SEDIMENT FLOW MODELING IN BHAGIRATHI RIVER USING ARTIFICIAL NEURAL NETWORKS

Ph.D. THESIS

by

NANDITA SINGH

DEPARTMENT OF EARTH SCIENCES
INDIAN INSTITUTE OF TECHNOLOGYROORKEE
ROORKEE-247667 (INDIA)

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A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

of

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ROORKEE

CANDIDATE'S DECLARATION

I hereby certify that the work, which is being presented in the thesis entitled "**SEDIMENT FLOW MODELING IN BHAGIRATHI RIVER USING ARTIFICIAL NEURAL NETWORKS**" in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy and submitted in the Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee, is an authentic record of my own work carried out during the period from August, 2009 to December, 2014 under the supervision of Dr. G. J. Chakrapani, Professor, Department of Earth Sciences, Indian Institute of Technology Roorkee

.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

(NANDITA SINGH)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(G. J. Chakrapani)
Supervisor

Date: December , 2014

ABSTRACT

A river system is a complex network of intertwining channels with an ongoing interaction of flow and sediment transport processes. The prediction of sediment transport is of vital interest due to its importance in understanding river hydraulics, geomorphology, irrigation, hydropower, design and management of water resources projects etc. Hydrodynamic models have been widely used for the analysis, prediction, design, and management of a wide range of water– sediment systems. However, due to the spatial heterogeneity of various physical and geomorphologic properties, a river system cannot be easily represented, and data requirements are large for modeling. A river network covers a vast area comprising of many watersheds and sub- basins, where a complete set of data may not be available. This results in the need for a practical user-friendly model which enables quick simulations and predictions with minimum data requirement and without significantly compromising the model accuracy. ANN has the characteristics of parallel link, error correction, and nonlinear transfer and is an emerging technique for the flow and connection of information. The advantage of using ANN is that every step of the modeling process can be configured and improved based upon model performance. This increases flexibility and also the understanding of the procedure which is otherwise rather complex to comprehend. In the present study, Artificial Neural Networks (ANN) have been employed to model sediment flow in the Himalayan Bhagirathi River, using multi annual time series data at four locations viz. Gangotri, Maneri, Uttarkashi and Rishikesh (Ganges River).

ANN modeling in the present study has been carried out by- understanding the geo-hydrological processes and parameters which control the variations in sediment load in the Bhagirathi River, description and analysis of time series data, development of representative models, training, testing and evaluation. The possibility of modeling sediment concentration with Artificial Neural Networks at Gangotri, the source of Bhagirathi River has been explored. Considering discharge, rainfall and temperature to be the main controlling factors of variations in sediment concentration in the dynamic glacial environment of Gangotri, fourteen feed forward neural networks with error back propagation algorithm with different inputs have been created, trained and tested for prediction of sediment concentration. The inputs applied in the models are either the variables mentioned above as individual factors (single input networks) or a combination of them (multi-input networks). The suitability of employing antecedent time-step values as network inputs has been checked by comparative analysis of model performance in two different

modes. The simple feed forward network has been improvised with a series parallel NARX [non-linear autoregressive with exogenous input] architecture wherein true values of sediment concentration have been fed as input during training. Daily data of discharge, rainfall, temperature and sediment concentration for the melt period of May-October, when maximum sediment movement takes place, for five years, from the year 2000 to 2004, has been used for modeling and high Coefficient of Determination values [0.77-0.88] have been obtained between observed and ANN predicted values of sediment concentration. According to the performance parameters (R and R^2 values), among discharge, temperature and rainfall as independent variables, the sediment concentration is most affected by rainfall (highest R^2 value). In this scenario, according to the performance parameters, the rainfall-temperature (T7) combination of inputs is seen to work relatively better. The overall performance range is not too large with the values of coefficient of determination ranging from 0.777 to 0.885. This implies that the generally accepted belief of better performance of multi-input ANN models may not hold true always. It is also seen that use of previous time step values as inputs (updating mode) may not necessarily improve model performance and vice versa. The study has brought out relationships between variables that are not reflected in normal statistical analysis. A strong rainfall: sediment concentration and temperature: sediment concentration relationship is shown by the models which is not reflected in statistical correlation. It has also been observed that usage of antecedent time step values as network inputs does not necessarily lead to improvement in model performance.

At Maneri, a simple technique for prediction of suspended sediment concentration [SSC] is presented. ANN models have been developed using short time period data of discharge and sediment concentration during the high activity monsoon period of June to October, 2004, when variations are maximum. Two modeling approaches have been employed, a daily approach and a three hourly approach. Although the time period considered is the same in both the approaches, the modeling performance is marginally better in the three hourly approach where there is a six fold increase in the dataset. The Levenberg-Marquardt optimization function, improvised with NARX [non-linear autoregressive with exogenous input] architecture has been used and high values of coefficient of determination have been obtained [0.89-0.97]. This study shows that short duration time series data can be used for successfully predicting geo-hydrological variables in the highly complex Himalayan river scenario.

Single series modeling using Nonlinear Autoregressive networks has been carried out considering six water years discharge data at Maneri, Uttarkashi and Rishikesh. In this form of modeling, the present time discharge values were predicted using antecedent discharge values. High values of coefficient of determination were obtained in the study [R^2=0.92-0.95]. The study validates the possibility of single series prediction in the Bhagirathi River. Prediction would not just help in filling gaps in hydrological data but will also enable continuous monitoring of sediment concentration which is difficult in the Himalayan Rivers where floods and other such eventualities commonly occur.

The present work, besides validating the use of ANN in geo-hydrological modeling, discusses several finer nuances of this technique. For instance, the pros and cons of- using single/multiple inputs in models, the use of previous time step values as network inputs, long duration data vs short duration data, daily vs high frequency three hourly data, the importance of data normalization, pre- modeling data analyses with statistical methods, prediction with a single series etc. Such a study would be of great help in understanding the relationships that exist between hydrologic variables and the degree to which they affect sediment movement. ANN prediction can also be useful for filling up the gaps in hydrologic data. This study shows that geo-hydrological time series data invariably has inherent trends which can be exploited for ANN modeling and predictions.

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(Nandita Singh)

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CHAPTER 1

INTRODUCTION

1.1 GEO-HYDROLOGICAL MODELING

A river system is a complex network of streams with an ongoing interaction of several spatially and temporally varying geo-hydrological parameters and processes. Understanding sediment transport along with estimation and prediction of sediment concentration has implications in water resource management, land use, territorial hazards and damage to engineering structures by morphological evolution of river bed. However, no direct or indirect empirical model developed for evaluating this process has gained universal acceptance (Abrahart et al. 2008) and there is a growing need for development of minimalist empirical approaches that are sensitive to climatic factors, catchment characteristics and antecedent conditions. The development of the sediment rating curve, which is by far the most conventional method of estimation of sediment concentration, is seen to result in under-prediction (Asselman, 2000; Walling and Webb, 1988). Several mathematical corrections have been applied to the basic linear regression equations to overcome this problem and non-linear regression equations have also been developed (Crowder et al., 2007; Holtschlag, 2001). Many studies in the recent times have indicated the potential advantage of Artificial Neural Networks(ANN) in sediment modeling (Abrahart and White, 2001; Cigizoglu, 2002a, b, 2004; Cigizoglu and Kisi, 2006; Jain, 2001; Kaur et al., 2003; Kisi, 2004; Nagy et al., 2002; Sarangi and Bhattacharya, 2005). There is a constant issue of requirement of detailed topographical and morphometric data in the application of conventional models while it is known that a river network covers a vast area consisting of many watersheds and sub-basins, where a complete set of data may not be available. In such a case, ANN presents a practical, user-friendly model for quick simulations and predictions with minimum data requirement and without significantly compromising the model accuracy (Yitian and Gu, 2003).

Modeling geo-hydrological variables and processes in the Himalayan Rivers with the ANN technique can be quite interesting and challenging. Here, the rivers carry large sediments loads draining through a great range of relief and climate, active tectonic zones and easily erodible rocks (Hasnain and Thayyen, 1999). The relatively young age of the Himalayan Mountains, with their large and rapidly moving glaciers, high seismicity, steep valleys with frequent landslides and avalanches and intense monsoonal rainfall, contribute to high erosion rates (Hasnain and Chauhan, 1993). The study of such huge water resource systems is important not just from the academic point of view but also in light of proper watershed management which involves water supply, flood control, irrigation, drainage, water quality, power generation, recreation, and fish and wildlife propagation (Tokar et al 1999).

1.2 AIM AND SCOPE OF THE PRESENT WORK

The main objective of the present study is to develop ANN model(s) with the capability to predict suspended sediment concentration (SSC) at Gangotri, Maneri and Uttarkashi on Bhagirathi River and Rishikesh on the Ganges River up to a high degree of accuracy. The study validates the practical capability and usefulness of ANN as a tool for simulating complex non-linear real world river system processes in the Himalayan scenario. The study not only gives an insight into ANN modeling in the Himalaya but it also focuses on the importance of understanding a river basin and the factors that affect sediment concentration, before attempting to model it. The objective has been achieved systematically by -

1. Understanding the underlying processes: sediment flow, the hydrological parameters involved, seasonal variations especially in the Himalayan context.
2. Data description and analysis: statistical analysis of time series data for Bhagirathi River, data trends and internal structure.
3. Understanding the technique: artificial neural networks, it's components and working based on procedures such as, data pre-partitioning, determination of model inputs and optimum network architecture, selection of algorithms etc.
4. Application of ANN: training, testing and performance evaluation of ANN models and interpretation of results.

In the present work, for the first time, ANN has been employed for modeling Sediment Concentration in the Bhagirathi River. ANN modeling has been carried out using multi annual hydrological data at four locations viz. Gangotri, which is the source of the river, Maneri, Uttarkashi, which are located downstream before the confluence of the river with Alaknanda and Rishikesh which is located on the Ganges. The Bhagirathi River sediment load variations are controlled by several socio-geohydrological parameters. The main controlling factors have been considered for ANN modeling in the present work. The thesis has been systematically structured into six chapters and written in a lucid manner so that it is as comprehensive as possible. The write up is extensively substantiated with diagrams, graphical illustrations and plots. Chapter one gives an introduction to the main theme of the study, elucidating the need for ANN modeling of hydrologic variables in general and in the Himalayan scenario. The objectives have been stated clearly and a summary of the underlying geo-hydrological processes and factors controlling sediment transport is given. An exhaustive review of previous and current works on global rivers has been given in Chapter two along with a review of ANN application to geo-hydrology. The study area details have been described in Chapter three. Chapter four pertains to the methodology adopted in the study i.e. data description, statistical analysis and most importantly ANN overview. Application of ANN to the study area and development of models is also presented in chapter four. The results have been discussed in chapter five. Finally, main conclusions of the work have been enlisted in Chapter 6 along with the future scope of the work.

1.3 RIVERS AND SEDIMENT DISCHARGE

Rivers are a dynamic and important part of the physical environment and water flowing down to the sea over the face of the land, is the dominant agent of landscape alteration (Bloom, 1978). Their behavior is of interest to a wide variety of concerns, ranging from flood control, navigation, water resource development to recreation. They pose a potential threat to human populations through floods, drought and erosion. They therefore have political, social and economic relevance. Sediment transfer from continents to oceans via rivers is one of the important processes regulating river-bank stabilization, soil formation, crustal evolution and many other earth-related processes (Chakrapani, 2005a). The enormity of this transport is well understood as it is known that globally, rivers transport around 34.7×10^{12} m^3 yr^{-1} of water and 13.5×10^{12} kg yr^{-1} of suspended sediments from continents to oceans (Milliman, et al., 1983). Mass transport by large rivers with high water flows such as, the Amazon, Mississippi, Nile, etc. are not very significant in terms of sediment flux. The Himalayan Rivers such as the Ganga and Brahmaputra, however, contribute large quantities of sediments to the oceans (Chakrapani and Saini, 2009). (Table 1.1)

The Ganga drainage basin in India occupies an area of about 1.0×10^6 km^2 of the subcontinent and carries a tremendous volume of water. The river with its large basin, transports approximately 520×10^6 ton sediment annually to the ocean (Shuguang *et al*., 2001). Table 1.2 shows the monthly discharge and sediment concentration characteristics of Alaknanda, Bhagirathi

Table 1.1 Water and sediment discharge in some large rivers of the world [McLennan,1993]

River	Water Discharge (km^3/yr)	Drainage area (10^6 km^2)	Sediment discharge (10^6 t/yr)	Sediment yield (t/km^2/yr)
Amazon	6300	6.15	1200	195
Columbia	251	0.67	10	15
Congo (Zaire)	1250	3.72	43	12
Danube	206	0.81	67	83
Ganges/Brahmaputra	971	1.48	1060	716
Huang He	49	0.75	1050	1400
Indus	238	0.97	59	61
Mackenzie	306	1.81	42	23
Mekong	470	0.79	160	202
Mississippi	580	3.27	210	64
Niger	192	1.21	40	33

and Ganga rivers at Srinagar, Maneri and Rishikesh respectively. The water flux in Alaknanda River is approximately three times of the Bhagirathi River. However, the sediment concentration in Bhagirathi River is relatively more than that of Alaknanda River which could be attributed to the higher gradient in the former (Chakrapani and Saini, 2009).

Table 1.2 Monthly total suspended concentration (TSM, mg/l) and load during water year 2004-05, at Srinagar, Maneri and Rishikesh for Alaknanda, Bhagirathi and Ganga respectively. (Saini, 2007)

Month	Alaknanda Discharge (10^{12}l)	TSM (ppm)	Bhagirathi Discharge (10^{12}l)	TSM (ppm)	Ganga Discharge (10^{12}l)	TSM (ppm)
July 2004	3.45	939	1.168	1370	4.7	872
August 2004	4.86	927	1.187	1046	6.5	894
September 2004	2.65	276	0.599	243	3.4	316
October 2004	1.80	137	0.217	120	2.2	139
November 2004	0.51	48	0.131	27	0.8	65
December 2004	0.43	21	0.103	25	0.6	29
January 2005	0.43	27	0.081	22	0.5	35
February 2005	0.23	50	0.070	27	0.5	41
March 2005	0.28	70	0.089	29	0.5	62
April 2005	0.43	198	0.140	86	0.7	130
May 2005	0.65	418	0.424	344	1.1	305
June 2005	1.69	608	0.704	722	2.2	566
Annual	**17.41**		**4.912**		**23.7**	

It is estimated that the present-day sediment load in rivers has been greatly altered due to large-scale human perturbations (Chakrapani, 2005a). The flash floods in Uttarakhand in June 2013 are a recent example where the catastrophic increase in water discharge is being attributed to human intervention in the form of indiscriminate construction of highways and dams. Figure 1.1 shows the discharge time series data at Maneri and Uttarkashi from 2008 to 2014. The abnormal rise in discharge during the catastrophic floods is well recorded in the data. Following the catastrophic floods in Uttarakhand, the Comptroller and Auditor General of India's report titled "Hydropower Development through Private Sector Participation," quoted the "negligence of environmental concerns was obvious as the muck generated from excavation and construction activities was being openly dumped into the rivers contributing to increase in the turbidity of water" (Thakkar and Upadhyay, 2013).

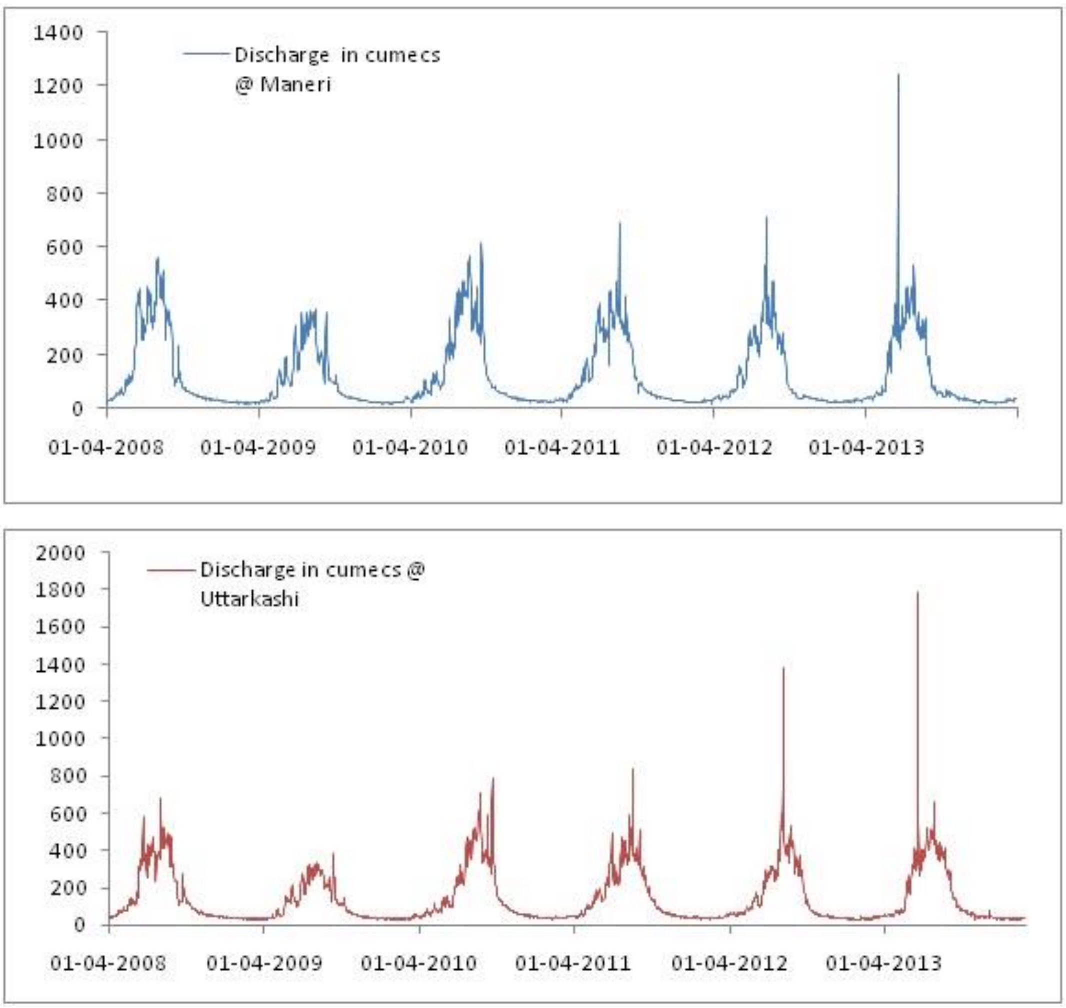


Figure 1.1- Discharge time series data at Maneri from 2008 to 2014

Hence, it is becoming increasingly critical to plan, design, and manage water resource systems carefully and intelligently. Detailed research involving exhaustive study of river basins, hydro-meteorological characteristics, rainfall and water discharge trends needs to be carried out. In light of the above, the need to develop models for prediction of water resource variables becomes imperative.

1.4 **THE MECHANISM OF SEDIMENT TRANSPORT**

Sediment, the end product of land surface erosion, plays an important role in sustainable development of water resource systems because it controls riverine hydrology, river channel morphology, water quality, aquatic ecology and so forth (Melesse et al., 2011; Walling, 2009). The total sediment transport composes of suspended and bed load. The suspended portion is predominant and commonly accounts for about 90% (Francke et al., 2008; Walling and Fang, 2003; Zhang et al., 2012). Of the total sediment transported to the sea, about 85-90 % is contributed by rivers (Garrels and Mackenzie, 1971). The process of sediment transport in rivers is a result of fluid flow-material interaction and is the sum total of the processes of erosion and entrainment, transport and deposition of sediment. The relationship between the forces of gravity and friction ultimately determines the ability of flowing water to erode and transport debris. **Velocity**, a vector quantity with both magnitude and direction, is one of the most sensitive properties varying in four dimensions- distance from the stream bed, across the stream (figure 1.2), downstream and with time (temporal variations). Velocity is usually measured at selected points in the flow cross section and expressed as an average value.

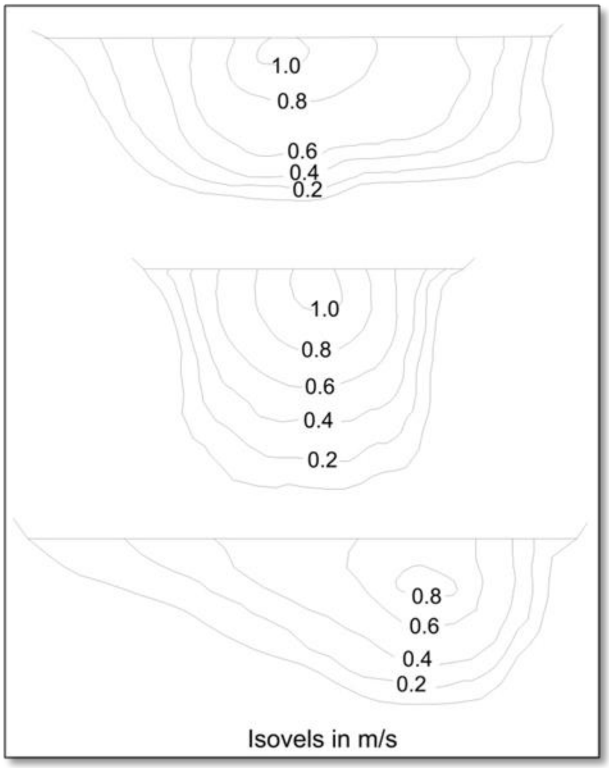


Figure 1.2- Variations in streamflow velocity at natural channel cross sections-after Knighton, 1984.

It is strongly related to **flow resistance**. Resistance in a flow carrying sediments comprises several components- grain or surface roughness, form roughness, channel irregularities and suspended material in the flow. Another component in flow mechanics is the energy of streams to perform mechanical work which is mainly potential and kinetic. This energy is expended by- work done against viscous shear and turbulence, work done against friction at the channel boundary, work done in eroding the channel boundary and work done in transporting the sediment load. Bagnold, 1977, has related sediment transport rate to available stream power where power per unit length of stream is-

$$\mathbf{\Omega = \gamma Q s}$$

where γ (=ρg) is the specific weight of water, Q is discharge and s is slope. Since energy must first be used to maintain the flow against internal and boundary friction, a critical energy level must be reached before a stream can perform erosional and transportational work. The concept of an erosion threshold is therefore fundamental to sediment transport. The entrainment and subsequent movement of particles depends on their physical properties, notably size, shape and density. Grain size has a direct influence on mobility. In cohesive sediments, which include particles in the silt-clay range, resistance to erosion depends more on the strength of cohesive bonds between particles than on the physical properties. Erosion of the bed and bank, both contribute to sediment in the rivers. Direct hydraulic action at high discharges lead to shearing of banks and is one of the most effective ways of adding sediment to the rivers. On the river bed, as the flow over a surface of loose grains gradually increases, a condition is reached when the forces tending to move a particle are in balance with those resisting motion. In terms of velocity, the critical condition can be defined as- (Figure 1.3) In addition to the drag forces acting roughly parallel to the bed, there is a lift force normal to the bed which can entrain particles. This force arises in two ways- difference in flow velocity between the top and bottom of a grain sets up a pressure gradient which tends to move the particle vertically upwards and turbulent eddying may produce local velocity components which act directly upwards close to the bed. (Figure 1.4)

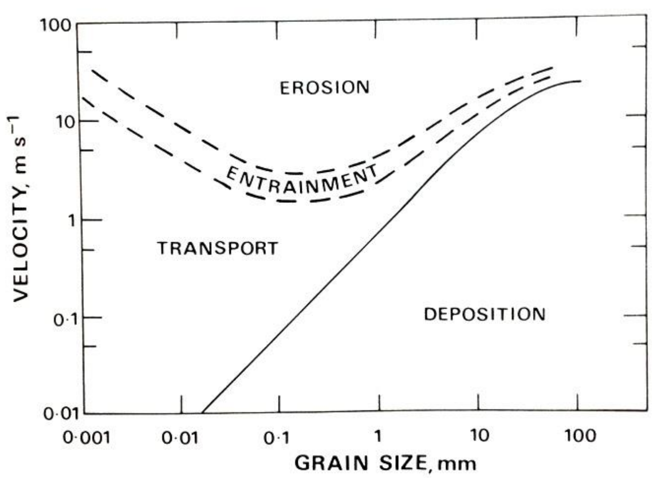


Figure 1.3 Erosion and deposition criterion defined in terms of threshold velocities - after Hjulstrom, 1935.

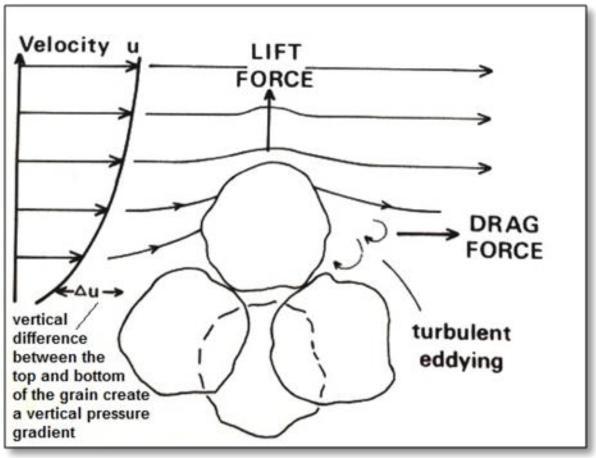


Figure 1.4 Lift and drag forces acting on a submerged particle -Knighton, 1984

After entrainment of particles, the process of sediment transport begins. Much of the sediment supplied to streams/rivers is so fine that its transport is controlled by the rate of supply rather than the transport capacity or **competence** of the river. In contrast, transport of coarser material (> 0.064 mm) is capacity limited and therefore intermittent. The load carried by rivers can be divided into dissolved load (compounds in solution or colloidal mixtures), suspended load (solid load with fine particles in suspension) and bed load (coarser particles that slide, roll or bounce along the stream bed). Dissolved load has no detectable effect on stream flow. The solutions are too dilute to affect viscosity, turbulence or density of the river water and hence no kinetic energy is expended in transport of dissolved load. Transport of suspended load is principally determined by its rate of supply from the drainage basin than the transport capacity of the river. The suspended sediment contributing processes are erosion of cohesive river banks, surface and sub-surface erosion in the catchment area by rain splash or surface wash. However, the rate of bed-load transport is almost entirely a function of the transporting capacity of the flow and there are numerous variables that affect it. The dynamics of bed load movement include rolling, sliding or saltation of particles along the bed. (Figure 1. 5)

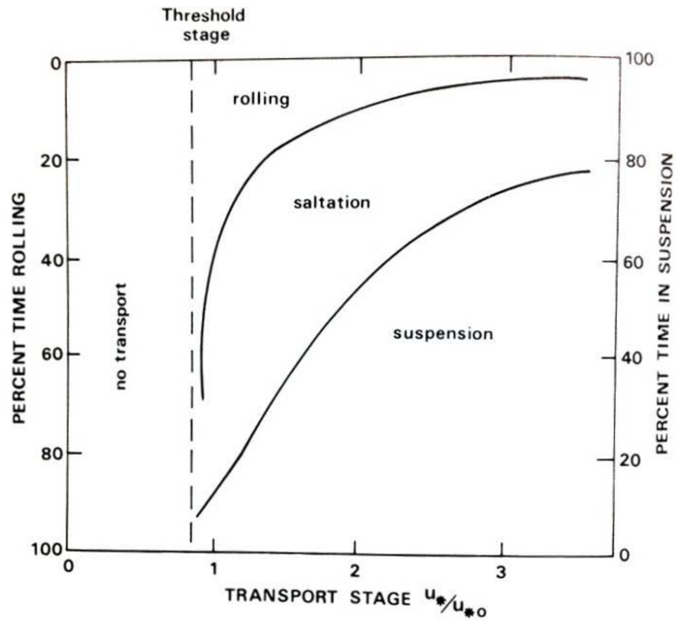


Figure 1.5- Percent of time particles in a water stream experience rolling, saltation and suspension as a function of transport stage. Percent of time in saltation is represented by the distance between the curves -after Abbott and Francis, 1977.

Because dissolved load has no effect on the hydraulic geometry of rivers, and bed load defies accurate measurement, the load of a river that is usually measured is the amount of suspended load (Bloom, 1971). Suspended sediment load is calculated with the help of water discharge and sediment concentration in the river water or,

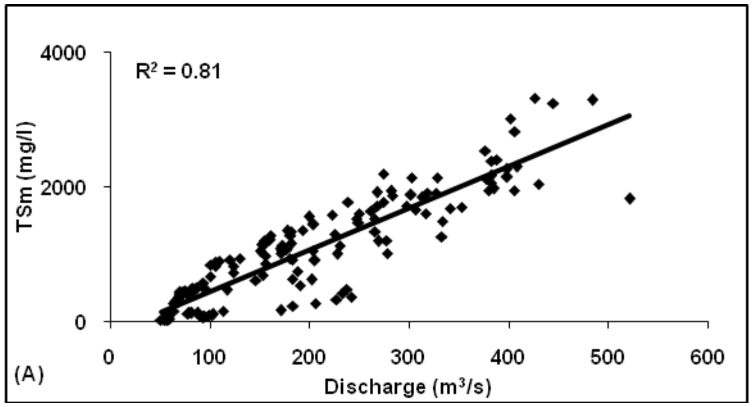
$$\mathbf{Q_s = \sum vac} \text{ and } \mathbf{Q = \sum va,}$$

where Q_s represents sediment load (mass/time), Q represents water discharge (volume/time), v represents mean velocity of river flow, a represents cross sectional area and c represents sediment concentration (mass/volume) (Nordin *et al.,* 1983). The equation relating suspended sediment load to discharge given by Leopold and Maddock, 1953 is $\mathbf{L=pQ^j}$, where L represents suspended sediment load, Q is discharge, p and j are numerical constants. **Sediment rating curves**, developed with this relation, are often used to analyze sediment transport characteristics. In general, as the discharge increases at a gauging station, the suspended sediment also increases. Values for the exponent ‘j’ range from 2.0-3.0. These large exponential values mean that as discharge increases ten-fold, the suspended sediment load may increase a hundred to a thousand fold. The suspended sediment load at a station increases much more rapidly with discharge than either channel width or depth, therefore, the enlargement of the channel by erosion cannot account for the entire increased load. Most of the suspended sediment comes from the watershed upstream from the gauging station, delivered newly to the stream by mass wasting and rill wash during the same rains or snowmelts that swell the discharge of the river. Measurements of channel shape and suspended sediment load confirm that streams move most of their loads during times of higher than average discharge.

1.5 FACTORS AFFECTING SEDIMENT LOAD OF RIVERS

1.5.1. Discharge

Water flow is important in determining the river energy and thus the scouring capacity of rivers, but it alone is not a deciding factor for sediment concentrations in rivers (Chakrapani, 2005a). Seasonality of water flow controls the sporadically high sediment loads in rivers. High discharge, together with ample sediment supply (as in a tectonically active region) and proximity to the sink of sediment (oceans) most certainly result in higher sediment loads from rivers. The suspended sediment discharge or denudation rates from various rivers indicate that large variations occur in sediment yield across rivers in different regions over the globe. Run-off or water flow of rivers does not necessarily indicate proportionate sediment load, as large rivers such as Amazon with high water flow carry less suspended sediments. The reason for this is that the Amazon River gets most of its sediment load from the Andes mountains, which constitute only about 10% of the river basin area and not from the Brazilian lowlands. As a result, for such a large river, the Amazon does not have a particularly high sediment yield per unit area. In fact, the sediment yield of the Amazon River is much less compared to some of the smaller rivers in southern Asia. The large islands of the western Pacific Ocean produce enormous sediments in rivers due to active tectonic activities, volcanism, steep slopes, heavy rainfall and intense human activity (Chakrapani, 2005a). Because of the highly variable character of sediment supply, plots of suspended sediment load against discharge (sediment rating curves) often show a wide scatter of points (Colby, 1963). Part of that scatter may be the result of hysteresis in which larger loads occur on the rising rather than falling stage at the same discharge. Figure 1.6 shows the degree of association between discharge and suspended sediment concentration in the Bhagirathi and Alaknanda rivers at Maneri and Lambagad respectively.



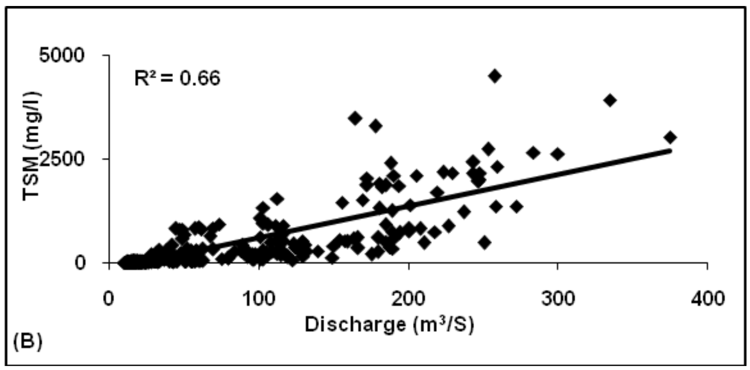


Figure 1.6 Scatter plots showing correlation between Discharge and TSM at (A) Bhagirathi at Maneri and (B) Alaknanda at Lambagad

1.5.2 Relief

There is a significant influence of basin elevation and morphology on river sediment fluxes, but only a few mathematical relationships are available. Pinet and Souriau, 1988, found river sediment fluxes to be linearly correlated with mean basin elevation. Looking mainly at river sediment yields of large world rivers, they proposed the following two equations to describe mechanical denudation globally:

$$D_s = 419 \times 10^{-6} \text{ Elev} - 0.245$$

(regions related to orogenesis < 250 Ma)

and

$$D_s = 61 \times 10^{-6} \text{ Elev}$$

(regions related to orogenesis > 250 Ma)

The high erosion rates in young continental crust are due to the relatively easy weatherability compared to the highly resistant old continental crust, and low relief and slope factors. Relief is a major factor as it induces greater mechanical erosion. Although factors such as lithology, climate, run-off and vegetation influence erosion rates, mean local relief is a primary control on erosion rates. Data of Ganges and Brahmaputra, which have their headwaters in the Himalayas, plot well above the trend defined by data of other rivers. Although factors such as lithology, climate, run-off and vegetation influence erosion rates, mean local relief is a primary control on erosion rates.

1.5.3. Geology

Lithology is an important factor which controls the rates of physical as well as chemical weathering. Rivers flowing over crystalline terrains erode with difficulty, whereas unconsolidated sedimentary rocks yield greater sediment loads to rivers. The enormous sediment loads in the Huang He is due to the presence of yellow loess derived from the deserts in Mongolia, whereas the Ganga–Brahmaputra Rivers carry huge sediment loads because they flow over the easily erodible carbonates and through the Himalayan terrains (Chakrapani, 2005a). The sediment yield is related with the weatherability of rocks, which is a direct result of the climate (temperature, precipitation, pH) and tectonics operating in the source area.

1.5.4. Temperature

Sediment load is related to basin relief, basin area and temperature by the relation

$$Q_s = aR^{3/2}A^{1/2}e^{kT},$$

where Q_s is the long-term sediment load (kg/s), R is relief defined as the highest point of elevation (m) minus the elevation of discharge station (m), A is basin area (km^2), T is mean surface temperature of the drainage basin and k and a are constants (2×10^{-5} and 0.1331 respectively) (Chakrapani, 2005a). Hence, the polar rivers with sub-zero temperatures show the lowest values in sediment yield (120 $t/km^2/yr$), whereas tropical rivers with temperatures of more than 30°C have extreme sediment yields (3648 $t/km^2/yr$).

1.5.5. Human Influence

Together with land-use changes, deforestation and soil conservation practices, the natural sedimentary cycle has been greatly altered because of river impoundments (dam reservoirs). Environmental effects include dislocation of human populations, silting of reservoirs, reduced sediment flux to the oceans, downstream scouring of channels, life cycle and habitat of aquatic organisms, eutrophication, anoxia and toxic conditions. A decrease in sediment load to the river through damming results in increase in coastal erosion and deterioration of coastal marine ecosystem. Four examples in which dam construction has impacted river sediment loads follow: the Nile River sediment discharge has changed from 100×10^6 tonnes per annum to almost zero after the closure of the Aswan Dam (Walling and Fang, 2003); the sediment load in the Colorado River decreased from approximately 125×10^6 tonnes per annum to 3×10^6 tonnes per annum due to the construction of the Hoover Dam (Meade and Parker, 1985); the total suspended load from the Red River has decreased by 70% since the impoundment of the Hoa Binh and Thac Ba reservoirs in the 1980s (Le et al., 2007); and Gupta and Chakrapani (2007) observed that 60–80% of sediments during the monsoon season get trapped in the reservoirs along the Narmada River in peninsular India. Dam constructions have become the main cause of sediment reduction from rivers worldwide (Syvitski et al., 2005). The dumping of muck from mining activities, road constructions, dam constructions etc is also known to cause anomalous increases in sediment load of rivers.

CHAPTER 2

LITERATURE REVIEW

2.1 STUDIES ON GLOBAL RIVERS

Water discharge is a key component in the global water cycle affecting our planet's climate (Harding et al., 2011), ecology (Doll et al., 2009) and anthropogenic activities like agriculture, drinking water, recreation (Biemans et al., 2011). The amount of water discharged by the World Rivers to the present-day oceans is estimated to be between 32 and $37x10^3 km^3 yr^{-1}$ McLennan, 1993. Milliman et al, 2008 have worked out the changes in discharge and precipitation patterns globally over a period of 50 years. Contrary to claims of increased 20th century river discharge (Probst and Tardy, 1987; Labat et al., 2004; Milly et al., 2005; Huntington, 2006), neither discharge nor precipitation changed significantly over the last half of the 20th century, offering little support to a global intensification of the hydrological cycle. Changes in individual rivers and at regional levels, however, have been noteworthy. They have identified three types of rivers in this analysis: normal, deficit and excess portraying markedly different situations. Because temporal trends in both precipitation and discharge in most normal rivers reflect climatic variability, 1951–2000 trends may not reflect long-term change. Deficit Rivers, on the other hand, reflect direct human impact on the flow and discharge of fluvial water. Given the increased demographic pressures in many of the water-scarce regions, the decreased discharge noted in deficit rivers seems unlikely to be reversed. Rather, the number of deficit rivers in these regions are likely to increase. More problematic are excess rivers, as they may in part reflect climatic changes and/or water storage. Given the present inability to define completely the cause(s) of this increased discharge, maintaining and augmenting global monitoring and data dissemination for excess rivers is critical to gain better synthetic and predictive models. Ironically, the number of river gauging stations at higher latitudes has declined in recent years (Vörösmarty et al., 2001), just when continuity in long-term data is most needed. Hartmann et al, 2014, have provided an overview of global river chemistry from the Global River Chemistry Database (GLORICH) which combines hydrochemical data from various sources with the catchment characteristics of sampling locations. The characteristics considered include catchment size, lithology, soil, climate, land cover, net primary production, population density and average slope gradient. About 1.27 million samples over 17000 sampling locations have been included in the database. In a recent work by Pavelsky et al, 2014, direct observation of variation in streamflow has been made using SWOT satellite data which provides high resolution images of terrestrial water surface height, inundation extent, global ocean surface elevation. Van Vliet et al, 2013, have studied the effects of climate change on global river flow and river water temperature. They have attempted to project discharge and water temperature values under future climate. Greater seasonality of discharge with an increase in high flows and decrease in low flows has been brought out. They have predicted a 0.8-1.6° C rise in average global river temperatures.

The sediment flux delivered by rivers is a crucial process that affects the geomorphologic evolution of river channels, deltas and estuaries. As a link between the land and the sea, rivers discharge approximately 200 x 10^8 t of sediment load globally into the sea every year (Milliman and Syvitski, 1992), which is of great importance in terms of geomorphology and geology. Quantifying sediment flux dynamics is a fundamental goal of earth-system science for its role in our planet's geology (Pelletier, 2012), biogeochemistry (Vörösmarty et al., 1997; Syvitski and Milliman, 2007) and anthropogenic activities (Kettner et al., 2010). Milliman and Syvitski, 2007, revised the global estimate of sediment flux to oceans to 18 billion tons per year, using the flux data of 280 rivers that included small mountainous rivers as well as data from gauging stations located near the river mouths. Meade, 1996, however, cautioned that these estimates are at best flux-calculated at most seaward gauging stations and may not exactly represent the true flux into oceans. Much of the sediments could also be deposited in the deltas between the most seaward gauging station and the open sea. In recent decades, the effects of human activities and climate change have significantly affected natural river processes and have led to a decrease in the sediment discharge into the sea (Vörösmarty et al., 2003; Walling and Fang, 2003; Siakeu et al., 2004; Walling, 2006). Decreased sediment loads have caused the erosion of many river deltas, such as the Nile in Egypt (Fanos, 1995), the Ebro in Spain (Mikhailova, 2003) and the Colorado (Carriquiry and Sanchez, 1999) and Mississippi Rivers (Blum and Roberts, 2009) in America. The erosion of river deltas has become a topic of global interest, attracting significant worldwide attention (Syvitski, 2008; Syvitski et al., 2009).

There is a dearth of sediment load data for rivers in many parts of the world (Isik, 2013). Our quantitative understanding and predictive capabilities of global river fluxes are lacking and this is, in part, due to the multi-scale nature of the processes involved (Pelletier, 2012) and the inadequacy in global gauging of rivers (Fekete and Vörösmarty, 2007). Availability of measured river fluxes is decreasing globally (Brakenridge et al., 2012) particularly for sediment (Syvitski et al., 2005). Sediment fluxes to the oceans are measured for less than 10% of the Earth's rivers (Syvitski et al., 2005) and intra-basin measurements are even scarcer (Kettner et al., 2010).

Numerical models can fill the gap in sediment measurements (e.g. Syvitski et al., 2005; Wilkinson et al., 2009) and offer predictive or analytical capabilities of future and past trends enabling the investigations of terrestrial response to environmental and human changes e.g. climate change (Kettner and Syvitski, 2009). Despite advances made in recent years (Kettner and Syvitski, 2008; Pelletier, 2012) simulating global riverine fluxes remains challenging. Quantifying riverine sediment flux and water discharge is an important scientific undertaking for many reasons. Climate change during the 21st century is projected to alter the spatio-temporal dynamics of precipitation and temperature (Bates et al., 2008) resulting in natural and anthropogenically induced changes in land-use and water availability. Estimating the effect of these spatially and temporally dynamic processes warrants sophisticated distributed numerical models. Using past trends is perhaps the best strategy for developing these models and improving our understanding of the dynamics and causality within these complex systems. Cohen et al, 2013, have presented and validated an improved version of the WBMsed global riverine sediment flux model which can capture long-term average and inter-annual suspended sediment fluxes but tends to overestimate daily fluxes (by orders of magnitudes) during high discharge events and underestimate these during low flow periods.

The Himalaya–Ganges–Brahmaputra system is one of the world's largest highland–lowland systems and transports a large quantity of sediment to oceans. The Himalayan and Tibetan regions cover only about 5% of the Earth's land surface but contribute about 25% of the dissolved load to the world's oceans (Raymo and Ruddiman, 1992). Ganga-Brahmputra together forms one of the world's largest river systems, it is first in terms of sediments transport and fourth in terms of water discharge (Sarin *et al.,* 1989). Further, they transport about 1670 million tons of suspended sediments to the Bay of Bengal, highest among all the global rivers (Krishnaswami *et al.,* 1999). It is estimated that the present sediment yield of the Ganga–Brahmaputra River system together is about one billion tonnes per year (Subramanian, 1993) in comparison to the global annual sediment of 15 billion tonnes per year (Milliman and Meade, 1983). Alaknanda and Bhagirathi rivers are mountainous streams which originate in the high Himalaya and combine at Devprayag where river Ganges gets its formal name. Chakrapani and Saini, 2009, have shown that >75% of annual sediment loads are transported during the monsoon season (June through September). They have estimated the annual physical weathering rates in the Alaknanda and Bhagirathi River basins at Devprayag to be 863 tons/km^2/year and 907 tons/ km^2/yr respectively, which are far in excess of the global average of 156 tons/ km^2/yr.

2.2 APPLICATION OF ANN TO GEO-HYDROLOGY

For any water-related development undertaking, long term sediment yield is required generally for various purposes such as design of reservoir life and its storage capacity (Morris and Fan, 1998). However, observations of sediment load are lacking for rivers in many parts of the world, especially in developing and remote regions (Heng and Suetsugi, 2013a; Walling, 2009). Artificial neural network (ANN) is the most well known and powerful data-driven model, especially in data-constraint regions. It has been proved to be useful in modeling complex hydrological processes or non-linear systems such as sediment transport (Haddadchi et al., 2013; Maier and Dandy, 1999; Nourani et al., 2012; Rezapour et al., 2010). The adoption of the Artificial Neural Network (ANN) technique for hydrological modeling has added a new dimension to the system theoretic modeling approach and it has been applied in recent years, as a successful tool, to solve various problems concerned with hydrology and water resources engineering (ASCE, 2000a,b). The objective of these studies is to find a formula between the selected input variables and the output based on a representative set of historic examples. The formula is then extended to predict the outcome of any given input. The computational efficiency of ANN has provided many promising results in the field of hydrology and water resources simulation (Sudheer et al. 2003). An attractive feature of ANN is their ability to extract the relationship between the inputs and outputs of a process, without the physics being explicitly provided to them. They are able to provide a mapping from one multivariate space to another, given a set of data representing that mapping. Even if the data are noisy and contaminated with errors, ANN have been known to identify the underlying rule (Govindaraju, 2000). ANN are data driven when compared to conventional approaches, which are model driven (Nagesh Kumar et al 2003). However there are some limitations of ANN too. Most ANN applications have been unable to explain in a comprehensive way the basic process by which ANN arrive at a decision. Another issue is that there is no standardized way of selecting network architecture (Nagesh Kumar 2001).

ANN have been used for a variety of water resource applications. Works by Karunanithi et al., 1994, Dawson and Wilby, 1998, Campolo et al., 1999 and Imrie et al.,2000, have demonstrated the capability of ANN in streamflow forecasting. The ANN they used performed much better than the conventional models. The application of an ANN for modeling the rainfall-runoff process started with a preliminary study by Halff et al., 1993, who used a three layer feedforward ANN for the prediction of hydrographs. Comprehensive review on the application of ANN in the areas of water resources and hydrology is provided by the ASCE Task Committee on Application of ANN in Hydrology (2000a, b), Maier and Dandy (2000), and Dawson and Wilby (2001). These include several themes such as rainfall forecasting and estimation (French et al., 1992; Navone and Ceccatto, 1994; Hsu et al., 1997), reservoir inflow time series (Raman and Sunilkumar, 1995), river salinity studies (Maier and Dandy, 1996). Hsu et al. (1995) proposed a new algorithm, called the linear least squares simplex (LLSSIM), for the training of an ANN. It uses a combination of linear least squares and multi-start simplex optimization. This algorithm was found to be more effective and efficient than the error backpropagation (EBP) algorithm, which is commonly used by most of the researchers. Smith and Eli, 1995, used the back-propagation artificial neural network model to predict peak discharge and time to peak by using simulated data from a synthetic catchment. The study by Minns and Hall, 1996, points out the importance of standardization of the data. For a simulation of sheet sediment transport, Tayfur, 2002, compared ANN with several physically-based models including one based on unit stream power, and found that ANN performs comparably with the others and better in some cases. Sajikumar and Thandaveswara, 1999, used a temporal back-propagation neural network (TBPNN) for monthly rainfall-runoff modeling in scarce data conditions. Tokar and Johnson, 1999, demonstrated the impact of the selection of training data on the accuracy of runoff prediction. Zhang and Govindaraju, 2000, used a modular neural network (MNN) for prediction of the catchment runoff and utilized Bayesian concept in deriving the training algorithm. Xiong et al., 2001, used the ANN for flow forecasting in a Karstic catchment, whereas Shamseldin, 1997, used the conjugate gradient method to train the network using data from six catchments from different climates and succeeded in enhancing the accuracy of flood forecasts by making use of the ANN in combining the simulation results of different black box and conceptual models of the rainfall-runoff process.

ANN also have been used for representing soil and water processes including soil moisture fluctuation (Altenford, 1992), groundwater cleanup strategies (Ranjithan et al., 1993), water table fluctuations (Shukla et al., 1996; Yang et al., 1996), pesticide movement in soils (Yang et al., 1997), drainage pattern determination from a digital elevation model (Kao, 1996) and water table management (Yang et al., 1998). ANN is often applied for modeling rainfall-runoff processes (Hall and Minns, 1993; Mason et al., 1996; Gautam et al., 2000; Chang and Chen, 2001; Zhang and Govindaraju, 2003). Sudheer et al., 2002, used soft computing tools to develop a new approach for designing the network structure in an ANN-based rainfall-runoff model. Reddy, 2003, used ANN and GIS tools in three watersheds of Daman, Ganga Catchments, Maharashtra and two watersheds in Lower Bhavani catchments, Tamil Nadu State, India, for prediction of runoff. Zhang and Govindaraju, 2003, developed a geomorphology-based ANN for prediction of watershed runoff. Shiri and Kisi, 2010, applied a wavelet-neuro-fuzzy conjunction model for predicting short-term and long-term streamflows. Rajurkar et al, 2004, have combined a simple linear black-box model with ANN, to predict run-off in the non-updating mode i.e. without using rainfall in the previous time steps as an input to the network. Sarangi and Bhattacharya, 2000, developed a regression model for prediction of sediment concentration from runoff rate, in association with certain geomorphological parameters. Nagy et al., 2002 used a feed-forward three-layer back propagation (BP) ANN model to predict the sediment concentration in rivers using eight input parameters reflecting sediment and riverbed information. Kaur et al., 2003, used the Soil and Water Assessment Tool (SWAT), to estimate runoff and sediment loss from Nagwan Watershed in the Upper Damodar Valley, India. Yitian and Gu, 2003, developed a mass-conservation transfer function for flow and sediment yield of rivers. Dogan et al, 2007, have attempted to develop an effective model for estimating sediment concentration which includes dependent as well as independent variables. They employed ANN and total sediment transport equations and on comparison found the results of the former to be superior. Rai and Mathur, 2007, developed a Feed Forward Back Propagation Algorithm with Gradient Descent and Bayesian regularization automation for computation of event based temporal variation of Sediment Yield. They compared the results with linear transfer function model and found ANN to perform better in computation of runoff hydrographs and sedimentographs. Cigizoglu, 2008, performed a comparative study of various ANN techniques like Feed Forward Back Propagation, Generalized Regression based Neural Networks and Radial basis function based Neural Networks in short-term continuous and intermittent daily stream forecasting and daily suspended sediment forecasting. They found the Radial-Basis Function based Neural Network to be superior to the other two techniques. Firat and Gungor, 2009, used the ANFIS (Adaptive Neuro Fuzzy Inference System) approach to construct a monthly sediment forecasting system n the Great Menderes Basin. They compared their results with ANN and Multilayer Perceptron approaches and found the ANFIS to be more reliable and accurate. Kisi, 2009, has applied the Neuro Wavelet technique by combining ANN and discrete wavelet transform for modeling daily Suspended Sediment Discharge relationship in the Tongue River in Montana. An increase in estimation accuracy is noticed with this technique. Rajaee et al, 2009, have carried out prediction of Suspended Sediment Load in a gauging station in the US by Neuro fuzzy- Wavelet analysis and neuro fuzzy- sediment rating curve conjunction. They have observed that Wavelet analysis and neuro fuzzy conjunction performs better in terms of prediction of extreme values and lesser errors. Garg, 2011, has introduced the Genetic Programming approach in estimating sediment yield considering various meteorological and geographic features of the Arno River basin in Italy. He has noticed that this approach can efficiently capture the trend of sediment yield even with a small data set. Mustafa et al, 2012, have employed four algorithms- Gradient Descent, Gradient Descent with Momentum, Scaled conjugate gradient and Levenberg Marquardt in Multilayer Feed Forward networks to predict the Suspended Sediment Discharge of Pari River in Malaysia. They found the latter two algorithms to be superior to the former two. In a recent study by Boukhrissa et al, 2013, performance of rating curves and ANN have been compared in sediment load prediction in Kebir catchment of Algeria. Such a study would help to understand and estimate reservoir sedimentation. ANN has so far not been applied for modeling hydrological processes in the Upper Himalayan Rivers.

CHAPTER 3

STUDY AREA

3.1 Physiography

3.2 Climate

3.3 Geology

3.4 Sediment Load Variations in Bhagirathi River

3.5 Anthropogenic Activities in Bhagirathi River

ANN has been employed for modeling Sediment Concentration at Gangotri, Maneri, Uttarkashi and Rishikesh. While Gangotri, is the source of Bhagirathi River, Maneri, is located around 75 km downstream. Uttarkashi is located further 20km downstream and Rishikesh is located much further, on the Ganges River.

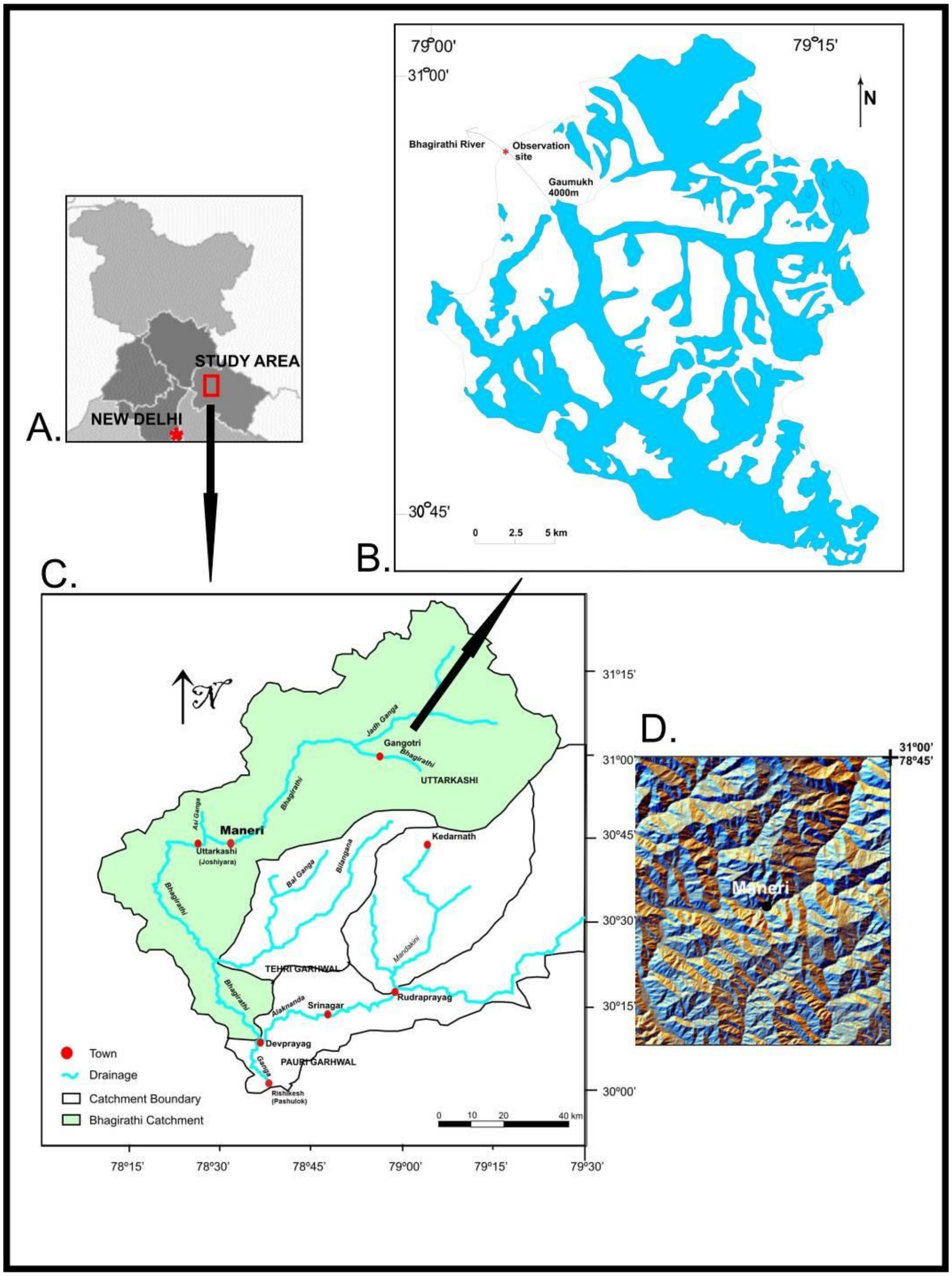


Figure 3.1- A- location of the study area. B- the Gangotri glacier. C- Bhagirathi basin. D- Shaded relief map of the area around Maneri.

The first location represents a dynamic glacial environment where maximum transport of water and sediment takes place during the ablation/melt period (May to October) due to high rates of physical weathering with minimal influence of anthropogenic activities. The Bhagirathi River originates at an altitude of 3892m at the snout of Gangotri glacier (Goumukh) in the Higher Himalayas. It flows for around 225 km across the Himalayas before its confluence with the Alaknanda River at Devprayag to form river Ganga. The Bhagirathi River Basin in the North Western part of Uttarakhand state in India, has a total catchment area of 7811 sq km out of which 2328 sq km is snowbound (Pandey et al., 1999). The basin can be divided into the Bhagirathi, Asi Ganga and Bhilangana sub-basins. The Gangotri glacier, one of the biggest and most important glaciers in the Himalayan region and is bound between latitudes 30°43'- 31°01' and longitudes 79°00'–79°17'. Gaumukh (meaning 'cow's mouth) is located at an elevation of about 4000 m above m.s.l (Singh et al., 2012). While Gangotri, where the first sampling location is situated, is the source of Bhagirathi river, Maneri, Uttarkashi and Rishikesh are situated approximately 75km, 90 km and ~260 km downstream. The total catchment area of the Gangotri glacier study basin up to the first sampling site is about 556 km^2, out of which about 286 km^2 (51.4%) is ice covered (Haritashya et al., 2006; Singh et al., 2006).

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3.1 PHYSIOGRAPHY

The catchment area of Bhagirathi River lies in Uttarkashi and Tehri Garhwal districts. This catchment can be sub divided into the watershed of the Bhagirathi, Bhilangana and Asi Ganga rivers. In the Bhagirathi sub-basin, the highest and the most fascinating zone is above 4000m elevation. This zone is the principal source of water and major tributaries of Ganga River emanate from this zone. The upper reaches are characterized by narrow glaciated valleys, deep gorges, waterfalls and cascades. Between 4000m and 3000m elevation the valleys are filled with glacial debris which is being slowly removed by rivers. This zone supports sub-alpine type trees. Gorges are abundant between 2000m and 3000m elevation. The terrain is rugged, sparsely populated with temperate forests and generally good vegetation. Between 2000m and 1000m river terraces are quite common, land is fertile and heavily cultivated and the area is densely populated.

Bhilangana and Asiganga are the major tributaries of Bhagirathi River. Asiganga joins Bhagirathi River upstream of Uttarkashi. Bhilangana River originates from Khatling glacier and joins Bhagirathi at Tehri (AHEC report, 2011). The Gangotri glacier is a cluster of many small and large glaciers comprising three main glacier tributaries, namely, Raktvarn glacier (length 15.90 km; area 55.30 km^2), Kirti glacier (length 11.05 km; area 33.14 km^2) and Chaturangi glacier (length 22.45 km; area 67.70 km^2) with main Gangotri glacier as the trunk part of the cluster system (length 30.20 km; area 86.32 km^2) (Naithani et al., 2001). The gradient of Kirti glacier is highest 0.317, whereas that of Gangotri glacier is lowest (0.045) followed by Chaturangi (0.146) and Raktvarn (0.210) glacier, respectively (Naithani et al., 2001). It is a temperate mountain valley glacier, which flows in the northwest direction. The major glacier tributaries of the Gangotri Glacier system are the Raktvarn, Chaturangi, Swachand and Maiandi glaciers that merge with the trunk glacier from the North-east, and the Meru, Kirti and Ghanohim Glaciers that merge with the trunk glacier from the South- west. The altitude range of these glaciers varies from 4000 to 7000 m. Besides these three major glaciers, some other tributary glaciers of this area directly drain into the Gangotri Glacier such as Swachand, Miandi, Sumeru and Ghanohim. Four other glaciers, which directly drain into the Bhagirathi River are Maitri, Meru, Bhrigupanth and Manda (Naithani et al., 2001). The most striking feature of Gangotri glacier is that a debris layer covers most of the ablation area. The thickness of the debris layer generally varies from a few millimeters to a few meters, although in some locations large rocks are piled up to several meters.

3.2 CLIMATE

The Bhagirathi river basin experiences strong climatic seasonal variations, which is also clearly reflected in the monthly variation in stream flows (Pandey et al. 1999). The terrain is characterized by deep gorges and high vertical cliffs, which govern the microclimatic conditions in the area. Monsoon currents penetrate deep through the valley and the rainfall is maximum during the monsoon months i.e. June to September. Winters are rather prolonged and severe. The climate of the Himalayan region in general and of study area in particular depends on the summer monsoon currents and associated cyclone system, westerly disturbances and local orographic and conventional thunderstorms that occurs in the afternoon during pre and post monsoon. In the study area, there exists a large variation of relief from 200m in south to more than 7,500m in the north. Besides this, at every ascend of 1000m, a decrease of temperature by 6°C is also observed [Saini, 2007]. The variation in temperature and rainfall conditions along the ridge and the valley areas are very prominent. The slope aspect ratio play an important role in determining the climate, as north facing slopes are much cooler and damp as compared to south facing slope due to insolation affect. Beside this, alignment of ranges, leeward and windward direction, proximity of water bodies and large stretch of forest cover and proximity to snow cover play an important role particularly in rainfall and temperature variations (Joshi et al., 1993). The basin area receives more than 70%-80% annual rainfall during the peak monsoon periods of mid June to mid September and the remaining precipitation occur during winter months i.e. from mid November to February by westerly disturbances in August. The average annual rainfall in the basin is about 1178 mm. Rainfall distribution is not uniform throughout the basin and varies between 1500 and 2986 mm. The average seasonal temperature near the snout of the Gangotri glacier is about 9.4 8C while average seasonal rainfall is about 260 mm. The distribution of rainfall varies from year to year (131–369 mm). Details of such climatic conditions prevailing in the study area have been reported by Singh et al., 2006, 2011. In most cases, maximum rainfall is witnessed in July and August. Average daily maximum and minimum temperatures are around 14.6 and 3.9 °C, respectively; wind speed is four times higher during daytime than in the night. The Bhagirathi River and its tributaries are dependent predominantly on glacier and snow melt and precipitation.

3.3 GEOLOGY

The river Bhagirathi and its tributaries drain largely through the rocks of the Lesser and Central crystallines (Figure 3.2). The Main Crystalline Thrust (MCT) passes through and beyond Bhatwari, about 20 km downstream, where it has almost an east-west course and separates granite gneisses and garnetiferous schists of the Central Crystalline and cream coloured quartzites. The upper catchment of the Bhagirathi is mainly composed of rocks of Central Crystalline rocks primarily consisting of schists, micaceous quartzites, calc-silicates, amphibolites, gneisses, granites, slates and phyllites. In the middle and lower reaches, the Bhagirathi flows through limestone and dolomite bearing Uttarkashi Formation (Pandey et al. 1999). The area from Dharasu to Devprayag in Tehri district falls in Lesser Himalayan belt of the Garhwal region. The river encounters siltstones and phyllites of Chakrata formation and sandstones interbedded with slates of Rautgara formation downstream of Dharasu and before confluence with Alaknanda, it passes through phyllites and micaceous graywack bearing Chandpur Formation near Chaam (Dudeja et al.

2013). Further downstream also, rocks of Chandpur formation comprising phyllites interbedded with thin beds of sandstone are observed up to Devprayag. Chandpur formation is also well exposed between Tehri and Devprayag. The Chandpur formation consists of laminated greenish gray to khaki laminated phyllite/slate interbeded with thin finely interbeded sandstone and white to brownish, purplish greywacke (Kumar, 2005).

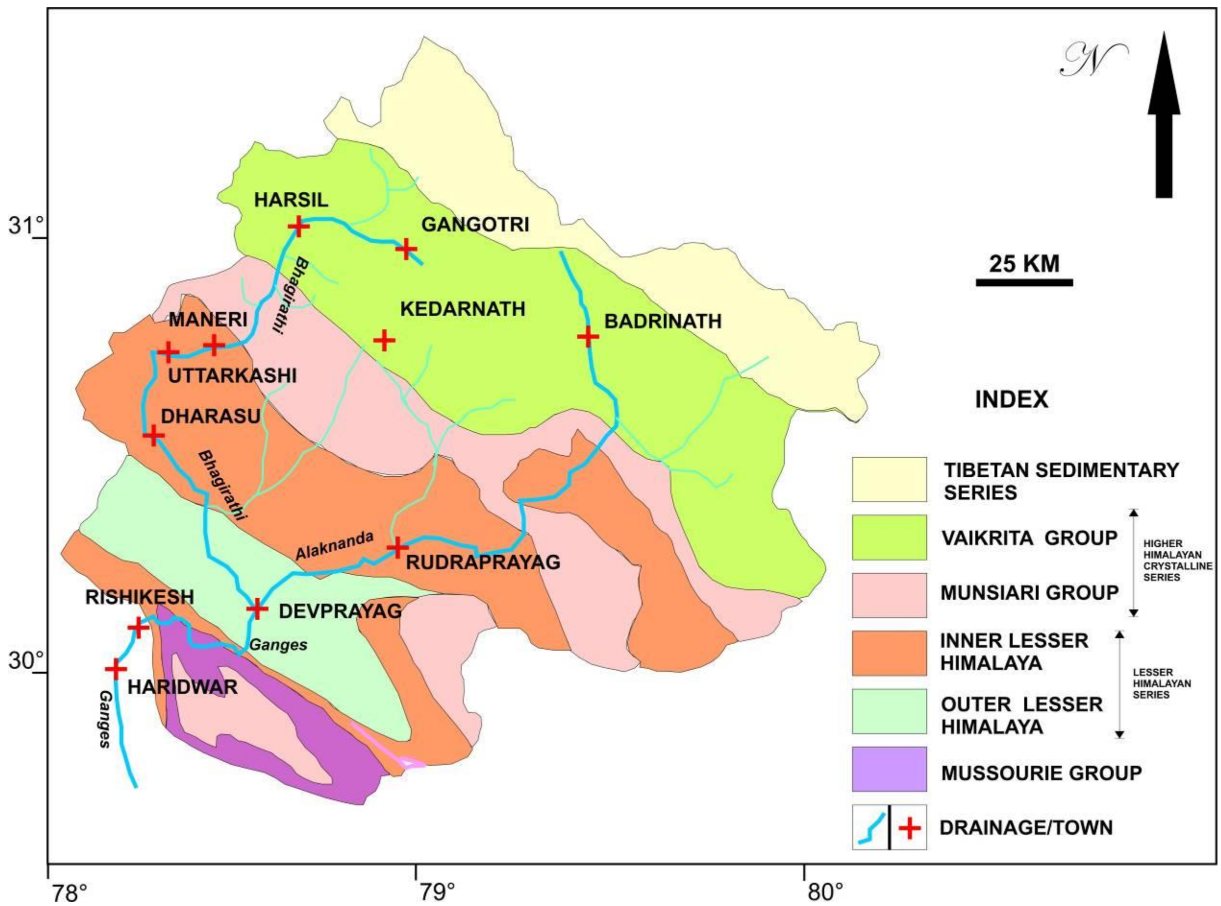

Figure 3.2- Geology observed along the course of Bhagirathi River. (after Bickle et al., 2003)

The Gangotri Glacier area lies in the Central Crystalline Zone. From Gangotri further northeast, the mica schist, which is the dominant rock type above the Main Central Thrust (MCT) is retrograded in chlorite schist and intruded by hard and massive granite (Gangotri granite) (Kumar et al 2009). It is exposed around the Gangotri Glacier region along the upper reaches of Bhagirathi River, including the peaks of Thalay Sagar (6904 m), Meru (6672 m), Shivling (6543 m), Bhagirathi (6856 m) and Bhrigupanth (6044 m) (Jowhar, 2010). The Gangotri granite is fine grained (1–2 mm), composed of {quartz + K-feldspar + plagioclase + tourmaline + muscovite}, biotite (present only in the biotite-rich facies), garnet (present only in the tourmaline-rich facies), beryl along with apatite as the most abundant accessory mineral (Jowhar 2010). Sulphide minerals like pyrite, chalcopyrite and arsenopyrite are found at the contact of quartz veinlets and massive, banded fine grained limestone (Bhatt, 1963). As reported by Jain et al. 2002, the Gangotri granite is exposed all along the upper reaches of the Bhagirathi River around the Gangotri Glacier area and is the largest body of the High Himalayan Leucogranite (HHL) with an estimated age, based on geochemistry and geochronology study, of early Miocene period (~21 Ma).

3.4 SEDIMENT LOAD VARIATIONS IN BHAGIRATHI RIVER

The Bhagirathi River has an annual water Discharge and Suspended Sediment Concentration of 4.91 x 10^{12} l/yr and 1.24 x 10^{3} mg/L respectively (Chakrapani et al., 2009). The discharge and sediment load variations observed in the Bhagirathi River affect downstream habitation, engineering structures and land use. The main controlling factors for variations in sediment load are relief, tectonic instability, lithology, rainfall and anthropogenic activities (Chakrapani, 2005a) and all of them are favorable for high sediment load in the Bhagirathi River. The Bhagirathi River is dotted with numerous human settlements, hydro power projects and dams which are immensely impacted by the variations in hydrologic variables like water discharge and sediment concentration. The river drains through a great range of relief and climate, active tectonic zones and easily erodible rocks of the Himalaya. The gradient from Goumukh to Harsil is rather steep, 1192 m in a zone of 42 km and 2002 m in a zone of 183 km from Harsil to Devprayag. The erosion rate in the Gangotri Glacier based on 4 years melt period (2000–2003) is 1.8 mm (Haritashya et al. 2006a). Bali et al., 2003, have documented well developed neotectonic activities in Quaternary time. Morphometric analysis carried out to evaluate the glacier recession reveals several parameters of the main trunk glacier, including overall glacier relief of 2880 m, a relief ratio of 0.045 m, and a present equilibrium line altitude of 5560 m (Naithani et al., 2001). The river hydrology is immensely affected by the monsoons when large variations in discharge and sediment load are observed in a relatively short time span [June to October]. The physical weathering rate [PWR~907 tons/km^2/yr] of the river is much higher than the global average PWR of 156 tons/km^2/yr despite its relatively small catchment [~7.8 x 10^3 km^2] because of predominantly silicate lithology undergoing intense physical breakdown under high gradient [Chakrapani and

Saini, 2007). Landslides and breach floods (Hewitt, 1998) are frequent along the river which further contributes to surges in sediment load in the river.

3.5 ANTHROPOGENIC ACTIVITIES IN THE BHAGIRATHI RIVER

In addition to the above, haphazard developmental activities in the Bhagirathi valley, like construction of dams and highways also impact sediment load variations in the river basin. Moreover, Bhagirathi River is an important pilgrim centre and attracts high tourist inflow during the months of March to October. Because of the increased vehicular traffic, new roads get constructed along the mountains, causing frequent landslides. These landslides and road construction debris add on to the river suspensions. Among the human influences on sediment load patterns in rivers, none exert as much influence as the effect of dams/reservoirs along the river courses. Between 1951 and 1982, large dams were being constructed at a rate of 900 per year (Syvitski et al., 2005). The Bhagirathi River is a potential site of medium and small hydropower projects because of the gradient and water flow. There are many existing small and micro hydroelectric projects and many upcoming ones on the River. These projects may cause the sediments to get deposited on the reservoirs. A large variation in suspended sediment concentration is observed in the river course before and after the reservoir site.

The upper Ganga Basin, consists of about 13 commissioned hydropower projects while 57 projects are under construction. Generation of hydropower does not consume any (significant quantity of) water but may cause significant changes in the stream flow variability by regulating natural flows and generating electrical energy in a way that the benefits are maximized. Normally, there is large energy generation for a maximum of only 4-6 hours in a day. Due to this, there are likely to be additional fluctuations in the flows downstream of the point where the outflow of the power plant of a project meets the river. As one travels further downstream, however, the fluctuations get moderated because of valley storage effect and lateral inflows to the river (AHEC Report, 2011).

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CHAPTER 4

METHODOLOGY

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4.3 ANN Model Development

4.3.1 Gangotri

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4.3.3 NAR model development

ANN modeling has been carried out on multi annual hydrological time series data at three stations on Bhagirathi River and one station on the Ganges River. The methodology in ANN modeling requires proper selection of model inputs and outputs which well represent the hydrological process being studied. Selection of problem representing input and output variables requires a detailed study of time series data of relevant variables and statistical analysis for data trends, structure and correlation. An in depth understanding of the working of ANN is a pre requisite. The sequence of processes involved in ANN modeling and the technique itself, has been described in the present chapter.

4.1 ARTIFICIAL NEURAL NETWORKS: OVERVIEW

A general framework can be followed for ANN modeling based on heuristics and experience. The goal of an ANN is to generalize a relationship of the form

$$Y = f(X)$$

where X is an n-dimensional input vector with variables $x_1,\ldots,x_n$ and Y is an m-dimensional output vector consisting of resulting variables of interest $y_1,\ldots..,y_m$. In hydrology, the values of x can be casual variables (ASCE, 2000a) like rainfall, temperature, previous flows, water levels, spatial locations, evaporation, basin area, elevation, slope, contaminant loads and so on. The values of y can be hydrological responses like runoff, stream flow, ordinates of a hydrograph, hydraulic conductivity, contaminant concentration etc. Although there are no fixed rules for developing an ANN, a general framework for its design is given in (ASCE, 2000a).

ANN is a flexible mathematical structure having an inter-connected assembly of simple processing elements or nodes, which emulates the functioning of neurons in the human brain. It is a massively parallel distributed processor made up of simple processing units, which has a natural propensity for storing information and making it available for use (Haykin, 1999). It has many distinct advantages and possesses the capability of representing the arbitrary complex non-linear relationship between the input and the output of any system. Mathematically, an ANN can be treated as a universal approximator having an ability to learn from examples without the need of explicit physics (ASCE, 2000a, b). ANN predicts the output of a process by training with a set of known inputs and outputs whereby it ‘learns’ and extracts the relationship between the inputs and outputs. It then tries to bring the predicted output closer to the observed by an internal network adjustment. The ANN functions as a data-mining tool, in which the input and output data set has to be fed to the software and trained before validating the model. The history of Artificial Neural Networks began in 1943 when the authors Warren McCulloch and Walter Pitts proposed a simple artificial model of the neuron. Their model, in a slightly modified and improved form, is what most Artificial Neural Networks are based on to this day. A law explaining the learning of a network of neurons was proposed by Hebb, 1949. The first ANN, namely the perceptron, was created by Rosenblatt, 1958, and it consisted of neurons arranged within one active layer. The research into application of ANN has blossomed since the introduction of the back propagation training algorithm for feed forward ANN in 1986 (Rumelhart, 1986). In recent years, Artificial Neural Networks (ANN) have become extremely popular for prediction and forecasting in a number of areas, including finance, power generation, medicine, water resources and environmental science. A review of ANN application to hydrology is presented in ASCE (2000b). ANN have been used by researchers for rainfall-runoff modeling, stream-flow prediction, groundwater modeling, water quality, water management, precipitation forecasting, time series, reservoir operations etc.

4.1.1 Structure of ANN

A Typical ANN consists of several nodes or artificial neurons arranged in layers, where information processing takes place (Figure 4.1). Signals are passed between nodes through connection links. Each connection link has an associated weight that represents its connection strength and each node applies a non-linear transformation called an activation function to its net input to determine its output signal.

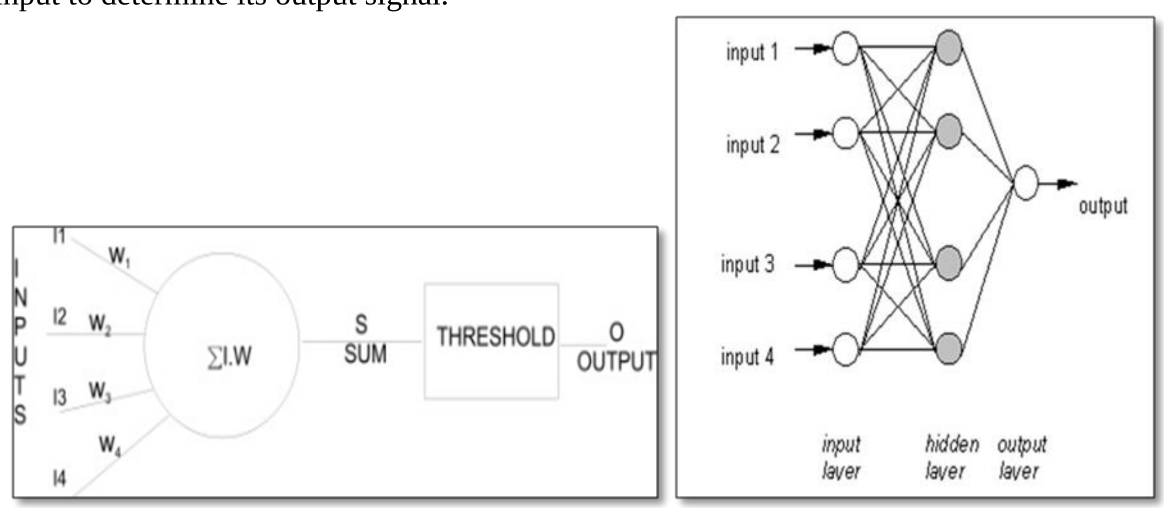


Figure 4.1 (Left) A typical artificial neuron and (right) a three layered ANN.

In typical three layer feed forward networks [which have also been used in the present work], very commonly used by researchers, nodes or artificial neurons are arranged in three layers, an Input layer where the data is introduced to the network; a hidden layer where data is processed and an output layer where results are produced (Tokar et al., 1999). The inputs to the neuron, represented by X, are weighted by a factor which represents the strength of the signal/synaptic connection, represented by W, the Synaptic Weight. The sum of these inputs and their weights is called the activity or activation of the neuron. The output variable is thus given by,

$$\mathrm{Y(x)} = g\left(\sum_{i=0}^{n} Wi\ Xi\right)$$

where, the activation parameter, g, could be a simple binary threshold function like

$$g(x) = \begin{cases} 1 & if\ x+t > 0 \\ 0 & if\ x+t \leq 0 \end{cases} \quad \text{or}$$

a non linear sigmoid function like

$$g(x) = \frac{1}{1+e^{-2s\,(x+t)}}$$

which is a continuous transformation function (Figure 4.2), producing an output between zero and one making the network more flexible.

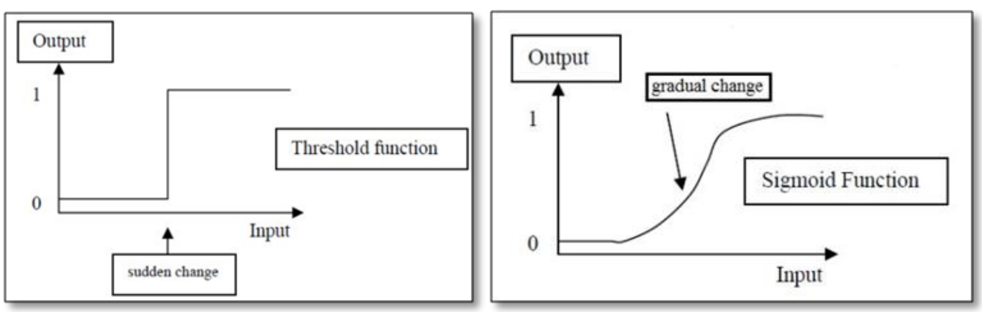


Figure 4.2 (Left) A simple binary threshold function and (right) a non-linear sigmoidal transfer function.

Here, t is the value that pushes the centre of the activation function away from zero and s is a steepness parameter. The role and need of ***bias*** in ANN is usually not mentioned clearly in literature. The bias neuron lies in one layer, is connected to all the neurons in the next layer, but none in the previous layer and it always emits 1. It is known that for the network to 'learn', the weights are adjusted. Since the bias neuron emits 1, the weights, connected to the bias neuron, are added directly to the combined sum of the other weights. The bias neuron simply shifts the activation function to the left or right (Figure 4.3).

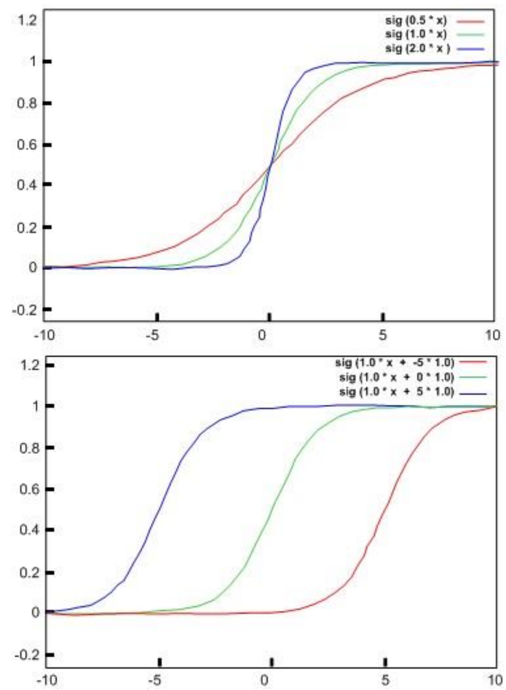


Figure 4.3 The sigmoid curve (above) without and (below) with bias

4.1.2 Types of ANN

ANN can be classified on the basis of number of layers present. The simplest form of an ANN is the single-layer network (Hopfield nets). They possess recurrent connectivity, short term memory and a dynamic behaviour. There are bilayer networks (Carpenter/ Grossberg Adaptive Resonance Networks) and Multi-layer networks (most networks using Back propagation) consisting of an input, output and a hidden layer, the concept arising only after the discovery of back propagation (Figure 3.4)

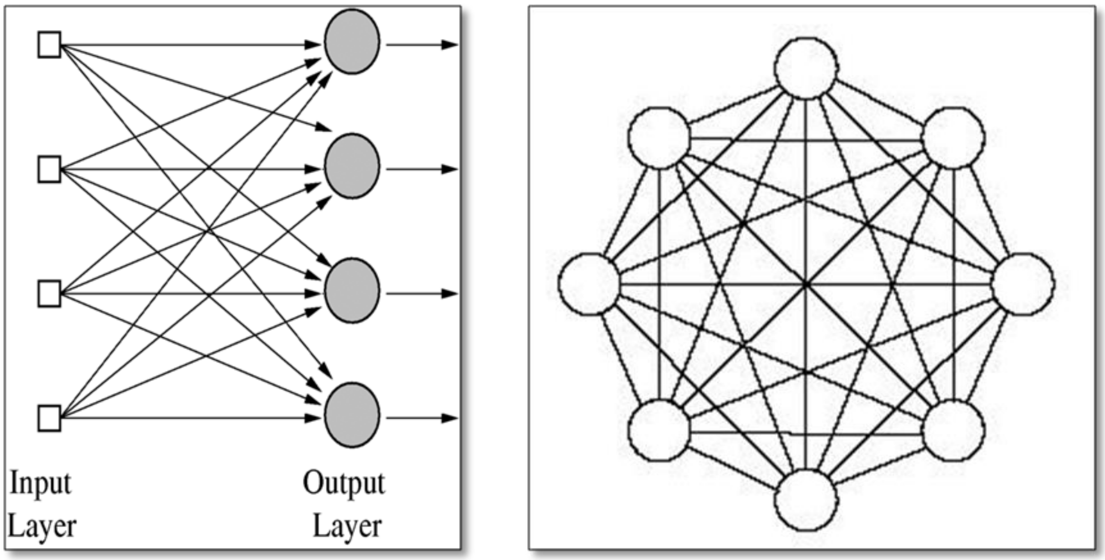


Figure 4.4 (Left) A bilayer neural network and (right) A Hopfield Network.

ANN can also be categorized based on the direction of information flow and processing. In a feed-forward network, the nodes are generally arranged in layers, starting from a first input layer and ending at a final output layer. There can be several hidden layers each having one or more nodes. Information passes from the input to the output side. The nodes in one layer are connected to all nodes in the next layer but not to those in the same layer. Thus, the output of a node in a layer is only dependent on the inputs it receives from the previous layer and the associated synaptic weights. On the other hand, in a recurrent ANN, information flows from the nodes in both the directions, from the input side to the output and vice-versa.

4.1.3 Modeling Requisites

4.1.3.1 Selection of proper input and output variables

A good understanding of the hydrologic system under consideration is a prerequisite for successful application of ANN. For instance, physical insight into the problem being studied can lead to better choice of input variables for proper mapping. This will help in avoiding loss of information that may result if key input variables are omitted and also prevent inclusion of wrong inputs that tend to confuse the training process. A sensitivity analysis can be used to determine the relative importance of a variable when sufficient data is available (Maier and Dandy, 1996).

4.1.3.2 Determination of optimal ANN architecture

This includes selection of appropriate number of input and output nodes and selecting a proper algorithm for training. Minimal network can offer better generalized performance than more complex networks (Rumelhart et al., 1994). The number of neurons in the input-output layer is defined by the problem. The flexibility lies in selecting the number of hidden layers and in assigning the number of nodes to each of these layers. A trial-and-error method is usually applied to decide the optimal architecture.

4.1.3.3 Data normalization

The data needs to be normalized before being applied to an ANN. The applications involving use of ANN have stressed the importance of scaling the input/output quantities before presenting them to the network. For problems exhibiting high non-linearity, the variables are scaled between range of (0,1) or some other suitable range. This kind of scaling tends to smooth the solution space and averages out some of the noise effects (ASCE 2000 a).

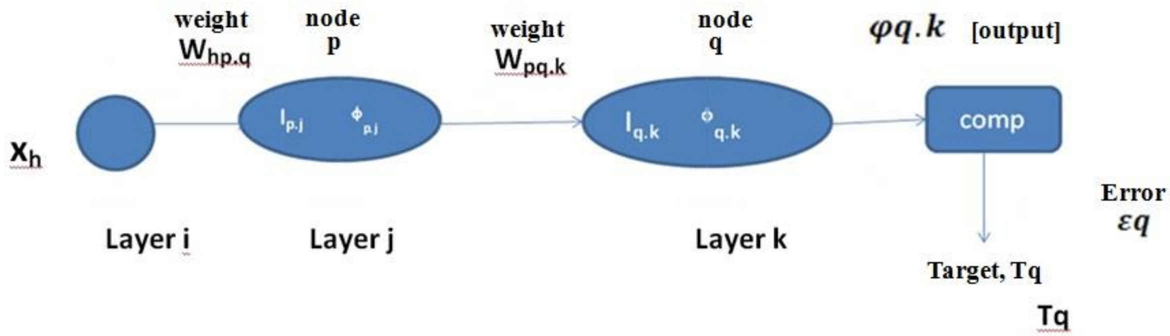
4.1.3.4 Training the network

The main objective of training is to produce desired set of outputs when a set of inputs is given to the ANN. The available data set is partitioned into training and testing data sets. It is important that the training dataset should contain sufficient patterns so that the network can mimic the underlying relationship between input and output variables adequately. Each pass through the training data is called an epoch and during training process the ANN learns through overall change in weights accumulated over many epochs. Finally the optimal weight matrices and bias vectors are found which minimize a predetermined error function, such as sum of squares of errors (Bishop, 1994). After proper training is accomplished, the ANN generates reasonable results given unknown inputs. The training process is stopped when no appreciable change in the values associated with the connection links is observed or some termination criterion is satisfied. However, there is a danger of overtraining a network in this fashion, which is also termed as over-fitting. This happens when the network parameters are too fine-tuned to the training dataset. The network, in the process of trying to learn the underlying rule, has started to fit the noise component of the dataset. When this happens, the network performs very well during training, but fails to generalize when given an unknown input. To prevent this, help of the testing dataset is taken to stop the training when the network begins to over-train. Initially, error for both the training and testing dataset reduces. After an optimal amount of training has been achieved, the error for the training set continues to decrease, but that for the testing dataset begins to rise. This is an indication that further training may result in over-fitting the training data by a network. The training is stopped at this time, and the set of weights are assumed to be optimal (ASCE, 2000a). The ANN is now ready to be used as a predictive tool.

4.1.3.5 Network Creation and Training with Feed Forward Back Propagation Algorithm

Training is a process by which the connection weights are adapted through a continuous process of stimulation by the environment in which the network is embedded. The primary goal of training is to minimize the error function by searching for a set of connection strengths and threshold values that cause the ANN to produce outputs that are close or equal to targets. This can be achieved by adjusting the number of layers, the number of nodes and the pattern of connections. The manner in which the nodes of an ANN are structured is closely related to the algorithm used to train it. In training with back propagation algorithm an ANN is built with chosen inputs, hidden and output units and the weights are generated randomly. A training pair is chosen from the training set and inputs are applied. Network output is calculated and then the error, difference between computed network output and observed output. The summed products of weights and errors in the output layer are back propagated into the network to calculate error on hidden units. Weights are updated into each unit until the error is sufficiently low. The process is repeated till error is acceptably low.

The illustration below shows updation of weights in the output layer of a three layered network with i,j and k layers and associated nodes p and q. Weights,W, associated with a particular layer and node have been given superscripts. Φ is the transfer/activation sigmoid function associated with the particular node. So,



Summation of weighted inputs I,

$$I = \sum_{i=1}^{n} Xi.Wi \qquad \text{------1}$$

Sigmoidal function,

$$\phi I = \frac{1}{1+e^{-\alpha I}} \qquad \text{------2}$$

Differentiating, with respect to ϕI,

$$\partial \phi I / \phi I = \alpha(1-\phi)\phi \qquad \text{------3}$$

Error, difference of computed output from observed,

$$\varepsilon = \varepsilon_q = (T_q - \phi_{q.k}) \qquad \text{------4}$$

Squaring,

$$\varepsilon^2 = \varepsilon_q^2 = (T_q - \phi_{q.k})^2 \qquad \text{-------5}$$

Delta Rule- The change in weight, ΔW, is propotional to the rate of change of squared error w.r.t. weight.

$$\Delta W_{pq.k} = -\eta_{p.q} \cdot \frac{\partial \varepsilon_q^2}{\partial W_{pq.k}} \qquad \text{-------6}$$

$$\frac{\partial \varepsilon_q^2}{\partial W_{pq.k}} = \frac{\partial \varepsilon_q^2}{\partial \phi_{q.k}} \cdot \frac{\partial \phi_{q.k}}{\phi I_{q.k}} \cdot \frac{\phi I_{q.k}}{\partial W_{pq.k}} \qquad \text{--------7}$$

$$= -\delta_{pq.k} \cdot \phi_{p.j} \qquad \text{--------8}$$

Where,

$$\delta_{pq.k} = 2\varepsilon . \frac{\partial \phi_{q.k}}{\partial I_{q.k}} \qquad \text{--------9}$$

Substituting 8 in 6,

$$\Delta W_{pq.k} = -\eta_{p.q} \cdot \delta_{pq.k} \cdot \phi_{p.j}$$

and

$$W_{pq.k}(N+1) = W_{pq.k}(N) - \eta_{p.q} \cdot \delta_{pq.k} \cdot \phi_{p.j}$$

'N' being the number of iterations involved. Error term is used to adjust weights of output layer and it is propagated back through the network. This process is repeated till the error is acceptably low. Once the model is validated, it can be tested to predict the output for any given input.

4.1.3.6 Performance Evaluation Criteria

There exists a wide array of numerical performance indicators used in hydrological studies. Some of the important and commonly used criteria for performance evaluation are-

(1) Coefficient of Determination

It is used to measure the degree of association between observed and model estimated values of output variable and is given by

$$R^2 = \frac{\sum (Q_i - \overline{Q})^2 - \sum (Q_i - \hat{Q}_i)^2}{\sum (Q_i - \overline{Q})^2}$$

Where R^2 is the coefficient of determination, Q_i are the observed values, $\overline{Q}$ is the mean of the observed values and $\hat{Q}$ are the estimated values by the model. The first term in the numerator is called the initial variation whereas the second term in the numerator is called the residual or unexplained variation. High value of R^2 indicates good model result whereas a low value denotes otherwise but it does not indicate existence of systematic errors.

(2) Coefficient of Efficiency

This coefficient is also known as Nash-Sutcliffe coefficient of efficiency. It is analogous to the coefficient of determination in linear regression but not identical. It gives the proportion of variance of the observation accounted for by the model. It is given by

$$E^2 = \frac{F_0 - F}{F_0}$$

where,

$$F_0 = \sum(Q - \overline{Q})^2; \overline{Q} = \frac{1}{N}\sum_{i=1}^{N} Q_i$$

$$F = \sum(Q_i - \hat{Q}_i)^2$$

F_0 = Measure of variability of observed values and their mean i.e. the crudest possible prediction

F = Measure of association between predicted and observed flows or an index of residual error which reflects the extent to which a model is successful in reproducing the observed discharges.

In training the E_2 is identical to R_2 and varies between zero and one. In testing period the value of $\overline{Q}$ used is still the mean of training period i.e. the initial variance is calculated as the sum of squares of deviations in testing period from the mean of training period, because the E_2 criterion expresses a comparison of model prediction with the no model situation. The only forecast which could be made for testing period is the mean value of discharges in training period. E_2 may take negative values in validation. This coefficient can be used for comparing the relative performances of different models. For example

$$e^2 = \frac{F_1 - F_2}{F_1}$$

In this equation, F_1 is the initial variance unaccounted for by model 1, which is subsequently accounted for by model 2, the initial variance of which is F_2.

(3) **Mean Square Error (MSE):** It measures the residual variance. The optimal value for this is zero. It is computed as (notations carry the same meaning)-

$$mse = \frac{1}{N}\sum_{i=1}^{N}(Q_i - \hat{Q}_{1)})^2$$

(4) **Percentage of Volume error (VE):** It measures the percent error in volume under the observed and simulated hydrograph/sedimentograph, summed over the data period. Ideal value for this parameter is zero. A positive value indicated underestimation and negative value indicates overestimation. It is calculated as follows-

$$VE(\%) = \frac{(\sum Q_i - \sum \hat{Q})}{\sum Q_i} X100$$

(5) Magnitude and Time to Peak- The magnitude and time to peak of the hydrograph/sedimentograph are also important criteria and are widely used.

Based on all or some of these criteria, the modeling performance is quantitatively evaluated. These are further substantiated by regression/scatter plots between observed (or target) and predicted (or computed) values. Linear graphs, error autocorrelation plots etc are also created for graphical representation of model performance.

4.1.3.7 Merits and Demerits of ANN

ANN have an advantage over deterministic models as- the data needs are usually less and they are well suited for long-term forecasting, they have the ability to mimic non-linear processes even with noisy data, their adaptivity in nonstationary environments etc. There are three primary situations where ANN are advantageous- (1) Situations where only a few decisions are required to be taken from a massive amount of data, (2) Situations where non-linear mapping is automatically required, (3) Situations where a near optimal solution to an optimization problem is required very quickly. However, disadvantage of the ANN is that it is based on a ‘black box’ approach since the internal structure of the model is generally not known and must be developed by a trial and error process. Also, there is no standardized way of selecting network architecture. The commonly face problems with back propagation algorithm are long, ambiguous training process, local minima, moving target and network paralysis (Nagesh Kumar, 2004).

4.2 DATA DESCRIPTION AND ANALYSIS

4.2.1 Gangotri

Daily Temperature(T), Rainfall(R) and Discharge(Q) data of the melt period (May – October) of five years, from the year 2000-2004 {Data source Haritashya 2005} at a location two km downstream from the snout of the Gangotri glacier has been used for modeling sediment concentration. Besides prediction, this study would also give better insight into dependencies of variables in an area where anthropogenic controlling factors are negligible or rather absent. The dependence patterns of sediment concentration with discharge, rainfall and temperature have been studied in detail by Haritashya et al, 2006; P. Singh et al, 2006, with the help of variation diagrams and other statistical plots. In these studies, it has been observed that, a majority of sediment is transported in the period of July to August due to intensive melting and sediment availability. In the months of May and June, the area of melting is low which leads to relatively lesser sediment load. From September to October, although melting is substantial, the sediment load is again low as most of it has been flushed out in the preceding months. The occurrence of rainstorms has a significant impact on glacier runoff as well as the sediment flux. Heavy rain occurring for short durations influences the increase of sediment in melt water more than the increase in melt runoff (Tempany and Grist, 1958). Sediment availability during rainstorms is also necessary for higher sediment loads. Rainstorms during earlier part of melt period release more sediment due to its availability whereas in the later part of melt period rainstorms do not release much sediment as most of it has already been flushed earlier. The relationship between mean monthly Suspended sediment concentration (SSC) and discharge (R^2= 0.99) is much better than the daily SSC and discharge (R^2= 0.40) because variability of both parameters is averaged-out on monthly scale. Mean monthly SSC and mean monthly SSL provide a good exponential relationship with mean monthly air temperature. These results are relevant for planning and management of water resources in the high altitude areas and for designing hydropower projects (Haritashya et al., 2006). The variation of Temperature, Rainfall, Discharge and Sediment concentration during the melt period for five years, 2000-2004, has been shown in the line graphs below.

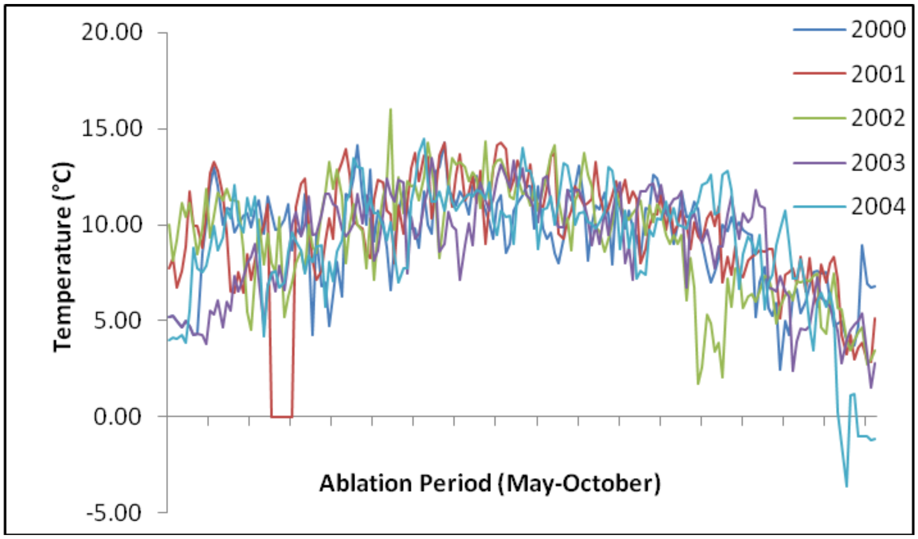


Figure 4.5a Variation in Temperature data at Gangotri over five melt periods (2000-2004)

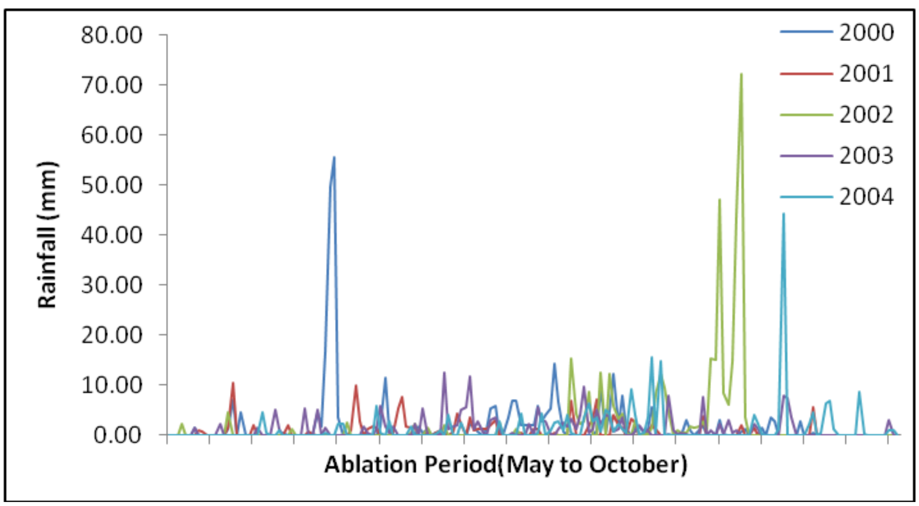


Figure 4.5b- Variation in Rainfall data at Gangotri over five melt periods (2000-2004)

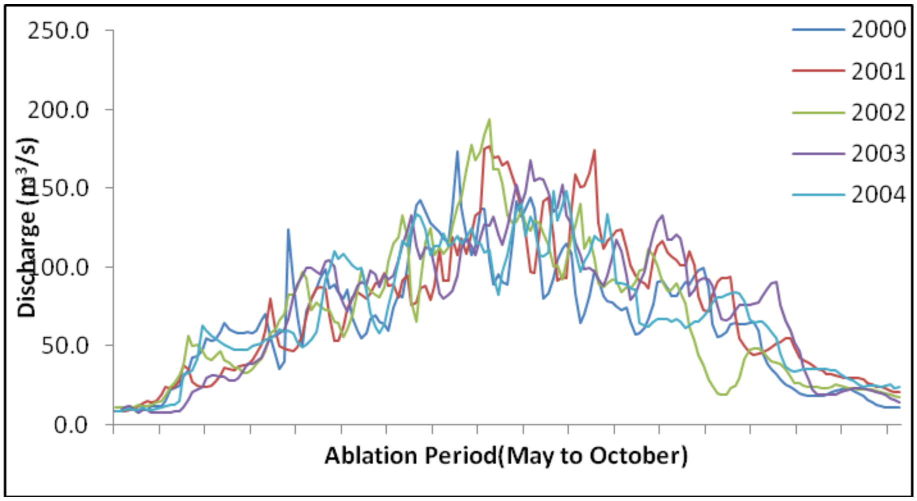


Figure-4.5c Variation in Discharge data at Gangotri over five melt periods (2000-2004)

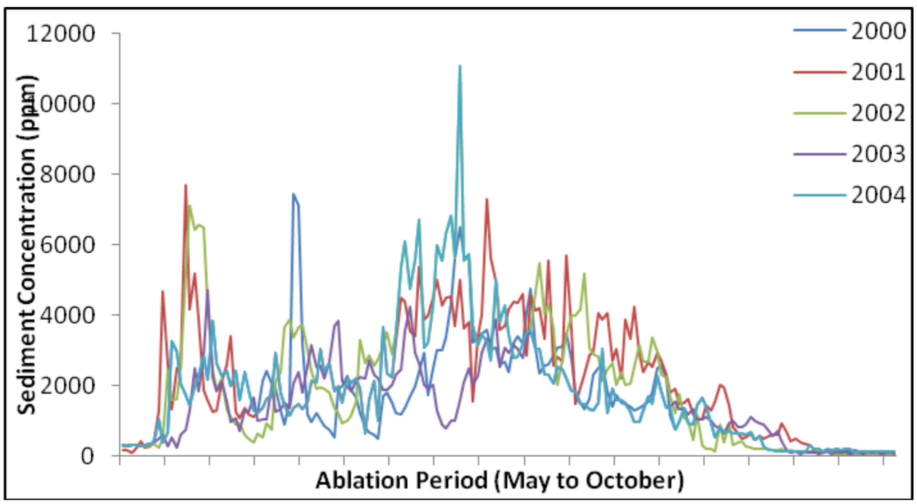


Figure 4.5d Variation in Sediment conc. data at Gangotri over five melt periods (2000-2004)

Basic statistical analysis of the data was carried out to bring out internal structure of the data. A maximum temperature of 16 ^{0}C on 24.06.2002 has been observed on and a minimum temperature value of -3.60 ^{0}C has been observed on 13.10.2004. Rainfall data shows maximum value of 72.2 mm on 13.09.2002 and minimum value of 0 mm has been observed on several days with nil rainfall. Discharge data shows a maximum value of 193.5m^3/s on 22.07.2002 and minimum value of 8 m^3/s on 06.05.2000, 06.05.2003 and 09.05.2003. Sediment concentration values vary from a high of 11093 ppm in 15.07.2004 to a low of 70 ppm three times in October 2003. Statistical parameters like mean, median, mode, standard deviation and skewness have been used to study the data shape, symmetry and dispersion (Table-4.1).

The mean, median and mode values for TSM are quite apart from each other, suggesting that the data is not normally distributed. Standard Deviation values are high for all variables, signifying that the data is dispersed and not centred around the mean. Skewness value is positive for all except Temperature meaning that the data is non-symmetrical and skewed to the right of the mean. kurtosis values less than three suggest a Platykurtic or flat distribution where most values are not concentrated around the mean, however for Temperature, this does not hold true. The result of this simple analysis can be well corroborated with the highly variable flow during monsoon period.

Table 4.1- Descriptive Statistics for Variables used at Gangotri

	TSM (ppm)	**Discharge (m^3/s)**	**Rainfall (mm)**	**Temp (^0C)**
Mean	1911.31	71.38	1.46	9.28
Standard Error	54.76	1.41	0.17	0.10
Median	1590	70	0	9.9
Mode	130	23.2	0	10.75
Std Deviation	1610.66	41.39	4.96	2.80
Sample Variance	2594221	1712	24.63	7.86
Kurtosis	2.72	-0.75	93.50	0.32
Skewness	1.30	0.29	8.63	-0.76
Range	11023	185.50	72.2	16
Minimum	70	8	0	-3.60
Maximum	11093	193.5	72.2	16
Sum	1653283	61746	1262	8026
Count	865	865	865	865

4.2.2 Maneri

High frequency (daily and three-hourly) time series data for water discharge and sediment concentration during the high activity monsoon period of June to October of the year 2004 has been used for modeling. Daily and three-hourly discharge and sediment concentration data covering the monsoon period from Maneri, Uttarkashi was made available by Uttaranchal Jal

Vidhut Nigam Limited (UJVNL). Basic statistical analysis of the data was carried out to bring out internal structure of the data such as trend, variation and autocorrelation. Water Discharge data shows a maximum value of 45011 km^3/s in the month of August and minimum value of 4432 km^3/s during late October. Sediment Concentration values vary from a high of 3329 mg/L in August to a low of 35 mg/L in late October. Statistical parameters like mean, median, mode, standard deviation and skewness have been used to study the data shape, symmetry and dispersion (Table-4.2). The mean, median and mode values in both cases are far apart from each other, suggesting that the data is not normally distributed. Standard Deviation values are high for both variables, signifying that the data is dispersed and not centered around the mean. Skewness value is positive in both cases meaning that the data is non-symmetrical and skewed to the right of the mean. kurtosis values less than three suggest a Platykurtic or flat distribution where most values are not concentrated around the mean. The result of this simple analysis can be well corroborated with the highly variable flow during monsoon period. Another interesting characteristic of time series data is autocorrelation. A strong correlation of the series with its own past and future values can be seen in the present data. It has been observed in the line graph (Figure 4.6) that positive discharge values follow positive discharge values and vice versa. The scatter plot (inset, Figure 3.6) between Discharge and sediment concentration shows a high degree of association between them. It can be easily observed from the data that both the values acme at the same time in the month of August and their low values too, correlate well in time. This clearly tells that the two variables are intimately related with each other.

Table 4.2- Descriptive Statistics for discharge [Q km^3/s] and sediment conc. [S mg/L] at Maneri

	Mean	**Std Error**	**Median**	**Mode**	**Std Dev**	**Kurtosis**	**Skewness**	**Range**	**Min**	**Max**	**Count**
Q	16584	814	14970	5910	10037	-1	1	40579	4432	45011	152
S	1028	65	936	138	796	0	1	3294	35	3329	152

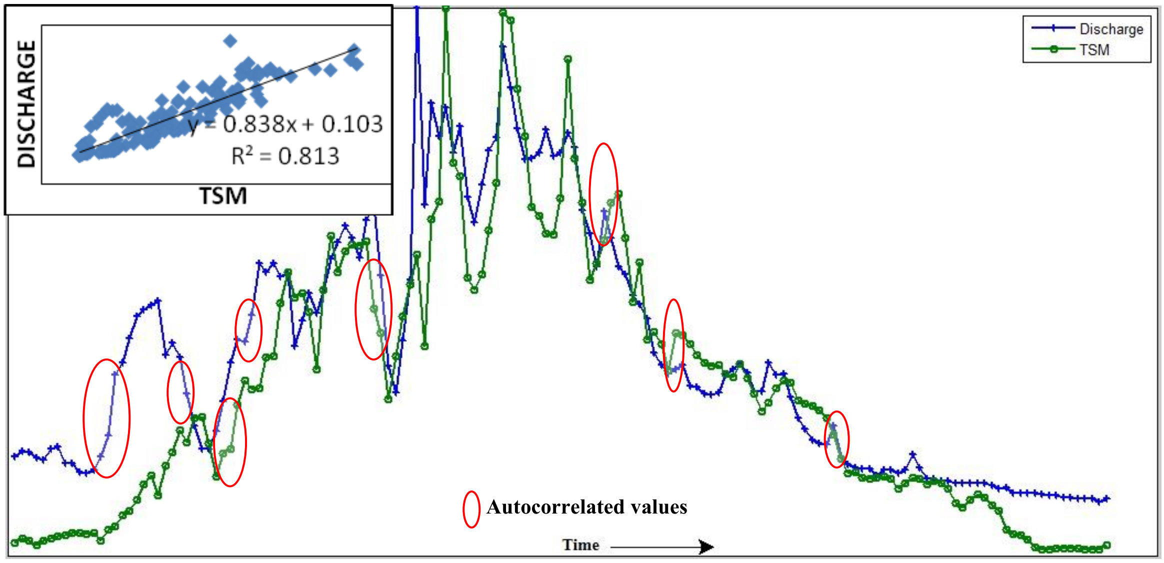


Figure 4.6- Line graph for daily Water Discharge and Sediment Concentration(TSM) variation from June-October 2004. Inset- Scatter plot showing relationship between Water Discharge and Sediment Concentration

4.2.3 Discharge data for single series modeling

Daily discharge data for six years from 1st April 2008 to 31st March 2014 at three locations viz. Maneri, Uttarkashi and Rishikesh were obtained from UJVNL. While Maneri and Uttarkashi are located on the Bhagirathi River, Rishikesh is located further downstream on the Ganges, much after the confluence of Bhagirathi and Alaknanda Rivers. Beyond Rishikesh, the River emerges from the narrow valley confines and widens its channels. The discharge seen at Rishikesh, is therefore, the discharges of Bhagirathi and Alaknanda Rivers combined. The area of cross-section of the channel at Rishikesh is also much larger resulting in greater discharges.

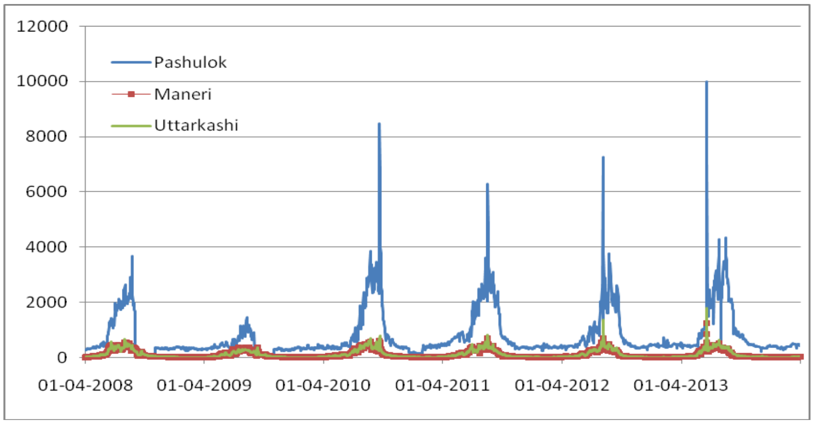


Figure 4.7- Line graph for daily Water Discharge (m^3/s) variation from April 2008-March 2014 [six water years].

The highest discharge at all the three locations has been observed on 17.06.2013, which coincides with the period when the Kedarnath floods took place in the state. The low discharge values are observed in April (at Maneri and Uttarkashi) and in October (at Rishikesh). The lowest discharge value at Rishikesh is nearly 2.5 times higher than the value at Maneri and Uttarkashi. The descriptive statistics show the data range, shape, structure and dispersion.

Table-4.3 Descriptive Statistics for Discharge at Maneri, Uttarkashi and Rishikesh

Parameter	Maneri	Uttarkashi	Rishikesh
Mean	121	137	798
Std. Error	3	3	18
Median	53	62	447
Mode	27	31	400
Std. Dev.	130	148	842
Variance	17006	21847	709266
Kurtosis	4	11	16
Skewness	2	2	3
Range	1228	1764	9948
Minimum	19	23	52
Maximum	1247	1786	10000
Sum	264185	299317	1748676
Count	2191	2191	2191

4.3 ANN MODEL DEVELOPMENT

4.3.1 Gangotri

The present study explores for the first time, the possibility of modeling sediment concentration with Artificial Neural Networks at Gangotri, the source of Bhagirathi River in the Himalaya. Considering discharge, rainfall and temperature to be the main controlling factors of variations in sediment concentration in the dynamic glacial environment of Gangotri, seven ANN models using Feed Forward Back Propagation algorithm with different inputs have been created, trained and tested for prediction of sediment concentration in the non-updating mode where previous time-step values have not been used as input to the model. The inputs applied in the models are either the variables mentioned above as independent factors or a combination of them. The suitability of employing previous time-step values as network inputs has also been checked by creating seven corresponding models in the updating mode. Daily data of discharge, rainfall, temperature and sediment concentration for the melt period of May-October, when maximum sediment movement takes place, for five years, from the year 2000 to 2004, has been used for modeling.

The study area presents an ideal environment where maximum transport of water and sediment takes place during the ablation/melt period (May to October) due to high rates of weathering with minimal influence of anthropogenic activities. A lot of geo-hydrological research has been carried out in and around Gangotri. The factors responsible for variations in suspended sediment concentration and transport have been deftly discussed by Hasnain, 1996, Barnard et al., 2004, have made use of cosmogenic radionuclides to date glacial geomorphic features thereby discussing the timing and style of sedimentation and de-sedimentation processes as a response to landscape adjustment with changing environmental conditions in the monsoon influenced dynamic glacial environment of Gangotri. Voluminous work has been carried out by Singh et al., 2005, 2006, on the hydrological characteristics of Gangotri glacier by studying the diurnal variations in suspended sediment load to understand the melt-runoff delays. Haritashya et al., 2006, 2010 have carried out particle size distribution and studied the inter-relationships of hydrological variables at Gangotri thus explaining the sediment delivery and evacuation patterns in the light of water resource planning and management. V.B. Singh et al., 2014, have studied the seasonal variation in solute and suspended sediment load to bring out the role of geochemical weathering processes in controlling melt water chemistry at Gangotri. The possibility of modeling sediment concentration in a high altitude glacial environment of the Himalaya has not been explored so far.

The statistical analysis of Gangotri data performed by earlier workers shows that there is an inherent trend in time series river flow data, despite the uncertainties, which makes it predictable. To understand these distribution patterns, seven Artificial Neural Networks were created using the Neural Network Time Series application and neural network tool in MATLAB (R2013a) routines to model the hydrologic flow process at Gangotri, the source of Bhagirathi River. Seven networks (T1-T7) were trained in the non-updating mode with independent (Q or R or T) as well as combination (Q, R or R, T or Q, T or Q, R, T) of inputs. The non updating mode refers to the modeling scenario in which previous time-step values of any variable are not used as network inputs. Simultaneously, seven corresponding neural networks were created (T1a-T7a) representing the updating mode i.e. network inputs included values of variables at previous time-step. Training consisted of as many as 865 data and the goodness of fit characteristics of the computed and observed outputs were evaluated. The number of layers remained three in every case and the weights were selected randomly. Gradient Descent with momentum and adaptive learning rate (traingdx) Back Propagation Algorithm using a non-linear log-sigmoidal transfer function in the hidden layer and a pure linear function in the output layer was employed. Training and evaluation subsets were created by dividing the dataset respectively into 70% and 15% of the complete dataset. The training dataset must represent most, if not all, of the variations observed in the data. The data was first trained and configured from time to time by changing training parameters such as no. of inputs, no. of hidden layer neurons, learning rate, no. of iterations etc. 30% of the data was employed for evaluation of the model. It is important to note that the evaluation data is *not* employed during training and is a separate subset of the whole data. The fourteen networks created, employed a combination of variables such as discharge, rainfall and temperature in the updating and no-updating modes. The Sediment concentration values computed/predicted by the model during training and testing were compared with the observed/target values with the help of regression plots and line graphs. The performance of ANN in both the modes was compared.

Table 4.4 Model characteristics for development of ANN models at Gangotri

Model	Input(s)	Output	I-H-O	Net. Type	Training Fn.	Transfer Fn.	No. of Iterations	No. of Data
T-1	Q(t)	S(t)	1-10-1	FFBP	GDX	Logsig	100000	865
T-1a	Q(t),Q(t-1)	S(t)	2-12-1	-do-	-do-	-do-	-do-	-do-
T-2	Q(t),R(t)	S(t)	2-12-1	-do-	-do-	-do-	-do-	-do-
T-2a	Q(t),Q(t-1),R(t),R(t-1)	S(t)	4-12-1	-do-	-do-	-do-	-do-	-do-
T-3	Q(t),R(t),T(t)	S(t)	3-14-1	-do-	-do-	-do-	-do-	-do-
T-3a	Q(t),Q(t-1),R(t),R(t-1),T(t),T(t-1)	S(t)	6-14-1	-do-	-do-	-do-	-do-	-do-
T-4	R(t)	S(t)	1-11-1	-do-	-do-	-do-	-do-	-do-
T-4a	R(t).R(t-1)	S(t)	2-16-1	-do-	-do-	-do-	-do-	-do-
T-5	T(t)	S(t)	1-13-1	-do-	-do-	-do-	-do-	-do-
T-5a	T(t),T(t-1)	S(t)	2-13-1	-do-	-do-	-do-	-do-	-do-
T-6	Q(t),T(t)	S(t)	2-14-1	-do-	-do-	-do-	-do-	-do-
T-6a	Q(t),Q(t-1),T(t),T(t-1)	S(t)	4-14-1	-do-	-do-	-do-	-do-	-do-
T-7	R(t),T(t)	S(t)	2-15-1	-do-	-do-	-do-	-do-	-do-
T-7a	R(t-1),T(t-1)	S(t)	4-15-1	-do-	-do-	-do-	-do-	-do-

Note- S-suspended sediment concentration (mg/L), Q- discharge (m3/s), T-temperature (°C), R-rainfall (mm);(t) - present time-step, (t-1)- one previous/antecedent time-step,2 ; I-H-O-neurons in input-hidden-output layers;FFBP-Feed Forward BackPropagation;GDX-Gradient Descent with adaptive learning rate;Logsig-Logsigmoid

4.3.2 Maneri

After successful application of ANN at Gangotri, the source of Bhagirathi, modeling was carried out at Maneri, a location around 75 km downstream from the source. The study validates the practical capability and usefulness of this tool for simulating complex non-linear real world river system processes in a Himalayan river scenario. Two modeling approaches have been employed in the study- a daily approach and a three hourly approach during the highest activity monsoon period of June to October. The trend of daily time-series data for the period (June 2004-October-2004) was studied and it was observed that the discharge and sediment concentration data correlates with its own past and future values. Exploiting this fact, six ANN models (T1-T6) with different network configurations, were created and trained using Levenberg Marquardt Back Propagation Algorithm in the Matlab routines. Six corresponding networks incorporating three hourly data of the same variables for the same time period were simultaneously created. Employing three hourly data for the same period not just increases data frequency but also the data numbers by almost six times. The networks were configured from time to time by trial and error based on performance. The study not only gives an insight into ANN modeling in the Himalayan River scenario but it also focuses on the importance of understanding a river basin and the factors that affect sediment concentration, before attempting to model it.

In the past, ANN has been generally been applied in modeling geo-hydrological variables using continuous time series data of long durations. In the present work, an attempt has been made to model the daily water discharge- sediment concentration relationship in the Bhagirathi River during the monsoon period of June-October 2004 when the variations in discharge and sediment concentration are maximum. For the same period, simultaneously, ANN models have been developed using high frequency three hourly water discharge and sediment concentration data. This allows us to have a comparative analysis of the modeling response of short duration-daily data on one side and high frequency, three-hourly data for the same duration on the other.

The statistical analysis shows that there is an inherent trend in time series river flow data, notwithstanding the uncertainties. Moreover, an autocorrelated time series is predictable, probabilistically, because future values depend on current and past values. Exploiting this fact, six ANN models (T1-T6) were created using the Neural Network Time Series application in MATLAB (R2013a) to model daily water discharge-sediment concentration relationship at Maneri, in the Bhagirathi River Basin. Six networks were trained with as many as 153 data and the goodness of fit characteristics of the computed and observed outputs were evaluated.

Table 4.5 Model characteristics for development of ANN models at Maneri

Model	Input(s)	Output	I-H-O	Net. Type	Training Fn.	Transfer Fn.	No. of Iterations	Data
T-1	Q(t)	S(t)	1-10-1	FFBP	LM	Logsig	50000	152
T-1a	Q(t)	S(t)	1-12-1	-do-	-do-	-do-	-do-	865
T-2	Q(t),Q(t-1)	S(t)	2-14-1	-do-	-do-	-do-	-do-	152
T-2a	Q(t),Q(t-1)	S(t)	2-12-1	-do-	-do-	-do-	-do-	865
T-3	Q(t),Q(t-1),Q(t-2)	S(t)	3-14-1	-do-	-do-	-do-	-do-	152
T-3a	Q(t),Q(t-1),Q(t-2)	S(t)	3-14-1	-do-	-do-	-do-	-do-	865
T-4	Q(t),Q(t-1),S(t-1)	S(t)	3-20-1	-do-	-do-	-do-	-do-	152
T-4a	Q(t),Q(t-1),S(t-1)	S(t)	3-16-1	-do-	-do-	-do-	-do-	865
T-5	Q(t),Q(t-1),Q(t-2),S(t-1)	S(t)	4-15-1	-do-	-do-	-do-	-do-	152
T-5a	Q(t),Q(t-1),Q(t-2),S(t-1)	S(t)	4-14-1	-do-	-do-	-do-	-do-	865
T-6	Q(t),Q(t-1),Q(t-2),S(t-1),S(t-2)	S(t)	5-13-1	-do-	-do-	-do-	-do-	152
T-6a	Q(t),Q(t-1),Q(t-2),S(t-1),S(t-2)	S(t)	5-14-1	-do-	-do-	-do-	-do-	865

Note- S-suspended sediment concentration (mg/L), Q- discharge (m^3/s); (t) - present time-step, (t-1)-one previous/antecedent time-step,(t-2)-two previous time steps ; I-H-O-neurons in input-hidden-output layers; FFBP-Feed Forward Back Propagation; LM-Levenberg Marquardt ; Logsig- Log sigmoid

Six, corresponding ANN models were created (T1-a to T6-a) using high frequency three-hourly data for the same time-period at the same location. In this approach, the networks were trained with as many as 865 data and the performance was compared with the earlier scenario. The number of layers remained three in every case and the weights were selected randomly.

Levenberg-Marquardt Back Propagation Algorithm using a non-linear log-sigmoidal transfer function in the hidden layer and a pure linear function in the output layer was employed. Training and evaluation subsets were created randomly by dividing the dataset respectively into 70%, 30% of the complete dataset. Since the log-sigmoid transfer function can accept X_{norm} values in the range [0, 1], before modeling, the data was normalized in the range [0.1, 0.9] by the equation: $X_{norm}= 0.1 + 0.8 (X_i/X_{max})$ where X_{norm} is the normalized dimensionless variable, X_i is the observed value of the variable and X_{max} is the maximum value in the data set (Rajurkar et al., 2004).

4.3.3 Non Linear Autoregressive [NAR] model development

Experimental ANN modeling was further carried out using a single variable. The discharge values at three locations viz. Maneri and Uttarkashi on Bhagirathi River and Rishikesh on the Ganges in Uttarakhand were modeled using Artificial Neural Networks (ANN). After successful application of ANN at Gangotri, the source of Bhagirathi and at Maneri, modeling was further carried out with discharge data of these three locations. This study was taken up in order to verify the possibility of modeling a different type of a time series situation where only one series/variable is involved. The future values of a time series y(t) [y= discharge in this case] are predicted only from the past values of that series. This form of prediction is called Nonlinear Autoregressive or NAR and can be written as y(t)= fy(t-1),…., y(t-d)). No companion variable/time series is used in such models.

The trend of daily discharge data for six years from 1st April 2008 to 31st March 2014 at three locations viz. Maneri, Joshiyara and Pashulok were studied and three NAR networks were created for the three locations. The networks were trained using Levenberg Marquardt Back Propagation Algorithm in the Matlab routines. The networks were configured from time to time by trial and error based on performance. The study explores the possibility of modeling with a single variable in the highly complex Himalayan river systems.

Table 4.6 Model characterististics for development of ANN models with NAR

Model	Input(s)	Output	I-H-O Type	Net. Fn.	Training Fn.	Transfer Fn.	No. of Iterations	No. of Data
Maneri	Q(t-1)	Q(t)	1-11-1	FFBP	LM	Logsig	50000	2291
Uttarkashi	Q(t-1)	Q(t)	1-14-1	-do-	-do-	-do-	-do-	2291
Rishikesh	Q(t-1)	Q(t)	1-12-1	-do-	-do-	-do-	-do-	2291

Note :Q- discharge (m^3/s); (t) - present time-step, (t-1)-one previous/antecedent time-step ; I-H-O-neurons in input-hidden-output layers; FFBP-Feed Forward Back Propagation; LM- Levenberg Marquardt ; Logsig- Log sigmoid

4.4 MODEL IMPROVISATION

. The feed forward networks for all the locations were supplemented with NARX (non-linear autoregressive with exogenous input) architecture (Figure 4.8a) to improve the model performance. This involves feeding the estimated output back into the input of the network. As a further improvisation into the model, the estimated output values were replaced with the true output values (because they were available) and fed as a parallel input into the network (Figure 4.8b) during training. This improvisation has two advantages, one, the input to the feed forward network is more accurate and two, the resulting network has a purely feed forward architecture and normal back propagation can be easily applied.

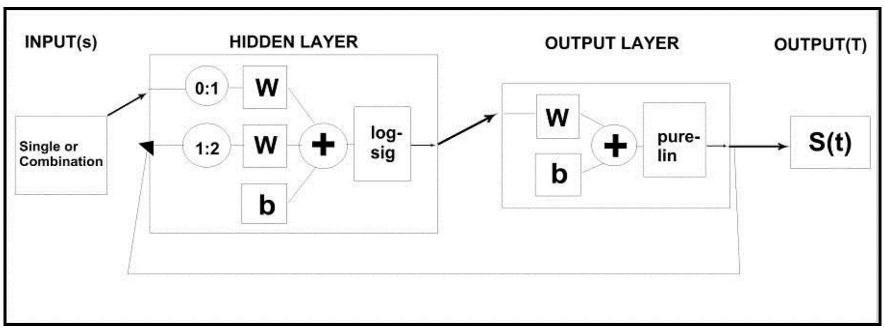


Fig 4.8a- Schematic representation of improvised NARX Network architecture used in training.

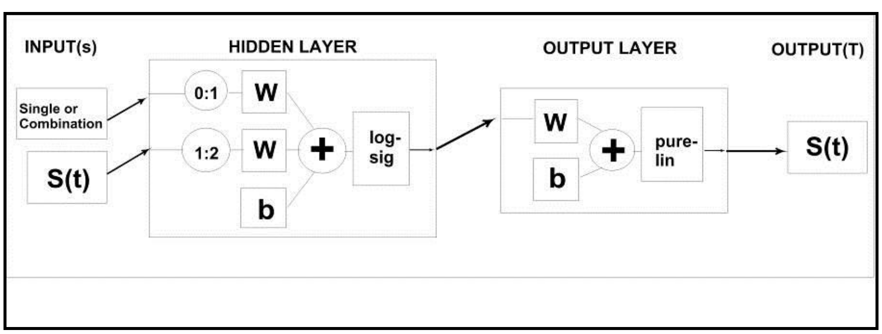


Fig 4.8b Schematic representation of improvised series parallel NARX Network architecture used in training.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

5.1.1 Gangotri

i) Model T-1 and T-1a: A simple one input-one output network representing sediment concentration S at time t, as a function of water discharge, Q was created. i.e. **S(t)= f{Q(t)}**. Previous time step values of discharge were not used as inputs and hence the network was trained in the non-updating mode. A corresponding network T-1a was created in the updating mode in which the previous day's discharge was also included as an input i.e. **S(t)= f{Q(t), Q(t-1)}**. The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.1a).

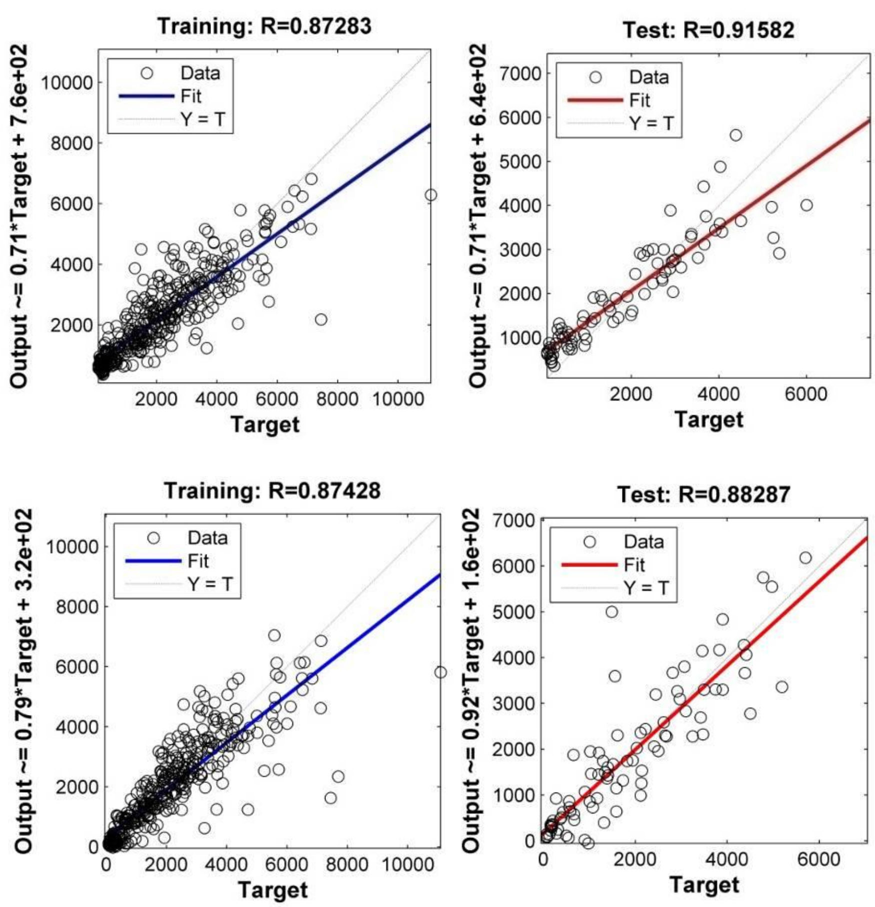


Figure 5.1a- Regression plots for training and testing datasets of model T1 (above) and T1-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

Regression plots have been created for models T1 and T1- a showing results of training and testing. The correlation coefficient obtained during training of models T1 and T1-a are 0.872 and 0.874 respectively. However, correlation coefficients obtained during testing of both the models are 0.915 and 0.882. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

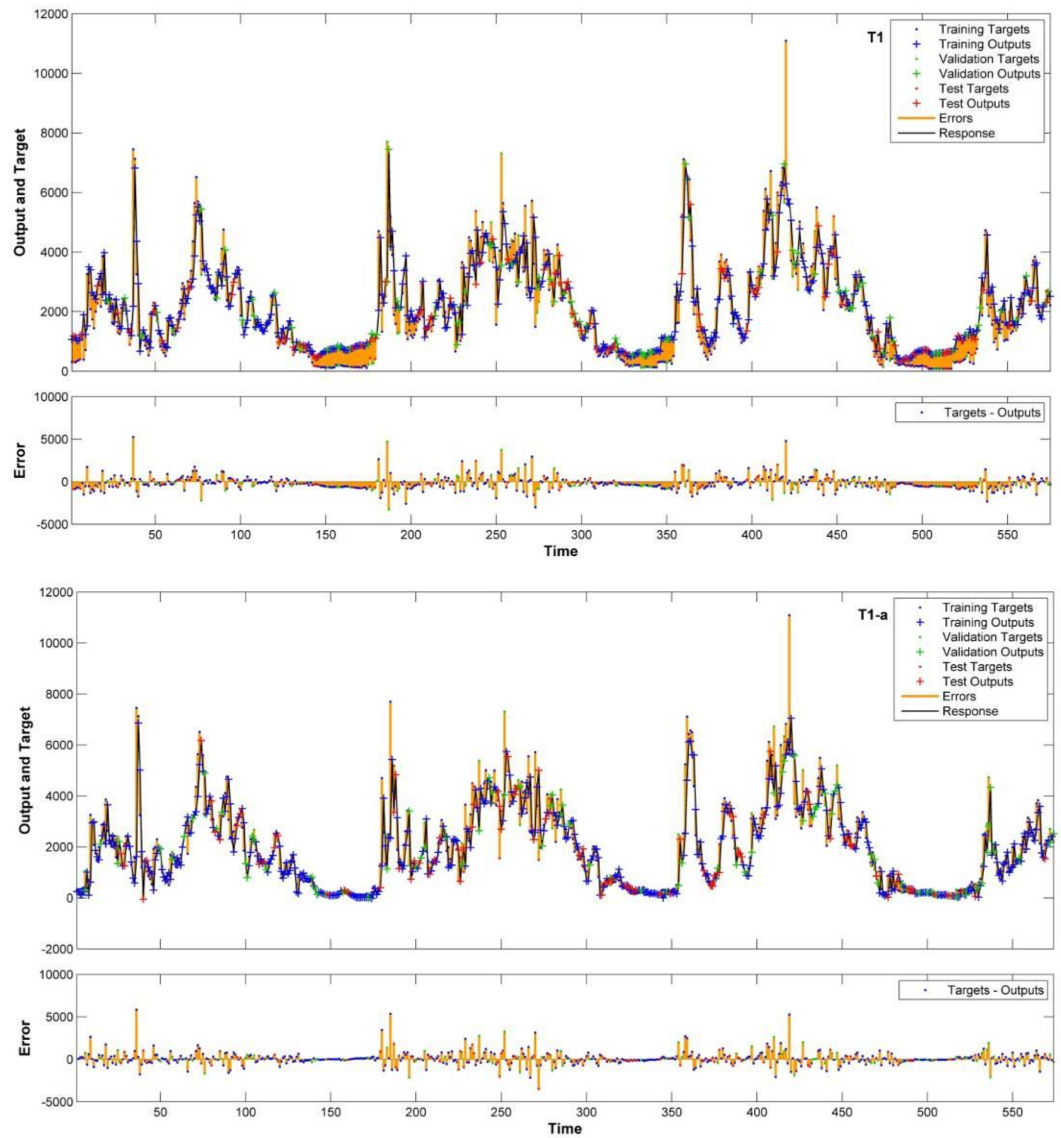


Figure 5.1b- Response of models T1 and T1-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

The response of models T1 and T1-a can be seen in Figure 5.1b where the target and output values have been plotted against time. The entire training dataset is further divided into training, validation and testing subsets. The targets and outputs for training, validation and testing datasets have been plotted against time in the response diagram and the calculated errors, i.e. the difference between targets and outputs have also been plotted against time below the response diagram for both the models. It is clear from the diagram below that the errors, shown in yellow, are greater in model T1 than in model T1-a

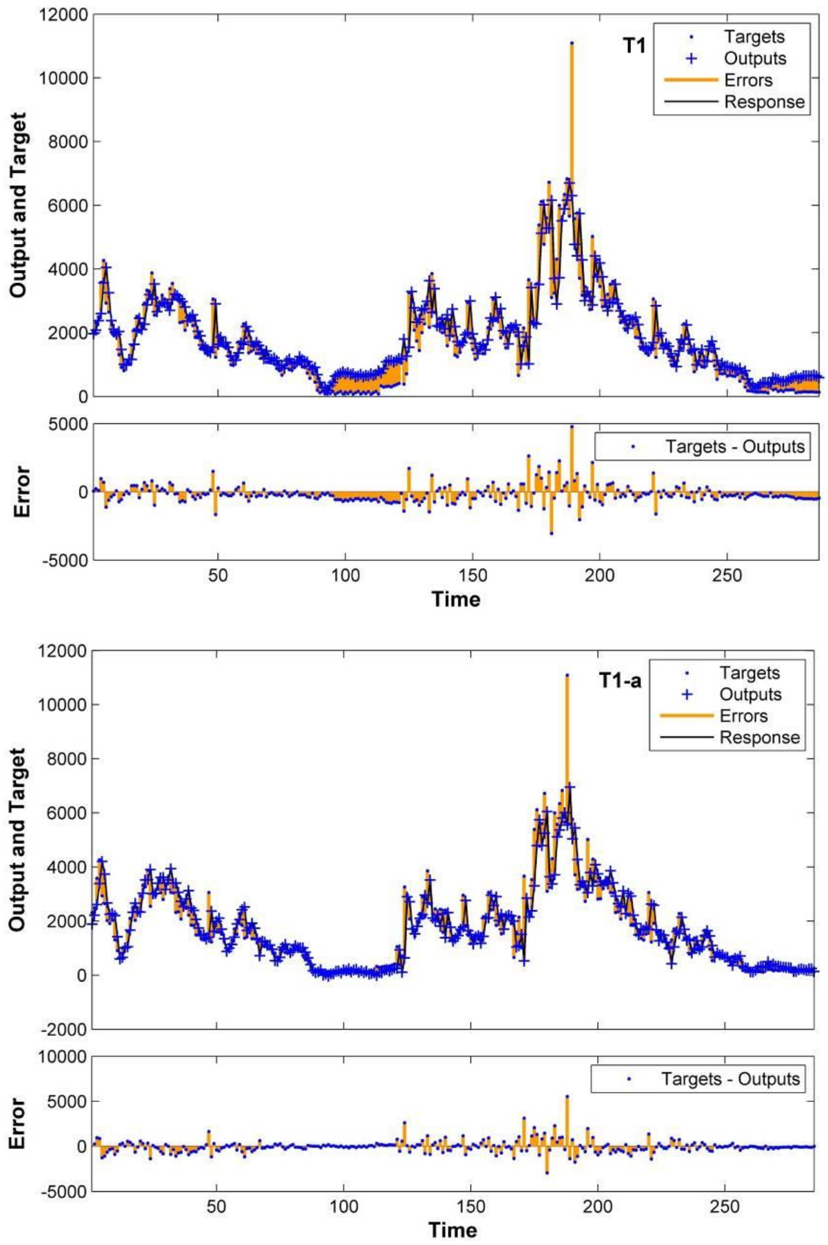


Figure 5.1c- T1 and T1-a Model evaluation at Gangotri- Comparison between target and computed values of sediment concentration along with errors varying with time.

. The performance of the models was further evaluated with the evaluation dataset, which has not been used in the earlier training, validation and testing of models. During evaluation, the outputs are not provided to the model and it predicts the outputs on the basis of relationships ‘learnt’ during training. Evaluation of the models helps in confirming the performance of models.

ii) Model T-2 and T-2a: The sediment concentration as a function of water discharge (in m^3/s) along with rainfall (in mm) at time t was modeled in T2 representing the non-updating mode and the model performance was evaluated. Although the Water discharge as an input remains same, another element i.e. R(t) is added in this model i.e. **S(t)= f{Q(t),R(t)}.** The corresponding network T-2a in updating mode i.e. **S(t)= f{Q(t), Q(t-1),R(t), R(t-1)}** was also simultaneously created and trained. The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.2a).

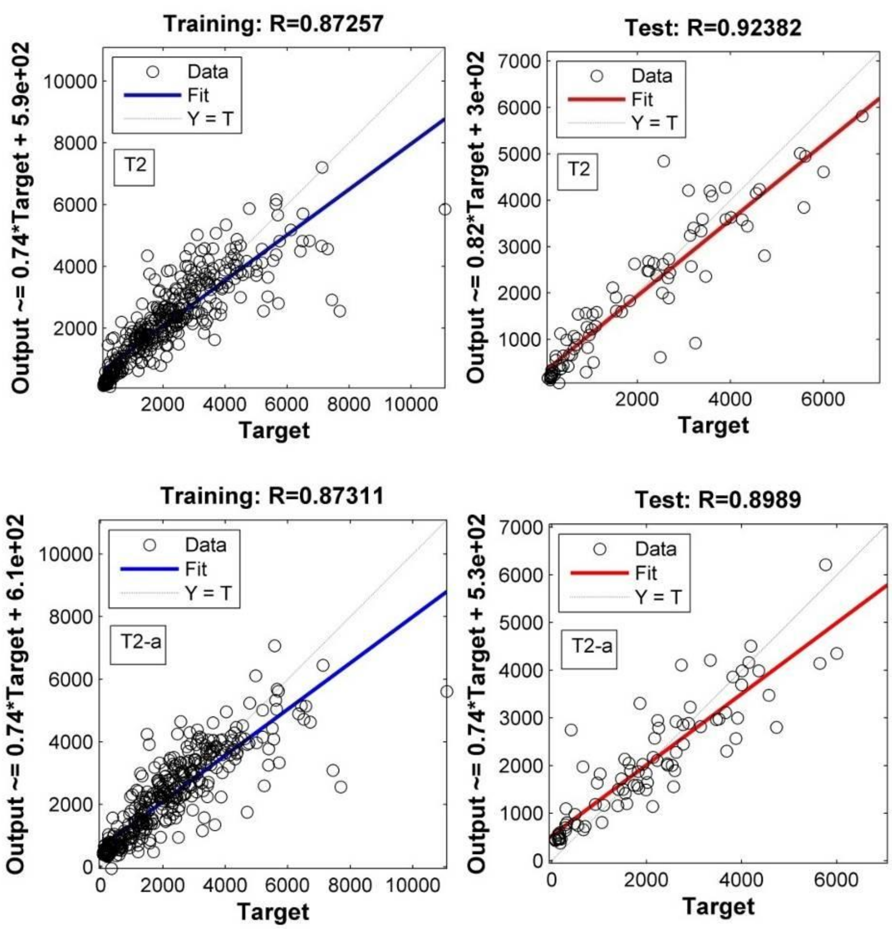


Figure 5.2a Regression plots for training and testing datasets of model T2 (above) and T2-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

The correlation coefficient obtained during training of models T2 and T2-a are 0.872 and 0.873 respectively. However, correlation coefficients obtained during testing of both the models are 0.923 and 0.898. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

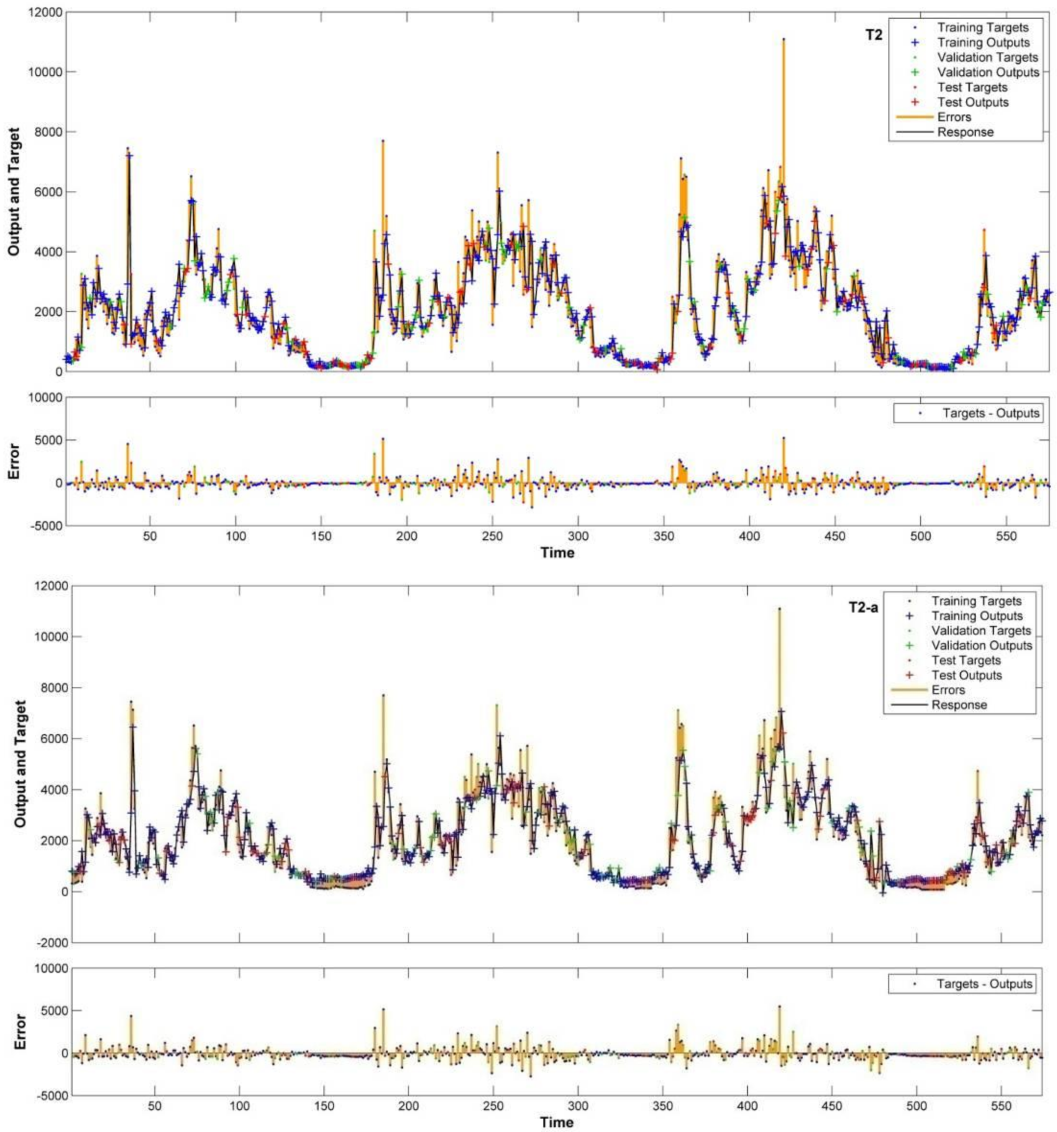


Figure 5.2b- Response of models T2 and T2-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

The response of models T2 and T2-a can be seen in Figure 5.2b where the target and model computed values have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.2b that the errors, shown in yellow, are greater in model T2-a than model T2. Evaluation of the models (Figure 5.2c) shows smaller errors and a closer match between computed outputs and target values of sediment concentration in non-updating model T2 than in model T2-a.

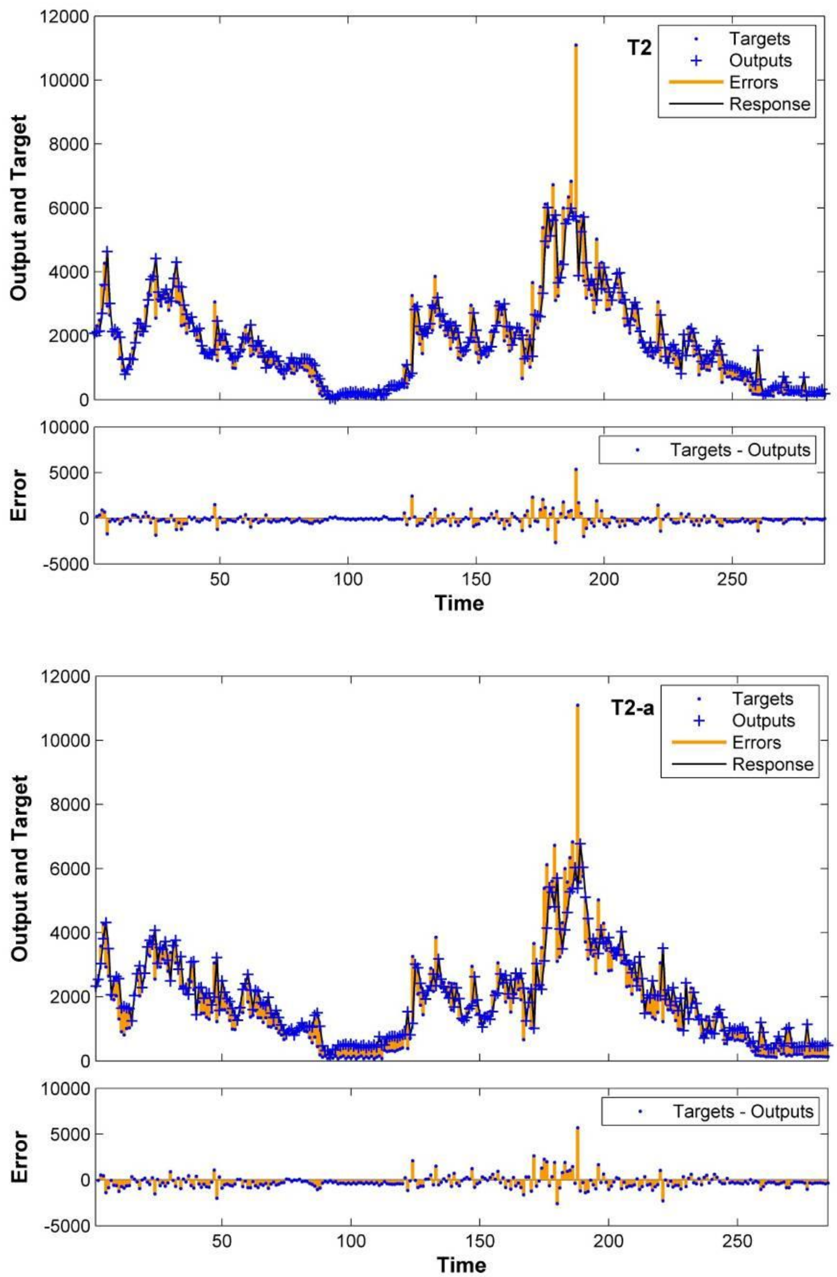


Figure 5.2c- T2 and T2-a Model evaluation- Comparison between target and computed values of sediment concentration along with errors varying with time.

(iii) Model T-3 and T-3a: In the next network, three inputs were used, water discharge (in m^3/s), rainfall (in mm) and temperature (in °C) at time t i.e. **S(t)= f{Q(t),R(t),T(t)}** in the non-updating mode. The corresponding updating mode network, T-3a, i.e. **S(t)= f{Q(t),R(t),T(t), Q(t-1),R(t-1),T(t-1)}** was also created and trained.

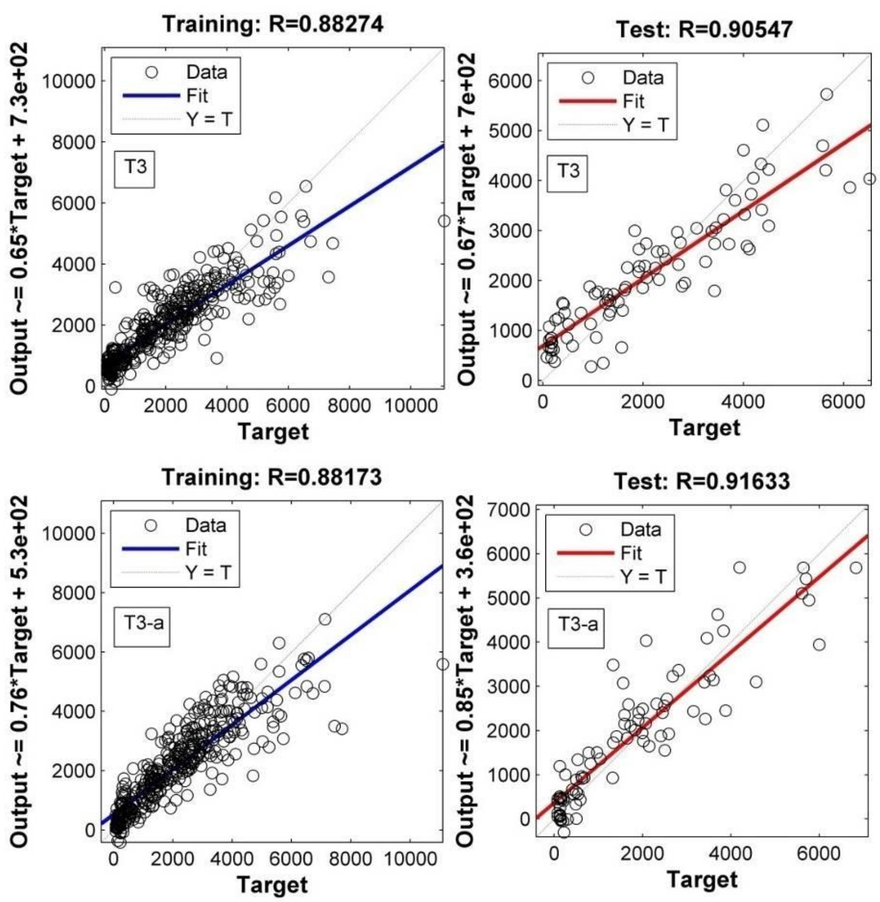


Figure 5.3a- Regression plots for training and testing datasets of model T3 (above) and T3-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.3a). The correlation coefficient obtained during training of models T3 and T3-a are 0.882 and 0.881 respectively. However, correlation coefficients obtained during testing of both the models are 0.905 and 0.916. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established. The response of models T3 and T3-a can be seen in Figure 5.3b where the target and model computed values have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.3b that the errors, shown in yellow, are greater in model T3 than in model T3-a. Evaluation of the models (Figure 5.3c) shows smaller errors and a closer match between computed outputs and target values of sediment concentration in model T3a than in model T3.

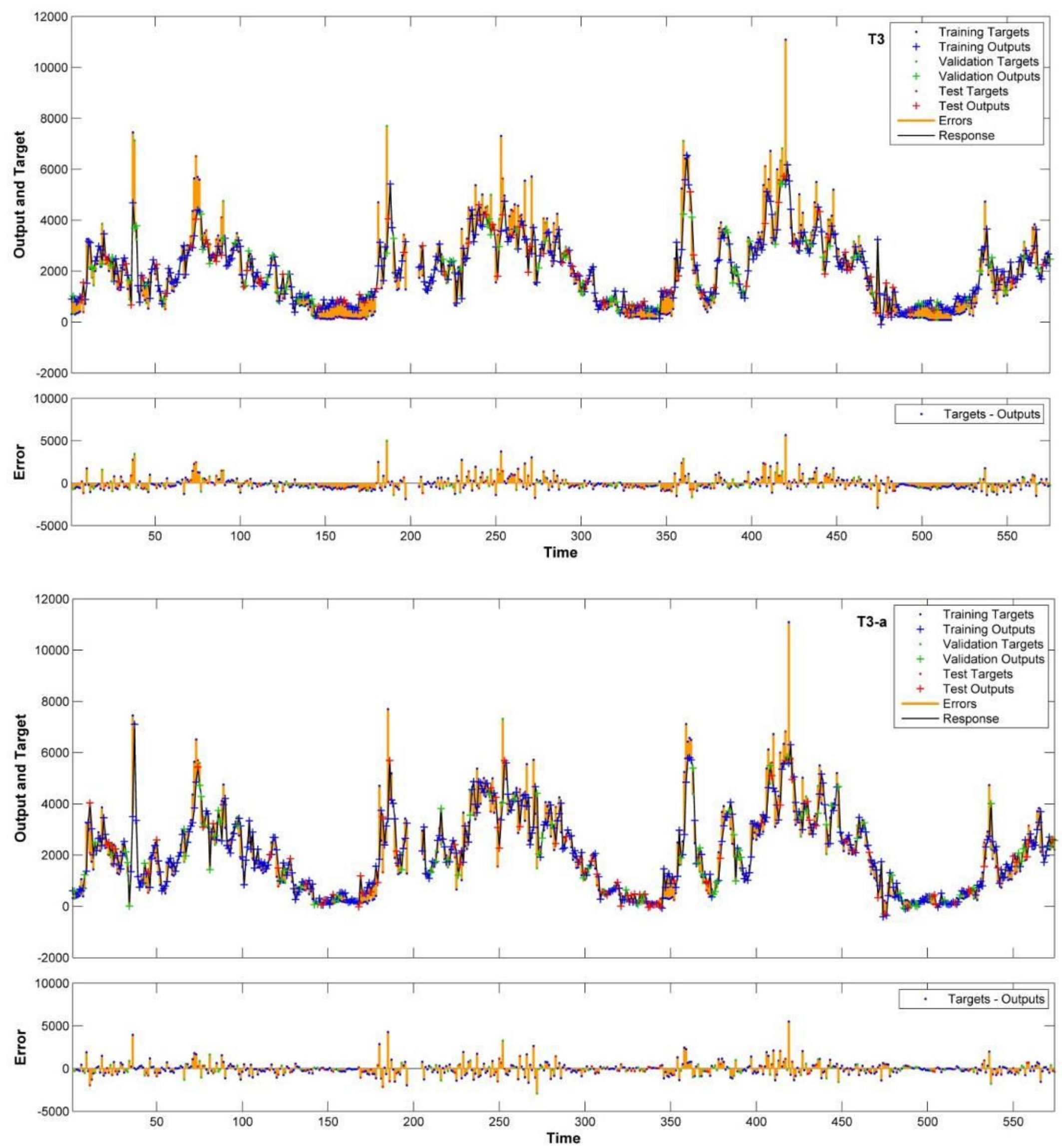


Figure 5.3b- Response of models T3 and T3-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

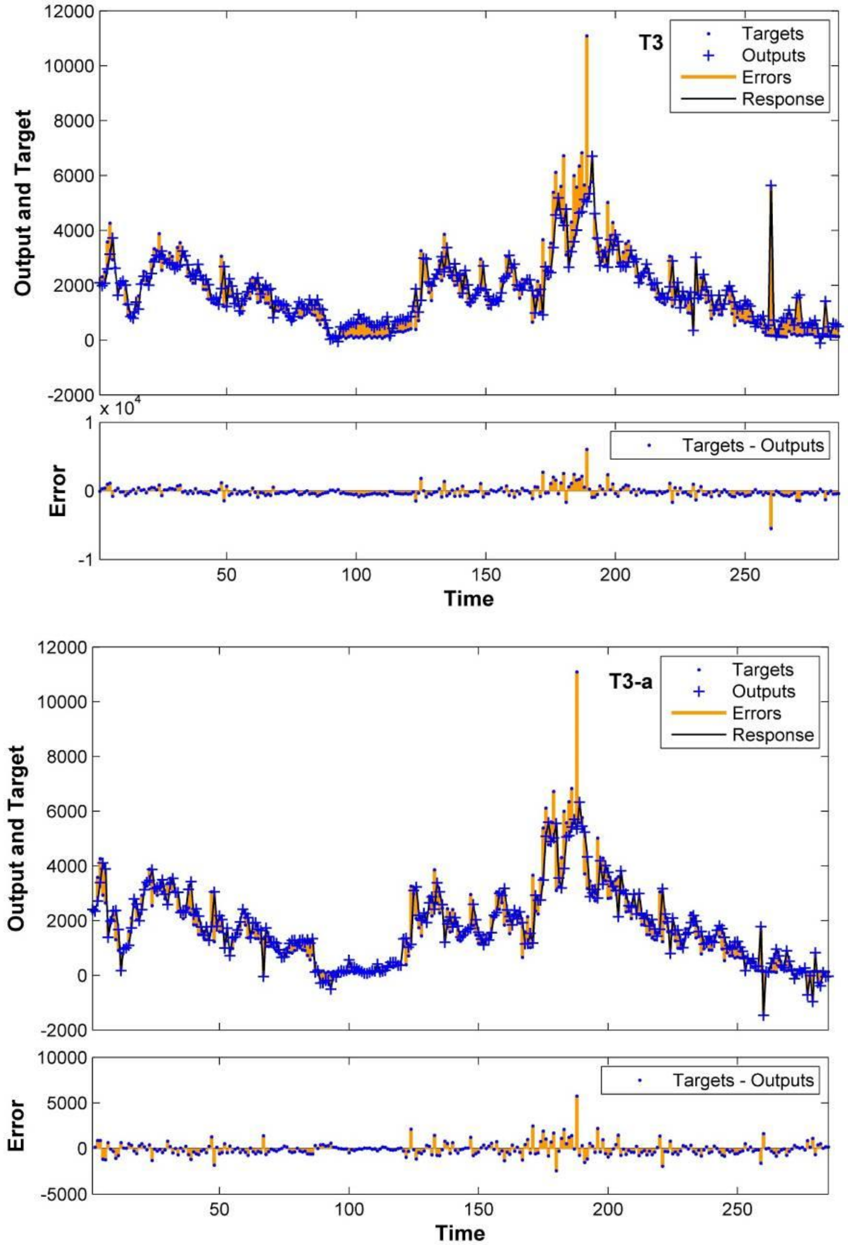


Figure 5.3c- T3 and T3-a Model evaluation at Gangotri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(iv) Model T-4 and T-4a: In this neural network, only rainfall (in mm) at time t has been modelled against sediment concentration (in mg/L) i.e. **S(t)= f{R(t)}** in the non-updating mode. The updating mode network T-4a, **S(t)= f{R(t), R(t-1)}** was simultaneously trained.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.4a). The correlation coefficient obtained during training of models T4 and T4-a are 0.874 and 0.868 respectively. However, correlation coefficients obtained during testing of both the models are 0.905 and 0.941. It can be observed that the testing values are higher for both the models.

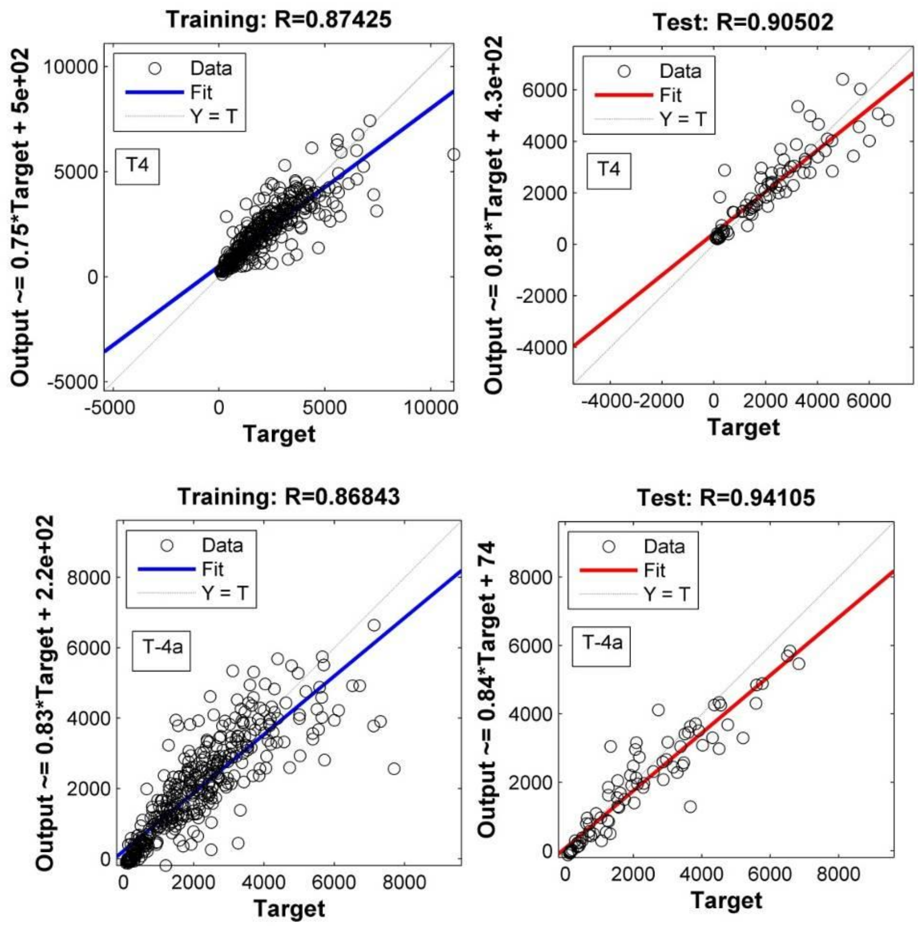


Figure 5.4a- Regression plots for training and testing datasets of model T4 (above) and T4-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established. The response of models T4 and T4-a can be seen in Figure 5.4b where the target and model computed values have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.4b that the errors, shown in yellow, are overall less in the two models compared with the previous models. Evaluation of the models (Figure 5.4c) shows smaller errors and a close match between computed outputs and target values of sediment concentration in both the models.

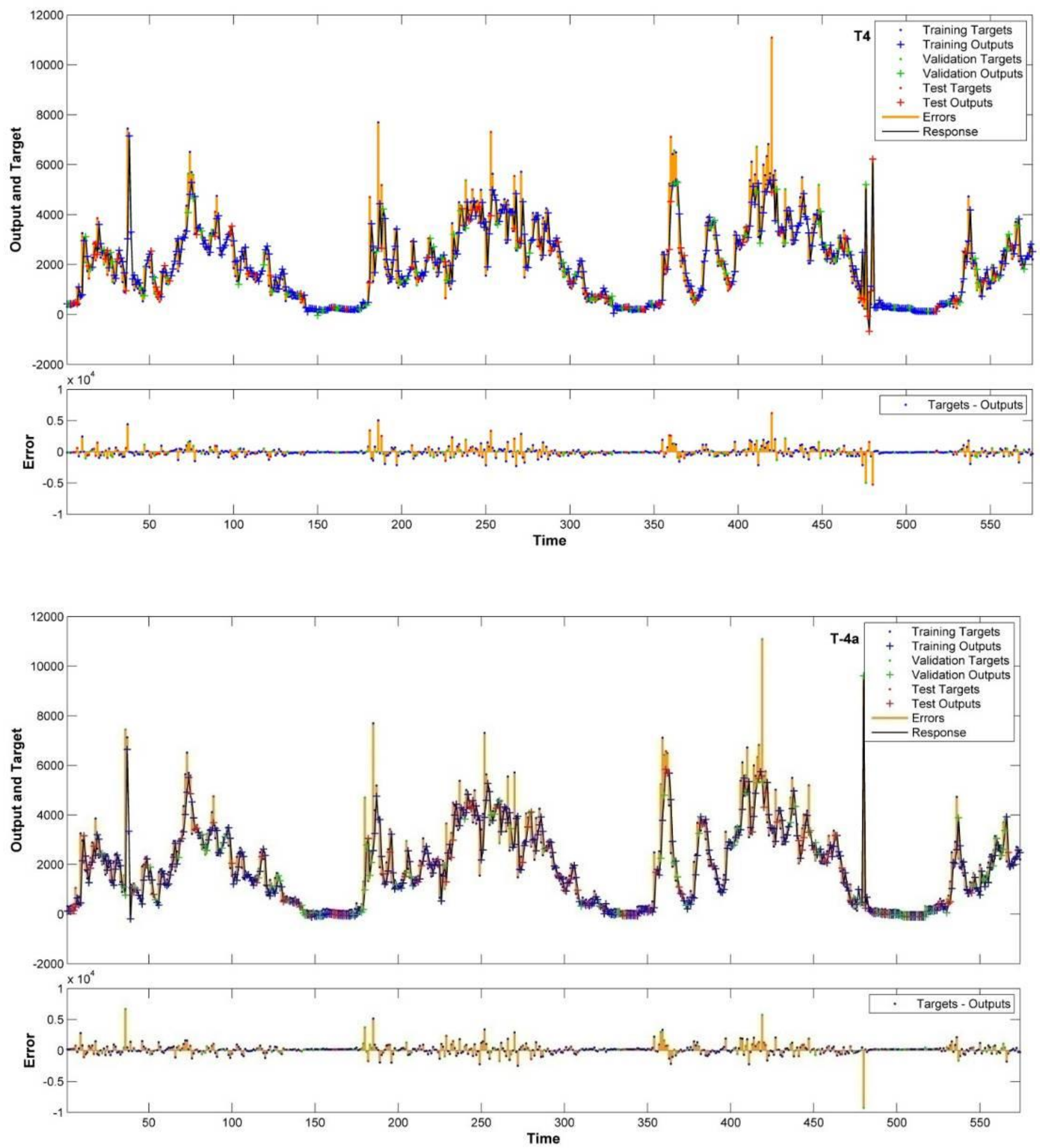


Figure 5.4b- Response of models T4 and T4-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

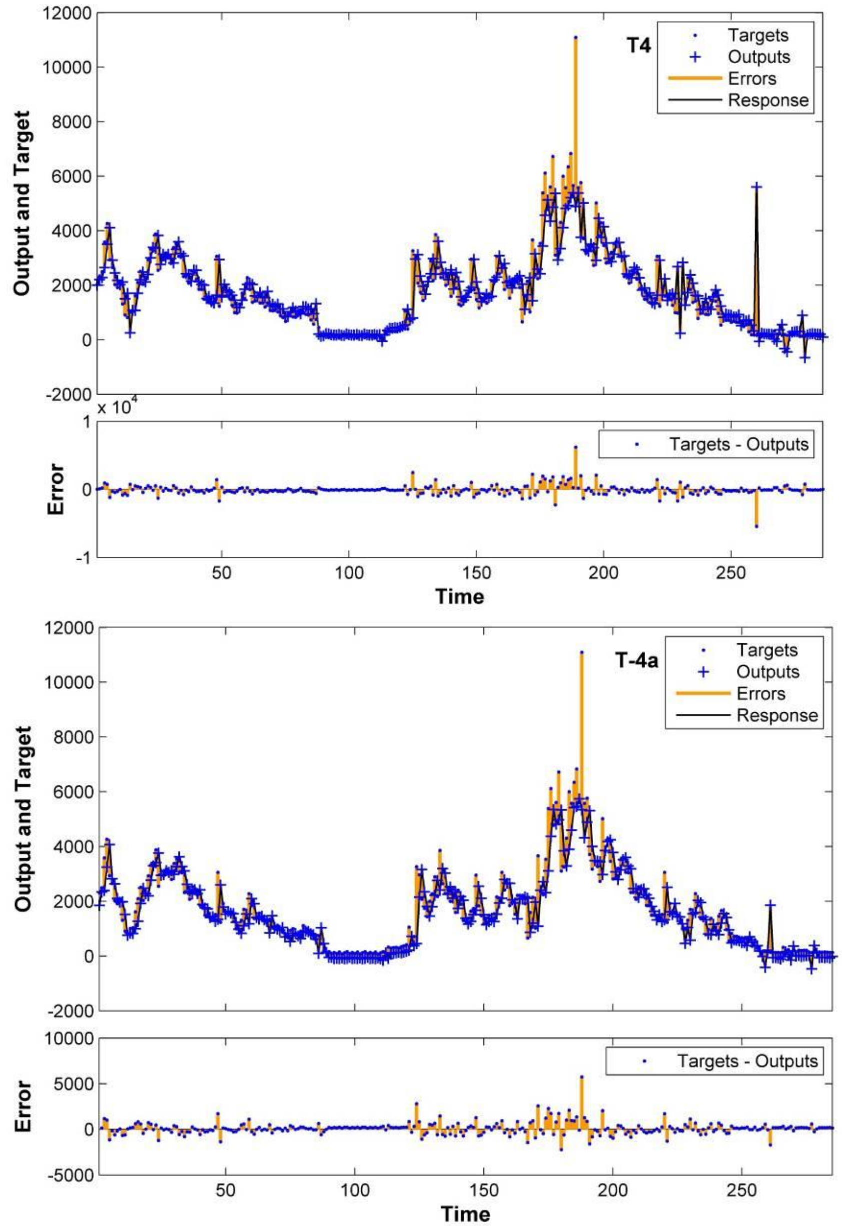


Figure 5.4c- T4 and T4-a Model evaluation at Gangotri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(v) Model T-5 and T-5a: Temperature (°C) at time t was modelled against sediment concentration at time t in the next non-updating mode network i.e. **S(t)= f{T(t)}.** The corresponding updating mode network T-5a, **S(t)= f{T(t), T(t-1)}** was also created and trained. The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.5a). The correlation coefficient obtained during training of models T5 and T5-a are 0.886 and 0.876 respectively. However, correlation coefficients obtained during testing of both the models are 0.910 and 0.894. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

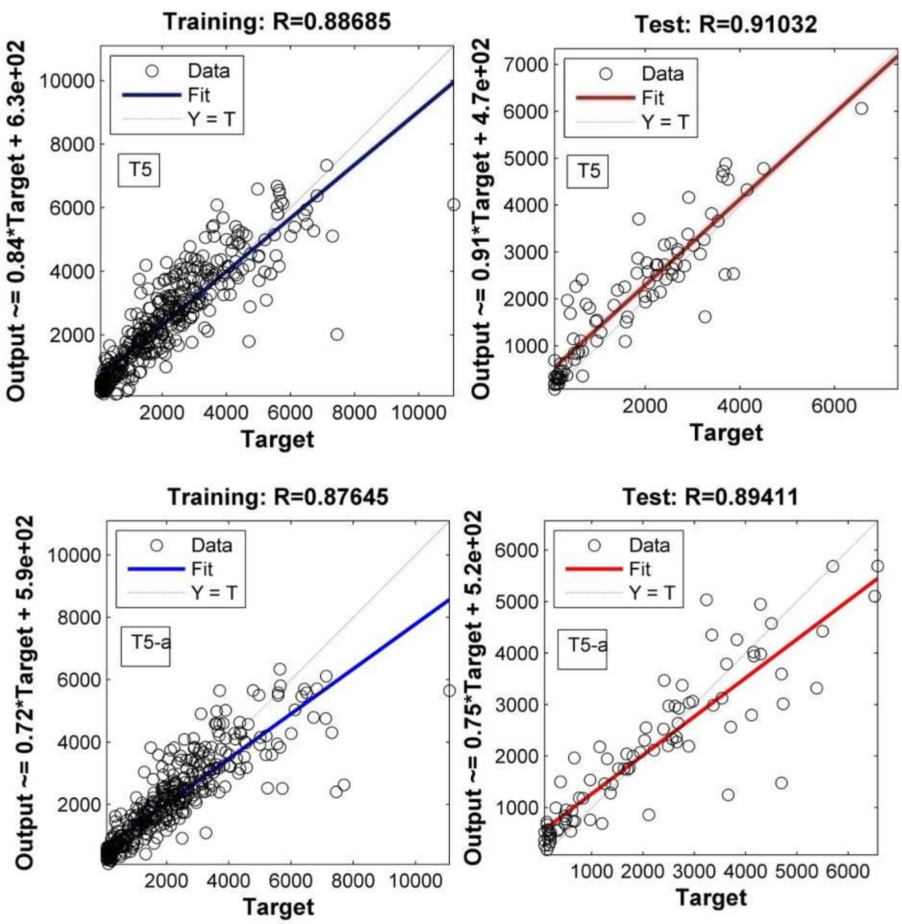


Figure 5.5a- Regression plots for training and testing datasets of model T5 (above) and T5-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

The response of models T5 and T5-a can be seen in Figure 5.5b where the target and model computed values have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.5b that the errors, shown in yellow, are more or less the same in both models. Evaluation of the models (Figure 5.5c) shows smaller errors and a close match between computed outputs and target values of sediment concentration in model T5-a than in model T5.

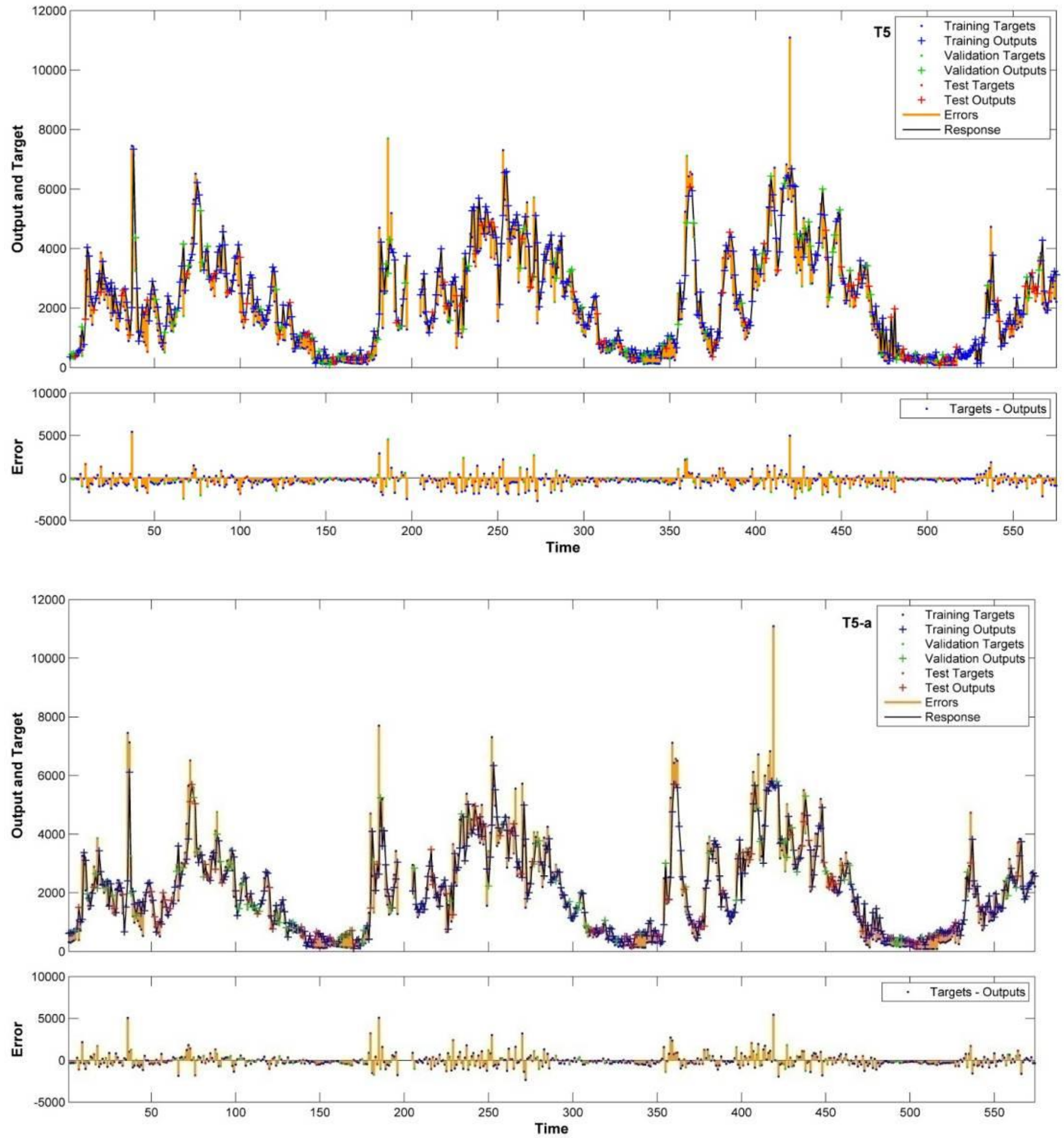


Figure 5.5b- Response of models T5 and T5-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

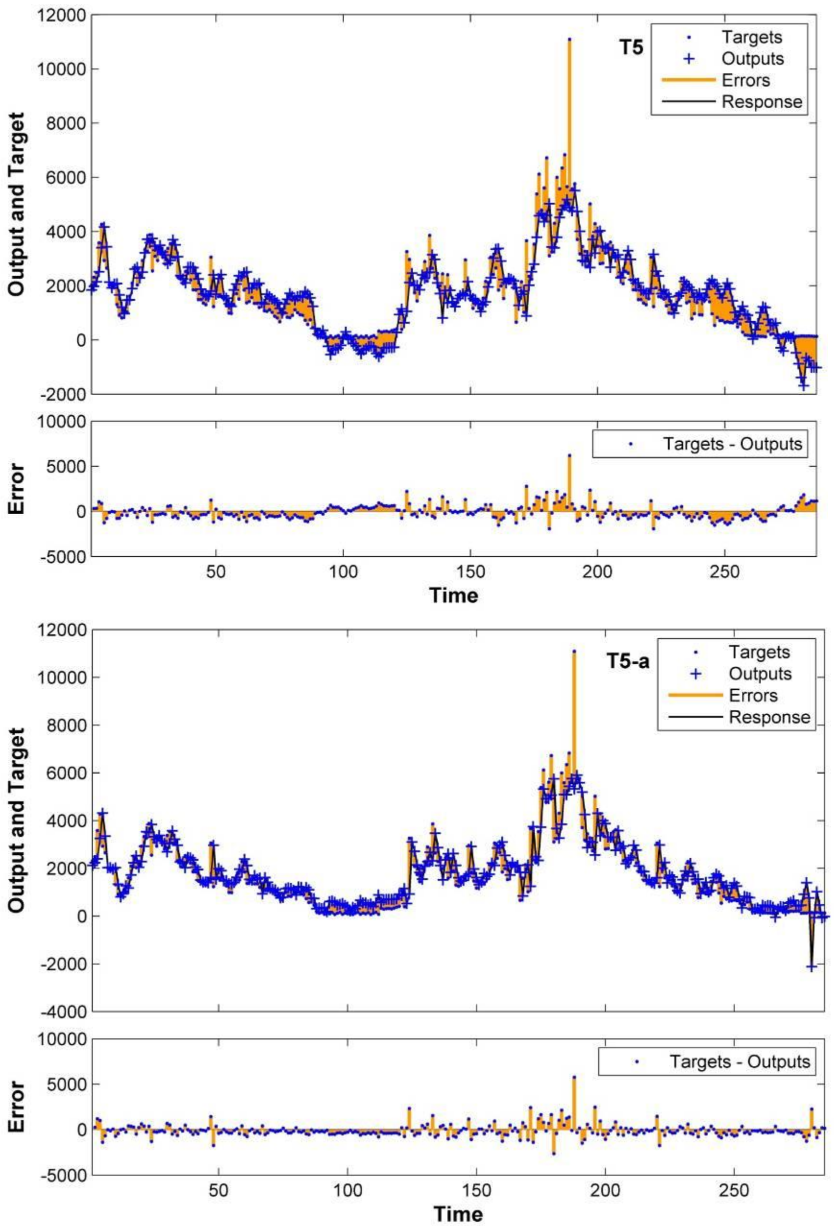


Figure 5.5c- T5 and T5-a Model evaluation at Gangotri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(vi) Model T-6 and T-6a: In this network, Water discharge (m^3/s) and temperature (°C) at time t have been modelled against sediment concentration (mg/L) at time t, i.e. **S(t)= f{Q(t), T(t)}** in the non-updating mode and simultaneously the updating mode network T-6a, **S(t)= f{Q(t), T(t), Q(t-1), T(t-1)}** was also created and trained. The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.6a).

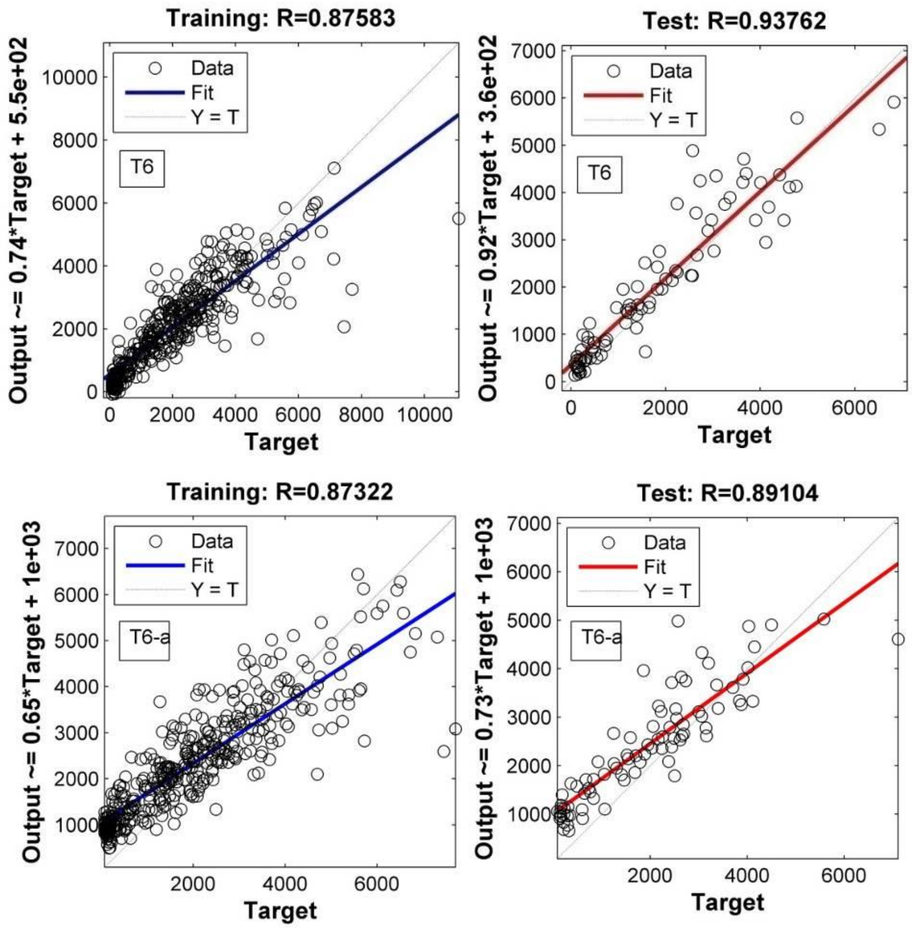


Figure 5.6a- Regression plots for training and testing datasets of model T6 (above) and T6-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

The correlation coefficient obtained during training of models T6 and T6-a are 0.875 and 0.873 respectively. However, correlation coefficients obtained during testing of both the models are 0.937 and 0.891. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

The response of models T6 and T6-a can be seen in Figure 5.6b where the target and model computed values have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.6b that the errors, shown in yellow, are larger for model T6-a than in model T6. Evaluation of the models (Figure 5.6c) shows smaller errors and a close match between computed outputs and target values of sediment concentration in model T6 than in model T6a.

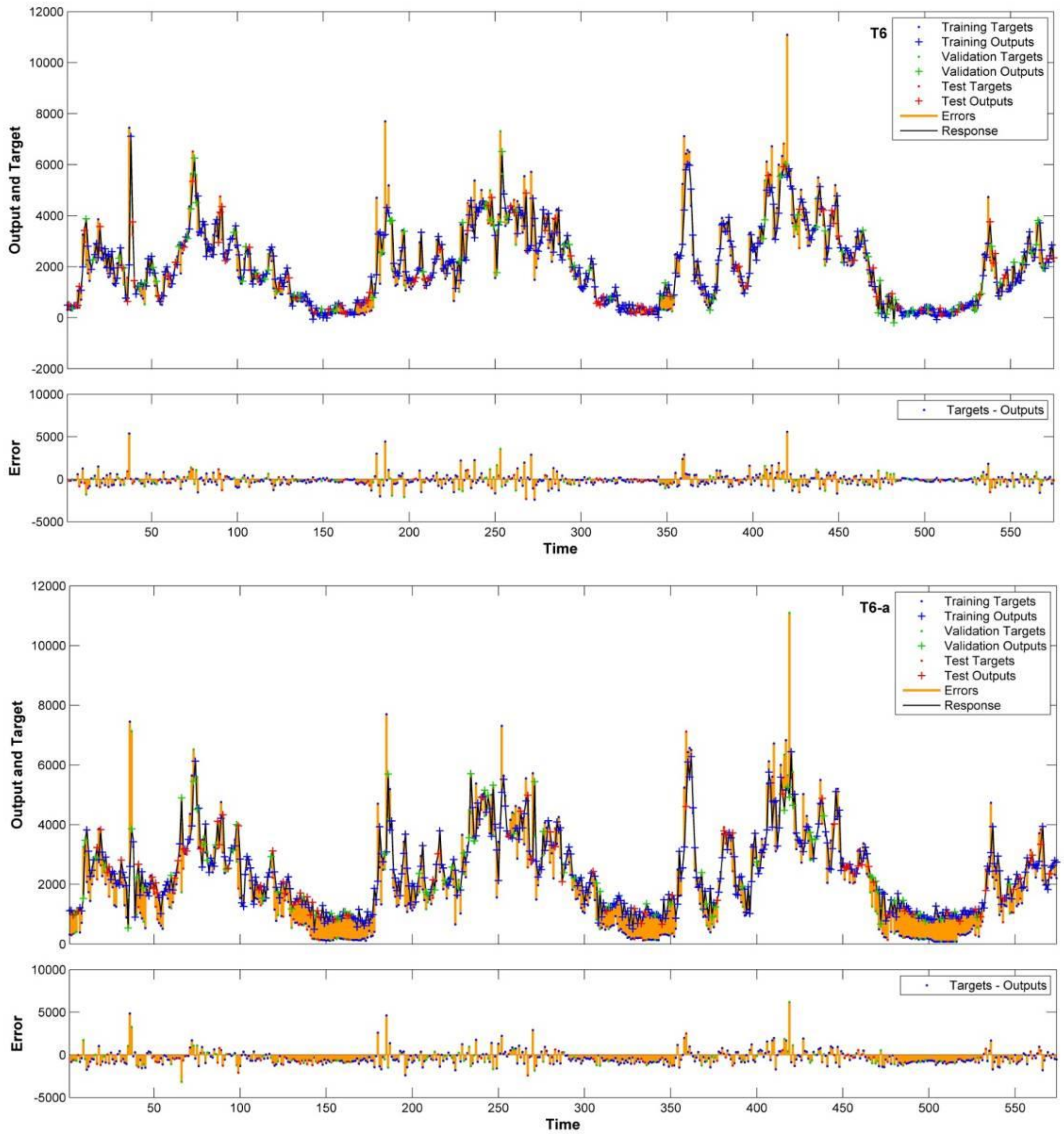
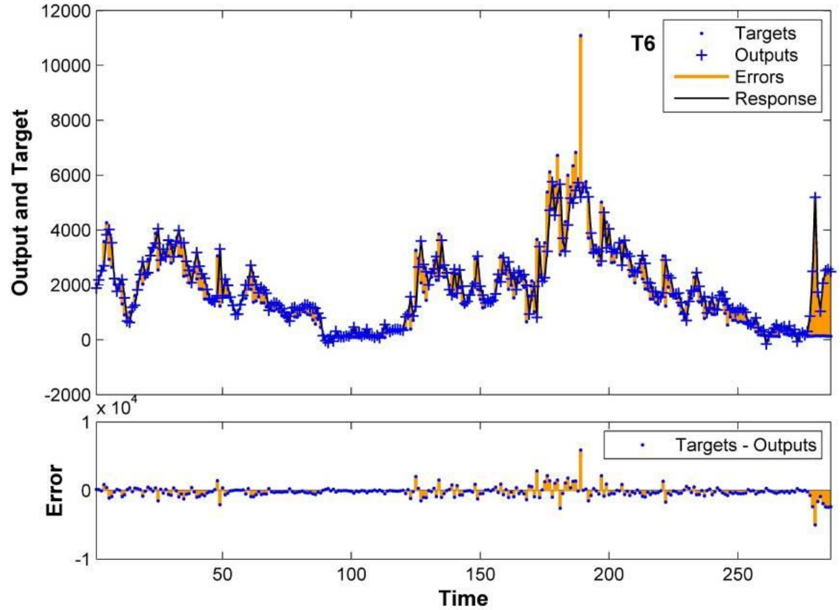


Figure 5.6b- Response of models T6 and T6-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.



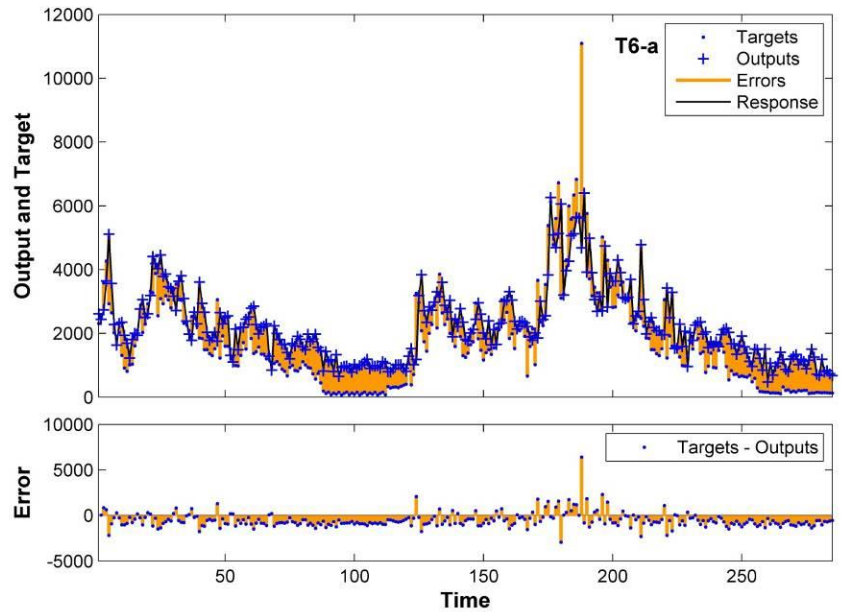


Figure 5.6c- T6 and T6-a Model evaluation at Gangotri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(vii) Model T-7 and T-7a: In this network, Temperature (in °C) and Rainfall (in mm) at time t have been modelled against sediment concentration (mg/L) at time t, i.e. **S(t)= f{T(t), R(t)}** in the non-updating mode and modelled as **S(t)= f{T(t), R(t), T(t-1), R(t-1)}** in the updating mode network T-7a.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.7a). The correlation coefficient obtained during training of both the models, T7 and T7-a, is 0.869. However, correlation coefficients obtained during testing of both the models are 0.918 and 0.905. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established. The response of models T7 and T7-a can be seen in Figure 5.7b where the target and model computed values have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.7b that the errors, shown in yellow, are larger for model T7 than in model T7-a. Evaluation of the models (Figure 5.7c) shows smaller errors and a close match between computed outputs and target values of sediment concentration in model T7a than in model T7.

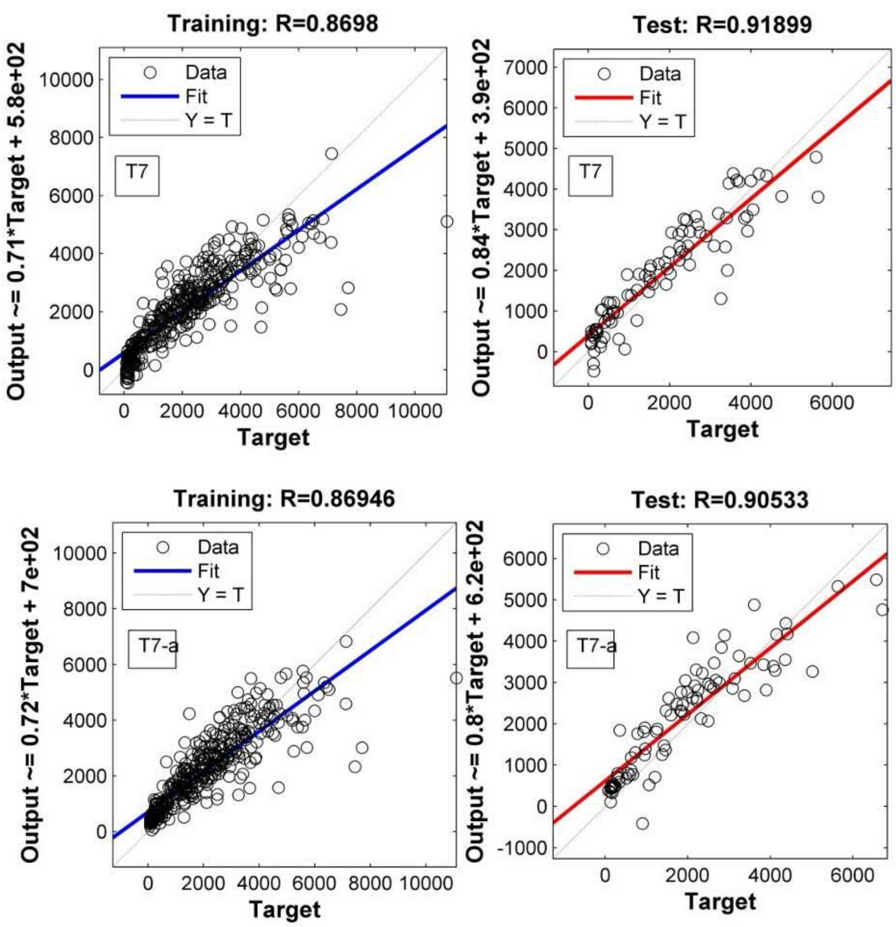


Figure 5.7a- Regression plots for training and testing datasets of model T7 (above) and T7-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Gangotri.

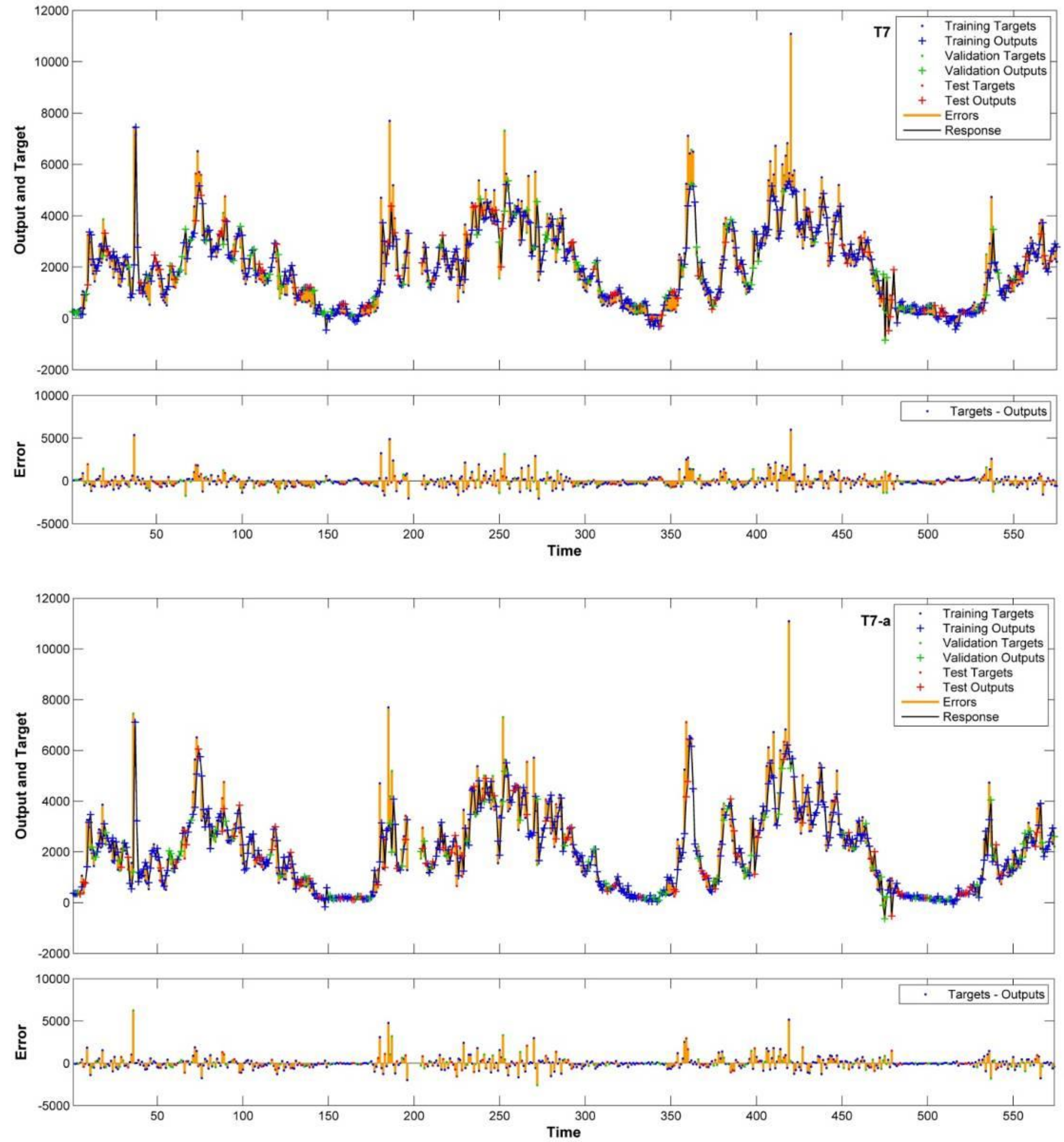


Figure 5.7b- Response of models T7 and T7-a after training, testing and validation at Gangotri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

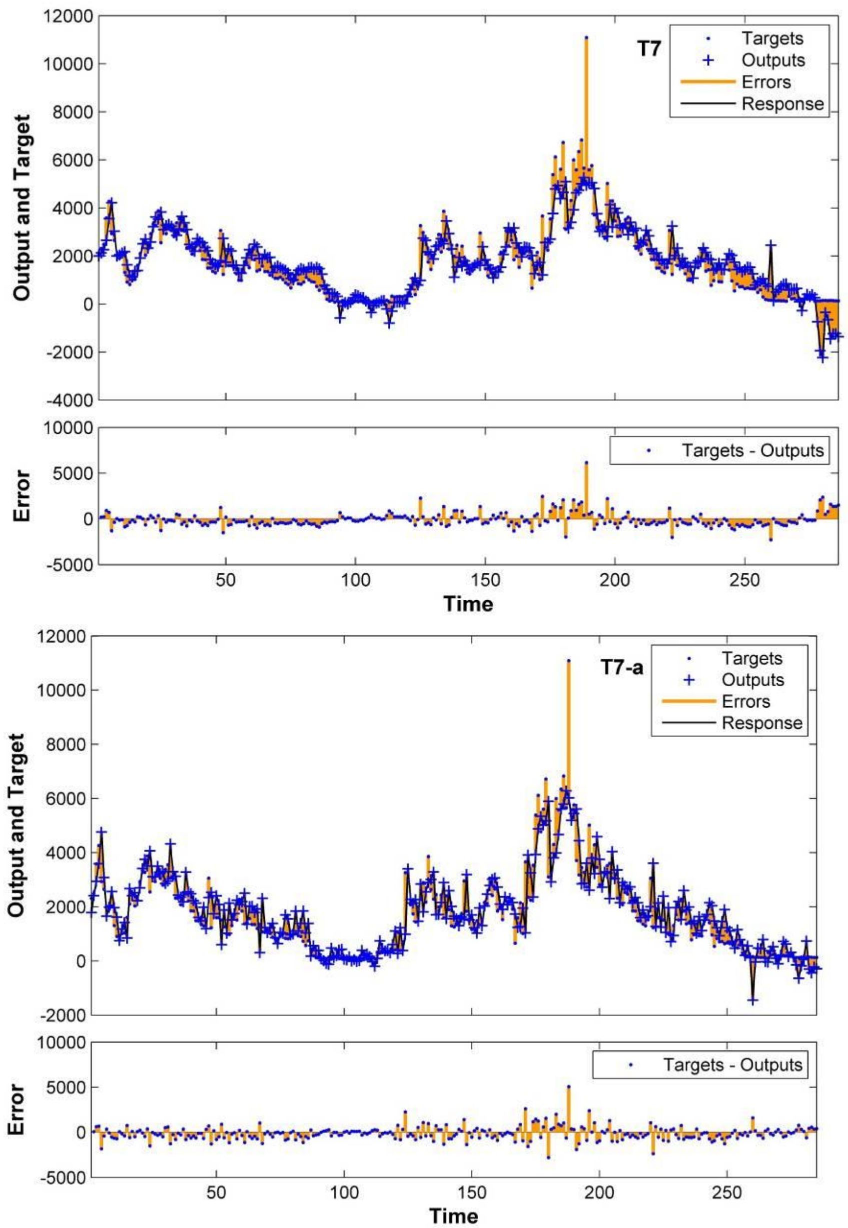


Figure 5.7c- T7 and T7-a Model evaluation at Gangotri- Comparison between target and computed values of sediment concentration along with errors varying with time.

5.1.2 Maneri

(i) Model-T1 and T1-a: A simple one input-one output network representing sediment concentration S (in mg/L) at time t, as a function of water discharge, Q (in m^3/s) was created. i.e. **S(t)= f{Q(t)}** and trained. Model T1-a was also created and trained with similar input although a larger dataset was employed in this case.

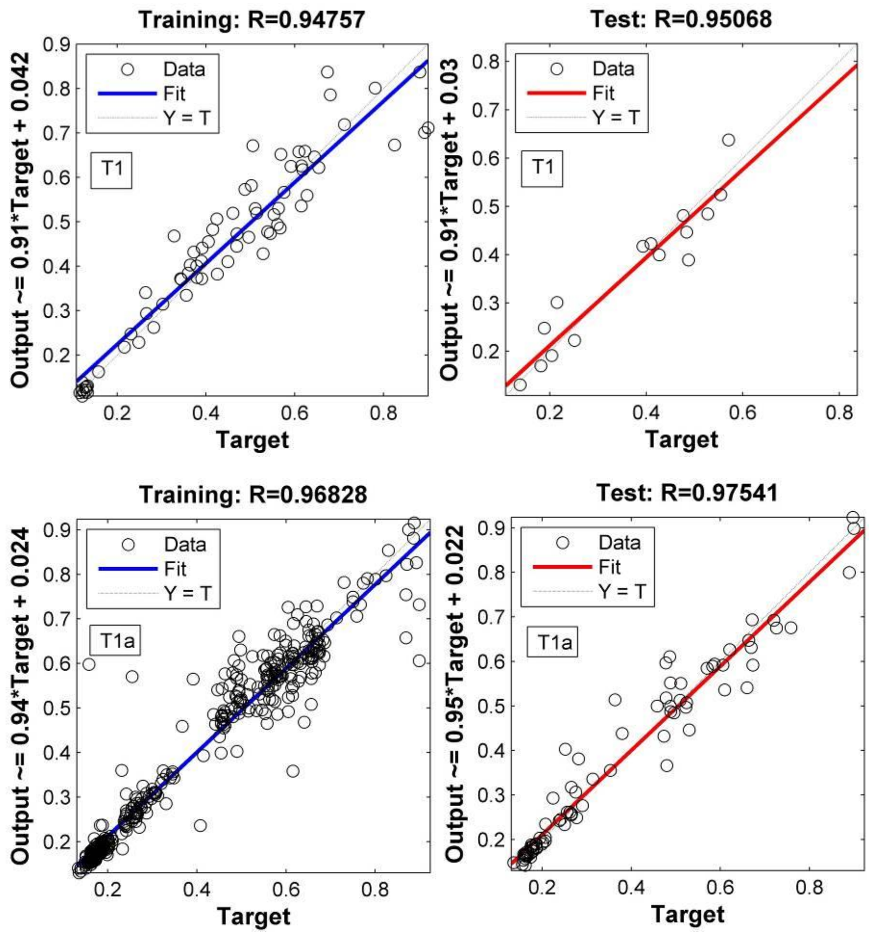


Figure 5.8a- Regression plots for training and testing datasets of model T1 (above) and T1-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Maneri.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.8a). The correlation coefficients obtained during training of model T1 and T1-a are 0.94 and 0.96 respectively. However, correlation coefficients obtained during testing of are 0.95 and 0.97 for model T1 and T1- respectively. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

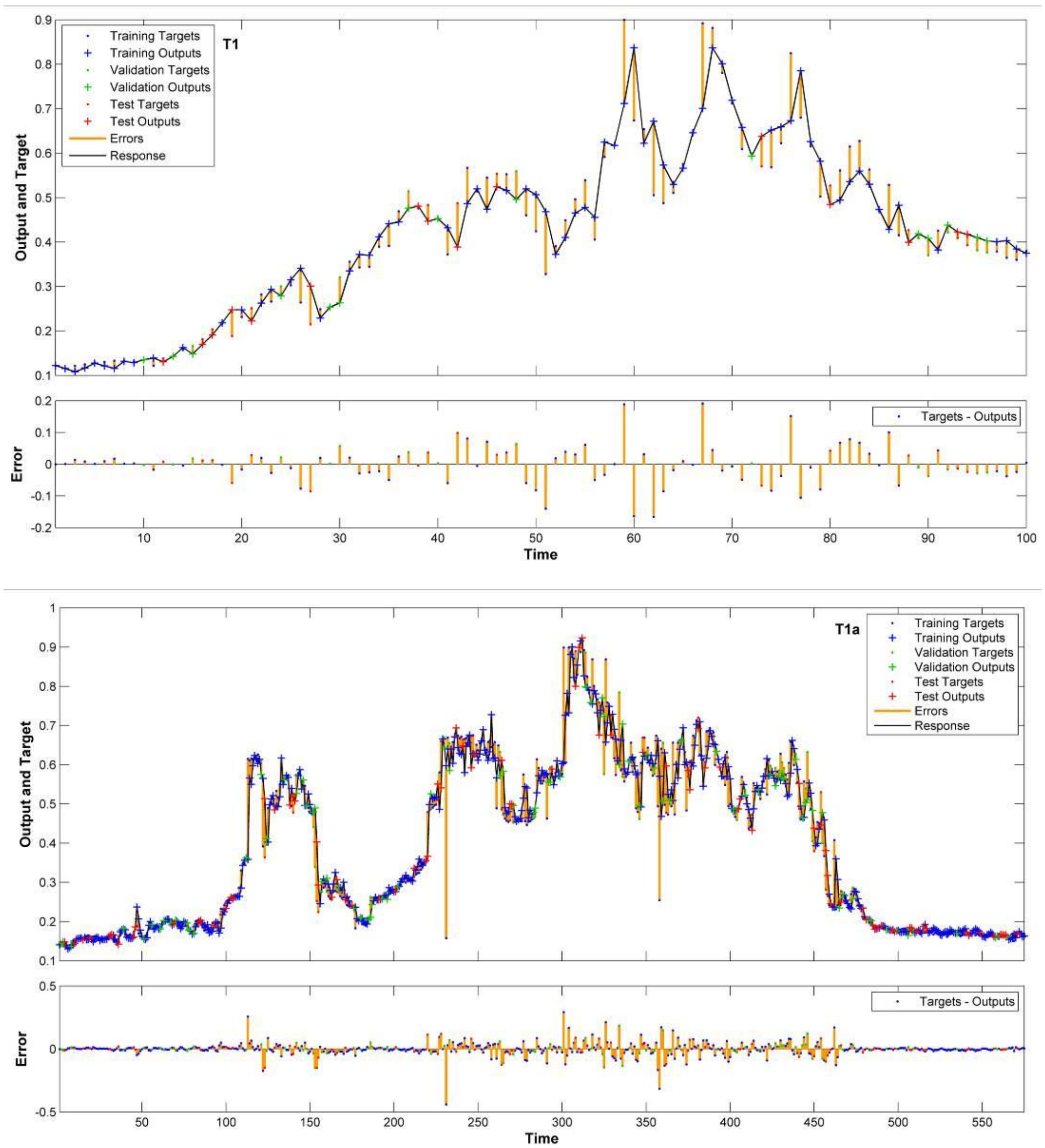


Figure 5.8b- Response of models T1 and T1-a after training, testing and validation at Maneri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

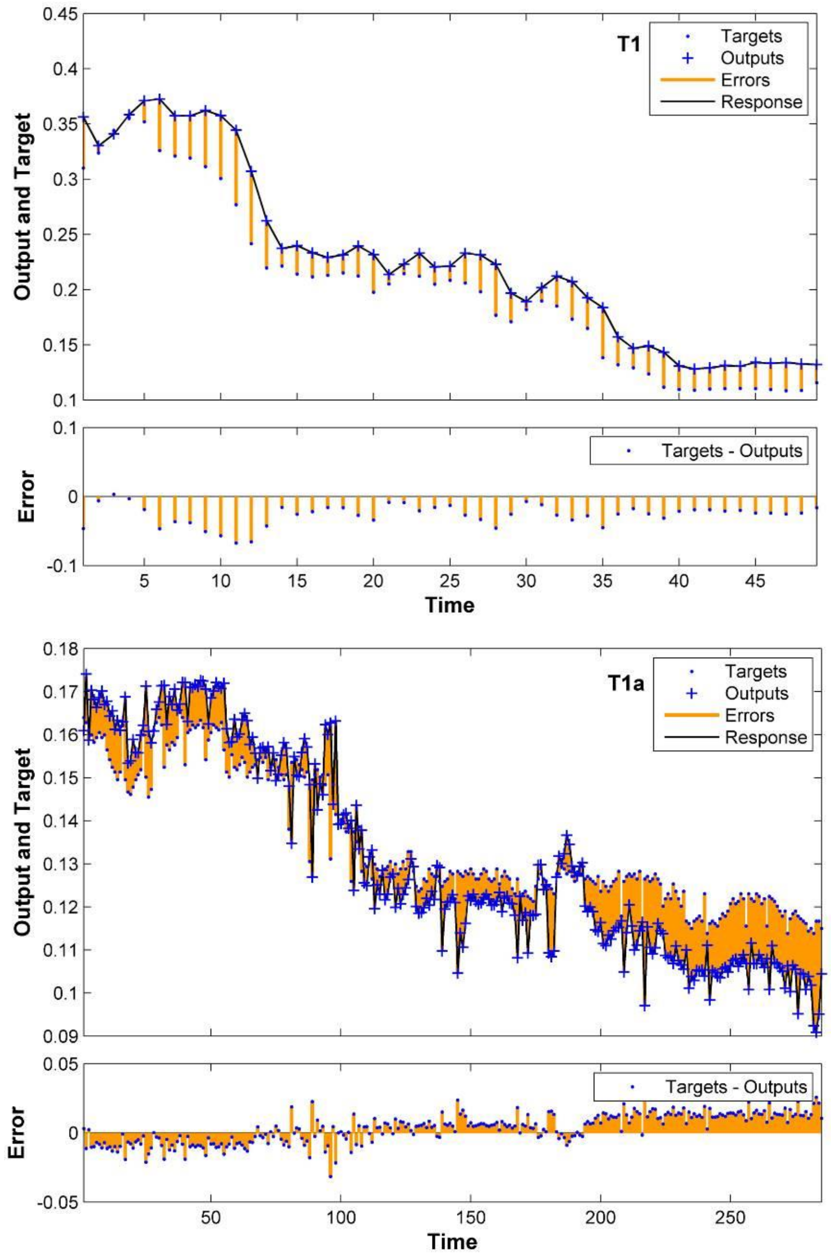


Figure 5.8c- Ta and T1-a Model evaluation at Maneri- Comparison between target and computed values of sediment concentration along with errors varying with time.

The response of models T1 and T1-a can be seen in Figure 5.8b where the target and model computed values of sediment concentration (in mg/L) have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.8b that the errors, shown in yellow, are quite large for both the models T1 and T1-a. Evaluation of the models (Figure 5.8c) shows a comparison between observed and model computed values of sediment concentration along with variation of errors with time.

(ii) Model-T2 and T2-a: Water discharge (in m^3/s) at one previous time-step was included as an input and the model performance evaluated in the next non-linear input- output network.

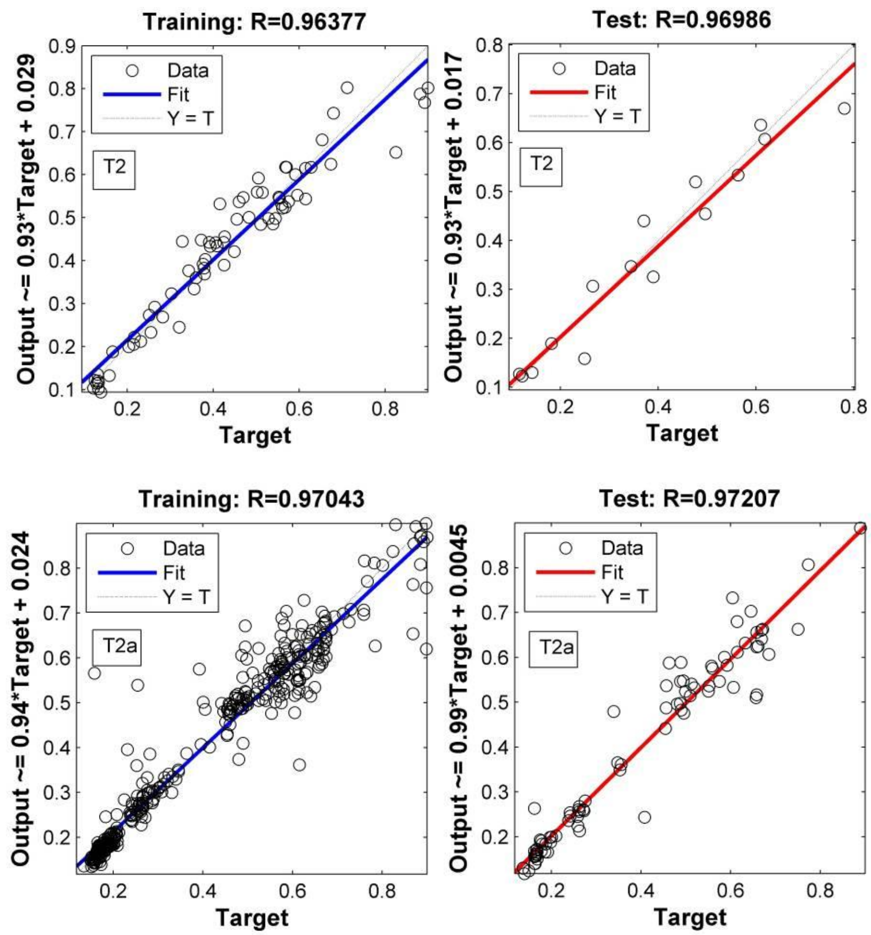


Figure 5.9a- Regression plots for training and testing datasets of model T2 (above) and T2-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Maneri.

Although the input variable remains the same, another element i.e. Q(t-1) is added in this model i.e. **S(t)= f{Q(t),Q(t-1)}.** Model T2-a was also created with the high frequency dataset. The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.9a). The R (correlation coefficient) values obtained during training for model T2 and T2-a area 0.96 to 0.97 respectively while these values during testing are 0.96 and 0.97 respectively. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

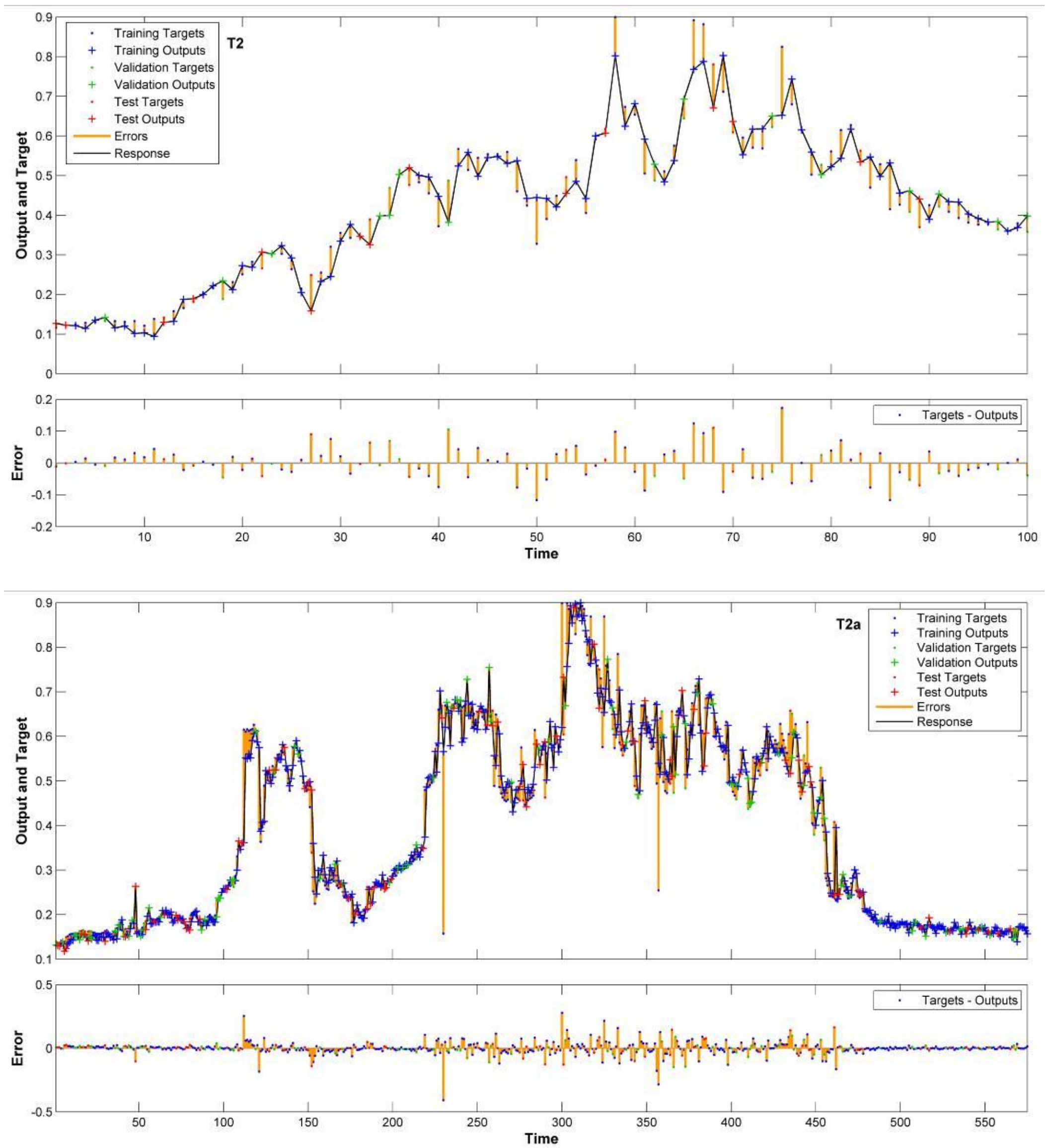


Figure 5.9b- Response of models T2 and T2-a after training, testing and validation at Maneri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

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The response of models T2 and T2-a can be seen in Figure 5.9b where the target and model computed values of sediment concentration (in mg/L) have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.10b that the errors, shown in yellow, are large for both the models T2 and T2-a. Evaluation of the models (Figure 5.9c) shows a comparison between observed and model computed values of sediment concentration along with variation of errors with time.

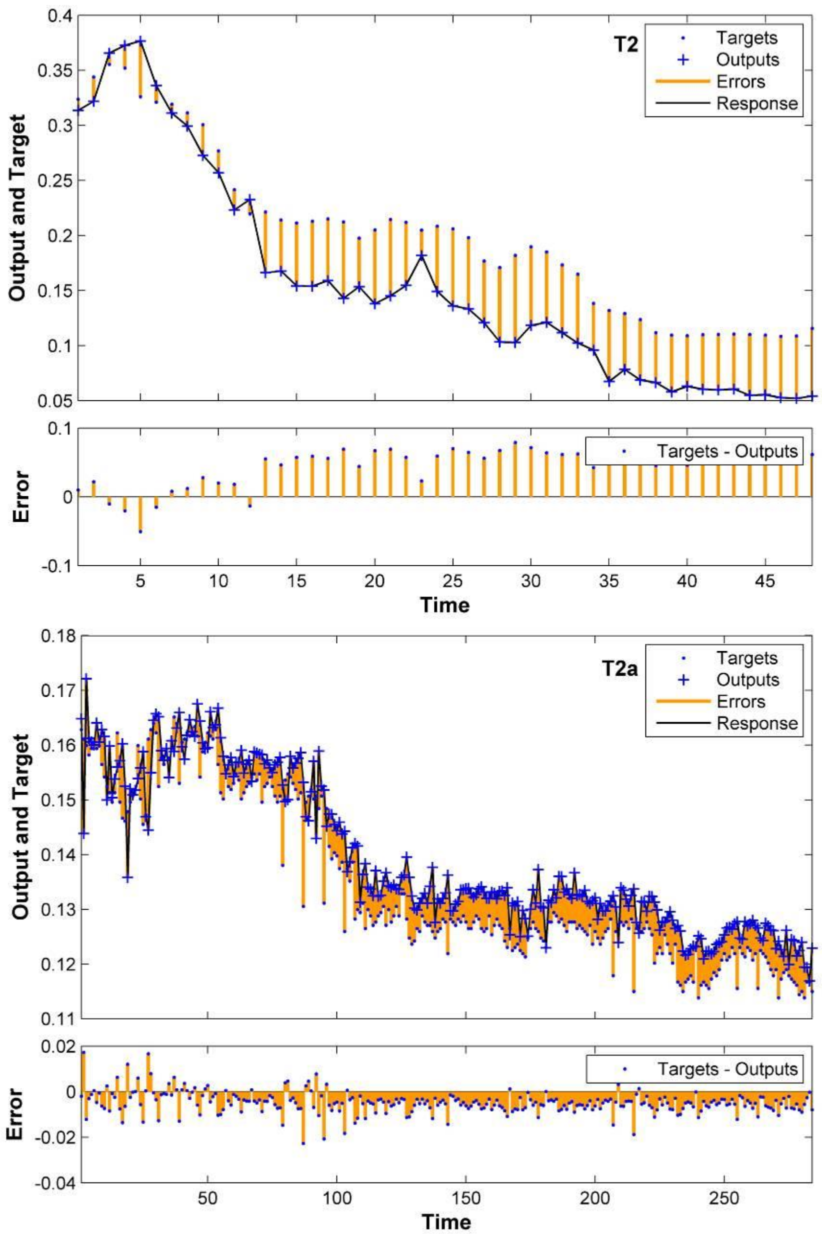

Figure 5.9c- T2 and T2-a Model evaluation at Maneri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(iii) Model-T3 and T3-a: In the next network, water discharge at two previous time-steps was also included as an input. So three elements were included in the input variable i.e. **S(t)= f{Q(t),Q(t-**

1),Q(t-2) against sediment concentration values. Model T3-a using the high frequency dataset was also created and trained.

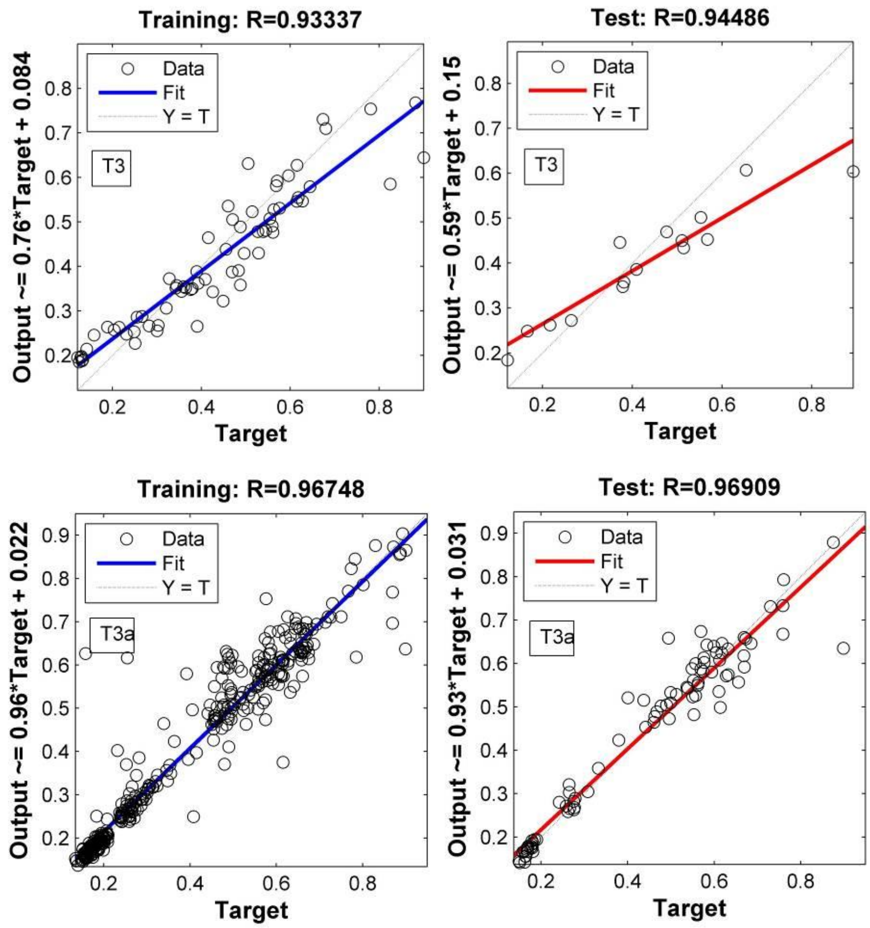

Figure 5.10a- Regression plots for training and testing datasets of model T3 (above) and T3-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Maneri.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.10a). The R (correlation coefficient) values obtained during training for model T3 and T3-a are 0.93 and 0.967 respectively while these values during testing are 0.94 and 0.969 respectively. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

The response of models T2 and T2-a can be seen in Figure 5.10b where the target and model computed values of sediment concentration (in mg/L) have been plotted against time. The errors obtained in the process have also been plotted against time. It is clear from Figure 5.11b that the errors, shown in yellow, are large for both the models T2 and T2-a. Evaluation of the models (Figure 5.10c) shows a comparison between observed and model computed values of sediment concentration along with variation of errors with time.

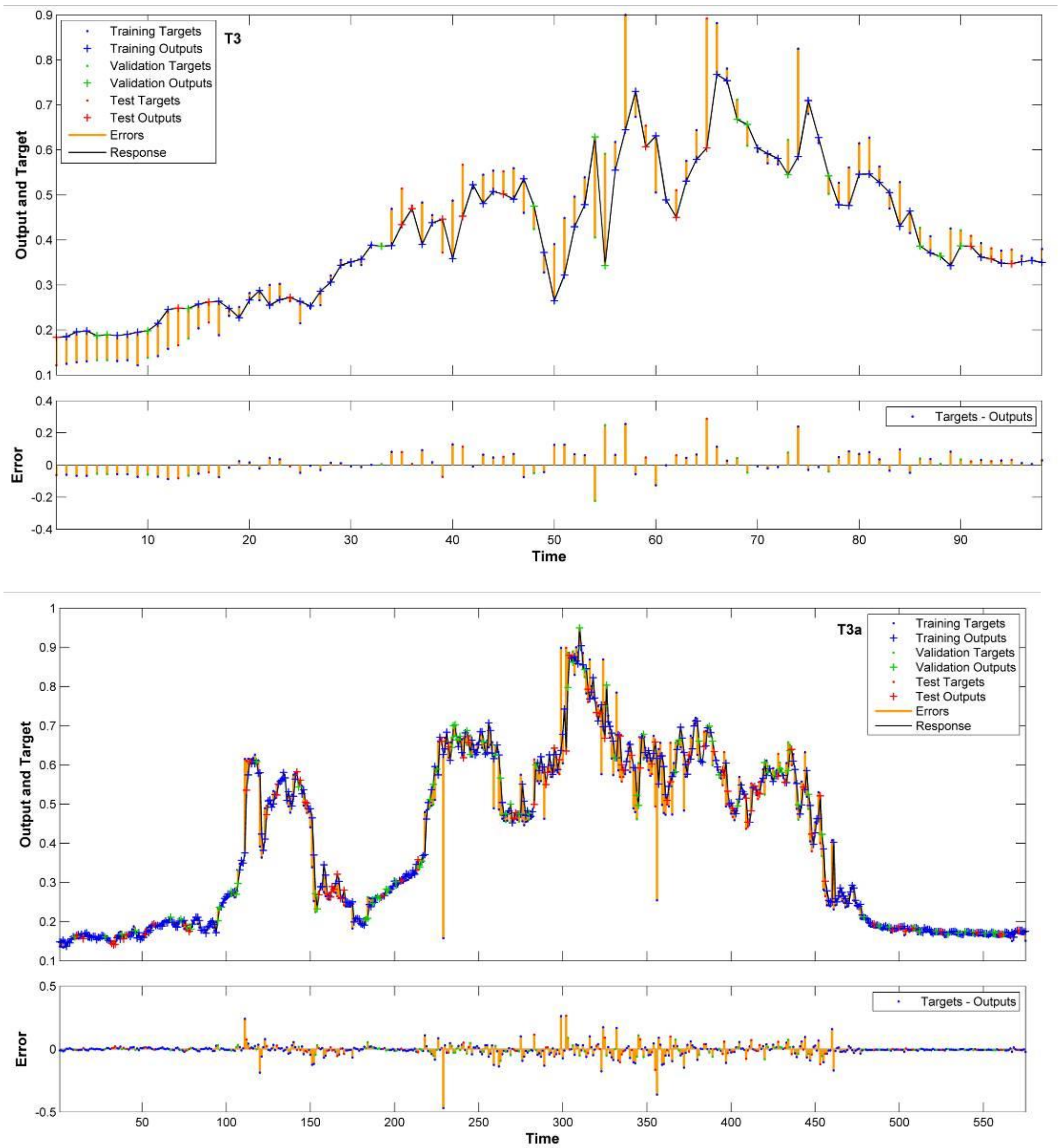

Figure 5.10b- Response of models T3 and T3-a after training, testing and validation at Maneri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

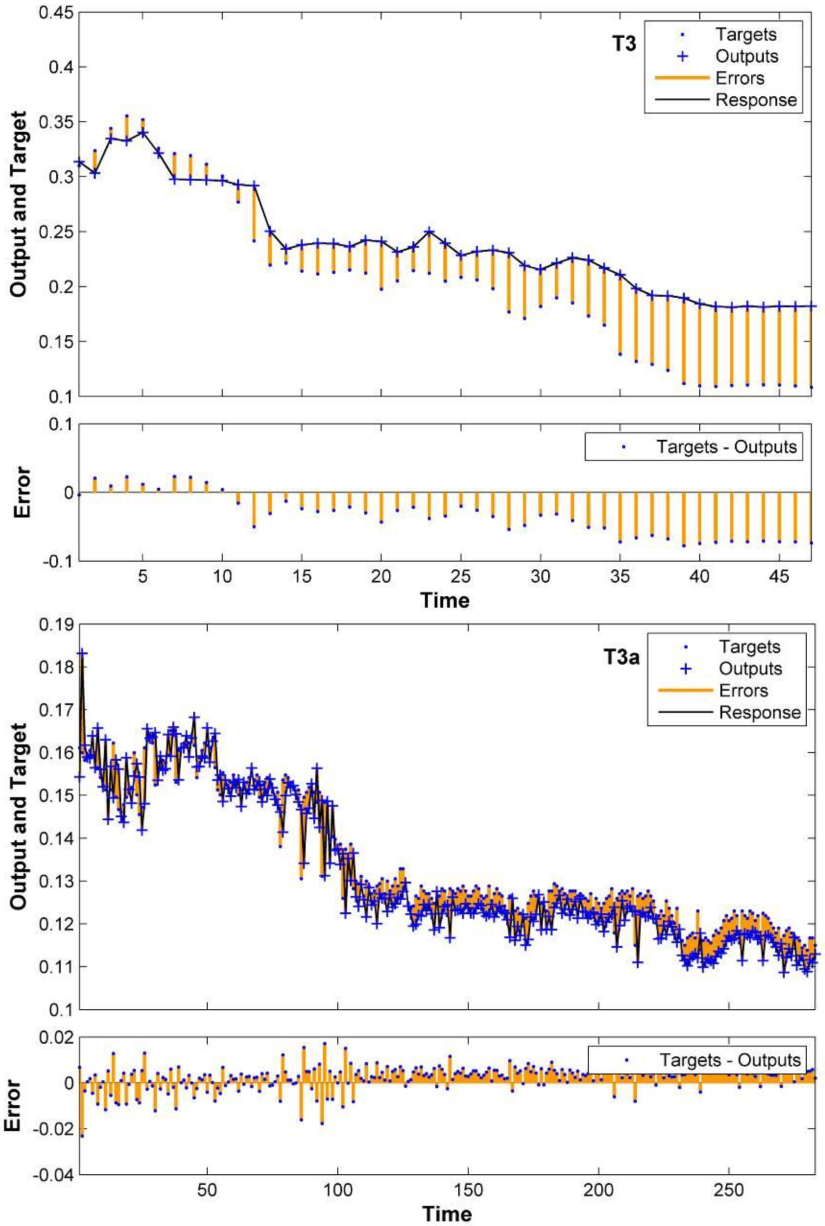

Figure 5.10c- T3 and T3-a Model evaluation at Maneri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(iv) Model-T4 and T4-a: In the next networks, water discharge at two previous time-steps was replaced by sediment concentration at the previous time-step. i.e. **S(t)= f{Q(t),Q(t-1),S(t-1)}**. Model T4-a was also created and trained with the higher frequency dataset. The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.11a).

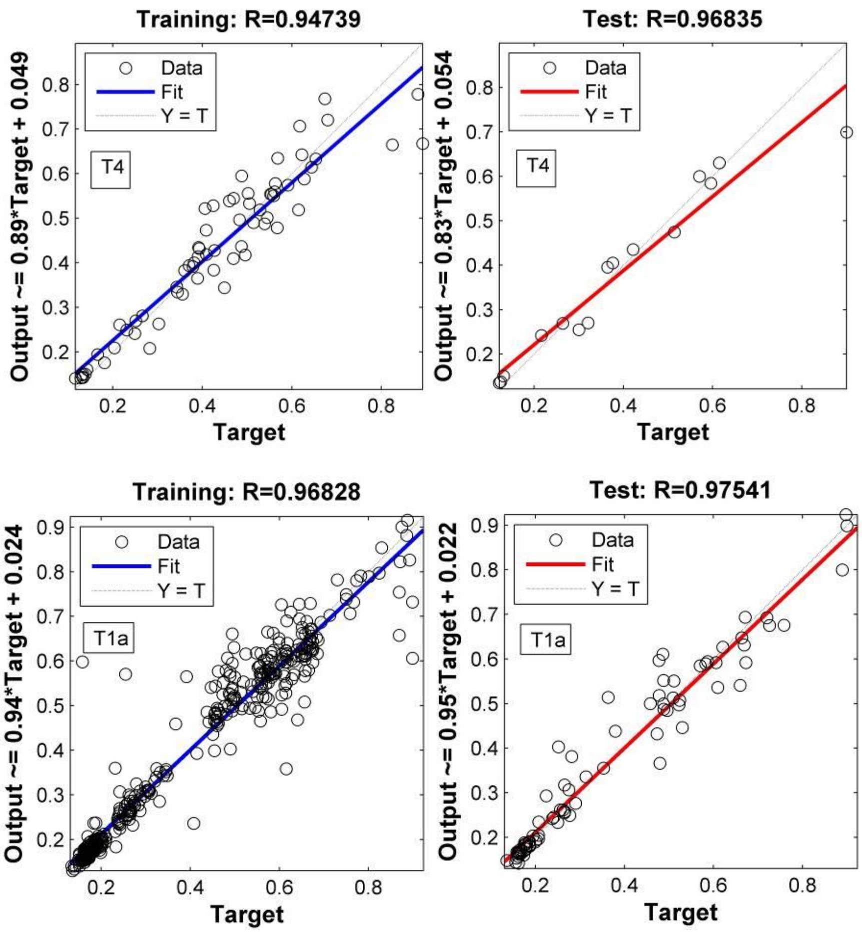

Figure 5.11a- Regression plots for training and testing datasets of model T4 (above) and T4-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Maneri.

The R (correlation coefficient) values obtained during training for model T4 and T4-a are 0.94 and 0.968 respectively while these values during testing are 0.968 and 0.975 respectively. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established.

The response of models T4 and T4-a can be seen in Figure 5.11b where the target and model computed values of sediment concentration (in mg/L) have been plotted against time. The errors obtained in the process have also been plotted against time. Evaluation of the models (Figure 5.12c) shows a comparison between observed and model computed values of sediment concentration along with variation of errors with time.

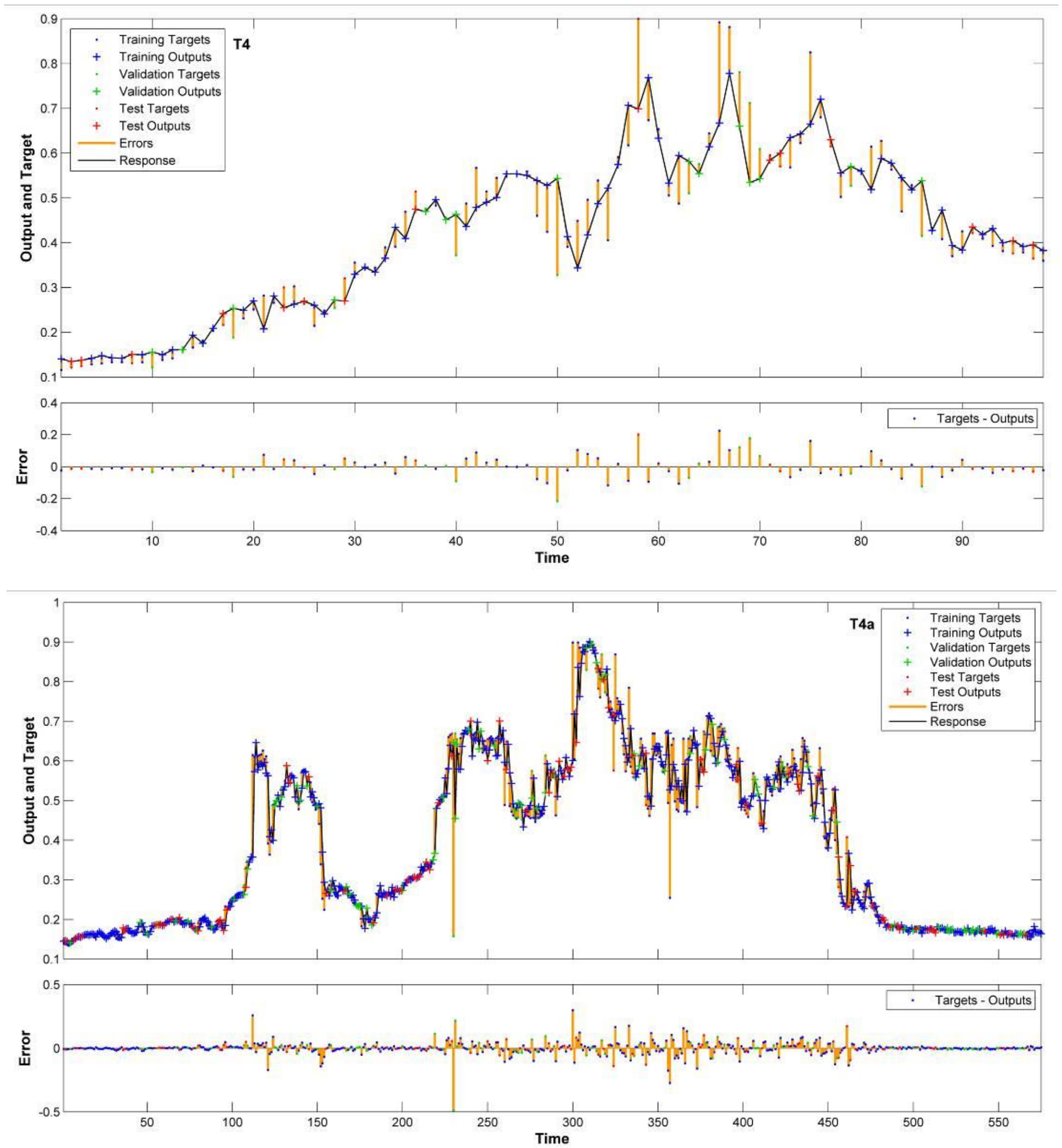

Figure 5.11b- Response of models T4 and T4-a after training, testing and validation at Maneri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

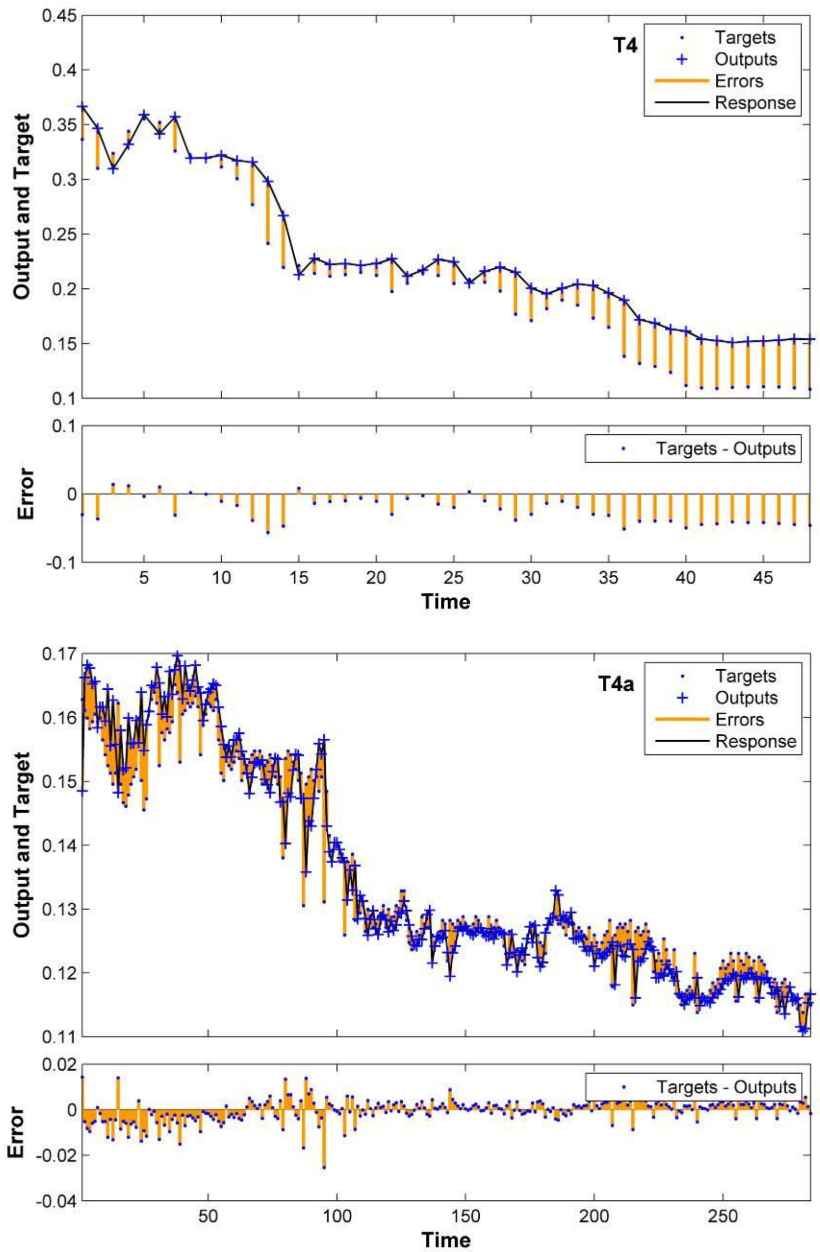

Figure 5.11c- T4 and T4-a Model evaluation at Maneri- Comparison between target and computed values of sediment concentration along with errors varying with time.

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(v) Model-T5 and T5-a: Water discharge at two previous time-steps along with the above configuration, was also included as an input. i.e. S(t)= f{Q(t),Q(t-1),Q(t-2),S(t-1)} in the next network. Model T4-a was also created and trained with the higher frequency dataset.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.12a).

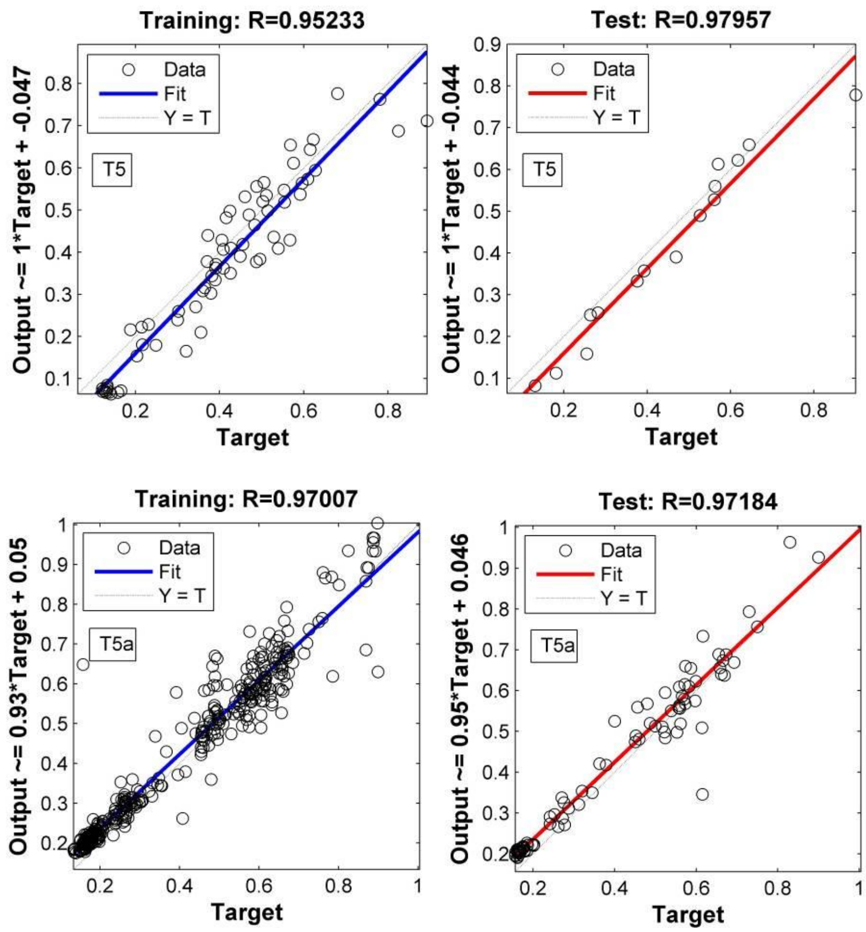


Figure 5.12a- Regression plots for training and testing datasets of model T5 (above) and T5-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Maneri.

The R (correlation coefficient) values obtained during training for model T5 and T5-a are 0.952 and 0.970 respectively while these values during testing are 0.979 and 0.971 respectively. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established. The response of models T5 and T5-a can be seen in Figure 5.12b where the target and model computed values of sediment concentration (in mg/L) have been plotted against time. The errors obtained in the process have also been plotted against time. Evaluation of the models (Figure 5.12c) shows a comparison between observed and model computed values of sediment concentration along with variation of errors with time.

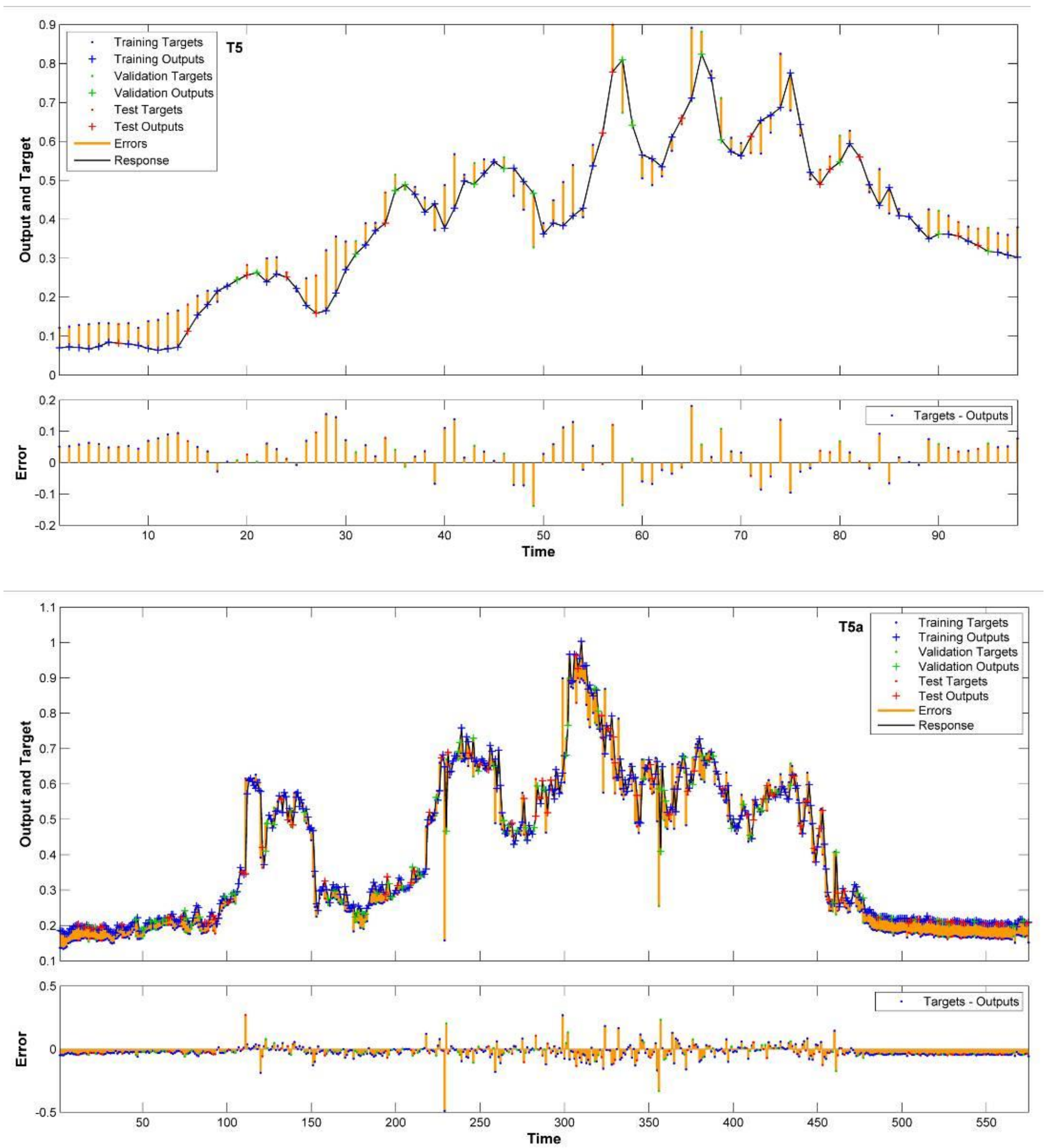


Figure 5.12b- Response of models T5 and T5-a after training, testing and validation at Maneri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

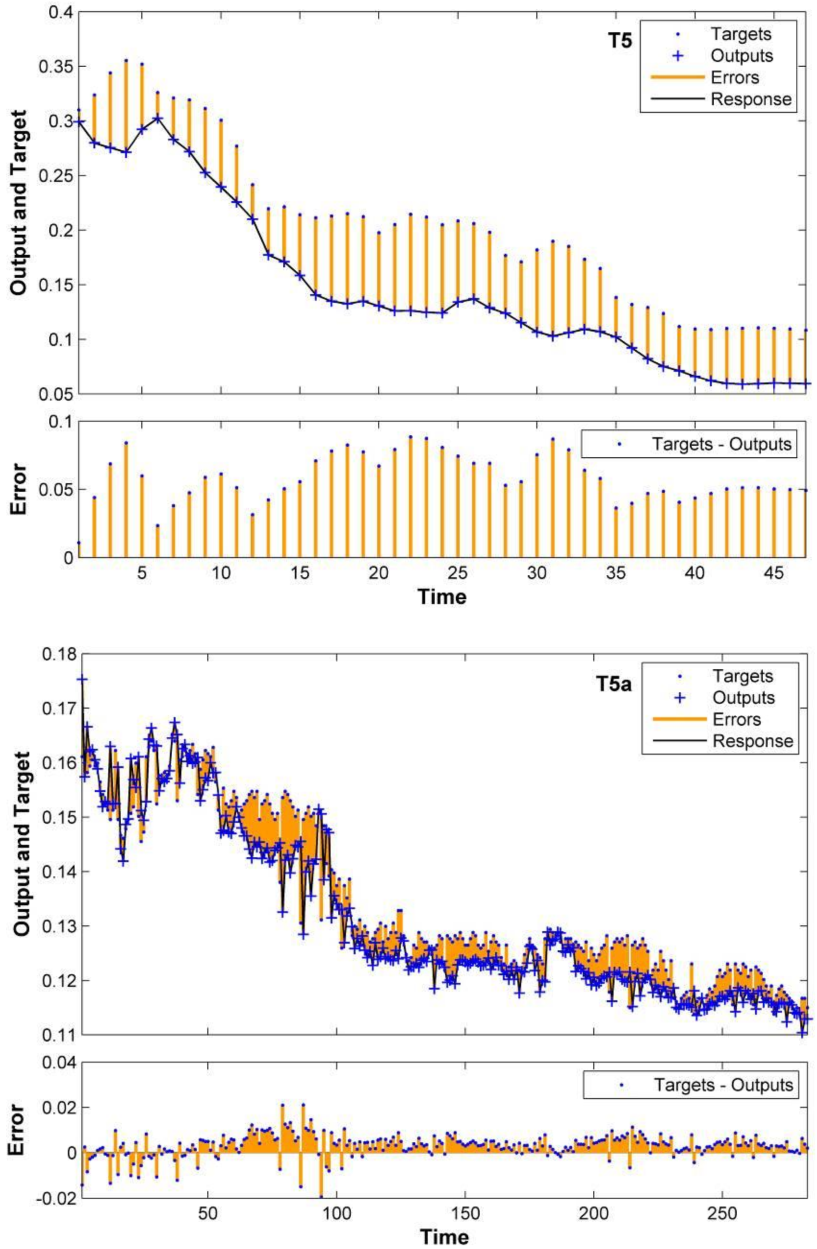


Figure 5.12c- T5 and T5-a Model evaluation at Maneri- Comparison between target and computed values of sediment concentration along with errors varying with time.

(vi) Model-T6 and T6-a: Water discharge at two previous time-steps along with the above configuration, was also included as an input. i.e. **S(t)= f{Q(t),Q(t-1),Q(t-2),S(t-1) S(t-2)}** in the next network. Model T6-a using the high frequency dataset was also created and trained.

The relationship between target values and model predicted output values of sediment concentration can be understood with the help of regression plots (Figure 5.13a).

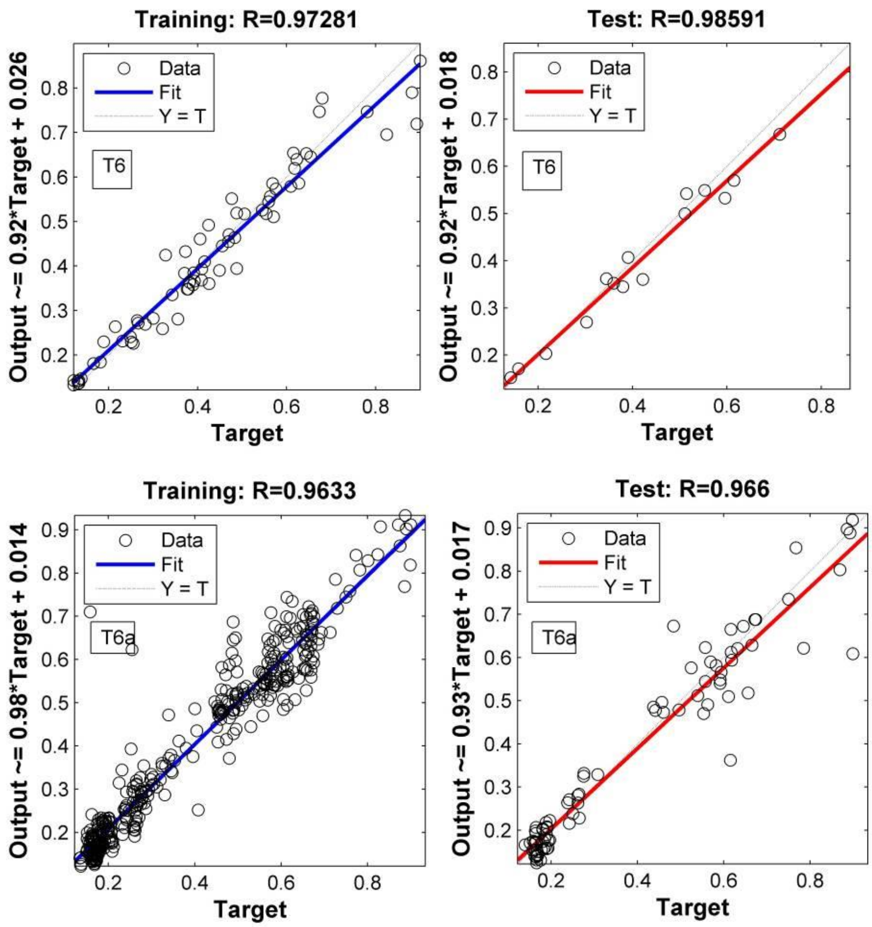


Figure 5.13a- Regression plots for training and testing datasets of model T6 (above) and T6-a (below) showing relationship between target and model computed values of sediment concentration in mg/L at Maneri.

The R (correlation coefficient) values obtained during training for model T6 and T6-a are 0.97 and 0.963 respectively while these values during testing are 0.985 and 0.966 respectively. It can be observed that the testing values are higher for both the models. Regression equations are also shown in the ordinate label of the plots wherein a direct relationship between targets and outputs is established. The response of models T6 and T6-a can be seen in Figure 5.13b where the target and model computed values of sediment concentration (in mg/L) have been plotted against time. The errors obtained in the process have also been plotted against time. Evaluation of the models (Figure 5.13c) shows a comparison between observed and model computed values of sediment concentration along with variation of errors with time.

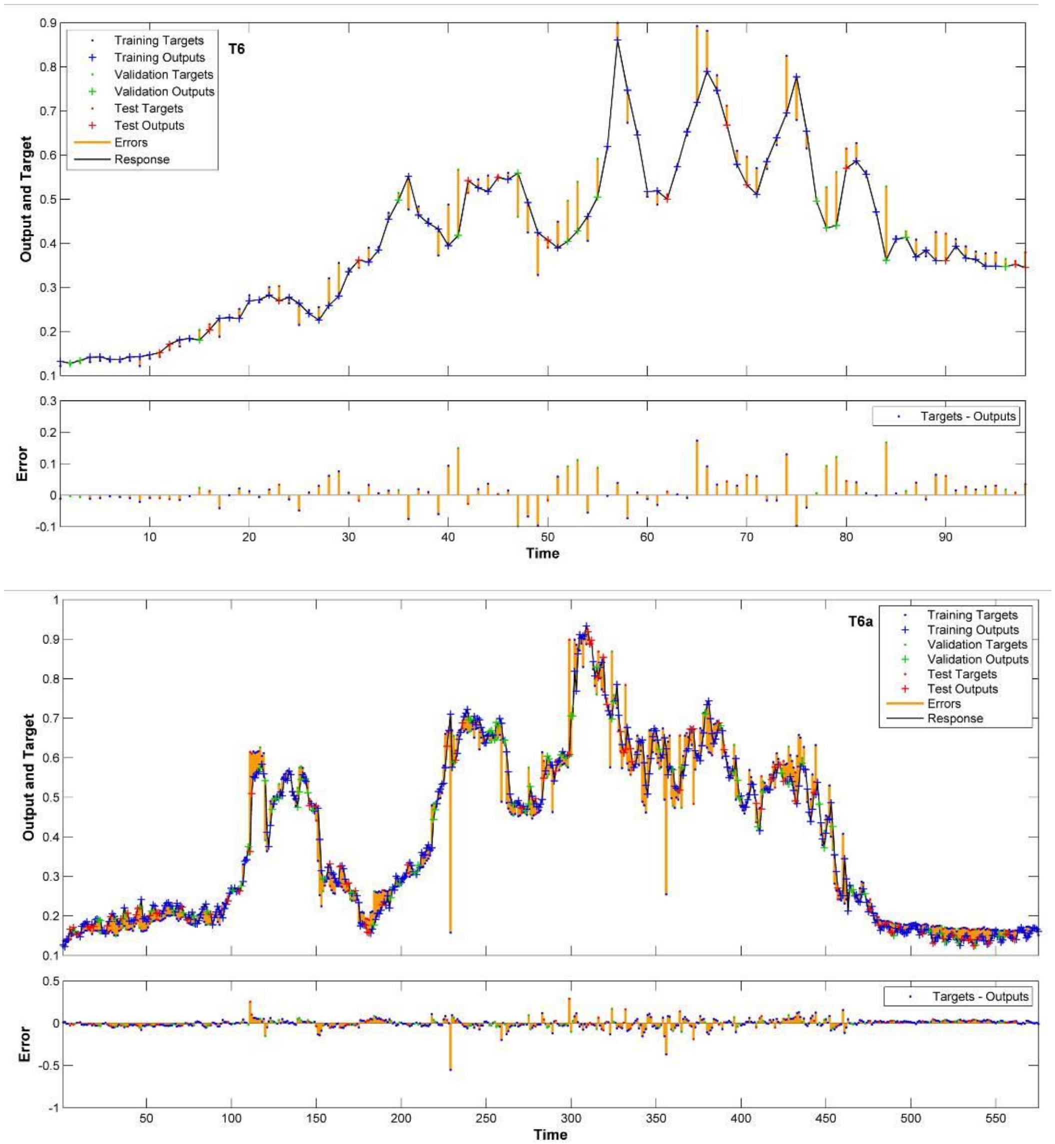


Figure 5.13b- Response of models T6 and T6-a after training, testing and validation at Maneri: Plot showing comparison between target and model computed values of sediment concentration (mg/L) along with network errors with time.

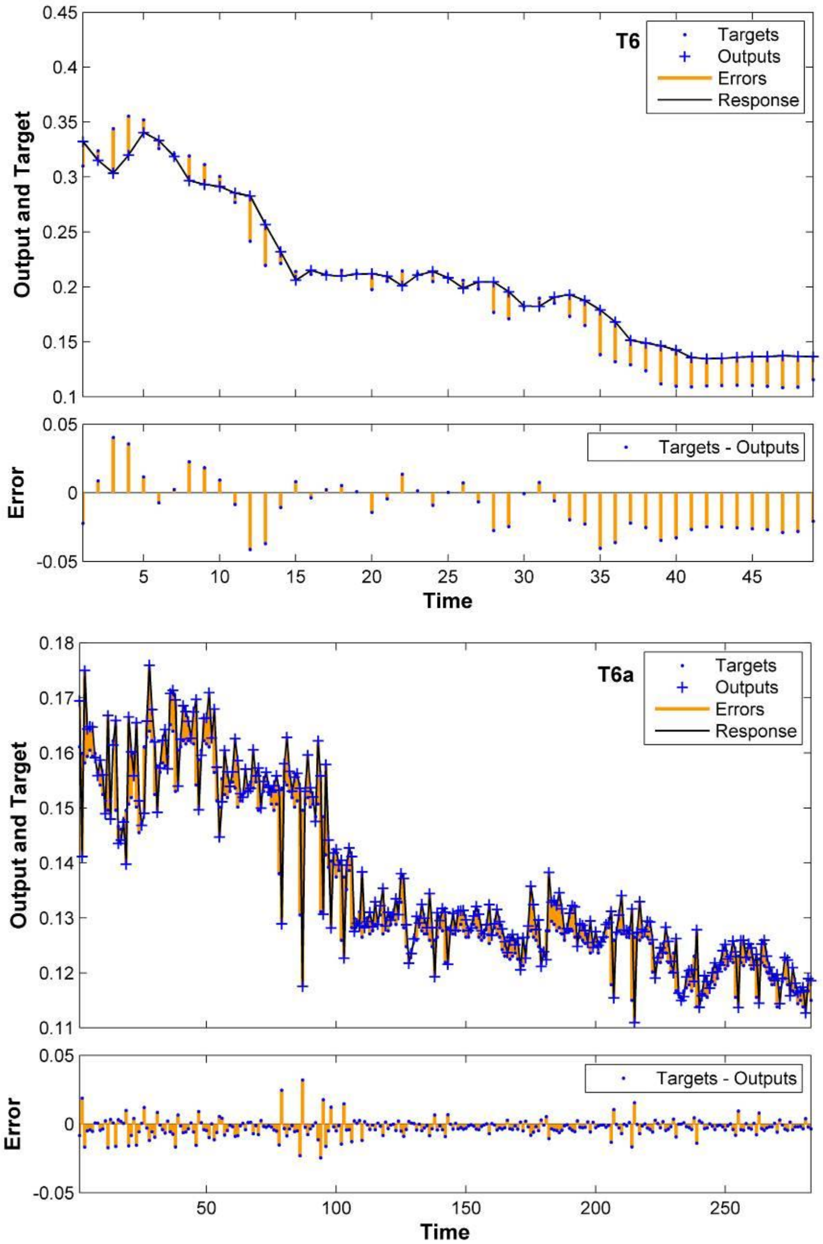


Figure 5.13c- T6 and T6-a Model evaluation at Maneri- Comparison between target and computed values of sediment concentration along with errors varying with time.

5.1.3 NAR

More that 2000 discharge values (in m^3/s) were used for modeling in the study. One step previous discharge values were used as input to predict the discharge values at the present time step in all the three locations. The training, validation and testing results are shown below.

i) **Maneri:** A correlation coefficient (R) value of 0.964 during training and 0.976 during testing has been obtained at Maneri. This implies that the coefficients of determination (R^2) are 0.92 and 0.952 for training and testing respectively. The response plot also shows a close match between observed and predicted values of discharge.

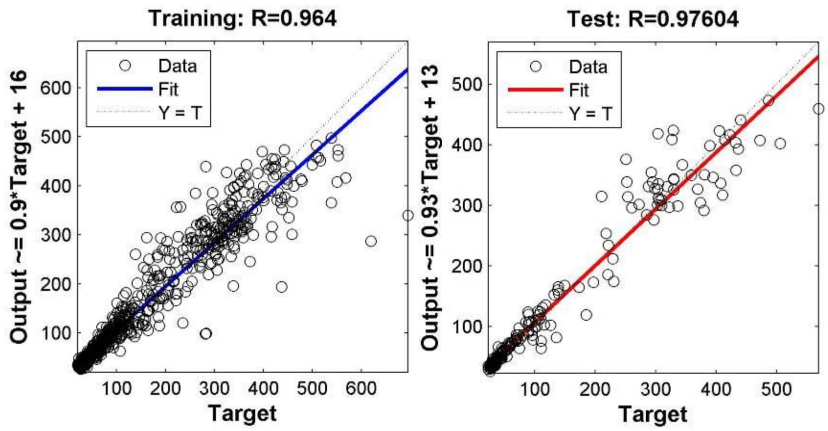


Figure 5.14a- Regression plots for NAR training and testing datasets at Maneri showing relationship between target and model computed values of discharge in m^3/s.

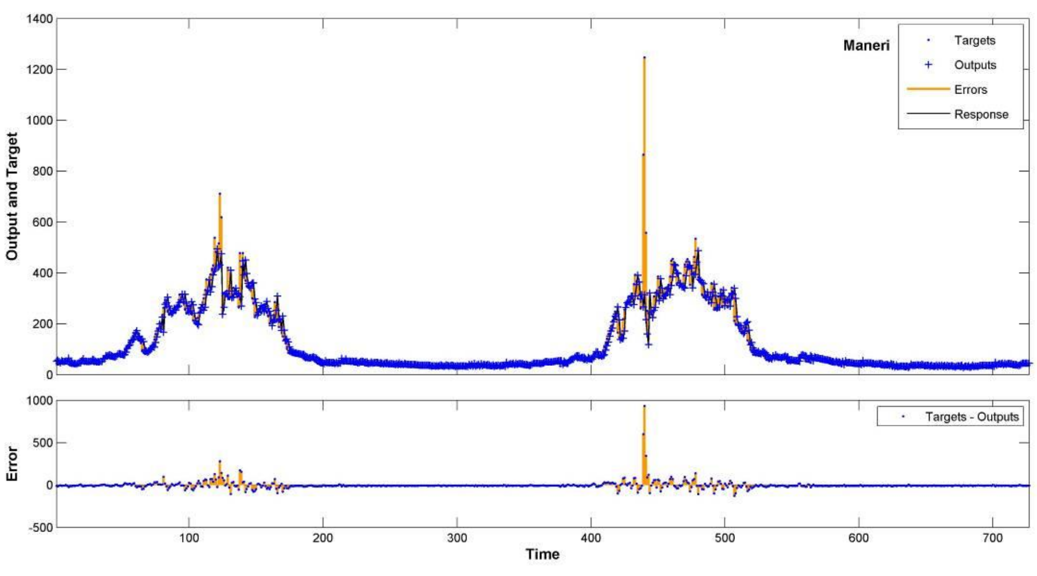


Figure 5.14b- Response of NAR models at Maneri after training, testing and validation: Plot showing comparison between target and model computed values of discharge (m^3/s) along with network errors with time.

ii) **Uttarkashi:** At Uttarkashi, a correlation coefficient (R) value of 0.95 during training and 0.962 during testing has been obtained. This implies that the coefficients of determination (R^2) are 0.90 and 0.92 for training and testing respectively. The response plot also shows a close match between observed and predicted values of discharge.

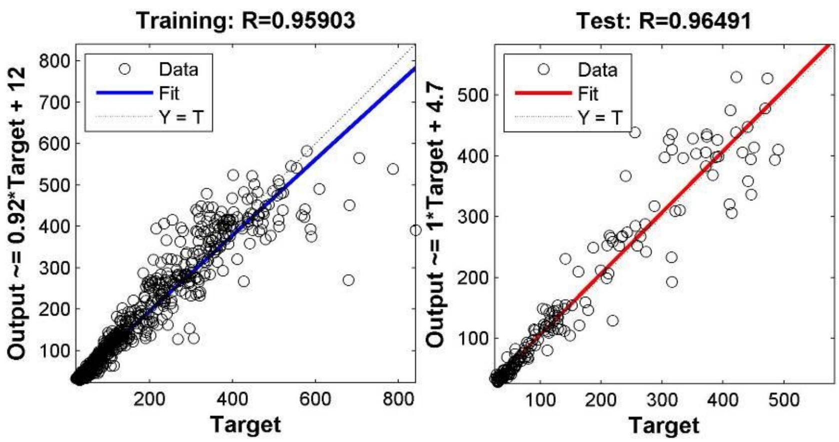
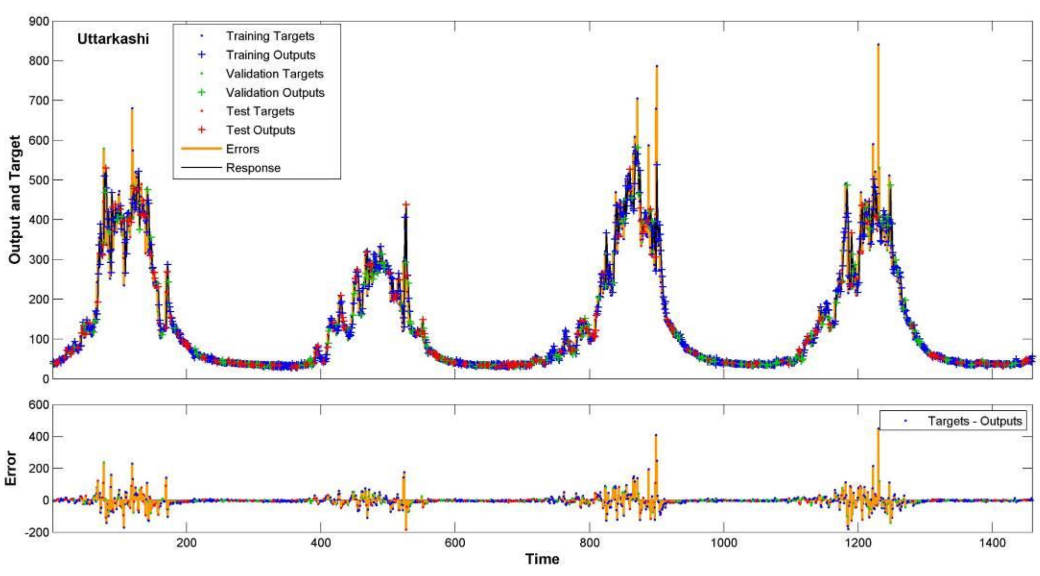


Figure 5.15a- Regression plots for NAR training and testing datasets at Uttarkashi showing relationship between target and model computed values of discharge in m^3/s.



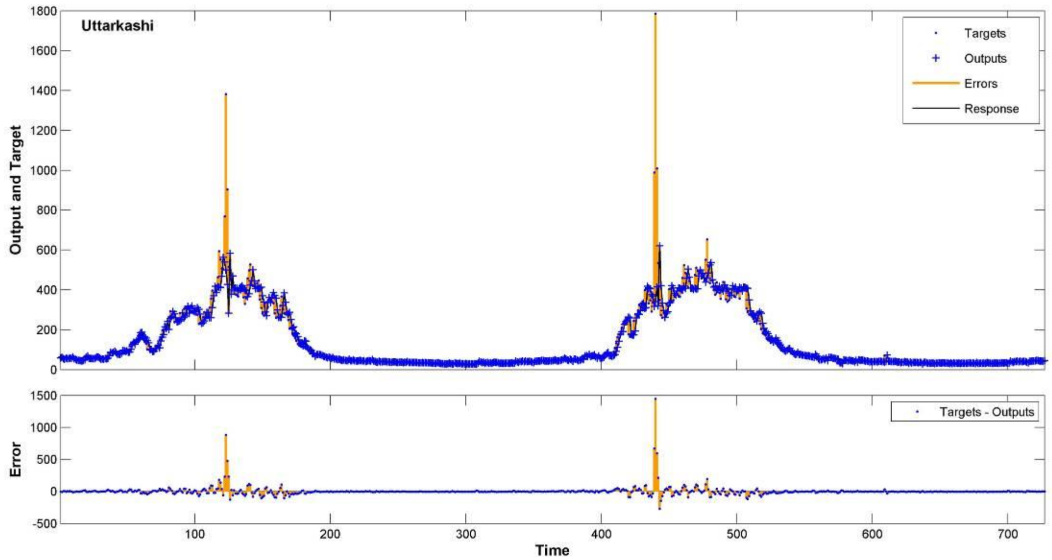


Figure 5.15b- Response of NAR models at Maneri after training, testing and validation: Plot showing comparison between target and model computed values of discharge (m^3/s) along with network errors with time.

iii) **Rishikesh**: At Rishikesh, a correlation coefficient (R) value of 0.954 during training and 0.968 during testing has been obtained. This implies that the coefficients of determination (R^2) are 0.910 and 0.937 for training and testing respectively. The response plot also shows a close match between observed and predicted values of discharge.

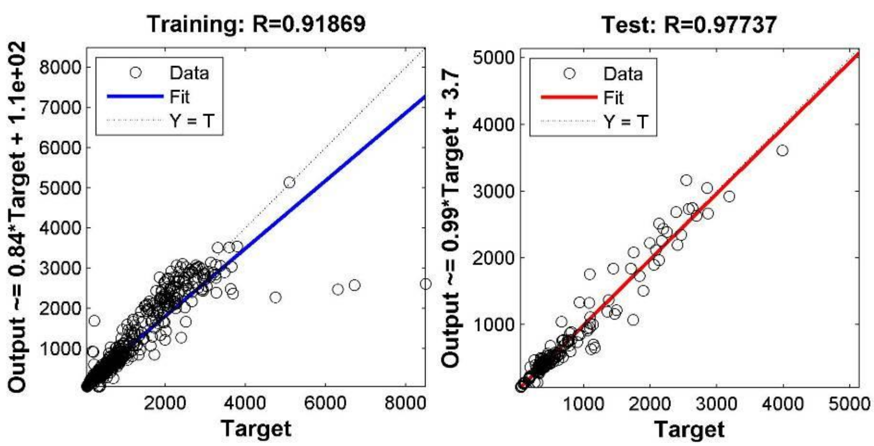
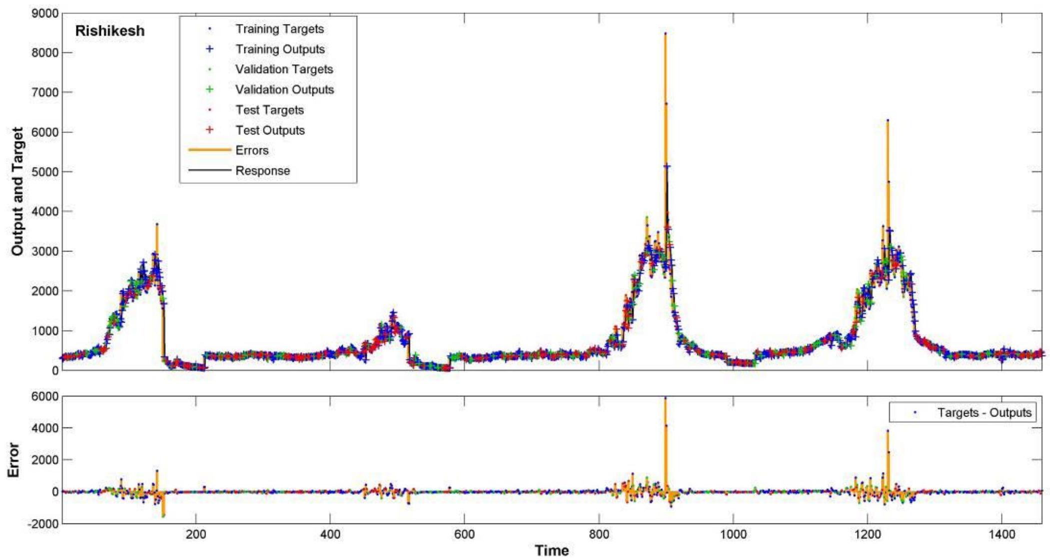


Figure 5.16a- Regression plots for NAR training and testing datasets at Uttarkashi showing relationship between target and model computed values of discharge in m^3/s .



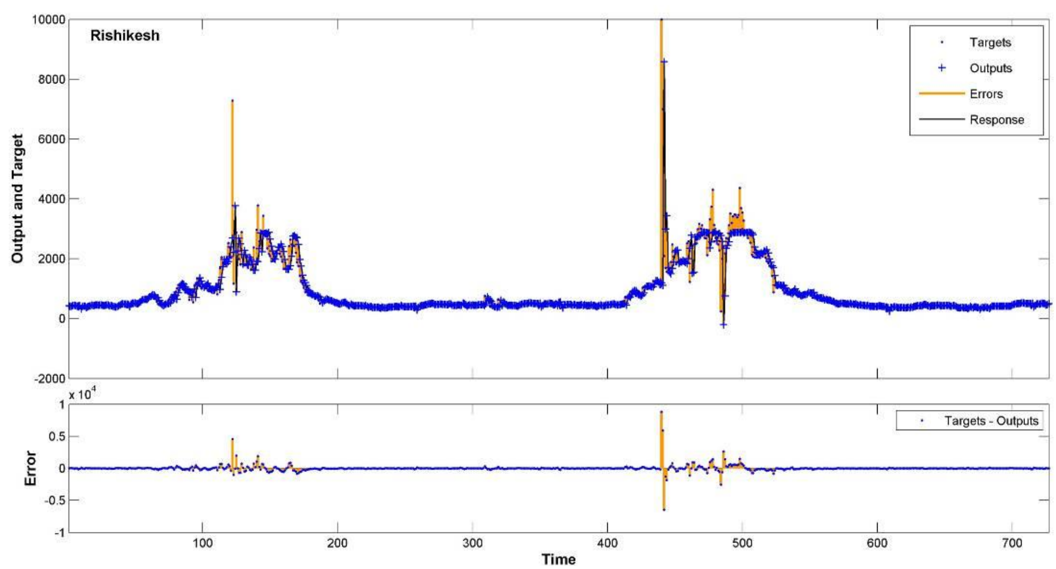


Figure 5.16b- Response of NAR models at Maneri after training, testing and validation: Plot showing comparison between target and model computed values of discharge (m^3/s) along with network errors with time.

5.2 DISCUSSION

The performance criteria of ANN models are the comparison of R, R^2 and MSE values (discussed in Chapter 4). The Correlation Coefficient or R value is commonly used to evaluate goodness of fit of hydrologic variables, and is obtained by performing linear regression between the ANN-predicted values and the targets.

Table 5.1- Performance estimates of ANN Models

	Model	R^2	MSE
GANGOTRI	**T1/1a**	0.837/0.777	0.0028/0.0079
	T2/2a	0.851/0.806	0.0051/0.0068
	T3/3a	0.819/0.848	0.009/0.0055
	T4/4a	0.819/0.885	0.0023/0.0034
	T5/5a	0.828/0.799	0.0098/0.0061
	T6/6a	0.877/0.793	0.009/0.0097
	T7/7a	0.842/0.819	0.0033/0.0042
MANERI	**T1/1a**	0.902/0.95	-0.009/-0.002
	T2/2a	0.938/0.94	-0.002/-0.004
	T3/3a	0.891/0.938	0.0016/-0.0004
	T4/4a	0.937/0.956	-0.009/-0.0019
	T5/5a	0.958/0.942	-0.0008/0.004
	T6/6a	0.970/0.933	-0.005/0.0001
NAR	**Maneri**	0.95	0.00087
	Uttarkashi	0.92	0.0076
	Rishikesh	0.93	0.0095

R equal to 1 indicates perfect correlation between the target and predicted values, whereas R equal to 0 indicates no correlation between. The mean square error or MSE value is another parameter for evaluation of the prediction capability of the ANN. The ANN performance is considered good when the MSE values are close to 0. R and R^2 values closer to one with smaller MSE values indicate better performance. The model characteristic and performance parameters have been tabulated in table 3.1.

i) **Gangotri-** The regression plots were made between observed and computed values of sediment concentration and they show that at Gangotri, the overall performance range is not too large with the values of coefficient of determination ranging from 0.777 to 0.885 in the updating mode and from 0.819 to 0.877 in the non-updating mode. The range of performance is wider for the updating mode than that of the non-updating mode. However, on the basis of average performance, the non-updating mode performs better (avg. R^2 = 0.839) than the updating mode (avg. R^2 = 0.818). In the present study, models T1, T4 and T5 are simple one input one output non-updating models where the relationship of sediment concentration with discharge, rainfall and temperature as independent variables has been explored. According to the performance parameters (R and R^2 values), among discharge, temperature and rainfall as independent variables, the sediment concentration is most affected by rainfall (highest R^2 value). In the real scenario also, we know that rainfall has a direct effect on sediment concentration as an increase in rainfall leads to an increase in discharge which in turn increases sediment concentration. Also, higher rainfall leads to greater erosion resulting in higher sediment supply to the river. This indirect relationship between rainfall and discharge, although physically observable, is not seen in the statistical analysis. The rainfall data contains several nil values due to which the degree of association between rainfall and sediment concentration, as seen in statistical correlation is very low. However, this indirect relationship is very well brought out with ANN modeling as model T4a is the best performing model. Models T2, T6 and T7 have used a combination of either discharge-rainfall; discharge-temperature or rainfall-temperature as input parameters against sediment concentration. In this scenario, according to the performance parameters, the rainfall-temperature (T7) combination of inputs is seen to work relatively better. The performance is the best for the model in which only rainfall has been used as input (T4-a). This implies that the generally accepted belief of better performance of multi-input ANN models may not hold true always. Model T3 has used all three variables as inputs and the model is seen to perform well with high R^2 value and low error. However, it is not the best performing model. Models T1-T7 have been trained in the non-updating mode where previous time-step values have not been employed as network input. Models T1a-T7a, represent the updating mode models. Non updating models T1, T2, T5, T6 and T7 are seen to perform better than the corresponding models in the updating mode. However, updating models T3-a and T4-a perform better than corresponding non-updating models. This implies that use of previous time step values as inputs (updating mode) may not necessarily improve model performance and vice versa.

Some generalized and some model specific observations can be made from the response plots. The overall trend of sediment concentration is well captured by the models. It is also interesting to note in the response plots that when the magnitude of values of sediment concentration is smaller, the variation or fluctuation in it is also low and when the magnitude of values is larger, the fluctuation or variation is also large. The network error i.e. difference between observed and ANN predicted sediment concentration, is generally greater when values of observed sediment concentration are higher. In model T1, it can be seen that there is a general overprediction (Output>Target; negative errors) of sediment concentration when the magnitude of the variable is low (low points of the curve). On the contrary, there is a marked under prediction (Output<Target; positive errors) during the highest magnitude time (high points of the curve). The network errors are much smaller for model T1-a as can be seen in the response and evaluation plots. Among models T2 and T2-a, the errors are lesser for the former. Mostly, target values are greater than the model computed outputs resulting in under prediction which is markedly higher during peak sediment concentration period. Errors are larger for model T3 than for model T3-a with a similar under prediction of high values and over prediction of low values. In models T4 and T4-a, the overall trend is very well captured by ANN. Over prediction of low values is much lesser in this case although there is under prediction of higher values seen with the peaks in the response plots. The performance of models T5 and T5-a is also similar in the sense that the errors show similar variations and the response plot also shows similar phases of under and over prediction. Model T-6a has several continuous over predicted phases as compared with model T6 where sediment concentration values have been closely predicted and the overall trend has been well captured. Among models T7 and T7-a, the former has more errors than the latter.

It is clear from the above discussion that sediment concentration values are well predicted with ANN in the Gangotri scenario and relationships which are not expressed by normal statistical correlation are very well brought out with ANN. The best performing model is the one where only Rainfall is employed as the input parameter and previous time step values are also used as inputs (model T4-a).

ii) **Maneri-** In the present study, modeling has been carried out using two approaches- daily and three hourly and the inputs increase from model T1/1a to T6/6a. However, no clear increasing or decreasing trend of coefficient of determination with this increase is observed.

The regression plots show R values obtained for training and testing data subsets of models based on daily data (T-T6) as well as models based on three hourly data (T1-a to T6-a). Higher R values in the testing rather than training subsets in all the models indicates that no data over-fitting has occurred, which should be the case. The regression plots obtained during testing of data for models in both the approaches (T-T6 and T1a-T6a) have been shown. The performance is highest for model T6 (R^2=0.970) [Table 3] which employs maximum number of inputs in the daily approach. Overall, the range of coefficient of determination is 0.891 to 0.970 which indicates that the overall performance of the models is good and the SSC values have been closely predicted. It can be seen that as an average, that the three hourly approach models tend to perform relatively better than the corresponding daily approach models [Avg. R^2 in daily approach= 0.93; Avg. R^2 in three-hourly approach= 0.94]. It is also observed that the use of previous sediment concentration values as network inputs enhances model performance. The response of all the models was observed with the help of plots where the observed (target) values of SSC were plotted with the model calculated (output) values against time. The errors obtained in the process were also plotted against time. The training and evaluation response plots of best performing models for Maneri, T6 (daily approach) and T4a (three hourly approach)

The overall trend of SSC is well captured by the models, but there are two important characteristics of the observed (target) and ANN predicted (output) sediment concentration values which can be seen in the performance plots. Firstly, when the magnitude of values is smaller, the variation or fluctuation in it is also low. This can be seen during the earlier and later part of the curve. Secondly, when the magnitude is greater, the variation is also larger. This corresponds to the middle part of the curve. The performance plots show that the network error i.e. difference between observed and ANN predicted sediment concentration, is generally greater when values of observed sediment concentration are higher, approximately the period of July and August when discharge and sediment concentration and extremely high in the Bhagirathi river. Errors in the period before and after that are smaller and so are the observed values of sediment concentration. This time corresponds to the onset (June) and waning (September-October) respectively of monsoons in the study area. Also interesting to note is, there is a general under-prediction during the high sediment concentration period of July-August (observed values are mostly higher than predicted ones, as can be seen in the performance plots) and there is a general over-prediction in the low sediment concentration period of June, September and October (observed values are lesser than predicted values). Nevertheless, despite the high variation during the peak monsoon period, ANN has been able to closely predict the sediment concentration values.

This study shows that short duration geo-hydrological time series data can also be predicted by ANN modeling with substantial accuracy. Prediction would not just help in filling gaps in hydrological data but will also enable continuous monitoring of sediment concentration which is difficult in the Himalayan Rivers where floods and other such eventualities commonly occur.

iii) NAR

It can be seen in the response plots that most of the discharge values are near perfectly predicted by ANN. Extremely high values of coefficient of determination have been obtained [Maneri, 0.95; Uttarkashi, 0.92; Rishikesh, 0.93]. The predicted and observed discharge values closely match on the rising and falling limb of the discharge curve. However, it is observed that the peak values of discharge are under predicted by the model. In this particular case, despite the fact that the peak values of observed discharge are exceptionally high, ANN has still been able to predict them to an extent. The tail ends in the response plots are near perfectly predicted by the models. Errors are mostly confined to the peak areas although even there to an extent the values have been predicted. The discharge at Rishikesh is the combined discharge of Alaknanda and Bhagirathi Rivers and at this location the fluctuations in discharge are not as high as in the upstream rivers possibly because of lower gradient and wider channel.

The results of single series modeling at Maneri, Uttarkashi and Rishikesh show that even when a single variable is involved, ANN has the ability to learn and predict trends. The continuous monitoring of sediment concentration in the Himalaya is difficult and even concerned agencies normally collect monthly or fortnightly data. In such situations single series predictions can be used to make prediction of other variables. The experimental study indicates that ANN is a robust tool which has the ability to predict hydrologic variables even when a single series or variable is involved. In the present case, ANN has successfully predicted the values of discharge at three different locations on Bhagirathi and Ganges using only previous day values of discharge as input. Prediction using a single time series can be of immense use in scenarios where data availability is difficult and also in flood monitoring.

CHAPTER 6

CONCLUSIONS

6.1 CONCLUSIONS

- ANN models created have successfully predicted the Suspended Sediment Concentration [SSC] values in the Bhagirathi River at Gangotri, Maneri, Uttarkashi and Rishikesh to a high degree of accuracy, notwithstanding the temporal variations.

- High coefficient of determination values of 0.88 (at Gangotri), 0.97(at Maneri) and 0.92-0.95 [Maneri, Uttarkashi and Rishikesh] have been obtained. Mean square error, which measures the second moment of error, incorporating both bias and variance, has been used for error estimates. Small Mean square error values (<0.002) have been obtained for all models.

- The use of Levenberg Marquardt optimisation function has led to better, faster and more accurate performance than GDX function (Gradient Descent with adaptive learning rate). Overall, the use of NARX (Non linear Autoregressive with exogenous Input) improvisation has yielded good prediction results.

- Overall, the modeling performance is better at Maneri(short period) than at Gangotri (longer period) implying that longer time period data may not always result in better models. Although the length of data is short but it has a high frequency (three hourly values) which leads to performance improvement.

GANGOTRI

- Data trends and analysis shows Suspended Sediment Concentration [SSC] is greatly controlled by Discharge, Rainfall and Temperature. Statistical correlation shows good association between SSC and discharge. However, statistical correlation shows less degree of association between Rainfall-SSC and Temperature-SSC.

- Modeling has been carried out in two modes: updating [antecedent time values used as inputs] and non-updating [antecedent time values not used as inputs]. Ablation period [May-October] discharge, rainfall, temperature and SSC data of five years has been used. Modeling in the updating mode does not significantly improve model performance. Non-updating mode models perform marginally better (avg. $R^2 = 0.839$) than the updating mode (avg. $R^2 = 0.818$). This implies that the use of antecedent time values as inputs may not necessarily improve model performance.

- The performance range of ANN models is not too large: $R^2 =$ 0.777 to 0.885 [T1a-T7a, models using antecedent values i.e. updating mode]; R^2 = 0.819 to 0.877 [T1-T7, models not using antecedent values i.e. non-updating mode]. With the ANN models, best performance is achieved in Model T4a, implying SSC is most affected by Rainfall (Model T4a). Out of all the input combinations, the Rainfall-Temperature [model T7] combination performs better. The result thus brings out a relationship which is not reflected in normal statistical correlation.

- The overall trend of SSC is well captured by ANN models, but, a general over prediction/ over estimation (Computed values > Observed values; negative errors) of SSC is seen when the magnitude of SSC is low (seen at the tails of the response plots). Also, an under prediction/ under estimation (Computed values < Observed values; positive errors) of SSC when magnitude is high. When magnitude of SSC is low, the fluctuations in it are also lesser [earlier and later part of the curve]. On the other hand, when magnitude of SSC is high, fluctuations are also higher [middle part of the curve]. The network error, is generally greater when values of observed sediment concentration are higher.

MANERI

- Data trends and analysis shows a high degree of association between Discharge and SSC. Both the values acme at the same time in the month of August and their low values too, correlate well in time. Also, one fold increase in water discharge leads to 2-3 fold increase in sediment concentrations.

- Modeling has been carried out using two approaches: daily and three-hourly. Although the time period remains same in both the approaches, the dataset used in the three hourly approach is six times larger. Discharge and SSC data of highest activity period [June to October] of a short duration has been used. On an average, the three hourly approach models [Avg. R^2= 0.93] perform better than the daily approach models [Avg. R^2= 0.93]. Use of antecedent SSC values as network inputs enhances model performance in case of Maneri.

- The SSC values have been closely predicted. The range of coefficient of determination is not large (R^2 = 0.891 to 0.970). Performance is highest for model T6 (R^2=0.970), which has the maximum number of inputs in the daily approach. At Maneri, the inclusion of one and two previous time step values of Discharge and SSC along with present discharge as network inputs leads to best prediction results (Model T6).

Non Linear Autoregressive Models (NAR)

- Single series predictions have been successfully carried out at Maneri, Uttarkashi and Rishikesh. The present values of discharge have been predicted using previous time step values of discharge of six water years data.

- Extremely high values of coefficient of determination have been obtained at Maneri (0.95), Uttarkashi (0.92), Rishikesh (0.93). The discharge trends have been very closely predicted. Prediction using a single time series can be of immense use in scenarios where data availability is difficult and also in flood monitoring.

An interesting outcome of modeling at Gangotri is that the rainfall: SSC and temperature: SSC relationship, which is not reflected in statistical correlation is brought out well with ANN. ANN has hence proved to be a powerful tool capable of establishing unknown dependencies with less data requirements, more flexibility and less cumbersome procedure. However, it is a rather difficult proposition to generalize any criteria of determining the optimum network architecture in ANN. Modeling with ANN is largely area and problem dependent and hence no two study areas can be modeled with similar ANN structures. Also interesting to note is that there is a general under-prediction during the high sediment concentration period and there is a general over-prediction in the low sediment concentration period and future ANN models would require this refinement.

6.2 FUTURE SCOPE

In the future, a holistic hydro-social framework for modeling that integrates both water availability (hydrology) and water use (social sciences) should be developed. Understanding hydrological resource management and water use tends to fall into the domain of social scientists, who have the tools to analyze how and why societies use water in the ways they do. Five major human variables critical to hydrological modeling which have profoundly influenced water use over the last 60 years are: (1) political agendas and economic development; (2) governance: laws and institutions; (3) technology and engineering; (4) land and resource use; and (5) societal responses (Carey et al. 2014). Societal forces establish the legal, economic, political, cultural, and social drivers that actually shape water usage patterns via human modification of watershed dynamics.

Also important to understand and consider is the concept of Environment Flow Requirement (EFR) which has been developed to assess and minimize the impact of large withdrawals on the river ecosystem and the uses to which the river is put (AHEC, 2011). Environmental flows is a term to denote the quantity, timing, duration, frequency and quality of water flows required to sustain freshwater, estuarine and near shore ecosystems and the human livelihoods and well being that depend on them (Acreman and Ferguson, 2010). EFRs are essential for maintaining flow regime, sediment movement, river purity, acquatic biodiversity, societal needs and prevailing recreation. It depends on the size of the river, natural state or perceived sensitivity of the river, the desired state of the river and the uses of river water. Consequently, before defining EFR for a river, broader objectives must be determined/ quantified to indicate type of river desired. With the changing patterns of water use, it is extremely essential to make such assessments and incorporate these social variables into geo-hydrological models.

BIBLIOGRAPHY

[1] Abbott, J. E. and Francis, J.R.D. Saltation and suspension trajectories of solid grains in a water stream. Philos. Trans. R. Soc. London, Ser. A, 284, 225–254. 1977.

[2] Abrahart, R.J., See, L.M., Heppenstall, A.J., White, S.M. Neural Network Estimation of Suspended Sediment: Potential Pitfalls and Future Directions in Abrahart, R.J., See, L.M., Solomatine, D.P. Practical Hydroinformatics. Springer Verlag Berlin Heidelberg. 139-161. 2008.

[3] Abrahart, R.J. and White, S.M. Modeling Sediment Transfer in Malawi: Comparing Back propagation Neural Network Solutions against a multiple linear regression benchmark using small data sets. Physics and Chemistry of the Earth, B 26(1): 19–24. 2001.

[4] Acreman, M.C. and Ferguson, J.D. Environmental flows and the European water framework directive. Freshwater Biology. 55(32-48). 2010.

[5] Altenford, C.T. Using a neural network for soil moisture predictions. ASAE Microfiche No. 92-3557, ASAE, St. Joseph, Mich. 1992.

[6] Alternate Hydro Energy Center Report, Assessment of cumulative impact of hydropower projects in Bhagirathi and Alaknanda Basins. 2011.

[7] American Society of Civil Engineers (ASCE) Task Committee on Application of the Artificial Neural Networks in Hydrology. Artificial neural networks in hydrology I: preliminary concepts. Journal of Hydraulic Engineering, ASCE 5(2): 115–123. 2000a.

[8] ASCE Task Committee on Application of Artificial Neural Networks in Hydrology. Artificial neural networks in hydrology II: hydrologic applications. Journal of Hydraulic Engineering, ASCE 5 (2): 124–137. 2000b.

[9] Asselman, N.E.M. Fitting and interpretation of sediment rating curves. Journal of Hydrology, 234(3–4): 228–248. 2000.

[10] Bagnold, R.A. Bed load transport by natural rivers. Water Resources Research. 13: 303-312. 1977.

[11] Bali, R., Awasthi, D.D., Tiwari, N.K. Neotectonic control on the geomorphic evolution of the Gangotri Glacier valley, Garhwal Himalaya. Gondwana Research 6 (4): 829–838. 2003.

[12] Barnard, P.L., Owena, L.A., Finkela, R.C. Style and timing of glacial and paraglacial sedimentation in a monsoon-influenced high Himalayan environment, the upper Bhagirathi Valley, Garhwal Himalaya, Sedimentary Geology 165:199–221. 2004.

[13] Bates, B.C., Kundzewicz, Z.W.,Wu, S., Palutikof, J.P. (Eds.). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva. 2008.

[14] Bhatt, B.K. Preliminary study of the Bhagirathi basin between Uttarkashi and Gomukh. In: Proceeding of National Symposium on Himalayan Geology, Calcutta. Geological Society of India. Miscellaneous Publication 15:1–8. 1963.

[15] Bickle, J.M., Bunbury, J., Chapman, J.H., Harris, B.W.N., Fairchild, J.I., Ahmad, T., 2003. Fluxes of Sr into the headwaters of the Ganges. Geochim. Cosmochim. Acta. (14), 2567–2584. 2003.

[16] Biemans, H., Haddeland, I., Kabat, P., Ludwig, F., Hutjes, R.W.A., Heinke, J., von Bloh, W., Gerten, D. Impact of reservoirs on river discharge and irrigation water supply during the 20th century. Water Resour. Res. 47. 2011.

[17] Bishop, C.M. Neural Networks for Pattern Recognition, O.U.P New York. 1995.

[18] Bloom, A.L. Geomorphology. A systematic analysis of late Cenozoic landforms. Prentice-Hall. 1998.

[19] Blum, M.D. and Roberts, H.H. Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise. Nat. Geosci. 2, 488–491. 2009.

[20] Boukhrissa, Z.A., Khanchoul, K., Le Bissonnais, Y., Tourki, M. Prediction of sediment load by sediment rating curve and neural network (ANN) in El Kebir catchment, Algeria Journal of Earth System Sciences, 122(5), 1303-1312. 2013.

[21] Brakenridge, G.R., Cohen, S., de Groeve, T., Kettner, A.J., Syvitski, J.P.M., Fekete, B.M. Calibration of satellite measurements of river discharge using a global hydrology model. J. Hydrol. 475, 123–136. 2012.

[22] Campolo, M., Andreussi, P., Soldati, A. River flood forecasting with neural network model. Water Resour. Res. 35(4): 1191–1197. 1999.

[23] Carey, M., Baraer, M., Mark, B.G., French, A., Bury, J., Young, K.R., McKenzie, J.M. Toward Hydro-social modeling: Merging human variables and the social sciences with climate-glacier runoff models (Santa River, Peru). Journal of Hydrology. 518(60-70). 2014.

[24] Carriquiry, J.D. and Sanchez, A. Sedimentation in the Colorado River delta and upper gulf of California after nearly a century of discharge loss. Mar. Geol. 158, 125–145. 1999.

[25] Chakrapani, G.J. Factors controlling variations in river sediment loads. Current Science, 88(4), 569–575. 2005a.

[26] Chakrapani, G.J. and Saini, R.K. Temporal and spatial variations in water discharge and sediment load in the Alaknanda and Bhagirathi Rivers in Himalaya, India Journal of Asian Earth Sciences. 35: 545–553. 2009.

[27] Chakrapani, G.J., Saini, R.K., Yadav, S.K. Chemical weathering rates in the Alaknanda-Bhagirathi river basins in Himalayas, India. Journal of Asian Earth Sciences. 34:347-362. 2009.

[28] Chang, F.J. and Chen, Y.C. A counter propagation fuzzy-neural network modeling approach to real time streamflow prediction. Journal of Hydrology. 245: 153–164. 2001.

[29] Chidambaram, S., Ramanathan, A.L., Anandhan, P., Srinivasamoorthy, K., Prasanna, M.V . Vasudevan, S. A statistical approach to identify the hydrogeochemically active regimes in groundwaters of Erode district, Tamilnadu. Asian Journal of Water, Environment and Pollution. 5(3):123-135. 2008.

[30] Cigizoglu, H.K. Suspended sediment estimation and forecasting using artificial neural networks. Turkish Journal of Engineering and Environmental Sciences. 26:15–25. 2002a.

[31] Cigizoglu, H.K. Suspended sediment estimation for rivers using artificial neural networks and sediment rating curves. Turkish Journal of Engineering and Environmental Sciences. 26: 27–36. 2002b.

[32] Cigizoglu, H.K. Estimation and forecasting of daily suspended sediment data by multi layer perceptrons, Advances in Water Resources. 27:185–195. 2004.

[33] Cigizoglu, H.K. and Kisi, O. Methods to improve the neural network performance in suspended sediment estimation, Journal of Hydrology, 317(3–4): 221–238. 2006.

[34] Cigizoglu, H.K. Artificial Neural Networks in Water Resources. Integration of Information for Environmental Security. 115–148. 2008.

[35] Cohen, S., Kettner, A.J., Syvitski, J.P.M. WBMsed: a distributed global-scale riverine sediment flux model — model description and validation. Comput. Geosci. 2013.

[36] Colby, B.R. Fluvial sediments: a summary of source, transportation, deposition and measurement of sediment discharge. US Geological Survey Bulletin 1181-A, USGS, Washington D.C. 1963.

[37] Crowder, D.W., Demissie, M., Markus, M. The accuracy of sediment loads when log transformation produces nonlinear sediment load-discharge relationships. Journal of Hydrology. 336(3–4): 250–268. 2007.

[38] Das, S.K., Routh, J., Roychoudhury, A.N., Klump, J.V. Elemental (C, N, H and P) and stable isotope (δ15N and δ13C) signatures in sediments from Zeekoevlei, South Africa: a record of human intervention in the lake. Journal of Paleolimnology. 39(3):349-360. 2008.

[39] Dawson, C.W. and Wilby, R. An artificial neural network approach to rainfall–runoff modeling. Hydrological Sciences Journal. 43 (1): 47-66. 1998.

[40] Dawson, C.W. and Wilby, R.L. Hydrological modeling using artificial neural networks, Progress in Physical Geography. 25(1): 80–108. 2001.

[41] Deka, R.L., Mahanta, C., Pathak, H., Nath, K. K., Das, S. Trends and fluctuations of rainfall regime in the Brahmaputra and Barak basins of Assam, Theoretical and Applied Climatology. 114(1-2):61-71. 2013.

[42] Dogan, E., Yuksel, I., Kisi, O. Estimation of total sediment load concentration obtained by experimental study using artificial neural networks. Environ Fluid Mech. 7:271–288. 2007.

[43] Doll, P., Fiedler, K., Zhang, J. Global-scale analysis of river flow alterations due to water withdrawals and reservoirs. Hydrol. Earth Syst. Sci. 13 (12), 2413–2432. 2009.

[44] Dudeja, D., Bartarya, S.K., Khanna, P.P., Ionic sources and water quality assessment around a reservoir in Tehri, Uttarakhand, Garhwal Himalaya. Environ. Earth Sci. 69:2513–2527. 2013.

[45] Eriksson, P.G., Banerjee, S., Catuneanu, O., Sarkar, S., Bumby, A.J. and Mtimkulu, M.N. Prime controls on Archaean-Palaeoproterozoic sedimentation: change over time. Gondwana Research 12: 550-559. 2007.

[46] Equeenuddin, S. M., Tripathy, S., Sahoo, P. K., Panigrahi, M. K. Hydrogeochemical characterization of acid mine drainage and water pollution at Makum Coalfield, India. Journal of Geochemical Exploration. 105:75-82. 2010.

[47] Equeenuddin, S. M., Tripathy, S., Sahoo, P. K., Panigrahi, M. K. Geochemistry of ochreous precipitates from coal mine drainage in India. Environmental Earth Sciences. 61:723-731. 2010.

[48] Fanos, A.M. The impact of human activities on the erosion and accretion of the Nile delta coast. J. Coast. Res. 11, 821–833. 1995.

[49] Fekete, B.M. and Vörösmarty, C.J. The current status of global river discharge monitoring and potential new technologies complementing traditional discharge measurements. Predictions in ungauged basins: PUB kick-off. Proceedings of the PUB Kick-off meeting held in Brasilia, 20–22 November 2002. IAHS Publ., vol 309, pp. 129–136. 2013.

[50] Firat, M. and Gungor, M., River flow estimation using adaptive neuro fuzzy inference system. Mathematics and Computers in Simulation. 2006.

[51] Francke, T., López-Tarazón, J.A., Schröder, B. Estimation of suspended sediment concentration and yield using linear models, random forests and quantile regression forests. Hydrol. Process. 22 (25), 4892–4904. 2008.

[52] French, M.N., Krajewski, W.F., Cuykendall, R.R. Rainfall forecasting in space and time using a neural network. Journal of Hydrology 137, 1–31. 1992.

[53] Garg, V. Modeling catchment sediment yield: a genetic programming approach. Nat Hazards .70:39–50. 2014.

[54] Garrels, R. M. and Mackenzie, F. T. Evolution of Sedimentary Rocks, Norton, New York, pp 397. 1971.

[55] Gautam, M.R., Watanabe, K., Saegusa, H. Runoff analysis in humid forest catchment with artificial neural network. Journal of Hydrology, 235, 117–136. 2000.

[56] Ghosh, A., Saha, S., Saraswati, P.K., Banerjee, S., Burley, S. and Gundu Rao, T.K. Gallitellia - A Proxy for Palaeo-monsoonal upwelling on the western coast of India? Current Science 95: 1608-1611. 2008.

[57] Girija, T.R., Mahanta, C. Fuzzy Logic and Artificial Neural Network approaches for dissolved oxygen prediction. Int. J. of Environment and Waste Management. 6(3/4): 237 – 254. 2006.

[58] Govindaraju, R. S. and Rao, A. R. (eds). Artificial Neural Networks in Hydrology, Kluwer Academic Publishers, Amsterdam. 2000.

[59] Gupta, H. and Chakrapani, G.J. Temporal and spatial variations in water flow and sediment load in the Narmada river. Curr. Sci. 92 (5), 679–684. 2007.

[60] Haddadchi, A., Movahedi, N., Vahidi, E., Omid, M.H., Dehghani, A.A. Evaluation of suspended load transport rate using transport formulas and artificial neural network models (case study: Chelchay Catchment). J. Hydrodyn. 25 (3), 459–470. 2013.

[61] Halff, A.H., Halff, H.M., Azmoodeh, M. Predicting runoff from rainfall using neural networks. Proc. Engng. Hydrol., ASCE, New York. 768–775. 1993.

[62] Hall M.J. and Minns A.W. Rainfall-runoff modeling as a problem in artificial intelligence: experience with a neural network. BHS 4th National Hydrology Symposium, Cardiff 5.51–5.57. 1993.

[63] Harder, S.V., Amatya, D., Callahan, T, Trettin, C., Hakkila, J. Hydrology and water budget for a forested Atlantic coastal plain watershed, South Carolina. Journal of the American Water Resources Association. 43(3):563-575. 2007.

[64] Harding, R., Best, M., Blyth, E., Hagemann, S., Kabat, P., Tallaksen, L.M.,Warnaars, T., Wiberg, D., Weedon, G.P., van Lanen, H., Ludwig, F., Haddeland, I. WATCH: current knowledge of the terrestrial global water cycle. J. Hydrometeorol. 12 (6), 1149–1156. 2011.

[65] Haritashya, U.K. Glacio-hydrological studies of the Gangotri Glacier basin, Himalayas. Ph.D Thesis, Department of Earth Sciences, Indian Institute of Technology, Roorkee, India, 360 pp. 2005.

[66] Haritashya, U.K., Singh, P., Kumar, N., Gupta, R.P. Suspended sediments from Gangotri Glacier: quantification, variability and correlations with discharge and temperature, Journal of Hydrology: 321, 116–130. 2006a.

[67] Hartmann, J., Lauerwald, R., Moosdorfa, N. A brief overview of the GLObal River CHemistry Database, GLORICH Procedia Earth and Planetary Science. 10:23 – 27. 2014.

[68] Hasnain, S. I. and Chauhan, D. S. Sediment transfer in the glaciofluvial environment – a Himalayan perspective. Environ. Geol. 22, 205–211. 1993.

[69] Hasnain, S.I. Factors controlling suspended sediment transport in Himalayan glacier meltwaters. Journal of Hydrology 181: 49–62. 1996.

[70] Hasnain, S.I., Thayyen, R.J. Discharge and suspended-sediment concentration of meltwaters, draining from the Dokriani Glacier, Himalaya, India. Journal of Hydrology 218: 191–198. 1999.

[71] Haykin, S. Neural Networks: A Comprehensive Foundation. Prentice Hall. New Jersey. 1999.

[72] Hebb, D. O. The Organization of Behavior: A Neuropsychological Theory. New York: Wiley and Sons. 1949.

[73] Heng, S. and Suetsugi, T. Using artificial neural network to estimate sediment load in ungauged catchments of the Tonle Sap River Basin, Cambodia. J.Water Resour. Prot. 5(2), 111–123. 2013a.

[74] Hewitt, K. Catastrophic landslides and their effects on the upper Indus streams, Karakoram Himalaya, northern Pakistan, Geomorphology 26, 47–80. 1998.

[75] Hjulstrom, F. Studies of the morphological activities of rivers as illustrated by River Fyris. Bulletin of the Geological Institute, University of Uppsala. 25: 221-527. 1935.

[76] Holtschlag, D.J. Optimal estimation of suspended-sediment concentrations in streams. Hydrological Processes 15(7), 1133–1155. 2001.

[77] Hsu, K.L., Gao, X.G., Sorooshian, S., Gupta, H.V. Precipitation estimation from remotely sensed information using artificial neural networks. Journal of Applied Meteorology 36 (9), 1176–1190. 1997.

[78] Hsu, K.L., Gupta, H.V., Sorooshian, S. Artificial neural network modeling of the rainfall–runoff process. Water Resources Research 31 (10), 2517–2530. 1995.

[79] Huntington, T.G. Evidence for intensification of the global water cycle: review and synthesis. Journal of Hydrology 319, 83–95. 2006.

[80] Ileana B., La Torre, T., Amatya, D. Callahan, T. Interpreting historical streamflow data from a third-order coastal plain watershed: Runoff response to storm events. Proceedings of the South Carolina Water Resources Conference. 2008.

[81] Imrie, C. E., Durucan, S., Korre, A. River flow prediction using artificial neural networks: generalization beyond the calibration range. Journal of Hydrology 233(1–4): 138–153. 2000.

[82] Isik, S. Regional rating curve models of suspended sediment transport for Turkey. Earth Sci. Inform. 6 (2), 87–98. 2013.

[83] Jain, A.K., Singh, S., Manickavasagam, R.M. Himalayan Collision Tectonics. Memoir Gondwana Research Group 7:114. 2002.

[84] Jain, S.K. Development of integrated sediment rating curves using ANN, Journal of Hydraulic Engineering, ASCE, 127(1), 30–37. 2001.

[85] Joshi, S.C., Joshi, D.R., Dani, D.D. Kumaun Himalaya: A geographic perspective on resource development. Publisher, Gyanodaya Prakashan, Nainital, pp 324. 1993.

[86] Jowhar, T.N. Chemistry of Tourmalines from the Gangotri Granite, Garhwal Higher Himalaya. Earth Science India 3, 181–194. 2010.

[87] Kale, V.S. Geomorphic Effects of Monsoon Floods on Indian Rivers. Natural Hazards (28): 65–84. 2003.

[88] Kao, J. J. Neural net for determining DEM-based model drainage pattern. J. Irrig. Drain. Eng. 122(2):112–121. 1996.

[89] Karunanithi, N., Grenney, W.J., Whitley, D., Bovee, K. Neural networks for river flow prediction. J. Comp. Civ. Engng, ASCE 8 (2), 201–220. 1994.

[90] Kaur, R., Srinivasan, R., Mishra, K., Dutta, D., Prasad, D., Bansal, G. Assessment of SWAT model for soil and water management in India. Land Use Water Resources Research, 3: 1–7. 2003.

[91] Kettner, A.J., Restrepo, J.D., Syvitski, J.P.M. A spatial simulation experiment to replicate fluvial sediment fluxes within the Magdalena River, Colombia. J. Geol. 118, 363–379. 2010.

[92] Kettner, A.J. and Syvitski, J.P.M. HydroTrend v. 3.0: a climate-driven hydrological transport model that simulates discharge and sediment load leaving a river system. Comput. Geosci. 34 (10), 1170–1183. 2008.

[93] Kettner, A.J. and Syvitski, J.P.M. Fluvial responses to perturbations in the Northern Mediterranean since the Last Glacial Maximum. Quat. Sci. Rev. 2009

[94] Kisi, O. River flow modeling using artificial neural networks, Journal of Hydrologic Engineering, ASCE, 9(1), 60–63. 2004.

[95] Kisi, O. Daily river flow forecasting using artificial neural networks and auto- regressive models. Turk J Eng Environ Sci 29:9–20. 2009.

[96] Knighton, D. Fluvial forms and processes. Edward Arnold, London. 1984.

[97] Krishnaswami, S., Singh, S.K., Dalai, T.K. Silicate weathering in the Himalaya: Role in contributing to major ions and radiogenic Sr to the Bay of Bengal. In: Somayajulu, B.L.K. (Ed.), Ocean Science, Trends and Future Directions. Indian National Science Academy and Academia International, New Delhi, pp. 23–51. 1999.

[98] Kumar, D.N. ANN Applications in Hydrology - Merits and Demerits. Invited Article in: Integrated Water Resources Planning and Management: 5:31-42. 2004

[99] Kumar, K., Miral, M.S., Joshi, S., Pant, N., Joshi, V., Joshi, L.M. Solute dynamics of meltwater of Gangotri glacier, Garhwal Himalaya, India. Environmental Geology. 58: 1151–1159. 2009.

[100] Kumar, M., Ramanathan, A.L., Keshari, A.K. Understanding the extent of Interaction between surface and ground water through major ion chemistry and multivariate Statistical techniques. Hydrological processes. 23(2):297-310. 2008.

[101] Kundu, N., Panigrahi, M.K., Sharma, S.P., Tripathy, S. Delineation of fluoride contaminated groundwater around a hot spring in Nayagarh, Orissa, India using geochemical and resistivity studies. Environmental Geology. 43: 228-235. 2002.

[102] Kundu N., Panigrahi, M.K., Tripathy, S. Munshi, S. Hart, B.R., Powell, M.A. A geochemical appraisal of Fluoride contamination of ground water in Nayagarh District, Orissa, India. Environmental Geology. 41:451-460. 2001.

[103] La Torre, T., Ileana, B., Amatya, D., Sun, G., Callahan, T. Seasonal rainfall-runoff relationships in a lowland forested watershed in the southeastern USA. Hydrological Processes. 25:2032-2045. 2011.

[104] Le, T.P.Q., Garnier, J., Gilles, B., Sylvain, T., Chau, V.M. The changing flow regime and sediment load of the Red River, Vietnam. J. Hydrol. 334, 199–214. 2007.

[105] Leopold, L.B. and Maddock, T. The hydraulic geometry of stream channels and some physiographic implications. United States Geological Survey Professional Paper. 252: pp 57. 1953.

[106] Maier, H.R. and Dandy, G.C. The use of artificial neural networks for the prediction of water quality parameters. Water Resources Research. 32 (4): 1013–1022. 1996b.

[107] Maier, H.R., Dandy, G.C. Understanding the behaviour and optimising the performance of back-propagation neural networks: An empirical study. Environmental Modeling and Software 13 (2): 179–191. 1998b.

[108] Maier, H.R.,Dandy, G.C. Neural networks for the prediction and forecasting of water resources variables: a review of modeling issues and applications. Environ. Model. Softw. 15 (1), 101–124. 1999.

[109] Maier, H.R. and Dandy, G.C. Neural networks for the prediction and forecasting of water resources variables: a review of modeling issues and application. Environment Modeling and Software. 15: 101–124. 2000.

[110] Mason, J.C., Price, R.K., Tem'me, A. A neural network model of rainfall-runoff using radial basis functions." J. Hydraul. 34(4): 537–548. 1996.

[111] McLennan, S.M. Weathering and global denudation. Journal of Geology, 101:295–303. 1993.

[112] Meade, R. H. River sediment inputs to major deltas. In Sea-Level Rise and Coastal Subsidence (eds Milliman, J. D. and Haq, B. U.), Kluwer, Boston, pp. 63–85. 1996.

[113] Meade, R.H. and Parker, R.S. Sediment in rivers of the United States. National Water Summary, 1984. Water Supply Paper, vol. 2275. USGS, Reston, Virginia, USA, pp. 40–60. 1985.

[114] Melesse, A.M., Ahmad, S., McClain, M.E., Wang, X., Lim, Y.H. Suspended sediment load prediction of river systems: an artificial neural network approach. Agric. Water Manag. 98 (5), 855–866. 2011.

[115] Mikhailova, M.V. Transformation of the Ebro River Delta under the impact of intense human-induced reduction of sediment and runoff. Water Resour. 30 (4), 370–378. 2003.

[116] Milliman, J. D. and Meade, R. H. Worldwide delivery of river sediment to the oceans. J. Geol. 91:1–21. 1983.

[117] Milliman, J.D., Farnsworth, K.L., Jones, P.D., Xu, K.H., Smith, L.C. Climatic and anthropogenic factors affecting river discharge to the global ocean, 1951–2000. Global 8 and Planetary Change 62(3), 187-194. 2008.

[118] Milliman, J.M., Syvitski, J.P.M. Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. J. Geol. 100, 525– 544. 1992.

[119] Milly, P.C.D., Dunne, K.A., Vecchia, A.V. Global pattern of trends in streamflow and

[120] Minns, A.W. and Hall, M.J. Artificial neural networks as rainfall runoff models. Hydrologic Science Journal. 41 (3): 399–417. 1996.

[121] Morris, G.L. and Fan, J. Reservoir Sedimentation Handbook. McGraw-Hill, New York. 1998.

[122] Mustafa, M.R., Rezaur, R.B., Saiedi, S., Isa, M.H. River Suspended Sediment Prediction Using Various Multilayer Perceptron Neural Network Training Algorithms—A Case Study in Malaysia. Water Resour. Manage. 26:1879–1897. 2012.

[123] Nagy, H.M., Watanabe, K., Hirano, M. Prediction of sediment load concentration in rivers using artificial neural network model. Journal of Hydraulic Engineering. 128(6): 588–595. 2002.

[124] Naithani, A.K., Nainwal, H.C., Sati, K.K., Prasad, C. Geomorphological evidences of retreating of Gangotri glacier and its characteristics. Current Science. 80(1): 87–94. 2001.

[125] Navone, H. D., and Ceccatto, H. A. Predicting Indian monsoon rainfall: A neural network approach. Clim. Dyn. 10:305–312. 1994.

[126] Nordin C.F. Jr., Cranston C.C. and Mejia B.A. New Technology for Measuring Water and Suspended sediment Discharge of large rivers. Proceedings of the Second International

Symposium on River Sedimentation, 11-16th October, 1983, Nanjing, China. Beijing Water resources and Electric Power press, pp 1145-1158.

[127] Nourani, V.,Kalantari, O.,Baghanam, A. Two semidistributed ANN-basedmodels for estimation of suspended sediment load. J. Hydrol. Eng. 17 (12), 1368–1380. 2012.

[128] Paikaray, S., Banerjee, S., Mukherjee, S. Geochemistry of shales from the Paleoproterozoic to Neoproterozoic Vindhyan Supergroup: implications on provenance, tectonics and paleoweathering. Journal of Asian Earth Sciences 32: 34-48. 2008.

[129] Pandey, S.K., Singh, A.K., Hasnain, S.I. Weathering and geochemical processes controlling solute acquisition in Ganga Headwater-Bhagirathi river, Garhwal Himalaya, India; Aquatic Geochemistry, 5:357–379. 1999.

[130] Pavelsky, T.M., Durand, M.T., Andreadis, K.M., Beighley, R.E., Pajya, R.C.D, Allen, G.H., Miller, Z.F. Assessing the potential global extent of SWOT river discharge observations. Journal of Hydrology. 519B, 1516-1525. 2014.

[131] Pelletier, J.D. A spatially distributed model for the long-term suspended sediment discharge and delivery ratio of drainage basins. J. Geophys. 2012.

[132] Pinet, P. and Souriau, M. Continental erosion and large-scale relief. Tectonics.7:563–582. 1988.

[133] Probst, J.L. and Tardy, Y. Long range streamflow and world continental runoff fluctuations since the beginning of this century. Journal of Hydrology 94, 289–311. 1987.

[134] Rai, R.K. and Mathur, B.S. Event-based Sediment Yield Modeling using Artificial Neural Network. Water Resources Management. 22: 423–441. 2007.

[135] Rajaee, T., Mirbagheri, S.A., Nourani, V., Alikhani, A. Prediction of daily suspended sediment load using wavelet and neurofuzzy combined model. J. Environ. Sci. Tech. 7(1): 93-110. 2009.

[136] Rajurkara, M.P., Kothyari, U.C., Chaube, U.C. Modeling of the daily rainfall-runoff relationship with artificial neural network. Journal of Hydrology. 285: 96–113. 2004.

[137] Raman, H., and N. Sunilkumar. Multivariate modeling of water resources time-series using artificial neural networks. Hydrological Science Journal 40(2):145–163. 1995.

[138] Ramanathan, A.L., Vaithiyanathan, P., Subramanian, V. Das, B.K. Nature and Transport of Solute load in the Cauvery River Basin, India. Water Research (28):1585-91. 1993.

[139] Ranjithan, S., Eheart, J. W., and Rarrett, J. H. Neural network-based screening for groundwater reclamation under uncertainty. Water Resour. Res. 29(3):563–574. 1993

[140] Raymo, M.E. and Ruddiman, W.F. Tectonic forcing of late Cenozoic climate. Nature 359, 117–122. 1992.

[141] Reddy, S.B. Estimation of watershed runoff using artificial neural networks. Ph.D Thesis in Agricultural Engineering (unpublished) Post Graduate School, IARI, New Delhi. 2003.

[142] Rezapour, O.M.,Shui, L.T.,Ahmad, D.B. Review of artificial neural networkmodel for suspended sediment estimation. Aust. J. Basic Appl. Sci. 4 (8), 3347–3353. 2010.
Rivers. Glob. Planet. Chang. 39 (1–2), 111–126. 2003.

[143] Routh, J., Meyers, P.A., Hjorth, T., Baskaran, M., Hallberg, R. Sedimentary geochemical record of recent environmental changes around Lake Middle Marviken, Sweden. Journal of Paleolimnology. 37(4): 529-545. 2007.

[144] Routh, J., Meyers, P.A., Gustafsson, Ö., Baskaran, M., Hallberg, R., ScholdstrÖm, A. Sedimentary geochemical characteristics of Lake Brunnsviken, Sweden: A record of human-induced environmental changes in the watershed. Limnology and Oceanography. 49:1560–1569. 2004.

[145] Roymoulik, M., Banerjee, S. and Mukherji, S. Correlation between sorbent characteristics and metal sorption capacity of soils around Mumbai: implications on environmental hazard management. Journal of the Geological Society of India 66: 445-452. 2005.

[146] Rumelhart, D.E., Hinton, G.E., Williams, R.J. Learning internal representations by error propagation. In: Rumelhart, D.E., McClelland, J.L. (Eds.), Parallel Distributed Processing. MIT Press, Cambridge.1986.

[147] Sahoo, P. K., Tripathy, S., Equeenuddin, S. M., Panigrahi, M. K. Geochemical Characteristics of Coal Mine Discharge vis-à-vis Behavior of Rare Earth Elements at Jaintia Hill Coalfield, Northeastern India. Journal of Geochemical Exploration. 112: 235-243. 2012.

[148] Saini, R.K. Phd Thesis titled ‘Temporal and spatial variations on water chemistry of Alaknanda and Bhagirathi Rivers of Garhwal Himalaya”. 2007.

[149] Sajikumar, N. and Thandaveswara, B.S. A nonlinear rainfall runoff model using an artificial neural network. Journal of Hydrology. 216: 32–55. 1999.

[150] Sarangi, A. and Bhattacharya, A.K. Comparison of Artificial Neural Network and regression models for sediment loss prediction from Banha watershed in India, Agricultural Water Management. 78: 195–208. 2005.

[151] Sarangi, A. and Bhattacharya, A.K. Use of geomorphological parameters for sediment yield prediction from watersheds. J. Soil Water Conserv. 44 (1–2):99–106. 2000.

[152] Sarin, M.M., Krishnaswami, S., Dilli, k., Somayajulu, B.L.K., Moore, W.S. Major ion chemistry of the Ganga–Brahmaputra river system: weathering process and the fluxes of the Bay of Bengal. Geochimica et Cosmochimica Acta 53, 997– 1009. 1989.

[153] Shamseldin, A.Y. Application of a neural network technique to rainfall runoff modeling. Journal of Hydrology. 199: 272–294. 1997.

[154] Shiri, J. and Kisi, O. Short term and long term streamflow forecasting using a wavelet and neuro-fuzzy conjunction model. Journal of Hydrology 394, 486–493. 2010.

[155] Shuguang, L., Jian D., Di H., Honglin Y., Congxian L., Shouye Y. and Chalov R.S. Regional variation of sediment load of Asian rivers flowing into the ocean, Vol. 44 Supp. 2001.

[156] Shukla, M.B., Kok, R., Prasher, S.O., Clark, G., Lacroix, R.Use of artificial neural networks in transient drainage design. Transactions of the ASAE 39 (1): 119–124. 1996.

[157] Siakeu, J., Oguchi, T., Aoki, T., Esaki, Y., Jarvie, H.P. Change in riverine suspended sediment concentration in central Japan in response to late 20^{th} century human activities. Catena 55, 231–254. 2004.

[158] Singh, P., Haritashya, U.K., Kumar, N., Singh, Y. Hydrological characteristics of the Gangotri Glacier, central Himalayas, India. Journal of Hydrology. 327: 55–67. 2006.

[159] Singh, P., Haritashya, U.K., Ramasastri, K.S., Kumar, N. Diurnal variations in discharge and suspended sediment concentration, including runoff-delaying characteristics, of the Gangotri Glacier in the Garhwal Himalayas. Hydrological Processes. 19: 1445–1457. 2005a.

[160] Singh, P., Kumar, A., Kishore, N. Meltwater storage and delaying characteristics of Gangotri glacier (Indian Himalayas) during ablation season, Hydrological Processes. 25: 159–166. 2011.

[161] Singh, V.B., Ramanathan, A.L., Pottakkal, J.G., Kumar, M. Seasonal variation of the solute and suspended sediment load in Gangotri glacier meltwater, central Himalaya, India, Journal of Asian Earth Sciences. 79: 224–234. 2014.

[162] Skelton, A., Claesson, L., Chakrapani, G., Mahanta, C., Routh, J., Mörth, M., Khanna, P. Coupling Between Seismic Activity and Hydrogeochemistry at the Shillong Plateau, Northeastern India. Pure and Apllied Geophysics. 165(1):45-61. 2008.

[163] Smith, J. and Eli. R.N. Neural network models of rainfall runoff process. J. Water Resources Planning and Management, ASCE, 121 (6): 499–508. 1995.

[164] Subramanian, V., Sediment load of Indian rivers. Curr. Sci. 64, 928–930. 1993.

[165] Sudheer, K. P., Gosain, A. K., Ramasastri, K. S. A data driven algorithm for constructing artificial neural network rainfall runoff models. Hydrolog. Process. 16(6):1325-1330. 2002.

[166] Sudheer, K. P., Nayak, P. C., and Ramasastri, K. S. Improving peak flow estimates in artificial neural network river flow models. Hydrolog. Process.17(3):677–686. 2003.

[167] Syvitski, J.P.M. Deltas at risk. Sustain. Sci. 3, 23–32. 2008.

[168] Syvitski, J.P.M., Kettner, A.J., Overeem, I., Hutton, E.W.H., Hannon, M., Brakenridge, R., Day, J., Vörösmarty, C., Saito, Y., Giosan, L., Nicholls, R.J. Sinking deltas due to human activities. Nat. Geosci. 2, 681–686. 2009.

[169] Syvitski, J.P.M., Kettner, A.J., Peckham, S.D., Kao, S.J. Predicting the flux of sediment to the coastal zone: application to the Lanyang watershed, Northern Taiwan. J. coast. Res. 21, 580–587. 2005.

[170] Syvitski, J.P.M. and Milliman, J.D. Geology, geography, and humans battle for dominance over the delivery of fluvial sediment to the coastal ocean. J. Geol. 115 (1), 1–19. 2007.

[171] Syvitski, J.P.M., Vörösmarty, C.J., Kettner, A.J., Green, P. Impact of humans on the flux of terrestrial sediment to the global coastal ocean. Science 308, 376– 380. 2005.

[172] Tayfur, G. Artificial neural networks for sheet sediment transport. Hydrol. Sci. J. 47 (6), 879–892.2002.

[173] Tempany, H. and Grist, D.H. Introduction to Tropical Agriculture. Longmans, London. 1958.

[174] Thakkar, H. and Upadhyay, K. Damming Uttarakhand is not for the better. Article- The Hindu, Sep 27 2013.

[175] Tokar, A.S. and Johnson, P.A. Rainfall-runoff modeling using Artificial Neural Networks. Jouranal of Hydrologic Engineering. 4(3): 232. 1999.

[176] Tripathy, S., Panigrahi, M.K., Kundu, N. J. Soil geochemistry of a fluoride contaminated area in the Nayagarh district, Orissa, India: A factor analytical appraisal. Environmental Geochem. and Health, 27: 205-216. 2005.

[177] Valdiya, K.S. Dynamics of Himalaya, Hyderabad: Universities Press. 1998.

[178] Van Vliet, M.T.H, Franssen, W.H.P., Yearsley, J.R., Ludwig, F., Haddeland, I., Lettenmaier, D.P., Kabat, P. Global river discharge and water temperature under climate change. Global Environmental Change. 23:450–464. 2013.

[179] Vörösmarty, C.J., et al. Global water data: a newly endangered species. Eos, American Geophysical Union Transactions 82 (5), 54–58. 2001.

[180] Vorosmarty, C.J., Meybeck, M., Fekete, B., Sharma, K. The potential impact of neo-castorization on sediment transport by the global network of rivers. Int. Assoc. Hydrol. Sci. Publ. 245, 261– 273. 1997.

[181] Vorosmarty, C.J., Meybeck, M., Fekete, B.M., Sharma, K., Green, P., Syvitski, J., 2003. Anthropogenic sediment retention: major global impact from registered river impoundments. Glob. Planet. Change 39, 169– 190. 2003.

[182] Walling, D.E. Human impact on land-ocean sediment transfer by the world rivers . Geomorphology. 79, 192-216. 2006.

[183] Walling, D.E. The impact of global change on erosion and sediment transport by rivers: current progress and future challenges. The United Nations World Water development Report 3. The United Nations Educational, Scientific and Cultural Organization, Paris. 2009.

[184] Walling, D.E. and Fang, D. Recent trends in the suspended sediment loads of the world's

[185] Walling, D.E. and Webb, B.W. The reliability of rating curve estimates of suspended sediment yield; some further comments. In: Bordas, M.P., Walling, D.E. (eds), Sediment Budgets. IAHS Publication No. 174, IAHS Press, Wallingford, UK, 337–350. 1988.

[186] Wilkinson, S.N., Prosser, I.P., Rustomji, P., Read, A.M. Modeling and testing spatially distributed sediment budgets to relate erosion processes to sediment yields. Environ. Model Softw. 24, 489–501. 2009.

[187] Xiong, L., O’Connor, K.M., Goswami, M. Application of the artificial neural network in flood forecasting on a Karstic catchment. Proc. XXIX IAHR Congr., China. 29–35. 2001.

[188] Yang, C. C., Prasher, S. O., Sreekanth, S. An artificial neural network model for simulating pesticide concentrations in soil. Trans. ASAE. 40(5):1285–1294. 1997.

[189] Yang, C.C., Prasher, C.O., Lacroix, R. Applications of artificial neural networks to land drainage engineering. Transactions of the ASAE 39 (2): 525–533. 1996.

[190] Yitian, L. and Gu, R.R. Modeling flow and sediment transport in a river system using an artificial neural network. Environmental Management. 31(1): 122–134. 2003.

[191] Zhang, B. and Govindaraju, S. Prediction of watershed runoff using Bayesian concepts and modular neural networks.” Water Resour. Res. 36(3):753–762. 2000.

[192] Zhang, B. and Govindaraju, R. Geomorphology-based artificial neural networks (GANN) for estimation of direct runoff over watersheds. Jounal of Hydrology. 273:18–34. 2003.

[193] Zhang, W., Wei, X., Zheng, J., Zhu, Y., Zhang, Y. Estimating suspended sediment loads in the Pearl River Delta region using sediment rating curves. Cont. Shelf Res. 38 (15), 35–46. 2012.

Temperature (T), Rainfall (R),Discharge (Q) and Sediment Concentration (S) Data at Gangotri																			
DATE	**T**	**R**	**Q**	**S**	**DATE**	**T**	**R**	**Q**	**S**	**DATE**	**T**	**R**	**Q**	**S**	**DATE**	**T**	**R**	**Q**	**S**
	[°C]	**[mm]**	**[m^3/s]**	**[mg/L]**		**[°C]**	**[mm]**	**[m^3/s]**	**[mg/L]**		**[°C]**	**[mm]**	**[m^3/s]**	**[mg/L]**		**[°C]**	**[mm]**	**[m^3/s]**	**[mg/L]**
1-5-00	5.20	0.00	9.0	330	27-5-00	9.7	0	59.2	1590	22-6-00	10.1	0.7	68.0	1680	18-7-00	10.15	0.3	107.8	3235
2-5-00	5.23	0.00	8.6	290	28-5-00	9.8	0.4	58.4	2410	23-6-00	8.75	0	60.0	1250	19-7-00	9.25	0.3	113.4	3400
3-5-00	5.01	0.00	11.1	312	29-5-00	10.25	0	58.5	1900	24-6-00	6.6	0	55.0	830	20-7-00	11.15	3.6	137.2	3500
4-5-00	4.68	0.00	12.0	321	30-5-00	11.05	0	59.3	1300	25-6-00	8.95	0	58.0	705	21-7-00	11.5	7	137.2	3600
5-5-00	4.98	0.00	10.2	298	31-5-00	8.65	0	58.7	1250	26-6-00	10.75	0	67.0	615	22-7-00	8.5	6.8	104.9	3065
6-5-00	4.73	0.00	8.0	340	1-6-00	9.8	0	59.7	2130	27-6-00	11.7	0	70.0	510	23-7-00	9	2	88.9	3080
7-5-00	4.27	1.60	9.3	370	2-6-00	9.45	0	66.6	2430	28-6-00	11	0	66.0	1695	24-7-00	10.75	2.1	95.9	2620
8-5-00	4.33	0.00	10.0	410	3-6-00	11.55	0	70.8	2055	29-6-00	9.75	1.8	64.0	1805	25-7-00	11.15	2	91.1	2680
9-5-00	8.5	0	11.8	1060	4-6-00	8.9	0	55.7	1920	30-6-00	9.75	0.4	60.0	1520	26-7-00	11.5	2	89.6	2400
10-5-00	10.05	0	11.7	390	5-6-00	4.25	4.5	44.6	1300	1-7-00	8.75	1.4	75	1235	27-7-00	12	5.8	116.6	3245
11-5-00	12	0	12.1	710	6-6-00	9.45	1.8	35.5	895	2-7-00	11.75	0	83	1200	28-7-00	12	2.8	141.7	3400
12-5-00	13	0	15.1	3260	7-6-00	6.75	16.5	40.2	1570	3-7-00	10	0.4	80.9	1400	29-7-00	9.75	4	132.6	3200
13-5-00	12	0	22.7	2970	8-6-00	7	49.6	124	7450	4-7-00	9.5	0.6	100.6	1700	30-7-00	12	5.4	137.6	4115
14-5-00	9.95	0	23.6	2080	9-6-00	4.75	55.5	90	7130	5-7-00	12.75	0	121.4	2000	31-7-00	9.75	14.3	144.8	4755
15-5-00	10.85	1.3	24.8	1740	10-6-00	6.35	3.6	70.0	3250	6-7-00	13	0	139.3	2400	1-8-00	9.25	6.6	137.6	3065
16-5-00	10.8	7.1	30.6	1440	11-6-00	8.05	0	50.0	1200	7-7-00	14.25	0	142.7	2955	2-8-00	9.6	0.8	107.5	2375
17-5-00	9.6	0	35.2	2000	12-6-00	6.25	0	72.0	980	8-7-00	11.75	0	135.5	1735	3-8-00	8.55	0	80.4	2567
18-5-00	9.95	4.5	42.7	2280	13-6-00	11.6	0	80.0	1240	9-7-00	11.5	0	128.6	2525	4-8-00	8	0	83.9	2615
19-5-00	10.45	0	44.1	2890	14-6-00	11.45	0	87.0	1040	10-7-00	11	0	125.5	3020	5-8-00	9.25	0	93.6	2880
20-5-00	10.6	0	48.1	2170	15-6-00	12.45	0	93.0	860	11-7-00	11.75	2.4	122.6	3000	6-8-00	11.8	0	104.6	3095
21-5-00	9.85	0	55	3860	16-6-00	14.1	0	99.0	750	12-7-00	11.25	1.8	118.6	3370	7-8-00	11.7	0	112.4	3135
22-5-00	10.75	0	53.2	2640	17-6-00	11.4	0.2	87.0	530	13-7-00	10.5	0.8	115.8	4360	8-8-00	12	0	115.3	3495
23-5-00	11.25	0	54	2280	18-6-00	9.95	0	89.0	1925	14-7-00	12	0	137.1	5645	9-8-00	13.05	0	108.6	2765
24-5-00	9.5	0	58.8	2450	19-6-00	12.85	0	84.0	2000	15-7-00	12.5	1.2	173.8	6515	10-8-00	11.2	1	83.4	1860
25-5-00	11.45	0	65.1	2000	20-6-00	9.1	1.7	80.0	2300	16-7-00	11.5	5.4	138.2	5700	11-8-00	8.1	9.5	65.2	1540
26-5-00	10.6	0	60.6	2440	21-6-00	10.75	11.6	86.0	1885	17-7-00	10.75	5.8	120.5	5595	12-8-00	10	0.6	70.6	1340

APPENDIX I

13-8-00	11	4.9	81.7	1625	10-9-00	7	0	55.9	540	8-10-00	7.5	0	23.8	190	16-5-01	6.5	10.40	37.9	4195
14-8-00	10.8	12.2	98.6	2315	11-9-00	7.5	0	56.8	830	9-10-00	6	0	23.5	180	17-5-01	6.45	0.00	35.4	5190
15-8-00	11.65	2	92.9	2495	12-9-00	8.25	0	59.6	710	10-10-00	4.75	0	22.2	164	18-5-01	7.5	0.00	27.3	3900
16-8-00	10.5	8	81.9	2675	13-9-00	10	0.8	64.3	720	11-10-00	4.85	0	20	171	19-5-01	6.45	0.00	24.8	1890
17-8-00	7.9	1.2	78.9	1870	14-9-00	9.65	1.4	65	640	12-10-00	4.95	0	18.4	155	20-5-01	8.45	0.00	24.1	1590
18-8-00	11.4	0	78.3	1425	15-9-00	10.35	0	64.3	670	13-10-00	4	0	16.4	150	21-5-01	7.15	2.00	24.3	1260
19-8-00	10.85	1.7	75.6	1735	16-9-00	9.75	0	64.2	640	14-10-00	3.65	0	14.2	142	22-5-01	8.15	0.00	25.1	1310
20-8-00	9.75	1.7	73.1	1535	17-9-00	10.15	0	64.6	630	15-10-00	3.75	0	12.9	140	23-5-01	9.2	0.00	27.5	2090
21-8-00	10.75	0.5	74.5	1505	18-9-00	9.7	1.6	65.6	690	16-10-00	4.7	0	12.1	130	24-5-01	10	0.00	31.5	2620
22-8-00	9.75	1.3	65.5	1405	19-9-00	9.55	0	60.4	480	17-10-00	8.9	0	11.3	140	25-5-01	11.05	0.00	36.5	3425
23-8-00	9.4	5.6	57.9	1300	20-9-00	9.45	3.6	46.6	590	18-10-00	6.9	0	11.1	135	26-5-01	9.95	0.00	35.7	1280
24-8-00	8.25	0.3	58.7	1365	21-9-00	5.15	2.8	38.9	290	19-10-00	6.7	0	11.1	125	27-5-01	7.5	0.00	34.1	1075
25-8-00	10.85	0	61.7	1450	22-9-00	7	0	35.3	180	20-10-00	6.75	0	11	124	28-5-01	9.9	0.00	36.7	1370
26-8-00	10.8	0	67	1570	23-9-00	7.75	0	32	170	1-5-01	7.75	0.00	8.5	170	29-5-01	9.25	2.10	37.5	1200
27-8-00	12.6	0.2	76.8	1835	24-9-00	5.65	0	28.9	160	2-5-01	8.25	0.00	8.5	180	30-5-01	7.6	0.00	37.4	1125
28-8-00	12.4	0	91	2500	25-9-00	5.25	0	26	160	3-5-01	6.75	0.00	8.8	110	31-5-01	9.4	0.00	40.8	1230
29-8-00	11.55	0	91.7	2585	26-9-00	5.9	0	23.9	130	4-5-01	7.6	0.00	9.3	220	1-6-01	10.9	0	45.4	1385
30-8-00	10.6	0	86.6	2220	27-9-00	2.45	2.8	22.3	140	5-5-01	8.85	0.00	10.4	440	2-6-01	12.15	0	50.5	1645
31-8-00	10.25	3.1	82.1	1155	28-9-00	5	0	20.4	130	6-5-01	11.75	0.00	11.8	250	3-6-01	12.4	0.7	59.8	1735
1-9-00	8.95	0.9	82.1	780	29-9-00	4.25	0	19.5	130	7-5-01	9.95	0.00	13.5	280	4-6-01	10	0.15	79.9	2952
2-9-00	9.95	0	85.9	970	30-9-00	6.3	0.4	18.9	111	8-5-01	9.95	0.90	15.1	410	5-6-01	8.125	0	59.9	1830
3-9-00	11.75	1	90.6	1380	1-10-00	6.65	0	18.4	130	9-5-01	8.8	0.70	14.3	1320	6-6-01	7.15	0	49.8	1470
4-9-00	10.4	2	88.9	930	2-10-00	5.4	0	18.4	111	10-5-01	10.6	0.00	14.7	4700	7-6-01	7.6	0	48.4	1170
5-9-00	10.45	0	94.9	920	3-10-00	6	0	18.6	120	11-5-01	12.65	0.00	19.4	2570	8-6-01	9.125	0	47.5	1395
6-9-00	11.2	0	98.5	1460	4-10-00	6.75	0	19.2	130	12-5-01	13.25	0.00	23.8	1330	9-6-01	10.35	0	46.8	1490
7-9-00	10.8	0.3	100	1660	5-10-00	7.5	0	20.7	210	13-5-01	12.8	0.00	23.1	2490	10-6-01	9.25	0	49.0	1340
8-9-00	9.05	3	87.4	1410	6-10-00	7.6	0	21.5	170	14-5-01	11.5	0.00	23.7	2500	11-6-01	12.55	0	57.3	1545
9-9-00	7.8	0.3	63.9	960	7-10-00	7.45	0	23	220	15-5-01	9.5	1.40	28.2	7700	12-6-01	13.25	0	68.8	2160

13-6-01	13.9	1	79.6	2115	11-7-01	13.65	3.6	111.1	4290	8-8-01	12	2	93.3	5720	5-9-01	8.75	0.00	101.4	1210
14-6-01	12.6	9.8	86.2	3060	12-7-01	11.25	1	91.0	4500	9-8-01	11.5	3.2	137.2	3610	6-9-01	10.10	0.00	81.6	1090
15-6-01	10.2	2.7	87.6	2415	13-7-01	11.65	1.3	91.7	4550	10-8-01	11	7	158.8	1490	7-9-01	9.40	0.00	72.6	1040
16-6-01	10	0	86.6	2660	14-7-01	12.5	1.2	118.9	3700	11-8-01	11.1	0	150.3	1970	8-9-01	9.15	0.00	71.8	1470
17-6-01	9.8	1.2	69.5	1840	15-7-01	11.1	1.3	107.5	5000	12-8-01	11.35	0	151.6	2320	9-9-01	10.35	0.00	82.4	1300
18-6-01	8.5	1.9	53.0	1990	16-7-01	12.8	2.1	118.2	3650	13-8-01	13.25	0	160.0	2870	10-9-01	10.65	0.00	90.9	1550
19-6-01	8.25	1.5	53.0	1525	17-7-01	9	3.1	108.1	3830	14-8-01	11.5	4	174.0	2970	11-9-01	9.90	0.00	93.3	2020
20-6-01	11.35	0	61.8	2220	18-7-01	11.15	0	121.2	1560	15-8-01	10.55	2	127.8	4070	12-9-01	10.90	0.00	93.2	1950
21-6-01	12.3	0	73.5	2090	19-7-01	12.85	0	132.6	3420	16-8-01	10.85	1.5	111.9	3900	13-9-01	7.00	2.10	94.0	1470
22-6-01	12.2	0	80.9	2220	20-7-01	14.15	0	135.0	4050	17-8-01	11.5	0	116.6	4070	14-9-01	8.30	0.00	68.5	820
23-6-01	10.75	0.5	83.9	1910	21-7-01	14.25	0.1	175.0	7310	18-8-01	12.25	3.2	120.1	2730	15-9-01	7.40	0.00	54.8	640
24-6-01	10.5	5.2	82.7	660	22-7-01	13.9	0.3	176.7	5640	19-8-01	11.4	2.6	122.8	3040	16-9-01	8.85	1.50	49.9	500
25-6-01	8	7.6	80.4	1590	23-7-01	11.7	0.4	169.3	4970	20-8-01	12.3	0	123.9	2200	17-9-01	7.55	0.00	45.8	540
26-6-01	11	1.9	83.4	2150	24-7-01	12.35	0	170.1	3600	21-8-01	11.15	0	111.3	3880	18-9-01	7.25	0.00	44.0	670
27-6-01	9.5	1.6	89.7	1020	25-7-01	13.3	0	164.3	3700	22-8-01	11.75	0.5	101.3	3360	19-9-01	8.10	0.00	45.0	480
28-6-01	11.15	1.7	89.8	3660	26-7-01	12.5	1.3	166.6	4160	23-8-01	11.3	2	95.0	4250	20-9-01	8.30	0.00	45.8	590
29-6-01	12.9	0	96.3	2350	27-7-01	11.9	1.3	157.4	4410	24-8-01	8	1.2	91.0	2890	21-9-01	8.45	0.00	47.9	500
30-6-01	13.75	0	88.0	2240	28-7-01	13.1	0	149.5	4360	25-8-01	8.75	0	89.8	2380	22-9-01	8.65	0.00	49.3	570
1-7-01	12.25	0.6	89.2	3280	29-7-01	11.25	0	135.8	4620	26-8-01	9.95	0	86.4	2700	23-9-01	8.60	0.00	51.7	620
2-7-01	13.6	0	80.6	4500	30-7-01	11.05	0	122.6	2860	27-8-01	10.5	0	105.8	2550	24-9-01	8.75	0.00	52.6	630
3-7-01	13.5	0.6	91.3	4380	31-7-01	10.9	0.4	97.1	4570	28-8-01	10.5	0	113.3	2960	25-9-01	8.75	0.00	54.5	930
4-7-01	10.35	0.9	94.8	3560	1-8-01	11.9	0	96.6	4150	29-8-01	11.5	0	116.3	2740	26-9-01	7.40	0.00	55.0	680
5-7-01	11.6	0.6	76.0	3400	2-8-01	13.5	0	122.3	4210	30-8-01	9.75	0	108.9	2310	27-9-01	5.10	0.00	49.3	450
6-7-01	13.6	0	77.7	5380	3-8-01	13.75	0	142.0	3340	31-8-01	11	0	106.8	1820	28-9-01	7.40	0.00	42.8	500
7-7-01	14.25	0.7	86.3	3890	4-8-01	9.5	6.9	144.2	5550	1-9-01	9.50	0.00	104.6	1910	29-9-01	7.50	0.00	41.1	400
8-7-01	12.25	4.2	88.1	4000	5-8-01	9.25	0	119.4	2570	2-9-01	10.00	0.00	101.2	1500	30-9-01	7.75	5.50	39.6	370
9-7-01	10.9	2.4	79.5	4500	6-8-01	10.2	0	91.7	2830	3-9-01	10.75	0.00	101.2	1520	1-10-01	6.90	0.00	38.0	320
10-7-01	12.6	0	88.2	5010	7-8-01	10.7	0	93.8	2680	4-9-01	10.00	3.80	109.9	1650	2-10-01	8.30	0.00	35.0	210

3-10-01	6.50	0.00	34.2	230	11-5-02	9.35	0.00	15.0	2493	8-6-02	11.65	0.00	82.3	3371	6-7-02	8.25	0.00	65.5	6721
4-10-01	8.25	0.00	32.3	160	12-5-02	10.50	0.00	17.9	1614	9-6-02	13.25	0.00	82.2	3664	7-7-02	10.75	0.00	89.9	3107
5-10-01	6.50	0.00	32.0	190	13-5-02	11.70	0.00	23.8	1629	10-6-02	11.85	0.00	87.0	3743	8-7-02	12.00	0.00	116.0	3243
6-10-01	5.75	0.00	31.5	160	14-5-02	11.25	0.00	26.8	2536	11-6-02	12.90	0.00	97.0	3021	9-7-02	13.50	0.00	124.4	4307
7-10-01	7.90	0.00	30.5	210	15-5-02	11.85	4.70	31.1	5243	12-6-02	11.50	2.50	93.0	2443	10-7-02	13.15	0.00	107.8	6000
8-10-01	7.00	0.00	29.7	200	16-5-02	11.25	0.00	36.6	7114	13-6-02	8.00	0.00	73.0	1943	11-7-02	13.25	0.00	112.6	5579
9-10-01	8.00	0.00	29.6	210	17-5-02	11.30	0.00	56.2	6429	14-6-02	10.00	0.00	77.3	1971	12-7-02	13.00	0.00	108.1	6343
10-10-01	8.35	0.00	29.4	210	18-5-02	11.20	0.00	50.0	6571	15-6-02	11.10	0.00	75.0	1943	13-7-02	12.25	0.00	112.1	6829
11-10-01	7.10	0.00	29.7	120	19-5-02	8.65	0.00	50.6	6500	16-6-02	10.00	0.00	72.9	1821	14-7-02	12.75	0.00	125.1	5657
12-10-01	4.25	0.00	29.1	130	20-5-02	5.50	0.00	47.0	4386	17-6-02	9.65	0.00	73.0	1400	15-7-02	12.40	0.00	138.4	11093
13-10-01	3.25	0.00	26.7	130	21-5-02	4.55	0.00	43.0	2464	18-6-02	7.75	0.00	65.2	1250	16-7-02	10.85	0.00	144.3	5579
14-10-01	4.25	0.00	25.7	150	22-5-02	7.25	0.00	41.4	1914	19-6-02	10.35	0.00	64.3	950	17-7-02	14.35	0.00	162.1	5764
15-10-01	3.00	0.00	24.3	145	23-5-02	10.25	0.00	43.5	2214	20-6-02	7.15	0.00	55.5	1021	18-7-02	11.40	2.60	177.5	3707
16-10-01	3.60	0.00	24.3	140	24-5-02	7.95	0.00	46.3	1350	21-6-02	9.70	0.00	60.2	1157	19-7-02	13.00	0.00	167.4	3179
17-10-01	3.85	0.00	22.9	145	25-5-02	9.55	0.00	41.3	1143	22-6-02	11.50	0.00	69.1	1586	20-7-02	13.35	0.00	173.6	3450
18-10-01	2.90	0.00	21.8	135	26-5-02	8.00	0.00	39.1	907	23-6-02	12.25	0.00	84.5	3321	21-7-02	13.40	0.00	184.0	3271
19-10-01	2.85	0.00	21.0	130	27-5-02	7.55	0.00	36.3	950	24-6-02	16	0.00	97.4	2643	22-7-02	12.65	1.30	193.5	2729
20-10-01	5.15	0.00	20.8	130	28-5-02	10.40	0.00	36.4	621	25-6-02	9.75	0.00	88.4	2879	23-7-02	11.50	0.00	161.5	5021
1-5-02	10.00	0.00	11.0	301	29-5-02	5.20	0.00	33.2	500	26-6-02	12.50	0.00	84.8	2600	24-7-02	11.35	0.00	161.7	3814
2-5-02	8.11	0.00	11.3	320	30-5-02	6.25	1.20	32.7	393	27-6-02	10.60	0.50	82.5	2764	25-7-02	12.50	0.00	152.7	4293
3-5-02	9.23	0.00	11.1	317	31-5-02	7.00	0.00	35.7	671	28-6-02	12.25	2.20	80.4	3136	26-7-02	11.60	0.00	132.9	3457
4-5-02	11.11	2.20	12.2	325	1-6-02	8.00	0.00	38.9	564	29-6-02	12.00	0.00	87.1	3521	27-7-02	11.70	0.00	127.6	2814
5-5-02	10.43	0.00	11.2	308	2-6-02	8.70	0.00	42.2	936	30-6-02	12.10	0.00	103.1	2914	28-7-02	11.00	0.00	128.7	2829
6-5-02	11.12	0.00	12.3	290	3-6-02	7.55	0.00	46.3	757	1-7-02	11.25	1.60	114.7	3536	29-7-02	11.85	0.00	136.3	3207
7-5-02	9.87	0.00	11.7	319	4-6-02	10.00	0.00	58.3	2114	2-7-02	12.50	0.00	118.7	5386	30-7-02	10.75	0.00	127.7	3521
8-5-02	8.45	0.00	12.0	357	5-6-02	8.90	0.00	60.4	2414	3-7-02	14.25	0.00	132.8	6121	31-7-02	11.90	0.00	123.2	3607
9-5-02	9.80	0.00	13.0	250	6-6-02	8.55	0.00	66.1	3686	4-7-02	13.10	0.00	119.0	4779	1-8-02	12.60	0.00	129.5	4700
10-5-02	11.90	0.00	14.0	514	7-6-02	10.65	0.00	70.5	3914	5-7-02	11.25	2.00	78.6	5607	2-8-02	13.60	0.00	127.5	5500

3-8-02	14.15	0.00	121.5	4030	31-8-02	9.00	0.40	85.4	1730	28-9-02	6.35	0.00	26.2	150	6-5-03	4.73	0	8	340
4-8-02	11.25	15.30	113.9	4350	1-9-02	9.50	1.80	89.8	1260	29-9-02	6.55	0.00	24.7	170	7-5-03	4.27	1.6	9.3	370
5-8-02	9.95	4.40	100.0	3630	2-9-02	9.00	1.60	84.4	1790	30-9-02	6.10	0.00	24.2	170	8-5-03	4.33	0	10	410
6-8-02	10.35	2.40	101.3	2050	3-9-02	9.50	1.80	76.7	1100	1-10-02	7.05	0.00	24.1	160	9-5-03	4.25	0	8	500
7-8-02	8.70	2.70	91.9	2770	4-9-02	6.05	2.80	62.3	1010	2-10-02	7.0	0.00	23.7	170	10-5-03	3.8	0	8.1	620
8-8-02	11.25	8.80	103.3	3470	5-9-02	8.30	1.40	52.8	490	3-10-02	7.15	0.00	23.2	190	11-5-03	5.55	0	8.2	300
9-8-02	11.75	0.00	118.8	4020	6-9-02	6.75	15.40	44.1	1200	4-10-02	7.1	0.00	23.2	160	12-5-03	5.35	0	8.3	550
10-8-02	13.75	0.00	126.0	4010	7-9-02	1.75	15.20	38.1	350	5-10-02	7.35	0.00	24.0	160	13-5-03	6.05	2.4	8.4	250
11-8-02	12.60	12.60	140.2	4180	8-9-02	2.60	47.00	29.1	230	6-10-02	7.5	0.00	25.2	120	14-5-03	4.65	0	8.5	600
12-8-02	12.00	0.00	111.6	5200	9-9-02	5.35	8.40	24.5	220	7-10-02	4.7	0.00	24.9	80	15-5-03	5.975	0	8.7	750
13-8-02	9.90	12.40	118.8	3100	10-9-02	4.90	6.10	20.2	140	8-10-02	4.35	0.00	23.9	80	16-5-03	5.5	0	11	1320
14-8-02	9.65	5.80	104.7	2900	11-9-02	3.40	14.90	19.2	900	9-10-02	6.15	0.00	23.2	80	17-5-03	7.35	0	16.5	2500
15-8-02	8.60	3.30	90.0	2860	12-9-02	3.90	43.60	19.3	410	10-10-02	7.5	0.00	23.0	80	18-5-03	6.5	0	21.2	1870
16-8-02	9.25	4.40	87.6	2160	13-9-02	2.10	72.2	22.8	960	11-10-02	5.7	0.00	22.3	80	19-5-03	7.25	0	22.4	2920
17-8-02	10.10	0.60	89.5	2490	14-9-02	7.20	3.50	25.0	350	12-10-02	5.6	0.00	22.0	80	20-5-03	8	0	24.1	4730
18-8-02	11.75	0.00	91.8	2650	15-9-02	5.75	0.00	29.6	420	13-10-02	4	0.00	22.0	80	21-5-03	8.35	0	29.6	2240
19-8-02	11.00	3.00	91.4	2060	16-9-02	7.75	0.00	41.7	430	14-10-02	3.5	0.00	22.0	80	22-5-03	9	1.6	31.8	1850
20-8-02	10.45	0.20	83.9	2410	17-9-02	7.65	0.00	47.2	280	15-10-02	4	0.00	21.2	80	23-5-03	7.15	0	31.7	2140
21-8-02	10.25	0.20	87.0	2030	18-9-02	5.70	0.00	48.5	270	16-10-02	4.4	0.00	20.4	80	24-5-03	4.75	0	30.7	1560
22-8-02	10.60	0.30	86.6	2070	19-9-02	6.25	0.00	48.4	210	17-10-02	4.65	0.00	19.7	80	25-5-03	6.85	0	30.9	970
23-8-02	10.85	1.50	90.8	2540	20-9-02	6.40	0.00	46.8	220	18-10-02	2.75	0.00	19.4	80	26-5-03	7.55	5.2	28.6	1100
24-8-02	11.25	8.20	97.9	3160	21-9-02	6.00	0.00	42.5	240	19-10-02	3	0.00	18.5	80	27-5-03	6.5	1.2	27.9	730
25-8-02	9.50	12.20	98.9	2700	22-9-02	6.55	0.00	40.4	240	20-10-02	3.5	0.00	17.7	80	28-5-03	7.9	0	29.6	1290
26-8-02	11.00	9.40	111.3	2690	23-9-02	7.35	0.00	39.0	200	1-5-03	5.20	0.00	9.0	330	29-5-03	6.6	0	34.9	1270
27-8-02	10.15	4.90	106.7	3370	24-9-02	7.30	0.00	38.4	180	2-5-03	5.23	0.00	8.6	290	30-5-03	8.1	0	38.5	1660
28-8-02	11.05	0.00	100.9	3000	25-9-02	6.50	0.00	35.0	210	3-5-03	5.01	0.00	11.1	312	31-5-03	10	0	38.5	1020
29-8-02	10.65	1.00	90.6	2350	26-9-02	4.85	0.00	30.3	170	4-5-03	4.68	0.00	12.0	321	1-6-03	10.7	0	40.3	1060
30-8-02	9.50	0.50	84.5	2250	27-9-02	5.75	0.00	26.7	200	5-5-03	4.98	0.00	10.2	298	2-6-03	9.4	5.5	42.8	1050

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3-6-03	10.00	0.00	48.9	1990	1-7-03	9.55	0.00	95.1	2310	29-7-03	10.85	2.80	140.3	2800	26-8-03	12.10	0.00	108.8	1710
4-6-03	11.50	0.00	55.8	1270	2-7-03	11.05	0.00	104.6	2490	30-7-03	10.15	0.20	147.7	3380	27-8-03	12.15	8.00	121.3	1510
5-6-03	9.50	5.20	56.4	1340	3-7-03	11.80	0.00	114.7	3580	31-7-03	12.45	0.00	167.9	3550	28-8-03	11.25	1.00	129.2	2280
6-6-03	9.55	0.00	58.3	1520	4-7-03	13.50	0.00	123.5	4270	1-8-03	12.55	1.20	155.2	3060	29-8-03	12.10	0.20	133.0	1840
7-6-03	10.55	1.60	61.0	1370	5-7-03	12.40	12.60	132.7	2930	2-8-03	11.20	2.50	156.5	3040	30-8-03	10.60	0.60	117.4	1370
8-6-03	11.65	0.00	67.4	2080	6-7-03	8.60	1.30	113.5	2650	3-8-03	10.35	1.80	155.8	2320	31-8-03	11.00	0.30	117.2	1420
9-6-03	11.60	0.00	81.6	2400	7-7-03	9.00	1.70	105.0	2020	4-8-03	9.90	3.40	147.6	2340	1-9-03	11.35	0.00	120.6	1570
10-6-03	11.10	0.00	88.8	1800	8-7-03	10.70	2.00	112.4	1910	5-8-03	9.85	1.40	135.3	2080	2-9-03	11.40	0.00	118.0	1350
11-6-03	10.95	0.00	95.1	2590	9-7-03	9.95	5.20	112.1	2030	6-8-03	11.80	4.00	137.7	2530	3-9-03	11.75	0.00	104.1	1350
12-6-03	9.75	0.00	99.4	3150	10-7-03	9.75	5.60	100.4	1310	7-8-03	11.30	9.80	152.4	2470	4-9-03	6.75	7.60	81.5	1200
13-6-03	9.40	0.00	100.0	2540	11-7-03	7.15	11.70	83.8	910	8-8-03	11.80	0.60	133.4	2220	5-9-03	10.25	0.00	85.6	1350
14-6-03	9.65	0.00	96.9	2570	12-7-03	8.95	1.40	80.3	810	9-8-03	11.80	1.20	127.3	1850	6-9-03	10.65	1.00	91.3	1070
15-6-03	10.10	0.00	95.8	2230	13-7-03	10.10	2.90	83.0	1010	10-8-03	11.15	5.20	116.0	1840	7-9-03	9.75	0.00	93.1	1060
16-6-03	11.60	1.80	103.7	2700	14-7-03	8.95	0.80	84.8	1030	11-8-03	10.25	2.40	107.6	1490	8-9-03	9.10	2.40	92.4	1120
17-6-03	10.05	0.60	104.9	3710	15-7-03	11.50	0.00	95.1	1610	12-8-03	8.95	4.20	98.7	1490	9-9-03	9.75	0.20	88.6	1020
18-6-03	11.55	0.00	100.3	3840	16-7-03	12.20	3.20	111.6	2100	13-8-03	10.00	3.80	99.4	1360	10-9-03	8.90	3.00	75.4	880
19-6-03	10.75	1.30	85.3	2130	17-7-03	11.30	3.50	118.1	2510	14-8-03	9.00	0.90	96.9	1300	11-9-03	7.75	0.60	66.9	810
20-6-03	8.15	5.90	77.2	1990	18-7-03	10.75	1.40	113.2	2030	15-8-03	10.75	1.40	92.8	1520	12-9-03	8.85	1.00	66.2	670
21-6-03	8.70	1.80	72.5	1850	19-7-03	11.35	0.00	108.2	2290	16-8-03	9.50	3.70	88.1	3060	13-9-03	8.85	0.00	68.1	940
22-6-03	10.55	0.60	80.0	2140	20-7-03	12.45	0.00	119.6	2930	17-8-03	10.65	0.00	95.1	1230	14-9-03	10.55	0.00	73.1	1000
23-6-03	12.45	1.80	88.4	2240	21-7-03	13.15	0.60	127.7	3330	18-8-03	11.70	0.00	107.2	1920	15-9-03	11.50	0.00	75.8	840
24-6-03	11.60	0.00	91.0	2220	22-7-03	12.50	0.00	126.6	3270	19-8-03	12.25	0.80	117.7	1600	16-9-03	10.30	2.20	75.8	820
25-6-03	11.25	0.00	89.4	2710	23-7-03	11.95	0.00	131.9	3880	20-8-03	8.00	2.00	110.4	1600	17-9-03	9.25	1.20	75.8	910
26-6-03	12.35	0.00	98.2	2320	24-7-03	13.35	0.00	121.0	2550	21-8-03	8.90	0.70	94.7	1510	18-9-03	10.65	0.00	76.9	1110
27-6-03	12.20	0.00	95.5	2210	25-7-03	12.00	2.30	114.6	3090	22-8-03	7.15	1.00	79.7	1260	19-9-03	10.15	0.00	78.0	1010
28-6-03	7.50	2.30	87.5	1900	26-7-03	12.95	0.00	126.0	2930	23-8-03	10.75	0.00	83.2	990	20-9-03	10.40	0.00	82.1	930
29-6-03	10.40	0.00	95.3	1890	27-7-03	11.55	5.70	141.5	3180	24-8-03	11.75	0.00	90.1	980	21-9-03	11.85	0.00	86.4	910
30-6-03	9.25	5.50	92.5	2030	28-7-03	11.35	2.80	152.3	3050	25-8-03	11.75	0.00	97.3	1310	22-9-03	11.00	0.00	89.8	730

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23-9-03	10.90	8.00	90.5	570	1-5-04	4.00	0.00	9	330	29-5-04	7.05	0.00	47.68	1900	26-6-04	7.00	0.00	71.34	2150
24-9-03	6.75	7.40	76.0	740	2-5-04	4.13	0.00	8.9	290	30-5-04	8.65	0.00	47.92	1300	27-6-04	7.75	1.90	62.21	1020
25-9-03	6.65	3.60	66.5	450	3-5-04	4.11	0.00	9.7	312	31-5-04	9.65	0.00	50.27	1250	28-6-04	7.75	0.00	58.18	3660
26-9-03	6.50	0.00	59.7	190	4-5-04	4.25	0.00	10.3	321	1-6-04	9.13	0.00	50.82	1385	29-6-04	11.25	0.00	63.96	2350
27-9-03	7.30	0.00	52.9	120	5-5-04	3.85	0.00	10.1	298	2-6-04	8.70	0.00	52.33	1645	30-6-04	12.25	0.00	75.89	2240
28-9-03	6.50	0.00	46.8	160	6-5-04	5.55	0.00	10.01	340	3-6-04	7.50	0.00	54.76	1735	1-7-04	13.75	0.00	88.84	3536
29-9-03	6.25	0.00	36.7	80	7-5-04	8.80	0.00	11.03	370	4-6-04	8.40	0.00	55.57	2952	2-7-04	14.50	0.00	104.56	5386
30-9-03	2.40	0.00	29.5	130	8-5-04	7.75	0.00	10.05	410	5-6-04	8.08	0.00	57.76	1830	3-7-04	12.25	0.20	116.85	6121
1-10-03	3.9	0.00	23.0	90	9-5-04	7.55	0.00	9.93	1060	6-6-04	8.90	0.00	60.53	1470	4-7-04	11.25	1.00	113.54	4779
2-10-03	4.6	0.00	19.2	150	10-5-04	7.90	0.00	10.66	390	7-6-04	8.95	0.40	58.97	1170	5-7-04	11.25	0.00	124.88	5607
3-10-03	4.5	0.00	19.3	70	11-5-04	8.80	0.00	11.63	710	8-6-04	5.75	0.00	59.82	1395	6-7-04	11.75	4.00	134.09	6721
4-10-03	4.8	0.00	19.5	120	12-5-04	9.95	0.00	12.04	3260	9-6-04	8.10	0.00	58.74	1490	7-7-04	10.75	0.00	131.94	3107
5-10-03	5.9	0.00	19.0	160	13-5-04	8.70	0.00	12.86	2970	10-6-04	7.10	2.20	52.72	1340	8-7-04	12.00	0.00	124.00	3243
6-10-03	7.3	0.00	19.3	80	14-5-04	9.35	0.00	13.29	2080	11-6-04	8.60	2.40	49.59	1545	9-7-04	11.25	2.60	108.32	4307
7-10-03	6.2	0.00	20.8	130	15-5-04	10.80	0.00	15.05	1740	12-6-04	9.20	0.00	51.08	2160	10-7-04	10.75	0.00	113.75	6000
8-10-03	6.0	0.00	22.1	90	16-5-04	10.35	0.00	32.32	1440	13-6-04	11.20	0.00	54.18	2115	11-7-04	11.10	0.00	113.40	5579
9-10-03	5.8	0.00	23.0	150	38124	12.1	0	33.5658	2000	38152	11.6	0	59.1575	3060	38180	11.45	0	121.6572	6343
10-10-03	5.2	0.00	23.2	70	38125	10.25	0	34.945	2280	38153	13.5	0	72.49735	2415	38181	11.65	0	113.7492	6829
11-10-03	4.5	0.00	23.3	120	38126	9.65	0	42.4324	2890	38154	13	0	92.5453	2660	38182	11.5	0	115.5726	5657
12-10-03	2.8	0.00	23.2	160	38127	11.45	0	63.6173	2170	38155	12.95	0	98.44279	1840	38183	11.85	0	119.8479	11093
13-10-03	4.0	0.00	22.6	80	38128	10.5	0	60.3845	3860	38156	10.65	0	110.1552	1990	38184	11.75	0	115.5726	5579
14-10-03	4.5	0.00	21.9	130	38129	11.5	0	56.9782	2640	38157	11.45	5.8	105.8277	1525	38185	11.35	0	119.2005	5764
15-10-03	4.8	0.00	21.1	90	38130	9.25	4.5	54.9828	2280	38158	10.65	0.6	108.52	2220	38186	12.25	2.9	124.8078	3707
16-10-03	5.0	0.00	20.1	150	38131	4.2	0.5	52.724	2450	38159	10.6	0	105.4941	2090	38187	10.25	0	115.7136	3179
17-10-03	5.4	0.00	19.3	70	38132	6.85	0	51.422	2000	38160	9.95	2.8	101.1497	2220	38188	9.5	0	115.1502	3450
18-10-03	3.3	3.20	17.2	120	38133	7.5	0	49.1701	2440	38161	9.25	0	98.69867	1910	38189	10.75	0	109.6767	3271
19-10-03	1.5	0.00	16.0	160	27-5-04	7.60	1.00	47.92	1590	24-6-04	10.15	0.00	99.92	660	22-7-04	10.40	0.00	111.12	2729
20-10-03	2.8	0.00	14.8	80	28-5-04	6.75	0.00	48.17	2410	25-6-04	8.45	0.00	85.34	1590	23-7-04	10.50	4.40	94.78	5021

24-7-04	9.00	0.00	82.90	3814	21-8-04	8.80	0.60	89.38	1510	18-9-04	8.50	0.30	64.95	690	16-10-04	0.00	0.00	24.13	140
25-7-04	11.70	0.00	97.42	4293	22-8-04	10.10	3.60	87.22	1260	19-9-04	9.40	0.00	65.90	480	17-10-04	0.00	0.00	25.00	145
26-7-04	14.00	0.00	107.64	3457	23-8-04	7.25	15.60	86.34	990	20-9-04	9.10	0.00	65.50	590	18-10-04	0.00	1.10	25.80	135
27-7-04	12.85	0.40	123.85	2814	24-8-04	7.60	0.60	64.85	980	21-9-04	8.50	0.00	62.35	290	19-10-04	0.00	1.00	23.20	130
28-7-04	12.85	4.40	136.42	2829	25-8-04	7.40	14.90	63.03	1310	22-9-04	9.50	1.40	59.25	180	20-10-04	0.00	0.00	24.00	130
29-7-04	12.00	0.00	140.35	3207	26-8-04	9.75	0.00	62.11	1710	23-9-04	5.60	44.30	54.89	170					
30-7-04	8.75	1.00	120.21	3521	27-8-04	9.40	0.00	66.00	1510	24-9-04	7.00	0.00	45.13	160					
31-7-04	10.80	2.60	132.17	3607	28-8-04	10.35	0.00	67.05	2280	25-9-04	7.45	0.00	37.63	160					
1-8-04	10.90	2.80	126.36	3060	29-8-04	10.30	0.00	67.26	1840	26-9-04	8.95	0.00	34.57	130					
2-8-04	11.50	1.00	107.84	3040	30-8-04	11.25	0.00	67.21	1370	27-9-04	9.75	0.00	34.34	140					
3-8-04	10.00	4.20	106.83	2320	31-8-04	10.25	0.00	65.65	1420	28-9-04	10.75	0.00	35.15	130					
4-8-04	11.20	0.40	109.88	2340	1-9-04	10.90	0.00	67.77	780	29-9-04	9.10	2.20	35.80	130					
5-8-04	13.25	0.00	148.58	2080	2-9-04	10.00	0.00	65.75	970	30-9-04	7.25	4.70	35.60	111					
6-8-04	13.10	0.00	129.81	2530	3-9-04	9.95	0.00	61.77	1380	1-10-04	7.25	0.00	35.53	320					
7-8-04	12.05	3.50	139.80	2470	4-9-04	9.80	0.00	63.47	930	2-10-04	8.25	0.40	35.36	210					
8-8-04	10.05	6.40	148.42	2220	5-9-04	10.65	0.00	65.55	920	3-10-04	6.75	6.40	35.98	230					
9-8-04	10.60	2.80	131.49	1850	6-9-04	10.70	0.00	66.05	1460	4-10-04	4.75	6.80	35.98	160					
10-8-04	10.70	3.60	110.77	1840	7-9-04	11.25	0.00	68.84	1660	5-10-04	3.50	1.40	34.78	190					
11-8-04	10.15	0.70	97.42	1490	8-9-04	12.10	0.00	72.87	1410	6-10-04	6.00	0.00	34.67	160					
12-8-04	10.10	5.00	103.70	1490	9-9-04	12.25	0.00	77.98	960	7-10-04	6.50	0.00	32.09	210					
13-8-04	9.85	4.40	109.27	1360	10-9-04	12.65	0.00	81.12	540	8-10-04	5.75	0.00	31.03	200					
14-8-04	10.15	0.80	120.28	1300	11-9-04	10.55	0.00	81.52	830	9-10-04	6.50	0.00	29.38	210					
15-8-04	10.70	2.20	117.98	1520	12-9-04	10.70	0.00	82.61	710	10-10-04	5.40	0.00	28.14	210					
16-8-04	13.00	1.20	116.14	3060	13-9-04	12.65	0.00	83.94	720	11-10-04	0.30	8.80	26.10	120					
17-8-04	12.85	0.60	133.71	1230	14-9-04	12.85	0.00	84.29	640	12-10-04	0.00	0.30	24.07	130					
18-8-04	11.40	9.20	115.57	1920	15-9-04	11.85	0.00	83.76	670	13-10-04	0.00	0.00	24.90	130					
19-8-04	8.75	4.20	90.16	1600	16-9-04	9.25	4.00	78.53	640	14-10-04	1.15	0.00	25.00	150					
20-8-04	10.75	0.20	89.74	1600	17-9-04	6.70	2.40	67.26	630	15-10-04	1.20	0.00	24.80	145					

Daily Discharge (Q) and Sediment Concentration (S) Data at Maneri from June to October 2004																	
Date	Q	S	Date	Q	S	Date	Q	S	Date	Q	S	Date	Q	S	Date	Q	S
	m^3/s	ppm		m^3/s	ppm		m^3/s	ppm		m^3/s	ppm		m^3/s	ppm		m^3/s	ppm
06-01-04	94	78	6-28-04	101	683	7-25-04	204	1453	8-21-04	274	1778	9-17-04	151	1049	10-14-04	68	354
06-02-04	99	103	6-29-04	118	479	7-26-04	262	1648	8-22-04	327	1919	9-18-04	130	940	10-15-04	67	305
06-03-04	98	91	6-30-04	146	620	7-27-04	521	1828	8-23-04	302	2142	9-19-04	120	920	10-16-04	64	270
06-04-04	93	66	7-1-04	183	646	7-28-04	333	1272	8-24-04	274	2195	9-20-04	110	913	10-17-04	64	160
06-05-04	91	90	7-2-04	206	919	7-29-04	430	2045	8-25-04	268	1927	9-21-04	106	880	10-18-04	60	133
06-06-04	102	104	7-3-04	203	1064	7-30-04	399	2154	8-26-04	248	1540	9-22-04	106	835	10-19-04	60	121
06-07-04	103	119	7-4-04	228	1011	7-31-04	426	3329	8-27-04	239	1784	9-23-04	123	736	10-20-04	60	99
06-08-04	88	128	7-5-04	278	1018	8-1-04	383	2387	8-28-04	225	1313	9-24-04	94	589	10-21-04	60	49
06-09-04	88	138	7-6-04	269	1205	8-2-04	408	2304	8-29-04	193	1360	9-25-04	86	498	10-22-04	58	40
06-10-04	79	138	7-7-04	278	1212	8-3-04	341	1687	8-30-04	181	1284	9-26-04	83	505	10-23-04	57	38
06-11-04	78	130	7-8-04	265	1536	8-4-04	317	1613	8-31-04	173	1124	9-27-04	83	475	10-24-04	57	41
06-12-04	81	138	7-9-04	269	1724	8-5-04	353	1709	9-1-04	178	1355	9-28-04	83	464	10-25-04	55	43
06-13-04	94	90	7-10-04	200	1566	8-6-04	385	1979	9-2-04	181	1339	9-29-04	76	470	10-26-04	55	44
06-14-04	114	160	7-11-04	223	1595	8-7-04	398	2265	9-3-04	161	1286	9-30-04	81	479	10-27-04	54	43
06-15-04	171	175	7-12-04	249	1479	8-8-04	484	3297	9-4-04	160	1219	10-1-04	81	468	10-28-04	54	40
06-16-04	184	243	7-13-04	231	1133	8-9-04	445	3253	9-5-04	154	1171	10-2-04	78	406	10-29-04	54	35
06-17-04	206	275	7-14-04	250	1613	8-10-04	406	2833	9-6-04	152	1150	10-3-04	81	438	10-30-04	51	36
06-18-04	228	339	7-15-04	282	1944	8-11-04	377	2546	9-7-04	155	1160	10-4-04	96	476	10-31-04	54	65
06-19-04	234	431	7-16-04	297	1724	8-12-04	377	2120	9-8-04	172	1101	10-5-04	84	466			
06-20-04	238	485	7-17-04	313	1851	8-13-04	383	2063	9-9-04	177	1083	10-6-04	73	436			
06-21-04	242	369	7-18-04	302	1889	8-14-04	405	1958	9-10-04	182	1164	10-7-04	73	451			
06-22-04	191	546	7-19-04	284	1884	8-15-04	380	1949	9-11-04	174	1076	10-8-04	70	441			
06-23-04	202	629	7-20-04	319	1913	8-16-04	383	2174	9-12-04	156	984	10-9-04	70	408			
06-24-04	189	759	7-21-04	333	1499	8-17-04	401	3016	9-13-04	156	874	10-10-04	68	320			
06-25-04	154	691	7-22-04	266	1350	8-18-04	388	2413	9-14-04	183	931	10-11-04	68	295			
06-26-04	124	834	7-23-04	180	949	8-19-04	328	2144	9-15-04	172	1015	10-12-04	68	341			
06-27-04	101	844	7-24-04	155	1209	8-20-04	306	1674	9-16-04	173	1063	10-13-04	68	374			

Three hourly Discharge data at Maneri from July to August 2004

Date	Hr:3	6.00	9.00	12.00	15.00	18.00	21.00	24.00	Date	Hr:3	6.00	9.00	12.00	15.00	18.00	21.00	24.00
01-Jul	172.75	172.75	162.29	151.78	151.78	203.76	203.76	246.59	01-Aug	420.20	406.03	391.83	364.50	329.24	343.78	399.67	407.34
02-Jul	203.76	203.76	203.76	172.85	172.85	172.85	246.59	267.75	02-Aug	399.67	358.83	326.55	470.41	470.41	470.41	380.63	390.42
03-Jul	4.57	204.57	215.34	203.27	226.07	236.64	267.88	267.88	03-Aug	390.42	329.24	341.41	317.39	300.60	311.79	354.72	381.63
04-Jul	226.18	226.18	183.75	183.75	183.75	246.59	288.50	288.50	04-Aug	365.43	286.20	276.18	276.18	276.18	304.93	374.70	374.70
05-Jul	288.56	288.56	267.75	226.18	226.18	309.12	309.12	309.12	05-Aug	353.25	318.42	338.22	322.41	318.42	330.45	401.10	437.97
06-Jul	247.03	247.03	247.03	225.22	225.22	267.25	319.99	373.01	06-Aug	383.03	373.63	373.63	374.23	360.06	374.23	401.10	437.97
07-Jul	284.98	284.98	263.52	242.90	223.79	265.70	327.10	327.10	07-Aug	401.10	368.97	409.43	403.63	367.36	376.16	409.43	447.57
08-Jul	265.70	265.70	261.90	224.23	222.05	265.70	304.07	314.46	08-Aug	440.21	500.38	526.72	486.52	429.58	448.08	513.26	526.35
09-Jul	304.07	304.07	245.08	212.61	245.08	245.08	296.43	296.43	09-Aug	526.35	513.26	399.20	390.17	383.03	387.18	472.07	486.41
10-Jul	244.18	244.18	233.92	179.62	170	167.56	263.52	263.52	10-Aug	464.65	449.56	449.56	344.12	318.42	367.68	397.63	458.28
11-Jul	222.05	222.05	200.01	170.07	179.62	242.90	283.91	263.52	11-Aug	444.57	423.17	337.75	337.52	337.25	374.55	379.78	379.81
12-Jul	292.99	292.99	200.99	201.43	191.04	242.44	285.27	285.27	12-Aug	379.81	364.96	357.35	349.49	349.49	379.91	407.37	429.55
13-Jul	212.16	212.16	212.22	201.43	222.05	256.50	264.71	264.71	13-Aug	407.37	383.88	365.43	327.13	327.13	404.08	424.07	422.28
14-Jul	222.05	222.05	222.05	227.01	219.64	262.18	283.55	341.84	14-Aug	399.69	383.88	374.47	362.63	356.16	415.48	481.14	469.34
15-Jul	283.42	283.42	238.05	280.65	244.07	285.50	320.63	323.47	15-Aug	438.46	374.04	343.62	337.16	360.19	371.16	411.87	404.70
16-Jul	306.96	306.96	273.96	262.77	254.36	323.12	307.35	343.50	16-Aug	374.65	358.69	350.42	350.42	350.42	435.00	420.98	420.98
17-Jul	333.62	333.62	275.67	281.19	262.77	282.60	389.69	346.82	17-Aug	388.62	371.38	380.12	346.43	346.43	415.71	477.86	484.16
18-Jul	324.73	324.73	317.78	220.56	281.19	302.36	318.85	326.36	18-Aug	468.91	400.49	365.52	361.82	361.82	381.76	393.18	372.18
19-Jul	333.39	333.39	268.47	294.63	230.87	230.87	283.72	293.52	19-Aug	332.75	327.43	315.80	289.47	281.30	328.68	381.84	370.43
20-Jul	281.65	281.65	319.69	298.46	273.17	316.00	388.76	388.76	20-Aug	358.62	300.84	280.08	273.82	278.00	297.40	317.28	343.62
21-Jul	338.74	338.74	318.09	262.60	256.44	363.14	403.69	383.53	21-Aug	333.91	317.28	264.41	246.30	238.99	244.34	247.13	301.89
22-Jul	320.17	320.14	321.67	180.96	189.62	244.85	286.30	265.70	22-Aug	306.98	306.89	301.89	301.89	326.36	348.16	342.68	379.76
23-Jul	223.79	223.79	202.42	139.89	174.87	154.82	165.61	154.82	23-Aug	364.50	342.68	301.22	287.05	273.68	281.83	286.99	281.83
24-Jul	154.82	154.82	153.24	161.26	118.43	118.43	182.32	192.78	24-Aug	271.03	256.90	256.90	235.30	247.37	285.68	327.76	312.61
25-Jul	171.81	171.81	161.24	234.34	161.26	161.26	287.01	285.89	25-Aug	312.04	283.89	267.23	252.97	257.71	257.71	257.71	252.47
26-Jul	244.08	244.08	245.08	209.70	223.78	295.86	326.87	306.25	26-Aug	248.15	238.22	252.26	242.37	243.21	243.21	256.47	256.47
27-Jul	262.60	262.60	241.54	2209.38	209.38	313.07	324.46	344.67	27-Aug	256.47	243.21	233.51	228.97	228.97	233.51	242.92	242.92
28-Jul	384.24	384.24	321.84	289.70	266.52	278.22	355.66	383.41	28-Aug	233.23	230.73	221.01	221.01	221.01	232.61	220.41	220.41
29-Jul	383.41	383.41	377.06	442.00	428.46	447.15	502.97	474.15	29-Aug	211.55	211.55	209.28	192.80	165.43	179.77	185.42	189.80
30-Jul	424.64	424.64	398.13	398.00	317.47	352.97	420.70	452.88	30-Aug	199.17	194.53	170.92	172.00	164.03	148.72	198.98	198.98
31-Jul	452.88	452.88	476.44	386.19	380.20	386.19	460.09	413.18	31-Aug	189.51	177.37	174.88	153.72	153.72	154.38	207.31	175.09

APPENDIX III

Three hourly Discharge data at Maneri from September to October 2004																	
Date	**Hr:3**	**6.00**	**9.00**	**12.00**	**15.00**	**18.00**	**21.00**	**24.00**	**Date**	**Hr:3**	**6.00**	**9.00**	**12.00**	**15.00**	**18.00**	**21.00**	**24.00**
Sep. 01	178.55	176.88	169.39	169.39	170.22	169.58	191.88	194.11	Oct.1	81.40	81.40	81.30	81.35	81.28	81.28	81.28	81.25
Sep. 02	194.11	193.37	194.00	194.00	142.54	159.00	181.80	192.54	Oct.2	81.16	68.40	81.30	81.33	81.21	68.40	81.35	81.30
Sep. 03	181.80	171.41	171.41	171.41	117.76	119.42	171.69	182.32	Oct.3	81.40	94.21	94.07	83.40	88.80	68.40	68.40	68.40
Sep. 04	171.69	160.95	138.13	139.16	149.49	160.34	181.80	181.80	Oct.4	94.16	93.79	93.79	93.88	105.84	103.78	91.75	91.75
Sep. 05	160.54	149.95	149.95	149.95	128.83	160.34	160.34	170.68	Oct.5	91.53	91.16	94.80	79.30	79.30	79.19	79.19	74.20
Sep. 06	170.68	139.49	149.95	149.95	128.83	128.98	170.68	180.96	Oct.6	74.20	74.20	73.85	68.40	73.87	73.58	73.85	73.86
Sep. 07	160.34	160.34	139.49	139.49	139.49	149.95	160.34	191.19	Oct.7	73.90	73.93	73.87	68.40	79.86	73.79	68.40	68.40
Sep. 08	180.96	191.19	160.34	160.34	139.49	160.34	191.19	191.19	Oct.8	73.90	73.90	68.40	68.40	68.40	68.40	68.40	73.90
Sep. 09	170.68	170.68	160.34	160.34	160.34	160.34	217.65	217.65	Oct.9	73.90	73.90	73.94	68.40	68.40	68.40	68.40	68.40
Sep. 10	196.19	185.96	165.34	165.30	165.34	165.34	196.19	216.46	Oct.10	68.40	68.40	68.40	68.40	68.40	68.40	68.40	68.40
Sep. 11	196.19	175.68	172.75	172.75	94.60	185.37	195.78	196.54	Oct.11	68.40	68.40	68.40	68.40	68.40	68.40	68.40	68.40
Sep. 12	184.16	171.67	133.79	133.79	133.79	133.93	196.54	157.29	Oct.12	68.40	68.40	68.40	68.40	68.40	68.40	68.40	68.40
Sep. 13	171.81	159.53	120.84	120.94	120.94	121.12	209.40	220.89	Oct.13	68.40	68.40	68.40	68.40	68.40	68.40	68.40	68.40
Sep. 14	196.16	183.73	160.26	160.26	147.88	171.53	221.36	221.36	Oct.14	68.40	68.40	68.40	68.40	68.40	68.40	68.40	68.40
Sep. 15	196.16	171.24	151.48	151.48	150.92	151.20	200.17	201.13	Oct.15	64.60	68.40	68.40	68.40	68.40	57.00	68.40	68.40
Sep. 16	200.65	188.36	174.49	174.49	173.71	172.93	150.05	151.48	Oct.16	64.60	68.40	68.40	57.00	57.00	57.00	68.40	68.40
Sep. 17	175.64	148.89	137.98	137.98	138.72	163.30	151.20	151.20	Oct.17	57.00	68.40	68.40	57.00	57.00	68.40	68.40	68.40
Sep. 18	150.34	124.85	126.00	126.00	125.62	125.62	126.00	138.95	Oct.18	57.00	68.40	68.40	45.60	45.60	68.40	68.40	57.00
Sep. 19	138.95	139.42	125.91	125.91	112.33	98.40	111.28	111.35	Oct.19	57.00	68.40	68.40	45.60	45.60	68.40	68.40	57.00
Sep. 20	111.30	111.12	111.05	111.05	98.40	98.40	111.25	124.35	Oct.20	57.00	68.40	68.40	45.60	45.60	68.40	68.40	57.00
Sep. 21	123.98	98.40	98.40	98.40	98.40	98.40	111.33	124.16	Oct.21	57.00	68.40	68.40	45.60	45.60	68.40	68.40	57.00
Sep. 22	123.98	98.40	98.40	98.40	89.40	98.40	92.88	145.59	Oct.22	57.00	68.40	68.40	45.60	45.60	57.00	68.40	57.00
Sep. 23	145.82	145.94	149.74	149.74	98.40	98.40	98.40	101.30	Oct.23	45.60	68.40	68.40	41.80	41.80	68.40	68.40	57.00
Sep. 24	98.40	98.40	92.88	99.88	92.88	92.88	92.88	82.00	Oct.24	45.60	68.40	68.40	41.80	41.80	68.40	68.40	57.00
Sep. 25	94.90	94.95	82.00	82.00	82.00	93.51	80.90	81.09	Oct.25	45.60	68.40	68.40	45.60	38.00	68.40	68.40	38.00
Sep. 26	86.67	86.67	81.35	81.35	81.30	81.25	81.25	87.75	Oct.26	38.00	68.40	68.40	45.60	45.60	68.40	68.40	38.00
Sep. 27	87.75	87.75	81.35	81.35	81.25	81.25	81.28	81.30	Oct.27	38.00	68.40	68.40	45.60	38.00	68.40	68.40	38.00
Sep. 28	81.33	81.25	93.98	93.98	68.40	81.35	81.21	81.30	Oct.28	38.00	68.40	68.40	38.00	38.00	68.40	68.40	45.60
Sep. 29	81.35	81.33	68.40	68.40	68.40	74.87	81.33	81.35	Oct.29	38.00	68.40	68.40	38.00	38.00	68.40	68.40	45.60
Sep. 30	81.40	81.40	81.40	81.23	81.25	81.25	81.33	81.37	Oct.30	38.00	68.40	68.40	38.00	38.00	45.60	68.40	45.60
									Oct.31	38.00	68.40	68.40	38.00	38.00	68.40	68.40	45.60

Three hourly sediment concentration in ppm at Maneri from July to August 2004																	
Date	**Hr:3**	**6.00**	**9.00**	**12.00**	**15.00**	**18.00**	**21.00**	**24.00**	**Date**	**Hr:3**	**6.00**	**9.00**	**12.00**	**15.00**	**18.00**	**21.00**	**24.00**
01-Jul	660	660	680	690	640	630	590	620	01-Aug	9980	9040	9560	9320	9630	9680	9740	9430
02-Jul	690	860	890	960	980	990	990	990	02-Aug	9350	9680	9740	9450	9560	9680	6750	9530
03-Jul	1000	1090	1100	1130	1080	940	1080	1090	03-Aug	9240	6700	6450	6290	6200	6150	6210	6730
04-Jul	1080	1040	960	1000	990	980	1010	1030	04-Aug	6110	6150	6250	6290	6240	6170	8240	6180
05-Jul	1100	1010	890	850	880	1080	1120	1210	05-Aug	6010	6150	6180	6250	6290	6370	8920	8530
06-Jul	1290	1150	1130	1130	1180	1080	1280	1400	06-Aug	7960	7840	7960	8340	6290	8010	8570	8370
07-Jul	1530	1210	1070	1068	1080	1110	1230	1400	07-Aug	8140	8320	8380	8430	8340	8260	13860	8750
08-Jul	1480	1500	1530	1580	1560	1510	1540	1590	08-Aug	10930	13860	13630	13450	13380	13700	12660	13880
09-Jul	1640	1750	1750	1740	1760	1780	1760	1610	09-Aug	13660	13840	13750	13630	12560	11840	11460	13340
10-Jul	1520	1610	1680	1700	1700	1540	1410	1370	10-Aug	12160	11680	11570	11430	11280	10930	8260	13340
11-Jul	1340	1310	1580	1760	1790	1860	1640	1480	11-Aug	11430	11280	10860	9880	8960	8220	8970	11880
12-Jul	1340	1360	1380	1396	1480	1670	1725	1480	12-Aug	8430	8140	7930	8140	8260	8930	9650	8350
13-Jul	1340	1710	2310	2280	2460	2610	2680	2740	13-Aug	8980	6750	6590	6270	8760	9880	9880	8920
14-Jul	2810	2880	2860	2900	2810	3240	4000	4300	14-Aug	9430	8840	8450	8190	8270	9960	6840	2680
15-Jul	4260	4430	8940	8860	8950	8890	8930	8960	15-Aug	9380	9650	6900	6550	6470	6930	6840	9650
16-Jul	9130	8760	8880	5060	4570	5130	6760	6870	16-Aug	6480	8760	9650	9760	9580	9460	9240	6650
17-Jul	6980	6920	6870	7520	7200	7810	7960	7980	17-Aug	8160	8840	8760	99970	9870	10640	10760	9120
18-Jul	8110	8050	7970	7330	6840	6560	7360	8240	18-Aug	8910	8890	8780	10150	10180	10290	9920	10110
19-Jul	8300	8230	8000	7840	7740	6870	6760	6540	19-Aug	8660	9230	8910	8450	8260	8080	7780	9240
20-Jul	6600	5920	4150	2640	2160	2820	3070	3240	20-Aug	6840	6930	6840	6520	6370	6230	6740	7110
21-Jul	3430	3050	2870	2740	2710	3050	3100	3040	21-Aug	8140	7830	7560	7240	5850	5930	6480	7860
22-Jul	3010	2860	2770	2810	2860	2460	2410	2420	22-Aug	7640	7580	7340	7160	7930	7930	8480	7360
23-Jul	2400	2440	1440	1890	1910	1870	1620	1610	23-Aug	8870	8630	8360	8210	8530	8370	8420	9160
24-Jul	1560	1890	1940	2820	2790	2760	2810	2780	24-Aug	8780	8530	8240	8030	8760	9680	9560	8660
25-Jul	2870	2860	2830	2810	2880	2990	2960	3040	25-Aug	9150	7890	6730	6250	6860	7940	7620	9230
26-Jul	3010	3040	3300	3320	3250	3360	3480	3610	26-Aug	7270	6720	5290	4850	5460	6140	6080	7460
27-Jul	3460	3540	3560	3590	3680	3710	3820	3880	27-Aug	5210	4630	3150	2870	2460	2460	2420	5340
28-Jul	3890	4030	4160	4250	4390	6590	6670	6710	28-Aug	2280	2460	2740	3080	2840	2650	2580	2370
29-Jul	6780	6870	6910	7130	8340	9720	9810	9870	29-Aug	2410	2960	3240	3180	2670	2450	2390	2460
30-Jul	1000	9880	9630	8990	9680	9880	9910	9960	30-Aug	1870	1840	1860	1830	1680	1560	1510	1520
31-Jul	9850	9920	9780	9810	9860	9930	9560	9940	31-Aug	1470	1510	1490	1480	1430	1390	1420	1400

APPENDIX IV

Three hourly sediment concentration in ppm at Maneri from July to August 2004

Date	Hr:3	6.00	9.00	12.00	15.00	18.00	21.00	24.00	Date	Hr:3	6.00	9.00	12.00	15.00	18.00	21.00	24.00
Sep. 01	1400	1360	1250	1360	1340	1350	1380	1400	Oct.1	450	460	500	440	470	490	470	460
Sep. 02	1420	1430	1140	1380	1350	1290	1340	1360	Oct.2	420	400	460	390	400	410	390	380
Sep. 03	1380	1320	1180	1250	1310	1260	1290	1300	Oct.3	370	430	460	480	460	450	430	420
Sep. 04	1310	1280	1160	1230	1210	1170	1190	1200	Oct.4	400	480	480	510	500	480	490	470
Sep. 05	1180	1160	1060	1160	1180	1200	1220	1210	Oct.5	450	480	480	480	460	470	460	450
Sep. 06	1190	1150	1090	1140	1150	1140	1160	1180	Oct.6	440	470	410	450	430	410	430	450
Sep. 07	1150	1190	1240	1130	1180	1150	1110	1130	Oct.7	460	490	310	450	470	480	470	480
Sep. 08	1120	1090	1130	1070	1090	1100	1120	1090	Oct.8	460	490	260	460	470	450	460	480
Sep. 09	1070	1120	1060	1070	1080	1100	1090	1070	Oct.9	460	440	350	380	400	380	440	410
Sep. 10	1050	1200	880	1260	1270	1240	1210	1200	Oct.10	380	350	410	290	280	260	290	300
Sep. 11	1180	1230	890	1110	1090	1060	1040	1010	Oct.11	310	290	400	240	280	290	280	270
Sep. 12	1030	1050	1030	1040	980	940	910	890	Oct.12	300	320	310	330	360	380	360	370
Sep. 13	860	890	1080	860	810	800	830	860	Oct.13	400	380	270	400	380	370	400	390
Sep. 14	880	900	1040	870	790	820	1060	1090	Oct.14	360	380	270	390	380	370	350	330
Sep. 15	1110	1080	910	1000	980	1010	1000	1030	Oct.15	310	330	240	300	320	330	310	300
Sep. 16	1130	1110	920	1050	1060	1080	1070	1080	Oct.16	290	280	250	260	240	290	290	260
Sep. 17	1100	1070	940	1020	1050	1080	1070	1060									
Sep. 18	1090	980	890	870	960	910	900	920									
Sep. 19	950	930	870	890	910	920	940	950									
Sep. 20	930	950	860	910	920	940	910	880									
Sep. 21	860	880	660	930	950	940	920	900									
Sep. 22	870	890	530	860	880	900	870	880									
Sep. 23	840	880	540	840	720	680	700	690									
Sep. 24	650	670	450	650	610	670	490	520									
Sep. 25	510	540	460	520	500	470	480	500									
Sep. 26	510	530	470	520	480	500	530	500									
Sep. 27	570	570	490	430	410	420	460	450									
Sep. 28	500	480	470	470	450	430	450	460									
Sep. 29	490	480	380	490	480	470	490	480									
Sep. 30	500	480	460	460	480	500	490	460									

APPENDIX IV

Daily discharge (Q) data at Maneri for six water years

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
01-04-2008	19	28-04-2008	52	25-05-2008	118	21-06-2008	388	18-07-2008	304	14-08-2008	515	10-09-2008	89	07-10-2008	76	03-11-2008	50
02-04-2008	24	29-04-2008	52	26-05-2008	124	22-06-2008	336	19-07-2008	296	15-08-2008	424	11-09-2008	97	08-10-2008	72	04-11-2008	50
03-04-2008	36	30-04-2008	54	27-05-2008	120	23-06-2008	261	20-07-2008	303	16-08-2008	397	12-09-2008	97	09-10-2008	68	05-11-2008	49
04-04-2008	30	01-05-2008	56	28-05-2008	113	24-06-2008	288	21-07-2008	327	17-08-2008	399	13-09-2008	104	10-10-2008	68	06-11-2008	46
05-04-2008	31	02-05-2008	63	29-05-2008	106	25-06-2008	310	22-07-2008	345	18-08-2008	377	14-09-2008	104	11-10-2008	68	07-11-2008	50
06-04-2008	31	03-05-2008	63	30-05-2008	104	26-06-2008	337	23-07-2008	328	19-08-2008	257	15-09-2008	106	12-10-2008	68	08-11-2008	49
07-04-2008	31	04-05-2008	64	31-05-2008	117	27-06-2008	305	24-07-2008	330	20-08-2008	347	16-09-2008	109	13-10-2008	67	09-11-2008	46
08-04-2008	30	05-05-2008	82	01-06-2008	118	28-06-2008	256	25-07-2008	349	21-08-2008	340	17-09-2008	113	14-10-2008	66	10-11-2008	46
09-04-2008	30	06-05-2008	77	02-06-2008	120	29-06-2008	273	26-07-2008	402	22-08-2008	381	18-09-2008	114	15-10-2008	65	11-11-2008	45
10-04-2008	34	07-05-2008	70	03-06-2008	136	30-06-2008	303	27-07-2008	395	23-08-2008	363	19-09-2008	185	16-10-2008	64	12-11-2008	49
11-04-2008	36	08-05-2008	60	04-06-2008	155	01-07-2008	285	28-07-2008	390	24-08-2008	344	20-09-2008	235	17-10-2008	61	13-11-2008	46
12-04-2008	40	09-05-2008	59	05-06-2008	162	02-07-2008	310	29-07-2008	415	25-08-2008	336	21-09-2008	176	18-10-2008	61	14-11-2008	45
13-04-2008	37	10-05-2008	57	06-06-2008	171	03-07-2008	307	30-07-2008	430	26-08-2008	332	22-09-2008	147	19-10-2008	60	15-11-2008	41
14-04-2008	36	11-05-2008	56	07-06-2008	196	04-07-2008	311	31-07-2008	551	27-08-2008	320	23-09-2008	132	20-10-2008	59	16-11-2008	45
15-04-2008	39	12-05-2008	62	08-06-2008	224	05-07-2008	321	01-08-2008	568	28-08-2008	309	24-09-2008	119	21-10-2008	58	17-11-2008	45
16-04-2008	40	13-05-2008	65	09-06-2008	242	06-07-2008	354	02-08-2008	539	29-08-2008	367	25-09-2008	112	22-10-2008	59	18-11-2008	40
17-04-2008	43	14-05-2008	71	10-06-2008	274	07-07-2008	369	03-08-2008	552	30-08-2008	356	26-09-2008	98	23-10-2008	58	19-11-2008	46
18-04-2008	40	15-05-2008	84	11-06-2008	334	08-07-2008	377	04-08-2008	513	31-08-2008	335	27-09-2008	100	24-10-2008	58	20-11-2008	40
19-04-2008	41	16-05-2008	97	12-06-2008	380	09-07-2008	458	05-08-2008	487	01-09-2008	320	28-09-2008	87	25-10-2008	55	21-11-2008	43
20-04-2008	43	17-05-2008	106	13-06-2008	408	10-07-2008	387	06-08-2008	440	02-09-2008	320	29-09-2008	85	26-10-2008	58	22-11-2008	42
21-04-2008	44	18-05-2008	115	14-06-2008	390	11-07-2008	425	07-08-2008	417	03-09-2008	317	30-09-2008	83	27-10-2008	53	23-11-2008	43
22-04-2008	45	19-05-2008	104	15-06-2008	432	12-07-2008	435	08-08-2008	448	04-09-2008	307	01-10-2008	75	28-10-2008	53	24-11-2008	48
23-04-2008	57	20-05-2008	89	16-06-2008	389	13-07-2008	445	09-08-2008	462	05-09-2008	254	02-10-2008	76	29-10-2008	55	25-11-2008	36
24-04-2008	58	21-05-2008	92	17-06-2008	420	14-07-2008	421	10-08-2008	426	06-09-2008	192	03-10-2008	82	30-10-2008	50	26-11-2008	44
25-04-2008	60	22-05-2008	93	18-06-2008	436	15-07-2008	329	11-08-2008	410	07-09-2008	138	04-10-2008	78	31-10-2008	54	27-11-2008	40
26-04-2008	59	23-05-2008	130	19-06-2008	448	16-07-2008	348	12-08-2008	442	08-09-2008	119	05-10-2008	77	01-11-2008	50	28-11-2008	40
27-04-2008	54	24-05-2008	103	20-06-2008	389	17-07-2008	353	13-08-2008	486	09-09-2008	113	06-10-2008	79	02-11-2008	50	29-11-2008	40

APPENDIX V

Daily discharge (Q) data at Maneri for six water years																	
Date	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
30-11-2008	40	27-12-2008	31	23-01-2009	28	19-02-2009	23	18-03-2009	23	14-04-2009	28	11-05-2009	40	07-06-2009	142	04-07-2009	143
01-12-2008	39	28-12-2008	32	24-01-2009	27	20-02-2009	27	19-03-2009	26	15-04-2009	30	12-05-2009	45	08-06-2009	139	05-07-2009	140
02-12-2008	39	29-12-2008	32	25-01-2009	27	21-02-2009	26	20-03-2009	27	16-04-2009	29	13-05-2009	42	09-06-2009	125	06-07-2009	148
03-12-2008	35	30-12-2008	32	26-01-2009	26	22-02-2009	26	21-03-2009	28	17-04-2009	28	14-05-2009	47	10-06-2009	108	07-07-2009	166
04-12-2008	39	31-12-2008	32	27-01-2009	26	23-02-2009	28	22-03-2009	27	18-04-2009	37	15-05-2009	55	11-06-2009	107	08-07-2009	205
05-12-2008	39	01-01-2009	31	28-01-2009	27	24-02-2009	21	23-03-2009	27	19-04-2009	35	16-05-2009	68	12-06-2009	108	09-07-2009	208
06-12-2008	39	02-01-2009	30	29-01-2009	27	25-02-2009	27	24-03-2009	20	20-04-2009	41	17-05-2009	75	13-06-2009	110	10-07-2009	222
07-12-2008	38	03-01-2009	33	30-01-2009	28	26-02-2009	26	25-03-2009	27	21-04-2009	42	18-05-2009	111	14-06-2009	100	11-07-2009	230
08-12-2008	37	04-01-2009	29	31-01-2009	27	27-02-2009	23	26-03-2009	27	22-04-2009	36	19-05-2009	136	15-06-2009	101	12-07-2009	271
09-12-2008	37	05-01-2009	29	01-02-2009	27	28-02-2009	27	27-03-2009	26	23-04-2009	29	20-05-2009	126	16-06-2009	95	13-07-2009	269
10-12-2008	36	06-01-2009	31	02-02-2009	26	01-03-2009	27	28-03-2009	27	24-04-2009	29	21-05-2009	146	17-06-2009	87	14-07-2009	359
11-12-2008	40	07-01-2009	30	03-02-2009	26	02-03-2009	26	29-03-2009	26	25-04-2009	33	22-05-2009	146	18-06-2009	87	15-07-2009	297
12-12-2008	33	08-01-2009	29	04-02-2009	27	03-03-2009	22	30-03-2009	27	26-04-2009	35	23-05-2009	130	19-06-2009	89	16-07-2009	222
13-12-2008	35	09-01-2009	29	05-02-2009	27	04-03-2009	27	31-03-2009	29	27-04-2009	40	24-05-2009	122	20-06-2009	96	17-07-2009	254
14-12-2008	33	10-01-2009	30	06-02-2009	26	05-03-2009	28	01-04-2009	20	28-04-2009	46	25-05-2009	106	21-06-2009	111	18-07-2009	276
15-12-2008	34	11-01-2009	29	07-02-2009	27	06-03-2009	27	02-04-2009	27	29-04-2009	59	26-05-2009	93	22-06-2009	126	19-07-2009	300
16-12-2008	32	12-01-2009	27	08-02-2009	29	07-03-2009	27	03-04-2009	28	30-04-2009	56	27-05-2009	109	23-06-2009	155	20-07-2009	318
17-12-2008	33	13-01-2009	28	09-02-2009	30	08-03-2009	20	04-04-2009	27	01-05-2009	66	28-05-2009	111	24-06-2009	185	21-07-2009	280
18-12-2008	34	14-01-2009	30	10-02-2009	27	09-03-2009	27	05-04-2009	27	02-05-2009	67	29-05-2009	111	25-06-2009	221	22-07-2009	280
19-12-2008	35	15-01-2009	27	11-02-2009	21	10-03-2009	27	06-04-2009	26	03-05-2009	56	30-05-2009	99	26-06-2009	254	23-07-2009	246
20-12-2008	39	16-01-2009	28	12-02-2009	26	11-03-2009	27	07-04-2009	32	04-05-2009	52	31-05-2009	89	27-06-2009	307	24-07-2009	294
21-12-2008	33	17-01-2009	29	13-02-2009	27	12-03-2009	21	08-04-2009	31	05-05-2009	46	01-06-2009	97	28-06-2009	309	25-07-2009	309
22-12-2008	36	18-01-2009	29	14-02-2009	26	13-03-2009	27	09-04-2009	33	06-05-2009	46	02-06-2009	109	29-06-2009	290	26-07-2009	329
23-12-2008	36	19-01-2009	28	15-02-2009	27	14-03-2009	27	10-04-2009	28	07-05-2009	46	03-06-2009	162	30-06-2009	290	27-07-2009	357
24-12-2008	32	20-01-2009	29	16-02-2009	27	15-03-2009	26	11-04-2009	27	08-05-2009	41	04-06-2009	187	01-07-2009	244	28-07-2009	325
25-12-2008	31	21-01-2009	27	17-02-2009	26	16-03-2009	27	12-04-2009	32	09-05-2009	46	05-06-2009	195	02-07-2009	190	29-07-2009	293
26-12-2008	33	22-01-2009	28	18-02-2009	23	17-03-2009	26	13-04-2009	29	10-05-2009	40	06-06-2009	176	03-07-2009	166	30-07-2009	273

Daily discharge (Q) data at Maneri for six water years

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
31-07-2009	301	27-08-2009	185	23-09-2009	104	20-10-2009	53	16-11-2009	40	13-12-2009	31	09-01-2010	27	05-02-2010	23	04-03-2010	23
01-08-2009	296	28-08-2009	207	24-09-2009	102	21-10-2009	54	17-11-2009	40	14-12-2009	31	10-01-2010	27	06-02-2010	23	05-03-2010	27
02-08-2009	306	29-08-2009	206	25-09-2009	102	22-10-2009	52	18-11-2009	40	15-12-2009	32	11-01-2010	23	07-02-2010	27	06-03-2010	27
03-08-2009	323	30-08-2009	203	26-09-2009	102	23-10-2009	51	19-11-2009	39	16-12-2009	32	12-01-2010	27	08-02-2010	23	07-03-2010	23
04-08-2009	340	31-08-2009	217	27-09-2009	101	24-10-2009	47	20-11-2009	38	17-12-2009	30	13-01-2010	26	09-02-2010	25	08-03-2010	27
05-08-2009	367	01-09-2009	176	28-09-2009	98	25-10-2009	52	21-11-2009	38	18-12-2009	31	14-01-2010	25	10-02-2010	22	09-03-2010	23
06-08-2009	347	02-09-2009	162	29-09-2009	99	26-10-2009	44	22-11-2009	41	19-12-2009	31	15-01-2010	27	11-02-2010	22	10-03-2010	27
07-08-2009	330	03-09-2009	174	30-09-2009	98	27-10-2009	51	23-11-2009	40	20-12-2009	29	16-01-2010	27	12-02-2010	26	11-03-2010	27
08-08-2009	330	04-09-2009	155	01-10-2009	96	28-10-2009	44	24-11-2009	42	21-12-2009	29	17-01-2010	24	13-02-2010	27	12-03-2010	27
09-08-2009	330	05-09-2009	136	02-10-2009	97	29-10-2009	47	25-11-2009	33	22-12-2009	29	18-01-2010	27	14-02-2010	27	13-03-2010	23
10-08-2009	303	06-09-2009	95	03-10-2009	94	30-10-2009	45	26-11-2009	32	23-12-2009	29	19-01-2010	27	15-02-2010	27	14-03-2010	28
11-08-2009	317	07-09-2009	92	04-10-2009	96	31-10-2009	47	27-11-2009	34	24-12-2009	29	20-01-2010	23	16-02-2010	22	15-03-2010	24
12-08-2009	321	08-09-2009	283	05-10-2009	127	01-11-2009	44	28-11-2009	36	25-12-2009	28	21-01-2010	27	17-02-2010	27	16-03-2010	27
13-08-2009	336	09-09-2009	281	06-10-2009	97	02-11-2009	41	29-11-2009	36	26-12-2009	28	22-01-2010	23	18-02-2010	23	17-03-2010	31
14-08-2009	358	10-09-2009	362	07-10-2009	91	03-11-2009	45	30-11-2009	39	27-12-2009	28	23-01-2010	27	19-02-2010	27	18-03-2010	31
15-08-2009	360	11-09-2009	255	08-10-2009	90	04-11-2009	45	01-12-2009	31	28-12-2009	29	24-01-2010	22	20-02-2010	25	19-03-2010	37
16-08-2009	377	12-09-2009	231	09-10-2009	76	05-11-2009	47	02-12-2009	36	29-12-2009	28	25-01-2010	27	21-02-2010	27	20-03-2010	42
17-08-2009	319	13-09-2009	208	10-10-2009	68	06-11-2009	45	03-12-2009	36	30-12-2009	28	26-01-2010	23	22-02-2010	27	21-03-2010	45
18-08-2009	251	14-09-2009	155	11-10-2009	62	07-11-2009	46	04-12-2009	36	31-12-2009	28	27-01-2010	27	23-02-2010	27	22-03-2010	43
19-08-2009	211	15-09-2009	134	12-10-2009	64	08-11-2009	44	05-12-2009	35	01-01-2010	27	28-01-2010	22	24-02-2010	27	23-03-2010	43
20-08-2009	184	16-09-2009	118	13-10-2009	58	09-11-2009	43	06-12-2009	34	02-01-2010	27	29-01-2010	26	25-02-2010	26	24-03-2010	41
21-08-2009	174	17-09-2009	106	14-10-2009	61	10-11-2009	40	07-12-2009	34	03-01-2010	28	30-01-2010	25	26-02-2010	27	25-03-2010	46
22-08-2009	174	18-09-2009	106	15-10-2009	59	11-11-2009	46	08-12-2009	34	04-01-2010	27	31-01-2010	23	27-02-2010	24	26-03-2010	39
23-08-2009	187	19-09-2009	107	16-10-2009	59	12-11-2009	39	09-12-2009	31	05-01-2010	27	01-02-2010	23	28-02-2010	27	27-03-2010	39
24-08-2009	200	20-09-2009	106	17-10-2009	55	13-11-2009	39	10-12-2009	31	06-01-2010	27	02-02-2010	27	01-03-2010	26	28-03-2010	39
25-08-2009	171	21-09-2009	112	18-10-2009	59	14-11-2009	40	11-12-2009	32	07-01-2010	27	03-02-2010	23	02-03-2010	27	29-03-2010	38
26-08-2009	186	22-09-2009	106	19-10-2009	56	15-11-2009	41	12-12-2009	31	08-01-2010	27	04-02-2010	25	03-03-2010	27	30-03-2010	39

APPENDIX V

Daily discharge (Q) data at Maneri for six water years

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
31-03-2010	38	27-04-2010	51	24-05-2010	96	20-06-2010	137	17-07-2010	292	13-08-2010	426	09-09-2010	332	06-10-2010	109	02-11-2010	63
01-04-2010	32	28-04-2010	59	25-05-2010	114	21-06-2010	164	18-07-2010	294	14-08-2010	423	10-09-2010	282	07-10-2010	107	03-11-2010	63
02-04-2010	31	29-04-2010	58	26-05-2010	129	22-06-2010	164	19-07-2010	363	15-08-2010	414	11-09-2010	275	08-10-2010	107	04-11-2010	62
03-04-2010	32	30-04-2010	65	27-05-2010	134	23-06-2010	175	20-07-2010	416	16-08-2010	506	12-09-2010	317	09-10-2010	108	05-11-2010	63
04-04-2010	28	01-05-2010	61	28-05-2010	126	24-06-2010	194	21-07-2010	433	17-08-2010	506	13-09-2010	289	10-10-2010	101	06-11-2010	62
05-04-2010	29	02-05-2010	58	29-05-2010	102	25-06-2010	185	22-07-2010	354	18-08-2010	553	14-09-2010	276	11-10-2010	101	07-11-2010	61
06-04-2010	33	03-05-2010	55	30-05-2010	96	26-06-2010	183	23-07-2010	304	19-08-2010	508	15-09-2010	262	12-10-2010	92	08-11-2010	61
07-04-2010	37	04-05-2010	82	31-05-2010	95	27-06-2010	221	24-07-2010	337	20-08-2010	508	16-09-2010	241	13-10-2010	90	09-11-2010	59
08-04-2010	39	05-05-2010	107	01-06-2010	116	28-06-2010	241	25-07-2010	379	21-08-2010	500	17-09-2010	271	14-10-2010	88	10-11-2010	61
09-04-2010	46	06-05-2010	106	02-06-2010	140	29-06-2010	238	26-07-2010	452	22-08-2010	569	18-09-2010	373	15-10-2010	82	11-11-2010	58
10-04-2010	47	07-05-2010	90	03-06-2010	144	30-06-2010	245	27-07-2010	443	23-08-2010	517	19-09-2010	620	16-10-2010	79	12-11-2010	58
11-04-2010	40	08-05-2010	79	04-06-2010	120	01-07-2010	219	28-07-2010	422	24-08-2010	448	20-09-2010	538	17-10-2010	82	13-11-2010	56
12-04-2010	54	09-05-2010	72	05-06-2010	114	02-07-2010	183	29-07-2010	361	25-08-2010	405	21-09-2010	365	18-10-2010	80	14-11-2010	56
13-04-2010	39	10-05-2010	73	06-06-2010	103	03-07-2010	190	30-07-2010	354	26-08-2010	340	22-09-2010	325	19-10-2010	82	15-11-2010	55
14-04-2010	41	11-05-2010	72	07-06-2010	96	04-07-2010	206	31-07-2010	438	27-08-2010	296	23-09-2010	299	20-10-2010	86	16-11-2010	58
15-04-2010	44	12-05-2010	69	08-06-2010	102	05-07-2010	338	01-08-2010	386	28-08-2010	289	24-09-2010	264	21-10-2010	81	17-11-2010	53
16-04-2010	59	13-05-2010	63	09-06-2010	91	06-07-2010	288	02-08-2010	351	29-08-2010	301	25-09-2010	226	22-10-2010	82	18-11-2010	56
17-04-2010	61	14-05-2010	67	10-06-2010	83	07-07-2010	224	03-08-2010	422	30-08-2010	319	26-09-2010	198	23-10-2010	80	19-11-2010	50
18-04-2010	69	15-05-2010	60	11-06-2010	76	08-07-2010	203	04-08-2010	424	31-08-2010	374	27-09-2010	178	24-10-2010	77	20-11-2010	46
19-04-2010	61	16-05-2010	57	12-06-2010	78	09-07-2010	244	05-08-2010	477	01-09-2010	342	28-09-2010	161	25-10-2010	70	21-11-2010	46
20-04-2010	55	17-05-2010	69	13-06-2010	85	10-07-2010	253	06-08-2010	478	02-09-2010	400	29-09-2010	149	26-10-2010	69	22-11-2010	46
21-04-2010	53	18-05-2010	66	14-06-2010	86	11-07-2010	244	07-08-2010	441	03-09-2010	348	30-09-2010	143	27-10-2010	69	23-11-2010	46
22-04-2010	46	19-05-2010	65	15-06-2010	91	12-07-2010	218	08-08-2010	456	04-09-2010	340	01-10-2010	135	28-10-2010	69	24-11-2010	46
23-04-2010	50	20-05-2010	65	16-06-2010	100	13-07-2010	208	09-08-2010	473	05-09-2010	331	02-10-2010	127	29-10-2010	69	25-11-2010	46
24-04-2010	45	21-05-2010	56	17-06-2010	92	14-07-2010	186	10-08-2010	423	06-09-2010	305	03-10-2010	123	30-10-2010	69	26-11-2010	46
25-04-2010	43	22-05-2010	78	18-06-2010	86	15-07-2010	217	11-08-2010	441	07-09-2010	343	04-10-2010	118	31-10-2010	69	27-11-2010	46
26-04-2010	39	23-05-2010	111	19-06-2010	100	16-07-2010	231	12-08-2010	437	08-09-2010	459	05-10-2010	114	01-11-2010	62	28-11-2010	46

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s
29-11-2010	46	26-12-2010	34	22-01-2011	31	18-02-2011	30	17-03-2011	35	13-04-2011	39	10-05-2011	84	06-06-2011	112	03-07-2011	297
30-11-2010	46	27-12-2010	38	23-01-2011	30	19-02-2011	30	18-03-2011	36	14-04-2011	34	11-05-2011	83	07-06-2011	110	04-07-2011	306
01-12-2010	46	28-12-2010	35	24-01-2011	31	20-02-2011	30	19-03-2011	36	15-04-2011	40	12-05-2011	89	08-06-2011	117	05-07-2011	304
02-12-2010	46	29-12-2010	35	25-01-2011	30	21-02-2011	29	20-03-2011	36	16-04-2011	42	13-05-2011	89	09-06-2011	109	06-07-2011	292
03-12-2010	39	30-12-2010	35	26-01-2011	31	22-02-2011	28	21-03-2011	32	17-04-2011	46	14-05-2011	86	10-06-2011	109	07-07-2011	294
04-12-2010	46	31-12-2010	38	27-01-2011	30	23-02-2011	30	22-03-2011	33	18-04-2011	54	15-05-2011	87	11-06-2011	120	08-07-2011	307
05-12-2010	46	01-01-2011	37	28-01-2011	31	24-02-2011	28	23-03-2011	34	19-04-2011	58	16-05-2011	89	12-06-2011	160	09-07-2011	341
06-12-2010	38	02-01-2011	36	29-01-2011	30	25-02-2011	28	24-03-2011	36	20-04-2011	49	17-05-2011	105	13-06-2011	166	10-07-2011	309
07-12-2010	46	03-01-2011	34	30-01-2011	29	26-02-2011	27	25-03-2011	33	21-04-2011	40	18-05-2011	110	14-06-2011	197	11-07-2011	252
08-12-2010	41	04-01-2011	35	31-01-2011	30	27-02-2011	27	26-03-2011	38	22-04-2011	41	19-05-2011	111	15-06-2011	195	12-07-2011	251
09-12-2010	46	05-01-2011	35	01-02-2011	30	28-02-2011	27	27-03-2011	37	23-04-2011	41	20-05-2011	144	16-06-2011	211	13-07-2011	275
10-12-2010	39	06-01-2011	34	02-02-2011	27	01-03-2011	28	28-03-2011	42	24-04-2011	46	21-05-2011	152	17-06-2011	245	14-07-2011	302
11-12-2010	40	07-01-2011	33	03-02-2011	29	02-03-2011	27	29-03-2011	42	25-04-2011	53	22-05-2011	111	18-06-2011	210	15-07-2011	288
12-12-2010	46	08-01-2011	35	04-02-2011	29	03-03-2011	30	30-03-2011	39	26-04-2011	58	23-05-2011	101	19-06-2011	194	16-07-2011	283
13-12-2010	39	09-01-2011	33	05-02-2011	30	04-03-2011	28	31-03-2011	36	27-04-2011	68	24-05-2011	111	20-06-2011	215	17-07-2011	266
14-12-2010	39	10-01-2011	33	06-02-2011	29	05-03-2011	28	01-04-2011	39	28-04-2011	69	25-05-2011	136	21-06-2011	221	18-07-2011	263
15-12-2010	35	11-01-2011	33	07-02-2011	29	06-03-2011	28	02-04-2011	35	29-04-2011	73	26-05-2011	122	22-06-2011	255	19-07-2011	277
16-12-2010	46	12-01-2011	32	08-02-2011	27	07-03-2011	29	03-04-2011	23	30-04-2011	80	27-05-2011	158	23-06-2011	305	20-07-2011	288
17-12-2010	39	13-01-2011	34	09-02-2011	29	08-03-2011	28	04-04-2011	33	01-05-2011	77	28-05-2011	159	24-06-2011	340	21-07-2011	315
18-12-2010	38	14-01-2011	28	10-02-2011	35	09-03-2011	27	05-04-2011	38	02-05-2011	76	29-05-2011	191	25-06-2011	337	22-07-2011	162
19-12-2010	35	15-01-2011	34	11-02-2011	30	10-03-2011	27	06-04-2011	32	03-05-2011	74	30-05-2011	173	26-06-2011	318	23-07-2011	411
20-12-2010	40	16-01-2011	32	12-02-2011	30	11-03-2011	23	07-04-2011	31	04-05-2011	79	31-05-2011	164	27-06-2011	374	24-07-2011	437
21-12-2010	37	17-01-2011	32	13-02-2011	32	12-03-2011	23	08-04-2011	30	05-05-2011	84	01-06-2011	169	28-06-2011	353	25-07-2011	442
22-12-2010	37	18-01-2011	32	14-02-2011	32	13-03-2011	23	09-04-2011	30	06-05-2011	91	02-06-2011	137	29-06-2011	394	26-07-2011	405
23-12-2010	38	19-01-2011	32	15-02-2011	29	14-03-2011	25	10-04-2011	30	07-05-2011	79	03-06-2011	114	30-06-2011	359	27-07-2011	365
24-12-2010	36	20-01-2011	32	16-02-2011	31	15-03-2011	39	11-04-2011	29	08-05-2011	74	04-06-2011	104	01-07-2011	331	28-07-2011	360
25-12-2010	36	21-01-2011	31	17-02-2011	32	16-03-2011	34	12-04-2011	30	09-05-2011	81	05-06-2011	107	02-07-2011	283	29-07-2011	368

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
30-07-2011	352	26-08-2011	280	22-09-2011	131	20-10-2011	68	16-11-2011	50	13-12-2011	37	09-01-2012	30	05-02-2012	28	03-03-2012	27
31-07-2011	344	27-08-2011	283	23-09-2011	129	21-10-2011	67	17-11-2011	43	14-12-2011	37	10-01-2012	30	06-02-2012	28	04-03-2012	27
01-08-2011	342	28-08-2011	299	24-09-2011	117	22-10-2011	64	18-11-2011	46	15-12-2011	36	11-01-2012	30	07-02-2012	28	05-03-2012	29
02-08-2011	307	29-08-2011	278	25-09-2011	122	23-10-2011	64	19-11-2011	46	16-12-2011	36	12-01-2012	30	08-02-2012	28	06-03-2012	37
03-08-2011	295	30-08-2011	312	26-09-2011	119	24-10-2011	62	20-11-2011	46	17-12-2011	35	13-01-2012	30	09-02-2012	28	07-03-2012	31
04-08-2011	335	31-08-2011	329	27-09-2011	113	25-10-2011	61	21-11-2011	47	18-12-2011	35	14-01-2012	30	10-02-2012	28	08-03-2012	28
05-08-2011	314	01-09-2011	418	28-09-2011	106	26-10-2011	60	22-11-2011	44	19-12-2011	36	15-01-2012	30	11-02-2012	28	09-03-2012	28
06-08-2011	339	02-09-2011	370	29-09-2011	90	27-10-2011	59	23-11-2011	43	20-12-2011	31	16-01-2012	33	12-02-2012	27	10-03-2012	28
07-08-2011	373	03-09-2011	327	30-09-2011	93	28-10-2011	58	24-11-2011	44	21-12-2011	33	17-01-2012	30	13-02-2012	27	11-03-2012	28
08-08-2011	479	04-09-2011	294	01-10-2011	63	29-10-2011	57	25-11-2011	43	22-12-2011	34	18-01-2012	30	14-02-2012	27	12-03-2012	28
09-08-2011	428	05-09-2011	272	02-10-2011	93	30-10-2011	67	26-11-2011	43	23-12-2011	32	19-01-2012	29	15-02-2012	27	13-03-2012	27
10-08-2011	418	06-09-2011	251	03-10-2011	94	31-10-2011	55	27-11-2011	43	24-12-2011	34	20-01-2012	28	16-02-2012	27	14-03-2012	30
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17-08-2011	487	13-09-2011	235	10-10-2011	94	07-11-2011	51	04-12-2011	41	31-12-2011	30	27-01-2012	27	23-02-2012	28	21-03-2012	34
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19-08-2011	321	15-09-2011	242	12-10-2011	78	09-11-2011	53	06-12-2011	39	02-01-2012	31	29-01-2012	28	25-02-2012	28	23-03-2012	30
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24-08-2011	330	20-09-2011	152	17-10-2011	72	14-11-2011	43	11-12-2011	41	07-01-2012	31	03-02-2012	28	01-03-2012	28	28-03-2012	37
25-08-2011	310	21-09-2011	138	18-10-2011	71	15-11-2011	50	12-12-2011	36	08-01-2012	31	04-02-2012	28	02-03-2012	28	29-03-2012	34

Daily discharge (Q) data at Maneri for six water years

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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31-03-2012	41	27-04-2012	44	24-05-2012	82	20-06-2012	205	17-07-2012	199	13-08-2012	330	09-09-2012	230	06-10-2012	62	02-11-2012	46
01-04-2012	43	28-04-2012	46	25-05-2012	98	21-06-2012	181	18-07-2012	223	14-08-2012	343	10-09-2012	202	07-10-2012	57	03-11-2012	46
02-04-2012	44	29-04-2012	51	26-05-2012	108	22-06-2012	234	19-07-2012	245	15-08-2012	318	11-09-2012	209	08-10-2012	58	04-11-2012	52
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Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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14-12-2012	37	10-01-2013	26	06-02-2013	32	05-03-2013	31	01-04-2013	39	28-04-2013	57	25-05-2013	226	21-06-2013	224	18-07-2013	445
15-12-2012	33	11-01-2013	27	07-02-2013	27	06-03-2013	33	02-04-2013	43	29-04-2013	59	26-05-2013	249	22-06-2013	240	19-07-2013	455
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19-12-2012	33	15-01-2013	28	11-02-2013	33	10-03-2013	32	06-04-2013	41	03-05-2013	50	30-05-2013	137	26-06-2013	292	23-07-2013	399
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23-12-2012	31	19-01-2013	29	15-02-2013	32	14-03-2013	36	10-04-2013	45	07-05-2013	52	03-06-2013	276	30-06-2013	310	27-07-2013	382
24-12-2012	31	20-01-2013	27	16-02-2013	31	15-03-2013	35	11-04-2013	46	08-05-2013	59	04-06-2013	279	01-07-2013	316	28-07-2013	366

APPENDIX V

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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31-07-2013	305	27-08-2013	178	23-09-2013	61	20-10-2013	61	16-11-2013	39	13-12-2013	32	09-01-2014	30	05-02-2014	26	04-03-2014	39
01-08-2013	327	28-08-2013	165	24-09-2013	61	21-10-2013	58	17-11-2013	38	14-12-2013	31	10-01-2014	28	06-02-2014	27	05-03-2014	31
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04-08-2013	280	31-08-2013	199	27-09-2013	62	24-10-2013	55	20-11-2013	36	17-12-2013	32	13-01-2014	30	09-02-2014	25	08-03-2014	34
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11-08-2013	307	07-09-2013	80	04-10-2013	49	31-10-2013	48	27-11-2013	38	24-12-2013	26	20-01-2014	25	16-02-2014	25	15-03-2014	35
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23-08-2013	212	19-09-2013	66	16-10-2013	52	12-11-2013	45	09-12-2013	36	05-01-2014	30	01-02-2014	26	28-02-2014	29	27-03-2014	37
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Daily discharge (Q) data at Uttarkashi for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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05-04-2008	38	02-05-2008	75	29-05-2008	115	25-06-2008	322	22-07-2008	369	18-08-2008	436	14-09-2008	119	11-10-2008	89	07-11-2008	61
06-04-2008	39	03-05-2008	80	30-05-2008	112	26-06-2008	320	23-07-2008	363	19-08-2008	393	15-09-2008	121	12-10-2008	91	08-11-2008	60
07-04-2008	37	04-05-2008	76	31-05-2008	122	27-06-2008	300	24-07-2008	393	20-08-2008	316	16-09-2008	120	13-10-2008	92	09-11-2008	56
08-04-2008	37	05-05-2008	90	01-06-2008	106	28-06-2008	252	25-07-2008	388	21-08-2008	403	17-09-2008	122	14-10-2008	87	10-11-2008	55
09-04-2008	37	06-05-2008	81	02-06-2008	109	29-06-2008	376	26-07-2008	385	22-08-2008	479	18-09-2008	121	15-10-2008	87	11-11-2008	55
10-04-2008	41	07-05-2008	76	03-06-2008	133	30-06-2008	427	27-07-2008	370	23-08-2008	467	19-09-2008	219	16-10-2008	83	12-11-2008	58
11-04-2008	44	08-05-2008	73	04-06-2008	142	01-07-2008	399	28-07-2008	356	24-08-2008	324	20-09-2008	268	17-10-2008	87	13-11-2008	58
12-04-2008	49	09-05-2008	70	05-06-2008	169	02-07-2008	373	29-07-2008	425	25-08-2008	312	21-09-2008	213	18-10-2008	83	14-11-2008	57
13-04-2008	47	10-05-2008	76	06-06-2008	146	03-07-2008	325	30-07-2008	485	26-08-2008	341	22-09-2008	184	19-10-2008	81	15-11-2008	49
14-04-2008	40	11-05-2008	70	07-06-2008	163	04-07-2008	385	31-07-2008	681	27-08-2008	321	23-09-2008	185	20-10-2008	85	16-11-2008	53
15-04-2008	47	12-05-2008	80	08-06-2008	193	05-07-2008	382	01-08-2008	574	28-08-2008	276	24-09-2008	171	21-10-2008	75	17-11-2008	54
16-04-2008	51	13-05-2008	79	09-06-2008	244	06-07-2008	421	02-08-2008	406	29-08-2008	290	25-09-2008	154	22-10-2008	76	18-11-2008	49
17-04-2008	53	14-05-2008	80	10-06-2008	316	07-07-2008	398	03-08-2008	469	30-08-2008	268	26-09-2008	153	23-10-2008	75	19-11-2008	55
18-04-2008	49	15-05-2008	106	11-06-2008	295	08-07-2008	368	04-08-2008	461	31-08-2008	266	27-09-2008	141	24-10-2008	74	20-11-2008	50
19-04-2008	51	16-05-2008	108	12-06-2008	355	09-07-2008	412	05-08-2008	520	01-09-2008	235	28-09-2008	133	25-10-2008	70	21-11-2008	51
20-04-2008	53	17-05-2008	133	13-06-2008	332	10-07-2008	421	06-08-2008	475	02-09-2008	233	29-09-2008	128	26-10-2008	68	22-11-2008	49
21-04-2008	55	18-05-2008	129	14-06-2008	311	11-07-2008	463	07-08-2008	507	03-09-2008	229	30-09-2008	117	27-10-2008	66	23-11-2008	51
22-04-2008	56	19-05-2008	118	15-06-2008	317	12-07-2008	472	08-08-2008	516	04-09-2008	230	01-10-2008	120	28-10-2008	64	24-11-2008	57
23-04-2008	71	20-05-2008	110	16-06-2008	331	13-07-2008	390	09-08-2008	412	05-09-2008	230	02-10-2008	116	29-10-2008	66	25-11-2008	44
24-04-2008	71	21-05-2008	104	17-06-2008	329	14-07-2008	402	10-08-2008	446	06-09-2008	222	03-10-2008	114	30-10-2008	52	26-11-2008	52
25-04-2008	77	22-05-2008	112	18-06-2008	446	15-07-2008	393	11-08-2008	442	07-09-2008	169	04-10-2008	116	31-10-2008	73	27-11-2008	48
26-04-2008	72	23-05-2008	139	19-06-2008	579	16-07-2008	361	12-08-2008	439	08-09-2008	141	05-10-2008	112	01-11-2008	60	28-11-2008	46
27-04-2008	69	24-05-2008	112	20-06-2008	510	17-07-2008	376	13-08-2008	459	09-09-2008	134	06-10-2008	105	02-11-2008	66	29-11-2008	48

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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30-11-2008	47	27-12-2008	38	23-01-2009	35	19-02-2009	28	18-03-2009	25	14-04-2009	33	11-05-2009	44	07-06-2009	162	04-07-2009	160
01-12-2008	47	28-12-2008	38	24-01-2009	33	20-02-2009	31	19-03-2009	28	15-04-2009	37	12-05-2009	49	08-06-2009	155	05-07-2009	164
02-12-2008	44	29-12-2008	38	25-01-2009	34	21-02-2009	33	20-03-2009	28	16-04-2009	35	13-05-2009	44	09-06-2009	142	06-07-2009	166
03-12-2008	40	30-12-2008	38	26-01-2009	33	22-02-2009	31	21-03-2009	30	17-04-2009	32	14-05-2009	51	10-06-2009	128	07-07-2009	180
04-12-2008	44	31-12-2008	39	27-01-2009	31	23-02-2009	32	22-03-2009	29	18-04-2009	40	15-05-2009	61	11-06-2009	122	08-07-2009	219
05-12-2008	45	01-01-2009	39	28-01-2009	33	24-02-2009	25	23-03-2009	28	19-04-2009	38	16-05-2009	78	12-06-2009	124	09-07-2009	229
06-12-2008	44	02-01-2009	37	29-01-2009	34	25-02-2009	31	24-03-2009	23	20-04-2009	46	17-05-2009	86	13-06-2009	123	10-07-2009	229
07-12-2008	43	03-01-2009	41	30-01-2009	35	26-02-2009	31	25-03-2009	32	21-04-2009	50	18-05-2009	111	14-06-2009	116	11-07-2009	227
08-12-2008	43	04-01-2009	37	31-01-2009	34	27-02-2009	27	26-03-2009	30	22-04-2009	39	19-05-2009	122	15-06-2009	120	12-07-2009	254
09-12-2008	41	05-01-2009	37	01-02-2009	33	28-02-2009	30	27-03-2009	29	23-04-2009	31	20-05-2009	126	16-06-2009	110	13-07-2009	311
10-12-2008	41	06-01-2009	39	02-02-2009	34	01-03-2009	31	28-03-2009	30	24-04-2009	35	21-05-2009	147	17-06-2009	97	14-07-2009	323
11-12-2008	48	07-01-2009	37	03-02-2009	33	02-03-2009	32	29-03-2009	29	25-04-2009	36	22-05-2009	151	18-06-2009	104	15-07-2009	287
12-12-2008	41	08-01-2009	36	04-02-2009	33	03-03-2009	25	30-03-2009	29	26-04-2009	39	23-05-2009	146	19-06-2009	101	16-07-2009	209
13-12-2008	40	09-01-2009	36	05-02-2009	31	04-03-2009	33	31-03-2009	32	27-04-2009	45	24-05-2009	139	20-06-2009	109	17-07-2009	226
14-12-2008	39	10-01-2009	37	06-02-2009	33	05-03-2009	31	01-04-2009	23	28-04-2009	52	25-05-2009	128	21-06-2009	121	18-07-2009	277
15-12-2008	41	11-01-2009	37	07-02-2009	33	06-03-2009	31	02-04-2009	30	29-04-2009	76	26-05-2009	119	22-06-2009	131	19-07-2009	299
16-12-2008	39	12-01-2009	35	08-02-2009	32	07-03-2009	31	03-04-2009	30	30-04-2009	64	27-05-2009	128	23-06-2009	156	20-07-2009	298
17-12-2008	40	13-01-2009	34	09-02-2009	33	08-03-2009	24	04-04-2009	30	01-05-2009	77	28-05-2009	133	24-06-2009	189	21-07-2009	272
18-12-2008	41	14-01-2009	37	10-02-2009	32	09-03-2009	30	05-04-2009	30	02-05-2009	80	29-05-2009	133	25-06-2009	212	22-07-2009	256
19-12-2008	43	15-01-2009	34	11-02-2009	25	10-03-2009	30	06-04-2009	29	03-05-2009	67	30-05-2009	126	26-06-2009	241	23-07-2009	238
20-12-2008	47	16-01-2009	36	12-02-2009	31	11-03-2009	30	07-04-2009	37	04-05-2009	59	31-05-2009	110	27-06-2009	234	24-07-2009	297
21-12-2008	41	17-01-2009	36	13-02-2009	31	12-03-2009	25	08-04-2009	34	05-05-2009	54	01-06-2009	115	28-06-2009	259	25-07-2009	275
22-12-2008	41	18-01-2009	35	14-02-2009	31	13-03-2009	28	09-04-2009	30	06-05-2009	51	02-06-2009	123	29-06-2009	275	26-07-2009	300
23-12-2008	41	19-01-2009	35	15-02-2009	31	14-03-2009	30	10-04-2009	31	07-05-2009	51	03-06-2009	159	30-06-2009	272	27-07-2009	317
24-12-2008	39	20-01-2009	35	16-02-2009	33	15-03-2009	28	11-04-2009	32	08-05-2009	44	04-06-2009	190	01-07-2009	242	28-07-2009	303
25-12-2008	39	21-01-2009	35	17-02-2009	32	16-03-2009	30	12-04-2009	38	09-05-2009	49	05-06-2009	209	02-07-2009	202	29-07-2009	284
26-12-2008	41	22-01-2009	35	18-02-2009	28	17-03-2009	29	13-04-2009	33	10-05-2009	41	06-06-2009	191	03-07-2009	198	30-07-2009	264

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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31-07-2009	279	27-08-2009	199	23-09-2009	108	20-10-2009	63	16-11-2009	45	13-12-2009	34	09-01-2010	32	05-02-2010	28	04-03-2010	30
01-08-2009	291	28-08-2009	212	24-09-2009	108	21-10-2009	66	17-11-2009	44	14-12-2009	36	10-01-2010	32	06-02-2010	27	05-03-2010	36
02-08-2009	288	29-08-2009	217	25-09-2009	107	22-10-2009	63	18-11-2009	44	15-12-2009	37	11-01-2010	28	07-02-2010	33	06-03-2010	34
03-08-2009	331	30-08-2009	251	26-09-2009	104	23-10-2009	62	19-11-2009	39	16-12-2009	34	12-01-2010	30	08-02-2010	27	07-03-2010	28
04-08-2009	311	31-08-2009	237	27-09-2009	115	24-10-2009	55	20-11-2009	39	17-12-2009	33	13-01-2010	30	09-02-2010	36	08-03-2010	33
05-08-2009	319	01-09-2009	204	28-09-2009	112	25-10-2009	63	21-11-2009	41	18-12-2009	33	14-01-2010	28	10-02-2010	27	09-03-2010	28
06-08-2009	291	02-09-2009	187	29-09-2009	111	26-10-2009	54	22-11-2009	39	19-12-2009	33	15-01-2010	34	11-02-2010	28	10-03-2010	32
07-08-2009	303	03-09-2009	191	30-09-2009	110	27-10-2009	58	23-11-2009	40	20-12-2009	33	16-01-2010	34	12-02-2010	32	11-03-2010	34
08-08-2009	288	04-09-2009	170	01-10-2009	109	28-10-2009	53	24-11-2009	48	21-12-2009	31	17-01-2010	30	13-02-2010	33	12-03-2010	34
09-08-2009	292	05-09-2009	186	02-10-2009	108	29-10-2009	55	25-11-2009	42	22-12-2009	31	18-01-2010	35	14-02-2010	32	13-03-2010	30
10-08-2009	292	06-09-2009	141	03-10-2009	107	30-10-2009	52	26-11-2009	41	23-12-2009	27	19-01-2010	34	15-02-2010	34	14-03-2010	40
11-08-2009	267	07-09-2009	120	04-10-2009	112	31-10-2009	55	27-11-2009	37	24-12-2009	27	20-01-2010	28	16-02-2010	28	15-03-2010	32
12-08-2009	287	08-09-2009	296	05-10-2009	140	01-11-2009	51	28-11-2009	40	25-12-2009	32	21-01-2010	32	17-02-2010	34	16-03-2010	35
13-08-2009	297	09-09-2009	306	06-10-2009	113	02-11-2009	53	29-11-2009	39	26-12-2009	33	22-01-2010	26	18-02-2010	29	17-03-2010	38
14-08-2009	297	10-09-2009	377	07-10-2009	104	03-11-2009	51	30-11-2009	44	27-12-2009	32	23-01-2010	35	19-02-2010	32	18-03-2010	40
15-08-2009	285	11-09-2009	249	08-10-2009	96	04-11-2009	49	01-12-2009	34	28-12-2009	31	24-01-2010	29	20-02-2010	28	19-03-2010	45
16-08-2009	268	12-09-2009	255	09-10-2009	91	05-11-2009	48	02-12-2009	38	29-12-2009	33	25-01-2010	35	21-02-2010	32	20-03-2010	50
17-08-2009	262	13-09-2009	219	10-10-2009	85	06-11-2009	49	03-12-2009	39	30-12-2009	32	26-01-2010	30	22-02-2010	33	21-03-2010	55
18-08-2009	264	14-09-2009	195	11-10-2009	77	07-11-2009	49	04-12-2009	39	31-12-2009	32	27-01-2010	35	23-02-2010	36	22-03-2010	52
19-08-2009	240	15-09-2009	167	12-10-2009	75	08-11-2009	47	05-12-2009	36	01-01-2010	31	28-01-2010	28	24-02-2010	35	23-03-2010	45
20-08-2009	195	16-09-2009	134	13-10-2009	62	09-11-2009	45	06-12-2009	35	02-01-2010	31	29-01-2010	31	25-02-2010	34	24-03-2010	52
21-08-2009	237	17-09-2009	134	14-10-2009	69	10-11-2009	44	07-12-2009	35	03-01-2010	32	30-01-2010	29	26-02-2010	33	25-03-2010	51
22-08-2009	204	18-09-2009	115	15-10-2009	72	11-11-2009	49	08-12-2009	36	04-01-2010	33	31-01-2010	28	27-02-2010	27	26-03-2010	47
23-08-2009	198	19-09-2009	116	16-10-2009	68	12-11-2009	43	09-12-2009	32	05-01-2010	31	01-02-2010	30	28-02-2010	35	27-03-2010	45
24-08-2009	208	20-09-2009	114	17-10-2009	66	13-11-2009	43	10-12-2009	36	06-01-2010	31	02-02-2010	34	01-03-2010	35	28-03-2010	48
25-08-2009	209	21-09-2009	113	18-10-2009	71	14-11-2009	43	11-12-2009	34	07-01-2010	31	03-02-2010	29	02-03-2010	35	29-03-2010	46
26-08-2009	204	22-09-2009	111	19-10-2009	69	15-11-2009	46	12-12-2009	34	08-01-2010	32	04-02-2010	33	03-03-2010	35	30-03-2010	46

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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31-03-2010	48	27-04-2010	58	24-05-2010	104	20-06-2010	149	17-07-2010	317	13-08-2010	472	09-09-2010	378	06-10-2010	135	02-11-2010	74
01-04-2010	38	28-04-2010	68	25-05-2010	120	21-06-2010	164	18-07-2010	322	14-08-2010	455	10-09-2010	330	07-10-2010	132	03-11-2010	73
02-04-2010	39	29-04-2010	68	26-05-2010	132	22-06-2010	174	19-07-2010	358	15-08-2010	459	11-09-2010	311	08-10-2010	135	04-11-2010	72
03-04-2010	38	30-04-2010	74	27-05-2010	144	23-06-2010	184	20-07-2010	410	16-08-2010	567	12-09-2010	359	09-10-2010	128	05-11-2010	71
04-04-2010	36	01-05-2010	71	28-05-2010	141	24-06-2010	205	21-07-2010	469	17-08-2010	573	13-09-2010	336	10-10-2010	123	06-11-2010	70
05-04-2010	35	02-05-2010	68	29-05-2010	109	25-06-2010	206	22-07-2010	373	18-08-2010	609	14-09-2010	321	11-10-2010	121	07-11-2010	69
06-04-2010	40	03-05-2010	63	30-05-2010	99	26-06-2010	203	23-07-2010	316	19-08-2010	578	15-09-2010	360	12-10-2010	116	08-11-2010	69
07-04-2010	44	04-05-2010	93	31-05-2010	106	27-06-2010	233	24-07-2010	342	20-08-2010	541	16-09-2010	287	13-10-2010	115	09-11-2010	67
08-04-2010	47	05-05-2010	113	01-06-2010	130	28-06-2010	255	25-07-2010	389	21-08-2010	554	17-09-2010	276	14-10-2010	112	10-11-2010	70
09-04-2010	56	06-05-2010	110	02-06-2010	142	29-06-2010	255	26-07-2010	441	22-08-2010	705	18-09-2010	415	15-10-2010	106	11-11-2010	66
10-04-2010	56	07-05-2010	96	03-06-2010	151	30-06-2010	262	27-07-2010	450	23-08-2010	583	19-09-2010	679	16-10-2010	107	12-11-2010	65
11-04-2010	48	08-05-2010	89	04-06-2010	129	01-07-2010	255	28-07-2010	443	24-08-2010	507	20-09-2010	787	17-10-2010	107	13-11-2010	65
12-04-2010	64	09-05-2010	88	05-06-2010	132	02-07-2010	215	29-07-2010	391	25-08-2010	446	21-09-2010	423	18-10-2010	104	14-11-2010	65
13-04-2010	46	10-05-2010	88	06-06-2010	115	03-07-2010	226	30-07-2010	377	26-08-2010	401	22-09-2010	346	19-10-2010	105	15-11-2010	62
14-04-2010	46	11-05-2010	88	07-06-2010	119	04-07-2010	226	31-07-2010	446	27-08-2010	350	23-09-2010	336	20-10-2010	102	16-11-2010	65
15-04-2010	52	12-05-2010	78	08-06-2010	128	05-07-2010	321	01-08-2010	420	28-08-2010	334	24-09-2010	315	21-10-2010	101	17-11-2010	58
16-04-2010	68	13-05-2010	68	09-06-2010	113	06-07-2010	316	02-08-2010	351	29-08-2010	343	25-09-2010	273	22-10-2010	95	18-11-2010	63
17-04-2010	72	14-05-2010	72	10-06-2010	105	07-07-2010	240	03-08-2010	452	30-08-2010	350	26-09-2010	242	23-10-2010	105	19-11-2010	58
18-04-2010	80	15-05-2010	67	11-06-2010	89	08-07-2010	227	04-08-2010	448	31-08-2010	383	27-09-2010	216	24-10-2010	95	20-11-2010	54
19-04-2010	70	16-05-2010	61	12-06-2010	89	09-07-2010	252	05-08-2010	496	01-09-2010	371	28-09-2010	201	25-10-2010	92	21-11-2010	53
20-04-2010	65	17-05-2010	79	13-06-2010	96	10-07-2010	286	06-08-2010	510	02-09-2010	400	29-09-2010	188	26-10-2010	88	22-11-2010	58
21-04-2010	60	18-05-2010	73	14-06-2010	96	11-07-2010	256	07-08-2010	479	03-09-2010	393	30-09-2010	177	27-10-2010	82	23-11-2010	57
22-04-2010	58	19-05-2010	70	15-06-2010	100	12-07-2010	242	08-08-2010	511	04-09-2010	360	01-10-2010	196	28-10-2010	83	24-11-2010	55
23-04-2010	61	20-05-2010	71	16-06-2010	108	13-07-2010	222	09-08-2010	516	05-09-2010	364	02-10-2010	157	29-10-2010	83	25-11-2010	56
24-04-2010	53	21-05-2010	61	17-06-2010	101	14-07-2010	209	10-08-2010	460	06-09-2010	357	03-10-2010	148	30-10-2010	82	26-11-2010	53
25-04-2010	52	22-05-2010	82	18-06-2010	98	15-07-2010	232	11-08-2010	473	07-09-2010	392	04-10-2010	144	31-10-2010	79	27-11-2010	53
26-04-2010	47	23-05-2010	106	19-06-2010	113	16-07-2010	233	12-08-2010	486	08-09-2010	587	05-10-2010	140	01-11-2010	70	28-11-2010	53

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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24-12-2012	33	20-01-2013	28	16-02-2013	36	15-03-2013	39	11-04-2013	49	08-05-2013	64	04-06-2013	297	01-07-2013	367	28-07-2013	449

APPENDIX VI

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
29-07-2013	446	25-08-2013	277	21-09-2013	103	18-10-2013	51	14-11-2013	48	11-12-2013	37	07-01-2014	27	03-02-2014	29	02-03-2014	30
30-07-2013	398	26-08-2013	274	22-09-2013	105	19-10-2013	60	15-11-2013	48	12-12-2013	37	08-01-2014	30	04-02-2014	31	03-03-2014	31
31-07-2013	376	27-08-2013	271	23-09-2013	94	20-10-2013	46	16-11-2013	46	13-12-2013	32	09-01-2014	30	05-02-2014	31	04-03-2014	43
01-08-2013	439	28-08-2013	254	24-09-2013	92	21-10-2013	61	17-11-2013	43	14-12-2013	37	10-01-2014	32	06-02-2014	28	05-03-2014	39
02-08-2013	405	29-08-2013	242	25-09-2013	83	22-10-2013	62	18-11-2013	43	15-12-2013	34	11-01-2014	31	07-02-2014	34	06-03-2014	35
03-08-2013	385	30-08-2013	279	26-09-2013	78	23-10-2013	63	19-11-2013	42	16-12-2013	40	12-01-2014	31	08-02-2014	29	07-03-2014	40
04-08-2013	355	31-08-2013	291	27-09-2013	79	24-10-2013	58	20-11-2013	38	17-12-2013	37	13-01-2014	32	09-02-2014	30	08-03-2014	40
05-08-2013	417	01-09-2013	281	28-09-2013	87	25-10-2013	58	21-11-2013	41	18-12-2013	39	14-01-2014	33	10-02-2014	32	09-03-2014	44
06-08-2013	440	02-09-2013	229	29-09-2013	78	26-10-2013	57	22-11-2013	39	19-12-2013	29	15-01-2014	31	11-02-2014	29	10-03-2014	38
07-08-2013	422	03-09-2013	202	30-09-2013	79	27-10-2013	55	23-11-2013	41	20-12-2013	37	16-01-2014	32	12-02-2014	32	11-03-2014	43
08-08-2013	352	04-09-2013	181	01-10-2013	75	28-10-2013	53	24-11-2013	40	21-12-2013	32	17-01-2014	30	13-02-2014	29	12-03-2014	40
09-08-2013	341	05-09-2013	179	02-10-2013	74	29-10-2013	32	25-11-2013	39	22-12-2013	34	18-01-2014	27	14-02-2014	31	13-03-2014	41
10-08-2013	348	06-09-2013	171	03-10-2013	74	30-10-2013	32	26-11-2013	39	23-12-2013	34	19-01-2014	32	15-02-2014	35	14-03-2014	42
11-08-2013	405	07-09-2013	155	04-10-2013	72	31-10-2013	28	27-11-2013	41	24-12-2013	35	20-01-2014	28	16-02-2014	32	15-03-2014	39
12-08-2013	388	08-09-2013	148	05-10-2013	71	01-11-2013	49	28-11-2013	42	25-12-2013	35	21-01-2014	32	17-02-2014	31	16-03-2014	36
13-08-2013	421	09-09-2013	146	06-10-2013	71	02-11-2013	47	29-11-2013	40	26-12-2013	32	22-01-2014	30	18-02-2014	30	17-03-2014	33
14-08-2013	367	10-09-2013	134	07-10-2013	69	03-11-2013	46	30-11-2013	40	27-12-2013	34	23-01-2014	31	19-02-2014	30	18-03-2014	42
15-08-2013	365	11-09-2013	139	08-10-2013	65	04-11-2013	44	01-12-2013	37	28-12-2013	35	24-01-2014	29	20-02-2014	31	19-03-2014	42
16-08-2013	389	12-09-2013	148	09-10-2013	65	05-11-2013	48	02-12-2013	40	29-12-2013	25	25-01-2014	31	21-02-2014	31	20-03-2014	44
17-08-2013	389	13-09-2013	141	10-10-2013	62	06-11-2013	45	03-12-2013	71	30-12-2013	34	26-01-2014	27	22-02-2014	31	21-03-2014	44
18-08-2013	356	14-09-2013	130	11-10-2013	78	07-11-2013	45	04-12-2013	42	31-12-2013	36	27-01-2014	31	23-02-2014	30	22-03-2014	44
19-08-2013	394	15-09-2013	121	12-10-2013	70	08-11-2013	44	05-12-2013	42	01-01-2014	32	28-01-2014	29	24-02-2014	31	23-03-2014	47
20-08-2013	410	16-09-2013	111	13-10-2013	58	09-11-2013	39	06-12-2013	40	02-01-2014	30	29-01-2014	30	25-02-2014	31	24-03-2014	47
21-08-2013	416	17-09-2013	103	14-10-2013	51	10-11-2013	47	07-12-2013	41	03-01-2014	31	30-01-2014	28	26-02-2014	32	25-03-2014	44
22-08-2013	413	18-09-2013	96	15-10-2013	51	11-11-2013	36	08-12-2013	41	04-01-2014	29	31-01-2014	29	27-02-2014	31	26-03-2014	44
23-08-2013	306	19-09-2013	92	16-10-2013	52	12-11-2013	49	09-12-2013	42	05-01-2014	32	01-02-2014	30	28-02-2014	32	27-03-2014	44
24-08-2013	288	20-09-2013	97	17-10-2013	56	13-11-2013	47	10-12-2013	38	06-01-2014	31	02-02-2014	33	01-03-2014	33	28-03-2014	43

Daily discharge (Q) data at Rishikesh for six water years																	
Date	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**	**Date**	**Q**
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
01-04-08	302	28-04-2008	364	25-05-08	538	21-06-08	1400	18-07-08	1750	14-08-08	2213	10-09-08	109	07-10-08	107	03-11-08	374
02-04-08	299	29-04-2008	416	26-05-08	606	22-06-08	1405	19-07-08	1822	15-08-08	2348	11-09-08	102	08-10-08	106	04-11-08	378
03-04-08	288	30-04-2008	388	27-05-08	489	23-06-08	1161	20-07-08	1967	16-08-08	2250	12-09-08	103	09-10-08	103	05-11-08	378
04-04-08	318	01-05-2008	393	28-05-08	410	24-06-08	1133	21-07-08	2057	17-08-08	2943	13-09-08	112	10-10-08	93	06-11-08	359
05-04-08	329	02-05-2008	355	29-05-08	538	25-06-08	1078	22-07-08	2013	18-08-08	2927	14-09-08	119	11-10-08	89	07-11-08	346
06-04-08	340	03-05-2008	388	30-05-08	548	26-06-08	1132	23-07-08	1864	19-08-08	2516	15-09-08	121	12-10-08	91	08-11-08	392
07-04-08	357	04-05-2008	423	31-05-08	504	27-06-08	1272	24-07-08	1812	20-08-08	2144	16-09-08	120	13-10-08	92	09-11-08	358
08-04-08	343	05-05-2008	422	01-06-08	488	28-06-08	1301	25-07-08	1981	21-08-08	2272	17-09-08	122	14-10-08	87	10-11-08	358
09-04-08	316	06-05-2008	427	02-06-08	488	29-06-08	1180	26-07-08	1955	22-08-08	2569	18-09-08	121	15-10-08	87	11-11-08	371
10-04-08	327	07-05-2008	444	03-06-08	533	30-06-08	1671	27-07-08	2485	23-08-08	3683	19-09-08	219	16-10-08	83	12-11-08	362
11-04-08	355	08-05-2008	418	04-06-08	552	01-07-08	1998	28-07-08	2275	24-08-08	2275	20-09-08	268	17-10-08	87	13-11-08	362
12-04-08	335	09-05-2008	425	05-06-08	568	02-07-08	1733	29-07-08	1907	25-08-08	2051	21-09-08	213	18-10-08	83	14-11-08	355
13-04-08	328	10-05-2008	410	06-06-08	568	03-07-08	1527	30-07-08	2192	26-08-08	1912	22-09-08	184	19-10-08	81	15-11-08	344
14-04-08	336	11-05-2008	402	07-06-08	700	04-07-08	1572	31-07-08	2551	27-08-08	1970	23-09-08	185	20-10-08	85	16-11-08	334
15-04-08	366	12-05-2008	382	08-06-08	806	05-07-08	1668	01-08-08	2662	28-08-08	1986	24-09-08	171	21-10-08	75	17-11-08	318
16-04-08	337	13-05-2008	378	09-06-08	870	06-07-08	1815	02-08-08	2114	29-08-08	1750	25-09-08	154	22-10-08	76	18-11-08	342
17-04-08	323	14-05-2008	384	10-06-08	948	07-07-08	1759	03-08-08	2069	30-08-08	1680	26-09-08	153	23-10-08	75	19-11-08	368
18-04-08	348	15-05-2008	384	11-06-08	919	08-07-08	1707	04-08-08	2121	31-08-08	1560	27-09-08	141	24-10-08	74	20-11-08	337
19-04-08	355	16-05-2008	409	12-06-08	1133	09-07-08	1962	05-08-08	2232	01-09-08	235	28-09-08	133	25-10-08	70	21-11-08	366
20-04-08	351	17-05-2008	460	13-06-08	1120	10-07-08	1854	06-08-08	1997	02-09-08	233	29-09-08	128	26-10-08	68	22-11-08	377
21-04-08	342	18-05-2008	506	14-06-08	1287	11-07-08	1822	07-08-08	1969	03-09-08	229	30-09-08	117	27-10-08	66	23-11-08	346
22-04-08	368	19-05-2008	498	15-06-08	1314	12-07-08	2040	08-08-08	1959	04-09-08	230	01-10-08	120	28-10-08	64	24-11-08	329
23-04-08	383	20-05-2008	524	16-06-08	1352	13-07-08	2134	09-08-08	2092	05-09-08	230	02-10-08	116	29-10-08	66	25-11-08	360
24-04-08	392	21-05-2008	453	17-06-08	1181	14-07-08	2061	10-08-08	2081	06-09-08	222	03-10-08	114	30-10-08	52	26-11-08	336
25-04-08	412	22-05-2008	487	18-06-08	1209	15-07-08	2099	11-08-08	2224	07-09-08	169	04-10-08	116	31-10-08	73	27-11-08	344
26-04-08	426	23-05-2008	483	19-06-08	1437	16-07-08	1877	12-08-08	2173	08-09-08	141	05-10-08	112	01-11-08	60	28-11-08	317
27-04-08	350	24-05-2008	554	20-06-08	1352	17-07-08	1850	13-08-08	2210	09-09-08	134	06-10-08	105	02-11-08	66	29-11-08	331

APPENDIX VII

Daily discharge (Q) data at Maneri for six water years

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s		m^{3}/s
30-11-08	324	27-12-08	352	23-01-09	400	19-02-09	355	18-03-09	325	14-04-09	361	11-05-09	412	07-06-09	579	04-07-09	562
01-12-08	372	28-12-08	400	24-01-09	407	20-02-09	373	19-03-09	327	15-04-09	363	12-05-09	366	08-06-09	565	05-07-09	515
02-12-08	374	29-12-08	335	25-01-09	413	21-02-09	374	20-03-09	335	16-04-09	367	13-05-09	382	09-06-09	548	06-07-09	524
03-12-08	356	30-12-08	387	26-01-09	378	22-02-09	365	21-03-09	280	17-04-09	356	14-05-09	373	10-06-09	499	07-07-09	511
04-12-08	347	31-12-08	369	27-01-09	333	23-02-09	357	22-03-09	313	18-04-09	370	15-05-09	378	11-06-09	451	08-07-09	552
05-12-08	382	01-01-09	392	28-01-09	375	24-02-09	358	23-03-09	328	19-04-09	352	16-05-09	422	12-06-09	439	09-07-09	605
06-12-08	337	02-01-09	378	29-01-09	394	25-02-09	355	24-03-09	353	20-04-09	356	17-05-09	403	13-06-09	431	10-07-09	624
07-12-08	358	03-01-09	391	30-01-09	389	26-02-09	389	25-03-09	286	21-04-09	388	18-05-09	434	14-06-09	412	11-07-09	604
08-12-08	352	04-01-09	383	31-01-09	389	27-02-09	349	26-03-09	317	22-04-09	410	19-05-09	492	15-06-09	383	12-07-09	665
09-12-08	333	05-01-09	412	01-02-09	309	28-02-09	355	27-03-09	334	23-04-09	383	20-05-09	519	16-06-09	408	13-07-09	797
10-12-08	339	06-01-09	406	02-02-09	278	01-03-09	360	28-03-09	332	24-04-09	336	21-05-09	488	17-06-09	388	14-07-09	784
11-12-08	309	07-01-09	426	03-02-09	379	02-03-09	317	29-03-09	314	25-04-09	360	22-05-09	468	18-06-09	358	15-07-09	813
12-12-08	296	08-01-09	426	04-02-09	377	03-03-09	330	30-03-09	320	26-04-09	401	23-05-09	539	19-06-09	332	16-07-09	694
13-12-08	334	09-01-09	406	05-02-09	385	04-03-09	345	31-03-09	336	27-04-09	374	24-05-09	566	20-06-09	341	17-07-09	633
14-12-08	318	10-01-09	412	06-02-09	386	05-03-09	344	01-04-09	324	28-04-09	370	25-05-09	478	21-06-09	351	18-07-09	719
15-12-08	323	11-01-09	400	07-02-09	353	06-03-09	328	02-04-09	338	29-04-09	425	26-05-09	495	22-06-09	371	19-07-09	850
16-12-08	368	12-01-09	372	08-02-09	336	07-03-09	341	03-04-09	333	30-04-09	431	27-05-09	489	23-06-09	426	20-07-09	1145
17-12-08	353	13-01-09	402	09-02-09	345	08-03-09	333	04-04-09	350	01-05-09	494	28-05-09	463	24-06-09	474	21-07-09	1175
18-12-08	331	14-01-09	396	10-02-09	264	09-03-09	328	05-04-09	342	02-05-09	425	29-05-09	463	25-06-09	542	22-07-09	960
19-12-08	351	15-01-09	395	11-02-09	286	10-03-09	328	06-04-09	330	03-05-09	470	30-05-09	409	26-06-09	618	23-07-09	754
20-12-08	351	16-01-09	382	12-02-09	375	11-03-09	305	07-04-09	335	04-05-09	407	31-05-09	474	27-06-09	696	24-07-09	864
21-12-08	337	17-01-09	396	13-02-09	348	12-03-09	302	08-04-09	344	05-05-09	380	01-06-09	438	28-06-09	219	25-07-09	849
22-12-08	312	18-01-09	382	14-02-09	381	13-03-09	324	09-04-09	295	06-05-09	423	02-06-09	454	29-06-09	500	26-07-09	733
23-12-08	312	19-01-09	330	15-02-09	378	14-03-09	331	10-04-09	334	07-05-09	425	03-06-09	442	30-06-09	704	27-07-09	1007
24-12-08	358	20-01-09	378	16-02-09	353	15-03-09	324	11-04-09	358	08-05-09	392	04-06-09	478	01-07-09	690	28-07-09	906
25-12-08	347	21-01-09	371	17-02-09	335	16-03-09	327	12-04-09	356	09-05-09	401	05-06-09	547	02-07-09	658	29-07-09	1185
26-12-08	344	22-01-09	400	18-02-09	361	17-03-09	337	13-04-09	351	10-05-09	398	06-06-09	599	03-07-09	544	30-07-09	1054

Daily discharge (Q) data at Maneri for six water years

Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s	Date	Q m^3/s
31-07-09	967	27-08-09	875	23-09-09	108	20-10-09	63	16-11-09	331	13-12-09	269	09-01-10	382	05-02-10	350	04-03-10	384
01-08-09	863	28-08-09	862	24-09-09	108	21-10-09	66	17-11-09	352	14-12-09	294	10-01-10	355	06-02-10	348	05-03-10	383
02-08-09	805	29-08-09	917	25-09-09	107	22-10-09	63	18-11-09	346	15-12-09	320	11-01-10	376	07-02-10	352	06-03-10	395
03-08-09	776	30-08-09	946	26-09-09	104	23-10-09	62	19-11-09	342	16-12-09	304	12-01-10	393	08-02-10	337	07-03-10	372
04-08-09	877	31-08-09	943	27-09-09	115	24-10-09	55	20-11-09	349	17-12-09	307	13-01-10	405	09-02-10	359	08-03-10	380
05-08-09	1014	01-09-09	204	28-09-09	112	25-10-09	63	21-11-09	340	18-12-09	318	14-01-10	393	10-02-10	430	09-03-10	363
06-08-09	1335	02-09-09	187	29-09-09	111	26-10-09	54	22-11-09	315	19-12-09	310	15-01-10	412	11-02-10	476	10-03-10	362
07-08-09	1369	03-09-09	191	30-09-09	110	27-10-09	58	23-11-09	360	20-12-09	274	16-01-10	384	12-02-10	481	11-03-10	389
08-08-09	1465	04-09-09	170	01-10-09	109	28-10-09	53	24-11-09	261	21-12-09	307	17-01-10	350	13-02-10	373	12-03-10	366
09-08-09	1243	05-09-09	186	02-10-09	108	29-10-09	55	25-11-09	299	22-12-09	311	18-01-10	373	14-02-10	374	13-03-10	384
10-08-09	1076	06-09-09	141	03-10-09	107	30-10-09	52	26-11-09	332	23-12-09	312	19-01-10	380	15-02-10	351	14-03-10	465
11-08-09	941	07-09-09	120	04-10-09	112	31-10-09	55	27-11-09	281	24-12-09	318	20-01-10	374	16-02-10	342	15-03-10	499
12-08-09	1097	08-09-09	296	05-10-09	140	01-11-09	323	28-11-09	282	25-12-09	348	21-01-10	375	17-02-10	349	16-03-10	486
13-08-09	1090	09-09-09	306	06-10-09	113	02-11-09	317	29-11-09	255	26-12-09	340	22-01-10	276	18-02-10	345	17-03-10	387
14-08-09	1014	10-09-09	377	07-10-09	104	03-11-09	322	30-11-09	252	27-12-09	306	23-01-10	321	19-02-10	340	18-03-10	362
15-08-09	1195	11-09-09	249	08-10-09	96	04-11-09	316	01-12-09	258	28-12-09	328	24-01-10	358	20-02-10	369	19-03-10	383
16-08-09	1097	12-09-09	255	09-10-09	91	05-11-09	315	02-12-09	271	29-12-09	308	25-01-10	331	21-02-10	360	20-03-10	392
17-08-09	951	13-09-09	219	10-10-09	85	06-11-09	321	03-12-09	305	30-12-09	286	26-01-10	334	22-02-10	391	21-03-10	392
18-08-09	1093	14-09-09	195	11-10-09	77	07-11-09	315	04-12-09	316	31-12-09	303	27-01-10	344	23-02-10	333	22-03-10	408
19-08-09	1094	15-09-09	167	12-10-09	75	08-11-09	292	05-12-09	298	01-01-10	342	28-01-10	351	24-02-10	384	23-03-10	461
20-08-09	999	16-09-09	134	13-10-09	62	09-11-09	308	06-12-09	315	02-01-10	322	29-01-10	357	25-02-10	388	24-03-10	460
21-08-09	838	17-09-09	134	14-10-09	69	10-11-09	337	07-12-09	327	03-01-10	379	30-01-10	385	26-02-10	365	25-03-10	442
22-08-09	766	18-09-09	115	15-10-09	72	11-11-09	352	08-12-09	296	04-01-10	356	31-01-10	342	27-02-10	366	26-03-10	358
23-08-09	735	19-09-09	116	16-10-09	68	12-11-09	343	09-12-09	296	05-01-10	360	01-02-10	339	28-02-10	350	27-03-10	380
24-08-09	667	20-09-09	114	17-10-09	66	13-11-09	337	10-12-09	301	06-01-10	367	02-02-10	347	01-03-10	353	28-03-10	346
25-08-09	700	21-09-09	113	18-10-09	71	14-11-09	392	11-12-09	302	07-01-10	344	03-02-10	354	02-03-10	297	29-03-10	386
26-08-09	732	22-09-09	111	19-10-09	69	15-11-09	361	12-12-09	321	08-01-10	368	04-02-10	335	03-03-10	364	30-03-10	453

Daily discharge (Q) data at Maneri for six water years

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
31-03-10	322	27-04-10	399	24-05-10	383	20-06-10	431	40376	1168	13-08-10	2818	40430	-	06-10-10	1034	02-11-10	535
01-04-10	333	28-04-10	432	25-05-10	400	21-06-10	390	40377	1055	14-08-10	2574	40431	3040	07-10-10	932	03-11-10	519
02-04-10	341	29-04-10	451	26-05-10	449	22-06-10	485	40378	1209	15-08-10	2571	40432	2856	08-10-10	633	04-11-10	481
03-04-10	336	30-04-10	371	27-05-10	504	23-06-10	620	40379	1640	16-08-10	2796	40433	2742	09-10-10	762	05-11-10	463
04-04-10	323	01-05-10	374	28-05-10	523	24-06-10	677	40380	1468	17-08-10	2959	40434	3061	10-10-10	772	06-11-10	492
05-04-10	327	02-05-10	359	29-05-10	460	25-06-10	755	40381	1894	18-08-10	2937	40435	2648	11-10-10	856	07-11-10	454
06-04-10	375	03-05-10	328	30-05-10	466	26-06-10	762	40382	1050	19-08-10	2969	40436	2600	12-10-10	852	08-11-10	463
07-04-10	337	04-05-10	363	31-05-10	497	27-06-10	747	40383	1093	20-08-10	3187	40437	2427	13-10-10	832	09-11-10	424
08-04-10	336	05-05-10	383	01-06-10	433	28-06-10	740	40384	1374	21-08-10	3338	40438	2482	14-10-10	807	10-11-10	445
09-04-10	361	06-05-10	431	02-06-10	501	29-06-10	766	40385	1747	22-08-10	3863	40439	2341	15-10-10	798	11-11-10	418
10-04-10	391	07-05-10	426	03-06-10	495	30-06-10	885	40386	1468	23-08-10	3655	40440	8485	16-10-10	768	12-11-10	438
11-04-10	352	08-05-10	397	04-06-10	568	01-07-10	805	40387	1815	24-08-10	3257	40441	6717	17-10-10	715	13-11-10	404
12-04-10	411	09-05-10	409	05-06-10	457	02-07-10	640	40388	1421	25-08-10	3134	40442	5090	18-10-10	676	14-11-10	419
13-04-10	470	10-05-10	400	06-06-10	461	03-07-10	598	40389	1196	26-08-10	3380	40443	3984	19-10-10	673	15-11-10	400
14-04-10	450	11-05-10	424	07-06-10	435	04-07-10	644	40390	1980	27-08-10	2784	40444	3793	20-10-10	593	16-11-10	402
15-04-10	354	12-05-10	371	08-06-10	482	05-07-10	725	40391	2402	28-08-10	2382	40445	3409	21-10-10	538	17-11-10	395
16-04-10	452	13-05-10	336	09-06-10	555	06-07-10	1112	40392	2066	29-08-10	2348	40446	2543	22-10-10	566	18-11-10	411
17-04-10	397	14-05-10	321	10-06-10	511	07-07-10	847	40393	2046	30-08-10	2391	40447	2431	23-10-10	459	19-11-10	416
18-04-10	425	15-05-10	375	11-06-10	480	08-07-10	667	40394	1818	31-08-10	2685	40448	1857	24-10-10	626	20-11-10	401
19-04-10	414	16-05-10	342	12-06-10	480	09-07-10	594	40395	1993	01-09-10	2998	40449	1997	25-10-10	651	21-11-10	379
20-04-10	409	17-05-10	336	13-06-10	457	10-07-10	681	40396	2092	02-09-10	2485	40450	1663	26-10-10	646	22-11-10	361
21-04-10	389	18-05-10	343	14-06-10	458	11-07-10	683	40397	1862	03-09-10	3249	40451	1490	27-10-10	674	23-11-10	380
22-04-10	414	19-05-10	390	15-06-10	423	12-07-10	649	40398	1880	04-09-10	3263	40452	1389	28-10-10	679	24-11-10	385
23-04-10	381	20-05-10	387	16-06-10	407	13-07-10	576	40399	2280	05-09-10	2992	40453	1338	29-10-10	628	25-11-10	415
24-04-10	391	21-05-10	359	17-06-10	450	14-07-10	626	40400	2256	06-09-10	2829	40454	1299	30-10-10	605	26-11-10	422
25-04-10	339	22-05-10	325	18-06-10	437	15-07-10	668	40401	2502	07-09-10	2926	40455	1220	31-10-10	566	27-11-10	407
26-04-10	366	23-05-10	363	19-06-10	445	16-07-10	742	40402	2907	08-09-10	3481	40456	1087	01-11-10	557	28-11-10	377

Daily discharge (Q) data at Maneri for six water years																	
Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
29-11-10	335	26-12-10	196	22-01-11	169	18-02-11	387	17-03-11	465	13-04-11	483	10-05-11	782	06-06-11	564	03-07-11	1447
30-11-10	401	27-12-10	191	23-01-11	166	19-02-11	481	18-03-11	479	14-04-11	538	11-05-11	763	07-06-11	622	04-07-11	1250
01-12-10	389	28-12-10	191	24-01-11	168	20-02-11	499	19-03-11	492	15-04-11	519	12-05-11	766	08-06-11	652	05-07-11	1245
02-12-10	398	29-12-10	190	25-01-11	169	21-02-11	421	20-03-11	445	16-04-11	529	13-05-11	764	09-06-11	638	06-07-11	1364
03-12-10	401	30-12-10	190	26-01-11	166	22-02-11	356	21-03-11	390	17-04-11	590	14-05-11	789	10-06-11	644	07-07-11	1432
04-12-10	400	31-12-10	206	27-01-11	166	23-02-11	424	22-03-11	463	18-04-11	522	15-05-11	778	11-06-11	629	08-07-11	1876
05-12-10	396	01-01-11	244	28-01-11	163	24-02-11	414	23-03-11	482	19-04-11	481	16-05-11	776	12-06-11	618	09-07-11	2011
06-12-10	385	02-01-11	202	29-01-11	256	25-02-11	401	24-03-11	442	20-04-11	592	17-05-11	832	13-06-11	631	10-07-11	1838
07-12-10	391	03-01-11	198	30-01-11	430	26-02-11	379	25-03-11	460	21-04-11	538	18-05-11	897	14-06-11	666	11-07-11	1765
08-12-10	381	04-01-11	191	31-01-11	407	27-02-11	468	26-03-11	442	22-04-11	594	19-05-11	888	15-06-11	847	12-07-11	1504
09-12-10	407	05-01-11	190	01-02-11	472	28-02-11	442	27-03-11	525	23-04-11	559	20-05-11	898	16-06-11	875	13-07-11	1685
10-12-10	346	06-01-11	190	02-02-11	416	01-03-11	429	28-03-11	435	24-04-11	574	21-05-11	886	17-06-11	817	14-07-11	1662
11-12-10	363	07-01-11	184	03-02-11	409	02-03-11	429	29-03-11	475	25-04-11	603	22-05-11	592	18-06-11	816	15-07-11	1950
12-12-10	355	08-01-11	178	04-02-11	350	03-03-11	379	30-03-11	513	26-04-11	632	23-05-11	794	19-06-11	787	16-07-11	2107
13-12-10	357	09-01-11	178	05-02-11	302	04-03-11	394	31-03-11	482	27-04-11	621	24-05-11	846	20-06-11	610	17-07-11	1818
14-12-10	354	10-01-11	172	06-02-11	306	05-03-11	394	01-04-11	441	28-04-11	634	25-05-11	900	21-06-11	933	18-07-11	1668
15-12-10	355	11-01-11	172	07-02-11	360	06-03-11	455	02-04-11	491	29-04-11	669	26-05-11	906	22-06-11	933	19-07-11	1546
16-12-10	350	12-01-11	175	08-02-11	363	07-03-11	449	03-04-11	500	30-04-11	693	27-05-11	919	23-06-11	968	20-07-11	1700
17-12-10	351	13-01-11	169	09-02-11	365	08-03-11	462	04-04-11	435	01-05-11	703	28-05-11	923	24-06-11	1026	21-07-11	2516
18-12-10	211	14-01-11	178	10-02-11	413	09-03-11	450	05-04-11	457	02-05-11	689	29-05-11	871	25-06-11	1055	22-07-11	2064
19-12-10	194	15-01-11	182	11-02-11	455	10-03-11	418	06-04-11	529	03-05-11	695	30-05-11	958	26-06-11	1140	23-07-11	2209
20-12-10	203	16-01-11	184	12-02-11	420	11-03-11	469	07-04-11	476	04-05-11	711	31-05-11	930	27-06-11	787.05	24-07-11	2196
21-12-10	203	17-01-11	184	13-02-11	410	12-03-11	370	08-04-11	521	05-05-11	733	01-06-11	908	28-06-11	1322	25-07-11	2217
22-12-10	203	18-01-11	178	14-02-11	394	13-03-11	461	09-04-11	464	06-05-11	730	02-06-11	813	29-06-11	1728	26-07-11	2325
23-12-10	199	19-01-11	171	15-02-11	432	14-03-11	464	10-04-11	437	07-05-11	771	03-06-11	762	30-06-11	1496	27-07-11	2099
24-12-10	196	20-01-11	166	16-02-11	422	15-03-11	455	11-04-11	508	08-05-11	741	04-06-11	717	01-07-11	2046	28-07-11	2472
25-12-10	197	21-01-11	171	17-02-11	429	16-03-11	488	12-04-11	545	09-05-11	721	05-06-11	600	02-07-11	1647	29-07-11	2698

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
30-07-11	2666	26-08-11	2345	22-09-11	1340	20-10-11	604	16-11-11	354	13-12-11	410	09-01-12	430	05-02-12	382	03-03-12	384
31-07-11	2443	27-08-11	2867	23-09-11	1200	21-10-11	603	17-11-11	356	14-12-11	358	10-01-12	419	06-02-12	390	04-03-12	408
01-08-11	2225	28-08-11	3031	24-09-11	939	22-10-11	583	18-11-11	370	15-12-11	383	11-01-12	411	07-02-12	412	05-03-12	412
02-08-11	2334	29-08-11	2693	25-09-11	900	23-10-11	571	19-11-11	365	16-12-11	393	12-01-12	412	08-02-12	419	06-03-12	404
03-08-11	2135	30-08-11	2681	26-09-11	860	24-10-11	581	20-11-11	348	17-12-11	386	13-01-12	436	09-02-12	441	07-03-12	435
04-08-11	2147	31-08-11	2956	27-09-11	811	25-10-11	566	21-11-11	314	18-12-11	387	14-01-12	447	10-02-12	457	08-03-12	402
05-08-11	2209	01-09-11	3117	28-09-11	806	26-10-11	602	22-11-11	381	19-12-11	330	15-01-12	439	11-02-12	400	09-03-12	387
06-08-11	2217	02-09-11	2958	29-09-11	779	27-10-11	569	23-11-11	363	20-12-11	363	16-01-12	412	12-02-12	499	10-03-12	406
07-08-11	2468	03-09-11	2736	30-09-11	775	28-10-11	546	24-11-11	347	21-12-11	380	17-01-12	420	13-02-12	421	11-03-12	371
08-08-11	3276	04-09-11	2621	01-10-11	755	29-10-11	482	25-11-11	377	22-12-11	355	18-01-12	455	14-02-12	402	12-03-12	373
09-08-11	3632	05-09-11	2364	02-10-11	731	30-10-11	456	26-11-11	378	23-12-11	362	19-01-12	452	15-02-12	398	13-03-12	376
10-08-11	2369	06-09-11	2192	03-10-11	725	31-10-11	451	27-11-11	380	24-12-11	397	20-01-12	407	16-02-12	429	14-03-12	427
11-08-11	2279	07-09-11	1970	04-10-11	720	01-11-11	535	28-11-11	400	25-12-11	349	21-01-12	409	17-02-12	424	15-03-12	393
12-08-11	2541	08-09-11	1852	05-10-11	731	02-11-11	550	29-11-11	404	26-12-11	354	22-01-12	401	18-02-12	442	16-03-12	350
13-08-11	2816	09-09-11	2280	06-10-11	698	03-11-11	512	30-11-11	398	27-12-11	365	23-01-12	396	19-02-12	396	17-03-12	362
14-08-11	2057	10-09-11	2108	07-10-11	771	04-11-11	535	01-12-11	397	28-12-11	351	24-01-12	398	20-02-12	348	18-03-12	358
15-08-11	2173	11-09-11	2067	08-10-11	784	05-11-11	527	02-12-11	400	29-12-11	363	25-01-12	403	21-02-12	388	19-03-12	370
16-08-11	6305	12-09-11	2059	09-10-11	708	06-11-11	469	03-12-11	405	30-12-11	333	26-01-12	411	22-02-12	413	20-03-12	400
17-08-11	4750	13-09-11	2045	10-10-11	690	07-11-11	435	04-12-11	412	31-12-11	366	27-01-12	386	23-02-12	419	21-03-12	392
18-08-11	3594	14-09-11	2017	11-10-11	711	08-11-11	325	05-12-11	406	01-01-12	361	28-01-12	397	24-02-12	398	22-03-12	400
19-08-11	3304	15-09-11	2130	12-10-11	686	09-11-11	405	06-12-11	390	02-01-12	361	29-01-12	461	25-02-12	397	23-03-12	412
20-08-11	3157	16-09-11	2409	13-10-11	629	10-11-11	402	07-12-11	401	03-01-12	375	30-01-12	261	26-02-12	374	24-03-12	408
21-08-11	2764	17-09-11	2120	14-10-11	695	11-11-11	400	08-12-11	392	04-01-12	400	31-01-12	257	27-02-12	386	25-03-12	392
22-08-11	2517	18-09-11	1904	15-10-11	605	12-11-11	417	09-12-11	413	05-01-12	409	01-02-12	273	28-02-12	344	26-03-12	402
23-08-11	2659	19-09-11	1774	16-10-11	680	13-11-11	416	10-12-11	391	06-01-12	400	02-02-12	448	29-02-12	352	27-03-12	451
24-08-11	2629	20-09-11	1603	17-10-11	648	14-11-11	360	11-12-11	395	07-01-12	363	03-02-12	545	01-03-12	375	28-03-12	475
25-08-11	2414	21-09-11	1589	18-10-11	521	15-11-11	348	12-12-11	361	08-01-12	403	04-02-12	369	02-03-12	385	29-03-12	448

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
	m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s		m^3/s
30-03-12	358	26-04-12	455	23-05-12	486	19-06-12	798	16-07-12	933	12-08-12	1784	08-09-12	2074	05-10-12	691	01-11-12	428
31-03-12	404	27-04-12	437	24-05-12	530	20-06-12	737	17-07-12	916	13-08-12	1784	09-09-12	1901	06-10-12	602	02-11-12	430
01-04-12	442	28-04-12	432	25-05-12	567	21-06-12	587	18-07-12	915	14-08-12	2068	10-09-12	1666	07-10-12	501	03-11-12	433
02-04-12	417	29-04-12	444	26-05-12	618	22-06-12	908	19-07-12	940	15-08-12	1901	11-09-12	1662	08-10-12	598	04-11-12	429
03-04-12	396	30-04-12	447	27-05-12	622	23-06-12	1016	20-07-12	1023	16-08-12	1802	12-09-12	1658	09-10-12	622	05-11-12	421
04-04-12	413	01-05-12	449	28-05-12	638	24-06-12	1118	21-07-12	1042	17-08-12	1641	13-09-12	1765	10-10-12	648	06-11-12	417
05-04-12	430	02-05-12	423	29-05-12	630	25-06-12	1143	22-07-12	1154	18-08-12	1632	14-09-12	2431	11-10-12	615	07-11-12	413
06-04-12	446	03-05-12	430	30-05-12	639	26-06-12	1112	23-07-12	811	19-08-12	2381	15-09-12	2642	12-10-12	600	08-11-12	442
07-04-12	425	04-05-12	424	31-05-12	700	27-06-12	992	24-07-12	1302	20-08-12	1818	16-09-12	2476	13-10-12	594	09-11-12	394
08-04-12	410	05-05-12	401	01-06-12	732	28-06-12	961	25-07-12	1684	21-08-12	2976	17-09-12	2445	14-10-12	580	10-11-12	373
09-04-12	422	06-05-12	394	02-06-12	741	29-06-12	874	26-07-12	2051	22-08-12	3781	18-09-12	2430	15-10-12	555	11-11-12	392
10-04-12	434	07-05-12	385	03-06-12	802	30-06-12	870	27-07-12	1848	23-08-12	2582	19-09-12	2196	16-10-12	527	12-11-12	401
11-04-12	308	08-05-12	398	04-06-12	754	01-07-12	846	28-07-12	1818	24-08-12	2660	20-09-12	1887	17-10-12	526	13-11-12	359
12-04-12	408	09-05-12	430	05-06-12	716	02-07-12	623	29-07-12	1887	25-08-12	2917	21-09-12	1757	18-10-12	512	14-11-12	370
13-04-12	415	10-05-12	459	06-06-12	664	03-07-12	914	30-07-12	2029	26-08-12	3439	22-09-12	1431	19-10-12	485	15-11-12	372
14-04-12	409	11-05-12	488	07-06-12	688	04-07-12	968	31-07-12	2524	27-08-12	2932	23-09-12	1229	20-10-12	478	16-11-12	371
15-04-12	359	12-05-12	495	08-06-12	566	05-07-12	552	01-08-12	2380	28-08-12	2745	24-09-12	1165	21-10-12	512	17-11-12	387
16-04-12	407	13-05-12	475	09-06-12	481	06-07-12	1103	02-08-12	2027	29-08-12	2348	25-09-12	1037	22-10-12	531	18-11-12	356
17-04-12	417	14-05-12	482	10-06-12	463	07-07-12	1178	03-08-12	7283	30-08-12	2164	26-09-12	883	23-10-12	540	19-11-12	343
18-04-12	427	15-05-12	475	11-06-12	426	08-07-12	1336	04-08-12	1175	31-08-12	2090	27-09-12	895	24-10-12	534	20-11-12	381
19-04-12	456	16-05-12	476	12-06-12	474	09-07-12	1203	05-08-12	3718	01-09-12	1917	28-09-12	782	25-10-12	475	21-11-12	364
20-04-12	423	17-05-12	380	13-06-12	485	10-07-12	1080	06-08-12	2880	02-09-12	1932	29-09-12	779	26-10-12	441	22-11-12	353
21-04-12	441	18-05-12	498	14-06-12	508	11-07-12	1000	07-08-12	2257	03-09-12	2139	30-09-12	780	27-10-12	429	23-11-12	350
22-04-12	449	19-05-12	513	15-06-12	488	12-07-12	1079	08-08-12	1990	04-09-12	2218	01-10-12	720	28-10-12	486	24-11-12	360
23-04-12	451	20-05-12	504	16-06-12	524	13-07-12	1093	09-08-12	1801	05-09-12	2170	02-10-12	745	29-10-12	450	25-11-12	383
24-04-12	438	21-05-12	522	17-06-12	648	14-07-12	1149	10-08-12	2888	06-09-12	2331	03-10-12	751	30-10-12	419	26-11-12	386
25-04-12	448	22-05-12	501	18-06-12	712	15-07-12	1001	11-08-12	1911	07-09-12	2164	04-10-12	712	31-10-12	421	27-11-12	382

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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29-11-12	397	26-12-12	492	22-01-13	400	18-02-13	578	17-03-13	520	13-04-13	442	10-05-13	486	06-06-13	1057	03-07-13	1847
30-11-12	404	27-12-12	512	23-01-13	447	19-02-13	508	18-03-13	360	14-04-13	442	11-05-13	486	07-06-13	1039	04-07-13	1821
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02-12-12	382	29-12-12	458	25-01-13	432	21-02-13	422	20-03-13	485	16-04-13	456	13-05-13	453	09-06-13	1037	06-07-13	2517
03-12-12	388	30-12-12	475	26-01-13	460	22-02-13	448	21-03-13	497	17-04-13	459	14-05-13	449	10-06-13	1122	07-07-13	2584
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05-12-12	406	01-01-13	476	28-01-13	441	24-02-13	439	23-03-13	496	19-04-13	463	16-05-13	466	12-06-13	1245	09-07-13	2805
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09-12-12	388	05-01-13	474	01-02-13	462	28-02-13	410	27-03-13	442	23-04-13	437	20-05-13	431	16-06-13	1047	13-07-13	2520
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17-12-12	376	13-01-13	444	09-02-13	558	08-03-13	506	04-04-13	475	01-05-13	450	28-05-13	827	24-06-13	1889	21-07-13	2125
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23-12-12	457	19-01-13	529	15-02-13	383	14-03-13	501	10-04-13	432	07-05-13	449	03-06-13	1029	30-06-13	1865	27-07-13	2696
24-12-12	482	20-01-13	484	16-02-13	651	15-03-13	504	11-04-13	467	08-05-13	458	04-06-13	1049	01-07-13	1911	28-07-13	2669

APPENDIX VII

Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q	Date	Q
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30-07-13	2276	26-08-13	2042	22-09-13	966	19-10-13	578	15-11-13	439	12-12-13	358	08-01-14	418	04-02-14	364	03-03-14	475
31-07-13	242.6	27-08-13	2046	23-09-13	802	20-10-13	566	16-11-13	412	13-12-13	353	09-01-14	428	05-02-14	358	04-03-14	484
01-08-13	2002	28-08-13	2084	24-09-13	835	21-10-13	552	17-11-13	405	14-12-13	365	10-01-14	436	06-02-14	295	05-03-14	493
02-08-13	2417	29-08-13	2036	25-09-13	785	22-10-13	497	18-11-13	410	15-12-13	370	11-01-14	426	07-02-14	354	06-03-14	508
03-08-13	2179	30-08-13	2147	26-09-13	740	23-10-13	498	19-11-13	401	16-12-13	353	12-01-14	440	08-02-14	374	07-03-14	500
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05-08-13	2675	01-09-13	2156	28-09-13	793	25-10-13	495	21-11-13	402	18-12-13	370	14-01-14	448	10-02-14	380	09-03-14	525
06-08-13	3119	02-09-13	2042	29-09-13	782	26-10-13	517	22-11-13	401	19-12-13	404	15-01-14	412	11-02-14	356	10-03-14	518
07-08-13	3517	03-09-13	1918	30-09-13	784	27-10-13	503	23-11-13	426	20-12-13	403	16-01-14	415	12-02-14	364	11-03-14	513
08-08-13	3195	04-09-13	1853	01-10-13	810	28-10-13	501	24-11-13	420	21-12-13	421	17-01-14	432	13-02-14	330	12-03-14	498
09-08-13	3413	05-09-13	1768	02-10-13	865	29-10-13	503	25-11-13	416	22-12-13	435	18-01-14	429	14-02-14	371	13-03-14	504
10-08-13	3481	06-09-13	1714	03-10-13	829	30-10-13	477	26-11-13	401	23-12-13	425	19-01-14	404	15-02-14	413	14-03-14	501
11-08-13	3462	07-09-13	1429	04-10-13	832	31-10-13	496	27-11-13	399	24-12-13	427	20-01-14	371	16-02-14	411	15-03-14	504
12-08-13	3383	08-09-13	886	05-10-13	848	01-11-13	482	28-11-13	384	25-12-13	421	21-01-14	361	17-02-14	411	16-03-14	483
13-08-13	3469	09-09-13	1107	06-10-13	842	02-11-13	512	29-11-13	386	26-12-13	452	22-01-14	349	18-02-14	412	17-03-14	520
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16-08-13	3547	12-09-13	1071	09-10-13	679	05-11-13	468	02-12-13	373	29-12-13	426	25-01-14	351	21-02-14	416	20-03-14	485
17-08-13	3275	13-09-13	1075	10-10-13	681	06-11-13	497	03-12-13	358	30-12-13	426	26-01-14	360	22-02-14	411	21-03-14	497
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20-08-13	2699	16-09-13	841	13-10-13	672	09-11-13	447	06-12-13	375	02-01-14	431	29-01-14	350	25-02-14	415	24-03-14	513
21-08-13	2857	17-09-13	877	14-10-13	589	10-11-13	456	07-12-13	362	03-01-14	417	30-01-14	411	26-02-14	415	25-03-14	500
22-08-13	2539	18-09-13	857	15-10-13	652	11-11-13	436	08-12-13	366	04-01-14	429	31-01-14	364	27-02-14	414	26-03-14	506
23-08-13	2134	19-09-13	825	16-10-13	605	12-11-13	444	09-12-13	363	05-01-14	443	01-02-14	351	28-02-14	414	27-03-14	442
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