those concerning the natural environment (Maguire et al., 1991). GIS, which combines computer graphics techniques and databases, can become a platform which integrates knowledge and expertise from different disciplines and which is easily integrable with analytical techniques, such as remote sensing, interferometry, statistics and also operations research and management science (Fischbeck, 1994). Optimization techniques have been successfully integrated with GIS technology for route planning and facility location and multicriteria methods are useful within a GIS framework, with special reference to their joint use as a largely self-contained methodology for site selection and decision support (see for instance Janssen and Rietveld, 1990; Carver, 1991; Joerin, 1995; Laaribi, 1995). The problem situation that in this case requires a strong connection between analytical techniques and GIS technology has to be seen in a global context of knowledge structuring.

3.7 Digital Elevation Model (DEM)

A digital elevation model (DEM) is a digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM). DEM is one of the most important factors in the study. That can be used in flow calculations, catchment defining, and slope measurements of a Nilwala river basin.

3.8 Contours

The study area is covered with 80, 81, and 86,87,90,91 sheets of 1:50,000 scale maps. Contours created from merging all those 1:50000 sheets.
3.9 Data Processing, Transformation & Weighting

3.9.1 The Geodatabase

The above data layers and attributes collected from various sources were in different formats. Therefore, it was essential to convert all these data formats into a common database. ArcGIS geodatabase data model was selected due to many advantages in the model. The geodatabase is the common data storage and management framework for ArcGIS. It combines "geo" (spatial data) with "database" (data repository) to create a central data repository for spatial data storage and management (ESRI, 2010). Geodatabase is simply work as a common data storage which can be used to store various data types such as feature classes, attribute tables, raster datasets, network datasets, survey measurements, terrain datasets etc. In addition, sophisticated rules and relationships can be applied on the data stored in a geodatabase to maintain the high-precision of the dataset.

There are three types of Geodatabase:

- Personal Geodatabase
- File Geodatabase
- ArcSDE Geodatabase

A personal geodatabase was created in this purpose considering the amount and the types of the data available. A personal geodatabase is stored in an MS Access database (mdb) format which allows a single editor and single user at a time. Even though there are some limitations in personal geodatabases, it was selected due to some advantages which are very useful in the study. Especially, a personal geodatabase could be accessed directly through MS Access for attribute data handling and analysis. The feature dataset was created using local coordinate system and different spatial references of the data sets were transformed into that.
3.9.2 Feature Dataset

A feature dataset is a collection of related feature classes that share a common coordinate system. Feature dataset works like a sub folder created inside the geodatabase which can be used to store spatial data layers.

The spatial referencing parameters used in the data model are as follows;

Projection: Transverse Mercator
False_Easting: 200,000
False_Northing: 200,000
Central_Meridian: 80.771710
Scale_Factor: 7.000480
Linear Unit: Meter

Geographic Coordinate System: GCS_Kandawala
Angular Unit: Degree (0.017453292519943299)
Prime Meridian: Greenwich
Datum: D_Kandawala
Spheroid: Everest_1830
Semimajor Axis: 6377276.3449999997
Semiminor Axis: 6356075.41341302401
Inverse Flattening: 300.801699999998

After creating the geodatabase and the feature Dataset all required data layers were imported into the feature dataset. This is very important to prevent the projection errors of the layers and also keep all layers in same format.
Fig 3.2 Flow chart of the Methodology

Study Area

1:50000 Maps
1:10000 Maps
Google Earth

Situation Analysis

Identification of the spatial changes of drinking water issue and the impacts on the physical and human environment in study area

Determination of efficient criteria & factors

1:50000 Map
1:10000 Map
Geological Maps
Hydrological Maps
Climatic Maps
Salinity Data of well water
Population Data
Environmental Sensitive Areas
Google Earth
Other spatial Data

Collection of Data

Data processing & transformation
Converting data to shape file
Georeferencing
Reclassification

Preparing Factor

Data Weighting
Deciding the weight for each layer by the consultation of expert team

Apply the Multi criteria analysis of drinking water availability
Identify the factors for water salinity and scarcity of drinking water in NRB
3.10 Transformation of the data
Data Input layers usually are in different numbering systems and with different ranges. To combine the layers in an analysis each cell for each criteria must be reclassified into a common preference scale. Thus the vector data is transformed to raster format with common preference scale.

3.10.1 Euclidean distance
Euclidean distance is calculated from the center of the source cell to the center of each of the surrounding cells. True Euclidean distance is calculated in each of the distance tools. Conceptually, the Euclidean algorithm works as follows: for each cell, the distance to each source cell is determined by calculating the hypotenuse with x_max and y_max as the other two legs of the triangle. This calculation derives the true Euclidean distance, rather than the cell distance. The shortest distance to a source is determined, and if it is less than the specified maximum distance, the value is assigned to the cell location on the output raster.

![Source cells](Image)

**Figure No 3.3 Determining true Euclidean distance**

The above description is only a conceptual depiction of how values are derived. The actual algorithm computes the information using a two-scan sequential process. This process makes the speed of the tool independent from the number of source cells, the distribution of the source cells, and the maximum distance specified. In this study, Euclidean distance tool was utilized for making distance rasters with Stream network and Forest reserve layers.
3.10.2 Reclassification

The reclassification tools reclassify or change cell values to alternative values using a variety of methods. We can reclass one value at a time or groups of values at once using alternative fields; based on a criteria, such as specified intervals (for example, group the values into 10 intervals); or by area (for example, group the values into 10 groups containing the same number of cells). The tools are designed to allow to easily changing many values on an input raster to desired, specified, or alternative values.

Replacing values based on new information is the most important advantage of the reclassification. It is useful when we want to replace the values in the input raster with new values. This could be due to finding out that the value of a cell should actually be a different value, for example, the land use in an area changed over time.

And other advantage is the Grouping values together. We may want to simplify the information in a raster. For instance, we may want to group together various types of forest into one forest class. In this study all transferred layers into raster were reclassified before weighted overlay using values given by the expertise to each layer classes.
3.10.3 Data weighting

Various factors may have different importance. Thus before the factors are combined, the factors will be weighted or assigned a percentage influence, based on their importance. This step is conducted with the consultation of the expert team.

Multi criteria analysis

Weighted overlay is one of the overlay analysis tools included in the spatial analyst extension is used for this process. Commonly this is used to solve multi criteria problems such as suitability modeling. This technique is used to apply a common scale of values to diverse and dissimilar inputs to create the integrated analysis.

3.10.3 Weighted overlay

The Weighted Overlay tool lets us implement several of the steps in the general overlay analysis process within a single tool.

The tool combines the following steps:

- Reclassifies values in the input rasters into a common evaluation scale of suitability or preference, risk, or some similarly unifying scale
- Multiplies the cell values of each input raster by the rasters' weight of importance
- Adds the resulting cell values together to produce the output raster

The tool only accepts integer rasters as input, such as a raster of land use or soil types. Continuous (floating-point) rasters must be reclassified to integer before they can be used.

Generally, the values of continuous rasters are grouped into ranges, such as for slope, or Euclidean distance outputs. Each range must be assigned a single value before it can be used in the Weighted Overlay tool. The Reclassify tool allows for such rasters to be reclassified. We can either leave the value assigned to each range and assign weights to the cell values in the Weighted Overlay tool later, or you can assign weights at the time of reclassifying. With the correct evaluation scale chosen, simply add the raster to Weighted Overlay. The cells in the raster will already be set according to suitability or preference, risk, or some similarly unifying scale. The output rasters can be weighted by importance and added to produce an output raster.
Weights of the layers were decided by using following table. The attributes and the values were decided by informal discussion with the expertise. These percentages were used for the weighted overlay table.
Chapter 4
Data Analysis and Discussion

4.1. Introduction
This chapter appears the data analyzing part of this thesis. The data were collected by the mention methods in the chapter three. Drinking water availability in Nilwala River basin and there causes and relevant factors are the main analyzing part of this research and some basic data analyzes have done as the approach for this chapter as below.

4.2. Data integration and data analysis
The first stage consists in preparing data obtained from the information system. A digital elevation model (DEM) was created as well as a three-dimensional view of the territory, obtained by contour layer of 1:50000 metric map.

4.2.1 Data clip
Extracts input features that overlay the clip features. Use this tool to cut out a piece of one feature class using one or more of the features in another feature class as a cookie cutter. This is particularly useful for creating a new feature class also referred to as study area or area of interest that contains a geographic subset of the features in another, larger feature class. In this research relevant all of the considerable layers clip with Nilwala river basin. All the clip features model in study area are shown in figure 4.1.
4.2.2 Converting Raster Data

There is able to convert any feature class (polygon, polyline, or point) to a raster with the Feature to Raster tool. For more control over how the features are converted can use any of these:

- Polygon to Raster tool
- Polyline to Raster tool
- Point to Raster tool

- **Polygon features to raster data**
  When the convert polygons, cells are usually given the value of the polygon found at the center of each cell.

- **Polyline feature to raster data**
  When convert polylines, cells are usually given the value of the line that intersects each cell. Cells that are not intersected by a line are given the value of NoData. If
more than one line is found in a cell, the cell is given the value of the first line it encounters when processing. Using a smaller cell size during conversion can alleviate this.

- **Point feature to raster data**
  
  When you convert points, cells are usually given the value of the points found within each cell. Cells that do not contain a point are given the value of No Data. If more than one point is found in a cell, the cell is given the value of the first point it encounters when processing. Using a smaller cell size during conversion may alleviate this.
  
  Model of Converting feature to raster layers is shown in figure 4.2.

![Fig No. 4.2 Model of converting feature to raster](image-url)
4.3. Weighted overlay model

GIS is outlined as a powerful tool for aggregation of information used in multi-criteria analysis. It is also shown that coupled GIS-MCA model is very efficient tool for both functional connection between hierarchic decision levels and determination of the objective priorities. There are many factors which affect to the drinking water availability in Nilwala river basin. The most prudent way to assess and quantify the influence from number of likely factors is to incorporate such variables in to multi-criteria weighted overlay model. In this analysis method can identify the most preferred areas for water availability and can identify where the places of suitable areas for drinking water purposes. This multi-criteria weighted overlay suitability model was created regarding Nilwala river basin. The suitability is always depending on many geospatial factors. Therefore, ten (10) most influential geospatial factors were chosen. The most prominent factors which influence this research could be categorized as follows:

1. Nilwala River Basin
2. Stream Network
3. Rainfall
4. Elevation / slope
5. Forest Reservation
6. Soil Background
7. pH Data
8. Salinity Data
9. Land Use
10. Population

Water availability is not only affect the one factor, but also many factors relating to that. Therefore it is evident that the water availability of the study area has many facets. This cannot do the manually process.

Accordingly, the above individual factors were ranked into 05 classes base on the suitability. The value 5 was given for the areas where the considered factor is presented in most favorable manner for the hydropower projects while value 4, 3, 2 and 1 was given for the next suitability levels.
It is important to note the desired outcome of multi-criteria approach; which involves a use of number of alternatives having many attributes. This act as a useful tool in analyzing alternatives and evaluate the same against their comparative advantages and disadvantages. The outcome of the multi-criteria analysis is the ranking of alternatives which in turn provide us the opportunity to compare between the water availability areas. When an individual factor is considered, that can be classified in to several classes based on the values presented. For an example, rainfall layer can be classified into several classes based on the rainfall values. Then the classes can be assigned a weight base on the influence or the importance to the water availability areas. For an example, for the places where rainfall is less, a lower weight can be assigned while rainfall value is large, higher weight can be assigned. Another main purpose of assigning weights is to convert different units of values presented on the above factors in to a single unit. For an example, rainfall values are in millimeters and distances in kilometers while elevation in degrees. The assignment of weights converts all these values into a single unit such as 0 - 5 which 0 shows lower weight and 5 shows a higher weight. Multi criteria analysis refers to a whole set of procedures addressing a difficult decision on complex situations. Multi criteria analysis provides a resolution paradigm taking into account criteria that are likely to influence the decision.

A criterion is defined as a factor to consider when evaluating a given scenario or appreciating an opportunity of action (Hickey and Jankowski, 1997). Through explicit data processing, criterion and preferences, multi-criteria analysis supports transparency, communication, dialogue and involvement of all stakeholders (Debrincat and Meyère, 1998; Prévil, 2000). MCDA principles not only show practitionners’ evolution but also a major shift in the decision-making process (Roy and Bouyssou, 1993; Debrincat and Meyère, 1998). MCDA makes it possible to deal with multiplicity, divergence and nature (quantitative or qualitative) of criteria in order to find out acceptable compromises (Simos, 1990). Accordingly, the above individual factors were ranked into 05 class base on the suitability. The value 5 was given for the areas where the considered factor is presented in most favorable
manner for the hydropower projects while value 4, 3, 2 and 1 was given for the next suitability levels. Accordingly, the above selected spatial factors were assigned suitable values from 1 to 5 based on their attributes.

4.4 Rainfall

Rainfall is a major decisive factor for spatial variation of water availability. Water availability depends on the amount of rainfall falling to the catchment area. The rainfall values are collected using rainfall collection centers located all over the country. These values should be reasonably interpolated to make a rainfall surface map. Interpolation is always based on a geo statistical theory and often there is more than one option. The following methodology is followed in this study to make the rainfall map.

Annual average rainfall values of rainfall stations point layer interpolated by Inverse Distance Weighted (IDW) method. IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. Cell value is determined by number of points assigned to the search radius and 16 rainfall station’s average value assigns to create annual average rainfall map for the study area. Annual rainfall map of nilwala river basin is shown in Figure number 4.3.

Then annual rainfall map had to be re-classified to a define number of classes to scale factors. As described above, the highest suitable class was assigned 5 and least suitable class was assigned value 1. Assignment of scale factors on each class is shown in table 4.1.
Table No 4.1 Rainfall Distribution and the Assigned Scale Factors on Each Class

<table>
<thead>
<tr>
<th>Rainfall (mm)</th>
<th>Class</th>
<th>Value assign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1410 - 1566</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1566 - 1722</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1722 - 1878</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>1410 - 2034</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2034 - 2190</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
4.5 Stream Network

The main component of the study area is a Nilwala river. It is more important to the study area. Because of the Nilwala river is based to define the watershed or basin.

Figure No 4.3 Annual rainfall map of Nilwala river basin

Source: Field Survey 2014
area. As well as surface water drainage system depend on the river and tributaries network. But the some areas of the surface water were block with river bank erosion, escape river bed and sedimentary deposition. Like these environmental conditions impact to the water salinity variations and diverse of pH values. In this weighted overlay model assigned to value for the stream network. The buffers are created by 100 meter in 5 levels. That map is representing in figure 4.5. Figure 4.4 is shown model of Euclidean distance model.

Figure 4.4 Model of Euclidean distance
Reclassified Stream Network categories Map of Nilwala River Basin

Legend
- DSD Boundary
- Nilwala river basin
- reclassify_river

Value
- 1
- 2
- 3
- 4
- 5

Fig No 4.5 Map of Reclassified stream network in study area

Source: Field Survey 2014
4.6. Land use and Land cover of the area

Land use patterns are useful for identifying possible sources of pollutants. Land use within a watershed is classified into several categories. An example of a few land use classifications are industrial or commercial, farmland, and residential. If there are known pollutants in a water body, a land use of the watershed area could be helpful in identifying where the pollutant or pollutants may have come from. Based on prior land use and water quality studies, certain land uses have been associated with specific contaminants.

The land use is the human utilization of land for their various practices and the land cover is the natural process. Land cover data documents how much of a region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types. Water types include wetlands or open water. Land use shows how people use the landscape – whether for development, conservation, or mixed uses. Land cover can be determined by analyzing satellite and aerial imagery. Land use cannot be determined from satellite imagery. Land cover maps provide information to help managers best understand the current landscape. To see change over time, land cover maps for several different years are needed.

The different types of land cover can be managed or used quite differently. The figure number 4.1 shows the land use and land cover of this area. When consider the land cover most prominent land elements are forest, home garden, paddy and other one is stream network.

The existing land uses also one of the major factors of water availability. Values were assigned for land use classes considering their properties to retain water without evaporating. Therefore, the area covered with forest was assigned 5 as the scale factor other land uses also assigned relevant scale factors based on the characteristics. The scale factors assigned on the different land use categories are listed in the table 4.2 given below.
Table 4.2 Land Use Categories and Assigned Scale Factors for Each Class.

<table>
<thead>
<tr>
<th>Category</th>
<th>Class</th>
<th>Value Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>River</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Buildup area</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Coconut</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Chena</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Channel</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Forest</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Grass land</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Home garden</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Marshy land</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Paddy</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Rubber</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Rock</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Sand bar</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Scrub</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Sea</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Stream</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Tank</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Tea</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>Water body</td>
<td>20</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 4.5 shows the different land use categories presented in the study area extracted from 1: 50,000 topographic maps prepared by the Survey Department. Figure 4.6.1 shows the reclassify land use categories according to the assigned values.
Fig No 4.6 Land use categories in the study area

Source: Field Survey 2014
Fig No 4.6.1 Map of Reclassify Land use categories regarding assigned values

Source: Field Survey 2014
4.7. Slope

The rate of change of the surface in the horizontal and vertical directions from the center of a cell determines the slope. Slope is a crucial factor in determining the availability the water areas. Ground water table in high slop area are very deeper than low slop area. There for high slop areas haven’t well access for ground water availability. But it also varies in order to geological background and soil types in the significant areas.

Northern part the study area is hilly area with rugged terrain. Southern part is plain because it is near to the coastal area. One of the factor of water salinity of this area affected exposing the sea water.

Digital Elevation Model (DEM) created by couture is shown in figure number 4.6. There is identified the slope condition of the study area. As well as created the slope map trough the slope tool. It can be defined the slop gradient in the study area clearly. It will show the figure number 4.7.1.
Slop Map of Nilwala River Basin

Figure No4.7 Slop values in study area
Source: Field Survey 2014

61
Figure 4.7.1 Reclassified slope gradient map

Source: Field Survey 2014
4.8. Soil type

The soil type also one of the major factors of deciding suitability water availability, pH and salinity levels of water. Soil type often influence on water distribution in many ways including infiltration, stability etc. Red-Yellow Podzolic soils are the main soil type in the area and it can be assigned 5 and it is affect for quality of water. Major soil type categories of study area are shown in table 4.3 below.

Table 4.3 Soil Type Categories and Assigned Scale Factors for Each Class

<table>
<thead>
<tr>
<th>Soil type</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Alluvial soils of variable drainage and texture; flat terrain</td>
<td>4</td>
</tr>
<tr>
<td>2. Bog and Half-Bog soils; flat terrain</td>
<td>2</td>
</tr>
<tr>
<td>3. Red-Yellow Podzolic soils with semi-prominent Al orizon; hilly and rolling</td>
<td>3</td>
</tr>
<tr>
<td>terrain</td>
<td></td>
</tr>
<tr>
<td>4. Red-Yellow Podzolic soils soft or hard laterite, rolling and undulating terrain</td>
<td>3</td>
</tr>
<tr>
<td>5. Red-Yellow Podzolic soils; steeply dissected, hilly and rolling terrain</td>
<td>5</td>
</tr>
<tr>
<td>6. Reddish Brown Earths &amp; Immature Brown Looms; rolling, hilly and steep terrain</td>
<td>4</td>
</tr>
<tr>
<td>7. Regosol on recent beach sand; flat terrain</td>
<td>1</td>
</tr>
</tbody>
</table>
Soil Map of Nilwala River Basin

**Legend**

**CATEGORY**

- Alluvial Soils of variable drainage and texture; flat terrain (1)
- Bog and Half-bog Soils; flat terrain (3)
- Red-Yellow Podzolic Soils with semi prominent Al horizon; hilly and rolling terrain (1)
- Red-Yellow Podzolic Soils with soft or hard laterite; rolling and undulating terrain (2)
- Red-yellow Podzolic soils; steeply dissected; hilly and rolling terrain (1)
- Reddish Brown Earths and Immature Brown Loams; rolling, hilly and steep terrain (1)
- Regosols on recent beach sands; flat terrain (2)

**Figure No 4.8 Soil types of study area**

Source: Field survey 2014
4.9 pH data
The term pH comes from the French, pouvoir or hydrogen power. Soil reaction is an indication of the acidity or basicity of soil and is measured in pH units. The scale ranges from 0 -14 with pH 7 as the neutral point. At pH 7 Hydrogen ion concentration [H+] equals the hydroxyl ion concentration. From pH 7 – 0 the soil is increasingly more acidic; from pH 7 – 14 the soil is increasingly more alkaline (basic) (GUPTA 1999)

4.9.1 Importance of Soil pH
The soil pH is easily determined and provides clues about other soil properties. The soil pH greatly affects the solubility of minerals. Strongly acidic soils (pH 4-5) usually have high toxic concentrations of soluble aluminum and manganese. Most minerals are more soluble in acidic soils than in neutral or slightly basic solutions. The soil pH also influences plant growth by the pH effect on activity of beneficial microorganisms. Most nitrogen fixing legume bacteria are not very active in strongly acidic soil. Fungi usually tolerate acidity better than do other microbes.

On mineral soils most agriculture crops do best in slightly acidic soils (pH 6.5) on organic soils about pH 5.5. non leachate soils or those high in calcium may have pH values to 8.5 with increased exchangeable sodium, soil may reach values of pH 10, plants on soils of pH greater than about 9 usually have reduce growth of even die. Some plants are tolerant of high salt or high pH values (GUPTA, 1999). So this is more important factor to availability of drinking water in the Nilwala river basin.

The pH of a solution is the negative common logarithm of the hydrogen ion activity: pH = -log (H+) in dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration. The pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. An increased carbon dioxide concentration will therefore lower pH, whereas a decrease will cause it to rise. Temperature will also affect the equilibria and the pH. In pure water, a decrease in pH of about 0.45 occurs as the temperature is raised by 25 °C. In water with a
buffering capacity imparted by bicarbonate, carbonate, and hydroxyl ions, this temperature effect is modified. The pH of most raw water lies within the range 6.5–8.5.

4.9.2 pH Relationship with water-quality parameters

The pH is of major importance in determining the corrosivity of water. In general the lower the pH is the higher the level of corrosion. However, pH is only one of a variety of factors affecting corrosion.

Below figure represent the Distribution pattern of pH condition in Nilwala River Basin.
Figure No 4.9 pH Distribution pattern map of Nilwala River Basin

Source: Field survey 2014
4.10 Electrical Conductivity (EC)

In drinking water, the salty taste produced by chloride depends upon the concentration of the chloride ion. Water containing 250 mg/L of chloride may have a detectable salty taste if the chloride came from sodium chloride. The recommended maximum level of chloride in U.S. drinking water is 250 mg/L.

Some sources of Chloride Ions:
- River streambeds with salt-containing minerals
- Runoff from salted roads
- Mixing of seawater with freshwater
- The Use of Water softeners
- Irrigation water returned to streams
- Chlorinated drinking water

Salinity is the total of all non-carbonate salts dissolved in water, usually expressed in parts per thousand (1 ppt = 1000 mg/L). Unlike chloride (Cl−) concentration, salinity is a measure of the total salt concentration, comprised mostly of Na+ and Cl− ions. Even though there are smaller quantities of other ions in seawater (e.g., K+, Mg2+, or SO42−), sodium and chloride ions represent about 91% of all seawater ions. Salinity is an important measurement in seawater or in estuaries where freshwater from rivers and streams mixes with salty ocean water. The salinity level in seawater is fairly constant, at about 35 ppt (35,000 mg/L), while brackish estuaries may have salinity levels between 1 and 10 ppt. Since most anions in seawater or brackish water are chloride ions, salinity can be determined from chloride concentration. The following formula is used:

Salinity (ppt) = 0.0018066 × Cl− (mg/L)

A Chloride Ion-Selective Electrode can be used to determine the chloride concentration, which is converted to a salinity value using the above formula. Salinity can also be measured in freshwater. Compared to seawater or brackish water, freshwater has much lower levels of “salt ions” such as Na+ and Cl−; in fact, these ions are often lower in concentration than hard-water ions such calcium (Ca2+) and bicarbonate (HCO3−). Because salinity readings in freshwater will be
significantly lower than in seawater or brackish water, readings are often expressed in mg/L instead of ppt (1 ppt = 1000 mg/L).

Salinity is also of interest in bodies of water where seawater mixes with fresh water, since aquatic organisms have varying abilities to survive and thrive at different salinity levels. Saltwater organisms survive in salinity levels up to 40 ppt, yet many freshwater organisms cannot live in salinity levels above 1 ppt. In the below figure have shown salinity distribution pattern pf Nolwala River Basin according to the collected field data.
Figure No 4.10 Salinity Distribution Pattern of Nilwala River Basin

Source: Field survey 2014
4.11 Forest reservation area

One of the basic components in this study area is forest reservation. Particularly river basins are nourishing with forest reservations. Because of this forests are control the evaporation and save the ground water infiltration.

Therefore all of the forest reservation areas were assigned scale factor 5 in weighted overlay model while other areas were assigned 1. Forest reserves of the study area are shown by figure number 4.11.

Regarding the distance from reserve by few meter levels created multiple buffer zones to defining the spatial variation of water availability. So reclassed multiple buffer map shown in figure number 4.11.1.
Map no 4.11 forest reserves of the study area

Source: Field Survey 2014
Fig No 4.11.1 Buffer zones of Forest reserve

Source: Field Survey 2014
4.12. Population density and population of the study area

Population data of this research is one of most important analyzes for this research because the population acts a significant role of this research. Therefore drinking water is a basic requirement of the people. There are 28 DSDs included in study area. Most of them are concerned to the Matara District. Others are comprised to Galle, Rathnapura and Hambantota districts. Among those DSDs, highest population density represent in the Marara DSD. Because of that Matara is the major urban area of the study area. Likewise lowest population density represent in the Neluwa, Akuressa, Tawalama, Katuwana, Kolonna Korale DSDs. Those regions have concentrated the rural and poor human and physical infrastructures. According to these reasons water availability also deferent region to region.

Population must be consider when think the water availability. Because of the uses of water resources are population. There for all of the DSD's population in the study area reclassify according to the value and divided the 5 classes.

Table No 4.4 Population categories

<table>
<thead>
<tr>
<th>Population classes</th>
<th>Value assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>15000 - 40000</td>
<td>5</td>
</tr>
<tr>
<td>40000 - 65000</td>
<td>4</td>
</tr>
<tr>
<td>65000 - 90000</td>
<td>3</td>
</tr>
<tr>
<td>90000 - 115000</td>
<td>2</td>
</tr>
<tr>
<td>115000 - 140000</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure No 4.12 Population Density in Study area

Source: Field Survey 2014
4.13. Assigning Weights on the Factors

In the weighted overlay model, all the above factors were weighted based on the significance of each factor on deciding the water availability areas in spatially. All the factors are always not equally important, one factor may be highly important in the analysis while some other factor may not that much important. Therefore, assigning weights on each layer based on the significance of the relevant layer affected to the water quality. However, deciding the significance of each factor is quite difficult because there is no measurement to determine the significance. Therefore informal discussions held with professionals were the base for the comparative significant value for each factor with other factors. According to that relative values were assigned to the relevant data layers for the weighted overlay map. Weighted values were assigned as shown in the table number 4.5 below.

<table>
<thead>
<tr>
<th>Factors considered</th>
<th>Assigned weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream network</td>
<td>10%</td>
</tr>
<tr>
<td>Rainfall</td>
<td>20%</td>
</tr>
<tr>
<td>Slope</td>
<td>15%</td>
</tr>
<tr>
<td>Forest reserve</td>
<td>12%</td>
</tr>
<tr>
<td>Soil</td>
<td>15%</td>
</tr>
<tr>
<td>pH</td>
<td>5%</td>
</tr>
<tr>
<td>Salinity</td>
<td>10%</td>
</tr>
<tr>
<td>Land use</td>
<td>8%</td>
</tr>
<tr>
<td>Population</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multi criteria problems such as site selection and suitability models. Overlays several rasters using a common measurement scale and weights each according to its importance.
As the weighted overlay analysis, first of all define the problem, break the model into sub models, and identify the input layers. According to this research input layers are; Such as Stream network, Rainfall, Slope, Forest reserve, Soil, pH, Salinity, Land use, Population also.

Since the input criteria layers will be in different numbering systems with different ranges, to combine them in a single analysis, each cell for each criterion must be reclassified into a common preference scale such as 1 to 5, with 5 being the most favorable. An assigned preference on the common scale implies the phenomenon's preference for the criterion. The preference values are on a relative scale.

In this water availability model, there are 9 input criteria: Stream network, Rainfall, Slope, Forest reserve, Soil, pH, Salinity, Land use, Population. The Stream network is reclassed on a 1 to 5 scale according to importance of the relevant distance. Therefore it is needed to be creating the buffers regarding distance from 100m, 200 m, 300 m, and 400 m to 500 m. Therefore, the most favorable and assigned the higher values to 100m. As the stream network become far, they are assigned decreasing values, with the remote buffer (500m) being assigned a 1. Other reclassification process also applied the same to the other criteria regarding the favorable aspects. Each of the criteria in the weighted overlay analysis may not be equal in importance. Therefore did the weight regarding important criteria more than the other criteria. For instance, in this water availability model, forest reserve areas were assigned higher value (12%) than the other land use (8%).

The figure 4.13 shows the weighted overlay model. The figure 4.12 shows the weighted overlay map created with the model. The result was categorized in to five categories and labeled as Superb, Very Good, Good, Fair and Least Suitable based on the degree of suitability.
Figure 4.13 Weighted Overlay map of Drinking water availability in Nilwala River Basin

Source: Field Survey 2014
4.14 Impact of hydrological condition for spatial water availability

The water continuously moves through the vast global cycle, in which it evaporates from vegetation, lakes, oceans and lead to the formation of clouds. The clouds thus created precipitated though the atmosphere as rain or snow and reach towards vegetation, lakes, rivers and oceans to begin another cycle. The approach of the hydrological condition is to describe the physical mechanisms of the constitution of the water flows starting from the precipitation (rainfall). It also aims at why all the rainfall
does not reach towards water streams. Only a detailed investigation would enable us to properly identify and quantify the gap between precipitation and the river flow. The rainfall gap could be attributed to;

(a) Losses due to infiltration to the ground: This is largely due to geology, slope of the terrain and vegetation.

(b) Losses due to evapo-transpiration: This is essentially due to the evaporation of water through vegetation (will vary with the types of plants) and type of weather (wind speed, temperature and solar radiation).

4.15 Data Collection and Analysis

The data available for this study can be categorized in to following;

(a) Rainfall data collected by Department of Meteorology.

(b) pH and salinity data was collected by National Water Supply & Drainage Board.

(c) Layers of digital information (topographic maps) available in the form of contours, soil types, and land use.
Chapter 5
Conclusions & Recommendations

GIS is an important tool for Mapping, Analysis, and Visualization of spatial data. Its special capability for multi criteria analysis was very useful in developing the model discussed in this research. Furthermore, analysis tools such as 3D Analysis, Proximity Analysis, Hydrology Analysis were extensively used in this study.

The Nilwala river watershed is located entirely in the Matara district covering 960 sq. km. The river rises in the vicinity of Deniyaya at an altitude of 1050m and flows into the sea at Matara after traversing nearly 72km. The rainfall of the basin increases from south to north with the increasing elevation. In respect of the rainfall pattern, the Nilwala upper catchment belongs to the wet and ultra wet zones while the lower basin belongs to the intermediate zone. To reiterate, rainfall of the Nilwala river basin increases from south to north with the increasing elevation and altitude. The topography strongly influences the spatial distribution of rainfall and comparatively high rainfall is observed in the headwaters of the Nilwala River at the Deniyaya region.

If climate change as a result of global warming manifests, the need for freshwater storage will become even more acute. Increasing storage through a combination of groundwater and large and small surface water facilities is critical to meeting the water of the twenty-first century. This condition severe in drinking water because of it most of regions were developing react with natural environment.

In this research define all of the Nilwala basin area. Therefore I have to collect data randomly. According to that annual rainfall pattern classified to 5 classes. Rainfall pattern was varying 2034 to 1410. Elevation is gradually becoming lower rainfall also becoming decrease. So it is affect to the scarcity of lower catchment area. In addition to that rainfall becoming decrease, water table contaminate with chemical composition because of collecting water in one position.
Recommendations

As well as major factor of the water availability in Nilwala basin is land use pattern. Especially major factor of drinking water availability is forest reserve, slope and plantation type. According to that forest nearly areas more suitability for drinking water. In the area couture intervals 700 – 500 is more suitable for drinking water saturation area.

Water is essential for all socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users, and excessive pressure on the environment. The increasing stress on freshwater resources brought about by ever rising demand and profligate use, as well as by growing pollution worldwide, is of serious concern. According to that when consider as socially importance of the research is that can recommend to another area to solve drinking water issues. It is most useful social impact of this research.

The model in this research is very flexible and has the facility to build and expand further to accommodate more information layers pertaining to all aspects of planning and development of hydro resources. It could be a deployment of a diversion of water for a drinking water project or an irrigation scheme or planning for a major development project, to the river basin. The model developed in this research has the flexibility to integrate all such factors and there by transforming the same towards a complete hydro resource assessment tool. Due to time and resource constraints, it was not possible to utilize all the data available for the study area. However, judging by the findings, this research can be considered as the first step drinking water resource planning for small scale water project for rural communities.

It is possible to further strengthen the hydrology model developed in this research by using more rainfall and flow data and conducting validation tests with a view to develop runoff coefficients accurately. One of the key areas to be investigated in future studies is to develop sub catchment runoff coefficients instead of a single runoff value for a larger
river basin. This is very crucial when a river basin spread across a different climatic zones and comprise of different land uses and soil properties. Factors regarding the spatial variation of the drinking water availability dominate that vary important factors are land use, forest reserve, rainfall, slop, etc. As well as gradually becoming increase the well water, stream water and ground water salinity. Because of that excavate the irrigation channel for cultivation through the Nilwala project. In water related area after remain the saline water, and then spread the relative areas.

According to this research impact of the water scarcity is uneven distribution of water table. As well as various pH and salinity levels also affect to the drinking water scarcity.

The GIS base analysis in this research is very cost effective and quicker than the traditional approach of identifying spatial variation of drinking water availability areas. One of the salient features of this research is the fact that majority of the work can be completed by a desk study. Accordingly, valuable time and resources, which otherwise would have committed for field assessment work were saved. One of striking feature of study is that its capability to identify most prominent drinking water area relatively short period of time. It is very good opportunity to development of rural drinking water requirement. Most of the people are confront drinking water issues. Factors of this condition are changing the natural environment according to the demand of human society.
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