Technical Paper

ASSESSMENT OF WATER DEMAND IN LANGAT CATCHMENT USING WATER EVALUATION AND PLANNING (WEAP)

S., Azlinda and A. F., Mohd
Civil Engineering Faculty, Universiti Teknology Mara, UiTM

Abstract

The subject of water supply and demand is one of the central issues facing by the atmospheric sciences community today. The high growth rate of population has drawn heavily on the natural resources base on Malaysia particularly in Langat catchment, Selangor. This sudy investigates the water supply and demand situation in Langat catchment and evaluates a new accounting and analytical approach based on Water Evaluation and Planning (WEAP) system in result to major stresses of demand and supply in terms of water availability at the catchment scale. Operating on the basic principles of water balance, WEAP is applicable to municiple or agricultural systems, single catchment or complex transboundary river systems. Using WEAP, this study investigate the treand of supply and demand in Langat catchement, assessing the water availability in Langat Catchment and investigate the water storage capacity on supply and demand in Langat catchment. The assessment model is computed based on three (3) scenarios – Scenario 1: Higher Population Growth, Scenario 2:Water Year Method and Scenario 3: Extended Dry Climate Sequence, in order to see how Langat catchment respond to the supply of water resources.The study founds that Langat catchment is relatively sensitive to the growth of demands, suggesting that the slight changes in population growth will alter the present water availability. Based on the result, of the population increased to 7% with the incremental of climate variation from the current condition, the study area tends to experience a water scarce problem in the future.

Keywords: Water Evaluation and Planning, Water Demand, Water Supply, Langat catchment.

1. INTRODUCTION

Development has been the basis for the socio-economic development in Malaysia, where water resources and water supply are available. Lately, water supply situation for the country has changed from one relative abundance to one of scarcity. Over the years, population growth and urbanization, industrialization and the expansion of irrigated agriculture are arresting rapidly increasing in demands and pressure on the water resources, besides contributing to the rising of water pollution (Global Water Partnership, 2000). It is critically vital to develop the knowledge and soft skills that are necessary to safeguard our catchments and river basins without altering the socio-economic development, in order to manage the water resources availability in a sustainable way.

Among these overarching goals of water sustainability and conservation come under the framework for Integrated Water Resources Management (IWRM). From there, water demand managament (WDM) is essential being part of the challenge to sustain the water resources. It is well known that the main principle in WDM is “efficient use of water in order to maintain vital environment flow and to reduce dependence on costly infratructure projects”. For instance, a toilet may be flushed clean or laundry washed with one third than the amount of water that is normally used with equal or better efficiency (Wong, 2009).

Malaysia has experienced extensive economic development since the 1980s, resulting in increasing water demands in the commercial and industrial development centers. Being prepared to becoming fully industrialized nation by 2020, the effort to develop, conserve, utilize and manage this vital resource have to be guided by national perspectives with an integrated and environmentally sound basis. The main concern to the Malaysian goverment lied within the availibilty and sustainability of water resources especially in Selangor, where precious water resources is decreasing (Malaysian Water Sector, 2006). The Selangor and Kuala Lumpur region which is, political, commercial and industrial centre of the nation is the most vital focus for these high demands which are expected to continue their rapid growth into the 21st century. However, it well known that the water resources available within the Selangor and Kuala Lumpur region will not be able to meet the demands in the near future.

Being a foremost industrial state, Selangor have reached to a stage where the demand of raw water exceeds the water availability. In this critical condition, the available water resources within the state will soon face a critical shortfall in meeting the increasing demands. This is especially a great concern since water authority in Selangor is also responsible for water supplies to the Wilayah Persekutuan. The predicted shortfall in water supply necessitates the study of new sources of supply so as to avoid any possible social and economic damage.

Astonishingly, as an alternative, future water management will shift from building new water supply systems to better operating existing ones. The variation of water values in time and space will increasingly motivate efforts to address water scarcity and reduce water conflicts. In dealing with this condition, many integrated tools have been developed purposely to help manage water resources (Harou et al, 2009). System analysis such as hydrological modeling, economic modeling, hydro-economic modelling or system dynamic applied to water resources uses simulation and optimization models to explore the benefits of managing environmental systems as interdependent integrated units. For instance, hydro-economic models represent spatially distributed water resource systems, infrastructure, management options and economic values in an integrated manner. In this particular tool, water allocations and management are either driven by the economic value of water or economically evaluated to provide policy insights and reveal opportunities for better management.

Considering all the above issues, this study utilizes the integrated hydrology / water allocation model, Water Evaluation and Planning (WEAP) to evaluate the impact of demand and supply on water resources availability, particularly within Langat catchment. Therefore, the investigation consisted on the use of water consumption for human needs, for agricultural (irrigation) and industries in the study area, due to their position along the Langat basin.

1.1 Water Crisis in Selangor and Wilayah Persekutuan

Almost all the population in Selangor and Wilayah Persekutuan benefit form the treated water supply. Only an estimated number of about 5% of the rural population is yet to enjoy the treated water supply. At the beginning of 1998, the metered domestic water consumption was 1, 092 MLD, which is translated into 240 litres per capita per day. For the same year, metered industrial water consumption was 399 MLD with Kuala Lumpur accounted for 37.5% and 34% of the domestic and industrial water consumption respectively from the total comsumption in Selangor and Wilayah Persekutuan. Non revenue water accounts for 39% or 968 MLD of the total water production of 2, 459 MLD. The Detailed Environmental Impact Assessment Study for the Proposed Development of the Sungai Selangor Dam in Hulu Selangor in 1999 shows increasing water demand projection according to the districts in Selangor and Wilayah Persekutuan, as shown in Table 1.1.

Table 1.1: Water Demand Projections for Selangor and Wilayah Persekutuan by Districts up to 2010

District	**Demand (MLD)**			
	1998	**2000**	**2005**	**2010**
Gombak	236.9	249.4	323.3	425.7
Hulu Langat	231.7	280.0	354.9	427.3
Hulu Selangor	80.6	95.0	287.0	455.1
Klang	296.2	338.7	456.8	637.3
Kuala Langat	73.1	72.7	79.1	110.7
Kuala Selangor	52.7	52.1	58.0	70.4
Petaling	591.7	671.5	822.0	1 025.7
Sabak Bernam	48.5	52.5	70.2	81.1
Sepang	46.9	67.3	138.4	224.0
Wilayah Persekutuan	796.4	990.9	1 268.5	1 590.1
Total	**2 454.7**	**2 870.1**	**3 858.2**	**5 047.4**

Source: *The Detailed Environmental Impact Assessment Study for the Proposed Development of the Sungai Selangor Dam in Hulu Selangor by SMHB Sdn. Bhd., 1999.*

As seen from the table, the total population of Selangor and Wilayah Persekutuan is projectd to be approximately 8, 080, 823 in the year of 2010. Based on the guidelines given by Jabatan Kerja Raya (JKR) and Malaysian Water Association (MWA), the projection for the per capita domestic consumption rates are as follows in Table 1.2.

Table 1.2: Per Capita Domestic Consumption

Year	**Urban**	**Rural**	**WP KL**
	Unit: litres/capita/day		
1998	260	170	270
2000	285	190	310
2005	305	200	315
2010	315	210	320

Source: *The Detailed Environmental Impact Assessment Study for the Proposed Raw Water Transfer Project from Pahang to Selangor by MAB Environmental Consultants Sdn. Bhd., 2000.*

Based on the Final Report, Volume 1: Main EIA Report for the Proposed Raw Water Transfer Project from Pahang to Selangor, August 2000, the Government has embarked on various developments in the region of Selangor, which bounds to attract local and overseas instruments. The developments include Putrajaya and Cyberjaya, which lie in the Multi-Media Corridor as well as development of the new airport in the shape of KLIA and much more bigger port operations at Port Klang. These development will bring more population which then will contribute towards water demand.Wide publicity was given to the serious water shortage probelems in Selangor during the first eight (8) months of 1998. A low observed rainfall and runoff during the period of March to September 1998 caused a severe water supply shortage in Klang Valley. This led to the widespread water rationing in many parts of Selangor and Wilayah Persekutuan, affecting over one million consumers and also hundreds of industries.

The water crisis in 1998 illustrated the needs for sensible management of water resources and distribution. It emphasized the needs of additional water resources apart from the existing water resources to avoid the recurrence of the experience. There was much damage done to the social and economic well being of the population during the crisis.
There was significant cost incurred by the authorities in the immediate solution to the 1998 water crisis. Based on the figures from JBA Selangor, the cost of handling the crisis by the Government ran into about RM 56 million. The crisis affected an approximately 1.8 million consumers and 690 housing schemes. Cost incurred were dedicated for the rental and maintenance of mobile trucks from provate institution and Government agencies such as Army, operational costs, emolument of workers and purchase of mobile treatment facilities for treatment of water such as the one used at the lake in Mines Wonderland. Extra trucks were required to distribute water to the affected people and extra man-hours were spent to sort out the problem.Viewing at the projected demands for Selangor and Wilayah Persekutuan, the need for additional water supply is crucial and

critical. The surface water resources available in Selangor are insufficient and neither are the alternatives feasible.

1.2 Importance of the Hydrologicl Models towards Water Demand and Supply

Water Resource models perform one kind of function for one kind of environment, for example, hydrologic modeling of watershed, hydraulic modeling of rivers, and water quality modeling of lakes.

Hydrological models have become the basic tool in hydrology *(Edouard, 2005*). The development of hydrological models was closely linked with the increasing power of computer processing, which strated in early 1960s. It is now vital tools for planning, design, and management of hydrologically related infrastructure. Over the years, hydrological models can also be used as a tool to improve a system which required the decision making and policy analysis.

The numbers of hydrological models available has increased to an extent where selection of an appropriate models for a particular system has become a relatively difficult to choose one from amongst the other. Based on that, one could select an appropriate models by looking into the basis of their:-

Table 1.3: Criteria for hydrological models selection.

Criteria	Description
Function	Perspective models are used to make predictions of catchment behaviour and are used in engineering and regulation studies. Descriptive models are more specifically concerned with testing of conceptual theory and mainly applied in scientific research.
Structure	Three (3) groups of models exist depending on their structure. i. Deterministic models are physically-based and describe cause and effect relationships with mathematical equations; ii. Stochastic models use statistica properties of existing records and probability laws to solve hydrological problems; and iii. Conceptual models average inputs/outputs of an area to get rid of time and space heterogeneities that constitute a hydrological system.
Level of Spatial Disaggregation	Lumped models represent processes in a spatially averaged ways whereas distributed models represent them in a spatially dosaggregated ways.

Source: *A Study of the Development of Water Resources in the Olifants Catchment, South Africa: Application of WEAP Model, 2005.*

These criteria for the selection of model are mainly linked to the nature of the problem to be evaluated and the available resources (data and computing facilities). The nature of hydrologic effects depends on changes in the climatic conditions and the water resource characteristics of the region.

2. RESEARCH OUTLINES

2.1 Objective and Scope

This study intended to investigate the trend of demand and supply within Langat catchment, based on current condition and future condition. It focuses on the assessment of Water Evaluation and Planning (WEAP) model and how the Langat catchment could respond to major stresses of demand and supply in terms of water availability at the catchment scale.

This study also comprising the investigation on the potential factors of increasing or decreasing on demand and supply in the Langat catchment.

This study has been conducted in order to achieve the following objectives:

- To investigate the trend of supply and demand in Langat catchment;
- To assess the water availability in Langat Catchment using Water Evaluation and Planning (WEAP); and
- To investigate the water storage capacity and factors of fluctuation on supply and demand in Langat catchment.

This will lead to a better solution with the appropriate suitable water demand and supply model for the state of Selangor in order to balance the projected amount of demand and supply. Furthermore, the result from the analysis can be used in order to propose the alternative suitable technical and non-technical means in order to reduce water demand, particularly in Langat catchment.

Considering the importance of the above issues pertaining water resources and changes in climate, this study utilises the integrated hydrology and water allocation model, Water Evaluation and Planning (WEAP) to evaluate the impact of water resources availability towards the demand, development, and changes in climate.

2.2 Water Evaluation and Planning (WEAP)

Water Evaluation and Planning (WEAP) was developed by the Stockholm Environment Institute (SEI) and is a unique water resources and planning software where it stimulates hydrologic pattern based on climatic input. This is a vital tool to inform the society on the adaptation of climate change towards the policy making. WEAP uses climatic inputs such as precipitation, temperature, humidity, infiltration, and wind speed. All these inputs can be derived from baseline scenarios, and used to predict the amount of precipitation that falls into a particular area, run-off into streams, recharge of groundwater, or evatranspiration through vegetation.

WEAP also allows user to build scenarios with scenarios, for instance, increase in temperature or heavier rainfall, along with assumptions towards water demand, infrastructure and regulation. All human activities can be incorporate in WEAP in order to predict water shortage and water quality base on a model scenario.

WEAP can be used to demonstrate the result of water demand quantity is met during a month, the degree of potential water shortage, level of reservoir storage for future use and measurement of water quality. WEAP also assesses the adequacy of environmental water flows, the level of hydropower generation capacity, the evolution of soil moisture, evatranspiration rates, volume of surface run-off and the rate of groundwater recharge.

The WEAP model has a long history of development and used in the water planning arena (*SEI, 2001*). WEAP applications generally involve the following steps :-

- Problem definition including time frame, spatial boundary, system components and configuration;
- Establishing the 'current accounts', which provides a snapshot of actual water demand, resources, and supplies for the system;
- Building scenarios based on different sets of future trends based on policies, technological development and other factors that affect demand, supply and hydrology; and
- Evaluating the scenarios with regards to criteria such as adequacy of water resources, costs, benefits and environmental impacts.

WEAP has two (2) primary functions (*Sieber et al., 2005*) :-

- Simulation of natural hydrological processess (e.g., evatranspiration, runoff and infiltration) to enable assessment of the availability of water resources within a catchment; and
- Simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (e.g., consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use.

In order for users to allow simulation of water allocation, the elements that comprise the water demand-supply system and their spatial relationship are characterised for the catchment under consideration. The system is represented in terms of its various water sources (for instance surface water, groundwater, desalination and water re-use elements), withdrawal, transmission, reservoirs, wastewater treatment facilities and water demands (user-defined sectors but typically comprising industry, mines, irrigation, domestic and supply). The data structure and level of model detail can be customized (by combining demand sites) to correspond to the requirements of a particular analysis and constraints imposed by limited data. A graphical interface facilities visualisation of the physical features of the system and their layout within the catchment (*Purkey and Huber-Lee, 2006; Sieber et al., 2005*). One of the advantage from this perceptive graphical interface provides a simple yet powerful means for constructing, viewing and modifying the system and its data. The mian functions where loading the data, calculating and reviewing the results are handled through an interactive screen structure. WEAP also has a flexibility to accommodate the evolving needs of the user, such as availability of better information, changes in policy, planning requirements or local constrints and conditions.

2.3 Methodology

In this study, the primary objective is to evaluate the WEAP's ability to simulate the rainfall-runoff process of the Langat catchment. These model lead is then used to assess the impact of suggested water development projects within Langat catchment, and suitable water demand and supply model for Langat catchment is then proposed in order to balance the projected amount of demand and supply.

Hydrological processes occurring in the catchment were modeled and streamflow, simulated on a monthly time-step, was compared to the naturalized flow series available. Once the proposed model was simulating the naturalized flow series satisfactorily, water demand sites were added and WEAP was run in its water allocation mode using the rainfall-runoff parameters determined from the first phase. This was done in order to assess WEAP's ability to simulate water resources and water uses in the catchment. Simulated streamflow was compared to measured flow from four (4) different gauging stations located on the Langat main stream.

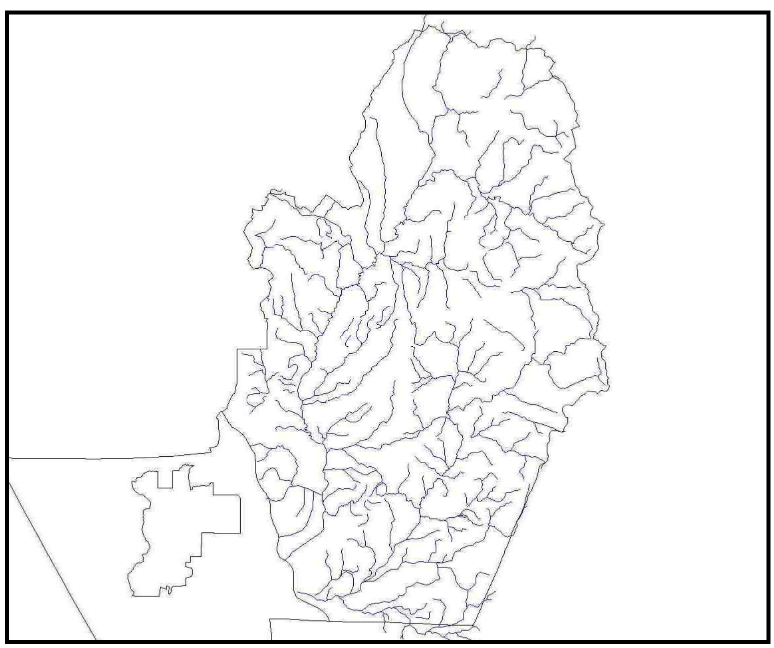

Figure 2.1: Schematisation of the Study Area in WEAP Model

The model as it used in this study operates at the WEAP subcatchment scale and on a monthly time-step. The period of the study was from 2000 – 2010, the period which naturalized flow data are available.

3. CASE STUDY OF LANGAT CATCHMENT

The Langat catchment is an important water catchment where it provides raw water supply and other facilities to approximately 1.2 million of people within the basin. Important conurbations served include towns such as Cheras, Kajang, Bangi, Government Centre of Putrajya and others. There are two (2) reservoirs within the catchment, which is Semenyih and Hulu Langat Dam and eigth (8) water treatment plants which provides clean and safe water to the users.

Langat river has a total catchment area of approximately of 1815 km^2. It lies within latitudes of 2^o 40'M 152"N to 3^o 16'M 15"N and longitudes of 101^o 19'M 20"E to 102^o 1'M 10"E. The length of the main river is 141 km and mostly situated 40 km east of Kuala Lumpur. The Langat river has a several tributeries, with the principal ones being the Semenyih river, the Lui river and the Beranang river. Two (2) reservoirs which Langat dam and Semenyih dam cater the for this catchment. The Langat dam which was built in 1981 with the catchment area of 54 km^2, while the Semenyih dam was built in 1942 with the catchment area of 41 km^2.

The use of Langat river is not only limited to water supply but also for other purposes such as recreation, fishing, effluent discharge, irrigation and even sand mining. Due to various activities involving the Langat river, it is vital to evaluate the demand and water resources pertaining this river. This study investigates the water supply and demand situation in Langat catchment, and formulates a new accounting and analytical approach based on WEAP model in result to major stresses of demand and supply in terms of the water availability at the catchment scale.

Langat catchment is drained by three (3) major tributeries – Langat River, Semenyih River and Labu River. However, the research undertaken the upper part of Langat catchment. The main tributary, Langat river flows about 182ckm from the main range (Banjaran Titiwangsa) at the Northeast of Hulu Langat District in south-southwest direction, and draining into the Straits of Malacca. Both the Langat and Semenyih River originate from hilly and forested areas in the western slope of Banjaran Titiwangsa, northest of Hulu Langat. The main reach of Semenyih River can be considered to start from the Semenyih Dam flowing south-southwest direction through the town of Semenyih, Bangi Lama and finally merges with Langat River at about 4km to the east of Bangi Lama town. Semenyih Rive is also supplemented by Beranang River and Pajam River. Both of these rivers originate from the northern part of Seremban District, Negeri Sembilan.

3.1 Data Requirement

All data used in the current study were obtained from the following agencies tabulated in Table 3.1

Table 3.1: Tabulation of Data Required and Related Agencies

No	Data Required	Related Agencies
1.	Satellite image	Department of Survey and Mapping Malaysia (JUPEM)
2	Catchment map	Department of Survey and Mapping Malaysia (JUPEM) Drainage and Irrigation Department (DID)
3.	Landuse map	Federal Department of Town and Country Planning Peninsular Malaysia
4.	Hydrological data	
	▪ Rainfall station data	Drainage and Irrigation Department (DID)
	▪ Groundwater recharge	
	▪ Evaporation	
	▪ Streamflow	
5.	Meteorological data	Local Authority and Mukim
6.	Population	Local Authority and Mukim
7.	Dam Storage	Drainage and Irrigation Department

3.2 Building the Model

In WEAP, models are called "areas". Building the area by adding GIS based Raster and Vector maps to the projected area. The map is ised to orient and construct the system and refine the necessary area boundaries. The background vector data can be added from a SHAPEFILE format. This format can be created by most GIS software.

Once the area is open, the Years, Time Steps and Units are set. In this study, the Current Accounts is set to be year 2000 with the Last Year Scenarios to year 2010. The Time Steps per year is set to be 12 and the Time Step Boundary to "Based on Calendar Month", starting with the month of January. The Year 1990 will serve as the "Current Accounts" year for this study. The Current Accounts year is choosen to serve as the base of the model, and all system information (for instance, demand and supply data) is the input into the Current Accounts. The Current Accounts is the dataset from which the scenarios are built. A default scenario, the “Reference Scenario” carries forward the Current Accounts data into the entire project specificied (2000-2010).

River path is drawn in WEAP by clicking on the “River” symbol in the Element window. The direction of the flowing river is bulit from the headwater (upper stream) of the main river. The whole process is contonued by building the entire network of Upper Langat Catchment.

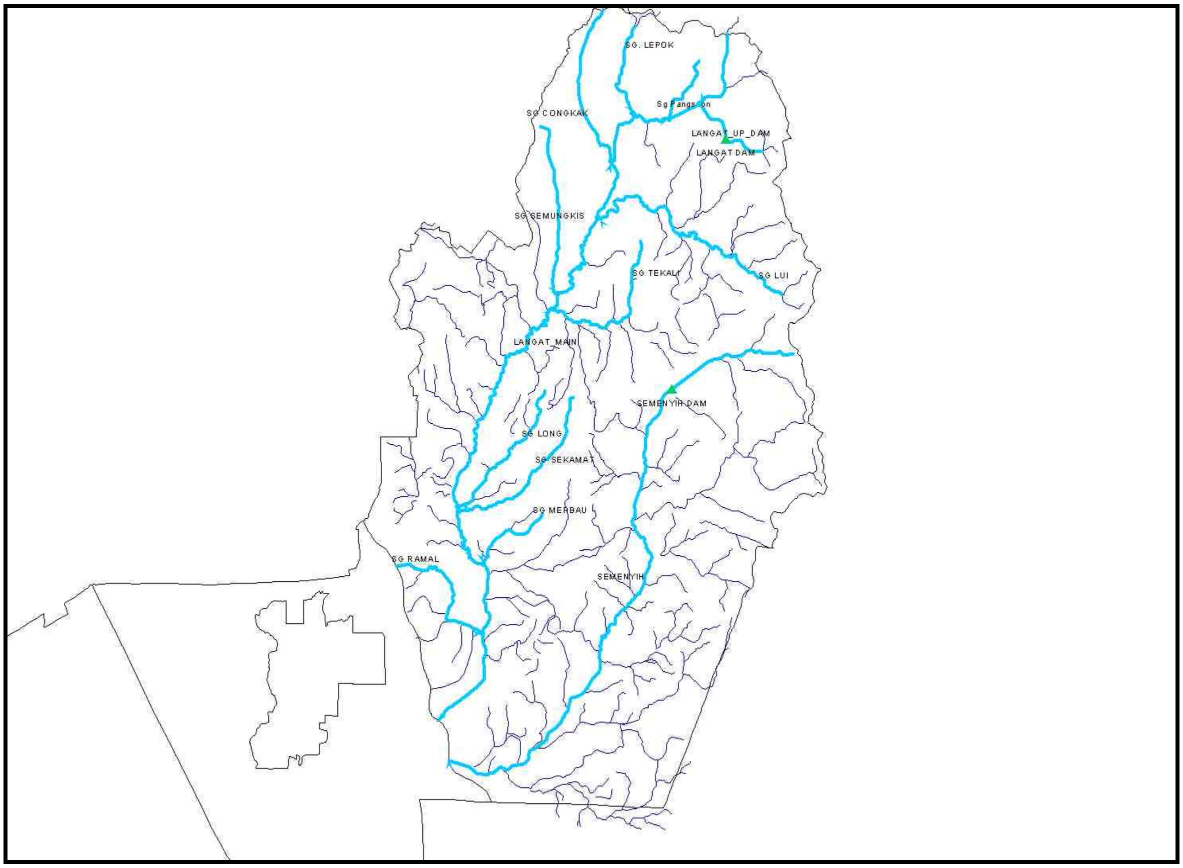

Figure 3.1: Schematic of the River Elements.

3.2.1 Demand Sites

The water demand is the total of water required to meet domestic, commercial, agriculture, institutional and industrial uses. The current water demand for domestic for the basin is estimated at about 300 - 350mld. For Sungai Langat river basin has an estimated total population of 951, 800 (2000). Over the last decade from 1991 to 2000, the population growth rate of the study area has been increasing at 7.64 percent per annum. There are four (4) major district under the Sungai Langat catchment namely Hulu Langat (upper basin), Kuala Langat, Sepang and Seremban. This study cover only the Hulu Langat (upper basin) with six (6) mukims (demand sites) as per Table 3.2 below.

Table 3.2: Population by Mukim in Hulu Langat District

No	Demand Sites (Mukim)	Population by year				
		1970	**1980**	**1991**	**2000**	**2010**
1	Hulu Langat	12,901	14,060	20,282	46,766	55,521
2	Cheras	13,289	22,210	55,551	163,550	244,563
3	Kajang	48,993	46,360	108,590	229,655	342,657
4	Semenyih	12,140	15,550	22,782	49,076	99,669
5	Hulu Semenyih	1,463	1,540	2,180	3,408	3.610
6	Beranang	7,371	7,600	9,351	14,071	49,772

Source: *Sungai Langat Integrated River Basin Management Study, Final Report, Volume 3, Technical Studies Part 1 of 4, 2005.*

3.2.2 Demand Sites for Agriculture

The expansion of urban area and the concominent erosion of agriculture land and forest reserves in the Basin over the last ten (10) years were reviewed using Department of Agriculture (DOA)'s Land Utilisation Map (1991, 1995, and 1997), aerial photographs (1998, 1999) and satellite images from MACRES (2001) are tabulated in Table 3.8 below. Currently, at least 74% of the basin, particularly at the lower and upper basin is still vegetated, either under agriculture or forest reserve. However, the increasing number of development approvals for residential and industrial projects in the basin threathens to change the land use distribution. Based on the data, the value for agriculture in Hulu Langat catchment for this study is 23,030 hectares.

Table 3.3: Breakdown of Major Land Use Categories by Districts, 2000, Sg Langat Catchment

	K. Langat (ha)	**Sepang (ha)**	**H. Langat (ha)**	**Klang (ha)**	**Seremban (ha)**	**Total Area (ha)**
Built-up areas	8,660 (12.7%)	7,980 (23.3%)	18,020 (22.4%)	2,580 (35.6%)	8,520 (18.9%)	45,760 (19.5%)
Agriculture areas	41,280 (60.5%)	13,580 (39.6%)	23,030 (28.7%)	3,560 (49.0%)	23,920 (53.1)	105,370 (44.8%)
Forest reserve	15,410 (22.5%)	1,830 (5.3%)	38,240 (47.6%)	1,030 (14.2%)	12,230 (27.3%)	68,740 (29.2%)
Others	2,920 (4.3%)	10,860 (31.7%)	950 (1.0%)	80 (1.0%)	320 (1.7%)	15,130 (6.4%)
Total land area	**68,2 70 (100%)**	**34,250 (100%)**	**80,240 (100%)**	**7,250 (100%)**	**444,990 (100%)**	**235,000 (100%)**

Source: *Sungai Langat Integrated River Basin Management Study, Final Report, Volume 3, Technical Studies Part 1 of 4, 2005.*

3.2.3 Supply and Resources

a) Streamflow

All data for streamflow were gcollected from the Department of Drainage and Irrigation, Ampang. There area total of four (4) streamflow stations identified for this research, namely:

Table 3.4: Streamflow Station

No	Streamflow Station No.	Streamflow Station Name
1	2816441	Sg. Langat di Dengkil
2	2917401	Sg. Langat di Kajang
3	2918401	Sg. Semenyih di Sg. Rinching
4	3118445	Sg. Lui di Kg. Lui

Source: *Department of Drainage and Irrigation (DID, 2000.*

All data for streamflow measurement were insert based on the Current Accounts for the year of 2000.

b) Reservoir

There were two (2) reservoirs built on the study are model referring to the existing impoundments within Langat Catchment (upper part), namely Sg Langat Dam and Sg. Semenyih Dam (Table 3.5).

Table 3.5: Dam Capacity for Langat Dam and Semenyih Dam

No	Dam Name	Dam Capacity (million cubic metre)	Heigth (m)	Crest Length (m)
1	Langat Dam	33.6	61	336
2	Semenyih Dam	60.6	49	800

Source: *Sungai Langat Integrated River Basin Management Study, Final Report, Volume 3, Technical Studies Part 1 of 4, 2005.*

Sg Langat Dam is located on Sg Langat and has a catchment area of 41.45 sq km. It was completed in 1979 for the purpose of water supply. It is an earth-fill dam with a maximum height of 61 m and a crest length of 336m. It creastes an impouding reservoir that has a fully-supply-level surface area of 2.27 sq km and a live storage of 33.6 million cubic metres.

Sg Semenyih Dam is located on Sg Semenyih, a tributary of Sg Langat and has a catchment area of 56.7 sq km. It was completed in 1986 for the purpose of water supply. It is an earth-fill dam with a maximum height of 49 m and the crest length of 800m. It creates an impounding reservoir that has a full-supply level surface area of 3.6 sq km and a live storage of 60.6 million cubic metres.

c) Rainfall Data

All data for rainfall were collected from the Department of Drainage and Irrigation, Ampang. There area total of nine (9) rainfall stations identified and used in this study, namely:

Table 3.6: Streamflow Station

No	Rainfall Station No.	Rainfall Station Name
1	3017106	Sg Serai Batu 12
2	3018101	Empangan Semenyih
3	3118101	Stn. Janaelektrik Lln Pansoon
4	3118102	Sek. Keb. Kg. Sg. Lui
5	3118103	Kg. Sg. Lui
6	3118105	Bt. 14. Hulu Langat (Balai Polis)
7	3119001	Sawah Sg. Lui
8	3119002	Lalang Sg. Lui
9	3218101	TNB Pansun

Source: *Department of Drainage and Irrigation (DID, 2000).*

d) Evaporation

All data for evaporation were collected from the Department of Drainage and Irrigation, Ampang. There area total of four (4) evaporation stations identified and used in this study, namely:

Table 3.7: Evaporation Station

No	Station No.	Evaporation Station Name
1	2916301	Prang Besar (Loji Air Semenyih)
2	2719301	Setor JPS Sikamat
3	3117370	Pusat Penyelidikan JPS Ampang
4	2719301	Kuala Kubu Bharu

Source: *Department of Drainage and Irrigation (DID), 2000).*

3.3 Connecting the Demand with Supply

In order to inform WEAP how the demand is satisfied, the user need to connect the supply system which been identified previously to each demand site. These can be accomplished in the schematic view where transmission link is added. The link need to be firt positioned on the river, then pointing to the demand node. This is include all six (6) demand site nodes and agriculture node.

3.4 Creating the Return Flow Links

In order to inform WEAP how the demand is satisfied, the user need to connect the return flow from the demand sites. The return flow links were connected back to the rivers. Next, the Return Flow Routing is set. The Return Flow Routing is the percent of total outflow from a demand node, then the Return Flow Routing for that link must be 100%.likewise, if multiple Return Flow links are created for a demand node, then Routing factors foa all of the links must be sum to 100%.

4. RESULTS AND DISCUSSION

The computation of the model was done by computing the entire model for the Reference Scenario – the default scenario that was generaterd using Current Accounts information for the period of time specified for the project (here, 2000 to 2010). The results will be appeared once the computation is complete.

In WEAP, the typical scenario modelling effort consist of three (3) steps:-

i) Current Accounts year is chosen to serve as the base year of the model. It this study year 2000 was selected to be the base;

ii) Reference scenario is established from the Current Accounts to simulate likely evolution of the system without intervention; and

iii) What-if scenarios can be created to alter the "Reference" scenario and evaluate the effects of changes in policies and/or technologies.

The following results for Sg Langat Catchment (upper part) were made based on three (3) scenarios :-

i) Current Account (Year 2000)

ii) Reference Scenario

iii) Scenario 1: High Population Growth (7%)

iv) Scenario 2: Using Water Yield Method to evaluate Climatic Variation

v) Scenario 3: Exteded Dry Climate Sequence

4.1 Current Account (Year 2000)

Under this condition, the demand site data were identified based on Annual Water Use Rate of 110 m^3 for all population (6 mukim). The total of agricultural are was taken into account where the total area is 23,030 hectare with 1000 m^3 of consumption per hectare.

Table 4.1 shows the water consumption for the year of 2000 (Current Accounts) for the seven (7) demand sites which are the main target of the study.

*Table 4.1:*Overall Water Demand for the Year 2000 (million cubic meter)

No	Demand Site	Population or Area	Water Demand (million m^3)
1	Hulu Langat	46,766	5.1
2	Cheras	163,550	18.0
3	Kajang	229,655	25.3
4	Semenyih	49,076	5.1
5	Hulu Semenyih	3,408	0.4
6	Beranang	14,071	1.5
	Total Population	**506,526**	
7	Agriculture	23,030 hectare	23.0
	Total		**78.1**

All the above data were act as the base input to the model in order to project the water demand in the next ten (10) years in the Reference Scenario.

4.3 Reference Scenario

The basic principle in WEAP is that the Reference Scenario is always exist where the changes in its description in the Area/Manage Scenario will reflec its actual role. In this model, the Reference Scenario is “Base Scenario with Population Growth of 2.2% and Increased of Irrigation Water Needs”. The population rate increased about 2.2% from year 1990-2000, based on the growth rate of Hulu Langat District.

Figure 4.1 shows the overall result derived from the Reference Scenario. Based on the overall result, it was noted that the Unmet Demand is a zero (0) value. Therefore, it is indicated that the water availability under the Reference Scenario (based of previous population growth rate of 2.2%) is relatively sufficient.

*Figure 4.1:*Overall Result for Reference Scenario

Figure 4.1 shows the projected water demand for the year of 2000 -2010. From the result, it was projected that in the year of 2001, the total water demand is increased to 82.9 million cubic meter, 87.1 million cubic meter in 2002, 91.4 million cubic meter in 2003, 95.6 million cubic meter in 2004, 100.0 million cubic meter in 2005, 104.3 million cubic meter in 2006, 108.7 million cubic meter in 2007, 113.1 million cubic meter in 2008, 117.5 million cubic meter in 2009, and 122 million cubic meter in 2010. The total water demand up to year 2010 is 1, 101.1 million cubic meter.

4.4 Scenario 1: Higher Population Rate (7%)

In order to foresee the impact of posisble condition to the model, a new scenario is created. The new scenario is to evaluate the impact of a population growth rate for Langat area higher than 2.2% for the period of 2001 – 2010. Using the Manage Scenario tool, a new scenario named "High Population Growth" is added (Figure 4.17 and 4.18) where the scenario description as "This Scenario looks into the impact of":-

- Increasing population growth rate from 2.2% to 7%.
- Increasing of agriculture area linearly.

Figure 4.2 shows the projection of water demand based on both scenarios, Reference Scenario and Scenario 1: Higher Population Growth (7%) for Langat Catchment. It is noted that the water demand for the case of higher population growth at 7% rate gaves two (2) times of water demand in 2010 compared to 2000. The total water demand for Scenario 1 is indicated to be a total amount of 2,213.2 million cubic meter comapred to the year 2000, a total amount of 1,101.1 million cubic meter (Refer Table 4.2).

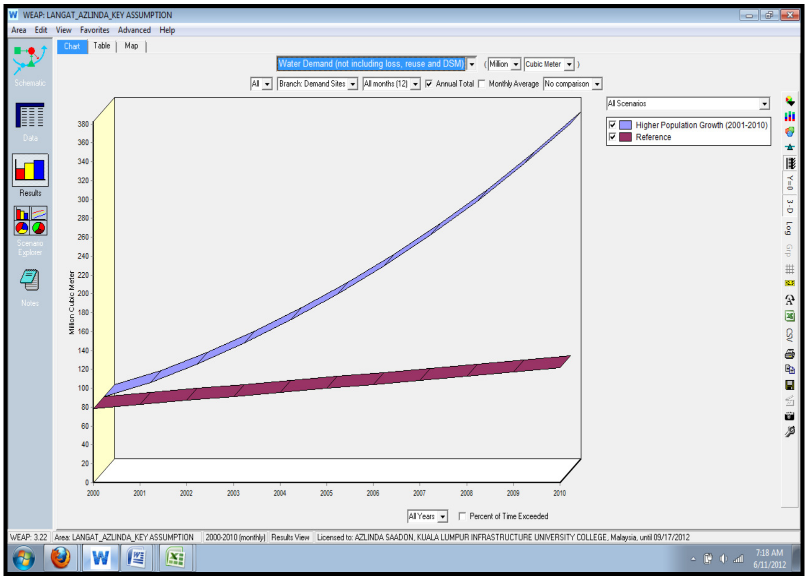

Figure 4.2: Water Demand Projection from 2000-2010 for Langat Catchment under Reference Scenario and Scenario 1: Higher Population Growth

Table 4.2: Water Demand Projection Data from 2000-2010 for Langat Catchment under Reference Scenario and Scenario 1: Higher Population Growth (million cubic meter)

Scenario	Water Demand (million cubic meter)											
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total**
Reference	78.7	82.9	87.1	91.4	95.6	100.0	104.3	108.7	113.1	117.5	122.0	**1,101.1**
Scenario 1	78.7	93.4	113.2	135.3	159.9	187.7	216.9	249.8	285.8	325.1	368.1	**2,213.2**

Figure 4.3 shows the overall result scenarios, Reference Scenario and Scenario 1: Higher Population Growth (7%) for Langat Catchment. The forth graph shows that there is Unmet Demand in year 2010 with the amount of 30.7 million cubic meter. This indicate that if the population is increased at a rate of 7% in 2010, there will be shortage of water. This also gave a significant impact to the reservoir storage volume. It is clearly shown that the level of reservoir volume have a significant drop in year 2009 and 2010.

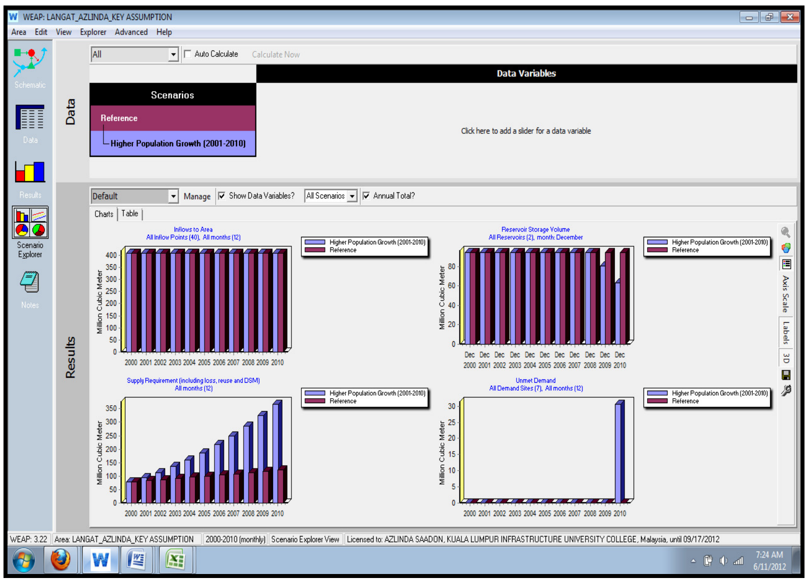

Figure 4.3: Overall Result for Langat Catchment under Reference Scenario and Scenario 1: Higher Population Growth

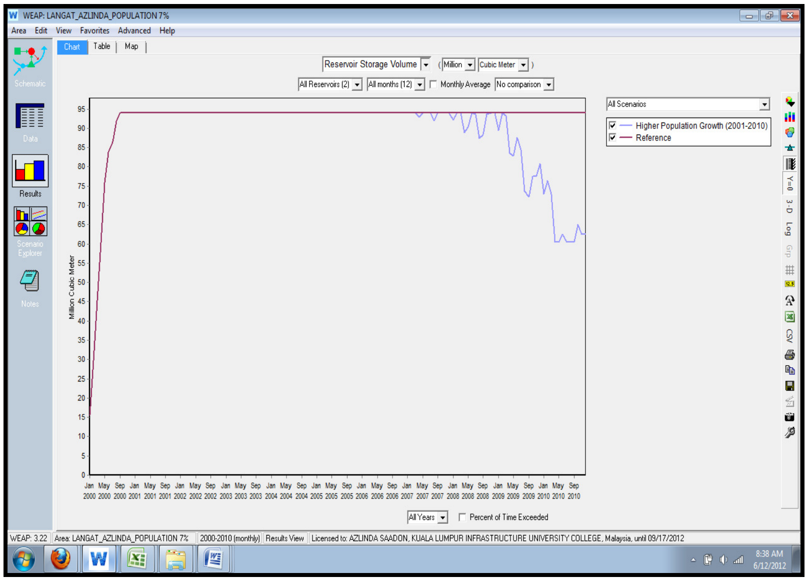

Figure 4.4: Reservoir Storage Volume under Reference Scenario and Scenario 1: Higher Population Growth

4.5 Scenario 2: Water Year Methods

In previous Scenario 1, the variation of demand have been predicted. In order to exercise the variation of supply and resources of water, the Water Year Method is used. The Water Year Method is a simple tool to represent the variation in climate data. The year sequence is created consist of the sequence of climatic variation for the scenario period. Each year of the period is assigned one of the climate categories. Figure 5.7 shows the setting of sequence of climate variation. The method first involves defining how different climate regimes (such as, very dry, dry, wet and very wet) compare relative to a normal year, which is given a value of 1. In this method, the dry years have a value less than 1, and very wet years have a value of larger than 1.

The climatic variation is then assigned to Scenario 1 and Reference Scenario in order to foresee the impact towards the water demand and supply. Figure 5.8 shows the graphical result for Unmet Demand for both scenarios using the Water Year Method.

The year sequence is created consist of the sequence of climatic variation for the scenario period. Each year of the period is assigned one of the climate categories. For the Reference Scenario, the following sequence is assigned (Table 4.3)

Table 4.3: Climate Categories for Scenario 2

Year	Sequence of Climate Variation
2000	Normal
2001	Normal
2002	Normal
2003	Dry

2004	Dry
2005	Wet
2006	Dry
2007	Normal
2008	Normal
2009	Dry
2010	Very Dry

Figure 4.5 shows the result for Unmet Demand for Water Year Method under the Scenario 1: Higher Population Growth (7%). From the graph, it is indiacted that the water supply only can accommodate up to year 2008. For year 2009, the agriculture demand is insufficient of 10.1 million cubic meter and 2010, water demand is insufficient of 46.6 million cubic meter. The same result shows for Kajang demand site where the insufficient value of water demand in 2010 is 38.4 million cubic meter.

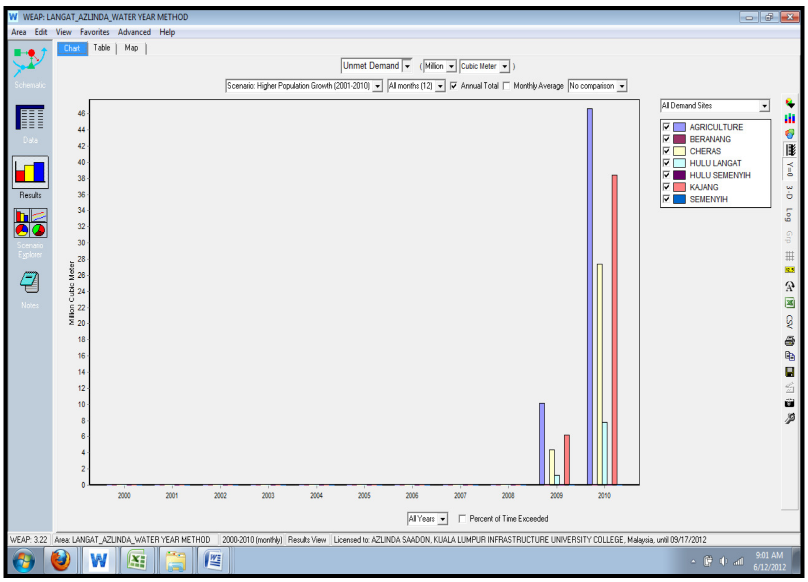

Figure 4.5: Graphical Result for Unmet Demand for Higher Population Growth Scenario under Water Year Method

4.6 Scenario 3: Extended Dri Climate Sequence

This scenario is created in order to evaluate the model towards the Extended Dry Climate Sequence in Langat Catchment. A new scenario is created from the Reference Scenario named the "Extended Dry Climate Sequence" and the climate variation is adjusted to evaluate the impact of water supply. For the Extended Dry Climate Sequence Scenario, the following sequence is assigned (Table 4.4).

Table 4.4: Climate Categories for Scenario 3

Year	Sequence of Climate Variation
2000	Normal
2001	Normal
2002	Normal
2003	Dry
2004	Dry
2005	Very Dry
2006	Very Dry
2007	Normal
2008	Very Dry
2009	Very Dry
2010	Very Dry

The climatic variation for Scenario 3: Extended Dry Climate Sequence is then assigned to Scenario 1: Higher Population Growth (7%) and Reference Scenario in order to foresee the impact towards the water demand and supply. Figure 5.11 shows the graphical result for Unmet Demand for both scenarios using the Water Year Method.

Figure 4.6 and Figure 4.7 shows the result for Scenario 3:Extended Dry Climate Sequence in comparison to the Reference Scenario. From the graph, it is shown that under Extended Dry Climate Sequence in comparison with Reference Scenario (Population of 2.2%), there is significant value of Unmet Demand.

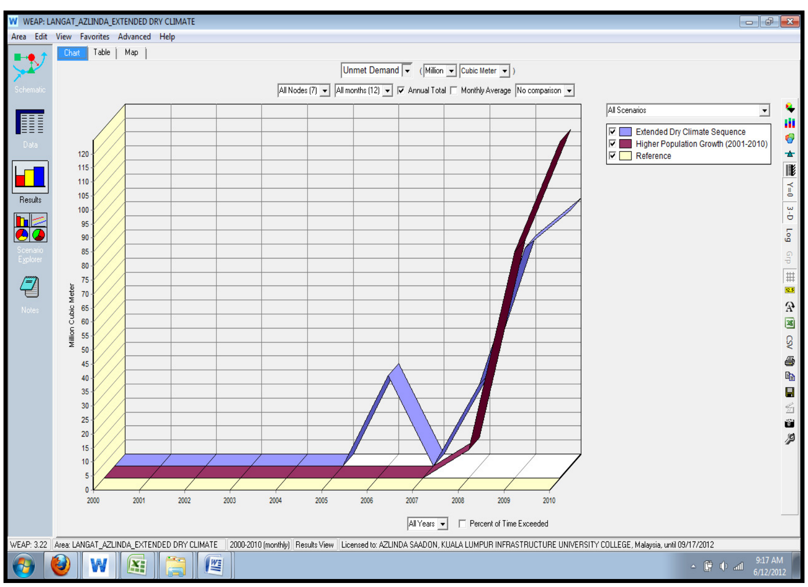

Figure 4.6: The Result for Unmet Demand for Scenario 3: Extended Dry Climate Sequence in Comparison with the Reference Scenario (2.2%)

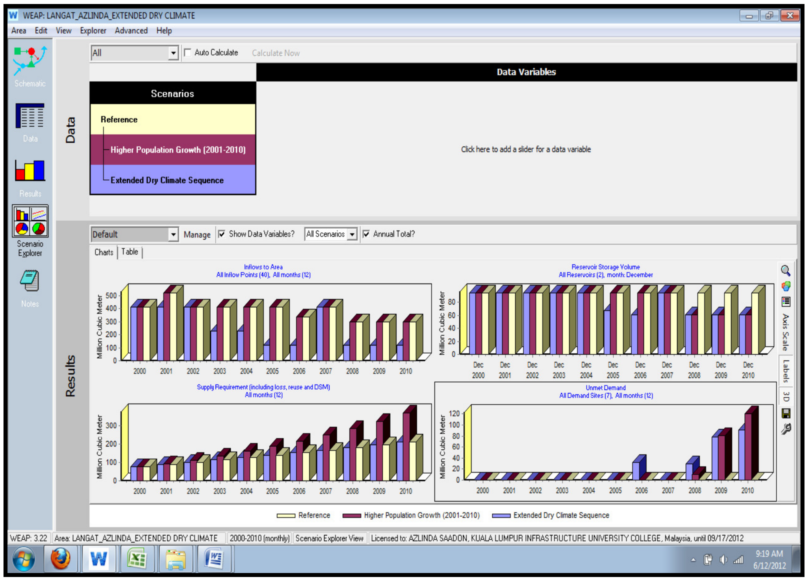

Figure 4.7: The Overall Result for Scenario 3: Extended Dry Climate Sequence in Comparison with the Reference Scenario (2.2%)

This scenario gave the Unmet Demand value of 32.4 million cubic meter starting in 2005, 28.9 million cubic meter in 2008 and 77.9 millin cubic meter in 2009 and 91.3 million cubic meter in 2010 (Refer Table 4.5).

Table 4.5: Unmet Demand Projection Data from 2000-2010 for Langat Catchment under Scenario 3: Extended Dry Climate Sequence in Comparison to Reference Scenario (Population of 2.2%) (million cubic meter)

Scenario	Unmet Water Demand (million cubic meter)											
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total**
Scenario 3	0	0	0	0	0	32.4	0	0	28.9	77.9	91.3	**230.5**
Reference Scenario	0	0	0	0	0	0	0	0	0	0	0	**0**

Figure 4.8 shows the result for Scenario 3:Extended Dry Climate Sequence in comparison to Scenario 1:Higher Population Growth (7%). From the graph, it is shown that under Extended Dry Climate Sequence in comparison with Scenario 1:Higher Population Growth (7%) there is significant value of Unmet Demand.

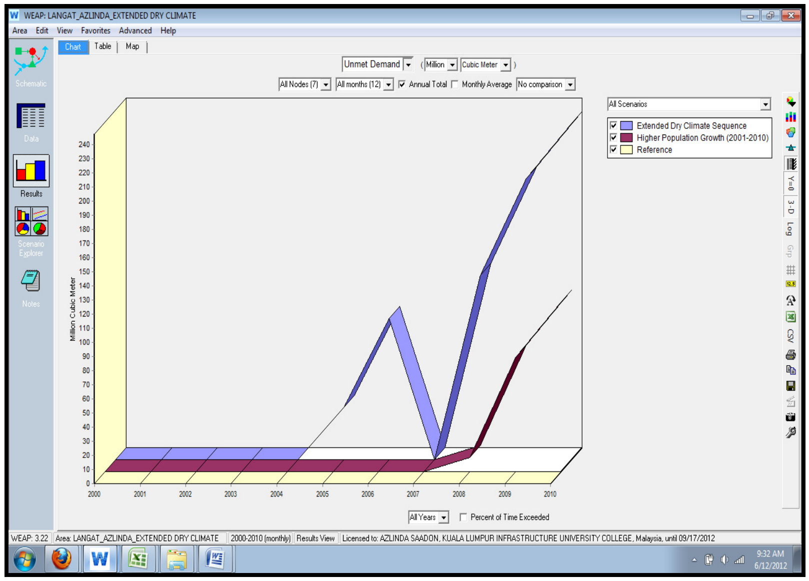

Figure 4.8: The Result for Unmet Demand for Scenario 3: Extended Dry Climate Sequence in Comparison with the Scenario 1: Higher Population Growth (7%)

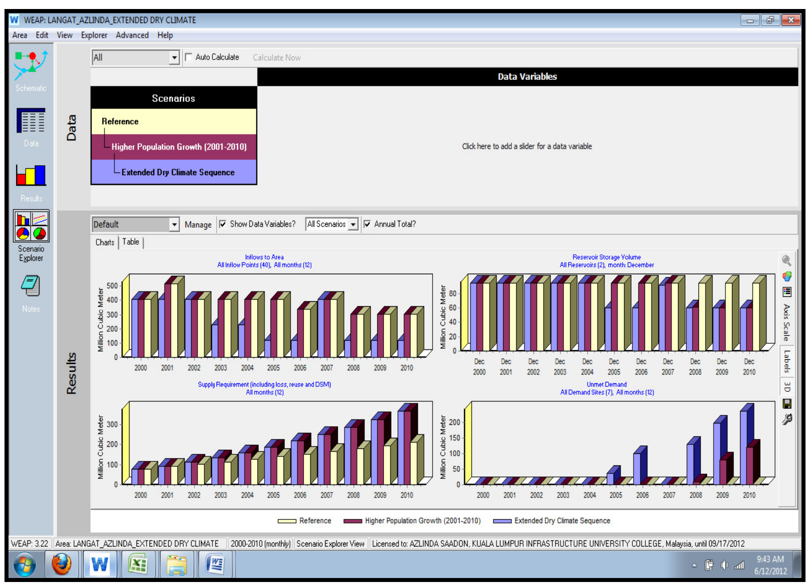

Figure 4.9: The Overall Result for Scenario 3: Extended Dry Climate Sequence in Comparison with the Scenario 1: Higher Population Growth (7%)

Table 4.6 indicates the result of Unmet Demand for Extended Dry Climate Sequence in comparison with Scenario 1:Higher Population Growth (7%). This scenario gave the Unmet Demand value of 37.0 million cubic meter starting in 2005, 100.0 million cubic meter in 2006, 130.8 million cubic meter in 2008 and 198.8 millin cubic meter in 2009 and 237.9 million cubic meter in 2010. This clearly showed that with the higher population growth rate and dryer climate, Unmet Demand increases substantially.

Table 4.6: Unmet Demand Projection Data from 2000-2010 for Langat Catchment under Scenario 3: Extended Dry Climate Sequence in Comparison to Scenario 1: Higher Population Growth (million cubic meter)

Scenario	**Unmet Water Demand (million cubic meter)**											
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total**
Scenario 3	0	0	0	0	0	37.0	101.1	0	130.2	198.8	237.9	**704.1**
Scenario 1	0	0	0	0	0	0	0	0	10.0	80.8	120.2	**211.0**

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the study conducted, the objectives of this study have been accomplished. In this study, the investigation of the trend for supply and demand in Langat Catchment has been conducted. The assessment of the water availability in Langat Catchment using Water Evaluation and Planning (WEAP) is completed based on the reference data for Year 2000. The investigation of the storage capacity and factors of fluctuations on supply and demand in Langat Catchment has been accomplished based on the scenarios conducted.

This study is important especially with the regards of Langat Catchment under going massive incremental of population over the past decades. The assessment using WEAP within Langat Catchment based on current condition and future condition gave the oppoturnity for user to evaluate how Langat Catchment react or could respond to various scenarios in terms of supply and demand of water availability.

In this study, the assessment model used to operates at the WEAP subcatchment scale and on a monthly time-step. The period of the study take into account from year 2000 – 2010, which the naturalized flow data is available. The computation of the assessment model was done by computing the entire model for the Reference Scenario, a default scenario that was generated using the Current Accounts information for the period of time specified for this study (2000 – 2010). Current Accounts year is chosen to serve as the base year of the assessment model. In this study, all the data in Current Accounts were base on the year 2000. The assessment model were computed based on three (3) scenarios :-

- Current Account (Year 2000) → Reference Scenario
- Scenario 1: High Population Growth (7%)
- Scenario 2: Using Water Yield Method to evaluate Climatic Variation
- Scenario 3: Exteded Dry Climate Sequence

Based on the result for the Reference Scenario (population at 2.2%), the availability of water resources is adequate up to the year 2010. The result for Unmet Demand analysis shows zero (0) value. However, when the assessment model is evaluated based on Scenario 1: Higher Population Growth (7% Population Growth), the result shows there were significant value of Unmet Demand in year 2010 with the amount of 30.7 million cubic meter. This indicate that if the population is increased at a rate of 7% in 2010, there will be shortage of water. This also gave a significant impact to the reservoir storage volume. It is clearly shown that the level of reservoir volume have a significant drop in year 2009 and 2010.

Based on the evaluation of the assessment model under Scenario 2, where the supply and resources data is adjusted using the Water Year Method. The Water Year Method is a simple tool to represent the variation in climate data. The year sequence is created consist of the sequence of climatic variation for the scenario period. Each year of the period is assigned one of the climate categories. The climatic variation is then assigned to Scenario 1 and Reference Scenario (2.2% Population) in order to foresee the impact towards the water demand and supply. Based on the computation, the result shows that Unmet Demand for Water Year Method assigned to Scenario 1: Higher Population Growth (7%). From the graph, it is indiacted that the water supply only can accommodate up to year 2008. For year 2009, the agriculture demand is insufficient of 10.1 million cubic meter and 2010, water demand is insufficient of 46.6 million cubic meter. The same result shows for Kajang demand site where the insufficient value of water demand in 2010 is 38.4 million cubic meter.

Finally, the assessment model were evaluated under Scenario 3: Extended Dry Climate Sequence. This scenario was assigned to the Reference Scenario (2.2% Population) and Scenario 1: Higher Population Growth. The result for reference scenario shows there was a significant value for Unmet Demand, but when compared to the Scenario 1, the impact of Unmet demand is relatively higher. This allows the judgement made where the higher population growth rate and dryer climate, Unmet Demand increases substantially.

In conclusion, with the use of this software in order to predict the supply and demand of a partcular catchment is crucial to ensure the sustainability of the water resources. Attention should be drawn to optamize the river within Langat Catchment, if not the scarce resources available in this catchment may not meet the future needs.

5.2 Recommendations

Several recommendations can be derived from the results obtained and its analysis. They can be summarised as the following:-

- Further development of the assessment model towards Langat Catchment is recommended in order to investigate the hydrological response and its consequences for the sake of the integrated river basin management in this catchement;

- A complete study should also take into consideration integrating other factors such as exisiting infrastructure development within Langat catchment, industrial growth in the basin, and the groundwater recharge within the basin to produce more relaistic water resoruces / availability scenarios;

- Further study of the assessment models of Langat catchment towards responding to the climate changes and policy adaptation is recommended;

- Clearly, major adaptation will be needed in response to increasing water scarcity, especially in agricultural activities. Adaptation may requires changes in cropping patterns, with the switch to new crops or varieties more tolerent to water scarcity in this study area.

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