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Operation of Roseires and Sennar Dams Using Artificial Neural Network

Thesis submitted in Partial Fulfilment of Requirements for The Degree of M.Sc in Water Resources Engineering

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Mawada

]Abstract

This study, describes the operation of Roseires and Sennar dams during the dry season when the demand is greater than the available water at El Deim station and tries to find out the relationship between water levels, amount of evaporation losses, predicted inflow discharges at El Deim station during the recession period and reservoirs contents of Roseires & Sennar dams.

Artificial neural network has been used to establish three models:

Model -1 : To predict inflow discharges at El Deim station .

Model -2 : To predict reservoir water level knowing reservoir content
and year of application.

Model -3 : To find out the numeric relationship between reservoir water
level & Evaporation losses.

Artificial Neural network using NeuroShell2 software, which provides a quick and flexible means of creating models for prediction, has been shown to perform well in comparison with conventional methods.

Different scenarios of different network structures have been tried, the best architecture for the three models is the three connected layer with specified hidden neurons, but the hidden layer in the first two models consist of two slabs.

The results obtained from model-1, model -2 and model -3 are used in a computer program to establish the emptying program of Roseires & Sennar reservoirs using M.S Excel software.

By assuming different areas of Wheat crop - its planting season start on 2nd period of October - the emptying of the two reservoirs has been run taking into considerations the following aspects:

i. At the beginning of the empting program, the two reservoirs of Sennar & Roseires dams are at their predetermined maximum water levels.

ii. Irrigation demands include projects upstream Sennar dam, Gezira & Managil schemes and minimum downstream requirements.

iii. At the end of emptying program, the water level of the two reservoirs should not drop below the minimum water level of both reservoirs respectively.

Different abstraction ratios for Sennar & Roseires have been tried to satisfy the above mentioned considerations.

The best ratio found is 1(Sennar): 4.4 (Roseires).

ملخص البحث

تتناول هذه الدراسة عملية تشغيل خزاني الروصيرص وسنار أثناء فترة الجفاف عندما تكون الاحتياجات المائية أكبر من المياه المتوفرة عند محطة الديم، كما أنها تعمل علي إيجاد علاقة بين منسوب المياه وكمية التبحر في بحيرتي الروصيرص وسنار والتصرفات المتنبأ بها عند محطة الديم والمحتوي المائي للبحيرتين.

تم استخدام شبكات الذكاء الاصطناعي في تكوين ثلاث نماذج :

نموذج (1) : للتنبؤ بالتصرفات الداخلة عند محطة الديم خلال فترة الجفاف.

نموذج (2) : للتنبؤ بمنسوب المياه للبحيرة بمعرفة محتوي البحيرة وسنوات التطبيق.

نموذج (3) : لإيجاد العلاقة بين منسوب المياه للبحيرة وفوا قد التبخر .

استخدمت شبكات الذكاء الاصطناعي برنامج يسمي (NeuroShell2) والذي يعتبر أداة مرنه وسريعة لتكوين نماذج التنبؤات مقارنه بالطرق التقليدية .

تم محاولة عدد مختلف من البنيات التركيبية لشبكات الذكاء الاصطناعي ووجد أن أفضل بنيه للنماذج الثلاثة هي الشبكة المتكونة من ثلاث طبقات متوالية بعدد محدد من خلايا الطبقة الوسطي، لكن النموذج الثالث نجد فيه الطبقة الوسطي مكونه من جزئين.

النتائج المتحصل عليها من نموذج (1) ، نموذج (2) ، نموذج (3) أستخدمت لتكوين برنامج التفريغ المقترح للبحيرتين باستخدام برنامج (M.S Excel).

بافتراض مساحات مختلفة لمحصول القمح - بداية موسم زراعته في الفترة الثانية من أكتوبر- نجد أن برنامج التفريغ قد أخذ بعض الاعتبارات الرئيسية التاليه للبحيرتين :

1. في بداية التفريغ تكون بحيرتي الروصيرص وسنار عند أعلي منسوب لهما.
2. الاحتياجات المائية للري تشمل احتياجات المشاريع أمام خزان سنار ومشروعي الجزيرة والمناقل ، والاحتياجات الدنيا أسفل خزان سنار.
3. في نهاية فترة التفريغ منسوب المياه عند البحيرتين يجب أن لا يهبط إلي أسفل المنسوب الأدنى لهما.

تم محاولة نسب سحب مختلفة لبحيرة الروصيرص وسنارلتحقيق الاعتبارات السابقة ، ووجد أن أفضل نسبة سحب هي 1 (سنار) : 4.4 (الروصيرص).

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CHAPTER ONE

1.0 Introduction

1.1 General

Water in Sudan is available either as surface water (rivers, wadies, precipitation, etc.) or sub surface water (aquifers).

Historically and up to a very recent date the common belief in the Sudan was that the Blue Nile is the basic supplier of its water resources while agriculture is its major consumer. That belief might have been justifiable at a time where the supplied water is much higher than the demand. At present, the vast expansion in the country's irrigated area, has unfortunately led to almost the total consumption of country's share of the Nile water, the sole traditional source according to the 1959 Nile Water Agreement between Sudan and Egypt. Hence the Sudan has to look for water from other resources, and to optimize between, more expensive sources in order to go further with its proposed irrigation development plans. Such new sources may include conservation of water from swampy regions, development of ground water improving various utilization efficiencies, controlling non-nilotic streams, recycling and desalination processes.

Due to the long dry season and high evaporation rates over most of the country, groundwater has always been a vital source of supply for people and livestock. Even along the Nile River, wells are increasingly being used for domestic water due to the degradation of quality of Nile water. The settled agriculture in the north of the country away from the rivers expands according to the availability of groundwater.

The most significant geological formation in terms of quantity of groundwater in the Sudan that acts as aquifers, are the Nubian Sandstone, Umm Rwaba and Gezira formation. Most of the other formations also act as aquifers but by far less in water quality.

The Sudan has a large number of rivers, wadies and khors. Major rivers such as the White Nile and the Blue Nile unite in Khartoum. They serve a large sector of the Sudan in various purposes, including drinking water, industrial, agricultural schemes and hydropower generation. Minor resources are locally important such as (e.g. wadies and khors) help in the recharge of need for water in the specific area.

Future-wise attention must be paid for the fastly growing claims of water for other important users. The planners for the Sudan water resources would hence be faced with many complicated options. On the sources of water and also on the purpose to which that source can be utilized. These options are, however made more complex by wide variation in the time and space.

Such a complex situation can only be resolved through a new approach to the management of the country's water resources. This new approach must pay a considerable attention to the hydrological economical and political effects.(National Council for Research, 1982)[7]

1.2 Reservoir

1.2.1 Purpose of the Reservoir

Reservoir is a man-made water body created in a river valley, which stores water during rainy season and to be used or redistributed during summer time. During summer time the daily demand is greater than the daily inflow; therefore water has to be withdrawn from the reservoir to supplement the daily inflow to meet the daily demand. Releasing too much or too little water may result in an economic loss, therefore water has to be released optimally to maximize the benefits from reservoirs on one hand and to meet the growing demands on other. This growing demand is caused, spatially in developing countries, by growing population and continuous and rapid urbanization. In developing countries, the urbanization increases demand in sector like power and recreation. Although these sectors are not water consumptive, but they may use water in away that may contradict satisfying the requirements in traditional largest water user; irrigation. To meet these growing demands, reservoir has to be operated optimally and water used efficiently by the rational water users (e.g. irrigation).(Dafalla ,1999)[3]

Alternatively, these demands could have been met by expansion of new facilities (reservoirs).

1.2.2 Reservoir's Zones

- Full reservoir level: It is the maximum level of storage in the reservoir.
- Dead storage level: It is the minimum level of storage.
- Live storage: It is the active storage bounded between the reservoir full level & dead level.
- Dead storage: It is storage below dead level, provided for accumulation of silt.

1.3 Dams in Sudan

In Sudan four dams have been constructed for different purpose:

The Khashm El Girba dam was constructed across the river Atbara between 1959-1964 for Ministry of Irrigation &Hydro Electric power as part of the scheme for developing anew town – ship and irrigated areas at this part of the Sudan, as so as to provide for population evacuated Wadi Hlfa as the result of the sub-mergence of that area by the reservoir to be formed by the Aswan High Dam also the aim of the dam is generation of power for project area.

Maximum reservoir water level 474 m and minimum reservoir water level 464 m with capacity 1.3 milliards m^3 initially, recently the capacity is about 0.66 milliards m^3.

Jebel Awlia Dam is the second oldest realized in 1932-1937 periods and has largest reservoir of 3.5 milliard m^3capacity.
It was constructed by the Egyptian government on the account of Egypt and for the benefit of Egypt in shortage period and requirement for the White Nile irrigation schemes.

The Filling of the reservoir during the flood time helps to lesser the danger of drastic flood on Egypt and northern Sudan.
Maximum reservoir water level 370.75 m and minimum reservoir water level 337.2 m.

The Sennar Dam in the Blue Nile was completed in 1925 initiated the Gezira irrigation scheme. At first 300,000 feddan in the fertile plain lying between the blue and White Niles were irrigated from the Sennar reservoir. The scheme was so successful that by 1952 it had expanded to include over 1000,000 feddans under cultivation. Further expansion of the scheme would have required a greater volume of stored water than was then available from Sennar reservoir.

During the early 1960 a major expansion on the Managil and other areas took place with more than double the scheme's total area, to over two million feddans (Gezira scheme gross area 1,236,400 feddan, Managil scheme 996,500 feddan). This is equivalent to more than 50% of the area irrigated from the Nile and it's tributaries in the Sudan, and nearly 10% of the country's total cultivated area. The large scale expansion of Managil and other areas after 1960 was made possible by the revised Nile Water Agreement of 1959 with the associated construction of **Roseires Dam** in the Blue Nile 1966. The area of irrigation of the Roseires and Sennar reservoirs has been determined on the criterion of an 80% flow year of the Blue Nile.

Based on this assume Roseires reservoir in connection with the Sennar reservoir can support a total net irrigatable area of 3512000 feddans water from the Blue Nile.

Now new dam under construction called **Merowi Dam** in northern of Sudan. This project which is concerned with the development of the water resources potential of the reach of the river Nile lying between Abu Hamaed and Merowe .The reach contains the fourth cataract of the Nile .The purpose of Merowe dam is mainly power generation besides irrigation. The storage is 12 milliard m^3 and the power generation is 1000 Mw. (Director of Dams & Nile Control, Report) [16]

1.4 Objectives of The Study

The case study, which is tackked in this project, is the Blue Nile reservoirs system in Sudan. It is an example of multipurpose and multiple reservoir system, located in semiarid tropical environment; it is composed of two reservoirs in series (Roseires & Sennar).

The system features are: -

- A short flood season and long low flow season.
- High fine sediment concentration occurring during the short flood season.
- High evaporation losses.
- The existence of large irrigation schemes.

Based on the above the aim of the study is: -

A. To use artificial neural network to predict the following:

i. Inflow discharges at Ed Deim station (110km upstream Roseires).
ii. Roseires water levels given Roseires water contents and accumulative years calculated from 1966 taken as zero point
iii. Sennar water levels given Sennar water contents and accumulative years calculated from 1925 taken as zero point.
iv. Evaporation losses at Roseires reservoir given the reservoir water levels.
v. Evaporation losses at Sennar reservoir given the reservoir water levels.

B. To obtain the optimum operation of the two reservoirs taking into Consideration:

i. Different demands.
ii. Different operation policies.

CHAPTER TWO

2.0 Operation Of Roseires & Sennar Dams

2.1 Blue Nile Hydrology

The Blue Nile flows out of the Lake Tana, in Ethiopian highland at an altitude of 850 m, and then passes through gorges until it reaches the Sudan plains at an elevation of 500 m.

Then it flows in northern westerly direction to its confluence with the White Nile at Khartoum.

Between Sennar and Khartoum it is joint by two tributaries of Dinder and Rahad.

The most upper gauging station for the Blue Nile is at El Deim in Ethiopian frontier, and the most downstream gauging station is at Khartoum.

The Blue Nile contributes by 60% of the annual discharge of the river Nile .The course of the Blue Nile in the Sudan is about 500 miles. The Blue Nile is highly variable, during the flood, the discharge may rise to 60 times that of the lower river, and in some years the discharge may be 300-400 times. From this we expect that the Blue Nile carries a great amount of solids during flood season due to its high erosion ability.

The Blue Nile Normally begins to feel the effect of rains on the Ethiopian plateau about the middle of May and starts to rise bringing the first red silt down to Khartoum a bout 20th of June. The rise continues irregularly to a peak at Khartoum about the end of August. Late in September it begins to fall rabidly.

In this period the river appears to be red in colour due to presence of red silt. (N.A.Elbakit, M.M.Saeed, 1990) [8]

To make use of this river, two dams have been constructed, the upstream one is located at Roseries and the other is at Sennar.

2.2 Sennar Dam

2.2.1 Design

The Sennar dam, 350km upstream Khartoum was completely built in May 1925 on granite ruble masonry. It may be divided into the Following elements:

i. The sluice dam (central portion), 600 m long containing 80No.sluice gates (8.4m high by 2.0m wide), which are adequate to pass the seasonal floods in most years. Maximum discharge of sluices is 9500m^3/s. It is containing 72 No. Spillway at higher level to pass the peaks of exceptional floods.

ii. The spillway dams, each spillway is (5m high by 3.4m wide), one on the east bank 150m long with 20 No. spillways and one on the west bank originally 150m long with 20 No. spillways but now reduced to 7 No. spillways, the reminder being replaced by the hydro-electric station with two 7.5 Mw Turbo generator units was built downstream of the west side of the dam.

iii. The solid dam, 140m long on the east bank and 567m long on the west bank incorporated with the head regulator for Gezira and Managil canals which are situated at the west end, the combined maximum discharge of these canals is 354m^3/s, Gezira canal regulator, 108m long, consists of 14 sluices 3m wide by 5m high with capacity 168 m^3/s and Managil canal regulator, 87m long, consist of 11 sluices 3m wide by 5 m high with capacity 186 m^3/s.

Gezira canal constructed with the dam in 1925 and Managil canal constructed later in 1959-1960.

iv. The masonry core walls, 835m long on the east bank and originally 443m long on the west bank with earth embankments upstream and downstream to protect Sennar town when the reservoir is at full supply level.

The total length of the dam 3025m with height of 30m.

2.2.2 The Reservoir

The maximum retention level of the reservoir is 421.7m with storage capacity is approximately 640million m^3 (Bathymetric survey 1985) and the downstream levels range from 404m to 414m.

The minimum levels of reservoir are 417.2m with dead storage 220million m^3 (Bathymetric survey 1985). The reservoir affected the river for approximately 50-60Km.

2.2.3 The Objective of the Construction

1. To meat the requirements of the irrigation for the reaches of the river upstream and downstream.
2. To maintain the minimum flow in the river at Khartoum of 5 million m^3/day and at least of 3.5 million m^3/day.
3. To maintain water requisite for generation of power and should normally not be less than 8 million m^3/day.
4. To supply Gezira and Managil canals by gravity flow.

2.3 Roseires Dam

2.3.1 Design

Roseires dam which spans the Blue Nile 630km upstream Khartoum was built between 1961 and 1966. The dam has structural height of 68m and length of 13.5km. The central section is a concrete buttress type about 1000m long flanged on either side by earth embankments, 8.5km long to the west and 4km long to the east. The standard buttresses which make up nearly half of the total of 68 buttresses are spaced at 14.0m centres.

Deep sluices are placed at the central section in the main river channel bed, at an inverted level of 435.5m. Each sluice is 10.5m high and 6m wide. To the west of the deep sluice is an overflow spillway is provided with a crest level of 463.7m, this has 7 radial gates, each 12m high by 10m wide.

Immediately west of the spillway structure, a small hydro-electric service station is contained between two buttress webs. The hydropower house, installed in 1971, has a discharge capacity of 2014 million m^3/month and a total installed of 280 Mw, 7 intakes each has capacity of 40 Mw (National Electricity Corporation, NEC, Sudan).

Near the western end of the concrete dam a head works has been constructed to divert water into the Kenana canal (5 gates). This canal will be capable of carrying 360m^3/s to supply the proposed Kenana Irrigation scheme between the Blue and White Niles. Ahead works of similar capacity has also been built adjacent to the eastern end of the concrete dam to supply the Dinder and Roseires project areas, (Rahad II). Concrete bulk heads now close off the intakes of both these head works until the canals are built.

2.3.2 The Reservoir

The design level is 480m, although the reservoir is now operated to a maximum level of 481m with 75km. A recent survey, carried out in 1992, showed that at the maximum level 481m the storage capacity is 2103.9 million m^3 and the dead storage is 60.3million m^3 at level 467m. There will be provision of future heightening by 10 meters to provide an ultimate gross storage of 7.6 milliards cubic meters.(proceedings,1994)[17]

2.3.3 The Objective of the Construction

1. Can be used as an extension for Sennar dam; the two reservoirs are considered as one system and they are operated accordingly:
2. To meet the requirement of the proposed Great Kenana and Rahad (II) projects.
3. To maintain suitable discharge and heads for the generation of the power.

2.4 General Regulation and Operation Rules for Roseires&Sennar Dams

2.4.1 Introduction

At present the Blue Nile system, including the Sennar and Roseires reservoirs, is operated with document (Regulation Rules for the working of the reservoirs, prepared by the Ministry of irrigation and water resources in 1968) [6.] The aim of the rules is to distribute stored water and natural river for irrigation and minimum flows at Khartoum. There is a provision for flow at Roseires and Sennar for power generation but this provision is subjected to irrigation demands.

2.4.2 Regulation Rules

The following rules are provided for the regulation of the reservoirs at Roseires and Sennar in accordance with such provision of working arrangement for the control of flows of the Nile.

a) The hydrological year will be reckoned as beginning on first of June and end of May 30.

b) The working of the two reservoirs must always be closely co-ordinate together in order to restrict the deposit of sediment in the reservoirs during the period of high flood. At this period no more water is kept in Roseires and Sennar reservoirs than that necessary from main reservoirs purposes.

c) If any difficulty should arise, or appear likely to arise, in meeting fully at any time the prospective requirements for all purposes, the requirements of irrigation shall in general have priority over the requirements for the power generation.

d) The date of beginning of the period of shortage on the Blue Nile (period during which the requirements of water for all purposes exceed the natural flow in the river), this date will vary considerably in different years, and it will end when the natural flows at El Deim exceed the requirements, as the river rises before the next flood.

2.4.3 Operation of Roseires & Sennar Dam

The system of operation works through four main stages:

1. Flood

Begin from early June to the starts of filling in September. The aim of operation in this stage is to maintain the level of reservoir at minimum water level 467.0m, 417.2m for Roseires and Sennar respectively to reduce siltation as far as the discharge facilities allow. How ever, if the floods are above normal the level in the reservoir will rise to the level required pass the discharge. The Blue Nile flow at El Deim has reached 50 million m^3/day and continues until the inflow reaches 200 million m^3/day, this should take place in one to three days.

2. Filing Program

At the level of 417.2m in Sennar reservoir and all sluice gates and spillways fully opened a flow of about 11,000 m^3/s can passes, when the flow rate exceed this figure, the level in the reservoir will rise higher. At the maximum permissible level in the reservoir of 421.7 m, it is believed a flow of about 17,000 m^3/s can passes. At level of 467m in Roseires reservoir with all spillway and sluice gates fully opened a flow of about 6400 m^3/s, when the flow rate exceed this figure then level in the reservoir will rise higher. A maximum flood flow of 17,600 m^3/s should pass safety without the level rising above 481m.

Filling is carried out on the falling flood and the rules are
Complicated by the need to delay filling as long as possible to reduce siltation. The starting date for filling varies from year to year according to the flow at El Deim upstream of Roseires reservoir and then follows a day program. The starting date for filling lies between 1st September and 26th September and filling is

completed within 45 days. Usually, the Filling of Roseires and Sennar reservoirs start on the same date.

The filling period begins on:

1. On first September if by that date the flow at El Deim either have never risen above 350 million m^3/day or have previously risen above that rate, has fallen below it.
2. On the date later than first September immediately following the day when the flow at El Deim has fallen to 350 million m^3/day.
3. On September 26 at latest, even if the flow at El Deim then is still greater than 350 million m^3/day.

Table (2.1) Filling Program for Roseires Dam 2003

Day	Level (m)	Content (million m^3)	Amount stored (million m^3)		Day	Level (m)	Content (million m^3)	Amount stored (million m^3)
1	467.00	60.3	39.5		24	480.07	1899.95	24.6
2	468.1	99.8	63.00		25	480.19	1924.55	20.55
3	469.16	162.8	110.7		26	480.29	1945.1	16.45
4	470.38	273.5	127.1		27	480.37	1961.55	16.7
5	471.42	400.6	121.3		28	480.45	1978.25	14.75
6	472.32	521.9	115.5		29	480.52	1993.00	12.7
7	473.12	637.4	119.95		30	480.58	2005.7	12.5
8	473.91	757.35	106.95		31	480.64	2018.2	10.35
9	474.58	864.3	107.3		32	480.69	2028.55	8.3
10	475.24	971.6	103.3		33	480.73	2036.85	6.25
11	475.83	1074.9	93.55		34	480.76	2043.1	6.2
12	476.37	1168.45	91.85		35	480.79	2049.3	7.3
13	476.88	1260.3	87.5		36	480.82	2056.6	7.9
14	477.35	1347.8	80.4		37	480.85	2064.5	5.25
15	477.78	1428.2	75.65		38	480.87	2069.75	5.25
16	478.17	1503.83	71.65		39	480.89	2075.00	5.25
17	478.52	1575.5	69.4		40	480.91	2080.25	5.25
18	478.83	1644.8	57.75		41	480.93	2085.5	5.25
19	479.11	1702.65	51.75		42	480.95	2090.75	5.25
20	479.36	1754.4	45.3		43	480.97	2096.00	2.6
21	479.58	1788.7	38.8		44	480.98	2098.6	2.65
22	479.77	1838.5	32.75		45	480.99	2101.23	2.65
23	479.93	1871.25	28.7		46	481.00	2103.9	-

3. Maintaining at Maximum Water Level

During this period the reservoirs is held at the 481m & 421.7 m for Roseires and Sennar and continue for period depend on the amount of water from El Deim and requirements of water downstream.

4. Empting Program (period of shortage)

The period of shortage on the Blue Nile is the period during which the requirement of water for all purpose, including irrigation and power, plus losses in transmission and by evaporation in reservoirs, plus the minimum flows to be passed in the river at Khartoum, exceed the natural flows in the river at El Deim. The date of the beginning of the period of shortage will vary considerably in different years, which the empty program starts. The period of empty will end when the natural flows at El Deim exceed the requirements, as the river rises before the next flow. The date when this occurs also will vary considerably in different years. Since it can not be forecast much in advance of its actual occurrence, it will be wise to assume the latest date which is likely to occur in a 90% year which for this purpose may be taken as first period of June.

The respective amounts of water to be drawn from either reservoir in any ten – day period may vary, the total requirements from storage about 75% or 66.7%should be drawn from Roseires reservoir and 25% or 33.3% from Sennar reservoir. Allowances will be made for transmission losses.

2.4.4 Daily Operation

Reservoir operation is closely related to and affected by the flow, water requirements, reservoir sedimentation and reservoir losses. Downstream releases of dam can be calculated by two methods:

- Water Balance Method:

$$Q_{out} = Q_{in} - EL - TL - Q_a + S \qquad (2.1)$$

Where:

Q_{out} = Total release downstream
Q_{in} = River inflow to dam
EL = Evaporation losses
TL = Transition losses
Q_a = Upstream abstraction
S = Change of reservoir, taking(- v) in the storage

- Calculation Downstream Release through dam body:

$$Q_{out} = Q_s + Q_{sw} + Q_{ph} + L \qquad (2.2)$$

Where:
Q_s = Discharge through sluices
Q_{sw} = Discharge through spillways
Q_{ph} = Discharge through power house
L = Leakage or seepage through dam body

CHAPTER FOUR

4.0 Reservoir System Simulation and Modeling

4.1 Concept of the Model

The basic purpose of a model is to simulate and predict the operation of the system, which is unduly complex, and reflect the effect of changes on this operation. It can be physical, analog or mathematical. Physical models have often been used to investigate the behaviour of hydraulic structures and hydrological system involving rivers and estuaries.

An analog model is a mechanical or electrical device whose operation is governed by the same fundamental equations as those of the system being modelled; thus there exists quantitative relationships between variables in the model and in the prototype. The model is useful if the variables can be more easily adjusted therein than on the system being modelled. Analog models provide easy solution for very complex mathematical relationships. Mathematical models simulate the behaviour of the system through a set of computer programs and mathematical relationships.

Research in large scale has been in recent years a major subject of interest within the mathematical programming community; its application to reservoir systems is very limited.

We are going to deal with a new method; which depend on modern aspect of computer programming, artificial neural network, this method depend on the accuracy and amount of the collection data and the relation between the chosen input and the required outputs.

This method depends also on the chosen software of learning process. Here in this study the software which use is NeuroShell2.

4.2 Neuro Shell2 Overview

NeuroShell2 is the software program that mimics the human brain's ability to classify patterns or to make predictions or decisions based upon past experience. The human brain relies on neural stimuli while the neural network uses data sets.

Neuro Shell2 enables you to build sophisticated custom problem solving applications without programming. You tell the network what you are trying to predict, and Neuro Shell2 will be able to "learn" patterns from training data and be able to make its own predictions when presented with new data.

It is a general purpose system contains sixteen classic neural networks. It combines ease of use and lots of control over how the networks are trained.

It is produced by Ward System Group that has been developed and began selling its first neural network software in)[10].WWW.Wardsystem.com1988.(

The system used in Neuro Shell2 is advanced neural network and Run facilities icon is used for creating (…def) files.

Both Neuro Shell2 and the brain are able to solve problems that cannot be solved by conventional computer software written in a step-by-step mode. Just like the brain, how ever, neural networks are not guaranteed to always give an absolutely "correct" answer, especially if patterns are in some way incomplete or conflicting. Results should be evaluated in terms of the percentage of answers that match those an expert might give.

This software is used here successfully to solve a problem formulated for a major system, the Blue Nile in Sudan, which has two reservoirs in series.

This program has two options:

1. Beginner's Neural Network module: It is a simplified set of procedure for building and executing a neural network application in a system that is easier to use than working with the advanced System.
2. Advanced System: which gives experienced neural network users the ability to create and execute a variety of neural network architectures with more user control compared to the Beginner's System.

The steps to be followed to use the program (Neuro Shell2):

1. Problem input: entering data through data grid of the program or by import file from other software using spreadsheets like MS Excel.
2. Build Neural Network: which include:
   a. Defining and classifying data to input/output and un used.
   b. Selecting learning and testing patterns (depends on the amount of available data).
   c. Choosing the suitable networks architectures and adopting learning restrictions (Training criteria and stop Training criteria).
   d. Starting training process.
3. Apply Neural network: in which:

a. Checking the maximum and minimum errors, sum of the squares errors and correlation coefficient of the data patterns.

b. When acceptable value have been reached attaching the result to data file.

4. Problem output: Opening the file, which the result have been attached to in order to examine the result of whole patterns.
5. Running the prediction program from other programming or programming language, by creating special files which has extension (def..) using (MS Excel), the prediction program can be run by using the function (predict); this function is added to excel from the software.

In this study Neuro Shell 2 has been used for:

- Prediction of inflow discharge at El Deim station.
- Prediction of reservoirs water level for Roseires & Sennar Dams.
- Determination of evaporation losses from Roseires and Sennar reservoirs.

4.3 Model -1 [Prediction of Water Inflow Discharges at El Deim Station]

4.3.1 General

The irrigation need and the operation of two dams depend mainly on the flow pattern of the river in the dry season period from October to May after the high flow passes.

The flow data for the Blue Nile are used to predict the future flow of the river through that dry period.

There are many different prediction methods each has its advantages and disadvantages but the main property which differentiate between these methods is the accuracy of the result. Graphical method is used by the Ministry of Irrigation to predict flow during the dry season, at Eldeim station.

The Graphical method consists of drawing different hydrographs for past characteristic years and then entering the actual flow of the specific ear from first ten day period of June to first ten days period of October in the same hydrograph and then to be completed to the end period of May based on pattern of the hydrographs of the past years. The hydrographs considered in the graphical method are for the year 1913, 1972, 1984, normal and 80% year.

4.3.2 Construction of Model-1

In this study using artificial neural network method, the ten days period flow data of El Deim station (1960-2000) which have been used as source data. (See appendix A)

Several example scenarios are solved to assess the ANN applicability.

Scenario (1):

- Input: Discharge of 1st period of June, 1st period of October and the volume of water from 1st period of June to 1st period of October.
- Output: discharge of 2nd period of October, 3rd period of October,1st period of November………to3rd period of May.(Using logistic activation function)

- Network Architecture type: Two Hidden Slab with different activation functions.
- Hidden layer :
  i. Upper slab: with 30 neurons. (Using Gaussian activation function)
  ii. Lower slab: with 25 neurons. (Using Gaussian comp activation function)

Scenario (2):

- Input: Discharge of 1st period of June, 1st period of October and the volume of water from 1st period of June to 1st period of October.
- Output: discharge of 2nd period of October,3rd period of October,1st period of November……to 3rd period of May. (Using logistic activation function)
- Network Architecture type: Two Hidden Slab with different activation functions.
- Hidden layer:
  i. Upper slab: with 30 neurons. (Using Gaussian activation function)
  ii. Lower slab: with 40 neurons. (Using Gaussian comp activation function)

Scenario (3):

- Input: Discharge of 1st period of June, 1st period of July, 1st period of August, 1st period of September and 1st period of October.
- Output: discharge of 2nd period of October,3rd period of October,1st period of November……to 3rd period of May. (Using logistic activation function)

- Network Architecture type: Two Hidden Slab with different activation functions.
- Hidden layer:
  i. Upper slab: with 30 neurons. (Using Gaussian activation function)
  ii. Lower slab: with 25 neurons. (Using Gaussian comp activation function)

*See Fig (4.1).

Scenario (4):

- Input data: Discharge of 1st period of June, 1st period of July, 1st period of August, 1st period of September and 1st period of October.
- Output: discharge of 2nd period of October,3rd period of October,1st period of November……to 3rd period of May. (Using logistic activation function)
- Network Architecture type: Two Hidden Slab with different activation functions.
- Hidden layer:
  i. Upper slab: with 30 neurons. (Using Gaussian activation function)
  ii. Lower slab: with 40 neurons. (Using Gaussian comp activation function)

10% of entered data patterns have been taken as testing patterns and 90% are used for training process.

4.3.3 Results & Discussion

The better network selected is scenario (3) as seen in Table (4.3) and Fig (4.2), Fig (4.3), Fig (4.4)…...to Fig (4.24). The accuracy of the model is sensitive towards the inputs and hidden neurons as well as sample size. The effect of number of the inputs is found more significant and the number of hidden neurons, less significant. See the results in Table (4.1), Table (4.2), Table (4.3), and Table (4.4).

The sum of the squares errors (MSE) is relatively small in scenario (3) compared with others scenarios.

The results of scenario (3) are reasonable although the efficiency of the model is not high, and that refer to relatively small amount of data and large number of outputs required (23 outputs).

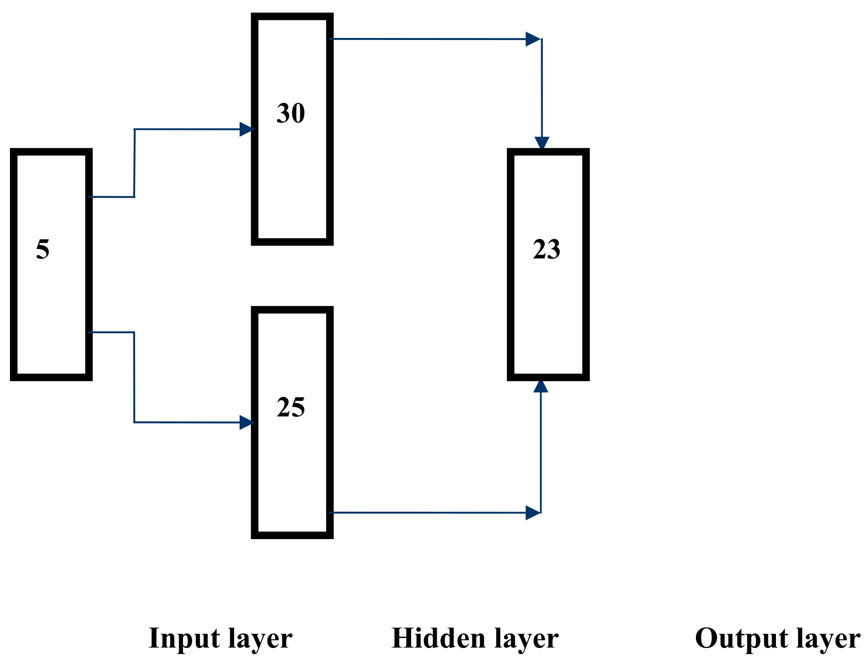


Fig (4.1): Network Architecture of Scenario (3), Two Hidden Slabs with Different Activation Functions

Table (4.1) **Model – 1: Prediction of Water Inflow Discharges at EL Deim station (Statistical Results)**

Scenario (1) Input: QJuane1, QOct1 , Vo (milliards m3) Output: QOct2 to QMay 3, activation function is logistic
Type of network: Two hidden slabs with different activation functions

Hidden layer: Upper slab: hidden neurons = 30, activation function is Gaussian
Lower slab: hidden neurons = 25, activation function is Gaussian comp

Patterns processed: 40

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
R squared:	0.9642	0.9372	0.895	0.8338	0.8954	0.9347	0.9611	0.9721	0.9646	0.9537	0.8744	0.9609
r squared:	0.9692	0.9483	0.8954	0.8526	0.9033	0.9404	0.9655	0.9774	0.9685	0.9594	0.9011	0.9643
Mean squared error:	802.731	327.57	150.7	92.398	40.279	18.629	6.7	3.946	1.913	1.789	4.322	0.774
Mean absolute error:	7.23	5.085	3.042	2.566	1.601	0.998	0.685	0.474	0.342	0.379	0.633	0.251
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	161.384	70.358	68.914	41.779	32.857	25.381	13.509	11.673	6.349	5.964	8.655	4.399
Correlation coefficient r:	0.9845	0.9738	0.9463	0.9234	0.9504	0.9697	0.9826	0.9886	0.9841	0.9795	0.9493	0.982
Percent within 5%:	90	90	92.5	92.5	90	95	92.5	92.5	95	90	90	92.5
Percent within 5% to 10%:	0	2.5	0	0	5	0	0	2.5	0	2.5	0	0
Percent within 10% to 20%:	2.5	0	2.5	2.5	0	2.5	5	5	2.5	5	0	5
Percent within 20% to 30%:	2.5	2.5	0	0	0	0	0	0	2.5	2.5	5	2.5
Percent over 30%:	5	5	5	5	5	2.5	2.5	0	0	0	5	0
Output:	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**	**C19**	**C20**	**C21**	**C22**	**C23**	**mean**
R squared:	0.9561	0.9368	0.7903	0.7428	0.8836	0.8898	0.9166	0.7665	0.8908	0.4824	0.7294	
r squared:	0.9613	0.9439	0.8014	0.7623	0.894	0.9105	0.9295	0.8064	0.8944	0.6042	0.7704	
Mean squared error:	0.693	0.613	2.342	3.009	3.206	1.806	1.796	8.51	4.677	61.837	70.307	70.0238
Mean absolute error:	0.224	0.221	0.355	0.418	0.49	0.396	0.371	0.825	0.561	1.888	2.082	1.35291
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	3.935	3.337	9.033	9.505	8.8	5.838	6.582	14.816	12.184	46.065	40.226	26.5888
Correlation coefficient r:	0.9805	0.9715	0.8952	0.8731	0.9455	0.9542	0.9641	0.898	0.9457	0.7773	0.8777	
Percent within 5%:	92.5	90	90	92.5	90	90	90	90	90	90	90	
Percent within 5% to 10%:	0	0	2.5	0	0	0	0	0	0	0	2.5	
Percent within 10% to 20%:	5	5	2.5	2.5	2.5	2.5	2.5	0	5	0	0	
Percent within 20% to 30%:	2.5	2.5	0	0	0	2.5	2.5	0	0	0	0	
Percent over 30%:	0	2.5	5	5	7.5	5	5	10	5	10	7.5	

Table (4.2) **Model – 1: Prediction of Water Inflow Discharges at EL Deim station (Statistical Results)**

Scenario (2)

Input: QJuane1, QOct1 , Vo (milliards m3) Output: QOct2 to QMay 3 , activation function is logistic

Type of network: Two hidden slabs with different activation functions

Hidden layer: Upper slab: hidden neurons = 30, activation function is Gaussian

Lower slab: hidden neurons = 40, activation function is Gaussian comp

Patterns processed: 40

Output:	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
R squared:	0.9626	0.938	0.9625	0.8682	0.9105	0.9083	0.9155	0.9652	0.9387	0.9434	0.8864	0.9452
r squared:	0.9673	0.9511	0.9678	0.8847	0.9208	0.923	0.9279	0.9663	0.952	0.9551	0.9145	0.9568
Mean squared error:	840.312	323.243	53.758	73.264	34.452	26.144	14.57	4.916	3.311	2.189	3.908	1.086
Mean absolute error:	7.284	4.936	2.167	2.58	1.766	1.393	1.022	0.567	0.525	0.411	0.553	0.283
Min. absolute error:	0.006	0.002	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	163.164	81.4	31	36.295	24.582	21	17.65	12.63	6.986	5.8	9.8	4.5
Correlation coefficient r:	0.9835	0.9752	0.9838	0.9406	0.9596	0.9607	0.9633	0.983	0.9757	0.9773	0.9563	0.9782
Percent within 5%:	90	92.5	90	90	90	92.5	92.5	90	92.5	92.5	90	92.5
Percent within 5% to 10%:	0	0	2.5	0	0	0	0	2.5	0	0	2.5	0
Percent within 10% to 20%:	2.5	0	2.5	2.5	5	0	2.5	5	2.5	2.5	0	5
Percent within 20% to 30%:	2.5	2.5	2.5	2.5	0	2.5	0	2.5	2.5	2.5	2.5	0
Percent over 30%:	5	5	2.5	5	5	5	5	0	2.5	2.5	5	2.5

Output:	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	mean
R squared:	0.9286	0.8992	0.9393	0.7773	0.5001	0.8238	0.9518	0.654	0.8141	0.8131	0.9873	
r squared:	0.9409	0.9177	0.9408	0.7936	0.6474	0.8475	0.9629	0.7303	0.8235	0.8268	0.9889	
Mean squared error:	1.127	0.977	0.678	2.605	13.766	2.889	1.038	12.608	7.963	22.326	3.293	63.06187
Mean absolute error:	0.313	0.272	0.206	0.409	1	0.518	0.207	0.902	0.866	1.334	0.504	1.30513
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0.001	0.000391
Max. absolute error:	4.7	4.7	4.699	9.047	20.4	7.122	6.281	16.3	10.904	18.393	8.272	22.85326
Correlation coefficient r:	0.97	0.958	0.9699	0.8909	0.8046	0.9206	0.9813	0.8546	0.9075	0.9093	0.9944	
Percent within 5%:	90	92.5	92.5	90	90	90	95	90	90	90	92.5	
Percent within 5% to 10%:	0	0	0	2.5	0	0	0	2.5	0	0	0	
Percent within 10% to 20%:	2.5	0	5	0	0	0	0	0	0	2.5	0	
Percent within 20% to 30%:	7.5	0	0	5	0	0	2.5	0	0	0	2.5	
Percent over 30%:	0	7.5	2.5	2.5	10	10	2.5	7.5	10	7.5	5	

Table (4.3) **Model – 1: Prediction of Water Inflow Discharges at EL Deim station (Statistical Results)**

Scenario (3)

Inputs: QJun1 , QJuly1 , QAug1 , QSep1 , QOct1 Output: QOct2 to QMay 3 , activation function is logistic

Type of network: Two hidden slabs with different activation functions

Hidden layer: upper slab: hidden neurons = 30, activation function is Gaussian

Lower slab: hidden neurons = 25, activation function is Gaussian comp

Patterns processed: 40

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
R squared:	0.9823	0.9333	0.8902	0.9255	0.9761	0.9561	0.9698	0.9912	0.9202	0.9352	0.9646	0.9842
r squared:	0.9838	0.9338	0.8927	0.9268	0.977	0.9594	0.971	0.9922	0.9309	0.9435	0.9691	0.9855
Mean squared error:	96.391	47.791	57.665	41.397	9.207	12.521	5.199	1.247	4.307	2.507	1.218	0.312
Mean absolute error:	5.341	4.45	3.315	1.646	0.698	0.837	0.522	0.299	0.541	0.388	0.247	0.148
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	86.509	101.975	55.218	33.831	16.112	16.509	11.907	5.239	10.468	8.439	5.413	2.479
Correlation coefficient r:	0.9919	0.9663	0.9449	0.9627	0.9884	0.9795	0.9854	0.9961	0.9648	0.9714	0.9845	0.9927
Percent within 5%:	92.5	92.5	92.5	92.5	95	95	95	92.5	92.5	92.5	95	92.5
Percent within 5% to 10%:	0	0	0	0	0	0	0	5	0	0	0	2.5
Percent within 10% to 20%:	0	2.5	0	2.5	0	0	0	2.5	2.5	5	2.5	5
Percent within 20% to 30%:	2.5	0	2.5	2.5	5	0	2.5	0	2.5	0	2.5	0
Percent over 30%:	5	5	5	2.5	0	5	2.5	0	2.5	2.5	0	0
Output:	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**	**C19**	**C20**	**C21**	**C22**	**C23**	**mean**
R squared:	0.8341	0.8244	0.835	0.9261	0.9375	0.7494	0.8851	0.8767	0.7475	0.7603	0.927	
r squared:	0.7863	0.7129	0.7965	0.9407	0.9417	0.787	0.5393	0.6213	0.773	0.7785	0.9286	
Mean squared error:	4.197	3.642	2.959	0.864	1.721	4.107	13.24	19.068	10.813	28.64	18.975	16.86904
Mean absolute error:	0.481	0.48	0.444	0.239	0.337	0.446	0.96	1.038	0.852	1.415	1.172	1.143304
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	11.837	10.3	8.167	4.394	6.239	11.863	17.6	24.2	15.442	25.459	18.1	22.07391
Correlation coefficient r:	0.8868	0.8444	0.8925	0.9699	0.9704	0.8871	0.7344	0.7882	0.8792	0.8823	0.9636	
Percent within 5%:	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	92.5	
Percent within 5% to 10%:	0	0	0	0	0	2.5	0	0	0	0	0	
Percent within 10% to 20%:	2.5	0	2.5	2.5	0	0	0	0	0	0	0	
Percent within 20% to 30%:	2.5	0	0	2.5	2.5	0	0	0	0	0	0	

Table (4.4) **Model – 1: Prediction of Water Inflow Discharges at EL Deim station (Statistical Results)**

Inputs: QJun1 , QJuly1 , QAug1 , QSep1 , QOct1

Scenario (4) Type of network: Two hidden slabs with different activation functions Output: QOct2 to QMay3 , activation function is logistic

Hidden layer: Upper slab: hidden neurons = 30, activation function is Gaussian
Lower slab: hidden neurons = 40, activation function is Gaussian comp

Patterns processed: 40

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
R squared:	0.9108	0.8042	0.7352	0.8438	0.9202	0.9829	0.9871	0.8914	0.8822	0.9246	0.8912	0.9112
r squared:	0.9152	0.8073	0.7505	0.8472	0.9222	0.9837	0.9877	0.8955	0.8903	0.9296	0.9048	0.9155
Mean squared error:	2001.111	1020.686	380.118	86.833	30.743	4.887	2.222	15.34	6.361	2.915	3.745	1.76
Mean absolute error:	9.743	7.706	5.022	2.414	1.308	0.478	0.319	0.799	0.538	0.375	0.484	0.274
Min. absolute error:	0.001	0	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	272.035	169.211	87.458	44.462	32.007	13.282	8.992	24.141	14.726	9.657	10.211	8.115
Correlation coefficient r:	0.9567	0.8985	0.8663	0.9204	0.9603	0.9918	0.9938	0.9463	0.9435	0.9641	0.9512	0.9568
Percent within 5%:	92.5	92.5	92.5	92.5	92.5	95	95	92.5	95	95	92.5	95
Percent within 5% to 10%:	0	0	0	0	0	2.5	2.5	5	0	0	0	0
Percent within 10% to 20%:	2.5	0	0	0	5	0	0	0	0	0	2.5	2.5
Percent within 20% to 30%:	0	0	0	2.5	0	0	2.5	0	2.5	2.5	2.5	0
Percent over 30%:	5	7.5	7.5	5	2.5	2.5	0	2.5	2.5	2.5	2.5	2.5
Output:	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**	**C19**	**C20**	**C21**	**C22**	**C23**	**mean**
R squared:	0.8372	0.6453	0.7221	0.7285	0.5672	0.8482	0.8672	0.8812	0.7498	0.4887	0.9782	
r squared:	0.8553	0.7246	0.7768	0.8016	0.6838	0.8632	0.8774	0.8928	0.7752	0.5955	0.9784	
Mean squared error:	2.569	3.44	3.104	3.177	11.919	2.488	2.859	4.329	10.714	61.087	5.669	159.4816
Mean absolute error:	0.321	0.47	0.399	0.432	0.674	0.356	0.349	0.409	0.766	1.997	0.548	1.573087
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0	4.35E-05
Max. absolute error:	9.72	9.848	9.4	9.029	21.487	9.031	10.388	12.765	18.949	41.17	13.304	37.3647
Correlation coefficient r:	0.9248	0.8512	0.8813	0.8953	0.8269	0.9291	0.9367	0.9449	0.8804	0.7717	0.9891	
Percent within 5%:	95	92.5	95	92.5	92.5	92.5	92.5	95	92.5	92.5	92.5	
Percent within 5% to 10%:	0	0	0	0	0	2.5	2.5	0	0	0	0	
Percent within 10% to 20%:	2.5	0	0	2.5	2.5	0	0	0	0	0	0	
Percent within 20% to 30%:	0	2.5	0	0	2.5	0	0	2.5	0	0	5	
Percent over 30%:	2.5	5	5	5	2.5	5	5	2.5	7.5	7.5	2.5	

Table (4.5): Statistical Result: (r2) for Different Patterns (Scenario 3)

Periods	Test Patterns	Training Patterns	Combined Patterns
Oct_{II}	0.88	1.00	0.98
Oct_{III}	0.91	0.95	0.93
Nov_{I}	0.84	0.99	0.89
Nov_{II}	0.90	0.95	0.92
Nov_{III}	0.96	1.00	0.98
Dec_{I}	0.92	1.00	0.96
Dec_{II}	0.94	1.00	0.97
Dec_{III}	0.98	0.99	0.99
Jan_{I}	0.93	0.91	0.93
Jan_{II}	0.88	0.97	0.94
Jan_{III}	0.98	0.92	0.97
Feb_{I}	0.98	0.99	0.99
Feb_{II}	0.58	0.99	0.79
Feb_{III}	0.57	0.95	0.71
Mar_{I}	0.71	0.98	0.80
Mar_{II}	0.87	0.99	0.94
Mar_{III}	0.85	1.00	0.94
Apr_{I}	0.57	0.99	0.79
Apr_{II}	0.20	0.99	0.54
Apr_{III}	0.36	0.98	0.62
May_{I}	0.57	0.97	0.77
May_{II}	0.58	0.98	0.79
May_{III}	0.86	0.99	0.92

- r^2 coefficient of determination
- Test patterns: years 1964/1965,1968/1969,1969/1970,1991/1992 (4 years)
- Training patterns: years 1960 to 2000 except test years (36 yeas).
- Combined patterns: Test patterns + Training patterns (40 years).

Predicted (Network) &Actual Average daily Discharge of (2nd period of Oct) – Data: (1960 to 2000)

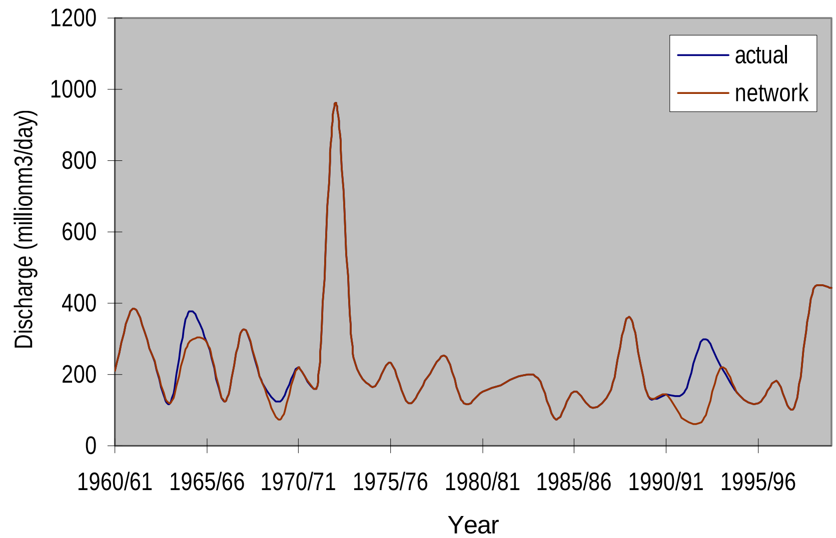


Fig (4.2)

Predicted (Network) &Actual Average daily Discharge of (3rd period of Oct) – Data: (1960 to 2000)

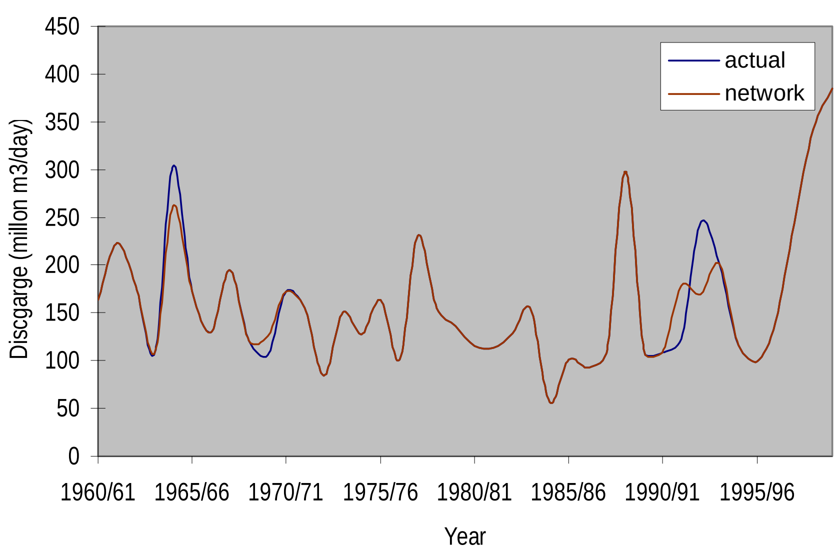
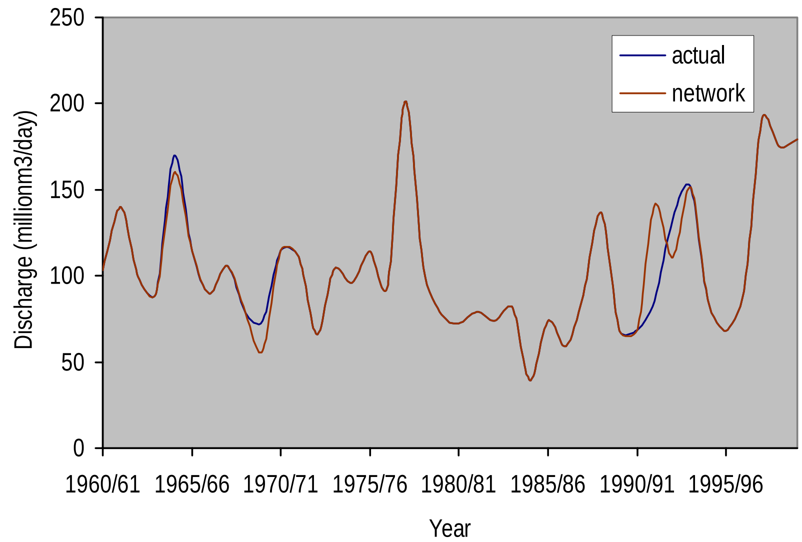


Fig (4.3)

Predicted (Network) &Actual Average daily

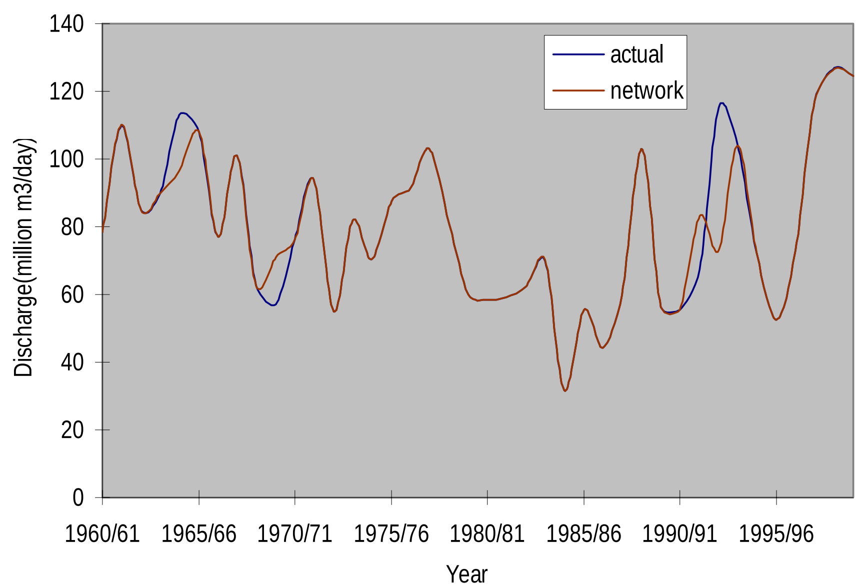
Discharge of (1st period of Nov) - Data: (1960 to 2000)



Fig(4.4)

Predicted (Network) &Actual Average daily

Discharge of (2nd period of Nov) - Data: (1960 to 2000)



Fig(4.5)

Predicted (Network) &Actual Average daily Discharge of (3rd period of Nov) - Data: (1960 to 2000)

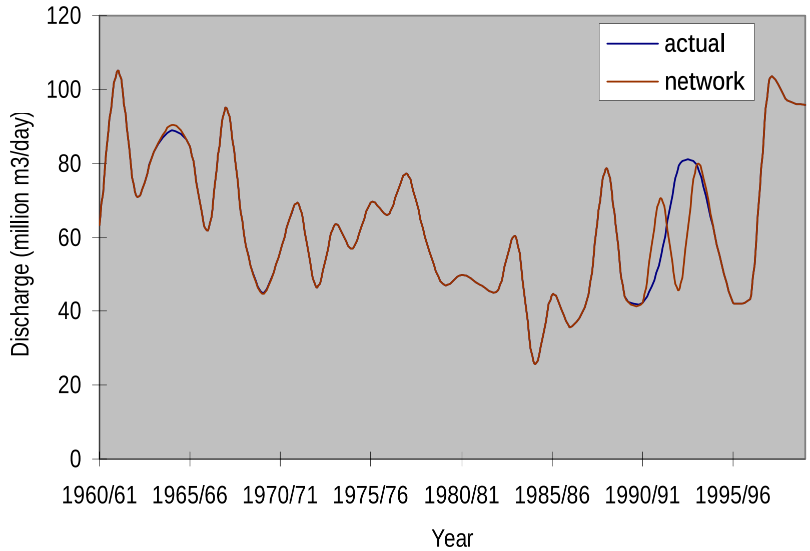
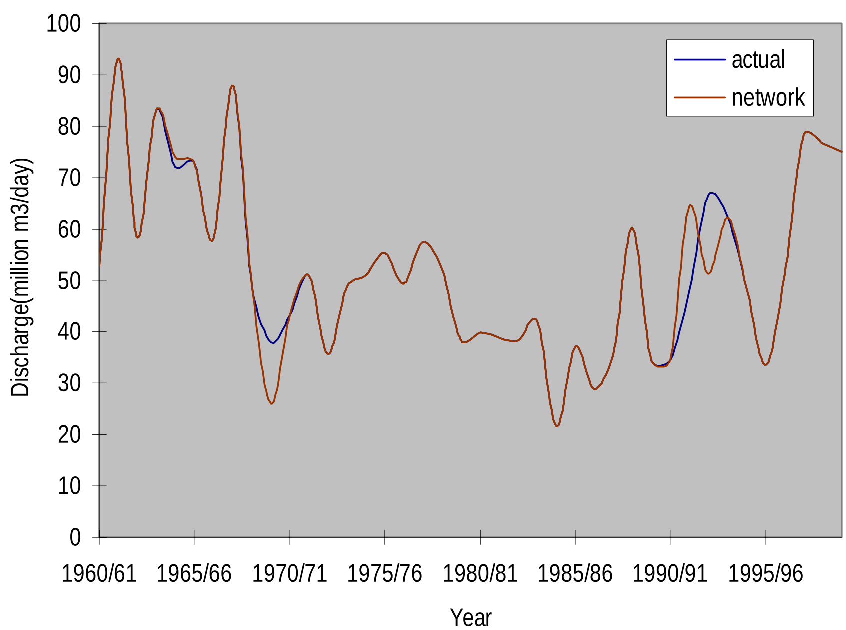


Fig (4.6)

Predicted (Network) &Actual Average daily Discharge of (1st period Dec) - Data: (1960 to 2000)



Fig(4.7)

Predicted (Network) &Actual Average daily

Discharge of (2nd period of Dec) - Data: (1960 to 2000)

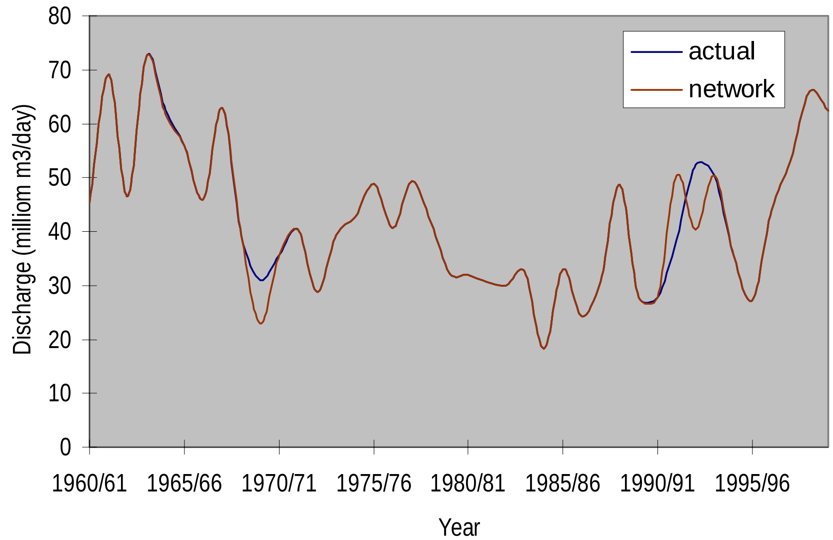


Fig (4.8)

Predicted (Network) &Actual Average daily

Discharge of (3rd period of Dec) - Data: (1960 to 2000)

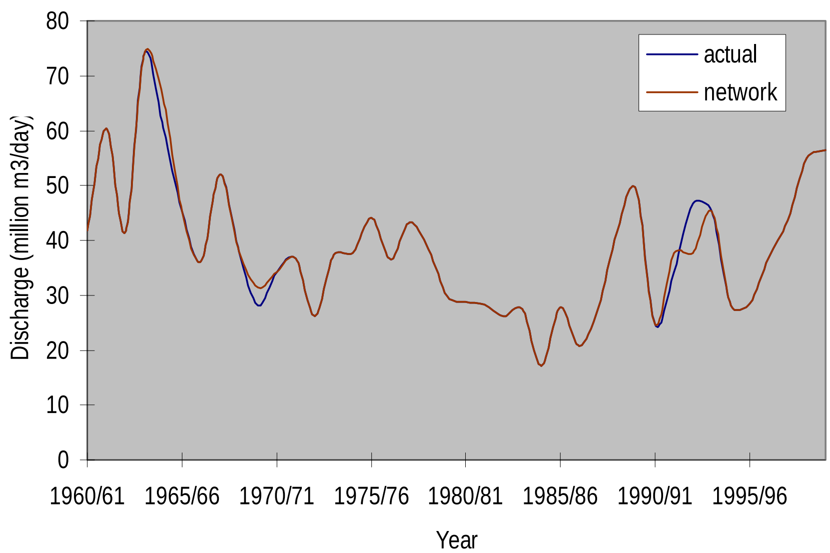


Fig (4.9)

Predicted (Network) &Actual Average daily Discharge of (1st period of Jan) - Data: (1960 to 2000)

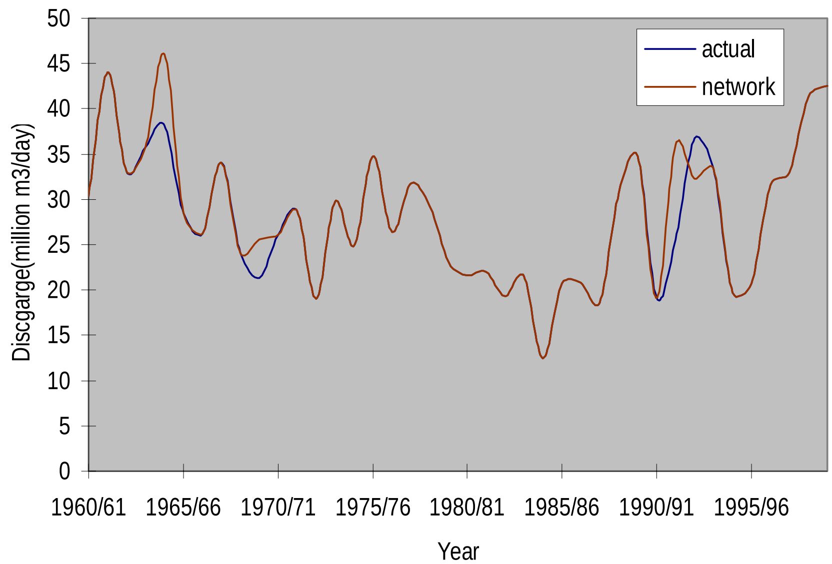


Fig (4.10)

Predicted (Network) &Actual Average daily Discharge of (2nd period of Jan) - Data: (1960 to 2000)

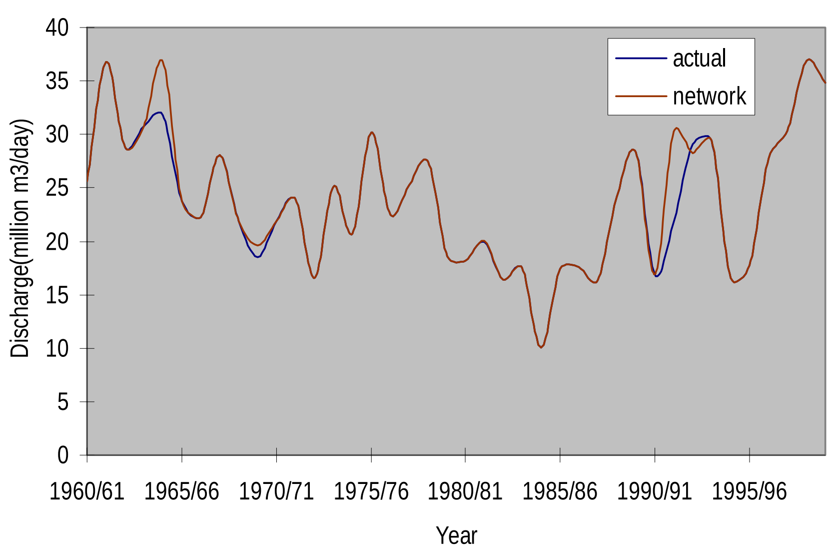


Fig (4.11)

Predicted (Network) &Actual Average daily Discharge of (3rd period of Jan) - Data: (1960 to 2000)

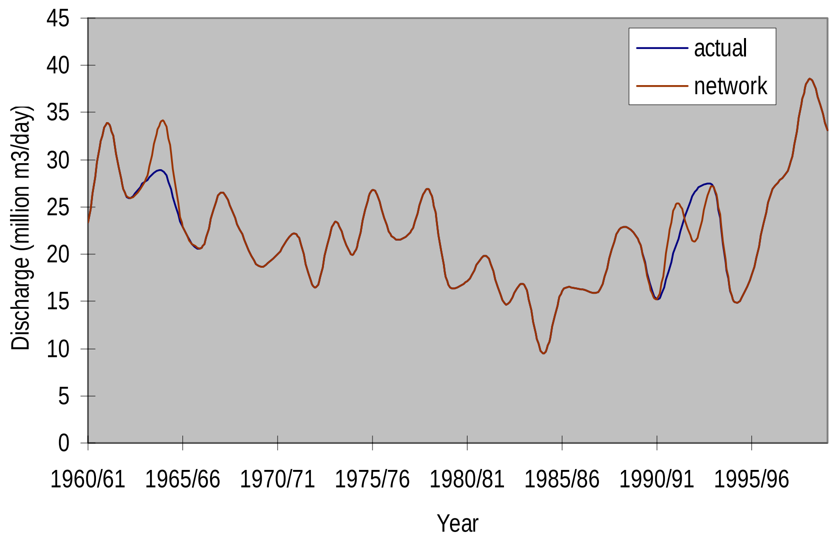


Fig (4.12)

Predicted (Network) &Actual Average daily Discharge of (1st period of Feb) - Data: (1960 to 2000)

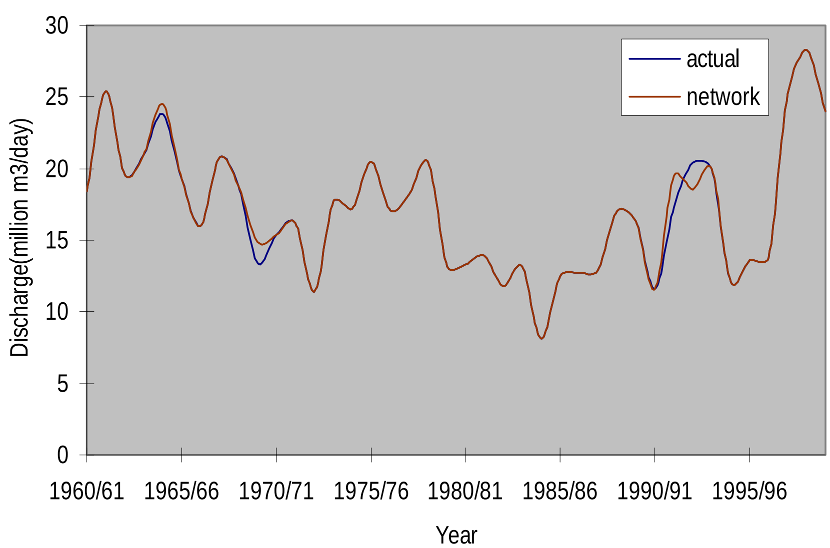


Fig (4.13)

Predicted (Network) &Actual Average daily Discharge of (2nd^{t} period of Feb) - Data: (1960 to 2000)

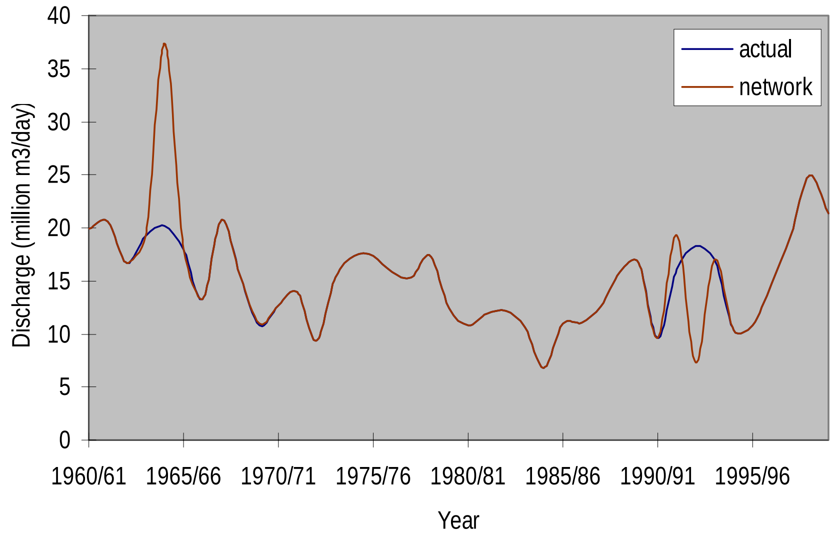


Fig (4.14)

Predicted (Network) &Actual Average daily Discharge of (3rd period of Feb) – Data : (1960 to 2000)

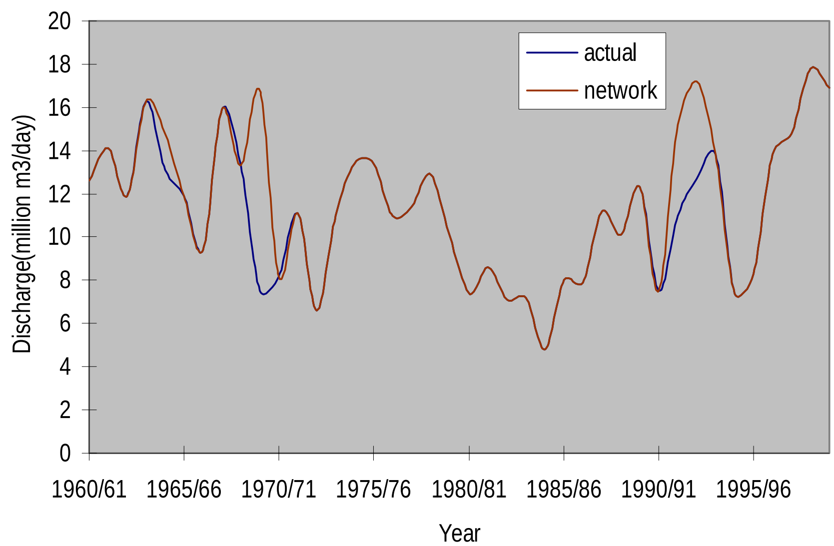


Fig (4.15)

Predicted (Network) &Actual Average daily

Discharge of (1st period of March) - Data: (1960 to 2000)

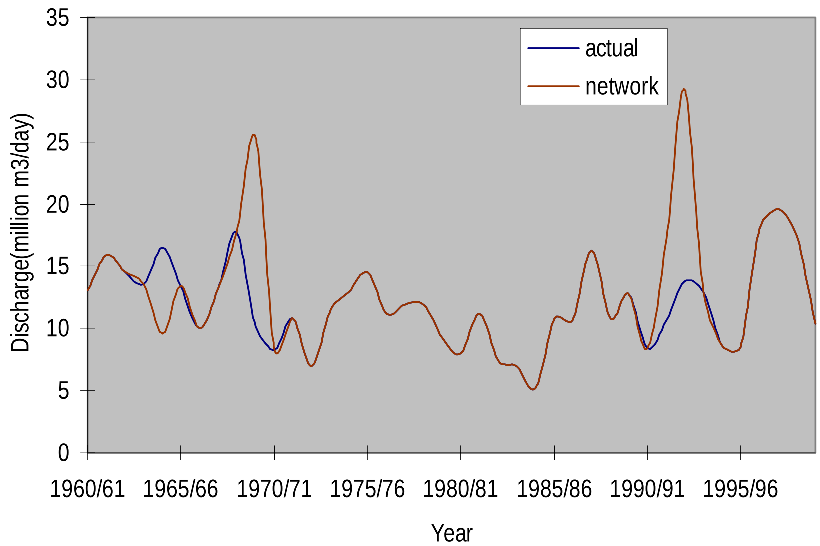


Fig (4.16)

Predicted (Network) &Actual Average daily

Discharge of (2nd period of March) - Data: (1960 to 2000)

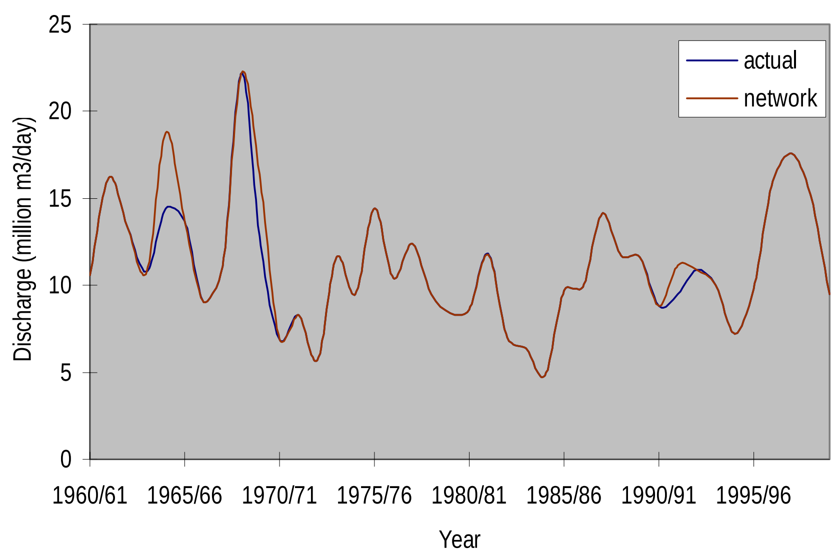


Fig (4.17)

Predicted (Network) &Actual Average daily Discharge of (3rd period of March) - Data: (1960 to 2000)

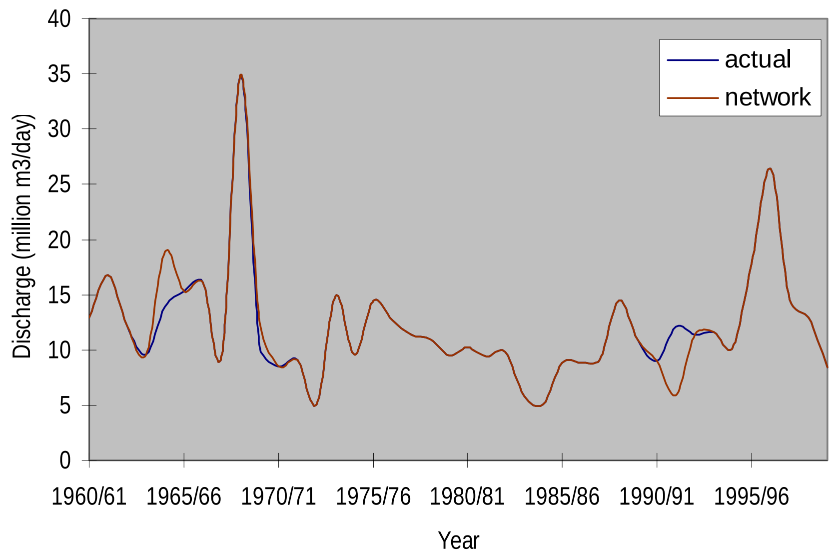


Fig (4.18)

Predicted (Network) &Actual Average daily Discharge of (1st period of April) - Data: (1960 to 2000)

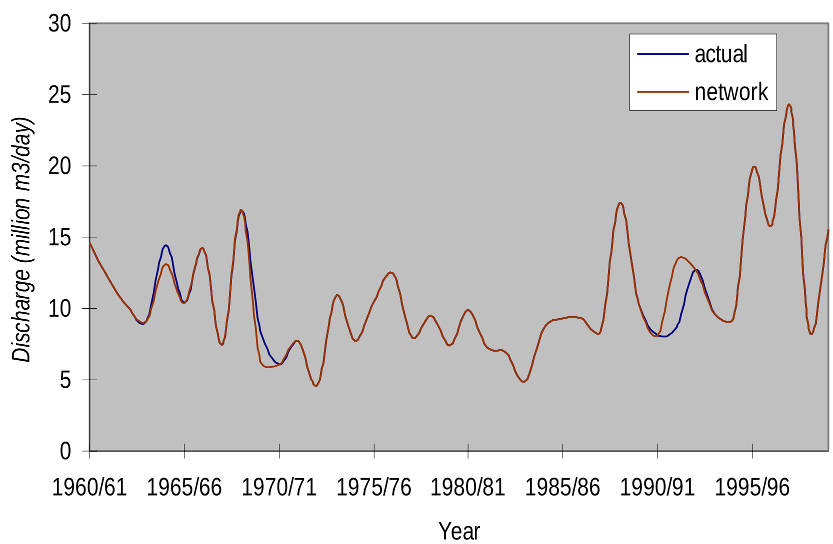
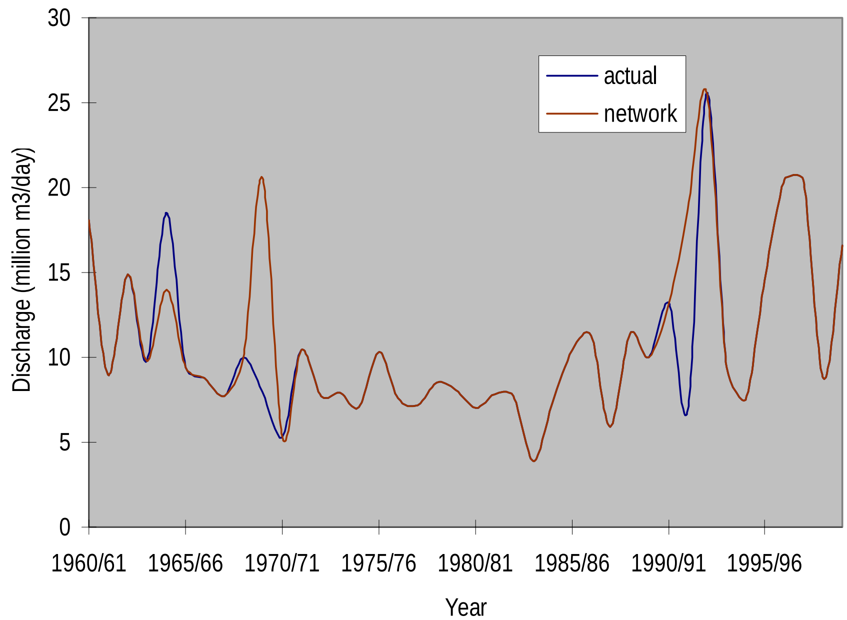


Fig (4.19)

Predicted (Network) &Actual Average daily Discharge of (2nd period of April) - Data: (1960 to 2000)



Fig(4.20)

Predicted (Network) &Actual Average daily Discharge of (3rd period of April) - Data: (1960 to 2000)

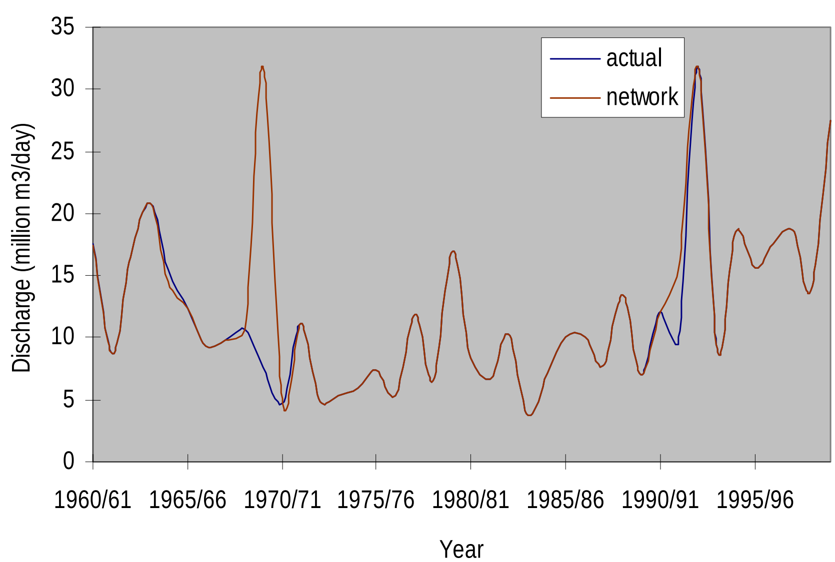


Fig (4.21)

Predicted (Network) &Actual Average daily Discharge of (1st period of May) –Data: (1960 to 2000)

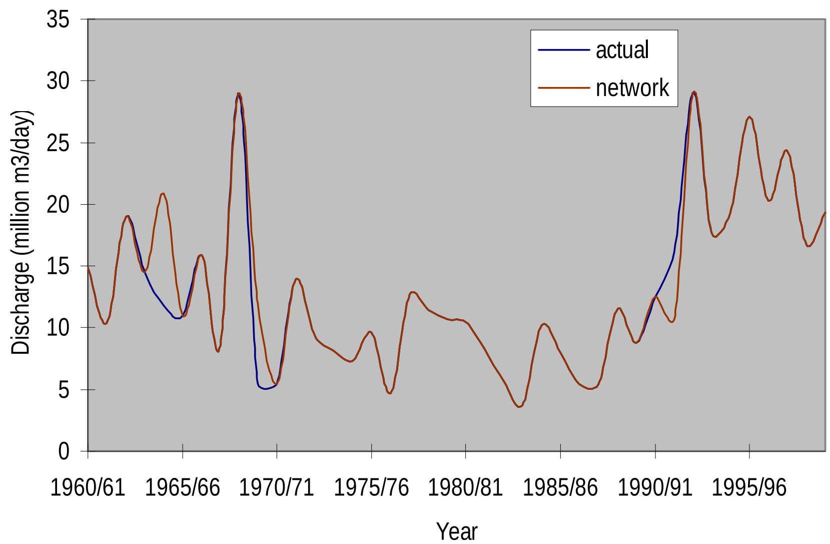


Fig (4.22)

Predicted (Network) &Actual Average daily Discharge of (2nd period of May) – Data: (1960 to 2000)

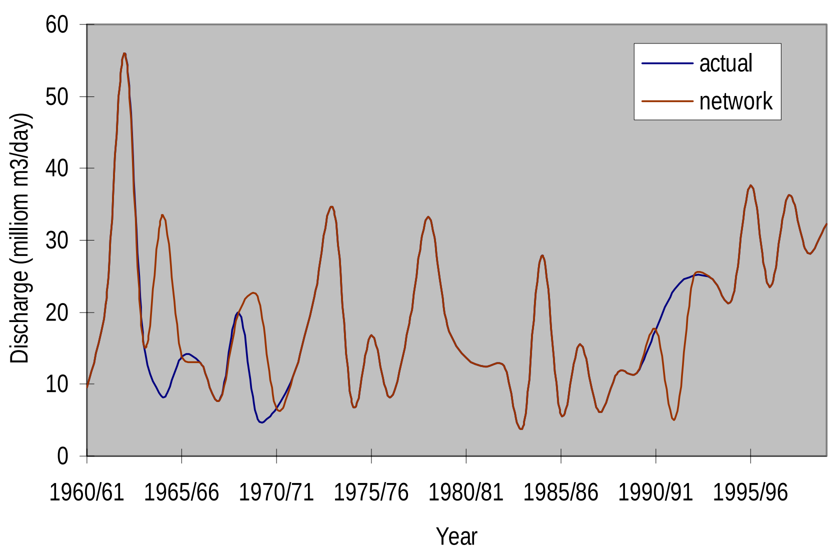


Fig (4.23)

Predicted (Network) &Actual Average daily Discharge of (3rd period of May) – Data: (1960 to 2000)

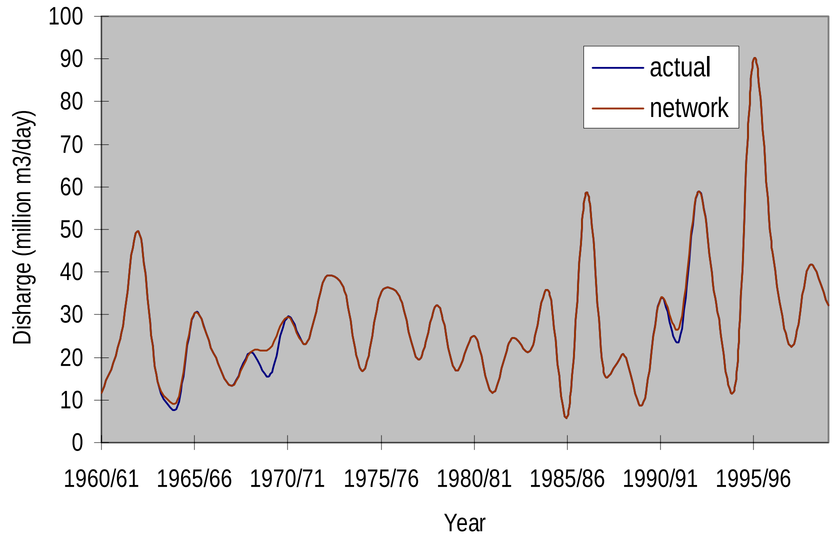


Fig (4.24)

4.4 Model – 2 [Prediction of Reservoir Water Level for Roseires & Sennar Dams]

4.4.1General

Sedimentation reduces reservoir capacity (both live and dead storage) and hence its capability to meet the irrigation and hydropower demands, may be affected.

The Blue Nile has been known from earliest recorded times to bring down considerable amounts of silt in its flood time, renewing the fertility of intermittently flooded areas along its banks. Each year the silt material originates mainly from heavy erosion in the upper catchments areas in Ethiopia, where the slope of the river is steep. As a result of this high silt load, the reservoir operation is un avoidably accompanied by reservoir sedimentation. The storage capacity has been considerably affected by siltation and is now about 30 percent less than originally for Roseires reservoir and 50 percent for Sennar reservoir. The initial capacity for Roseires at first filling in 1966 was 3.024 milliards m^3 at R.L 481.0 m and in 1992 the last bathymetric- survey, the capacity was 2.1039 milliards m^3 at 481.0 m. The initial capacity for Sennar at first filling in 1925 was 0.930 milliards m^3 at R.L 421.7 m and in 1985 was 0.640 milliards m^3 at R.L 421.7 m. Special operation strategy, by maintaining a low reservoir level and high, flow velocities during the passage of the flood, is applied to reduce the siltation.

An attempt will be made here to investigate the impact of the siltation on reservoir optimum operation. Therefore, four years have been selected for Sennar reservoir and three years for Roseires reservoir.

The basic data in this case is tables of contents of Roseires and Sennar reservoirs. (See appendix B, C)

4.4.2 Construction of Model – 2 (A) Prediction of Reservoir Water Level for Roseires **Dam**

Different scenarios have been established for each reservoir:

<u>Scenario (1):</u>

- Input:
    1. Reservoir content.
    2. Years of accumulation. (Initial year of operation is 1966)
- Output: Reservoir water level. (Using logistic activation

function)

- Network Architecture type: Two Hidden slab with different activation Function.
- Hidden Layer:
  i. Upper Slab: with 4 hidden neurons. (Using Gaussian activation function)
  ii. Lower Slab: with 4 hidden neurons. (Using Gaussian comp activation function)

See Fig (4.25)

Scenario (2):

- Input:
  i. Reservoir content.
  ii. Years of accumulation. (Initial year of operation is 1966)
- Output: Water level. (Using logistic activation function)
- Network Architecture type: Two Hidden slab with different activation function.
- Hidden Layer:
  i. Upper Slab: with 8 hidden neurons.(Using Gaussian activation function)
  ii. Lower Slab: with 8 hidden neurons.(Using Gaussian comp activation function)

4.4 .3 Construction of Model – 2 (B) Prediction of Reservoir Water Level for Sennar Dam

Scenario (1):

- Input:

i. Reservoir content.
ii. Year of accumulation. (Initial year of operation is 1925)

- Output: Water level. (Using logistic activation function)
- Network Architecture type: Two Hidden slab with different activation Function.
- Hidden Layer:
  i. Upper Slab: with 4 hidden neurons.(Using Gaussian activation function)
  ii. Lower Slab: with 4 hidden neurons.(Using Gaussian comp activation function)

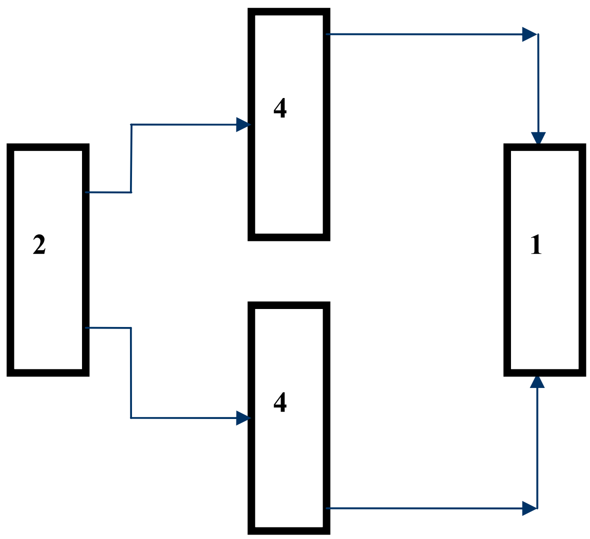
Scenario (2):

- Input:
  i. Reservoir content.
  ii. Year of accumulation. (Initial year of operation is 1925)
- Output: Water level. (Using logistic activation function)
- Network Architecture type: Two Hidden slab with different activation Function.
- Hidden Layer:
  i. Upper Slab: with 8 hidden neurons. (Using Gaussian activation function)
  ii. Lower Slab: with 8 hidden neurons. (Using Gaussian comp activation function)

10% of entered data have been taken as testing patterns and 90% are used for training process.

4.4.4Results & Discussion

The result of the models of both reservoirs shows that the number of hidden neurons is very effective in selection of the better scenario. For model-2, scenario (1) with 4 hidden neurons for upper and lower slabs gives better result than scenario (2) with 8 neurons for both slabs. See Table (4.6), Table (4.7), Table (4.8) and Table (4.9).



Input layer Hidden layer Output layer

Fig (4.25): Network Architecture of Scenario (1), Two Hidden Slabs with Different Activation Functions

Model-2 (A) Prediction of Reservoir Water level for Roseires (Statistical Results)

Table (4.6): Scenario (1)

Input layer: accumulation of year , content - Output layer : water level, activation function is logistic

Type of network: Two hidden slabs with different activation functions

Hidden layer:

Upper slab: hidden neurons = 4, activation function is Gaussian

Lower slab: hidden neurons = 4, activation function is Gaussian comp

Patterns processed: 51

Output:	**Network**
R squared:	0.9996
r squared:	0.9996
Mean squared error:	0.011
Mean absolute error:	0.04
Min. absolute error:	0
Max. absolute error:	0.505
Correlation coefficient r:	0.9998
Percent within 5%:	100
Percent within 5% to 10%:	0
Percent within 10% to 20%:	0
Percent within 20% to 30%:	0
Percent over 30%:	0

Table (4.7): Scenario (2)

Input layer: accumulation of year, content - Output layer: water level, activation function is logistic

Type of network: Two hidden slabs with different activation functions

Hidden layer:

Upper slab: hidden neurons = 8, activation function is Gaussian

Lower slab: hidden neurons = 8, activation function is Gaussian comp

Patterns processed: 51

Output:	**Network**
R squared:	0.9992
r squared:	0.9992
Mean squared error:	0.018
Mean absolute error:	0.081
Min. absolute error:	0.001
Max. absolute error:	0.504
Correlation coefficient r:	0.9996
Percent within 5%:	100
Percent within 5% to 10%:	0
Percent within 10% to 20%:	0
Percent within 20% to 30%:	0
Percent over 30%:	0

Model –2 (B) Prediction of Reservoir Water level for Sennar (Statistical Results)

Table (4.8)*: Scenario (1)*

Input layer: accumulation of year, content - Output layer: water level, activation function is logistic
Type of network: Two hidden slabs with different activation functions

Hidden layer:
upper slab: hidden neurons = 4, activation function is Gaussian
Lower slab: hidden neurons = 4, activation function is Gaussian comp

Patterns processed: 28

Output:	**Network**
R squared:	0.9994
r squared:	0.9994
Mean squared error:	0.002
Mean absolute error:	0.033
Min. absolute error:	0
Max. absolute error:	0.119
Correlation coefficient r:	0.9997
Percent within 5%:	100
Percent within 5% to 10%:	0
Percent within 10% to 20%:	0
Percent within 20% to 30%:	0
Percent over 30%:	0

Table (4.9) ; Scenario (2)

Input layer: accumulation of year, content - Output layer: water level, activation function is logistic
Type of network: Two hidden slabs with different activation functions
Hidden layer:
Upper slab: hidden neurons = 8, activation function is Gaussian
Lower slab: hidden neurons = 8, activation function is Gaussian comp

Patterns processed: 28

Output:	***Network***
R squared:	0.9986
r squared:	0.9987
Mean squared error:	0.005
Mean absolute error:	0.038
Min. absolute error:	0
Max. absolute error:	0.262
Correlation coefficient r:	0.9993
Percent within 5%:	100
Percent within 5% to 10%:	0
Percent within 10% to 20%:	0
Percent within 20% to 30%:	0
Percent over 30%:	0

4.5 Model – 3 [Relationships Between Reservoir Water Levels & Evaporation Losses for the Two Reservoirs Respectively]

4.5.1 General

The word evaporation is used to describe water loss from water or bare-soil surfaces. It is a process in which moisture is vaporized and moved up in the atmosphere.

Evaporation is of critical importance especially in day hot climates and may result in significant water losses.

Estimation of evaporation is one of the most difficult problems in meteorology. Considerable time and effort has been spent on trying to find a method, which gives a reliable estimate of evaporation loss from open water bodies, i.e. canals and reservoirs. These methods for evaporation estimate from water balance use evaporation pan approach, mass transfer approach or penman approach. It has been found that the later approach is among the methods that give good evaporation losses estimates (Daflla, 1999) [3]. Therefore it is applied here to estimate the evaporation losses from the Blue Nile River, which includes two in series reservoirs and a network of irrigation canals. Three stations have been chosen for this purpose are Damazin, Singa and Wad Medani. The first two stations are located nearby Roseires and Sennar reservoirs respectively while the third station lies in the heart of the irrigation area and the evaporation estimated using data from this station can, thus, represent evaporation losses from irrigation canals.

This study tries to find out the relation between water level and amount of evaporation at Roseires and Sennar reservoir respectively, using ANN method.

Table of evaporation loses for Roseires and Sennar reservoirs are considered as the basic data. (See appendix D, E)

4.5.2 Construction of Model – 3 (A) Relationships Between Reservoir Water Levels & Evaporation Losses for Roseires Dam

Scenario (1):

- Input: Reservoir water level.
- Output: Evaporation losses from month October… to May. (Using logistic activation function)
- Network Architecture type: Three layer, standard connections.
- Hidden layer: with 5 hidden neurons. .(Using logistic activation function)

*See fig (4.26)

Scenario (2):

- Input: Reservoir water level.
- Output : Evaporation losses from month June…. to May .(with logistic activation function)
- Network Architecture type: Three layer, standard connections.
- Hidden layer: with 5 hidden neurons.(Using logistic activation function)

4.5. 3 Construction of Model – 3 (B) Relationships Between Reservoir Water Levels & Evaporation Losses for Sennar Dam

Scenario (1):

- Input data: Reservoir water level.

- Output: Evaporation losses from month October…. to May. (Using logistic activation function)
- Network Architecture type: Three layer, standard connections.
- Hidden layer: with 5 hidden neurons. (Using logistic activation function)

*See Fig (4.26)

Scenario (2):

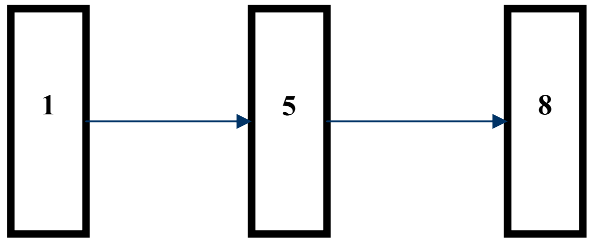
- Input data: Reservoir water level.
- Output: Evaporation losses for month June…. to May. (Using logistic activation function)
- Network Architecture type: Three layer, standard connections.
- Hidden layer: with 5 hidden neurons. .(Using logistic activation function)

10% of entered data patterns have been taken as testing patterns and 90% are used for training process.

4.4.4Results & Discussion

For model-3 scenario (1) with 5 neurons for the hidden layer and 8 outputs gives better results than scenario (2) with 5 neurons for hidden layer and 12 outputs, which reflects the effects of the number of the outputs. See Table (4.10), Table (4.11), Table (4.12) and Table (4.13)

The selected scenario of model-3 has 99% correlation coefficient and the sum squares (MSE) very small and close to zero.



Input layer Hidden layer Output layer

Fig (4.26): Network Architecture of Scenario (1), Three layers Standard Connections

Table (4.10) **Model – 3: (A) Relationship Between Reservoir Water Level & Evaporation Losses for Roseires Dam (Statistical Results)**

Scenario (1) , *Input : water level* *Output: Evaporation Losses (October to May)*

Type of network: three layer (standard connection), Hidden Neurons: 5

Patterns processed: 32

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**mean**
R squared:	0.9979	0.9993	0.9994	0.9995	0.9996	1.0	0.9988	0.9995	
r squared:	0.9979	0.9994	0.9995	0.9996	0.9996	1.0	0.9988	0.9995	
Mean squared error:	0	0	0	0	0	0	0	0	0
Mean absolute error:	0.007	0.008	0.009	0.009	0.009	0.013	0.013	0.008	0.0095
Min. absolute error:	0.001	0	0	0	0	0	0	0	0.000125
Max. absolute error:	0.058	0.042	0.034	0.034	0.04	0.101	0.102	0.039	0.05625
Correlation coefficient r:	0.999	0.9997	0.9997	0.9998	0.9998	0.9994	0.9994	0.9998	
Percent within 5%:	90.625	96.875	96.875	96.875	96.875	96.875	96.875	96.875	
Percent within 5% to 10%:	6.25	0	0	0	0	0	0	0	
Percent within 10% to 20%:	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	
Percent within 20% to 30%:	0	0	0	0	0	0	0	0	
Percent over 30%:	0	0	0	0	0	0	0	0	

Table(4.11)

Scenario (2) *Input : water level* *Output: Evaporation Losses (January to December)*

Type of network: three layer (standard connection) **,** *Hidden neurons 5*

Patterns processed: 32

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**mean**
R squared:	0.9993	0.9993	0.9984	0.9984	0.9992	0.9988	0.9988	0.9985	0.9927	0.9974	0.9989	0.9991	
r squared:	0.9994	0.9994	0.9985	0.9985	0.9993	0.9989	0.999	0.9987	0.993	0.9975	0.999	0.9992	
Mean squared error:	0	0	0.001	0.001	0	0	0	0	0	0	0	0	0.000
Mean absolute error:	0.011	0.012	0.016	0.014	0.011	0.009	0.005	0.004	0.009	0.008	0.009	0.011	0.009
Min. absolute error:	0	0	0	0	0	0	0	0	0	0	0	0	0
Max. absolute error:	0.041	0.037	0.121	0.119	0.043	0.038	0.019	0.017	0.071	0.066	0.054	0.046	0.056
Correlation coefficient r:	0.9997	0.9997	0.9992	0.9992	0.9996	0.9994	0.9995	0.9993	0.9965	0.9988	0.9995	0.9996	

Percent within 5%:	96.875	96.875	96.875	96.875	96.875	96.875	96.875	96.875	90.625	93.75	96.875	96.875	
Percent within 5% to 10%:	0	0	0	0	0	0	0	0	6.25	3.125	0	0	
Percent within 10% to 20%:	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.125	
Percent within 20% to 30%:	0	0	0	0	0	0	0	0	0	0	0	0	
Percent over 30%:	0	0	0	0	0	0	0	0	0	0	0	0	

Table (4.12)

Model – 3. (B) Relationship Between Reservoir Water Level & Evaporation Losses for Sennar Dam (Statistical Results)

Scenario (1) , *Input : water level* *Output: Evaporation Losses (October to May)*

Type of network: three layer (standard connection) , Hidden Neurons: 5

Patterns processed: 20

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**mean**
R squared:	0.9938	0.9944	0.9873	0.993	0.9943	0.9934	0.9947	0.9929	
r squared:	0.9967	0.997	0.9912	0.9966	0.997	0.9966	0.9969	0.9966	
Mean squared error:	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000875
Mean absolute error:	0.014	0.018	0.025	0.021	0.022	0.027	0.024	0.023	0.02175
Min. absolute error:	0.003	0	0	0.002	0.001	0.001	0	0.001	0.001
Max. absolute error:	0.059	0.082	0.098	0.094	0.099	0.121	0.108	0.106	0.095875
Correlation coefficient r:	0.9983	0.9985	0.9956	0.9983	0.9985	0.9983	0.9984	0.9983	
Percent within 5%:	90	90	80	90	90	90	90	90	
Percent within 5% to 10%:	0	0	5	0	0	0	0	0	
Percent within 10% to 20%:	5	5	10	5	5	5	5	0	
Percent within 20% to 30%:	0	0	0	0	0	0	0	5	
Percent over 30%:	5	5	5	5	5	5	5	5	

Table (4.13)

Scenario(2) , *Input : water level* *Output: Evaporation Losses (January to December)*

Type of network: three layer (standard conection) , Hidden Neurons: 5

Patterns processed: 20

Output:	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**mean**

R squared:	0.9896	0.9883	0.9898	0.9862	0.9883	0.9858	0.9876	0.9886	0.9898	0.9855	0.9865	0.9825	
r squared:	0.9959	0.996	0.9952	0.9959	0.9954	0.9939	0.995	0.9946	0.9948	0.9955	0.9964	0.991	
Mean squared error:	0.001	0.002	0.002	0.003	0.002	0.002	0	0	0	0.001	0.002	0.002	0.001417
Mean absolute error:	0.026	0.031	0.031	0.039	0.029	0.026	0.014	0.009	0.01	0.02	0.029	0.031	0.024583
Min. absolute error:	0.002	0.002	0.001	0.007	0.005	0	0	0.001	0.001	0.001	0	0.003	0.001917
Max. absolute error:	0.115	0.141	0.153	0.167	0.137	0.135	0.069	0.043	0.05	0.089	0.122	0.109	0.110833
Correlation coefficient r:	0.9979	0.998	0.9976	0.998	0.9977	0.9969	0.9975	0.9973	0.9974	0.9978	0.9982	0.9955	
Percent within 5%:	90	90	90	80	90	90	90	90	90	85	90	75	
Percent within 5% to 10%:	0	0	0	10	0	0	0	0	0	5	0	10	
Percent within 10% to 20%:	0	0	0	0	0	0	0	0	0	0	0	5	
Percent within 20% to 30%:	5	5	5	5	5	5	5	5	5	0	5	5	
Percent over 30%:	5	5	5	5	5	5	5	5	5	10	5	5	

CHAPTE FIVE

5.0 Emptying Program Based on The Neural Network Approach

5.1 Steps Followed for The Emptying Program

Step-1 : Inflows at El Deim station are predicted by ANN method.

Step-2 : Evaporation losses are determined depending on assuming water level, which is corrected as the computation is carried out.

Step-3 : Transmission losses are taken as 1% between El Deim and Roseires dam and 2% between Roseires and Sennar dams.

Step-4 : Assume a certain area of wheat for all projects.

Step-5 : Compute the ten-day period irrigation demand the of Wheat crop.

Step-6: Find the total irrigation

demands of crops (Cotton,

Forests, Gardens…etc) for all schemes.

Step-7: Adopt a certain program of emptying for the two dams using water balance method, which can be expressed as follows:

$$Q_{out} = Q_E - E - T - Q_{u/s} - (G + M) - W + \Delta \tag{5.1}$$

$$\Delta = Q_{out} - Q_E + E + T + (G + M) + W + Q_{u/s} \tag{5.2}$$

Roseires and Sennar dams are considered as one *System*.

Where:

Q_{out} = D/S Release from Sennar dam (provide Eljuneid project needs (50 million m^3) + other needs).

Q_E = Discharge at El Deim station.

E = Evaporation losses at Roseires & Sennar reservoir (Reva, Seva)

TL = Transition losses

$$T = T_R + T_S \qquad (5.3)$$

Where:

T_R = 0.01 from the discharge at El Deim.

T_S = 0.02 from the discharge down stream Roseires.

$Q_{u/s}$ = Upstream abstraction (zero for Roseires and have constant value for Sennar).

G + M = Irrigation water requirements for all crops without Wheat for Gezira and Managil.

W = *Irrigation water requirements for the wheat for all* projects.

Δ = Total abstraction, from Roseires and from Sennar .

The assumed ratio for the abstraction of the two reservoirs is 1(Sennar) : 4.4 (Roseires) or 81.5% & 18.5% of the total abstraction for Roseires & Sennar reservoirs.

Substituting the above terms and the assumed ratio in equation (5.2) so the total abstraction will be:

$$\Delta = [Q_{out} + (G + M) + W + Q_{u/s} + S_{evapo} + 0.98R_{evapo} - 0.9702Q_E]/0.9837 \quad (5.4)$$

The abstraction from Roseires reservoir should be the first before Sennar reservoir to reduce the high level to avoid the seepage problem.

- When minimum water level of each one of the System reservoirs is reached, the abstraction from that one should be stopped.
- If there is excess water at the end of May, then the area of the wheat should be increased.

Step-8: Repeat the above steps until the optimum area of wheat is found.

Note: The minimum requirements downstream Sennar as shown in Table (5.1), Table (5.2) & Table (5.3) column (V).

5.2 Computation of The Emptying Program

Emptying program depends on good expectation (prediction) of flow discharges, among each season; this will lead to good irrigation planning during the different agricultural seasons.

The following will be the steps for the expected emptying program for year 1999 – 2000 of the two reservoirs showing the equations used in the programmed M.S.Excel sheet, using the final results of Model-1, Model-2 and Model-3.

Column **Description**

A ***Month: from October to May***

B Monthly periods, three periods per month.

C Inflow at El Deim per day, which predicted by ANN.

Formula: predict ("c:\NeuroShell \discharge a.def";

Input cells; output cells no).

Inputs: Q_{JuneI},Q_{JulyI},Q_{AugI},Q_{SepI},Q_{OctI}.

Outputs: 1-23 for all periods in (B).

D Total inflow at Roseires reservoir per period.

Formula: 10*0.99*C

E Evaporation losses at Roseires reservoir per day,

which predicted by ANN.

Formula: predict (“c:\NeuroShell 2/ evapo(Rose).def ”; input cells;outputcells no).

Inputs: initial water level in (L).

Outputs:1 to 8 according to month in column (A).

F Evaporation losses at Roseirs reservoir per period.

Formula: E*10

G Balance stat.

Formula: (V+R+T+U+Q+0.98*F- 0.9702*10*C)/ .9837

H Total abstraction.

Formula: If (G>0;G;0)

I Roseires reservoir change of content.

Formula: If ((L) < 480; 81.5%*H; H)

J Accumulation of year 1999-2000, taking year 1966 as zero point.

K Roseires reservoir

content.

Formula: K (i+1)=K(i)-I(i+1) , K(1) =2103.9

L Initial water level of Roseires. (u/s level (1))

Assume initial value 481.0 m

M Predicted Roseires water level. (u/s level (2))

Formula: predict ("c:\NeuroShell \Roseires a.def";

input cells; output cells no).

Inputs: Roseires content (K), output no = 1

N Down stream release from Roseires.

Formula: D-F+I

O Inflow to Sennar reservoir.

Formula: 0.98*N

P Evaporation losses at Sennar reservoir per day, which predicted by ANN.

Formula: predict ("c:\NeuroShell2 Sennar

(evapo). def"; input cells; outputcells no).

Input: initial Sennar water level in column (AA)

Output: 1to 8 according to month in column (A)

Q Evaporation losses at Sennar reservoir per period

Formula: P*10

R Demand of (G+M) schemes.

S Wheat factor (irrigation requirements in M3/feddan/day).

T Demand of wheat crop (million m3/period).

U Demand of schemes U/S Sennar.

V Minimum D/s release of Sennar.

W Actual D/s release Sennar.

Formula: O-Q-R-T-U

X change of content of Sennar reservoir.

Formula: IF ((L) <480; 18.5%*H; 0)

Y Accumulation of years 1999-2000, taking year 1925 as zero point.

Z Sennar reservoir content.

Formula: Z(i+1)=Z(i)-X(i+1),Z(1)=640

AA Initial water level of Sennar. (U/s level (1))

Assume initial value 417.2 m.

AB Predicted water level of Sennar. (U/s level (2))

Formula: predict (“c:\NeuroShell \Sennar a def”; input cells; output cells no).

Inputs: Sennar content (Z), output no = 1

Note:

1. Appendix (F) showing Irrigation Water Requirements For Blue Nile Projects.

2. The results of the final emptying program explained in

Table (5.1), Table (5.2) and Table (5.3).

5.3 Discussion

The criteria, used for the operation of the two dams are:

a) Abstraction from Sennar reservoir never starts before the R.L at Roseires falls to 480 m.

b) The withdrawn water is 81.5% & 18.5% of total abstraction from Roseires reservoir and Sennar reservoir respectively.

Different areas of wheat crop have been tried through the three following alternatives;

Alternative (1)

i. Area of wheat is 500,000 feddan.

ii. Table (5.1), reflects that:

a) Roseires reservoir has extra volume of water not utilized of 382.8 millions m^3.

b) Sennar

reser

voir has extra volume of water not utilized of 87 millions m^3.

Therefore this alternative should be rejected.

Alternative (2)

i. Area of wheat is 885,500 feddan.

ii. Table (5.2), reflects that water level at Sennar and Roseires reservoirs reached the dead levels at end of May.

So this alternative will be considered the best one for the optimum operation of the two reservoirs.

The actual area of wheat which plant at all projects beside the Blue Nile considered small compared with the area result from alternative (2) because this study try to make future planning to maximize the benefit of the two reservoirs by increasing the area of wheat crop as possible.

So the actual water levels will be different from the predicted water levels in the emptying program alternative (2). See table (5.4)

Alternative (3)

i. Area of wheat is

1,000,000 feddan.

ii. Table (5.3), reflects that the level at both reservoirs drop below the dead storage levels respectively before end of May.

So this alternative should be rejected.

Table (5.4): Comparison between Actual & Predicted Discharges at ElDeim and Actual & Predicted U/S Water Levels for Roseires and Sennar Reservoirs at the Emptying Program for year 1999/2000 (Alternative 2)

Periods	Actual Discharge at El Deim	Predicted Discharge at El Deim	Actual* Water levels For Roseires	Predicted** Water levels For Roseires	Actual* Water levels For Sennar	Predicted** Water levels For Sennar
Oct_{II}	441.90	441.90	480.01	481.00	420.12	421.70
Oct_{III}	385.00	385.00	480.03	481.00	419.87	421.70
Nov_{I}	179.50	179.50	480.49	481.00	420.81	421.70
Nov_{II}	124.60	124.60	480.94	481.00	421.43	421.70
Nov_{III}	95.70	95.70	480.98	481.00	421.64	421.70
Dec_{I}	75.10	75.10	480.99	480.80	421.70	421.70
Dec_{II}	62.40	62.40	481.00	480.00	421.70	421.70
Dec_{III}	56.50	56.50	481.00	479.10	421.70	421.36
Jan_{I}	42.50	42.50	480.97	478.20	421.70	421.01
Jan_{II}	34.80	34.80	481.00	477.1	421.70	420.58
Jan_{III}	33.10	33.10	480.96	475.80	421.70	420.09
Feb_{I}	24.00	24.00	480.93	474.90	421.68	419.72
Feb_{II}	21.40	21.40	480.82	474.40	421.55	419.53
Feb_{III}	16.90	16.90	480.54	473.60	421.52	419.25
Mar_{I}	10.40	10.40	480.03	472.50	421.26	418.85
Mar_{II}	9.50	9.50	479.38	471.10	420.96	418.43
Mar_{III}	8.40	8.40	478.38	469.30	420.56	417.82
Apr_{I}	15.50	15.50	477.45	468.60	419.85	417.60
Apr_{II}	16.60	16.60	476.54	467.80	418.97	417.40
Apr_{III}	27.50	27.50	475.67	467.80	418.85	417.40

May_I	19.30	19.30	474.59	467.02	418.86	417.28
May_{II}	32.20	32.20	473.16	467.02	418.82	417.28
May_{III}	32.30	32.30	471.49	467.00	418.68	417.28

* i. Data concerning area of wheat is not available on records according to Ministry of Agriculture.

ii. These levels are not following the regulation rules of Roseires & Sennar Reservoirs as the filling program continuous up to Dec_{II} and it should be ended on 9 th Nov(the start date of filling 26September).

**i. Area of wheat is 885,500 feddan.

ii. These levels following the regulation rules.

Here are The Emptying Program Three Alternatives

See Excel file which has name of emptying program

CHAPTER SIX

6.0 Summary, Conclusions & Recommendations

6.1 Summary

Artificial neural networks (ANN) have been widely used for various forecasting problems. Their flexible non-linear modelling capability is particularly useful for many complex real-problems.

The neural networks through the NeuroShell2 software have been used for:

i. Prediction of inflow discharges at El Deim station during the recession period.(Model-1)

ii. Prediction of Roseires and Sennar water levels.(Model-2)

iii. Determination of evaporation losses for both reservoirs. (Model-3)

<u>Description of Model-1</u>

- Input: Discharge of 1^{st} period of June, 1^{st} period of July, 1^{st} period of August, 1^{st} period of September and 1^{st} period of October.
- Output: discharge of 2^{nd} period of October,3^{rd} period of October,1^{st} period of November……to 3^{rd} period of May, 23 outputs. (Using logistic

activation function)

- Network Architecture type: Two Hidden Slab with different activation functions.
- Hidden layer:
  i. Upper slab: with 30 hidden neurons. (Using Gaussian activation function)
  ii. Lower slab: with 25 hidden neurons. (Using Gaussian comp activation function)

Description of Model-2 [for each of Roseires & Sennar Reservoirs]

- Input :
  i. Reservoir content.
  ii. Year of accumulation. (Initial year of operation is 1966 and 1925 for Roseires & Sennar dams respectively).
- Output: Reservoir water level .(Using logistic activation function)
- Network Architecture type: Two Hidden slabs with different activation Function.
- Hidden Layer :
  i. Upper Slab: with 4 hidden neurons. (Using Gaussian activation function)
  ii. Lower Slab: with 4 hidden neurons. (Using Gaussian comp activation function)

Description of Model-3[for each of Roseires & Sennar Reservoirs]

- Input: Reservoir water level.

- Output: Evaporation losses from month October….. to May, 8 outputs .(Using logistic activation function)
- Network Architecture type: Three layers, standard connections.
- Hidden layer: with 10 hidden neurons. .(Using logistic activation function)

Acceptable results have been found for Model-1, Model-2 and Model-3. A computer program has been established for the emptying of Roseires & Sennar reservoirs using M.S Excel software.

Description of Reservoirs Emptying Program

Data required: i. Predicted discharges at El Deim station.

ii. Evaporation losses at Roseires & Sennar reservoir.

iii. Irrigation demands for Projects U/S & D/S Sennar for all crops, other than wheat.

iv. Crop water requirements data for wheat per feddan.

v. Tables of content for Roseires & Sennar reservoirs.

Objective of the Emptying Program:

Using the above mentioned data with assumed area of wheat and a certain abstraction ratio for the two reservoirs, the final water levels for the two reservoirs, at the 3rd period of May, are obtained respectively.

If the obtained water level for each reservoir, at 3rd period of

May is less than minimum reservoir level, then the assumed wheat area should be decreased.

If the obtained water level for each reservoir, at 3rd period of May is greater than minimum reservoir level, then the assumed wheat area should be increased.

6.2 Conclusions

Through this study, artificial neural network models result in the following conclusions;

- Both inputs and hidden neurons can affect neural network modelling building and forecasting ability. However, the number of input neurons has stronger effects than the number of hidden neurons.
- Simple network models are adequate for Model-1, Model-2 and Model-3.
- Data sizes used for training neural network have large effect on model performance. However, with larger data sizes, more accurate results are obtained for the models.
- The real power of neural network is evident when the trained network is able to produce good results.
- Through the proposed emptying program for year 1999-2000, the optimum operation for both reservoirs has an abstraction ratio of 1 (Sennar): 4.4 (Roseires) that gives potential wheat area of 885,500 feddan.

6.3 Recommendations

- The outputs of Model-1

(prediction of inflow discharges at El Deim station) are very large, 23 outputs, that need huge amount of data. As the data is limited so the efficiency of the model is relatively not high.

More data should be used to obtain higher efficiencies

of the model.

- More bathymetric survey data for the two reservoirs is required for better establishment of Model-2.
- The ANN models are recommended to be used by the Ministry of Irrigation & Water Resources for the operation of Roseires & Sennar reservoirs.
- ANN will be a good tool for prediction of discharges at El Deim station instead of the graphical method used by the Ministry of Irrigation & Water Resources.
- Other techniques and softwares should be tried and compared with the results of NeuroShell2.
- This study can be applied for the operation of other reservoirs in Sudan such as Khashm El Girba, Jebel Awlia and Merowi reservoirs.

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Appendix (D) **Model $_{-3:}$ (A) Relationship Between Reservoir Water Level & Evaporation Losses for Roseires Dam**

Scenario 1

Input	Actual Output							
level	E10	E11	E12	E1	E2	E3	E4	E5
456.80	0.060	0.100	0.120	0.130	0.150	0.160	0.160	0.130
460.60	0.120		0.220	0.240	0.270	0.290	0.280	0.240
462.82	0.200	0.320	0.370	0.390	0.440	0.480	0.470	0.400
464.34	0.260	0.410	0.480	0.510	0.580	0.630	0.610	0.520
465.56	0.300	0.480	0.560	0.600	0.670	0.740	0.710	0.600
466.62	0.330	0.540	0.630	0.670	0.760	0.820	0.800	0.680
467.59	0.370	0.590	0.690	0.740	0.830	0.910	0.880	0.750
468.48	0.400	0.650	0.750	0.800	0.910	0.990	0.950	0.810
469.30	0.430	0.700	0.810	0.860	0.980	1.070	1.030	0.880
470.07	0.460	0.750	0.870	0.920	1.050	1.140	1.100	0.940
470.78	0.490	0.790	0.920	0.980	1.110	1.210	1.170	1.000
471.45	0.520	0.840	0.980	1.040	1.170	1.280	1.230	1.050
472.09	0.550	0.880	1.030	1.090	1.240	1.350	1.300	1.110
472.70	0.570	0.920	1.080	1.140	1.300	1.410	1.360	1.160
473.29	0.600	0.970	1.120	1.190	1.350	1.480	1.420	1.210
473.84	0.620	1.010	1.170	1.240	1.410	1.540	1.480	1.260
474.38	0.650	1.050	1.220	1.290	1.460	1.600	1.540	1.310
474.90	0.670	1.090	1.270	1.340	1.520	1.660	1.600	1.360
475.39	0.690	1.120	1.310	1.390	1.570	1.710	1.650	1.410
475.87	0.720	1.160	1.350	1.440	1.630	1.770	1.710	1.460
476.34	0.740	1.200	1.400	1.480	1.680	1.830	1.770	1.510
476.78	0.770	1.240	1.440	1.530	1.730	1.890	1.820	1.550
477.22	0.790	1.280	1.490	1.580	1.790	1.950	1.880	1.600
477.64	0.820	1.320	1.540	1.630	1.850	2.020	1.950	1.660
478.05	0.840	1.370	1.590	1.690	1.910	2.090	2.010	1.710
478.45	0.870	1.410	1.640	1.740	1.970	2.150	2.080	1.770
478.83	0.900	1.450	1.690	1.800	2.040	2.220	2.140	1.820

479.20	0.930	1.500	1.740	1.850	2.100	2.290	2.210	1.880
479.57	0.950	1.540	1.800	1.910	2.160	2.360	2.270	1.940
479.92	0.980	1.590	1.850	1.960	2.220	2.420	2.330	1.990
480.00	0.990	1.600	1.860	1.970	2.230	2.440	2.350	2.000
481.00	1.115	1.725	1.9850	2.095	2.355	2.7	2.6	2.125

Continue Appendix (D)

Network(1)	**Network(2)**	**Network(3)**	**Network(4)**	**Network(5)**	**Network(6)**	**Network(7)**	**Network(8)**
0.063	0.100	0.120	0.130	0.150	0.160	0.160	0.132
0.137	0.219	0.254	0.274	0.310	0.339	0.329	0.279
0.198	0.318	0.369	0.395	0.446	0.488	0.473	0.401
0.247	0.397	0.462	0.493	0.557	0.609	0.589	0.500
0.290	0.467	0.544	0.579	0.655	0.715	0.691	0.587
0.329	0.532	0.619	0.659	0.745	0.813	0.785	0.668
0.366	0.593	0.690	0.734	0.831	0.905	0.874	0.744
0.401	0.650	0.757	0.804	0.911	0.992	0.957	0.815
0.433	0.703	0.819	0.870	0.985	1.073	1.035	0.882
0.464	0.753	0.878	0.932	1.056	1.149	1.108	0.945
0.492	0.799	0.931	0.989	1.121	1.219	1.175	1.003
0.519	0.843	0.982	1.042	1.182	1.285	1.239	1.058
0.545	0.885	1.031	1.094	1.241	1.349	1.300	1.111
0.569	0.925	1.078	1.144	1.298	1.410	1.359	1.162
0.594	0.965	1.124	1.192	1.353	1.470	1.417	1.212
0.617	1.003	1.168	1.239	1.406	1.528	1.472	1.260
0.641	1.041	1.212	1.286	1.460	1.586	1.529	1.309
0.665	1.080	1.257	1.334	1.514	1.645	1.585	1.357
0.689	1.118	1.302	1.381	1.568	1.704	1.642	1.406
0.713	1.158	1.348	1.430	1.624	1.765	1.700	1.455
0.739	1.199	1.396	1.482	1.681	1.829	1.762	1.507
0.765	1.240	1.444	1.532	1.739	1.892	1.823	1.559
0.793	1.284	1.495	1.586	1.799	1.960	1.889	1.613

0.821	1.329	1.546	1.641	1.860	2.028	1.955	1.668
0.850	1.374	1.598	1.696	1.921	2.098	2.022	1.723
0.879	1.419	1.650	1.751	1.983	2.169	2.090	1.779
0.908	1.462	1.700	1.803	2.042	2.237	2.156	1.831
0.936	1.504	1.749	1.854	2.098	2.303	2.221	1.882
0.963	1.545	1.796	1.904	2.153	2.368	2.284	1.932
0.988	1.583	1.838	1.948	2.202	2.428	2.342	1.977
0.994	1.591	1.848	1.958	2.213	2.441	2.355	1.987
1.0572	1.6827	1.9512	2.0664	2.3325	2.5888	2.4981	2.0954

Continue Appendix (D)

Act-Net(1)	Act-Net(2)	Act-Net(3)	Act-Net(4)	Act-Net(5)	Act-Net(6)	Act-Net(7)	Act-Net(8)
-0.00284	-0.00004	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00187
-0.01729	-0.02910	-0.03378	-0.03419	-0.03999	-0.04865	-0.04909	-0.03944
0.00195	0.00238	0.00147	-0.00509	-0.00643	-0.00829	-0.00286	-0.00142
0.01313	0.01268	0.01840	0.01690	0.02271	0.02087	0.02092	0.01977
0.01031	0.01255	0.01640	0.02057	0.01487	0.02460	0.01871	0.01263
0.00104	0.00813	0.01103	0.01120	0.01477	0.00699	0.01481	0.01238
0.00387	-0.00289	-0.00034	0.00600	-0.00071	0.00453	0.00589	0.00618
-0.00092	0.00002	-0.00710	-0.00438	-0.00081	-0.00203	-0.00735	-0.00531
-0.00332	-0.00310	-0.00916	-0.00987	-0.00542	-0.00261	-0.00480	-0.00198
-0.00389	-0.00317	-0.00760	-0.01160	-0.00580	-0.00860	-0.00783	-0.00497
-0.00215	-0.00938	-0.01148	-0.00857	-0.01078	-0.00878	-0.00527	-0.00321
0.00111	-0.00304	-0.00234	-0.00239	-0.01219	-0.00512	-0.00901	-0.00833
0.00543	-0.00489	-0.00105	-0.00400	-0.00107	0.00122	-0.00016	-0.00124
0.00068	-0.00514	0.00214	-0.00364	0.00232	-0.00003	0.00099	-0.00216
0.00631	0.00529	-0.00383	-0.00243	-0.00330	0.00972	0.00310	-0.00223
0.00298	0.00750	0.00227	0.00094	0.00361	0.01212	0.00773	-0.00003
0.00923	0.00911	0.00770	0.00358	-0.00026	0.01356	0.01142	0.00146
0.00528	0.01049	0.01286	0.00593	0.00562	0.01458	0.01468	0.00274
0.00144	0.00216	0.00837	0.00864	0.00201	0.00598	0.00826	0.00449
0.00660	0.00237	0.00218	0.00956	0.00649	0.00503	0.00956	0.00455
0.00061	0.00088	0.00402	-0.00157	-0.00123	0.00136	0.00818	0.00265
0.00457	-0.00048	-0.00396	-0.00247	-0.00857	-0.00225	-0.00320	-0.00889
-0.00321	-0.00437	-0.00484	-0.00641	-0.00918	-0.00996	-0.00858	-0.01336
-0.00136	-0.00855	-0.00601	-0.01057	-0.00991	-0.00835	-0.00465	-0.00794
-0.01023	-0.00353	-0.00803	-0.00556	-0.01142	-0.00824	-0.01225	-0.01326
-0.00947	-0.00871	-0.01018	-0.01060	-0.01284	-0.01874	-0.01048	-0.00854
-0.00786	-0.01217	-0.01022	-0.00334	-0.00155	-0.01688	-0.01647	-0.01144
-0.00566	-0.00430	-0.00858	-0.00423	0.00192	-0.01325	-0.01081	-0.00246

-0.01310	-0.00546	0.00432	0.00630	0.00708	-0.00845	-0.01405	0.00795
-0.00829	0.00719	0.01172	0.01163	0.01767	-0.00795	-0.01180	0.01317
-0.00390	0.00893	0.01233	0.01179	0.01680	-0.00114	-0.00461	0.01330
0.05779	0.04231	0.03375	0.02856	0.02255	0.10118	0.10188	0.02965

Appendix (C) Model $_{-2}$: (B) Prediction of Reservoir Water Level for Sennar Dam

Scenario 1

	Inputs		Actual Outputs	Network	
year	accumulation of year	Content(million m3)	W.L(m)	Network(1)	Act-Net(1)
1925	0	230	416.0	416.00	0.00
	0	310	417.0	417.01	-0.01
	0	411	418.0	417.99	0.01
	0	537	419.0	419.02	-0.02
	0	678	420.0	419.97	0.03
	0	825	421.0	421.01	-0.01
	0	930	421.70	421.70	0.00
1966	41	236	416.0	416.02	-0.02
	41	312	417.0	416.97	0.03
	41	411	418.0	418.01	-0.01
	41	537	419.0	419.10	-0.10
	41	678	420.0	420.00	0.00
	41	825	421.0	421.00	0.00
	41	930	421.70	421.70	0.00
1981	56	160	416.0	416.00	0.00
	56	220	417.0	417.08	-0.08
	56	265	418.0	417.90	0.10
	56	380	419.0	419.12	-0.12
	56	445	420.0	419.90	0.10
	56	560	421.0	421.01	-0.01
	56	665	421.70	421.70	0.00
1985	60	160	416.0	416.04	-0.04

	60	210	417.0	416.94	0.06
	60	265	418.0	418.07	-0.07
	60	345	419.0	418.96	0.04
	60	445	420.0	420.01	-0.01
	60	556	421.0	421.02	-0.02
	60	640	421.70	421.68	0.02

Appendix (B) Model $_{-2}$: (A) Prediction of Reservoir Water Level for Roseires Dam

Scenario 1

	Output		Actual	Network	
year	accumulation of year	Content (million m3)	W.L(m)	Network(1)	Act-Net(1)
1966	0	452	465	465.02	-0.02
	0	540	466	465.97	0.03
	0	638	467	467.01	-0.01
	0	745	468	468.03	-0.03
	0	862	469	469.00	0.00
	0	991	470	469.98	0.02
	0	1132	471	470.98	0.02
	0	1285	472	472.00	0.00
	0	1450	473	473.01	-0.01
	0	1629	474	474.00	0.00
	0	1821	475	475.00	0.00
	0	2027	476	476.01	-0.01
	0	2249	477	477.01	-0.01
	0	2487	478	477.97	0.03
	0	2744	479	479.03	-0.03
	0	3024	480	480.51	-0.51
	0	-	481	480.51	0.49
1985	19	46	465	465.00	0.00
	19	71	466	466.01	-0.01
	19	106	467	467.03	-0.03
	19	159	468	467.97	0.03
	19	238	469	468.99	0.01
	19	342	470	470.02	-0.02
	19	470	471	471.02	-0.02
	19	610	472	471.98	0.02
	19	760	473	472.98	0.02
	19	919	474	474.01	-0.01
	19	1088	475	475.03	-0.03
	19	1263	476	476.00	0.00
	19	1444	477	476.98	0.02
	19	1630	478	477.99	0.01
	19	1822	479	479.01	-0.01
	19	2020	480	480.02	-0.02
	19	2227	481	480.98	0.02
1992	26	23.8	465	465.10	-0.10
	26	37.9	466	465.88	0.12
	26	60.3	467	466.95	0.05
	26	95.4	468	468.05	-0.05
	26	151.7	469	469.01	-0.01
	26	234.9	470	469.97	0.03
	26	347.1	471	471.01	-0.01
	26	477.7	472	472.02	-0.02
	26	620	473	472.99	0.01
	26	771.4	474	473.97	0.03
	26	932.4	475	474.99	0.01
	26	1104.2	476	476.03	-0.03

	26	1282.4	477	477.02	-0.02
	26	1470.5	478	477.97	0.03
	26	1680.1	479	479.00	0.00
	26	1885.6	480	480.01	-0.01
	26	2103.9	481	481.00	0.00

Appendix (A) **Model $_{-1}$: Prediction of Water Inflow Discharges at EL Deim Station**

Year	QJun1	QJul1	QAug1	QSep1	QOct1	Q1(2nd Oct)	Q2(3rdoct)	Q3(1st Nov)	Q4(2nd Nov)	Q5(3rd Nov)
1960-61	24.5	109	513	529	326	209	163.9	103	78.5	63.3
1961-62	19.3	130	458	674	498	386	223.3	140	110	105
1962-63	40.8	97.9	402	528	461	255	178.2	99.4	84.9	71.5
1963-64	35.4	100	550	542	258	119	108.7	89.6	89.8	83
1964-65	44.2	97.5	508	512	384	372	303.6	170	113	89
1965-66	13.5	104	336	420	243	289	172.7	114	108	84.5
1966-67	21.9	114	347	423	156	125	129.8	89.5	77.2	61.8
1967-68	24.4	118	461	492	452	326	194.7	106	101	95
1968-69	23	138	549	339	299	178	121	78.8	62.6	60.7
1969-70	21.9	144	618	422	173	125	105.6	74	57	45
1970-71	20.5	96.3	450	493	292	220	171.6	115	76.2	56.3
1971-72	37.3	122	490	473	241	168	155.1	111	94	69.1
1972-73	38.1	92.8	294	228	142	961	83.8	65.8	55	46.4
1973-74	42.6	104	427	433	252	248	150.7	104	81.8	63.3
1974-75	63.4	221	495	417	289	164	127.6	95.9	70.4	56.9
1975-76	28.8	122	469	637	326	233	163.9	114	87.5	69.3
1976-77	27.6	103	484	385	174	119	100.8	93.1	91.5	66.3
1977-78	46.7	142	405	432	218	192	231	201	103	77.3
1978-79	37.2	129	359	356	372	250	155.1	105	80.5	60.1
1979-80	34.8	88.6	435	292	181	120	136.4	77.5	60.1	47.4
1980-81	35	97.7	459	384	199	153	115.5	72.2	58.3	49.8
1981-82	24.7	70.8	461	404	246	169	113.3	79	59.3	47.2
1982-83	24.8	102	270	299	207	195	128.7	74.1	62.4	45.6

Continue Appendix (A)

1983-84	31.8	85.3	381	423	23	190	154	81	70	60
Year	**QJun1**	**QJul1**	**QAug1**	**QSep1**	**QOct1**	**Q1(2nd Oct)**	**Q2(3rdoct)**	**Q3(1st Nov)**	**Q4(2nd Nov)**	**Q5(3rd Nov)**
1984-85	35.6	113	340	276	117	74.2	56.4	39.1	31.6	25.8
1985-86	29.2	109	464	166	206	151	101.3	73.7	55.4	44.5
1986-87	19.6	154	381	333.8	179.8	107.3	92.4	59	44.2	35.7
1987-88	90.5	84.6	255	272	157	157	108	88.5	60.1	44.6
1988-89	42.8	212	661	536	352	362	298.1	137	103	78.7
1989-90	20.4	109	287	430	235	140	109	67.9	56.3	44
1990-91	9.7	77.8	361.8	392.2	256.1	145.4	108.5	68.4	55.4	42.3
1991-92	29.4	173.7	382.2	458.8	199.9	150.3	123.1	85.6	67.6	54.5
1992-93	24.3	105.8	212	407.6	246.6	298.5	243.7	132.4	115.3	79.4
1993-94	98.6	173.3	564.3	550.5	359.5	219	201.7	151.5	104	79.7
1994-95	55.5	160.5	569.2	599.4	193.3	140.6	116	86.2	72.2	60.3
1995-96	34.4	99.6	438	366	166	118	99.6	68	52.5	42.2
1996-97	108.7	179.4	461.2	418.9	269.9	181.7	139.7	91.2	73	44.2
1997-98	69.9	152.4	352.5	263.8	143.6	107.8	244	191.2	117	102.6
1998-99	32.8	119.6	595.1	631.5	371.5	440.3	342.5	175.2	126.8	97
1999-2000	56	165.6	453.2	520.9	348.4	441.9	385	179.5	124.6	95.7

Continue Appendix (A)

Q6 (1st Dec)	Q7 (2nd Dec)	Q8 (3rd Dect)	Q9 (1st Jan)	Q10 (2nd Jan)	Q11 (3rd Jan)	Q12 (1st Feb)	Q13 (2nd Feb)	Q14 (3rd Feb)	Q15 (1st Mar)	Q16 (2nd Mar)
52.8	45.3	41.8	30.4	25.6	23.4	18.4	19.9	12.6	13.1	10.6
93.1	69.1	60.4	44	36.8	33.9	25.4	20.6	14.1	15.9	16.2
58.3	46.6	41.5	33.1	28.8	26.2	19.6	16.7	11.9	14.6	13.3
83.2	72.5	73.9	35.8	30.8	27.7	21	19.2	16.3	13.6	10.8
72.1	62.6	60.6	38.1	31.8	28.7	23.8	20.2	13.1	16.5	14.4
73	55.9	45.3	28.5	23.8	22.9	19.3	18	11.9	13.4	13.7
58	46.1	36.2	26.2	22.2	20.7	16	13.3	9.4	10	9
87.8	63	52	34.1	28.1	26.5	20.8	20.8	15.9	13.3	11.1
48.8	39.4	38	24.1	21.9	22.6	18.8	15.4	13.3	17.7	22.2
38	31	28.1	21.3	18.5	18.8	13.4	10.8	7.5	10.2	12.3
43.2	35.6	34.3	26.1	21.9	20	15.4	12.7	8.2	8.3	6.9
51	40.3	36.7	28.7	23.9	22.1	16.2	14	11.1	10.8	8.3
35.7	28.8	26.2	19	16.6	16.5	11.4	9.4	6.6	7	5.7
48.6	39.4	37.4	29.8	25.1	23.4	17.7	15.3	11	11.5	11.6
51	42.6	37.7	24.9	20.7	20	17.2	17.4	13.4	12.9	9.5
55.4	48.9	44.1	34.8	30.2	26.8	20.5	17.4	13.4	14.5	14.4
49.4	40.6	36.5	26.4	22.5	21.9	17.1	15.8	11	11.2	10.4
57.5	49.4	43.3	31.8	25.3	22.3	18.2	15.3	11.4	11.9	12.4
52.3	41.6	38.4	29.2	27.4	26.8	20.4	17.4	12.9	11.9	9.5
38.5	32.1	29.8	23	18.6	16.8	13.2	12.4	10.1	9.2	8.4
39.9	31.9	28.8	21.6	18.2	17.1	13.3	10.8	7.4	8	8.6
38.9	30.6	28.3	22	20	19.8	13.9	11.9	8.6	11.2	11.8
38.4	29.9	26.2	19.3	16.4	14.7	11.8	12.2	7.1	7.4	7

Continue Appendix (A)

42	32.5	27.5	21.5	17.5	16.8	13.2	10.6	7.2	7	6.4
21.7	18.2	17.1	12.5	10.1	9.5	8.1	6.8	4.8	5.2	4.8
37.1	32.9	27.9	20.7	17.4	16.1	12.5	11	8	10.8	9.7
Q6 (1st Dec)	**Q7 (2nd Dec)**	**Q8 (3rd Dec)**	**Q9 (1st Jan)**	**Q10 (2nd Jan)**	**Q11 (3rd Jan)**	**Q12 (1st Feb)**	**Q13 (2nd Feb)**	**Q14 (3rd Feb)**	**Q15 (1st Mar)**	**Q16 (2nd Mar)**
28.9	24.3	20.7	20.8	17.6	16.3	12.7	11.1	7.9	10.7	9.9
35.5	30.8	27.6	18.6	16.4	16.3	12.9	12.6	11.2	16.3	14.1
60.2	48.7	41.7	30.7	24.2	22.6	17	15.8	10.1	10.8	11.7
34.4	27.8	49.3	34.8	28.3	21.6	16.3	16.7	12.3	12.8	11.6
34.5	27.7	24.7	19.1	16.9	15.2	11.6	9.6	7.5	8.4	8.8
47.8	38.5	34.3	25.6	21.8	20.9	17.3	16.1	11	10.7	9.5
66.4	52.4	46.8	36.8	29.1	26.6	20.4	18.3	12.7	13.8	10.9
62.3	50.4	45.3	33.4	29.4	27.1	20	17	13.8	12.9	10
48.1	35.6	28.1	19.7	16.6	15.2	12.1	10.4	7.4	8.6	7.2
33.6	27.3	28.4	20.7	17.8	17.8	13.6	10.8	8.3	8.5	9.8
51.4	43.8	36.9	31.6	27.7	26.3	13.8	14.7	13.8	18	16
78.4	53.1	43.6	33	30.4	29.4	25.2	19.2	14.8	19.6	17.6
76.6	66	54.9	41.3	36.9	38.5	28.3	24.9	17.8	17.5	15.2
75.1	62.4	56.5	42.5	34.8	33.1	24	21.4	16.9	10.4	9.5

Continue Appendix (A)

Q17 (3rd Mar)	Q18 (1st Apr)	Q19 (2nd Apr)	Q20 (3rd Apr)	Q21 (1st May)	Q22 (2nd May)	Q23 (3rd May)	Network(1)	Network(2)	Network(3)	Network(4)
12.9	14.6	18.1	17.5	14.9	9.5	11.7	209.0023	163.9010	103.0003	78.5005
16.8	12.1	9	8.7	10.4	21.2	24.3	385.9998	223.2998	140.0000	110.0002
12.2	10.1	14.9	16.5	19	56	49.6	254.9993	178.1985	99.3999	84.8995
9.6	9.1	9.8	20.8	14.5	15.4	14.4	119.0016	108.7004	89.6003	89.8004
13.9	14.4	18.5	15.5	11.8	8.1	7.8	285.4911	261.6249	159.8061	96.6169
15.3	10.4	9.4	12.3	11	13.8	30.3	288.9980	172.7004	113.9999	108.0006
16.1	14.2	8.8	9.3	15.9	12.9	21	124.9937	129.7965	89.4996	77.1993
9.6	7.5	7.7	9.8	8.4	7.8	13.4	325.9996	194.6999	106.0000	100.9995
34.9	16.9	10	10.6	29	20	21.2	177.9987	121.0005	78.8002	62.6000
10.2	8.4	8	7.6	5.5	5.1	15.6	74.2000	125.8293	56.8310	70.8306
8.5	6.1	5.3	4.7	5.4	6.6	29.4	219.9989	171.6002	115.0003	76.2001
9.1	7.7	10.4	11.2	13.9	12	23.3	168.0046	155.1007	111.0000	93.9999
5.1	4.6	7.7	4.8	9.4	22.2	38.7	960.9994	83.7996	65.8001	55.0000
14.9	10.9	7.9	5.3	8.1	34.3	36.4	247.9961	150.6995	104.0003	81.8001
9.6	7.7	7.1	5.9	7.3	7.1	16.7	163.9940	127.5966	95.8998	70.3992
14.5	10.5	10.3	7.4	9.6	16.8	35.4	232.9987	163.8999	114.0003	87.4999
12.7	12.5	7.6	5.3	4.7	8.1	34.3	119.0095	100.8006	93.1007	91.5003
11.4	8	7.2	11.9	12.7	18.5	19.5	192.0050	230.9998	200.9999	103.0001
11	9.5	8.5	6.6	11.4	33.3	32.1	249.9984	155.0984	105.0000	80.4999
9.5	7.4	8.1	16.9	10.7	18.2	16.9	119.9980	136.4023	77.5006	60.1008
10.2	9.9	7	8.3	10.5	13.7	24.9	152.9382	115.4773	72.1980	58.2951

Continue Appendix (A)

9.4	7.3	7.8	6.7	8.3	12.4	11.6	169.0264	113.3123	79.0004	59.3021
9.8	6.9	7.7	10.3	5.7	12.5	24.4	195.0026	128.7004	74.0997	62.3993
5.8	4.9	3.9	3.7	3.7	4.2	21.6	190.0008	154.0012	81.0001	70.0003
5.1	8.6	7.3	7.1	10.2	27.9	35.6	74.2005	56.4002	39.1005	31.6007
Q17 (3rd Mar)	**Q18 (1st Apr)**	**Q19 (2nd Apr)**	**Q20 (3rd Apr)**	**Q21 (1st May)**	**Q22 (2nd May)**	**Q23 (3rd May)**	**Network(1)**	**Network(2)**	**Network(3)**	**Network(4)**
8.8	9.3	10.4	10	8	5.8	6.1	150.9995	101.2988	73.6997	55.3996
8.8	9.3	11.3	10.1	5.4	15.6	58.6	107.3033	92.4021	59.0002	44.2004
9.2	8.4	5.9	7.8	5.4	6.2	15.8	157.0002	107.9998	88.5000	60.0999
14.5	17.4	11.4	13.5	11.5	11.7	20.8	362.0012	298.0999	137.0004	103.0000
10.9	10.3	10	7	8.8	11.5	8.8	140.0090	109.0030	67.9002	56.3000
9	8.1	13.2	12.1	12.5	17.6	33.6	145.3895	108.4926	68.4004	55.3991
12.1	8.7	6.9	9.7	16.2	23.2	24.2	74.2000	178.8089	140.8177	83.1870
11.4	12.7	25.6	31.8	29.1	25.1	58.9	74.2000	168.8089	110.8177	73.1870
11.6	9.6	9.4	8.8	17.7	24.6	32.2	219.0017	201.7013	151.5003	104.0003
10.2	9.3	7.5	18.5	19.3	21.7	13.8	140.6009	116.0006	86.2000	72.2002
17.8	19.8	14.5	15.6	27.1	37.6	89.9	118.0387	99.6104	68.0001	52.5014
26.4	15.8	20.5	17.5	20.3	23.5	44.8	181.6980	139.6991	91.1999	72.9999
14.6	24.2	20.4	18.6	24.3	36.3	22.5	107.7993	244.0004	191.2002	117.0000
12.9	8.4	8.8	13.8	16.8	28.3	41.6	440.2957	342.4965	175.1998	126.7993
8.4	15.5	16.6	27.5	19.3	32.2	32.3	441.8981	385.0000	179.4999	124.6000

Continue Appendix (A)

Network(5)	Network(6)	Network(7)	Network(8)	Network(9)	Network(10)	Network(11)	Network(12)	Network(13)	Network(14)	Network(15)
63.2997	52.8002	45.3000	41.8000	30.3999	25.6002	23.3996	18.3999	19.9002	12.6000	13.1001
104.9996	93.1000	69.1001	60.4000	44.0000	36.8001	33.8998	25.3999	20.6000	14.1000	15.9000
71.5011	58.2995	46.5998	41.5000	33.1001	28.7998	26.2004	19.6001	16.6999	11.8999	14.6000
82.9997	83.2003	72.5000	73.8998	35.8000	30.8001	27.6997	20.9999	19.2000	16.3000	13.6000
90.4569	74.062	61.736	65.839	46.00	36.7689	34.1127	24.5206	37.3811	14.8000	9.6000
84.4991	73.0005	55.9001	45.3000	28.5000	23.8003	22.8996	19.2999	18.0001	11.9000	13.4001
61.8012	57.9992	46.0998	36.2003	26.2000	22.1997	20.7004	16.0000	13.3000	9.3999	10.0000
95.0000	87.7998	62.9999	51.9999	34.1000	28.0998	26.5002	20.8001	20.7999	15.9000	13.2999
60.6997	48.800	39.400	38.000	24.10	21.9000	22.5999	18.8000	15.4000	13.3000	17.7000
44.6777	26.020	22.911	31.456	25.58	19.5914	18.7439	14.8791	10.9365	16.8000	25.3670
56.3000	43.2000	35.5999	34.3001	26.1000	21.9000	19.9998	15.3999	12.7000	8.2000	8.3000
69.0999	50.9999	40.3000	36.7001	28.7000	23.8999	22.1001	16.2000	14.0000	11.1000	10.7999
46.4003	35.7000	28.8000	26.2000	19.0001	16.6000	16.5000	11.4000	9.4000	6.6000	7.0000
63.2999	48.6000	39.4001	37.4001	29.8000	25.1000	23.3998	17.6999	15.3000	11.0000	11.5000
56.9017	50.9991	42.5998	37.7002	24.9001	20.6997	20.0008	17.2002	17.3999	13.3999	12.9001
69.3001	55.4000	48.9000	44.1001	34.7999	30.2000	26.8000	20.5000	17.4000	13.4000	14.5000
66.3002	49.4000	40.6001	36.4999	26.4001	22.4999	21.9000	17.1000	15.8000	11.0000	11.2000
77.3001	57.5000	49.4000	43.2997	31.8001	25.3000	22.3001	18.2001	15.3000	11.4000	11.9000
60.1004	52.2997	41.5999	38.4001	29.2000	27.3999	26.8000	20.4000	17.4000	12.9000	11.9000
47.3988	38.5007	32.1003	29.8001	22.9999	18.6001	16.7993	13.1998	12.4001	10.1001	9.1999

Continue Appendix (A)

49.8097	39.8944	31.8982	28.8019	21.6000	18.1985	17.1044	13.3010	10.7997	7.3991	8.0008
47.1949	38.9032	30.6010	28.2990	21.9999	20.0008	19.7980	13.8996	11.9002	8.6004	11.1998
45.6006	38.3999	29.8999	26.1999	19.3000	16.3998	14.7004	11.8002	12.1999	7.1000	7.3999
59.9993	42.0005	32.5001	27.4999	21.5000	17.5002	16.7996	13.1999	10.6001	7.2000	7.0000
25.8000	21.7004	18.2001	17.1000	12.5000	10.1003	9.5000	8.1000	6.8001	4.8000	5.2001
Network(5)	**Network(6)**	**Network(7)**	**Network(8)**	**Network(9)**	**Network(10)**	**Network(11)**	**Network(12)**	**Network(13)**	**Network(14)**	**Network(15)**
44.5004	37.0997	32.8999	27.9001	20.7000	17.3999	16.1003	12.5001	10.9999	8.0000	10.8000
35.6992	28.9006	24.3002	20.7000	20.7999	17.6000	16.2996	12.6999	11.1000	7.9001	10.7000
44.6001	35.4999	30.7999	27.6000	18.6000	16.4000	16.3001	12.9000	12.6000	11.2000	16.3000
78.7000	60.2001	48.7000	41.6999	30.7000	24.2000	22.5999	17.0000	15.8000	10.1000	10.8000
43.9993	34.4004	27.8001	49.2998	34.8000	28.2999	21.5998	16.2999	16.6999	12.3000	12.7998
42.3031	34.4981	27.6996	24.7006	19.1000	16.8994	15.2011	11.6002	9.5999	7.4997	8.4002
70.6120	64.3093	50.4066	37.6419	36.0685	30.2392	25.3074	19.5037	19.3082	15.1845	17.1854
45.6120	51.309	40.407	37.642	32.30	28.2392	21.3074	18.5037	7.3082	17.1845	29.1854
79.6994	62.3004	50.4001	45.3000	33.4000	29.4001	27.0996	19.9999	17.0000	13.8001	12.9000
60.2997	48.1002	35.6001	28.0999	19.7000	16.6001	15.1997	12.0999	10.4000	7.4000	8.6000
42.1960	33.6023	27.3007	28.3990	20.7002	17.8005	17.7988	13.5998	10.8000	8.3003	8.4996
44.2004	51.3998	43.7999	36.9000	31.6000	27.6999	26.3002	13.8001	14.7000	13.8000	18.0000
102.6000	78.4001	53.1000	43.6000	33.0000	30.4000	29.4000	25.2000	19.2000	14.8000	19.6000
97.0014	76.5992	65.9997	54.9002	41.3002	36.8997	38.5000	28.3000	24.9000	17.7998	17.5000
95.7000	75.1001	62.4000	56.5000	42.4999	34.8000	33.0999	24.0000	21.4000	16.9000	10.4000

Continue Appendix (A)

Network(16)	Network(17)	Network(18)	Network(19)	Network(20)	Network(21)	Network(22)	Network(23)	Act-Net(1)	Act-Net(2)	Act-Net(3)
10.6000	12.9001	14.5999	18.1001	17.4999	14.9001	9.4999	11.7002	-0.0023	-0.001006	-0.0003
16.2000	16.8000	12.1000	9.0000	8.6999	10.4000	21.2000	24.3001	0.0002	0.000203	0.0000
13.3001	12.1997	10.1001	14.8998	16.5003	19.0000	56.0000	49.6001	0.0007	0.001497	0.0001
10.8000	9.6002	9.0999	9.8001	20.7999	14.5000	15.3999	14.4000	-0.0016	-0.000403	-0.0003
18.7940	18.8978	13.0997	13.9890	14.5353	20.8526	33.5591	9.2623	86.5089	41.97508	10.1939
13.6999	15.3001	10.4000	9.4001	12.3000	11.0000	13.8001	30.3004	0.002	-0.000403	0.0001
9.0002	16.0994	14.2001	8.7996	9.3004	15.9000	12.9000	21.0003	0.0063	0.003503	0.0004
11.1000	9.6001	7.5000	7.7000	9.8000	8.4000	7.8001	13.3994	0.0004	9.69E-05	0.0000
22.1999	34.9000	16.9000	10.0000	10.5999	29.0001	20.0000	21.2001	0.0013	-0.000458	-0.0002
15.8533	12.4264	6.2629	20.6000	31.8000	11.9724	22.2234	22.1205	50.8	-20.22931	17.1690
6.8999	8.5002	6.1000	5.3001	4.6999	5.4000	6.5999	29.4002	0.0011	-0.000194	-0.0003
8.3000	9.1001	7.6999	10.4001	11.1999	13.8999	12.0003	23.2997	-0.0046	-0.000694	0.0000
5.7000	5.1000	4.6000	7.7000	4.8001	9.4001	22.1999	38.7002	0.0006	0.000403	-0.0001
11.6000	14.9000	10.8999	7.9001	5.2999	8.1001	34.3000	36.4003	0.0039	0.000497	-0.0003
9.5003	9.5993	7.7002	7.0996	5.9006	7.2999	7.1000	16.7002	0.006	0.003398	0.0002
14.4000	14.4999	10.5000	10.2999	7.4001	9.5999	16.8001	35.4002	0.0013	9.39E-05	-0.0003

Continue Appendix (A)

10.4000	12.7002	12.4999	7.6003	5.2998	4.7001	8.0998	34.3002	-0.0095	-0.000597	-0.0007
12.4000	11.4003	8.0000	7.2001	11.9000	12.7001	18.4997	19.5000	-0.005	0.0002	0.0001
9.5001	10.9997	9.5001	8.4999	6.6001	11.4000	33.3000	32.1003	0.0016	0.001606	0.0000
8.3999	9.5004	7.3998	8.1003	16.8998	10.6999	18.2000	16.9002	0.002	-0.002306	-0.0006
8.6012	10.1954	9.9013	6.9968	8.3036	10.4997	13.7001	24.9023	0.0618	0.0227	0.0020
11.7994	9.4024	7.2994	7.8013	6.6981	8.3001	12.4000	11.5984	-0.0264	-0.012297	-0.0004
7.0001	9.7999	6.9000	7.6999	10.3001	5.7000	12.5002	24.3997	-0.0026	-0.000403	0.0003
6.3999	5.8003	4.8999	3.9002	3.7000	3.7000	4.2000	21.6001	-0.0008	-0.0012	-0.0001
Network(16)	**Network(17)**	**Network(18)**	**Network(19)**	**Network(20)**	**Network(21)**	**Network(22)**	**Network(23)**	**Act-Net(1)**	**Act-Net(2)**	**Act-Net(3)**
4.8000	5.1004	8.6000	7.3000	7.0998	10.2000	27.9000	35.6003	-0.0005	-0.000198	-0.0005
9.7001	8.7998	9.3001	10.3999	10.0001	8.0000	5.8000	6.1000	0.0005	0.001203	0.0003
9.8999	8.8003	9.2999	11.3001	10.0999	5.4001	15.6000	58.5999	-0.0033	-0.002098	-0.0002
14.1000	9.2000	8.4000	5.9000	7.8000	5.4000	6.1999	15.8000	-0.0002	0.0002	0.0000
11.7000	14.5001	17.4000	11.4001	13.4999	11.5000	11.7000	20.7999	-0.0012	0.000106	-0.0004
11.5999	10.9005	10.2999	10.0003	6.9995	8.8001	11.4998	8.7990	-0.009	-0.003	-0.0002
8.8003	8.9987	8.1003	13.1994	12.1008	12.5000	17.6000	33.6008	0.010494	0.0074	-0.0004
11.1264	5.8612	13.3776	18.7128	15.5468	10.7000	5.1663	27.1000	76.1	-55.7089	-55.2177
10.9001	11.3997	12.7001	25.5995	31.8000	29.0999	25.0999	58.9001	224.3	74.89107	21.5822
9.9999	11.6002	9.5999	9.4001	8.7998	17.7000	24.5999	32.1999	-0.0017	-0.001303	-0.0003
7.1999	10.2001	9.2999	7.5001	18.4999	19.3000	21.7000	13.8001	-0.00089	-0.0006	0.0000
9.7996	17.8015	19.7995	14.5010	15.5990	27.1001	37.6002	89.8969	-0.0387	-0.010402	-0.0001
16.0000	26.3998	15.8000	20.4999	17.5001	20.3000	23.5000	44.8001	0.001997	0.000897	0.0001
17.6000	14.6000	24.2000	20.4000	18.6000	24.3000	36.3000	22.4999	0.000703	-0.0004	-0.0002
15.2001	12.8996	8.4001	8.7998	13.8003	16.8000	28.2999	41.6002	0.004288	0.0035	0.0002
9.5000	8.4000	15.5000	16.6000	27.5000	19.3000	32.2000	32.3000	0.001894	0	0.0001

Continue Appendix (A)

Act-Net(4)	Act-Net(5)	Act-Net(6)	Act-Net(7)	Act-Net(8)	Act-Net(9)	Act-Net(10)	Act-Net(11)	Act-Net(12)	Act-Net(13)	Act-Net(14
-0.0005	0.0003	-0.0002	0.0000	0.0000	0.0001	-0.0002	0.0004	0.0001	0.0000	0.0000
-0.0002	0.0004	0.0000	-0.0001	0.0000	0.0000	-0.0001	0.0002	0.0001	0.0000	0.0000
0.0005	-0.0011	0.0005	0.0002	0.0000	-0.0001	0.0002	-0.0004	-0.0001	0.0000	0.0001
-0.0004	0.0003	-0.0003	0.0000	0.0002	0.0000	-0.0001	0.0003	0.0001	0.0000	0.0000
16.3831	-1.4569	-1.9625	0.8642	-5.2394	-7.9000	-4.9689	-5.4127	-0.7206	0.0000	-1.7000
-0.0006	0.0009	-0.0005	-0.0001	0.0000	0.0000	-0.0003	0.0004	0.0001	0.0000	0.0000
0.0007	-0.0012	0.0008	0.0002	-0.0003	0.0000	0.0003	-0.0004	0.0000	0.0000	0.0001
0.0005	0.0000	0.0002	0.0001	0.0001	0.0000	0.0002	-0.0002	-0.0001	0.0000	0.0000
0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
-13.8306	0.3223	11.9805	8.0893	-3.3559	-4.2792	-1.0914	0.0561	-1.4791	0.0000	-9.3000
-0.0001	0.0000	0.0000	0.0001	-0.0001	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000
0.0001	0.0001	0.0001	0.0000	-0.0001	0.0000	0.0001	-0.0001	0.0000	0.0000	0.0000
0.0000	-0.0003	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
-0.0001	0.0001	0.0000	-0.0001	-0.0001	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000
0.0008	-0.0017	0.0009	0.0002	-0.0002	-0.0001	0.0003	-0.0008	-0.0002	0.0000	0.0001
0.0001	-0.0001	0.0000	0.0000	-0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
-0.0003	-0.0002	0.0000	-0.0001	0.0001	-0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
-0.0001	-0.0001	0.0000	0.0000	0.0003	-0.0001	0.0000	-0.0001	-0.0001	0.0000	0.0000
0.0001	-0.0004	0.0003	0.0001	-0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
-0.0008	0.0012	-0.0007	-0.0003	-0.0001	0.0001	-0.0001	0.0007	0.0002	0.0000	-0.0001
0.0049	-0.0097	0.0056	0.0018	-0.0019	0.0000	0.0015	-0.0044	-0.0010	0.0000	0.0009

Continue Appendix (A)

-0.0021	0.0051	-0.0032	-0.0010	0.0010	0.0001	-0.0008	0.0020	0.0004	0.0000	-0.0004
0.0007	-0.0006	0.0001	0.0001	0.0001	0.0000	0.0002	-0.0004	-0.0002	0.0000	0.0000
-0.0003	0.0007	-0.0005	-0.0001	0.0001	0.0000	-0.0002	0.0004	0.0001	0.0000	0.0000
-0.0007	0.0000	-0.0004	-0.0001	0.0000	0.0000	-0.0003	0.0000	0.0000	0.0000	0.0000
0.0004	-0.0004	0.0003	0.0001	-0.0001	0.0000	0.0001	-0.0003	-0.0001	0.0000	0.0000
-0.0004	0.0008	-0.0006	-0.0002	0.0000	0.0001	0.0000	0.0004	0.0001	0.0000	-0.0001
0.0001	-0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000

Act-Net(4)	**Act-Net(5)**	**Act-Net(6)**	**Act-Net(7)**	**Act-Net(8)**	**Act-Net(9)**	**Act-Net(10)**	**Act-Net(11)**	**Act-Net(12)**	**Act-Net(13)**	**Act-Net(14**
0.0000	0.0000	-0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
0.0000	0.0007	-0.0004	-0.0001	0.0002	0.0000	0.0001	0.0002	0.0001	0.0000	0.0000
0.0009	-0.0031	0.0019	0.0004	-0.0006	0.0000	0.0006	-0.0011	-0.0002	0.0000	0.0003
-15.5870	-16.1120	-16.5093	-11.9066	-3.3419	-10.4685	-8.4392	-4.4074	-2.2037	0.0000	-4.1845
42.1130	33.7880	15.0907	11.9934	9.1581	4.5000	0.8608	5.2926	1.8963	0.0000	-4.4845
-0.0003	0.0006	-0.0004	-0.0001	0.0000	0.0000	-0.0001	0.0004	0.0001	0.0000	-0.0001
-0.0002	0.0003	-0.0002	-0.0001	0.0001	0.0000	-0.0001	0.0003	0.0001	0.0000	0.0000
-0.0014	0.0040	-0.0023	-0.0007	0.0010	-0.0002	-0.0005	0.0012	0.0002	0.0000	-0.0003
0.0001	-0.0004	0.0002	0.0001	0.0000	0.0000	0.0001	-0.0002	-0.0001	0.0000	0.0000
0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0007	-0.0014	0.0008	0.0003	-0.0002	-0.0002	0.0003	0.0000	0.0000	0.0000	0.0002
0.0000	0.0000	-0.0001	0.0000	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000

Continue Appendix (A)

Act-Net(15)	Act-Net(16)	Act-Net(17)	Act-Net(18)	Act-Net(19)	Act-Net(20)	Act-Net(21)	Act-Net(22)	Act-Net(23)
-0.0001	0.0000	-0.0001	0.0001	-0.0001	0.0001	-0.0001	0.0001	-0.0002
0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	-0.0001
0.0000	-0.0001	0.0003	-0.0001	0.0002	-0.0003	0.0000	0.0000	-0.0001
0.0000	0.0000	-0.0002	0.0001	-0.0001	0.0001	0.0000	0.0001	0.0000
6.9000	-4.3940	-4.9978	1.3003	4.5110	0.9647	-9.0526	-25.4591	-1.4623
-0.0001	0.0001	-0.0001	0.0000	-0.0001	0.0000	0.0000	-0.0001	-0.0004
0.0000	-0.0002	0.0006	-0.0001	0.0004	-0.0004	0.0000	0.0000	-0.0003
0.0001	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0006
0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	-0.0001	0.0000	-0.0001
-15.1670	-3.5533	-2.2264	2.1371	-12.6000	-24.2000	-6.4724	-17.1234	-6.5205
0.0000	0.0001	-0.0002	0.0000	-0.0001	0.0001	0.0000	0.0001	-0.0002
0.0001	0.0000	-0.0001	0.0001	-0.0001	0.0001	0.0001	-0.0003	0.0003
0.0000	0.0000	0.0000	0.0000	0.0000	-0.0001	-0.0001	0.0001	-0.0002
0.0000	0.0000	0.0000	0.0001	-0.0001	0.0001	-0.0001	0.0000	-0.0003
-0.0001	-0.0003	0.0007	-0.0002	0.0004	-0.0006	0.0001	0.0000	-0.0002
0.0000	0.0000	0.0001	0.0000	0.0001	-0.0001	0.0001	-0.0001	-0.0002
0.0000	0.0000	-0.0002	0.0001	-0.0003	0.0002	-0.0001	0.0002	-0.0002
0.0000	0.0000	-0.0003	0.0000	-0.0001	0.0000	-0.0001	0.0003	0.0000
0.0000	-0.0001	0.0003	-0.0001	0.0001	-0.0001	0.0000	0.0000	-0.0003

Continue Appendix (A)

0.0001	0.0001	-0.0004	0.0002	-0.0003	0.0002	0.0001	0.0000	-0.0002
-0.0008	-0.0012	0.0046	-0.0013	0.0032	-0.0036	0.0003	-0.0001	-0.0023
0.0002	0.0006	-0.0024	0.0006	-0.0013	0.0019	-0.0001	0.0000	0.0016
0.0001	-0.0001	0.0001	0.0000	0.0001	-0.0001	0.0000	-0.0002	0.0003
0.0000	0.0001	-0.0003	0.0001	-0.0002	0.0000	0.0000	0.0000	-0.0001
-0.0001	0.0000	-0.0004	0.0000	0.0000	0.0002	0.0000	0.0000	-0.0003
0.0000	-0.0001	0.0002	-0.0001	0.0001	-0.0001	0.0000	0.0000	0.0000
0.0000	0.0001	-0.0003	0.0001	-0.0001	0.0001	-0.0001	0.0000	0.0001
Act-Net(15)	**Act-Net(16)**	**Act-Net(17)**	**Act-Net(18)**	**Act-Net(19)**	**Act-Net(20)**	**Act-Net(21)**	**Act-Net(22)**	**Act-Net(23)**
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
0.0000	0.0000	-0.0001	0.0000	-0.0001	0.0001	0.0000	0.0000	0.0001
0.0002	0.0001	-0.0005	0.0001	-0.0003	0.0005	-0.0001	0.0002	0.0010
-0.0002	-0.0003	0.0013	-0.0003	0.0006	-0.0008	0.0000	0.0000	-0.0008
-6.4854	-1.6264	6.2388	-4.6776	-11.8128	-5.8468	5.5000	18.0337	-2.9000
-15.3854	-0.0001	0.0003	-0.0001	0.0005	0.0000	0.0001	0.0001	-0.0001
0.0000	0.0001	-0.0002	0.0001	-0.0001	0.0002	0.0000	0.0001	0.0001
0.0000	0.0001	-0.0001	0.0001	-0.0001	0.0001	0.0000	0.0000	-0.0001
0.0004	0.0004	-0.0015	0.0005	-0.0010	0.0010	-0.0001	-0.0002	0.0031
0.0000	0.0000	0.0002	0.0000	0.0001	-0.0001	0.0000	0.0000	-0.0001
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
0.0000	-0.0001	0.0004	-0.0001	0.0002	-0.0003	0.0000	0.0001	-0.0002
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix (F) **Irrigation Water Requirements For Blue Nile Projects(million m^3) 1999/2000**

MONTH	GAZIRA&MANAGIL CANAL	NORTH WEST SENNAR SUGAR	EL RAHAD	EL SUKI	KENANA SUGAR	PUMPS
July	761	20.16	160	93	61.86	166.67
August	715	13.82	69	263	22.36	193.33
September	898	20.97	97	41	72.95	267.33
October	991	21.11	138	46	89.81	291.00
November	822	26.07	87	46	79.49	284.00
December	759	23.52	90	29	76.22	292.33
January	555	18.44	57	36	71.99	316.33
February	476	18.96	80	22	67.42	137.00
March	329	22.66	65	21	80.59	120.00
April	83	23.09	18	13	80.63	114.33
May	104	19.07	17	2	91.14	122.00
June	394	20.14	78	29	89.85	147.00

Appendix (E) **Model – 3: (B) Relationship Between Rese**

Scenario 1 **Evaporation Losses f**

Input	Actual Output				
level	E10	E11	E12	E1	E2
411.40	0.120	0.170	0.160	0.180	0.210
413.24	0.180	0.260	0.240	0.270	0.310
414.48	0.270	0.380	0.350	0.400	0.460
415.40	0.320	0.460	0.420	0.480	0.550
416.20	0.390	0.550	0.500	0.570	0.660
416.85	0.470	0.660	0.610	0.700	0.800
417.20	0.530	0.730	0.690	0.790	0.900
417.41	0.560	0.790	0.730	0.830	0.950
417.90	0.600	0.860	0.790	0.900	1.030
418.33	0.640	0.910	0.840	0.960	1.100
418.72	0.690	0.970	0.900	1.020	1.180
419.10	0.730	1.040	0.860	1.090	1.250
419.46	0.770	1.090	1.010	1.150	1.320
419.81	0.790	1.120	1.040	1.180	1.360
420.15	0.810	1.150	1.070	1.210	1.390
420.49	0.830	1.180	1.090	1.240	1.420
420.83	0.840	1.200	1.100	1.250	1.440
421.17	0.860	1.220	1.120	1.280	1.470
421.50	0.870	1.230	1.140	1.300	1.490
421.70	0.880	1.250	1.150	1.310	1.510
420.49	1.240	1.420	1.600	1.580	1.370
420.83	1.250	1.440	1.620	1.600	1.390
421.17	1.280	1.470	1.650	1.640	1.420
421.50	1.300	1.490	1.670	1.660	1.440
421.70	1.310	1.510	1.700	1.680	1.460

Continue Appendix (E)

Network(1)	Network(2)	Network(3)	Network(4)	Network(5)	Ne
0.179401413	0.252440274	0.245290264	0.274443448	0.309175998	0.35
0.212904721	0.29979676	0.287375271	0.322424561	0.365163773	0.41
0.261989295	0.369273752	0.349605709	0.393468112	0.447658509	0.50
0.323245198	0.45616281	0.427822858	0.482924223	0.551254928	0.62
0.398905694	0.563739359	0.525057018	0.594340146	0.680051625	0.77
0.474537939	0.671512306	0.622791469	0.706503093	0.809577942	0.91
0.518527508	0.734284282	0.679827452	0.772013009	0.885210872	0.99
0.545287728	0.772496343	0.714577317	0.811938107	0.931310534	1.05
0.60669297	0.860237539	0.794424117	0.903691232	1.037302017	1.16
0.656961918	0.932106316	0.859847069	0.978862405	1.124229789	1.26
0.697905183	0.990651906	0.913123548	1.040053368	1.195086598	1.34
0.732765853	1.040494919	0.958444178	1.092077136	1.255421758	1.41
0.761060178	1.080937743	0.995176017	1.134213686	1.30437088	1.46

0.784357607	1.11422503	1.025368333	1.168824434	1.344644547	1.51
0.803375721	1.141385317	1.049966931	1.197003365	1.377488732	1.54
0.819265127	1.164066195	1.070476055	1.220481992	1.404899359	1.57
0.832468569	1.182903886	1.087480903	1.239937067	1.427649617	1.60
0.84340626	1.198501229	1.101535797	1.25600791	1.446473241	1.62
0.852209508	1.211049438	1.112821937	1.268906593	1.461605549	1.64
0.856806397	1.21759975	1.118704438	1.275627136	1.469499946	1.6

Continue Appendix (E)

Act-Net(1)	**Act-Net(2)**	**Act-Net(3)**	**Act-Net(4)**	**Act-Net(5)**	**Ac**
-0.059401415	-0.082440272	-0.085290268	-0.09444344	-0.099176005	-0.1
-0.032904714	-0.03979677	-0.047375277	-0.05242455	-0.055163771	-0.0
0.008010715	0.010726243	0.000394285	0.006531894	0.012341499	0.01
-0.003245205	0.003837198	-0.007822871	-0.002924234	-0.001254916	0.00
-0.008905709	-0.013739347	-0.025057018	-0.024340153	-0.020051599	-0.0
-0.00453794	-0.01151228	-0.012791455	-0.006503105	-0.00957793	-0.0
0.011472464	-0.004284263	0.010172546	0.017987013	0.014789104	0.02
0.014712274	0.017503679	0.015422702	0.018061876	0.018689454	0.01
-0.006692946	-0.000237525	-0.004424095	-0.003691256	-0.007302046	0.00
-0.016961932	-0.02210629	-0.019847095	-0.018862426	-0.024229765	-0.0
-0.007905185	-0.020651877	-0.013123572	-0.020053387	-0.015086651	-0.0
-0.002765834	-0.000494957	-0.098444164	-0.002077103	-0.005421758	-0.0
0.008939803	0.00906229	0.014823973	0.01578629	0.015629172	0.01
0.005642414	0.005774975	0.014631629	0.011175513	0.015355468	0.01
0.006624281	0.008614659	0.020033121	0.012996674	0.012511253	0.0
0.010734856	0.015933752	0.019523978	0.019518018	0.015100598	0.02
0.007531404	0.017096162	0.012519121	0.010062933	0.01235044	0.01
0.016593754	0.021498799	0.018464208	0.023992062	0.023526788	0.02
0.017790496	0.018950582	0.027178049	0.031093359	0.028394461	0.02
0.023193598	0.03240025	0.031295538	0.034372807	0.040500045	0.04