WATER DEMAND FORECASTING USING ARTIFICIAL NEURAL NETWORK FOR HOUSING ESTATE - CASE STUDY

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For my dear parents and siblings whom I love unconditionally

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ABSTRAK

Rangkaian Neural Buatan ialah satu alat yang agak baru, telah digunakan untuk mensimulasi data untuk mendapatkan permintaan air bulanan untuk tahun 2008. Kawasan yang dianalisa ialah Taman Desa Ilmu. Penggunaan air bulanan untuk tahun 2007 dan 2008 telah digunakan sebagai input data dan juga sasaran untuk melatih rangkaian neural. Model tersebut telah digunalan untuk menjangka permintaan air bulanan untuk tahun 2008. Pelbagai kombinasi parameter telah dianalisa untuk mendapatkan model yang terbaik. Keputusan dari kedua dua latihan dan cubaan menunjukkan keputusan peratusan ketepatan yang agak memberansangkan. 0.4 *Learning Rate* dan 30 *hidden neurons* ialah parameter yang terbaik untuk model ini dengan 88% ketepatan.

ABSTRACT

A relatively new tool, artificial neural network (ANN), was applied to simulate the data to obtain monthly water demand for the year 2008.Taman Desa Ilmu, Kota Samarahan is the study area for this case study. The monthly water consumption for the year 2007 and 2008 were used as the input and target to train the neural networks. The trained model was used to predict the monthly water demand for 2008. Different combinations of variables and parameters have been investigated to find the best forecasting model. Results from both training and testing simulation showed a relatively acceptable percentage of accuracy for the output obtained. A learning rate of 0.4 and 30 hidden neurons were the best parameter for this modeling with a 88% accuracy.

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CHAPTER 1

INTRODUCTION

1.1 Background

Water insufficient and the growing demand for good quality water in many urban areas have initiated efforts to develop optimal water resources management measures. Water shortages cause deterioration of standard of living and pose threats to overall societal prosperity. Water stress is manifested when the demand for water exceeds the available resources or when poor water quality restricts the water use. Assessment of available water resources and the prediction of water demand are essential for proper water resources planning and management. In classical water demand estimations, population growth is the primary decision variable.

This study will focus mainly for Kuching City which is the administrative capital of Sarawak. The current population of Kuching City is 510 000 (2005 cencus). The projected population of Kuching City for the year 2020 is 700 000. By the year 2020, it is important to ensure the water supply is sufficient for the amount of population, hence water demand management is greatly in need to maintain enough supply of water to the population.

Efficiency production of water demand is significant since the growth of population in Kuching City is increasing rapidly year by year. Kuching City is developing vastly especially for housing estates projects and also the development of industrial estates. The standard of living of Kuching City residents are also increasing economically hence the water demands for daily use also increased due to the presence of convenience products such as washing machines, dishwasher, etc.

For Kuching city, water supply is supplied by Kuching Water Board (KWB). KWB is a non-profit oriented and is a public service organization devoted solely for the purpose of providing a good and reliable supply of potable water to the consumers of Kuching City and its surrounding areas which was established in 1959. The Board is responsible for the administration, management and supervision of all waterworks within its area of supply and the policy of the Board is to extend mains and to develop other facilities to provide adequate and reliable supply of fully treated quality water within its area of supply.

Originally, the area of supply covered only 44.8km2 (17.3 sq.miles). The supply area was subsequently increased in stages over the years to cater for the water demand of developments outside it as they could not be conveniently or feasibly supplied by Jabatan Kerja Raya. In 1963 and 1973, the supply area was increased to 90.7km2 (35 sq. miles) and 225km2 (87 sq. miles) respectively. The supply boundary was extended further in 1988 to cover the current area of 730km2 (282 sq. miles) as shown in Figure 1.1.

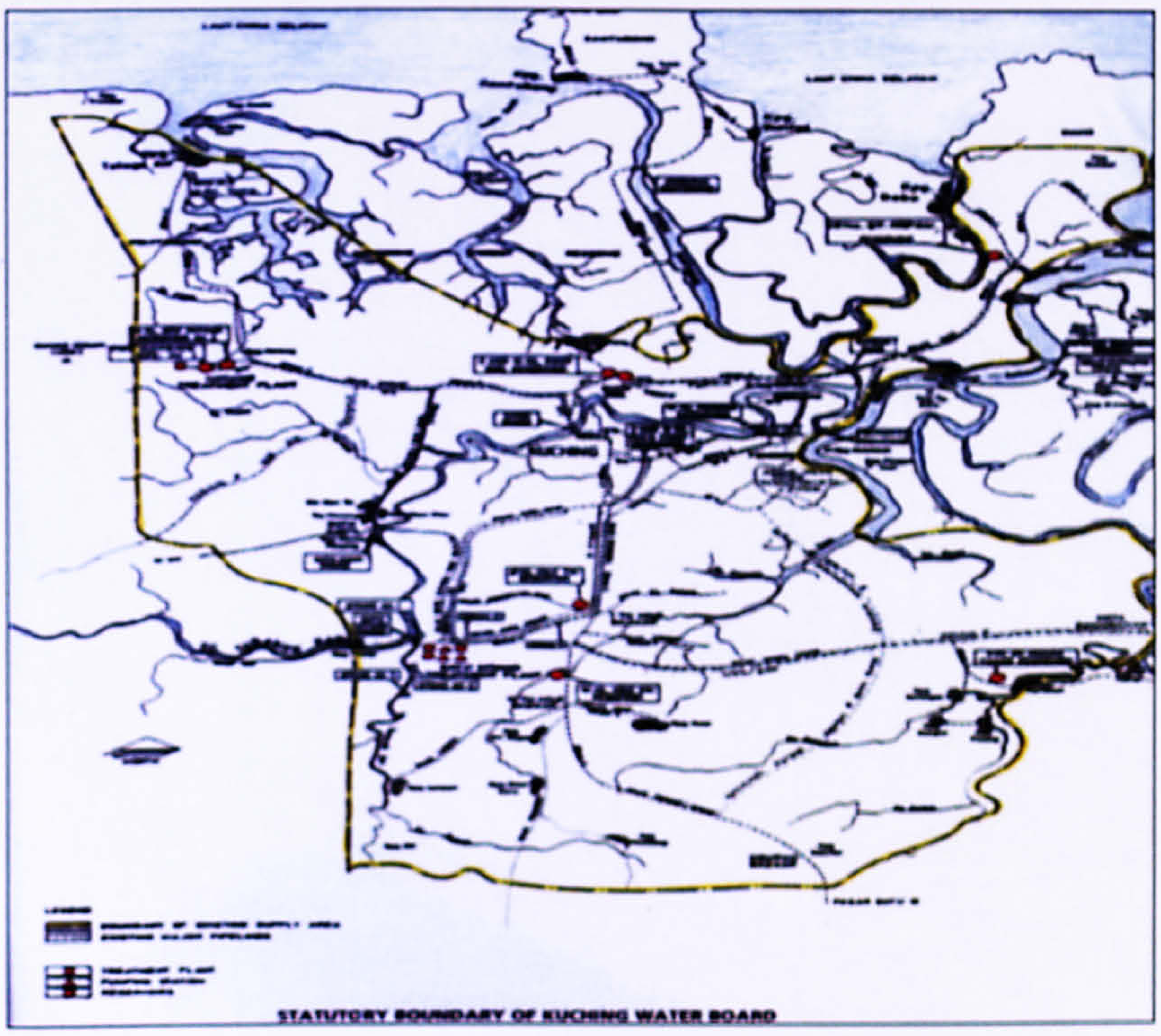

Figure 1.1: Statutory Boundary of Kuching Water Board area of water supply.

Water supplied by KWB is from two water treatment plant which are Batu Kitang Treatment Plant and Matang Treatment Plant. The Batu Kitang Treatment Plant accounts for more than 98% of the total water production for Kuching City. It is located near the bank of Sungai Sarawak Kiri about 40 miles from the sea.

The Treatment Plant is extended into 7 modules which was constructed since 1957 until the construction of Module No. 7 which was commence in 2002. Construction work of Batu Kitang Module 7 Plant (100Mld) is to cater for the increasing water demand up to the year 2010. Until 2007, the water production capacity of Batu Kitang Treatment Plant is 423 Mld while Matang Treatment Plant contribute to 2 % of water production.

Non revenue water (NRW) is water that has been produced and is "lost" before it reaches the customer. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example through theft or metering inaccuracies). High levels of NRW are disadvantageous to the financial viability of water utilities, as well to the quality of water itself. Sarawak will use the Ninth Malaysia Plan (9MP) initial allocation of RM800mil for electricity and water supply projects in rural areas. It was aimed at plugging leaking pipes, thus reducing the loss of non-revenue water to 20% by 2015.

To employ a weir concept to secure the reliability of the Batu Kitang water treatment plant water source from saltwater intrusion which is common during drier months, the Bengoh Dam is now under constructed upstream of Sungai Sarawak Kiri. The dam catchment's area is 122 km^2 and the roller compacted concrete dam with height of 62.5 m. The storage volume is 144.1 million m^3 and will be used for storage of water supply for Batu Kitang Treatment Plant. The dam will ensure adequate water supply for Kuching area up to year 2030.

1.2 Project Overview

The purpose of this study is to develop a model to produced relatively accurate results in any environment especially for water demand forecasting by using Artificial Neural Network (ANN) system.

Selection of a water demand forecast methodology is a function of three primary criteria: planning objective, available data and available resources. The planning objective for development of a water demand forecast defines the level of detail needed by the water resource decision-makers who will utilize the water demand forecast information. Thus, model selection must consider the planning objective to permit the development of alternative water demand scenarios through variation of factors that affect water demand.

Several researches have been adopted before for the forecasting of water demand. Water resources managers have adopted conventional modeling techniques such as regression analysis (Maidment and Parzen, 1984) or time series analysis (Franklin and

Maidment, 1986) for the purpose of short-term water demand forecast modeling. For years, many approaches were implemented for water demand forecasting but none of it gave accurate results.

Artificial Neural Network (ANN) - based tools, on the other hand, are able to model the strong but nontrivial and nonlinear relationships that exist between various parameters involved in water demand forecast through learning (Khotanzad, Zhou and Elragal, 2002). Artificial Neural Network (ANN) approach is used in this study as it has the ability to produce more accurate results.

A housing estate was chosen as an area of study for water demand forecasting. Taman Desa Ilmu housing estate was chosen to be the study area for the purpose of this study. The area is located in Kota Samarahan which formally known as Muara Tuang. It is said that Taman Desa Ilmu will be the next major city in Kuching. It is only as short as of 10 minutes from Tabuan Jaya and other main commercial centre, infrastructure and many other main attractions in Kuching City. Soon enough, Taman Desa Ilmu will be one of the main attractions in Kuching City. With all these developments, the water demand is increasing and might not be sufficient enough for future demand which is in another 5 to 10 years. Therefore, water demand forecasting is highly needed for this purpose.

1.3 Project Objective

The objectives of this study are to:

- Forecast water demand for short term for a selected housing estate in Sarawak
- And to identify the suitable training parameters for water demand forecasting

1.4 Basics of Artificial Neural Network

An artificial neural network (ANN) is either a hardware implementation or a computer program which strives to simulate the information processing capabilities of its biological exemplar. ANNs are typically composed of a great number of interconnected artificial neurons. The artificial neurons are simplified models of their biological counterparts.

The typical characteristics of ANNs differ very much from what is normally expected of a computer. These new properties include adaptive learning, self-organization, error tolerance, real-time operation and parallel information processing.

Learning in the context of ANNs means, that the network can adopt different behavior on the basis of the data that is given to the network. Unlike telling the network how to react to each data vector separately, as would be the case in the conventional programming, the network itself is able to find properties from the presented data. The network learning can be continued as new data becomes available. Thus learning an ANN is simple and adaptive.

As data is given to the ANN, it organizes its structure to reflect the properties of the given data. In most ANN models, the term self-organization refers to the determination of the connection strengths between neurons. The way the internal structure of an ANN is altered is determined by the used learning algorithm. Several distinct neural network models can be distinguished both from their internal architecture and from the learning algorithms that they use.

Error tolerance is an important aspect of an ANN. It refers to the network's ability to model the essential features of the given data. In other words, an ANN is capable of finding a generalization for the data. This powerful characteristic makes it possible to process new, imperfect and distorted data with neural networks.

Due to the parallel nature of the information processing in ANNs, real-time operation becomes possible. Basically, three entities characterize an ANN:

1. The network topology, or interconnection of neural 'units'
2. The characteristics of individual units or artificial neurons
3. The strategy for pattern learning or training

Advantages:

1 A neural network can perform tasks that a linear program cannot.

2. When an element of the neural network fails, it can continue without any problem by their parallel nature.
3. A neural network learns and does not need to be reprogrammed.
4. It can be implemented in any application.
5. It can be implemented without any problem.

Disadvantages:

1. The neural network needs training to operate.
2. The architecture of a neural network is different from the architecture of microprocessors therefore needs to be emulated.
3. Requires high processing time for large neural networks.

1.5 Outlines of chapters

Chapter 1: Introduction. This chapter explains the importance of sufficient water supply in Kuching City and brief description on the water supply in Kuching City. This chapter also explains briefly the purpose of this study and also basic review on Artificial Neural Network.

Chapter 2: Literature Review. This chapter will describe more on water demand forecasting and its purposes in the industry. It also explains the various methods of water demand forecasting used by many water managers. Other than that, this chapter explains more detail on Artificial Neural Network and its application in Civil Engineering especially on water demand forecasting.

Chapter 3: Methodology. This chapter will explain in detail the study area and, the data structure of this study and the software used as well.

Chapter 4: Results and Discussion. This chapter will include the analysis done for this study to obtain the accurate results and also the objectives of this study.

Chapter 5: Conclusion. In this chapter describe the objectives met for this study and also the recommendation that can be done for future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Per capita method is the most common for developing water demand forecasts. Most utilities' models use the per capita methodology as their foundation for developing their own forecast models. Per capita models are developed using utility and survey data of water use per person or household. Other variable information depends on survey detail and the number of respondents. Using current and historical demands, per capita consumption is estimated and multiplied by forecasted population to determine the future water demand totals. Depending on the desired details, the utility may include a number of urban sectors (i.e., residential, commercial, industrial) or land use types (Kame'enui, 2003).

For this study, a manual entitled Malaysian Water Association (MWA) Design Guideline for Water Supply System will be one of the reference materials to estimate the water demand for housing estate.

Other than that, other important data needed for this study will be collected from various institutions in Kuching City such as Kuching Water Board headquarter Batu Kitang treatment plant and also Jabatan Kerja Raya Kuching.

Artificial Neural Network (ANN) approach is used in this study and the area of study is for Desa Ilmu Housing Estate. This area is currently developing, thus it is very suitable to be the area of study to forecast for the water demand for a short-term which is in 2 to 5 years.

It is hoped that this study can forecast the water demand accurately for the housing estate for future use. The significant of the paper is that it can be the guideline and the results can be used for water supply in the future. An accurate forecast of water demand will enable water resources manager to maintain the sufficient of water supply for population of the housing estate. In this chapter, comparison with the conventional methods which are also used by many water managers will also be discussed briefly.

2.2 Short-term and Long-term Water Demand

2.2.1 Short-term Water Demand

Short-term water demand forecasting will help water managers to make more up to date water management decisions to balance the needs of water supply, residential and also industrial demands. Short-term demands help utilities in planning and managing water demands for near-term events.

Short-term projection can also help managers make decisions during unexpected climate conditions, emergencies, or an unanticipated financial change. Short-term forecasting models are typically based upon recent trends and actual conditions. For water demands, factors considered the most influential include recent water demands, forecasted climate, seasonal considerations, and water management policies. Demand models consider these factors and also incorporate population growth, water rate changes and regional conservation efforts (Kame'enui, 2003).

Despite potential errors in its narrow perspective on daily weather or human behavior, short-term methods of modeling water demands play an important role in seasonal water resource management techniques (Bauman et.al., 1998; Billing and Jones, 1996).

2.2.2 Long-term Water Demand

Water resource engineers commonly use the past as a guide to the future, planning as if events that have not occurred are unlikely to occur. However, the future's uncertainty has required planners to predict the future water demand. Long-term forecasts have allowed resource managers to be liberal in their estimates of water demand. Long-term water demand modeling is a difficult task, thus it requires robust data sets and consideration of uncertain climate, economic, and cultural conditions. Therefore, water resource managers felt the professional responsibility to generate demands that are unlikely to be exceeded (Kame'enui, 2003).

Long-term models are helpful for supply planning, reservoir or urban infrastructure changes, extended conservation programming or plumbing code changes, and regional urban planning and development. Unlike short-term models, long-term water demand models do not contribute to near-term or seasonal operations' policies regarding drought, instream flows, or climate variability. Instead, long-term models provide extended foresight for resource managers to address overall system capacity and management (Bauman et. al., 1998).