GROUNDWATER PROFILE PREDICTION OF KECHERY WATERSHED

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INTRODUCTION

- Water is a major renewable resource and is a fundamental element in sustaining integrity of the natural environment.

- Both urban and rural areas utilize the groundwater for drinking, agriculture and industrial purpose.

- The process of replenishment of groundwater is greatly affected by changes in climate because groundwater mainly gets recharged by infiltration and percolation from precipitation and seepage.

- Though many hydrologic models are available for simulating changes in water dynamics, simulation of groundwater table depth is usually difficult and rarely attempted.

CONTINUED…

- Thus extending the SWAT capabilities by computing groundwater table depth from the SWAT output file, has a greater scope in the current scenario.

- The relationship between groundwater fluctuation and amount of recharge entering the aquifer is used for calculating groundwater depth from SWAT output.

- Once the model is made, it can be used to generate long term data series for groundwater depth which can later be used for forecasting the groundwater table depth.

OBJECTIVES

- Model the temporal and spatial variation of groundwater depth in Kechery watershed Using Soil and Water Assessment Tool.

- Forecast the groundwater depth using Empirical Mode Decomposition model.

- Development of required future groundwater profile for any season using the IDW tool.

METHODOLOGY

- Simulation of Ground Water Percolation Using SWAT
- Estimation of Ground Water Depth
- Forecasting Ground Water Depth using EMD method

SIMULATION OF GROUND WATER TABLE DEPTH USING SWAT

- SWAT outputs are used to compute groundwater table depth for sub watersheds located within the Kechery river basin based on the relationship between ground water depth and amount of recharge entering aquifer.

- The simulation of ground water percolation is achieved by following steps:

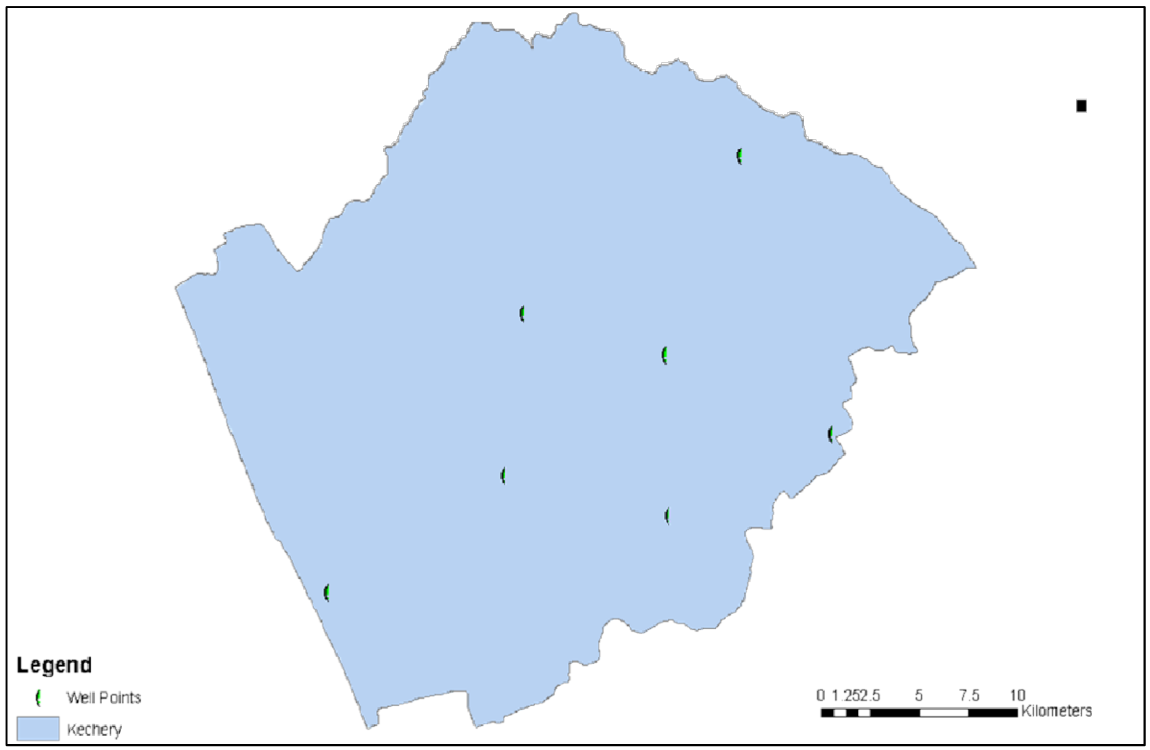
1. Watershed delineation, 2. HRU analysis 3. Data input 4. SWAT simulation

STUDY AREA

- Kechery river basin
- North latitude - 10°25’44.41” to 10^{0}43’17.77”

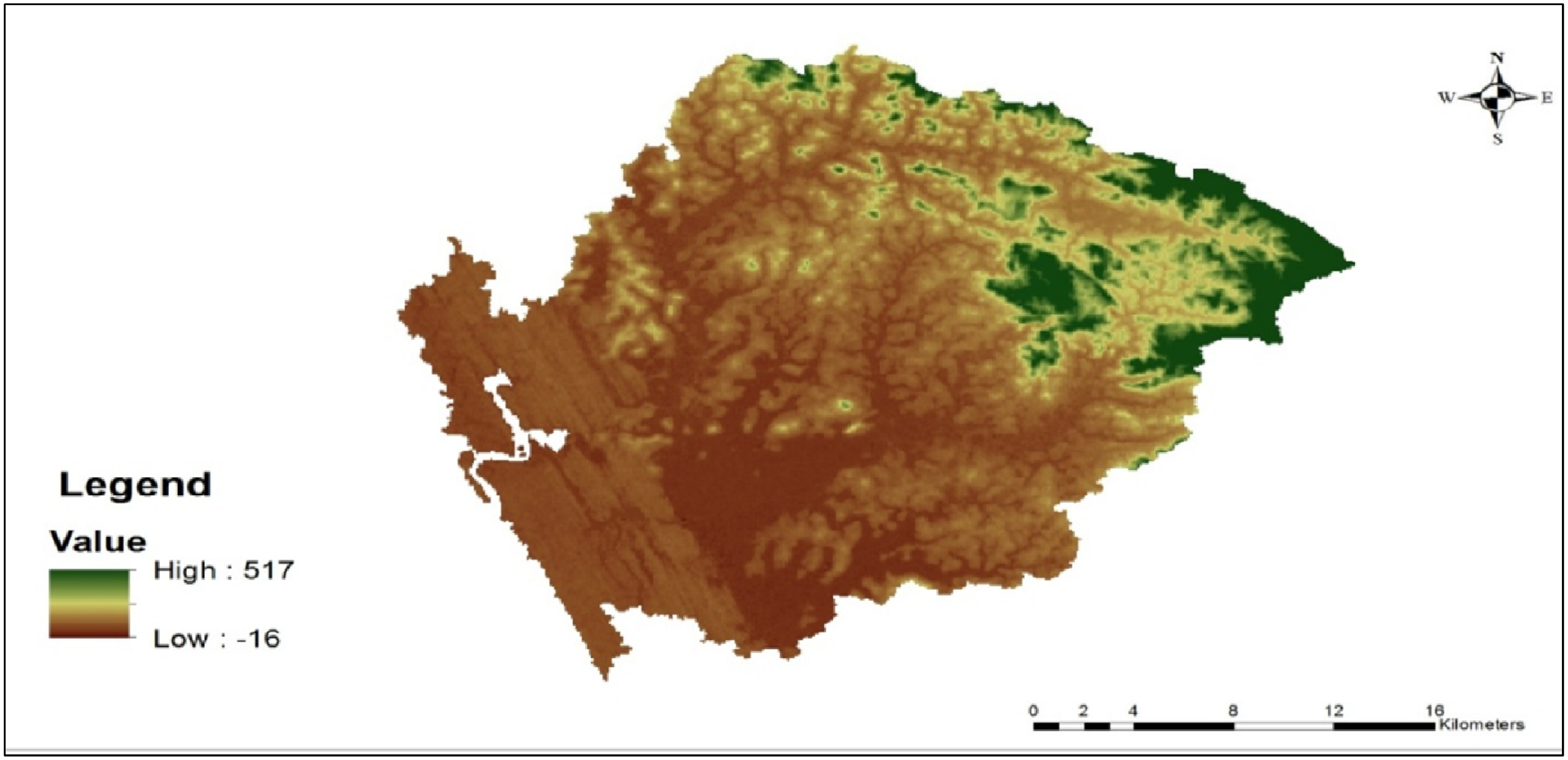
  East longitude - 76^{0}02’05” to 76^{0}21’26.25”
- Area – 712.63 Km^2

Location Map Of Well Points In Kechery Watershed



DATA INPUTS

Digital Elevation Map of Kechery River [STEM 30m]



Source: USGS earth explorer.

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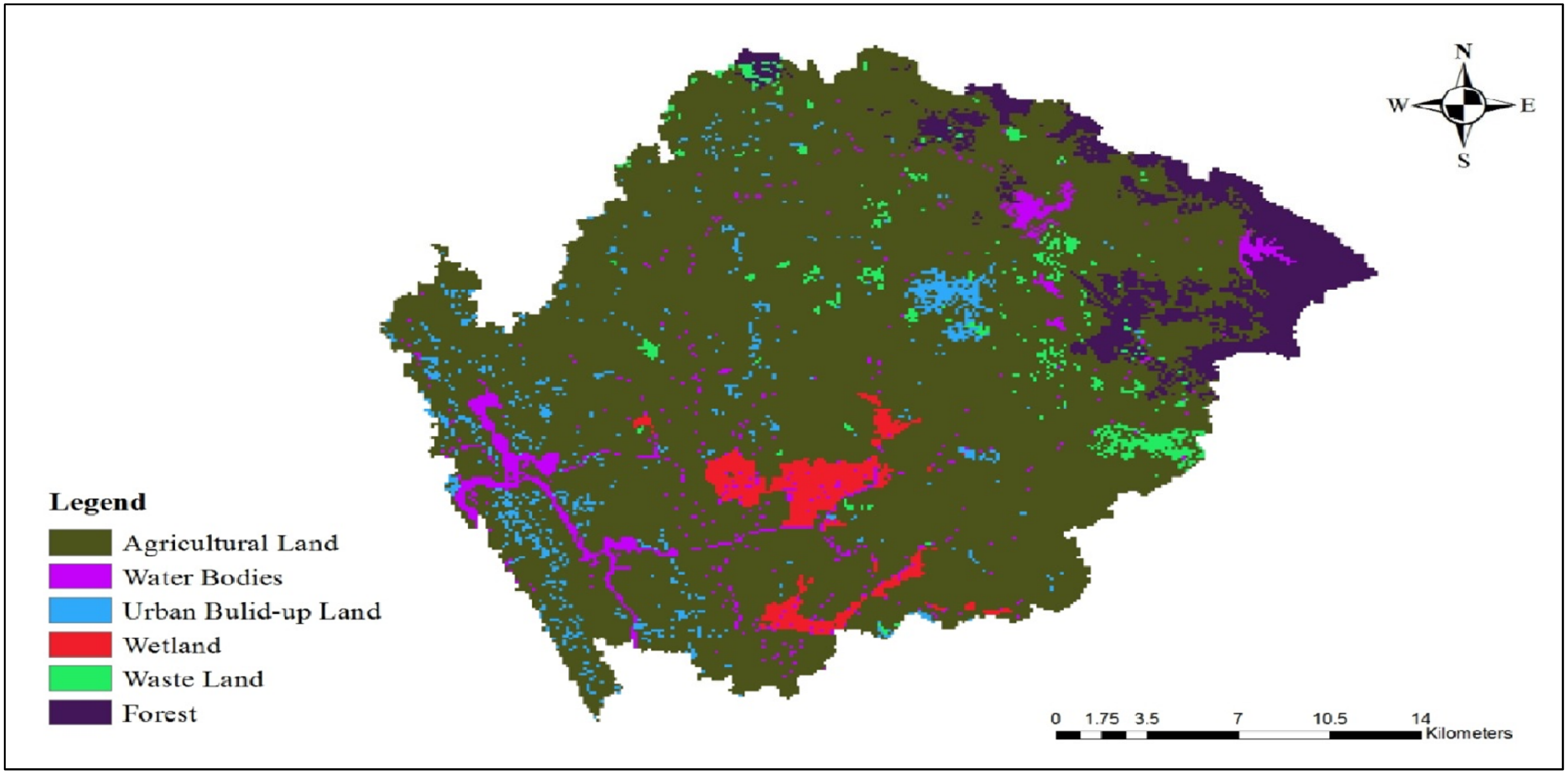
Land use map of Kechery watershed for the year 2008



Source: Kerala Forest Research Institute

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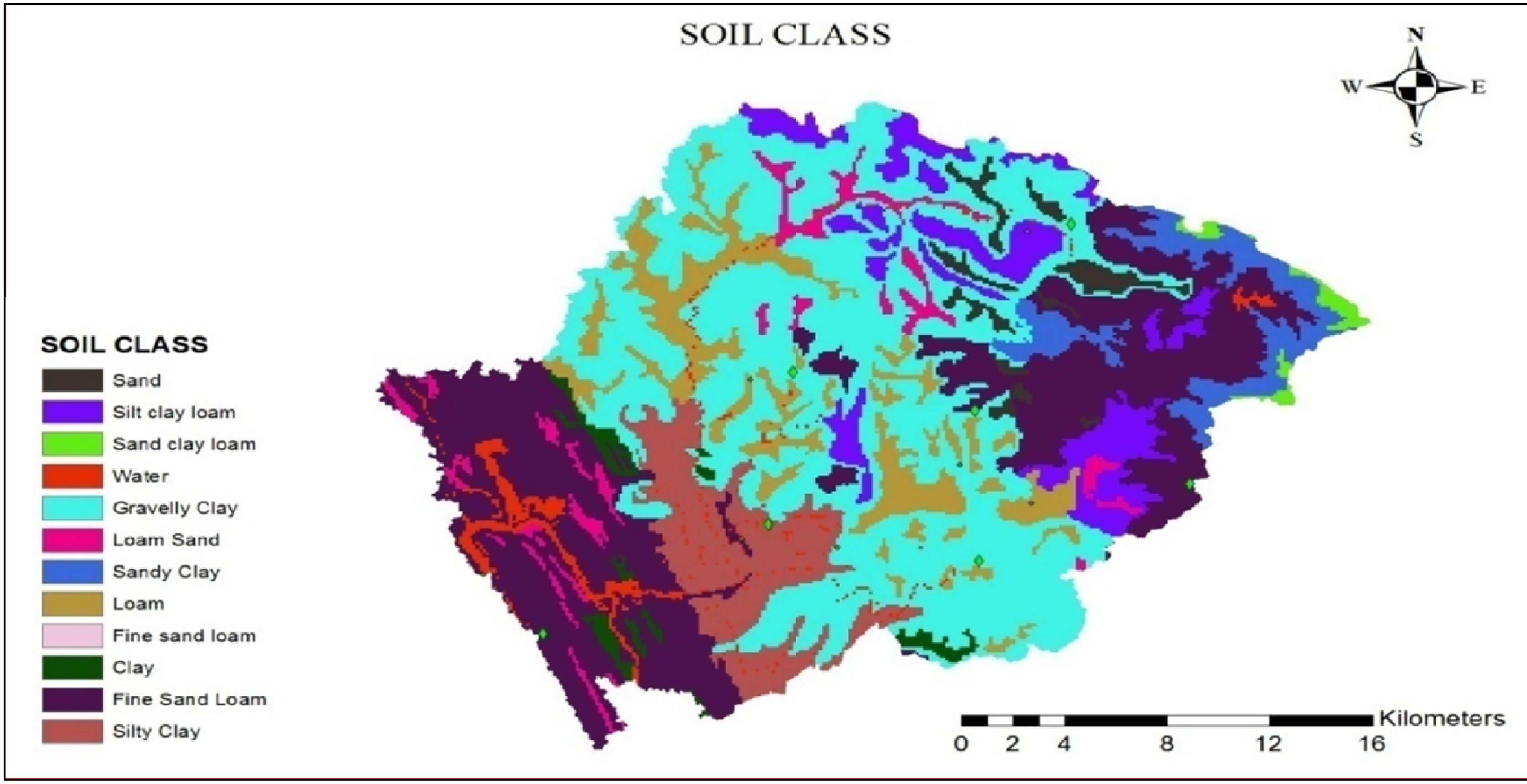
Soil Map of Kechery Watershed



Source: Soil Survey Department

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Weather and Groundwater depth data

- Daily weather data for precipitation, maximum and minimum temperature, solar radiation, wind and dew point are obtained from the records of the IMD Thrissur for the period 1985-2009.

- Seasonal ground water depth in seven observation wells located in Kechery river basin is obtained from the Central Ground Water Board, Trivandrum for a period of seven years

GROUND WATER DEPTH CALCULATION

$$h_{wt,i} = h_{wt,i-1} * \exp\left[-\alpha_{gw} * \Delta t\right] + \frac{W_{rehrg}\left[1 - \exp\left[-\alpha_{gw} * \Delta t\right]\right]}{800 * \mu * \alpha_{gw}}$$

where

$h_{wt,i}$ = Water table depth on day i (m).

$h_{wt,i-1}$ = Water table depth on day i-1 (m).

α_{gw} = Base flow recession constant. -ALPHA_BF

Δt = Time step (1 day).

W_{rchrg} = Amount of recharge entering the aquifer on the day (mmH_2O)

μ = Specific yield of a aquifer (m/m). - GW_SPYLD

CONTINUED…

$$w_{rchrg,i} = (1 - \exp(-1/\delta_{gw})) * w_{seep} + \exp(-1/\delta_{gw}) * w_{rcrg,i-1}$$

Where

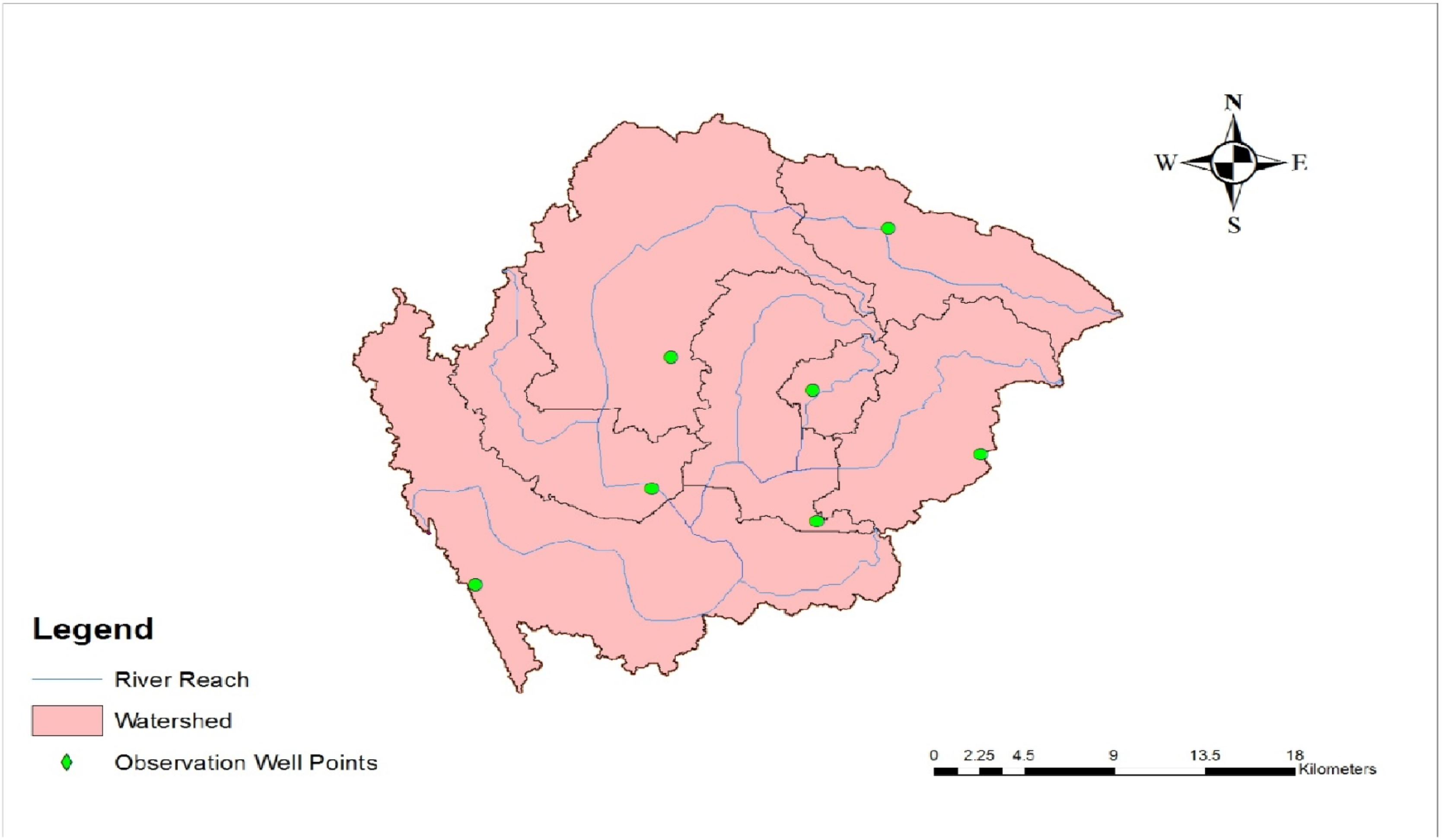
$$w_{seep} = w_{perc} + w_{crk}$$

w_{seep} = Total amount of water exciting on soil bottom profile (mmH_2O).

w_{perc} = Groundwater percolation (PERC) (mm).

w_{crk} = Amount of water flow past the lower boundary of soli profile (mmH_2O).

DELINEATED WATERSHED



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- 2009 and 2010 - Model calibration
- 2011-2012 - Model validation.
- The SWAT input parameters based recession flow constant (ALPHA_BF) and Specific yield of an aquifer (GW_SPYLD) are found out during calibration by adjusting its value between its limits.
- The base recession constant can take value between 0.1 and 1 and specific yield can take value between 0.003 and 0.4.

SWAT SIMULATION

- The SWAT model is simulated for the period 1985-2008.
- Daily groundwater depth is calculated for this period from SWAT output PERC.
- Since this height is from aquifer bottom level and observed data is from ground surface, the simulated depth is subtracted from highest groundwater level for the dry season.
- This groundwater level for the dry season is different for each sub- basin.
- For the purpose of comparison, monthly values are computed for the months for which the observed data are available (January, April, August, and December).

FORECASTING MODELS

- Empirical Mode Decomposition (EMD)

EMPIRICAL MODE DECOMPOSITION (EMD)

- Empirical mode decomposition (EMD), is a time series decomposition technique, used for non-linear and non-stationary time series data.
- Considering non-linearity in groundwater depth , the data set is decomposed into IMFs and residue.
- The IMFs are oscillating around zeros and have positive instantaneous frequency.
- For groundwater depth data it has been observed that nonlinearity and stationarity decreases in higher IMFs compared to previous IMF.

DEVELOPMENT OF IMFS FROM GROUNDWATER DEPTH

- Identify local maxima and minima of distorted groundwater depth series, s(t).

- Perform cubic spline interpolation between the maxima and the minima to obtain the envelopes $e_M(t)$ and $e_m(t)$, respectively.

- Compute mean m(t) of the envelopes.

- Extract $c_1(t) = s(t) - m(t)$.

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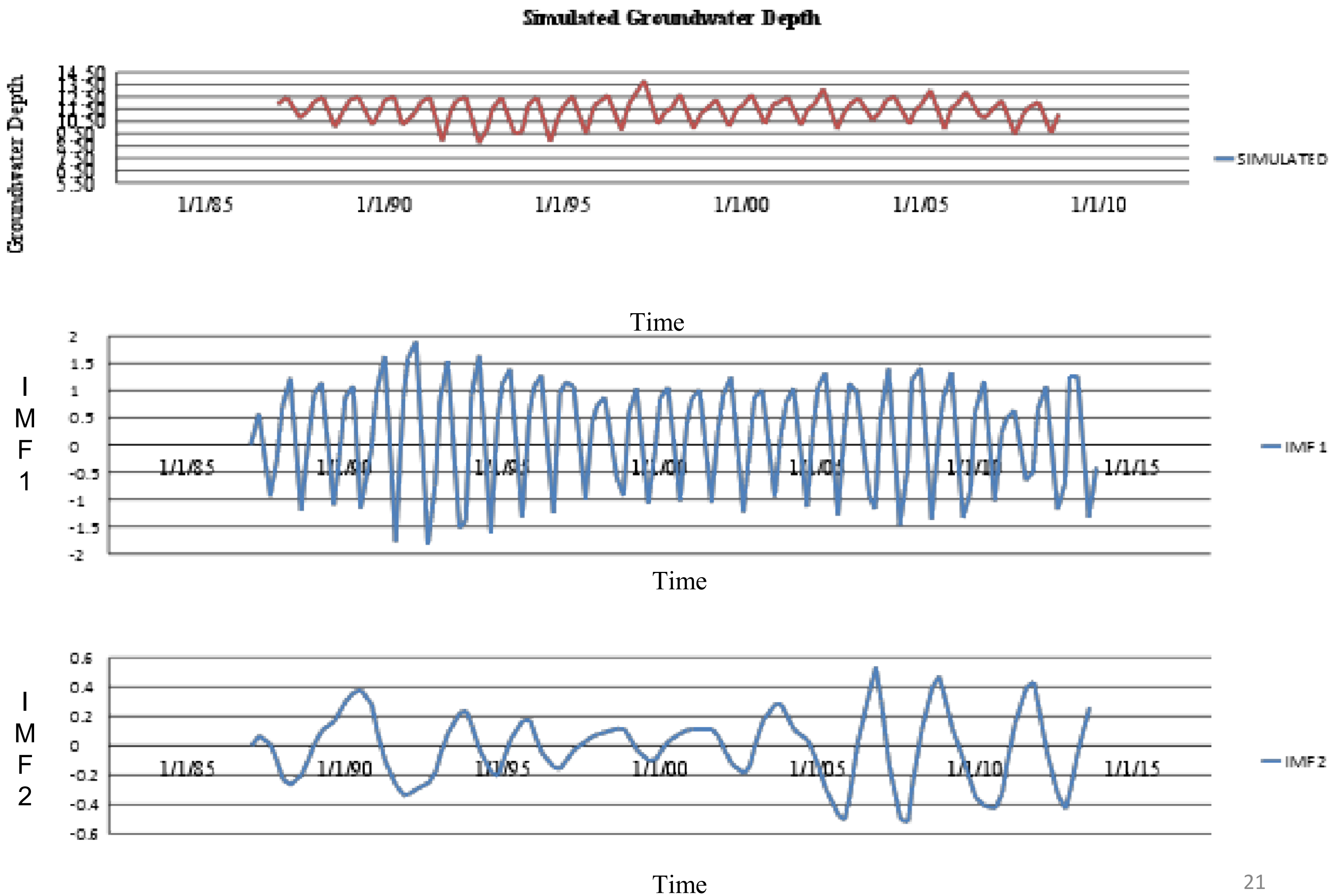
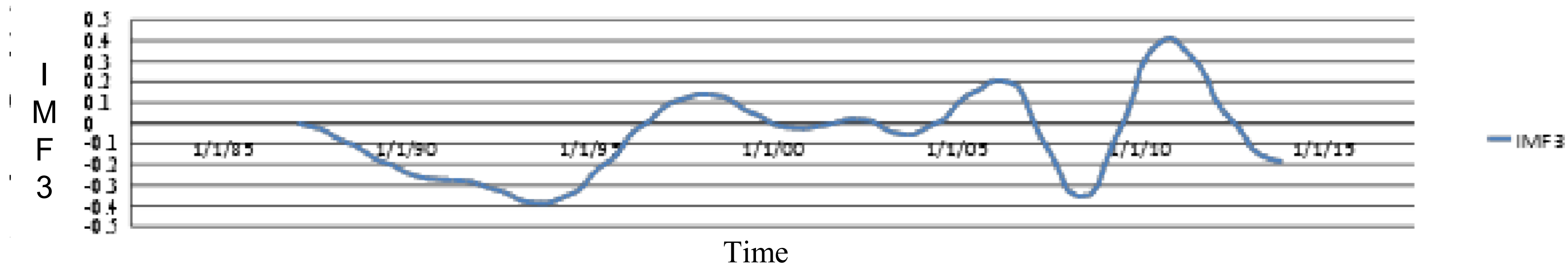
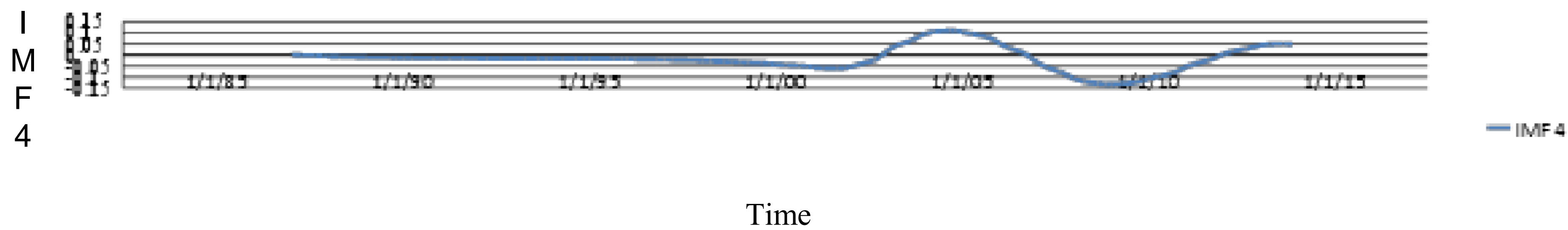
- c_1 (t) is an IMF if the number of local extrema of c_1 (t), is equal to or differs from the number of zero crossings by one, and the average of c_1 (t) reasonably zero. If c_1 (t) is not an IMF, then repeat steps 1-4 on c_1 (t) instead of s (t), until the new c_1 (t) obtained satisfies the conditions of an IMF.
- Compute the residue, $r_1(t) = s(t) – c_1(t)$,
- If the residue, r_1 (t), is above a threshold value of error tolerance, then repeat steps 1-6 on r_1 (t), to obtain the next IMF and a new residue. This threshold value can be taken as Cauchy is type stopping criteria and can found using equation.

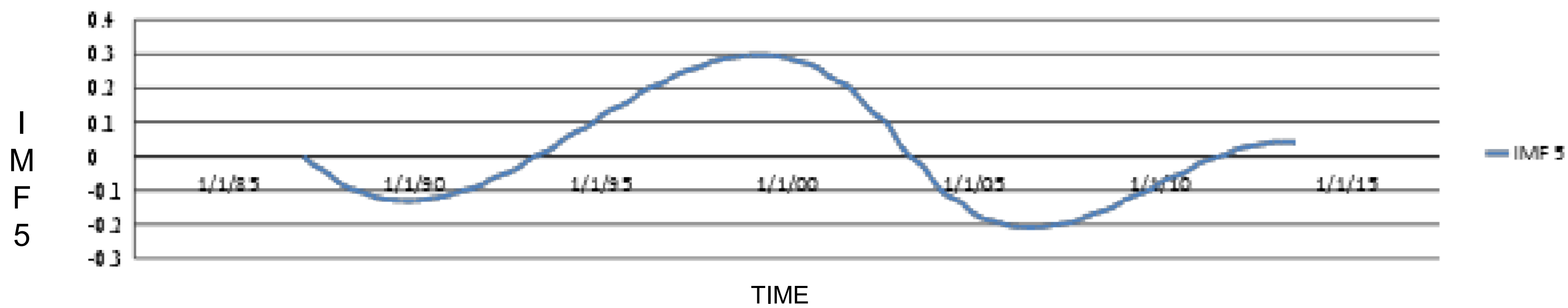
$$SD_{Thr} = \frac{r_{j,i-1} - r_{j,i}}{r_{j,i-1}}$$

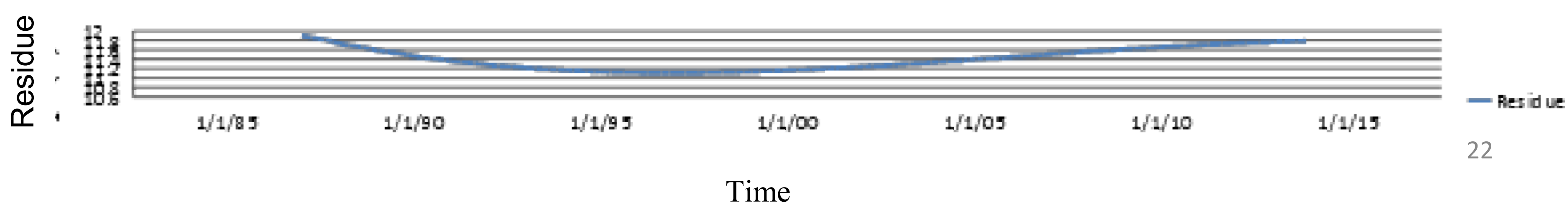
GENERATED IMFS OF TYPICAL SUB-BASIN



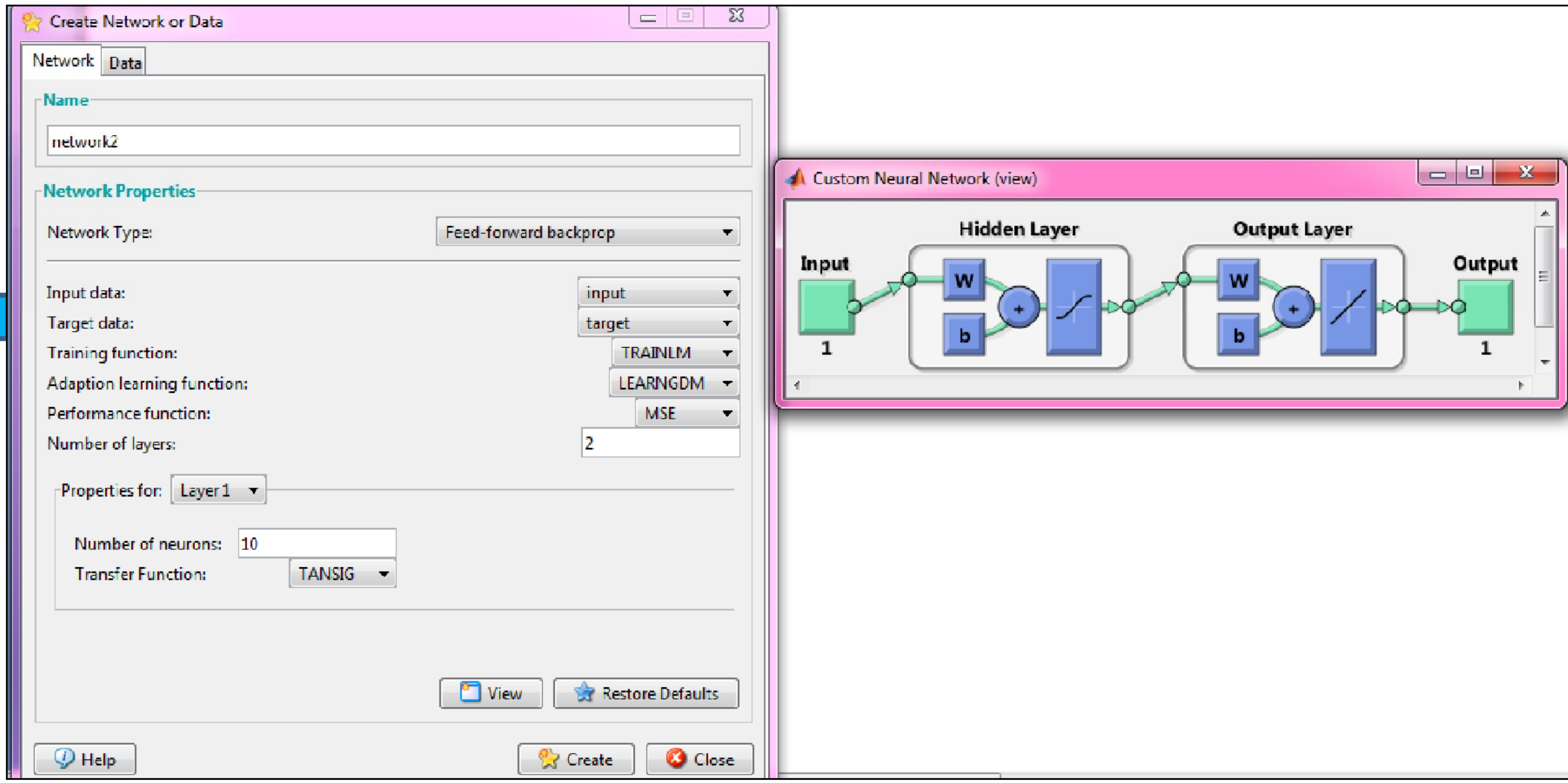

IMF 3
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1/1/85
1/1/90
1/1/00
1/1/05
1/1/15
IMF 3
Time


IMF 4
1/1/85
1/1/90
1/1/95
1/1/00
1/1/05
1/1/15
IMF 4
Time


IMF 5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
1/1/85
1/1/90
1/1/95
1/1/00
1/1/05
1/1/15
IMF 5
TIME


Residue
1/1/85
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
1/1/15
Residue
Time

FORECASTING OF IMFS AND RESIDUE

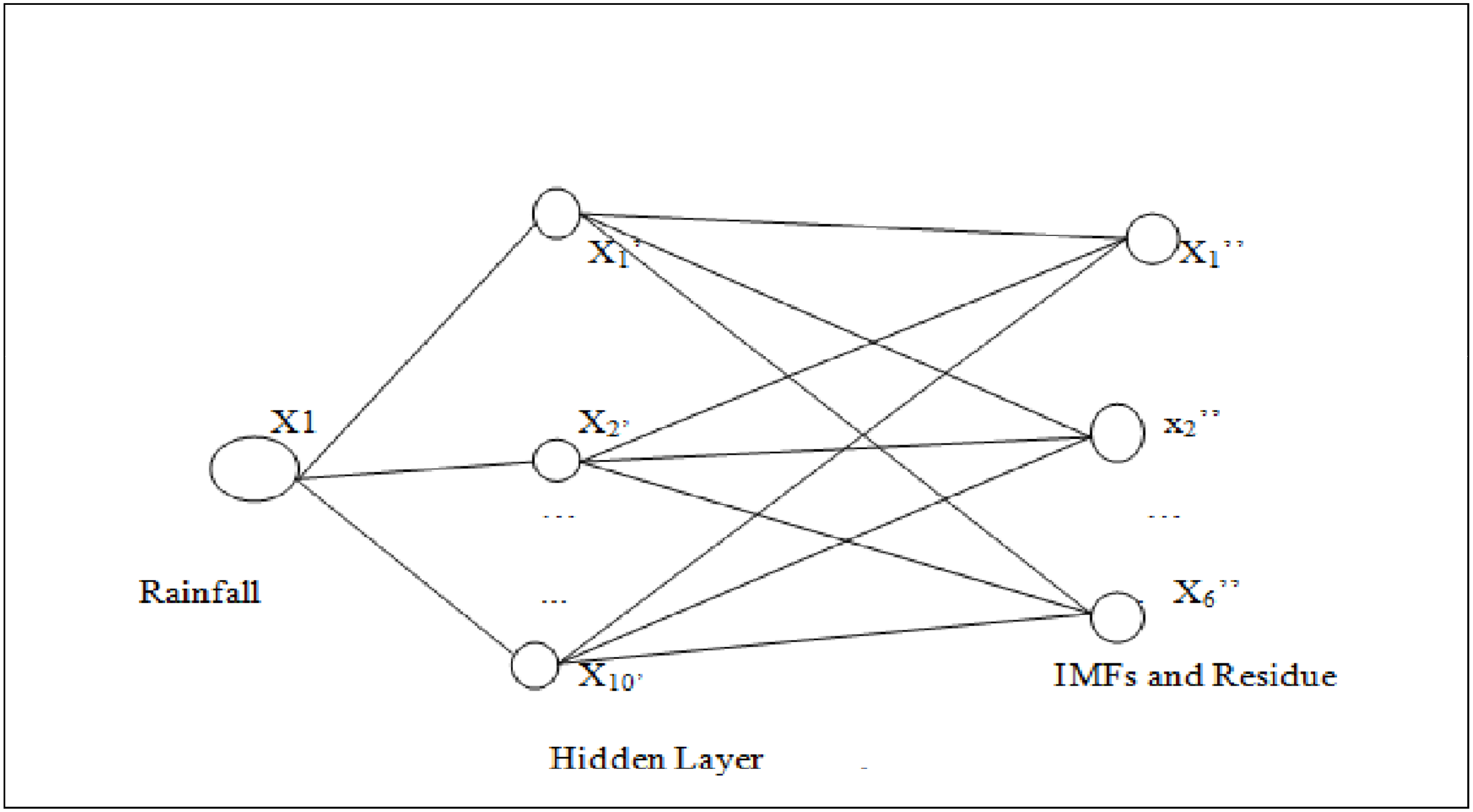


‘CREATE NETWORK OR DATA’
WINDOW

FORECASTING OF IMFS AND RESIDUE USING ‘nntool’

- Training function -TRANLM
- Adaption learning function -LEARNGDM.
- The input layer has one neuron, hidden layer has ten neurons and output layer has six or seven neurons.
- After training the network epochs are selected as 1000, which giving good performance curve.
- After checking the regression the network is simulated using forecasted rainfall for the period 2010-2014, which was the validation period.
- The IMFs and residue for the period 2010-2014 is obtained and the sum of these values gives predicted groundwater depth.

GENERAL ARCHITECTURE OF SELECTED NEURAL NETWORK



Result and discussion

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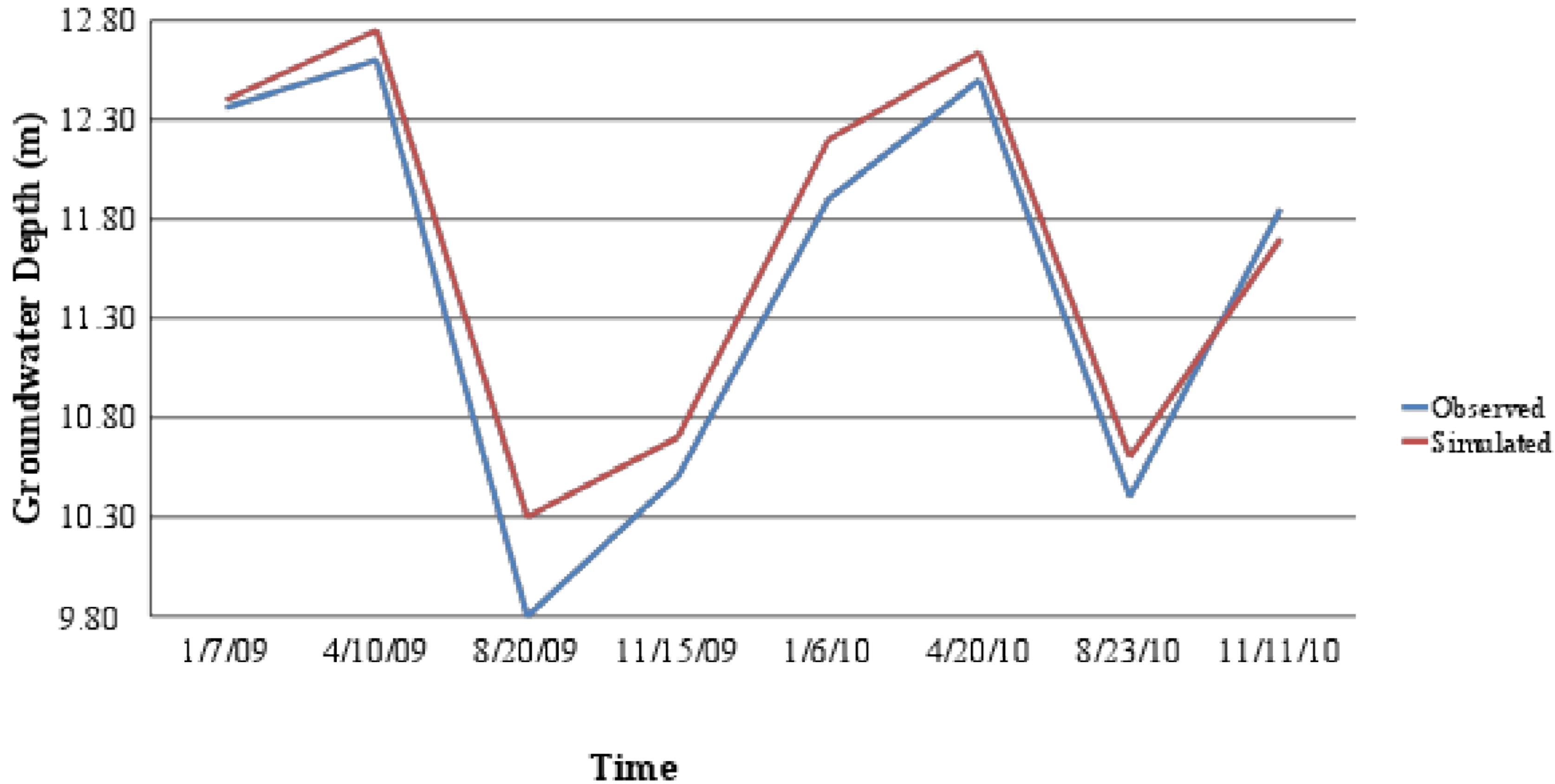
Typical example for calibration plot (Adatt Subbasin)



VALIDATION

Coefficient Of Determination (R^2) And
Nash -Sutcliffe Efficiency (NSE)
Between Actual And Simulated Groundwater Depth

Well Point	**Coefficient of Determination (R^2)**	**Nash -Sutcliffe Efficiency (NSE)**
Wadakkancherry	0.68	0.51
Kechery	0.77	0.77
Mulankunnathukavu	0.86	0.81
Pattikad	0.6	0.51
Adatt	0.8	0.85
Trichur	0.81	0.74
Engandiyur	0.79	0.74

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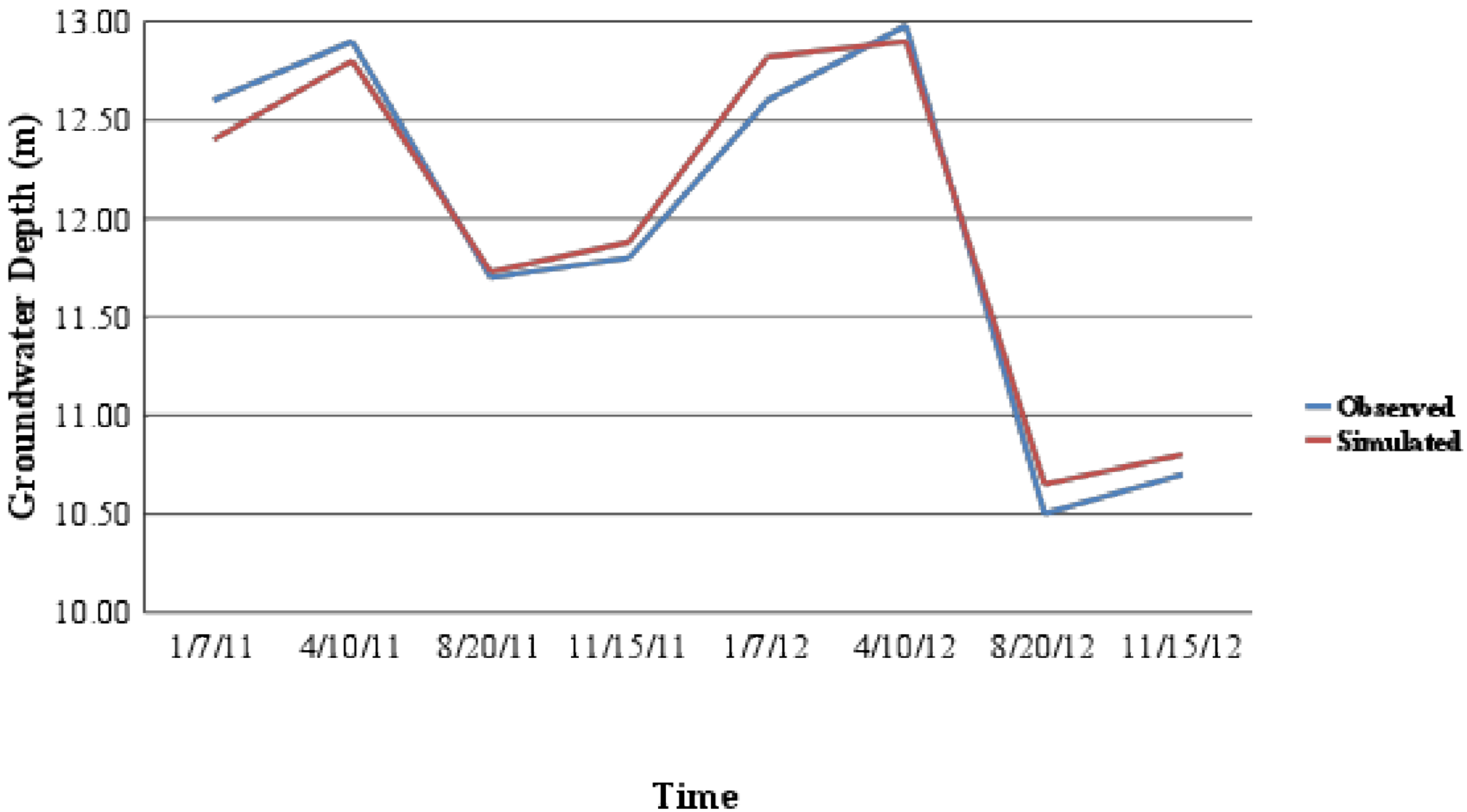
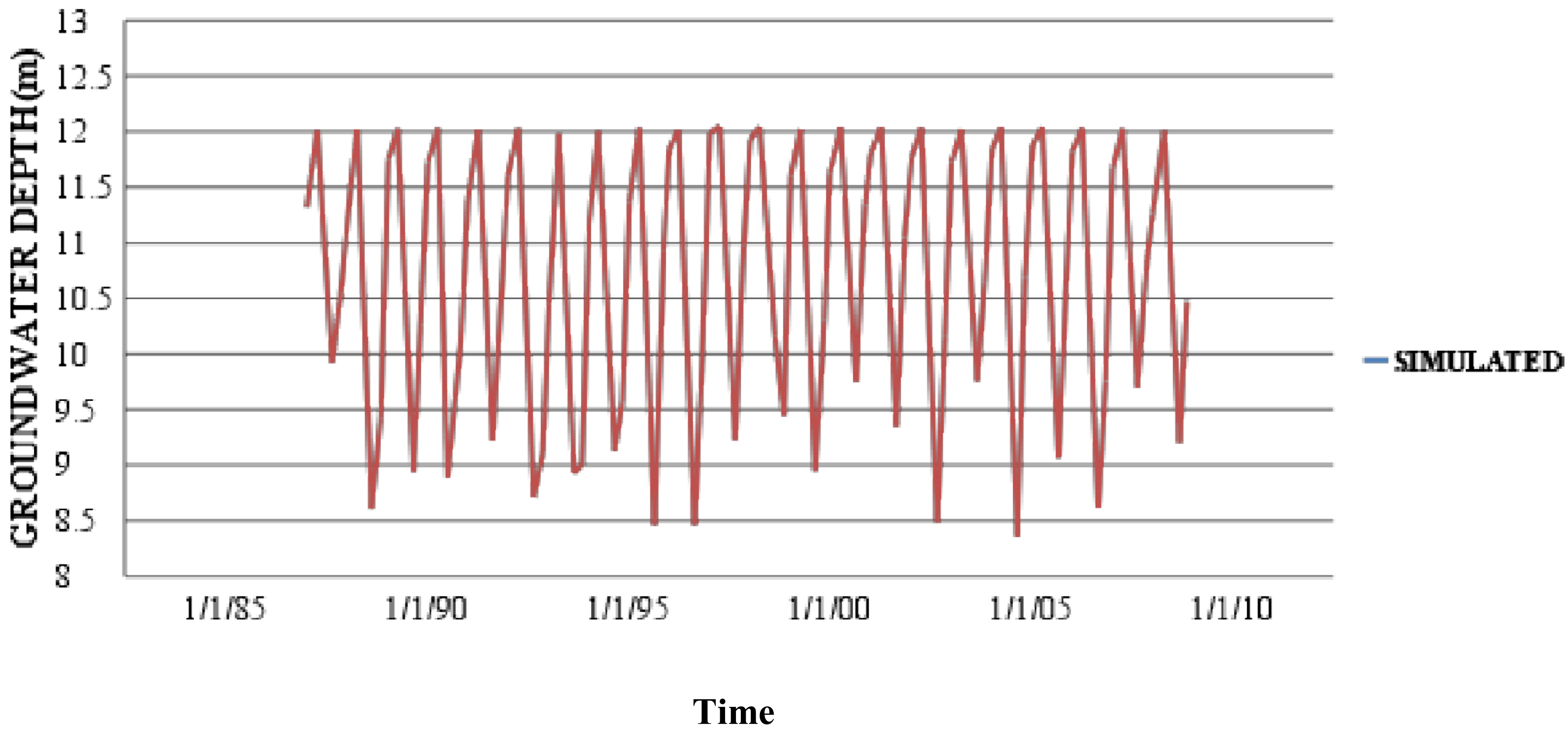
Typical example for validation plot (Adatt)



SIMULATED GROUNDWATER DEPTH

Groundwater Depth of Wadakkanchery Sub Watershed



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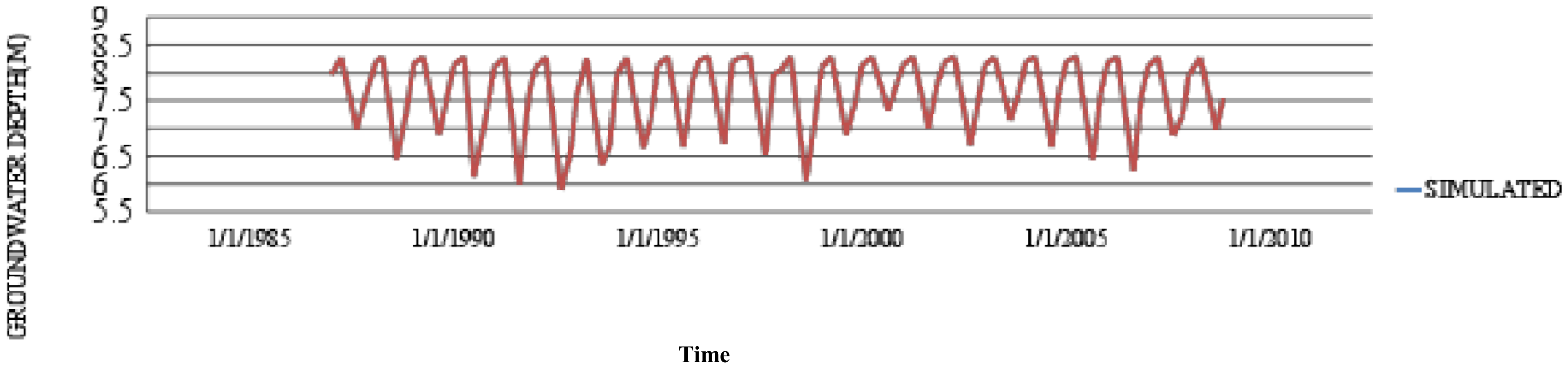
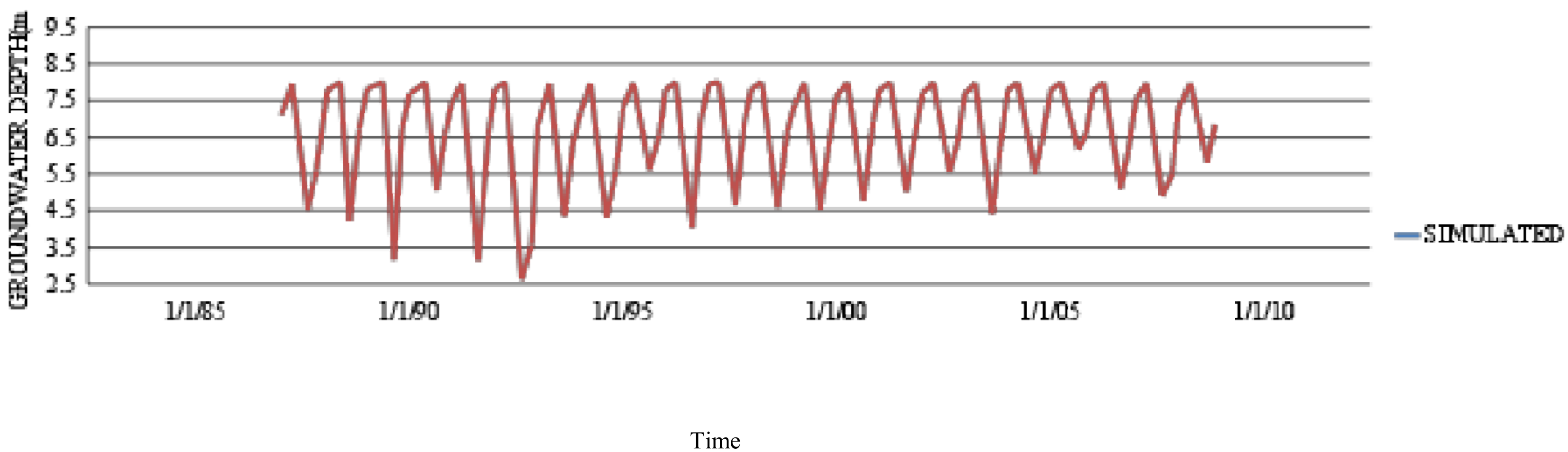
Groundwater Depth of Kechery Sub Watershed



Groundwater Depth of Mulagunathkavu Sub Watershed



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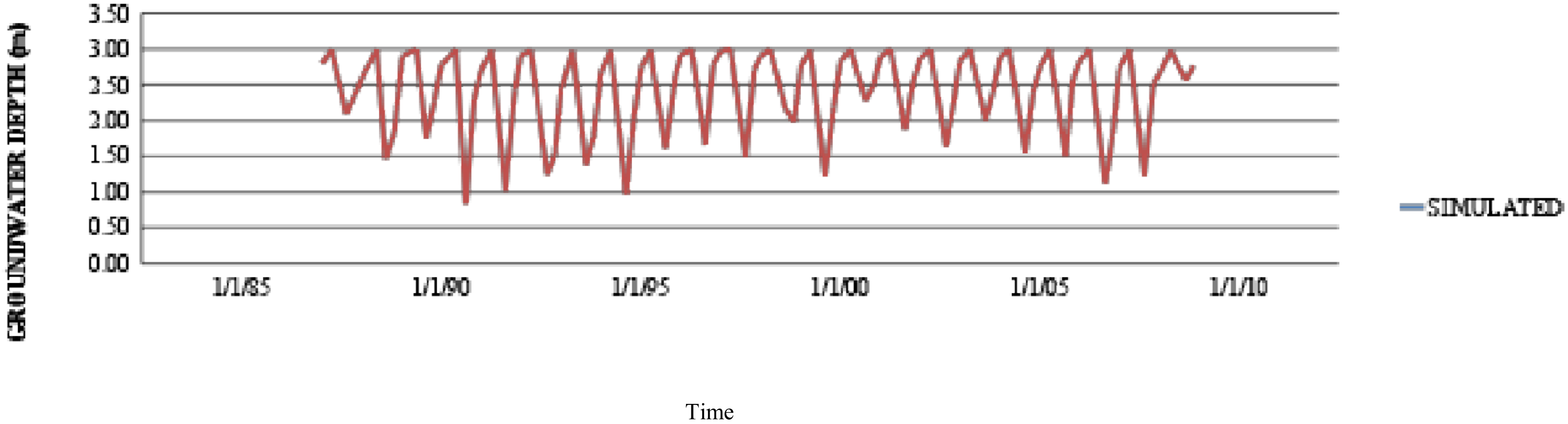
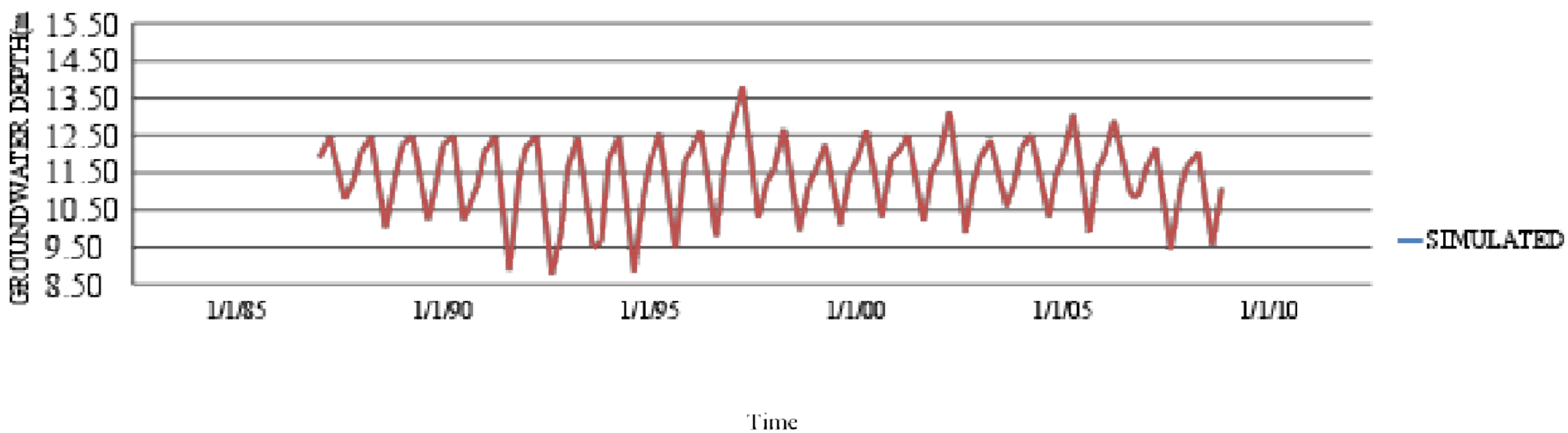
Groundwater Depth Of Pattikad Sub Watershed



Groundwater Depth of Adatt Sub Watershed



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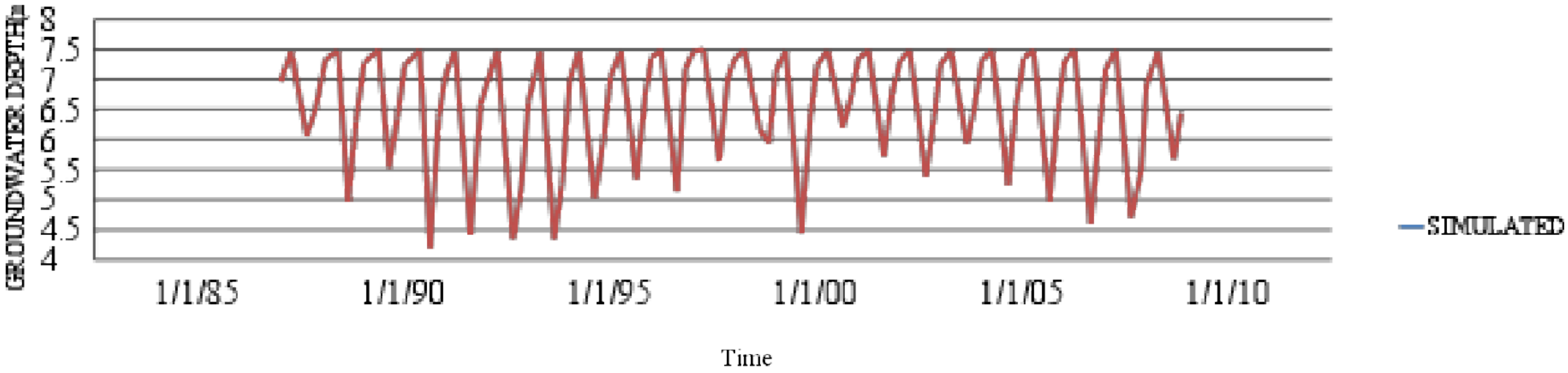
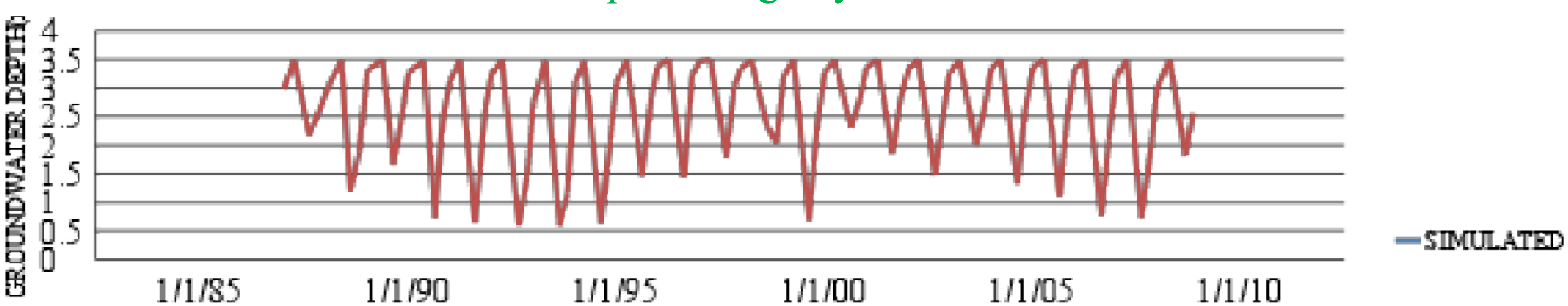
Groundwater Depth of Trichur Sub Watershed



Groundwater Depth of Egadiyur Sub Watershed

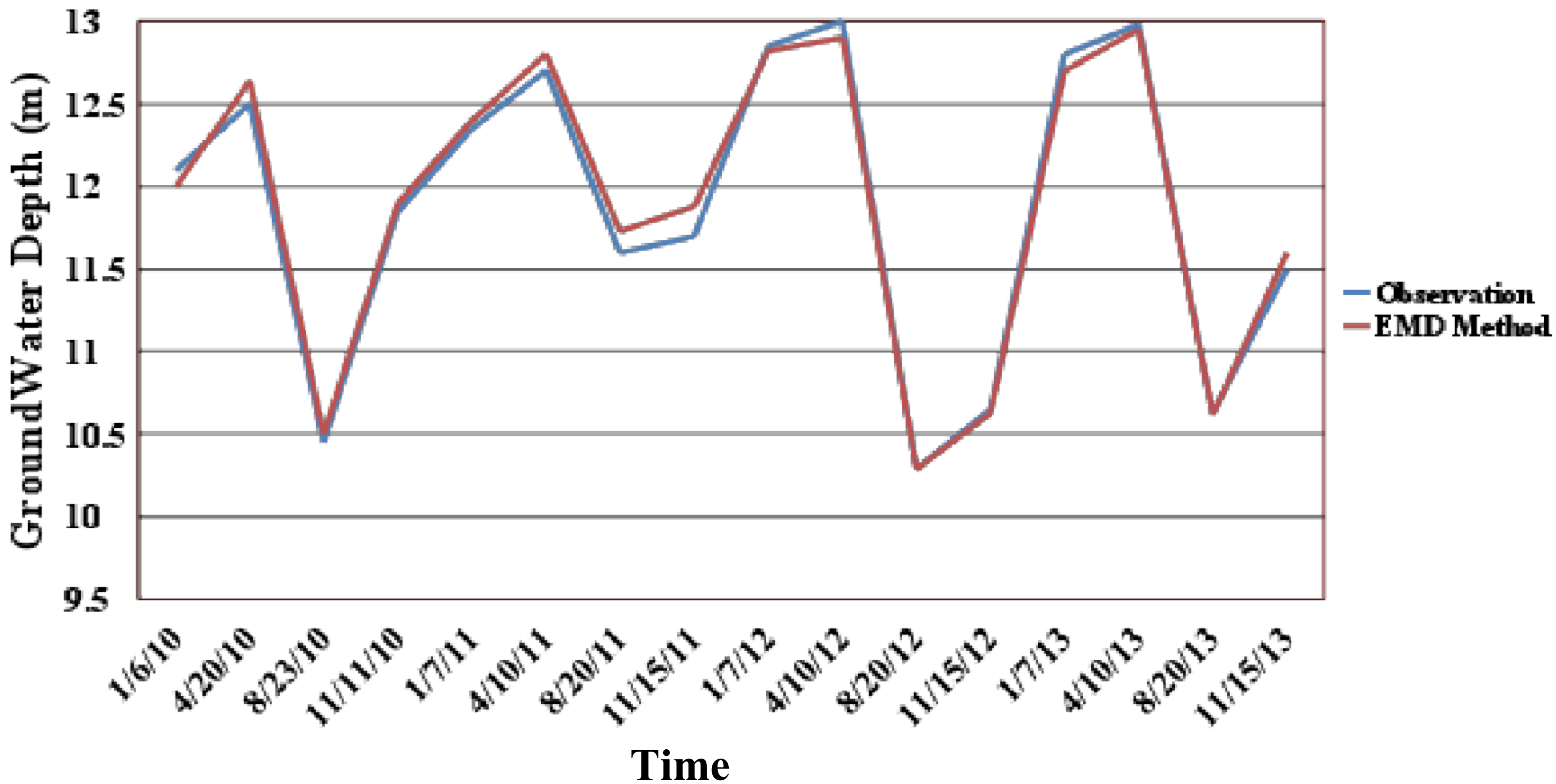


Time

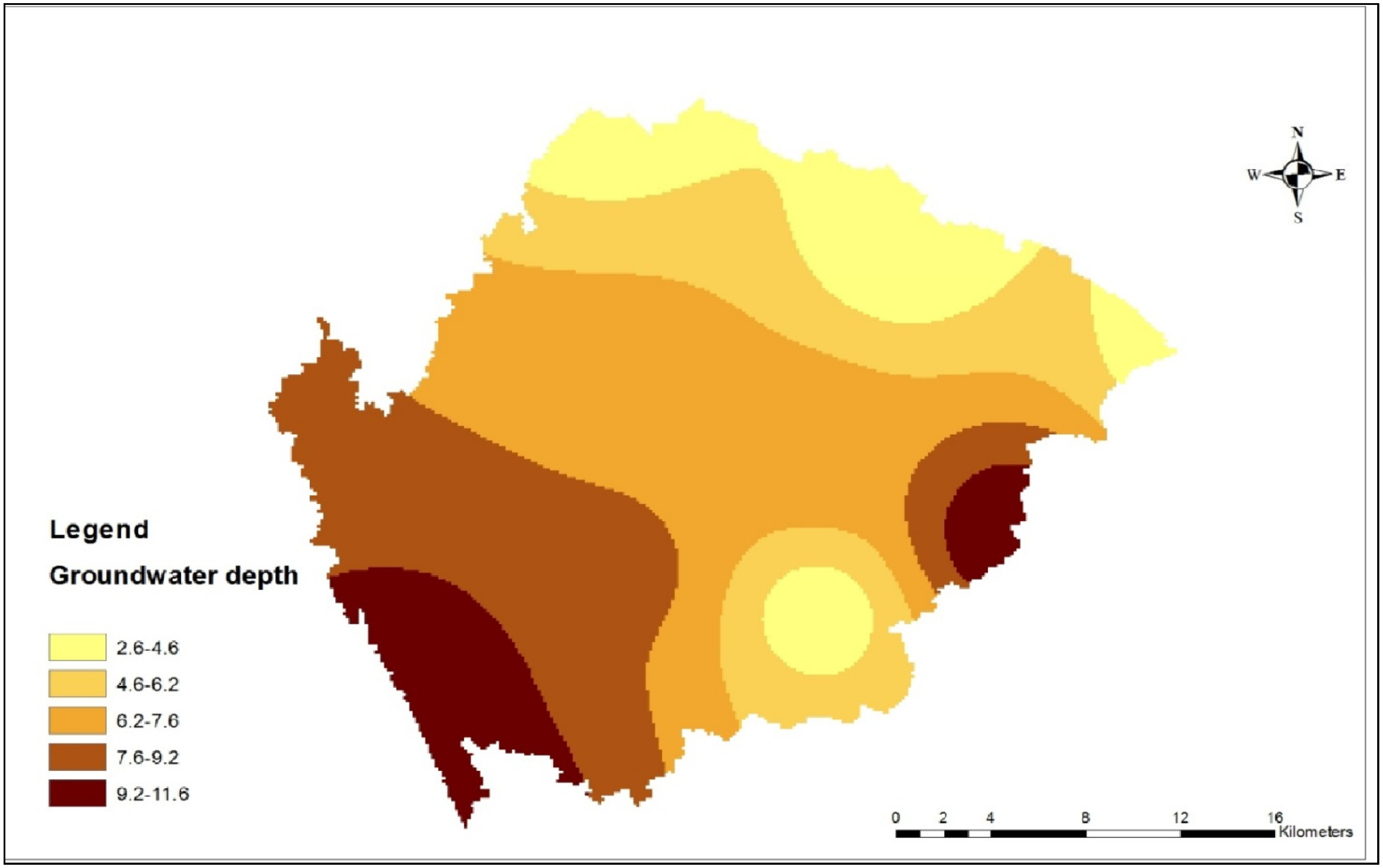
STATISTICAL PARAMETERS BETWEEN OBSERVED AND SIMULATED GROUNDWATER DEPTH (EMD METHOD)

Well Point	Coefficient of Determination (R^2)	Root Mean Square Error (RMS Error)
Wadakkancherry	0.972	0.089
Kechery	0.946	0.085
Mulankunnathukavu	0.979	0.0815
Pattikad	0.88	0.0895
Adatt	0.989	0.0797
Trichur	0.995	0.075
Engandiyur	0.901	0.086

COMPARISON OF FORECASTED GROUNDWATER DEPTH



GROUNDWATER PROFILE OF KECHERY WATERSHED (JANUARY, 2017) – IDW TOOL



CONCLUSION

- The Kechery watershed is modeled satisfactorily using the hydrologic modeling tool SWAT at the basin and sub-basin level.

- The model efficiency ($R^2$and NSE) are obtained between 0.7 and 0.85 during calibration and validation period for all the sub-basins except one which may be due to inaccurate observed data.

- The validated model is used to compute groundwater depth at the sub-basin level based on the relationship between groundwater recharge and depth. Satisfactory results were obtained for all sub-basins except one.

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- The prediction of groundwater depth using EMD method is found to be effective because it considers the non-linearity of input data and forecasting is done individually for each IMFs and residue.
- From the predicted groundwater depth available at different well points, the groundwater profile is developed using IDW method for any desired period.
- Knowledge about the water surface profile and its spatial and temporal variations would be very useful in the planning and implementation of water conservation policies

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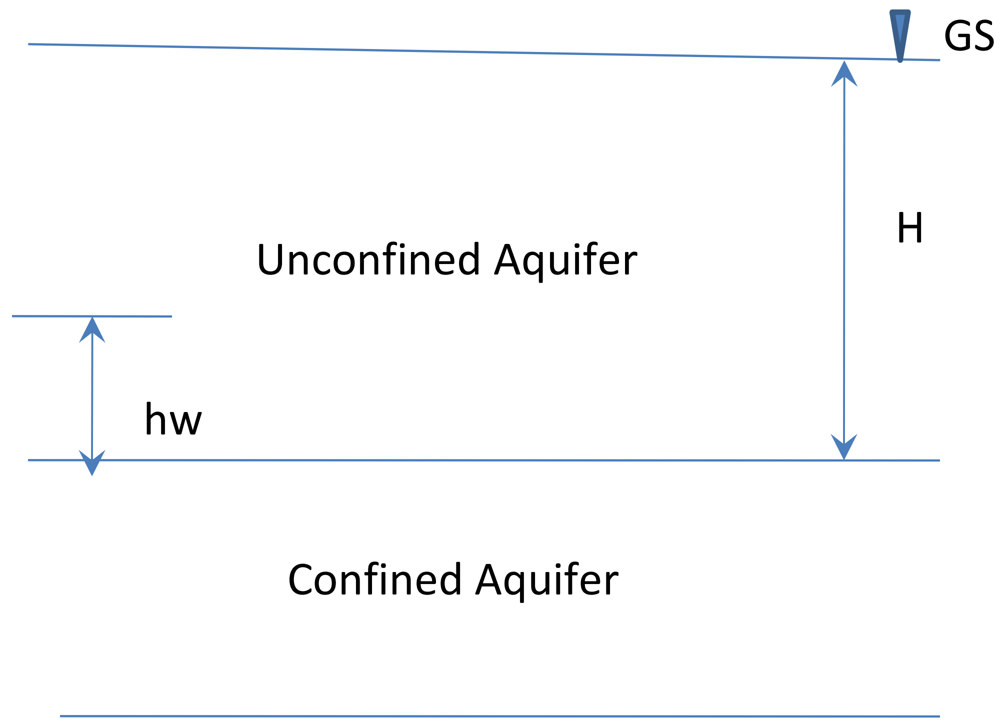
Thank You


GS
H
Unconfined Aquifer
hw
Confined Aquifer

$$Q_{gw,i} = Q_{gw,i-1} * \exp(-\alpha_{gw} * \Delta t) + w_{rchrg} (1 - \exp(-\alpha_{gw} * \Delta \mathrm{t}))$$

$$Q_{gw} = 800 * \mu * \alpha_{gw} * h_{wt}$$