CHAPTER 4

FORECASTING OF WATER DEMAND USING BACKPROPAGATION

4.1 Introduction

This chapter covers the experiment of water demand forecasting using backpropagation. Network development process will be described in details. Different data sets, learning rate, number of neurons are used to obtain the minimum mean squared error of testing data. Mean squared error (MSE) provided in Tables 3.2, 3.3 and 3.4 is selected as the performance function.

4.2 Network development process

Network development process for water demand forecasting from data selection to the comparison will be described in section 4.3 to 4.13.

4.3 Data selection and preparation

4.3.1 Variables selection

While the output of the artificial neural network is clearly the water demand, it is very important to choose the appropriate variables to be used as the input of neural network.

Vasinpongvanit (1999) recommended in his study about water demand of people in the MWA's responsible area that, by the multiple regression analysis, there are three factors concerning water demand. These factors are Gross Provincial

Product (GPP), water tariffs, and population per household. Hence, water demand forecasting with neural network in this study will use these variables with some modifications as the input of the network. Modification of each variable is described as follow:

1. Gross Provincial Product (GPP)

Using Gross Provincial Product is not possible because some of the data needed to be collected has not been issued yet. At the moment, the National Economics and Social Development Board has just issued the Gross Provincial Product of the Year 1999 which is not enough for this study. So in this study, Gross Domestic Product will be used instead of Gross Provincial Product.

2. Water tariffs

It is difficult to calculate the average water tariffs because the rates of tariffs are progressive. The more water the customers use, the more expensive tariff rate they have to pay. The rates of tariffs are also different due to different types of customer that are residential and non-residential. Using easier to calculate data such as increased water tariffs might be more appropriate.

3. Population per household

Population per household can be calculated by dividing the number of population by the number of household. Since some households in remote area have not been reached by the distribution system of the MWA yet, it might be unfair to include population per household. The number of connections or the number of customers of the MWA will be used instead.

Details of selected variables are described as follows:

1 Gross Domestic Product (GDP)

Gross Domestic Product Data from the Fiscal Year 1993 to 2001 at the Year 1988 Prices is collected to be the input of the network.

2 Increased Water Tariffs

Since the Fiscal Year 1993, water tariffs have been increased for three times in October 1996, March 1998 and July 1999. Each time the water tariffs are increased by 0.25 Baht per month for six consecutive months or 1.50 Baht per one

increase. Increased water tariffs data from the Fiscal Year 1993 to 2001 at the Fiscal Year 1993 prices are collected to be the input of the network.

3 Number of connections

The number of connections is the number of meters used for customers of the MWA. One meter not the population in the household is counted as one connection. Number of connections data from the Fiscal Year 1993 to 2001 is collected to be the input of the network.

4.3.2 Training data and Testing data

Data from the Fiscal Year 1993 to 2000 is set as Data Set 1 and data from the Fiscal Year 1999, 2000 and the first six months of the Fiscal Year 2001 is set as Data set 2.

1. Data Set 1

Data Set 1 has to be divided into two groups. Data from the Fiscal Year 1993 to 1998 is set as training data and data from the Fiscal Year 1999 to 2000 is set as testing data.

Training data contains input and output data. Input data comprises of GDP, increased water tariffs and number of connections while the output data is water demand. GDP, increased water tariffs, number of connections and water demand from the Fiscal Year 1993 to 1998 are shown in Tables 4.1, 4.2, 4.3 and 4.4 respectively.

***Table 4.1**: GDP (Million Baht) of the Fiscal Year 1993 – 1998*

Month/Year	1993	1994	1995	1996	1997	1998
1	190,214	218,764	241,313	254,691	266,732	254,525
2	190,214	218,764	241,313	254,691	266,732	254,525
3	190,214	218,764	241,313	254,691	266,732	254,525
4	201,156	224,197	244,605	255,478	258,919	239,314
5	201,156	224,197	244,605	255,478	258,919	239,314
6	201,156	224,197	244,605	255,478	258,919	239,314
7	196,169	214,161	242,100	258,251	256,772	220,299
8	196,169	214,161	242,100	258,251	256,772	220,299
9	196,169	214,161	242,100	258,251	256,772	220,299
10	208,197	218,800	240,688	259,413	254,656	219,152
11	208,197	218,800	240,688	259,413	254,656	219,152
12	208,197	218,800	240,688	259,413	254,656	219,152

***Table 4.2**: Increased Water Tariffs (Baht) of the Fiscal Year 1993 - 1998*

Month/Year	1993	1994	1995	1996	1997	1998
1	0.00	0.00	0.00	0.00	0.00	1.50
2	0.00	0.00	0.00	0.00	0.25	1.50
3	0.00	0.00	0.00	0.00	0.50	1.50
4	0.00	0.00	0.00	0.00	0.75	1.50
5	0.00	0.00	0.00	0.00	1.00	1.50
6	0.00	0.00	0.00	0.00	1.25	1.75
7	0.00	0.00	0.00	0.00	1.50	2.00
8	0.00	0.00	0.00	0.00	1.50	2.25
9	0.00	0.00	0.00	0.00	1.50	2.50
10	0.00	0.00	0.00	0.00	1.50	2.75
11	0.00	0.00	0.00	0.00	1.50	3.00
12	0.00	0.00	0.00	0.00	1.50	3.00

***Table 4.3**: Number of Connections (Connections) of the Fiscal Year 1993 – 1998*

Month/Year	1993	1994	1995	1996	1997	1998
1	1,096,007	1,146,038	1,198,060	1,245,231	1,292,182	1,346,269
2	1,099,861	1,150,698	1,201,506	1,248,783	1,297,048	1,351,162
3	1,102,491	1,154,088	1,205,235	1,252,891	1,300,894	1,355,104
4	1,104,918	1,157,835	1,208,538	1,257,249	1,304,453	1,357,357
5	1,108,148	1,161,122	1,210,842	1,261,210	1,309,791	1,359,109
6	1,111,164	1,164,466	1,214,805	1,264,847	1,313,429	1,360,758
7	1,114,664	1,170,335	1,220,444	1,269,832	1,317,985	1,363,055
8	1,117,829	1,174,259	1,225,592	1,274,890	1,322,589	1,365,098
9	1,120,922	1,178,833	1,229,734	1,279,076	1,329,167	1,367,138
10	1,128,405	1,182,856	1,234,212	1,282,132	1,334,466	1,368,095
11	1,133,956	1,188,348	1,237,158	1,285,615	1,337,560	1,368,803
12	1,139,299	1,194,161	1,241,380	1,289,168	1,341,838	1,369,728

***Table 4.4**: Water Demand (Million Cubic Meters) of the Fiscal Year 1993 - 1998*

Month/Year	1993	1994	1995	1996	1997	1998
1	101.640	106.229	109.445	123.746	139.990	139.690
2	97.130	102.493	110.809	120.349	135.687	132.816
3	99.790	103.957	117.758	124.944	137.224	132.507
4	99.682	101.410	118.473	123.205	135.310	127.791
5	92.121	90.221	102.663	119.704	123.206	115.680
6	105.099	98.018	118.762	131.345	138.264	131.821
7	101.422	96.274	113.941	130.486	134.520	128.608
8	107.395	103.422	121.067	134.677	139.995	133.325
9	103.262	106.468	120.748	131.146	135.022	127.774
10	105.838	110.187	125.127	135.779	139.166	130.188
11	106.608	109.563	124.999	139.484	138.470	129.880
12	104.895	106.011	121.433	134.495	135.535	125.130

Testing data also contains input and output data. Input data comprises of GDP, increased water tariffs and number of connections while the output data is water demand. GDP, increased water tariffs, number of connections and water demand of the Fiscal Year 1999 and 2000 are shown in Tables 4.5, 4.6, 4.7 and 4.8 respectively.

***Table 4.5**: GDP (Million Baht) of the Fiscal Year 1999 - 2000*

Month/Year	1999	2000
1	235,688	251,095
2	235,688	251,095
3	235,688	251,095
4	239,557	252,272
5	239,557	252,272
6	239,557	252,272
7	226,139	240,505
8	226,139	240,505
9	226,139	240,505
10	236,262	243,161
11	236,262	243,161
12	236,262	243,161

***Table 4.6:** Increased Water Tariffs (Baht) of the Fiscal Year 1999 - 2000*

Month/Year	1999	2000
1	3.00	4.00
2	3.00	4.25
3	3.00	4.50
4	3.00	4.50
5	3.00	4.50
6	3.00	4.50
7	3.00	4.50
8	3.00	4.50
9	3.00	4.50
10	3.25	4.50
11	3.50	4.50
12	3.75	4.50

Table 4.7: Number of Connections (Connections) of the Fiscal Year 1999 – 2000

Month/Year	1999	2000
1	1,369,059	1,386,151
2	1,368,376	1,387,902
3	1,368,310	1,390,169
4	1,368,924	1,391,796
5	1,370,030	1,393,451
6	1,370,995	1,395,831
7	1,372,873	1,397,931
8	1,374,324	1,399,760
9	1,375,433	1,402,128
10	1,376,725	1,404,199
11	1,378,676	1,406,594
12	1,384,958	1,410,101

Table 4.8: Water Demand (Million Cubic Meters) of the Fiscal Year 1999 - 2000

Month/Year	1999	2000
1	125.615	118.809
2	120.288	114.873
3	122.178	116.305
4	116.473	117.371
5	107.640	112.215
6	119.846	127.292
7	117.141	121.321
8	120.188	123.678
9	114.476	120.474
10	118.664	123.071
11	117.962	124.099
12	114.712	119.909

2. Data Set 2

Data Set 2 has to be divided for training and testing. Data from the Fiscal Year 1999 to 2000 is set as training data and data from the first sixth months of the Fiscal Year 2001 is set as testing data. So the testing data of Data Set 1 now becomes the training data of Data Set 2.

Training data contains input and output data. Input data comprises of GDP, increased water tariffs and the number of connections while the output data is water demand. GDP, increased water tariffs, number of connections and water demand of the training data are shown in Tables 4.5, 4.6, 4.7 and 4.8 respectively.

Testing data also contains input and output data. Input data comprises of GDP, increased water tariffs and number of connections while the output data is

water demand. GDP, increased water tariffs, number of connections and water demand of testing data is shown in Tables 4.9, 4.10, 4.11 and 4.12 respectively.

***Table 4.9**: GDP (Million Baht) of the first sixth months of the Fiscal Year 2001*

Month/Year	2001
1	259,050
2	259,050
3	259,050
4	256,699
5	256,699
6	256,699

***Table 4.10**: Increased Water Tariffs (Baht) of the first sixth months of the Fiscal Year 2001*

Month/Year	2001
1	4.50
2	4.50
3	4.50
4	4.50
5	4.50
6	4.50

***Table 4.11**: Number of Connections (Connections) of the first sixth months of the Fiscal Year 2001*

Month/Year	2001
1	1,412,441
2	1,415,146
3	1,417,804
4	1,422,046
5	1,424,796
6	1,427,228

***Table 4.12**: Water Demand (Million Cubic Meters) of the first sixth months of the Fiscal Year 2001*

Month/Year	2001
1	122.747
2	120.083
3	122.484
4	123.109
5	113.644
6	127.312

4.3.3 Data transformation

All data will be transformed to MATLAB required format. Normalization is used to map all data to the range between 0 and 1 that is appropriate for the calculation.

4.4 Network architecture

Network with two layers and one hidden layer is used here. Batch gradient descent with momentum is used as the training algorithm. Tan-Sigmoid and Log-Sigmoid are used as the activated function for the hidden layer and the output layer respectively. The architecture of neural network used in this study is shown in Figure 4.1.

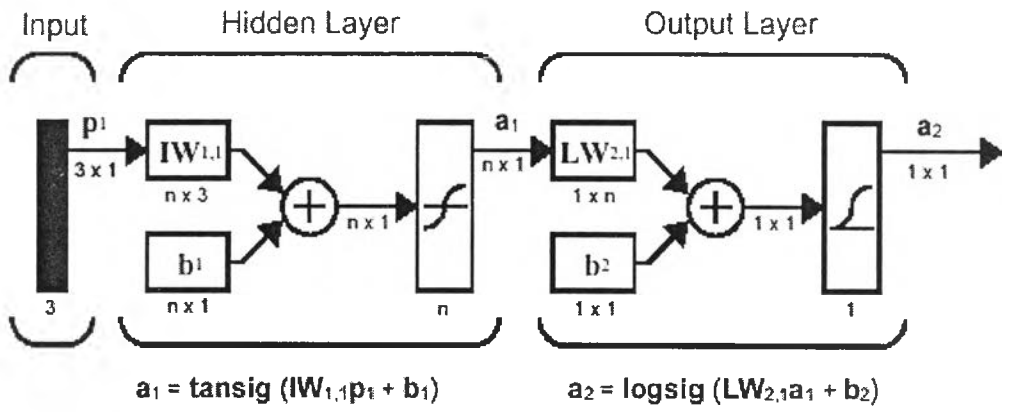

Figure 4.1: Architecture of the network used for forecasting

From Figure 4.1, "p_1" is a vector input. "a_1" is the output of hidden layer that will be transmitted to the output layer. "a_2" is the output of the output layer that is water demand. "$IW_{1,1}$" and "$LW_{2,1}$ are the weight matrix of the hidden layer and the output layer respectively. "b1" and "b2" are the biases of the hidden layer and the output layer respectively.

4.5 Experimental objectives

4.5.1 Comparison on forecasting result from training with different learning rate

Different training rate leads to different results. Too large learning rate can make the network become unstable that leads to inaccurate result. Too small learning rate makes the network learn too slow so the appropriate learning rate for the network should be found. Three test sets are conducted as follows:

1. Test Set 1: Data Set 1 with the learning rate at 0.005
2. Test Set 2: Data Set 1 with the learning rate at 0.01
3. Test Set 3: Data Set 1 with the learning rate at 0.05

4.5.2 Comparison on forecasting result from training with different sets of training data

Different sets of training data and testing data lead to different results. Figure 4.2 presents water demand of the Fiscal Year 1993 to 2000.

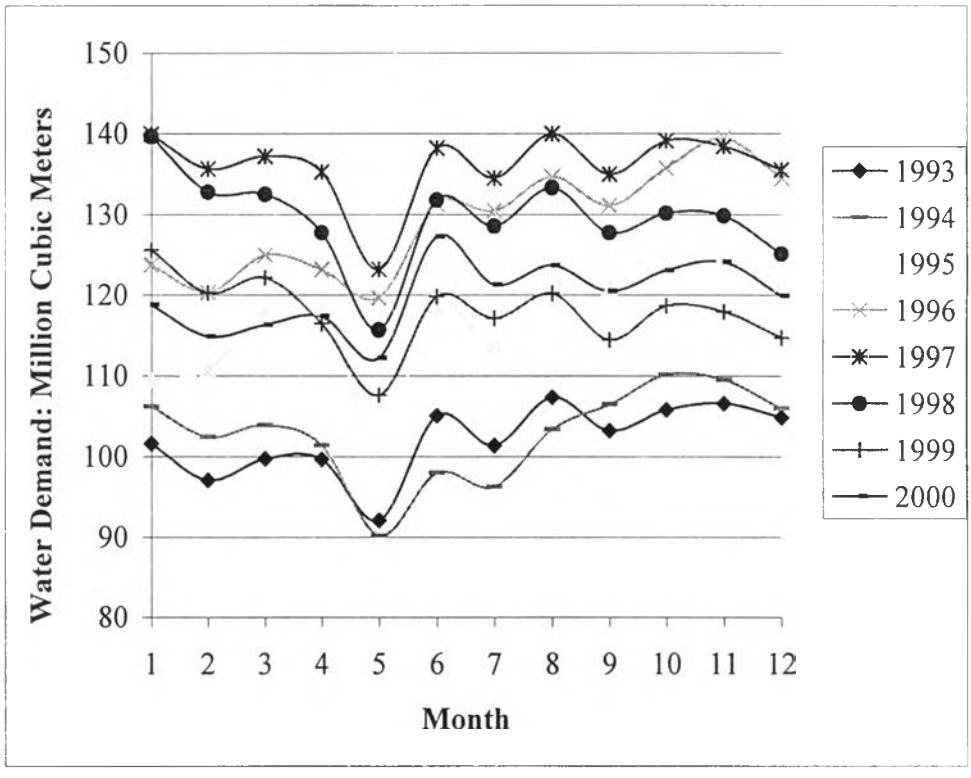

***Figure 4.2**: Graph of Water Demand from the Fiscal Year 1993 to 2000*

From Figure 4.2, some value of water demand in some Fiscal Years can be categorized as outliers. Including them in the training data might make the network become confused. In this section, different sets of training data are

conducted by extracting some training data. To find the set of data that leads to the best forecasting results, the following test sets are performed.

1. Test Set 4: Data Set 1 excluded the data from the Fiscal Year 1995 and 1996
2. Test Set 5: Data Set excluded the data from the Fiscal Year 1997 and 1998
3. Test Set 6: Data Set 1 excluded the data from 5^{th} and 6^{th} months of every Fiscal Year
4. Test Set 7: Data Set 1 divided into 4 Quarters
5. Test Set 8: Data Set 2

4.5.3 Comparison on forecasting result from training with another variable added as the additional input

To check the effect of adding order of months as the additional input variable, the following test sets are conducted.

1. Test Set 9: Data Set 1 added by order of months
2. Test Set 10: Data Set 2 added by order of months

4.6 Forecasting using different learning rate

This section covers Test Set 1, 2 and 3, which use different learning rates and different number of neurons.

Training data: Use training data of Data Set 1 but data from the Fiscal Year 1995 and 1996 are removed.

Testing data: Use testing data of Data Set 1

Initial parameters: Test Sets 1, 2 and 3 use the learning rate at 0.005, 0.01 and 0.05 respectively. Each Test Set has the number of neurons varying from 1 to 50. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Tables 4.13, 4.14 and 4.15

Test Set 1: Learning rate at 0.005

Table 4.13: Training Result of Test Set 1

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.031128	183.87
2	0.020196	62.96
3	0.062271	47.78
4	0.095629	76.43
5	**0.043461**	**28.74***
6	0.020481	133.20
7	0.064663	75.89
8	0.032720	61.24
9	0.193170	141.19
10	0.017598	98.73
11	0.010186	193.48
12	0.081712	331.56
13	0.024393	284.31
14	0.014195	184.95
15	0.020374	113.59
16	0.036275	113.27
17	0.079360	113.55
18	0.014363	62.74
19	0.022296	132.55
20	0.014622	138.14
21	0.021753	362.98
22	0.030783	38.69
23	0.014980	321.69
24	0.019977	165.07
25	0.025829	105.93
26	0.017184	135.11
27	0.017482	173.86
28	0.012888	169.18
29	0.017576	146.47
30	0.029958	120.16
31	0.017466	152.99
32	0.024911	206.43
33	0.013929	254.88
34	0.014438	121.48
35	0.013254	155.65
36	0.012611	165.01
37	0.026047	128.36
38	0.012861	187.63
39	0.012096	228.85
40	0.019331	52.02
41	0.013571	207.27
42	0.018496	259.73
43	0.010730	153.79
44	0.009472	247.99
45	0.019021	135.41
46	0.018481	83.43
47	0.013403	167.99

Table 4.13: Training Result of Test Set 1 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
48	0.015393	377.16
49	0.011216	84.95
50	0.014805	55.37

From Table 4.13, a network with 5 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 28.74.

Test Set 2: Learning rate at 0.01

Table 4.14: Training Result of Test Set 2

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.118129	74.19
2	0.018755	127.95
3	**0.048033**	**23.92***
4	0.017473	117.79
5	0.014440	71.53
6	0.021123	43.19
7	0.020238	48.66
8	0.019866	50.83
9	0.014003	52.16
10	0.012173	119.44
11	0.014357	69.44
12	0.012860	54.59
13	0.020877	129.34
14	0.021227	71.21
15	0.012551	151.02
16	0.014969	135.12
17	0.014895	184.50
18	0.010496	168.04
19	0.015809	45.25
20	0.014052	122.87
21	0.008332	149.21
22	0.013228	175.26
23	0.012822	98.98
24	0.014829	62.72
25	0.010573	87.99
26	0.012382	136.81
27	0.013714	137.85
28	0.016953	121.05
29	0.012570	128.60
30	0.008990	140.23
31	0.019189	133.95

Table 4.14: Training Result of Test Set 2 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
32	0.010214	167.80
33	0.013343	130.20
34	0.017246	184.26
35	0.012183	136.93
36	0.014205	179.72
37	0.017405	128.74
38	0.015925	191.11
39	0.013486	194.02
40	0.010847	35.28
41	0.008873	142.66
42	0.010898	133.98
43	0.016109	86.91
44	0.012377	75.44
45	0.026005	50.59
46	0.015026	99.35
47	0.012398	78.47
48	0.011709	61.96
49	0.013653	151.30
50	0.011052	162.61

From Table 4.14, a network with 3 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 23.92.

Test Set 3: Learning rate at 0.05

Table 4.15: Training Result of Test Set 3

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.027616	63.44
2	0.011804	153.24
3	0.016235	39.06
4	0.012752	45.60
5	0.016429	60.98
6	0.010209	85.54
7	0.011323	132.95
8	0.009244	81.19
9	0.009686	79.11
10	0.010748	102.18
11	0.010186	80.14
12	0.008667	81.09
13	0.008665	96.45
14	0.008937	71.37
15	0.014165	97.87

Table 4.15: Training Result of Test Set 3

No. of Neurons	MSE of Training Data	MSE of Testing Data
16	0.011030	73.56
17	0.010158	180.50
18	0.009871	181.27
19	0.009584	96.05
20	0.009881	66.11
21	0.008953	120.42
22	0.009395	151.25
23	0.008036	129.53
24	0.013710	111.85
25	0.012446	154.12
26	0.014640	150.92
27	0.009048	135.81
28	0.016019	88.94
29	0.013269	137.02
30	0.008595	143.01
31	0.015390	176.03
32	**0.010801**	**36.67***
33	0.015311	60.02
34	0.009559	43.41
35	0.008923	141.62
36	0.011143	86.63
37	0.009071	146.87
38	0.012613	131.45
39	0.009702	134.97
40	0.010035	83.21
41	0.008699	94.92
42	0.014352	126.68
43	0.007615	162.94
44	0.007819	109.92
45	0.009491	165.53
46	0.009337	124.71
47	0.008738	118.41
48	0.007442	165.57
49	0.009066	188.50
50	0.007848	72.81

From Table 4.15, a network with 32 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 36.67.

Among Test Sets 1, 2 and 3 which networks are trained with different learning rate, Test Set 2 that uses learning rate at 0.01 provides the least mean squared error. Hence the learning rate at 0.01 will be used as a default learning rate for the rest Test Sets.

4.7 Forecasting using Data Set 1 excluded data from the Fiscal Year 1995 and 1996

This section covers Test Set 4, which uses the different data set as used in section 4.6.

Training data: Use training data of Data Set 1 but data from the Fiscal Year 1995 and 1996 is removed.

Testing data: Use testing data of Data Set 1

Initial parameters: Use learning rate at 0.01. The number of neurons varies from 1 to 50. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.16

Test set 4: Data Set 1 excluded the data from the Fiscal Year 1995 and 1996

Table 4.16: Training Result of Test Set 4

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.037768	26.96
2	0.267009	37.12
3	**0.146572**	**20.63***
4	0.027695	80.09
5	0.020611	145.21
6	0.017382	110.42
7	0.015790	193.79
8	0.016098	131.13
9	0.013064	149.97
10	0.028719	33.06
11	0.012750	76.09
12	0.011686	102.75
13	0.019667	113.52
14	0.012762	92.00
15	0.015594	86.69
16	0.029653	139.27
17	0.013978	75.24
18	0.010937	75.54
19	0.011451	91.29
20	0.018542	139.44
21	0.012652	70.86
22	0.015096	101.10
23	0.016280	175.60
24	0.009816	84.50

Table 4.16: Training Result of Test Set 4 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
25	0.014751	121.08
26	0.011963	97.82
27	0.011913	80.30
28	0.017461	111.03
29	0.014417	160.98
30	0.011559	80.00
31	0.010471	106.38
32	0.015827	76.40
33	0.010283	95.18
34	0.009693	162.95
35	0.013057	111.53
36	0.013274	132.50
37	0.011233	82.78
38	0.027570	32.86
39	0.026467	35.27
40	0.021174	82.26
41	0.013364	142.29
42	0.009285	106.77
43	0.012579	69.87
44	0.009490	75.07
45	0.013641	48.75
46	0.011839	88.45
47	0.015395	97.76
48	0.014204	72.14
49	0.012297	101.13
50	0.013637	200.76

From Table 4.16, a network with 3 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 20.63.

4.8 Forecasting using Data Set 1 excluded the data of the Fiscal Year 1997 and 1998

This section covers Test Set 5, which uses another different data set as used in section 4.6.

Training data: Use training data of Data Set 1 but data from the Fiscal Year 1997 and 1998 is removed.

Testing data: Use testing data of Data Set 1.

Initial parameters: Use learning rate at 0.01. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.17

Test Set 5: Data Set 1 excluded the data from the Fiscal Year 1997 and 1998

Table 4.17: Training Result of Test Set 5

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.020845	138.65
2	**0.017057**	**20.30***
3	0.021389	82.08
4	0.098643	33.86
5	0.080180	53.53
6	0.020821	31.21
7	0.015275	41.16
8	0.010485	207.12
9	0.012054	91.11
10	0.016524	99.09
11	0.011108	61.52
12	0.032426	75.04
13	0.009943	83.96
14	0.018542	91.87
15	0.017214	118.91
16	0.012377	131.50
17	0.011514	145.49
18	0.009010	94.49
19	0.014011	66.08
20	0.010492	87.64
21	0.011077	195.15
22	0.009325	46.14
23	0.008811	111.36
24	0.010279	46.80
25	0.009175	95.11
26	0.008799	74.87
27	0.015368	65.58
28	0.015566	35.08
29	0.008796	56.17
30	0.010387	143.77
31	0.012695	146.80
32	0.016021	69.63
33	0.011645	66.59
34	0.007105	119.39
35	0.007390	149.91
36	0.010019	146.29

Table 4.17: Training Result of Test Set 5 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
37	0.009482	94.69
38	0.010673	192.44
39	0.011590	69.35
40	0.011646	41.81
41	0.010673	179.98
42	0.010492	89.57
43	0.017339	267.06
44	0.010643	105.56
45	0.008378	166.87
46	0.035770	99.86
47	0.008187	110.47
48	0.017999	106.68
49	0.014235	100.61
50	0.009189	196.52

From Table 4.17, a network with 2 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 20.30.

4.9 Forecasting using Data Set 1 excluded the data of 5th and 6th months of every Fiscal Year

This section covers Test Set 6, which uses another different set of data. Data of 5th and 6th months of every Fiscal Year is removed from both training data and testing data. From Figure 4.2 if the data of 5th and 6th months is categorized as the outliers, removing it from the test will improve forecasting accuracy.

Training data: Use Data Set 1 but data of 5th and 6th months of every Fiscal Year is removed.

Testing data: Use Data Set 1 but data of 5th and 6th months of every Fiscal Year is removed.

Initial parameters: Use learning rate at 0.01. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.18

Test Set 6: Data Set 1 excluded the data from 5th and 6th months of every Fiscal Year.

***Table 4.18**: Training Result of Test Set 6*

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.005600	40.43
2	**0.029107**	**22.92***
3	0.008151	203.30
4	0.009437	90.29
5	0.081311	47.54
6	0.007581	90.06
7	0.006210	101.07
8	0.005151	124.44
9	0.028327	25.61
10	0.005283	93.73
11	0.007039	36.09
12	0.008375	122.23
13	0.004531	40.79
14	0.005629	163.47
15	0.004443	181.24
16	0.005405	50.38
17	0.005903	138.18
18	0.006480	99.03
19	0.009304	44.41
20	0.007011	83.46
21	0.006303	105.52
22	0.005345	37.69
23	0.006108	97.80
24	0.006448	35.69
25	0.007752	117.80
26	0.006440	174.40
27	0.006053	161.22
28	0.003951	105.04
29	0.004178	86.02
30	0.005382	98.84
31	0.007310	49.11
32	0.004913	54.24
33	0.004685	82.27
34	0.009353	104.99
35	0.006451	73.20
36	0.004381	122.40
37	0.004492	75.37
38	0.005531	92.59
39	0.008416	73.97
40	0.005163	41.44
41	0.004136	44.79
42	0.006156	59.33
43	0.004899	109.58

Table 4.18: Training Result of Test Set 6 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
44	0.004880	57.21
45	0.004822	24.77
46	0.003753	85.39
47	0.004939	109.62
48	0.004717	267.28
49	0.006273	157.12
50	0.003685	95.06

From Table 4.18, a network with 2 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 22.92.

4.10 Forecasting result of using Data Set 1 divided into 4 Quarters

This section covers Test Set 7, which uses Data Set 1 as used in section 4.4 but especially for this test, the data set is divided into 4 Quarters. Then each data set is trained and tested separately. All results from 4 experiments are combined to be yearly result.

Training data: Use training data of Data Set 1.

Testing data: Use testing data of Data Set 1.

Initial parameters: Use learning rate at 0.01. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.19

Test Set 7: Data Set 1 divided into 4 Quarters.

Table 4.19: Training Result of Test Set 7

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.055287	48.10
2	0.032051	85.85
3	0.013086	91.26
4	0.036001	69.86
5	0.008876	60.41

Table 4.19: Training Result of Test Set 7 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
6	0.013366	83.74
7	0.069079	85.55
8	0.018469	56.25
9	**0.055200**	**29.51***
10	0.060222	94.58
11	0.014079	90.12
12	0.009622	141.54
13	0.010866	146.72
14	0.011867	106.63
15	0.048579	174.66
16	0.023074	142.21
17	0.009064	213.86
18	0.014518	91.62
19	0.012384	93.46
20	0.010287	130.43
21	0.010167	187.50
22	0.008181	90.62
23	0.010994	83.08
24	0.010405	97.07
25	0.009271	82.00
26	0.018317	105.36
27	0.014562	165.25
28	0.033126	75.16
29	0.011993	203.92
30	0.010233	122.24
31	0.008750	91.14
32	0.081055	71.66
33	0.010159	163.86
34	0.009335	54.51
35	0.053830	213.65
36	0.007261	135.37
37	0.010572	130.06
38	0.008130	148.21
39	0.009445	164.65
40	0.008355	163.16
41	0.010167	248.92
42	0.010380	167.18
43	0.007374	152.30
44	0.010883	159.69
45	0.052303	107.72
46	0.009745	118.13
47	0.009478	72.99
48	0.012139	100.25
49	0.011328	49.26
50	0.009517	54.38

From Table 4.19, a network with 9 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 29.51.

4.11 Forecasting result of using Data Set 2

This section covers Test Set 8. It uses the new data set that uses data from the Data Set 2.

Training data: Use training data of Data Set 2.

Testing data: Use testing data of Data Set 2.

Initial parameters: Use learning rate at 0.01. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.20

Test Set 8: Data Set 2

***Table 4.20**: Training Result of Test Set 8*

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.018064	26.42
2	0.011227	51.40
3	0.042233	27.96
4	0.030779	21.31
5	0.022673	49.58
6	0.011064	26.42
7	0.016063	48.79
8	0.014531	42.78
9	0.026121	23.21
10	0.007444	21.56
11	0.021930	18.76
12	0.007009	24.09
13	0.018157	21.48
14	0.010264	30.95
15	0.013592	32.69
16	0.030850	39.23
17	0.021838	83.02
18	0.014165	21.09
19	0.013496	31.14
20	0.008897	54.50
21	0.013874	32.79
22	0.010542	36.63

Table 4.20: Training Result of Test Set 8 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
23	0.013320	19.59
24	0.024962	22.19
25	0.011964	75.85
26	**0.012924**	**17.53***
27	0.018920	56.37
28	0.006987	74.82
29	0.010960	43.49
30	0.010044	62.15
31	0.009817	77.77
32	0.006862	39.45
33	0.008893	25.45
34	0.006109	160.28
35	0.009001	45.05
36	0.016122	44.29
37	0.013404	47.85
38	0.010696	35.00
39	0.005591	46.18
40	0.015518	31.70
41	0.011322	35.78
42	0.007503	19.86
43	0.009877	30.06
44	0.004746	109.29
45	0.007687	51.40
46	0.008879	31.40
47	0.015547	70.23
48	0.009554	19.33
49	0.006761	19.19
50	0.006538	105.79

From Table 4.20, a network with 26 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 17.53.

4.12 Forecasting using Data Set 1 added by order of months as the additional input

This section covers Test Set 9.

Training data: Use training data of Data Set 1 but order of months ranged from 1 to 12 are added as 4^{th} input data.

Testing data: Use testing data of Data Set 1 but order of months ranged from 1 to 12 are added as 4th input data.

Initial parameters: Use learning rate at 0.01. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.21

Test Set 9: Data Set 1 included order of months as the additional input.

***Table 4.21**: Training Result of Test Set 9*

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.037877	55.78
2	**0.091589**	**23.08***
3	0.104082	44.53
4	0.032719	104.14
5	0.020728	103.77
6	0.029206	68.16
7	0.071428	110.66
8	0.036083	117.29
9	0.042061	57.66
10	0.043791	41.90
11	0.021644	110.81
12	0.027652	70.62
13	0.027089	184.00
14	0.027483	135.83
15	0.018143	131.93
16	0.040573	84.36
17	0.032724	147.49
18	0.020043	77.95
19	0.014072	103.88
20	0.022298	176.80
21	0.017993	225.11
22	0.013165	90.36
23	0.011020	108.02
24	0.016770	90.41
25	0.011639	90.47
26	0.014842	145.06
27	0.013182	189.21
28	0.013798	141.72
29	0.016786	238.24
30	0.017391	144.68
31	0.017538	323.92
32	0.012566	127.68
33	0.016144	64.46
34	0.017148	149.25
35	0.010483	60.99
36	0.017993	131.92

Table 4.21: Training Result of Test Set 9 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
37	0.018744	88.79
38	0.012418	131.92
39	0.015402	59.28
40	0.016474	211.78
41	0.014604	151.80
42	0.009538	181.23
43	0.015729	166.95
44	0.014343	179.31
45	0.014907	107.97
46	0.013515	134.11
47	0.011881	198.28
48	0.011679	266.29
49	0.013184	133.92
50	0.015323	134.22

From Table 4.21, a network with 2 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 23.08.

4.13 Forecasting of using Data Set 2 included order of months as the additional input

This section covers Test Set 10.

Training data: Use training data of Data Set 2 but order of months ranged from 1 to 12 are added set 4^{th} input.

Testing data: Use testing data of Data Set 2 but order of months ranged from 1 to 12 are added as 4^{th} input.

Initial parameters: Use learning rate at 0.01. Momentum constant is set at 0.9. Epoch is set at 2,000.

The results are shown in Table 4.22

Test Set 10: Data Set 2 included order of months as the additional input.

Table 4.22: Training Result of Test Set 10

No. of Neurons	MSE of Training Data	MSE of Testing Data
1	0.008567	38.54
2	0.008832	23.53
3	0.018084	26.50
4	0.012990	34.23
5	0.012614	24.29
6	0.029977	19.26
7	0.025259	19.98
8	0.037689	19.93
9	0.010057	20.21
10	0.010080	83.22
11	0.010199	34.91
12	0.021942	19.02
13	0.006657	40.01
14	0.008241	32.50
15	0.010434	43.69
16	0.012420	32.44
17	0.014547	53.25
18	0.015050	120.44
19	0.019675	43.85
20	0.014370	33.46
21	0.007689	65.14
22	0.008799	101.23
23	0.011932	48.26
24	0.007412	40.13
25	0.006745	37.22
26	**0.012354**	**17.99***
27	0.008830	42.68
28	0.014175	65.77
29	0.013165	30.75
30	0.006398	37.61
31	0.007896	47.55
32	0.010645	74.08
33	0.006193	36.82
34	0.007587	32.41
35	0.023354	28.59
36	0.016985	39.58
37	0.008360	55.75
38	0.013915	29.45
39	0.004926	67.20
40	0.006115	108.20
41	0.010666	35.16
42	0.008023	33.74
43	0.008841	33.93
44	0.009675	53.94
45	0.007241	46.66
46	0.005463	79.03
47	0.017472	45.20

Table 4.22: Training Result of Test Set 10 (cont.)

No. of Neurons	MSE of Training Data	MSE of Testing Data
48	0.010157	44.54
49	0.011752	34.52
50	0.009814	40.57

From Table 4.22, a network with 26 neurons in the hidden layer generates the minimum mean squared error of testing data where the mean squared error is 17.99.

4.14 Analysis of the results

4.14.1. Forecasting results of the Fiscal Year 1999 and 2000

The best results of all Test Sets that use data from Data Set 1 are summarized in Table 4.23 as follows:

Table 4.23: The best result of all Test Sets that use data from Data Set 1

Test set No.	MSE of Testing Data
Test set 1	28.74
Test set 2	23.92
Test set 3	36.67
Test set 4	20.63
Test set 5	***20.30**
Test set 6	23.08
Test set 7	22.92
Test set 9	29.51

While the MSE of water demand forecasting using accrual moving average from Table B.1 is 89.19, it is noted that all Test sets in Table 4.23 provides the value of MSE much less than 89.19.

From Table 4.23, Test Set 5 generates the minimum mean squared among all Test Sets that uses data from Data Set 1. So forecasting result of Test Set 5

is now selected as the representative of all results from the artificial neural network. Then it is compared with the results from accrual moving average technique.

Table 4.24 presents the comparison between actual water demand and forecasting result from Test Set 5 which gives the best result among all results from artificial neural network technique.

***Table 4.24**: Comparison between Actual and Water Demand Forecast from Test Set 5 of the Fiscal Year 1999 and 2000*

Month/Fiscal Year	**Actual (million cu.m^3)**	**Forecast (million cu.m^3)**	**Error (million cu.m^3)**
1/1999	125.615	116.001	-9.614
2/1999	120.288	115.956	-4.332
3/1999	122.178	115.950	-6.229
4/1999	116.473	116.863	0.390
5/1999	107.640	116.931	9.291
6/1999	119.846	116.991	-2.855
7/1999	117.141	114.390	-2.752
8/1999	120.188	114.507	-5.681
9/1999	114.476	114.596	0.120
10/1999	118.664	116.534	-2.130
11/1999	117.962	116.734	-1.229
12/1999	114.712	117.571	2.859
Total for 1999 Error = -1.57%	**1,415.183**	**1,393.023**	**-22.161**
1/2000	118.809	119.598	0.789
2/2000	114.873	119.926	5.052
3/2000	116.305	120.645	4.339
4/2000	117.371	120.781	3.410
5/2000	112.215	120.889	8.674
6/2000	127.292	121.042	-6.250

Table 4.24: Comparison between Actual and Water Demand Forecast from Test Set 5 of the Fiscal Year 1999 and 2000 (cont.)

Month/Fiscal Year	Actual (million cu.m^3)	Forecast (million cu.m^3)	Error (million cu.m^3)
7/2000	121.321	121.910	0.589
8/2000	123.678	122.089	-1.590
9/2000	120.474	122.316	1.842
10/2000	123.071	122.148	-0.924
11/2000	124.099	122.349	-1.750
12/2000	119.909	122.639	2.729
Total for 2000 Error = 1.17%	**1,439.417**	**1,456.329**	**16.911**
Overall Error = -0.18%	**2,858.600**	**2,849.351**	**-5.249**

4.14.2. Forecasting result of the first sixth months of the Fiscal Year 2001

The best result of all Test Sets that uses data from Data Set 2 are summarized in Table 4.25.

Table 4.25: The best result of all Test Sets that use data from Data Set 2

Test set No.	MSE of Testing Data
Test set 8	***17.53**
Test set 10	17.99

From Table 4.25, Test Set 8 generates the minimum mean squared among all test sets that uses data from Data Set 2. This result is now compared with the results from accrual moving average.

While the MSE of water demand forecasting using accrual moving average from Table B.3 is 38.99, it is noted that both Test sets in Table 4.25 provides the value of MSE much less than 38.99.

Table 4.26 presents the comparison between actual water demand and forecasting result from Test Set 8 which gives the best result among all results from artificial neural network technique.

***Table 4.26**: Comparison between Actual and Water Demand Forecast from Test set 8 of the first sixth months of the Fiscal Year 2001*

Month/Fiscal Year	**Actual (million cu.m^3)**	**Forecast (million cu.m^3)**	**Error (million cu.m^3)**
1/2001	122.747	120.674	-2.073
2/2001	120.083	120.733	0.650
3/2001	122.484	120.857	-1.628
4/2001	123.109	121.930	-1.179
5/2001	113.644	122.869	9.225
6/2001	127.312	123.952	-3.360
Total	**729.379**	**731.014**	**1.635**
Error = 0.22%			

Table 4.27 presents the summary of comparison between forecasting result from neural network and that of accrual moving average technique from Tables 3.2 and 3.3.

***Table 4.27**: Comparison on percentages of error from neural network and accrual moving average*

Fiscal Year	**Artificial Neural Network**	**Accrual Moving Average**
1999	-1.57	9.81
2000	1.17	-3.20
First Sixth Months of 2001	0.22	-3.55

From Table 4.27, the comparison between the result of neural network and the result of accrual moving average presents that at any Fiscal Year, neural network is able to provide more accuracy than the accrual moving average.

4.14.3. Result on adding order of months as 4th variable input

The results of Test Sets 9 and 10, when compared with the result of Test Sets 2 and 8 respectively, present that adding order of months as the additional variable input to Test Set 9 and 10 does not give better results. So order of months should not be considered as the variable input to the network.

4.15 Conclusion

From all of the experiment made in this chapter, the following conclusion can be drawn.

1. Different sets of training data generate different results. User has to choose the appropriate set of training data in order to obtain the minimum mean squared error of the testing data. The training data that gives the minimum mean squared error for water demand forecast of the Fiscal Year 1999 and 2000 is the data from the Fiscal Year 1993 to 1996. The result is according to theory because the economics recession happened in the Fiscal Year 1997 and . So removing the data of the Fiscal Year 1997 and 1998 from input of training data leads to the best result.

2. Different numbers of neurons in the hidden layer network give different results. Network designer has to find the number of neurons that gives the minimum error of the testing data for each training set.

3. Too large learning rate can make the network become unstable and give inaccurate result. In contrast, too small learning rate can waste the time needed for training. From the result among Test Sets 1, 2 and 3, training with learning rate at 0.01 gives the least MSE.

4. Adding the order of months as the additional variable input does not improve any accuracy so it is not necessary to include the order of months in the input.

5. Not enough number of input for training leads to the increase number of neurons in the hidden layer of the network.

6. Though using different time period, neural network has proved that it can give more forecasting accuracy than that of the traditional accrual moving average technique.