

FLOOD FORECASTING AT KINABATANGAN RIVER, SABAH BY UTILIZING
ARTIFICIAL NEURAL NETWORK (ANN)

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ABSTRACT

Flood event is among the most influential disaster in Malaysia .Therefore, the developing of flood forecasting model is to minimize the effects of flood and to achieve a model with high accuracy by utilizing Artificial Neural Network (ANN). Artificial Neural Network is a highly non-linear and can capture the complex interactions among input variables in a system without any prior knowledge about the nature of these interactions. Nowadays, ANN is widely used in prediction and forecasting in water resources. The area of study the flood forecasting is carried out at the Balat Station, Kinabatangan River, Sabah where the hourly water level data is collected from Department of Irrigation and Drainage (DID) from year 2000 until 2014. The results indicated that the model develop a highest accuracy is 6 hour time interval for 4000 iteration where the NSC result is 0.996 with lower RMSE 155.341 compared to others iteration and time interval. This modal achieved 100% at allowable error less than 500 mm which is show the prediction of water level. As a conclusion, this model shows high accuracy and water level can be used alone. This can be applied in the real world to give out warning on imminent flood.

ABSTRAK

Peristiwa banjir adalah antara bencana yang paling berpengaruh di Malaysia. Oleh itu, membangunkan model ramalan banjir adalah salah satu cara bagi mengurangkan kesan banjir dan mencapai model dengan ketepatan yang tinggi dengan menggunakan rangkaian neural tiruan atau *artificial neural network (ANN)*. ANN adalah tidak linear dan boleh menangkap interaksi kompleks antara pembolehubah input dalam sistem tanpa apa-apa pengetahuan terlebih dahulu tentang sifat interaksi ini. Pada masa kini, ANN digunakan secara meluas dalam ramalan dan ramalan dalam sumber air. Kawasan kajian peramalan banjir dijalankan di Stesen Balat, Kinabatangan River, Sabah di mana data paras air setiap jam dikumpulkan daripada Jabatan Pengairan dan Saliran (JPS) dari tahun 2000 hingga 2014. Hasil kajian menunjukkan bahawa model membangunkan ketepatan tertinggi adalah selang masa 6 jam untuk lelaran 4000 di mana hasil NSC ialah 0.996 dengan rendah RMSE 155.341 berbanding dengan lelaran serta selang masa yang lain. Modal ini mencapai 100% pada kesilapan yang dibenarkan kurang daripada 500 mm yang menunjukkan ramalan paras air. Kesimpulannya, model ini menunjukkan ketepatan yang tinggi dan boleh menggunakan paras air sahaja. Ini juga boleh digunakan dalam dunia sebenar untuk memberi amaran pada banjir yang akan berlaku

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Flood is the most common occurrence in the Malaysia and it also known as the worst flood especially in the state of Pahang, Terengganu and Sabah. This event was affecting in term of population, property, financial cost, frequency and social economic damaged. Flood also may cause the death, damaged and destructive. The population in Malaysia about 30 million of people and the area of Malaysia is about 330,000km². In Peninsular Malaysia, the average mean rainfall is 2,400 mm while Sabah is about 2,600 mm and 3.800mm for Sarawak (DID, 2010). Malaysia has 189 basins including Sabah and Sarawak with the average mean rainfall over 2,000 mm to 4,000 mm per year. It is also mostly exposed to the flood event where the basin receives the amount of rainfall that may cause the basin overflow to the surrounding of area. Flood is a natural disaster event and temporary condition whether partial or completes inundation of normally dry land areas from overflow of inland or tidal waters from the unusual and rapid accumulation or runoff of surface waters from any source where flood is occurred from the combination of heavy rainfall that causing the rive or streams to overflow from their banks.

Sabah is the largest state of Malaysia after Sarawak with the area about 73,631 km² with the population about 3, 117,405 of people. Sabah is a state enriched with the natural nature but it is also one of the commonly occurs of flood. Kinabatangan, Sabah is have been known as a very serious flooding occurred such as village of Balat, Berek Manis, Tangkulap and Bukit Garam due to human error in term of the development of infrastructure. Every year, people at Kinabatangan faced the same problems where the landslide also occurs and it is the one of effect from flood.

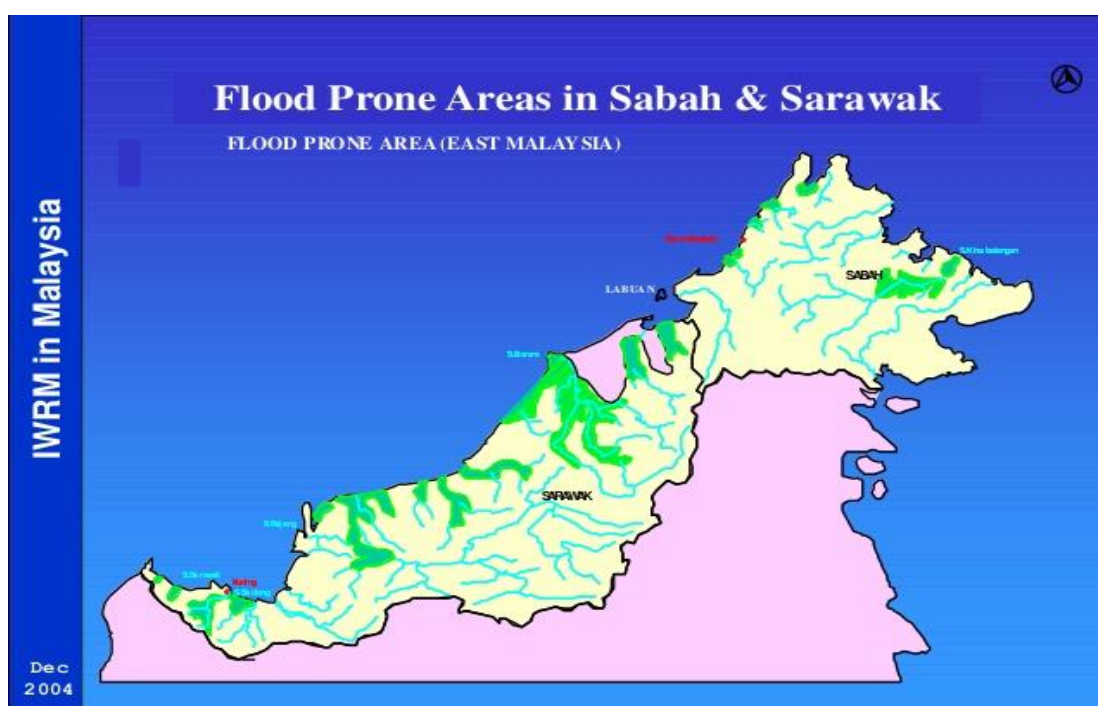


Figure 1.0: Flood Prone Areas in East Malaysia



Figure 1.1: Flooding In Kinabatangan, Sabah.

One of the strategies to reduce the flood is flood forecasting by using some software such as Artificial Neural Network (ANN). The applications of Artificial Neural Network (ANN) become more popular in water resources and have been used in prediction and forecasting of complex nonlinear process (Manish Kumar, Chandra Shekhar, 2014). An Artificial Neural Network is a powerful tool for modeling in hydrology that known as black-box models. In this case study, the hourly water level data is input to determine the outcome output. Artificial Neural Network is a highly non-linear and can capture the complex interactions among input variables in a system without any prior knowledge about the nature of these interactions. The area of study the flood forecasting is carried out at Kinabatangan River by using Artificial Neural Network. The data of rainfall-runoff can be collected from Department of Irrigation and Drainage, Sabah (DID) and the data is taken for hourly water level.

1.2 PROBLEM STATEMENT

The one problems faced by the citizen at Kinabatangan town every year is flood which is can causes the damaging and destructive of property and infrastructures. Flood occurs due the increasing of population in this area lead to development of infrastructure which causes the water movement is changed. Besides, landslide always occurs because of flood. Flood happens when the amount of the rainfall intensity is higher than the soil infiltration rate. During this monsoon, not only a lot of resident's properties were damaged but they also lack of food and drinks, water, clothes and others.

Flood warning system is required to enable people take any action to save live and belonging but due to the lack of flood forecasting equipment and data based on previous flood level, the authorities failed to give a warning to people (Hussin,2010). Furthermore, past study on flood forecasting has been used mathematical model such as regression model. It proves to give high accuracy model but data is costly to obtain and can be time to consuming.

Therefore, the Artificial Neural Network is a powerful tool for modeling especially in forecasting where it solved a complex problem.

1.3 OBJECTIVE

The objectives of this study are:

- i) To develop a model for forecasting flood event at Kinabatangan River, Sabah
- ii) To examine whether water level data can be used alone in Artificial Neural Network modeling.
- iii) To achieve a model with high accuracy by utilizing Artificial Neural network

1.4 SCOPE OF STUDY

The area of study is at Kinabatangan River, Sabah and the data will be collect from the authority of Department of Irrigation and Drainage, Malaysia (DID) which is the requirement period data such as water level data is from 2004 until 2014. The hourly data will be based on water level data. The prediction of the flood event is by utilizing feed-forward Artificial Neural Network (ANNs).

1.5 RESEARCH SIGNIFICANT

The expected outcome of flood forecasting for this research is to minimize the economic losses and the risk to people. This study also able to increases the awareness among people about the next flood event by predict the water level and also to help responsible agencies or authority to design the best model to overcome the flood event in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Flood is a natural disaster than can be happen at any time in wide variety of locations which can causing a huge damaged in term of livelihood or property in every year. Sometimes flood event came with a little or without warning. Flood event also dangerous where it can be killed people. Flood event give impact on human activities which can threaten people's lives, property and environment .Last year 2013, Kuantan, Pahang has been known as the worst flood where two victims were drowned during the flood event (Awani, 2013). The history of flood was began since 1920 where the major floods occurs in the years of 1926, 1963, 1965, 1967, 1969, 1971, 1973, 1979, 1983, 1988, 1993, 1998 and 2005. In fact, flood event also occurs in Johor in the end of the years 2006 and January 2007 due to heavy precipitation which causing the massive floods and about RM 1.5 million cost of these flood disasters which known as the highest cost flood event in Malaysian history on 2006-2007. More than RM200 billions property was damaged and 61 victims was death in flood event at Kuala Lumpur. The cost of flood event including the damage in infrastructures, bridges, roads, agriculture, residential properties and private commercial (DID, 2007).

2.2 WATER CYCLE

2.2.1 Precipitation

Precipitation or rainfall is a liquid that formed from the rain. Rainfall is a main role in hydrological phenomena where it is important as primary sources to the human beings, animals, plants and earth.

2.2.2 Runoff

Runoff is one part of the rainfall or irrigation water and it is occur when there have a rainfall. Without rainfall, there will no runoff. This is because runoff will occur if the amount of water failing or precipitation to the ground is higher than the infiltration rate of surfaces.

2.2.3 Process Of Water Cycle

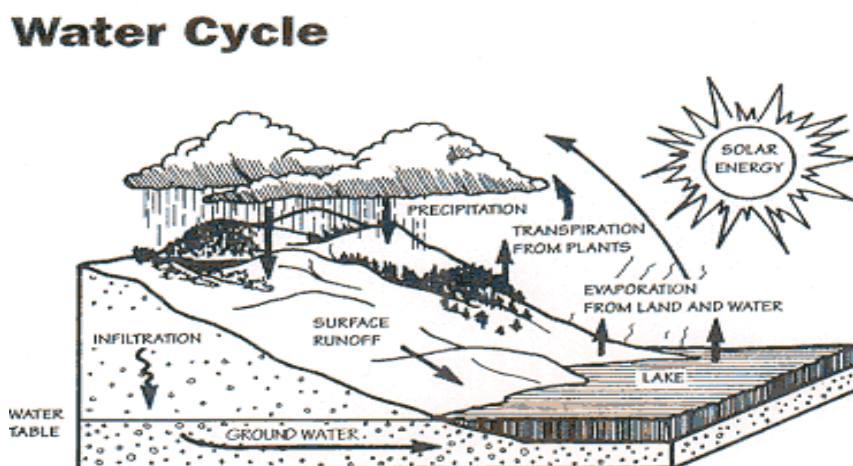


Figure 2.0: Water Cycle

In this water cycle, it is a continuous cycle where the water that evaporates from the lake rises in the air in the form of water vapor. Then, water vapor is cooled down and condenses to become clouds. The drops become heavy if enough water condense and will fall to the ground as a rain or snow. The process of precipitation will return to the lake via runoff to begin the cycle again.

2.3 TYPES AND CAUSES OF FLOOD

The type of flooding is different in terms of forms and degree which can be dangerous to peoples, property, and environment. This due to the different of depth, velocity, duration and the others hazards that related to floods. There are two majors of flooding which are coastal floods and inland flooding (Smith et al, 1998).

2.3.1 Coastal Flooding

Coastal flood event happen when the sea level is higher than normal and storm surges causing the sea water pushed to ashore. As a result, the sea water will overflow onto the land. Coastal flood is influenced by this combination of work when the tide is higher; a low pressure area which forms a storm and a wave action depends on wind speed and direction.

2.3.2 Inland Flooding

Inland flood event is causes by the protracted or intense rainfall. There are several different types of inland flooding which are overland flow flooding, river flooding occurs and flooding from artificial drainage system. Overland flow flood occurs when the intensity of rainfall is higher than the soil's infiltration rate of the ground to absorb it. This event will affect to the localized area only. River flooding is occurs when the catchment area of river receive a greater amount of water than usual such as rainfall or melting snow. The river cannot cope the exceed water which may causes the water level higher and floods disaster will occurs.

2.4 IMPACTS OF FLOOD

Flood event is a common occurring natural event in Malaysia which leaves a massive effect to human, property, infrastructures and environment.

2.4.1 Impacts on Human

Flooding may cause physical injury, illness and death to livelihood. Fast flowing or rapidly rising flood water can be dangerous to people where it is more risk when floodwater carrying the debris. It might cause the physical injuries to people that contact with floodwater. Not only that, floodwater also can hide other hazards for pedestrians such as the manhole that covered by floodwater. Diseases is one of the impacts to people during the flood event where floodwater might be contaminated by sewage or other pollutants which can affect their health (OPW, 2009).

2.4.2 Impacts on Property And Infrastructures

Flooding may cause huge damage to property and infrastructures such as transport or utilities which impacts on local and regional economies. Flooding of primary roads or railways can deny access to large areas beyond those directly affected by the flooding for the duration of the flood event, as well as causing damage to the road or railway itself. Flooding of water distribution infrastructure such as pumping stations or of electricity sub-stations can result in loss of water or power supply over large areas. This can magnify the impact of flooding well beyond the immediate community. The long-term closure of businesses, for example, can lead to job losses and other economic impacts (OPW, 2009).

2.4.3 Impacts on Environment

Significant detrimental environmental effects of flooding can include soil erosion, bank erosion, land sliding and damage to vegetation as well as the impacts on water quality, habitats and flora and fauna caused by bacteria and other pollutants carried by flood water. Flooding can however play a beneficial role in natural habitats. Many wetland habitats are dependent on annual flooding for their sustainability and can contribute to the storage of flood waters to reduce flood risk elsewhere (OPW, 2009).

2.5 FLOOD FORECASTING IN MALAYSIA

2.5.1 Flood Warning System

The purpose of flood warning system is to facilitate people to save their lives and belongings and help agencies to carry out evacuation of population during floods. The flood warning system was provided since 1925 for flood event the first installed along Kinta River, Perak, Kelang River, Selangor River and Bernam River in Selangor.

Components of flood warning system is to monitor of rainfall and river flows that may lead to flooding. Besides, determine the flood impacts on the community by interpretation of prediction. The construction and dissemination of warning messages is to describe what is happening and will happen, the expected impacts and the actions should be taken during flood event. This message warning will be spread by agencies involved to all community members. Warning message will be disseminated through media social such as television, radio or others. After the flood event, the warning system will be reviewed (DID, 2014).

Besides, the number of telemetry station in Malaysia for rainfall is 140 station, water level is 39 station and for combined is 274 station. This telemetry station is to monitor the rainfall and river flows.

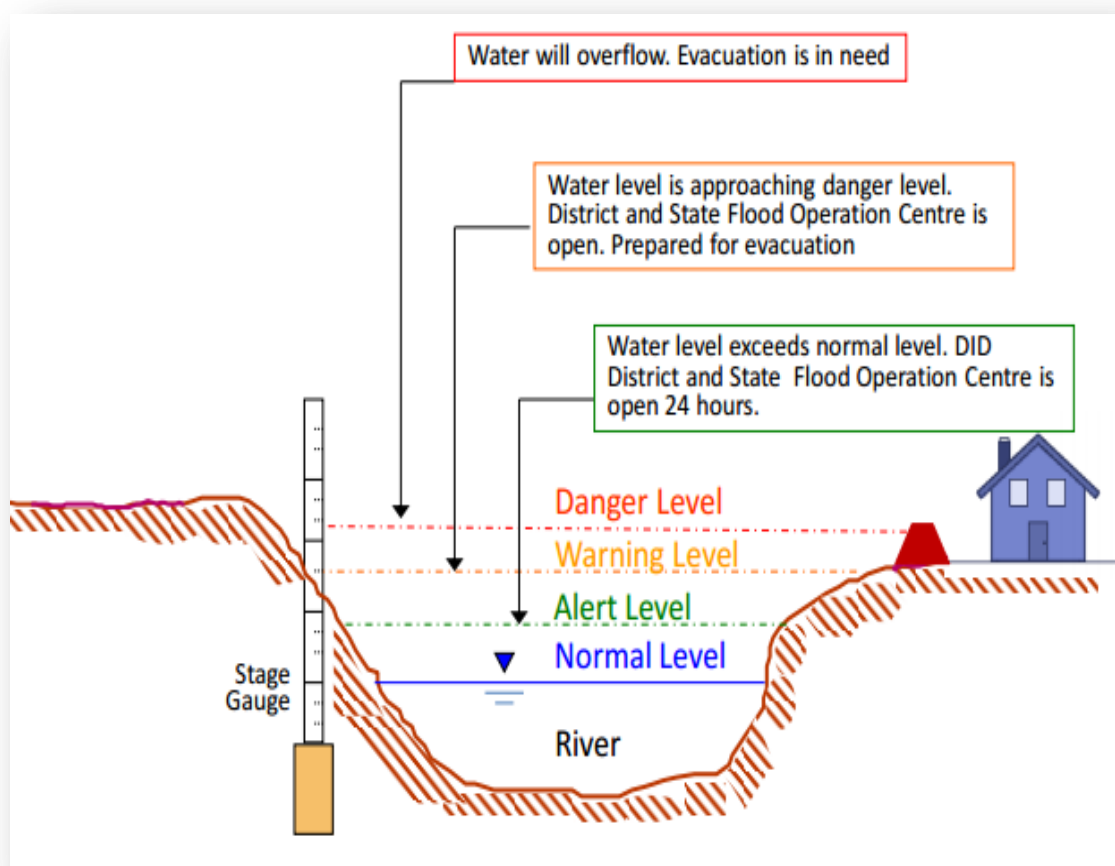


Figure 2.1: Classification of Water Level at Flood Warning Centre, Malaysia (DID, 2013)

Figure 2.1 shows the classification of water level at flood warning centre in Malaysia. Regarding to the operating procedures under the relief mechanism, when the river at any station reach at the alert level then DID begin to monitor the flood situation. If the river at any station reaches at warning level, then DID will inform to other agencies involved and prepare for evacuation.

2.6 ARTIFICIAL NEURAL NETWORK (ANN)

The history of artificial neural network (ANNs) was begin in 1943 when a neuroscientist, Warren McCulloch and a logician, Walter Pitts was combined their ideas to proposed a simple model of neurons which is called McCulloch-Pitts neurons or MCP neurons for a short name. This neuron is about the computation of the logical function.

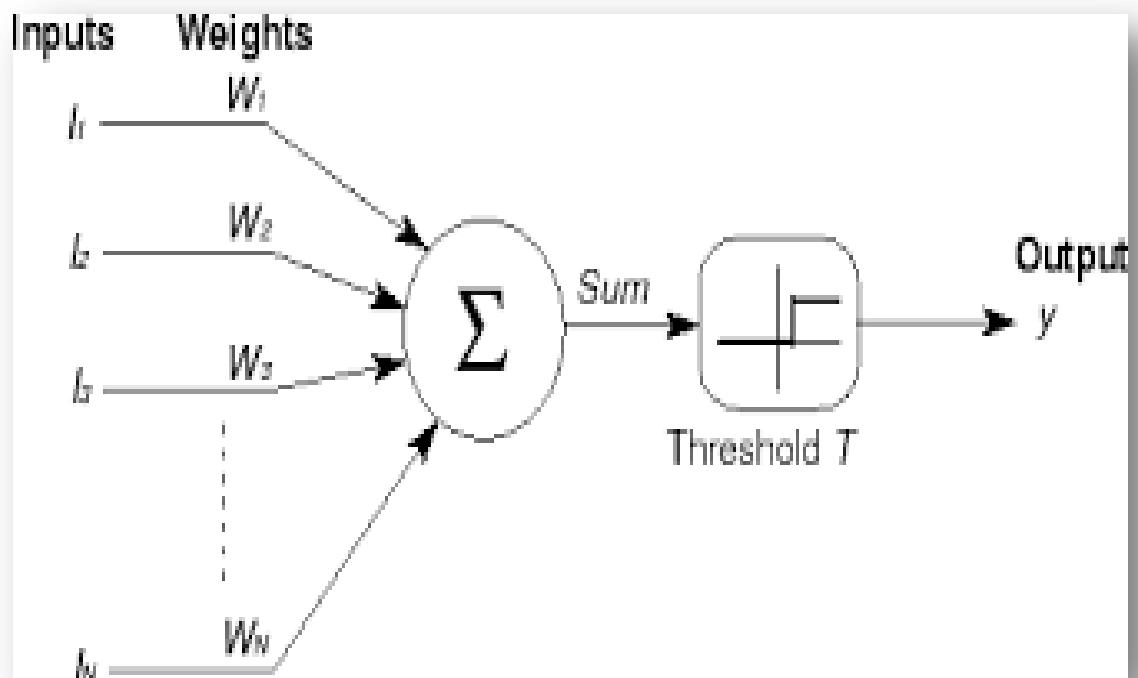


Figure 3.4: McCulloch Pitts Neuron (1943)

Donald Hebb (1949) was proposed learning on the plasticity in neural network which is depends on the plasticity of the circuits in the brain and the ability of the neurons to changes the efficiency of the synaptic transmission. Hebb's law is created to become a learning of the neuron. P. Junsawang et al (2007) proposed a feed forward ANN as a tool for estimation of runoff in Mae Tun River, Thailand and trained by using back-propagation algorithm. K. K. Kuok et al (2007) and M. R. Yazdani et al (2009) used two models of neural network namely Multilayer Perceptron (MLP) and Recurrent Network (REC) for prediction of rainfall runoff which is the result showed that MLP is slightly better than REC network. P. Mittal et al (2012) proposed a dual artificial neural network (D-ANN) which is to improve the model performance and carried out for hourly river flow data of Kolar Basin, India. It is also used the feed forward artificial neural network (FF-ANN) which are in-terms of statistical indices such as coefficient of correlation, coefficient of efficiency, root mean square and compared it with D-ANN model. The result indicated that D-ANN is better than FF-ANN

CHAPTER 3

METHODOLOGY

3.1 STUDY AREA AND DATA COLLECTION

The Kinabatangan River is the largest and longest in Sabah, Malaysia. Kinabatangan River is a large proportion water supplier to Sandakan, Sabah's second largest urban center to people living in village within Kinabatangan River such as Balat, Berek Manis, Bukit Garam and Tangkulap. The total of population is about 86,783 people live in Kinabatangan Town. Kinabatangan River with 560 km is the major river which is located at 117° 35' 50 longitude and 5° 18' 35 latitude with the catchment area 16,800 km² is a part of the Kinabatangan basin, Sabah. The elevation of study area is 23 meters and its covers almost 23 percent of the total land area of Sabah. Mean annual rainfall in the basin about 2,300 mm to 3,000 mm per year. Figure 3.1 shown the location of Kinabatangan River and its river cross section station.

The purpose of choosing Kinabatangan River as the study area is because flooding occurred since year 1963, 1967, 1986 and 1996 along the rivers which causing serious damaged to livelihoods and property. It is also the largest remaining floodplain. Flood Forecasting is carried out to minimize the flood event. Therefore, water level data is used for flood forecasting which is selected from Belat station and water level data were obtained from Department of Drainage and Irrigation (DID) Sabah from year 2004 until 2014. As we can see in the Figure 3.2, the water level at Belat Station is near to Alert Level where the authorities from DID is start to monitor flood situation.

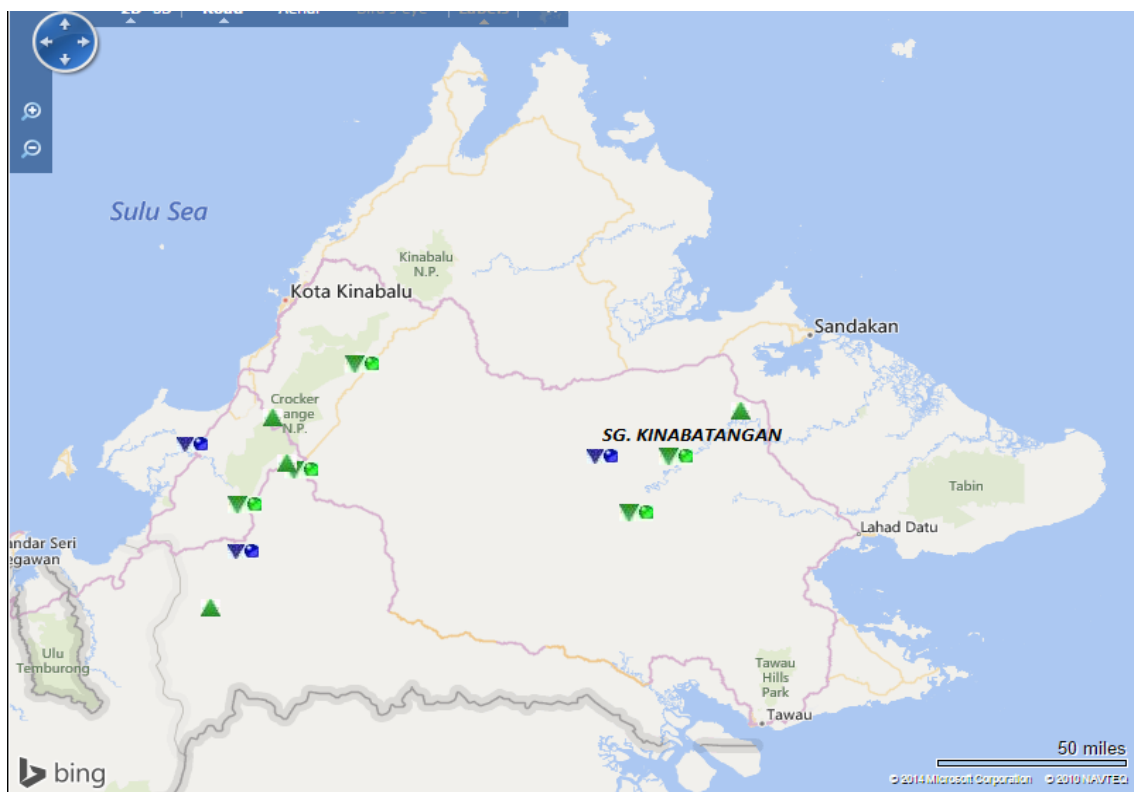


Figure 3.1: Kinabatangan River, Sabah (DID)

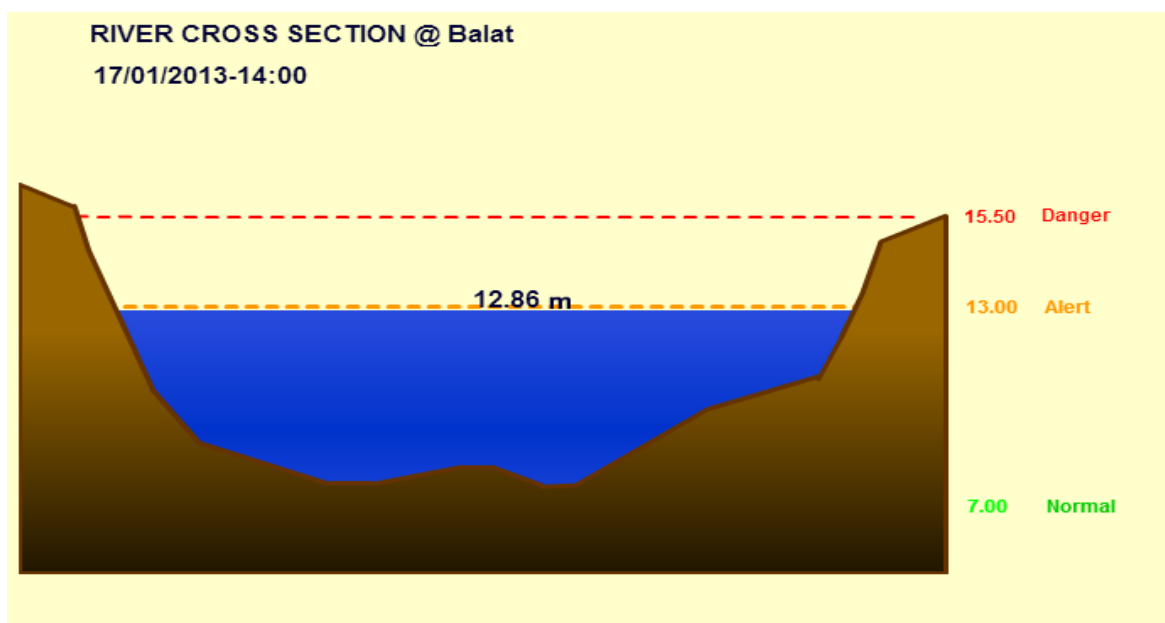


Figure 3.2: Water Level Elevation status at Kinabatangan River section

3.2 ARTIFICIAL NEURAL NETWORK (ANN)

In recent years there has been a confluence of ideas and methodologies from several different disciplinary areas to give rise to an extremely interesting research called Artificial Neural Network (ANNs). Artificial Neural Network is an extremely simplified model of the brain. The process of this network is related to brain function of biological inspiration where it consists of a large number of highly connected elements called neuron. In biological, neurons have three major components which are dendrites, the cell body and the axon. The dendrites are network of nerve fibers that carry electrical signals into the cell body. The axon is a single long fiber that carry the signal out from the body cell to the others neurons while the cell body is the important cell where is to sums and thresholds incoming signals in and out. The connection between an axon and dendrites is called as synapses. Figure is a simplified schematic diagram of biological neuron.

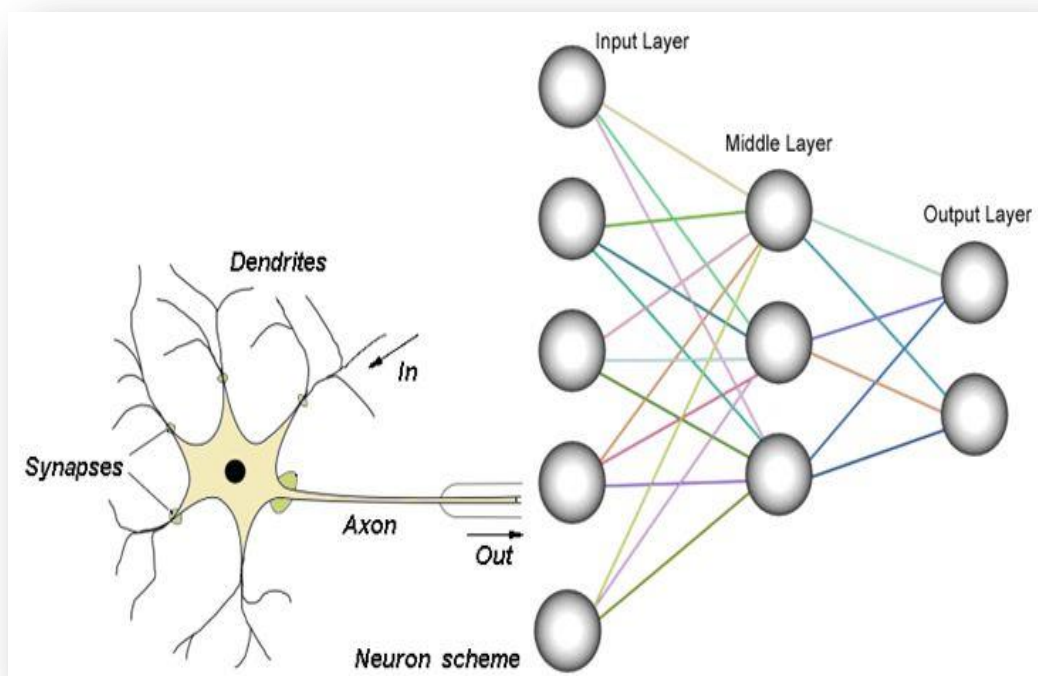


Figure 3.3: Neuron Scheme