Agricultural Water demand Modeling using HEC HMS Soil Moisture Accounting for Ajay River basin, India

by

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Outline of Presentation

- Purpose of Work
- Chosen study area in Eastern India: Ajay River Basin
- Part I: The HEC HMS Model
- Part II: Hydrological Modeling of the Ajay River using HEC HMS Model

Purpose of Work

- Ajay River basin in Eastern India was selected and studied for assessment of water availability with emphasis on soil moisture accounting. A futuristic look into water availability for the year 2050 was attempted. In order for a successful analysis, a tools like Hydrological Engineering Centre Hydrological Modelling System (HEC HMS) were used.

- Once the hydrological simulation of the river basin was made, soil moisture accounting was given due priority, the futuristic prediction of water availability was achieved based on the projected rainfall data generated out of the regional climatic change models keeping primarily in view the land cover and land use pattern.

Introduction

- Ajay River is an important rivers in West Bengal. These natural resources of water support a large and vitally important variety of economic activities such as fishery, recreation and irrigation.

- The intensive use of land and water in the watersheds for purposes of agricultural irrigation, domestic, municipal and wildlife make the rivers susceptible to drying up/depletion of resources.

Description 1/2

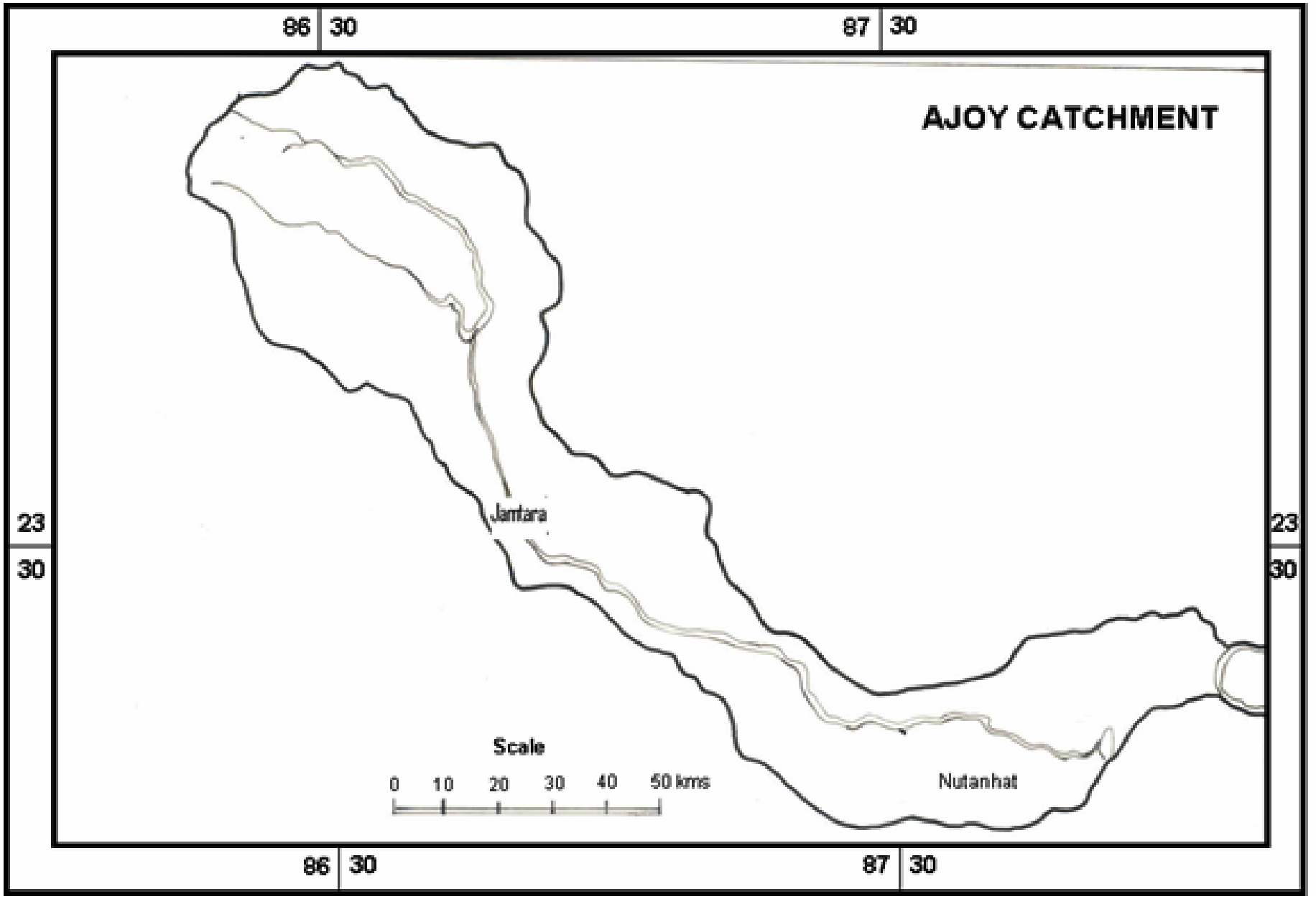
- The catchment located in the plateau of Santhal Parganas, lies between 23°27′ to 24°40′ N latitudes and between 86°15′ to 88°10′ E longitudes and is covered by Survey of India toposheets nos. 72L/6,7,8,10,11,12,15,16, 73I/13, 73M/ 1,2,5,6,7,10,11,14,15 and 79A/1 in the scale of 1:50,000 and 1:36,360.

- It spreads over Deoghar, Dumka, Giridhi, Munger & Jamui district of Bihar and the Burdwan and Birbhum districts of West Bengal.

Description 2/2

- The total basin area of Ajay River is 6,888 square km. The basin area in Jharkhand is 3,554 square km, which is 51.6 percent of the total basin area. In West Bengal, the basin area is 3,334 square km, which is 48.4 percent of the total. The basin area in Jharkhand is hilly whereas that in West Bengal is mostly plain. About 7 percent of the total area is under forests and about 63 percent is under cultivation.

- The observed discharge for two gauge stations in Ajay River located at Jamtara, in Jharkhand and Natunhat in Barddhaman district in West Bengal was collected from CWC,Asansol.

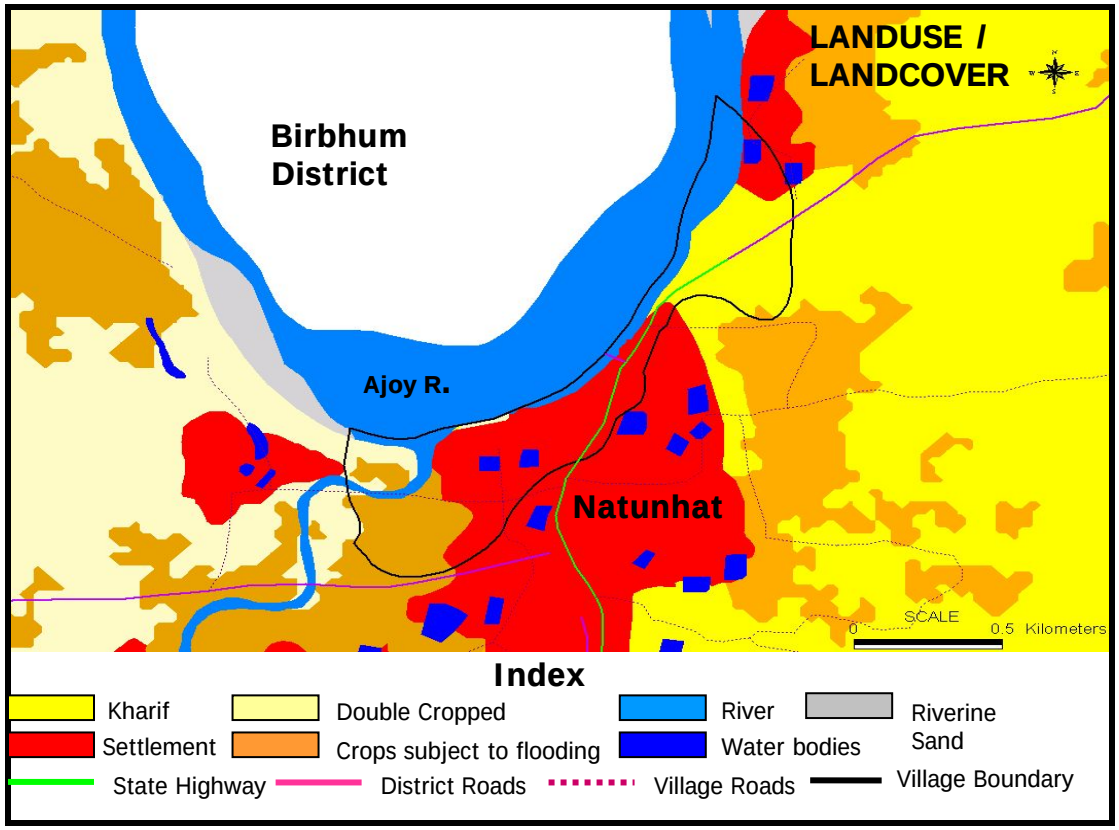

86 30
87 30
AJOY CATCHMENT
23 30
Jantara
Nutanhat
Scale
0 10 20 30 40 50 kms
86 30
87 30

Jamtara and Natunhat Subbasins

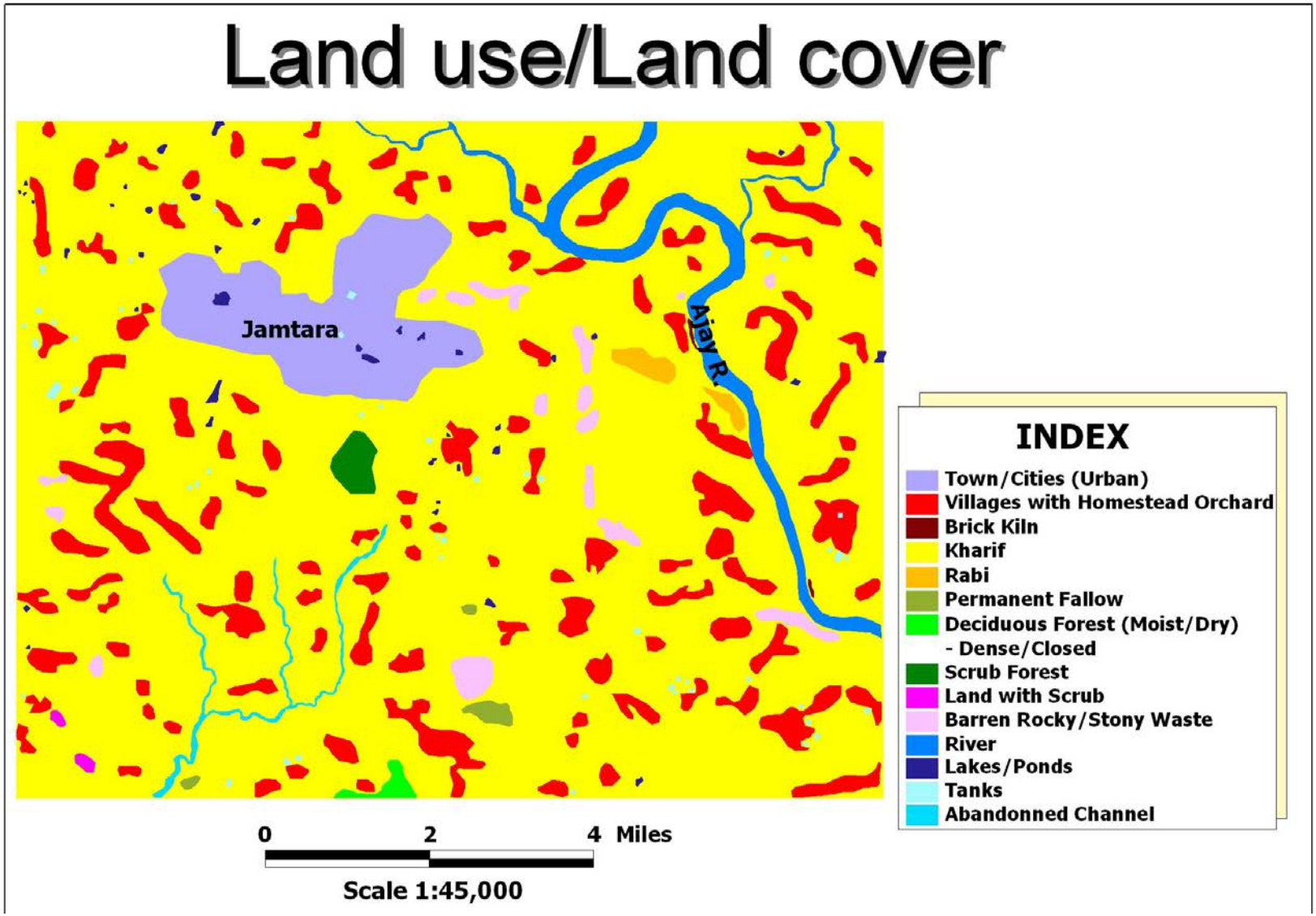
- The river basin between these two gauge stations represents the study area. The Jamtara station is located at latitude 23°58′18″ and longitude 86°54′25″ and the Natunhat station is located at latitude 23°32′44″ and longitude 87°54′25″.

- The basin area between these two stations is about 2906 square km. Average annual precipitation of the study area is about 120 cm. The elevation of the study area ranges from 232m to 48m. The major portion of the study area is under agriculture. Soils of the study area are red loamy soil, older alluvium and younger alluvium. The average slope varies from 1 in 700 to 1 in 2500.

Land Use of Ajay River at Natunhat



Jamtara Subbasin



Part I: The HEC HMS Model

Modeling

- In general a model can be defined as a deliberately simplified construct of nature erected for the purpose of understanding a phenomenon **(Batchelor, 1994)**.

- A watershed hydrology model is an assemblage of component models corresponding to different components of hydrologic cycle **(Singh, 1995)**.

Introduction

- HEC HMS can simulate the rainfall-runoff at any point within a watershed when given the physical characteristics of the watershed.

- It is a tool for watershed management that can be developed to determine the effect on the magnitude, quantity and timing of runoff at points of interest. Results from the model can be used by a number of other programs to determine impact in areas such as water quality and flood damage.

- It has been developed by the US Army Corps of Engineers, USA

Model Development

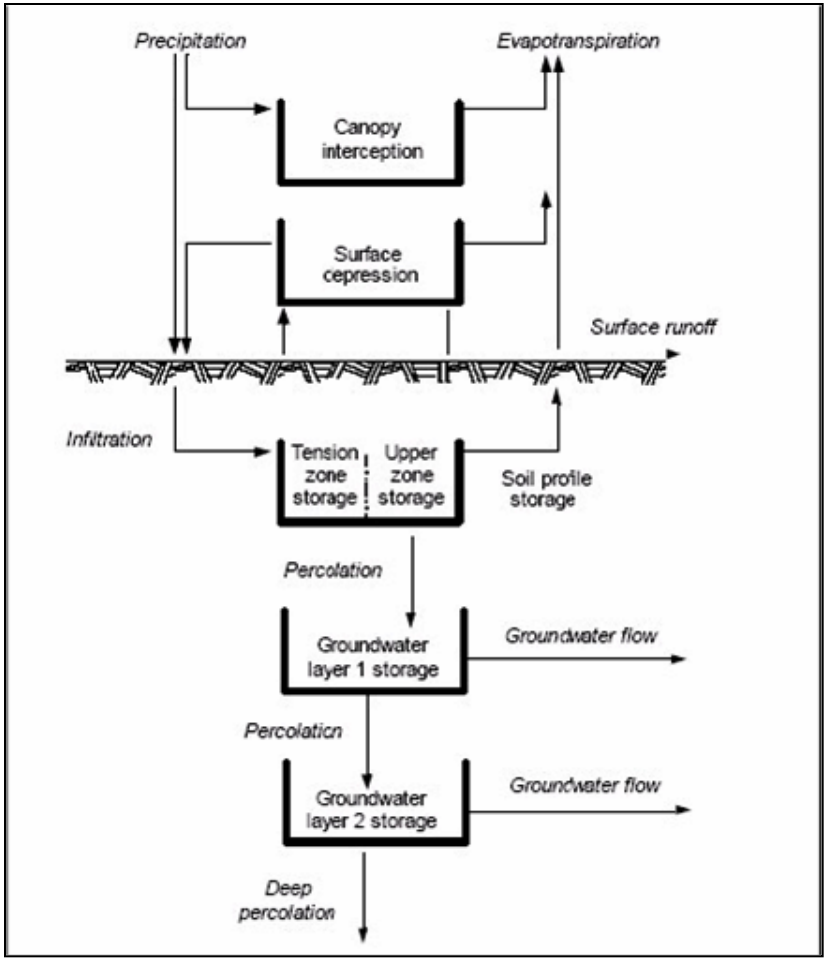
- Identify the decision required.
- Determine what information is required to make a decision.
- Identify methods that can provide the information, identify criteria for selecting one of the methods and select a method.
- Calibrate and verify the model.
- Apply the model.
- Process results to derive required information.

Soil Moisture Accounting (SMA)

- SMA within HEC HMS method allows for long-term continuous simulation of hydrologic processes that occur and change over time in a watershed.

- This is achieved by simulating the movement of precipitation through storage volumes that represent canopy interception, surface depressions, the soil profile and two groundwater layers.

Soil Moisture Accounting within HEC HMS Model



Input to Model

- Climatic Data
- Topographical information
- Soil type
- Land use pattern
- Hydrological information

Limitations of HEC HMS

- Availability of information for calibration or parameter estimation
- Appropriateness of the assumptions inherent in the model

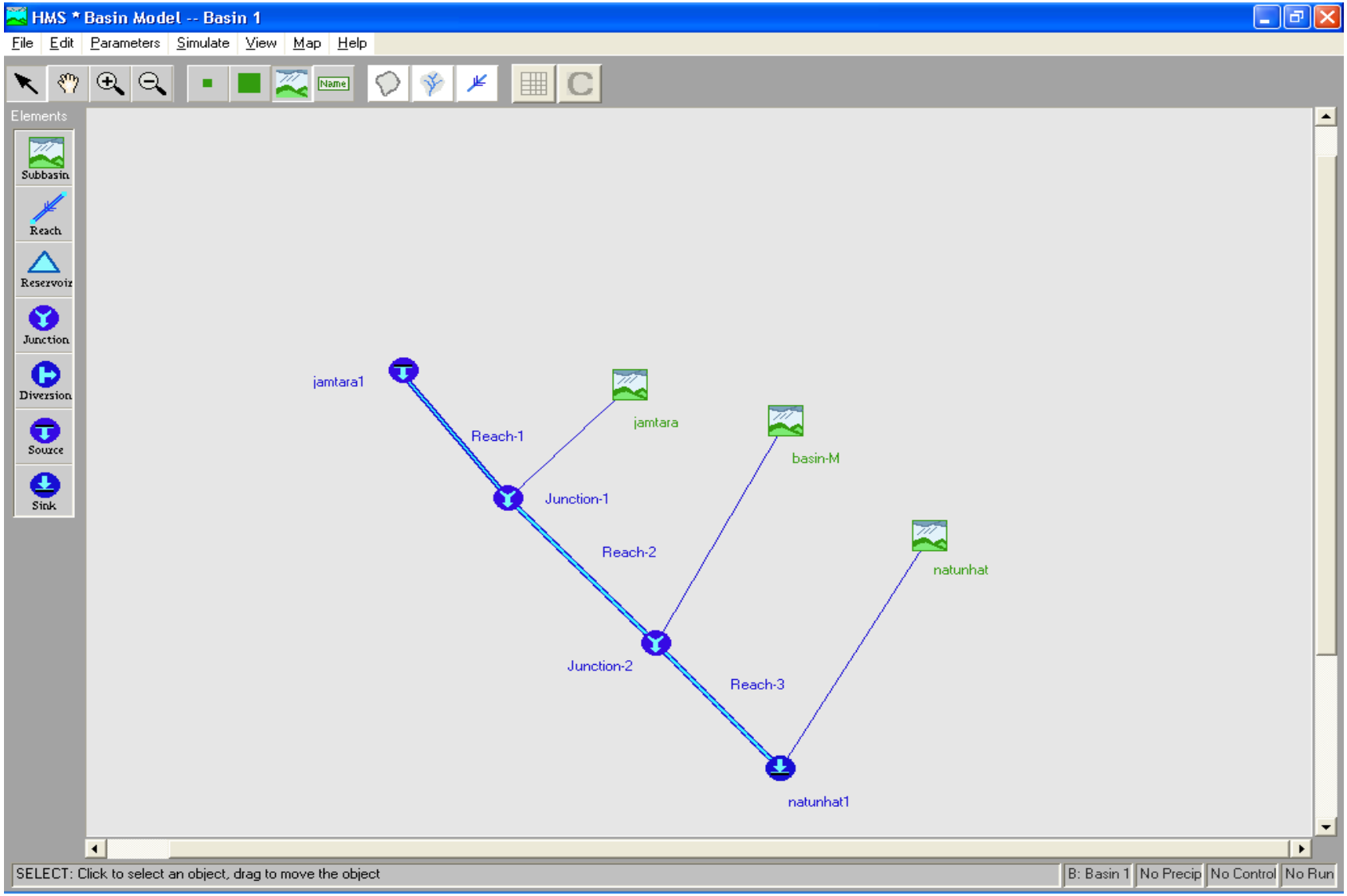
Part II: Hydrological Modeling of the Ajay River using HEC HMS Model

Introduction

- The HEC HMS model was applied to the Ajay River basin spanning Bihar and West Bengal.

- The following slides illustrate the calibration and subsequent graphs generated over the Ajay River basin using the HEC HMS model. The subbasins that were chosen within the Ajay River basin were Jamtara in Jharkhand and Natunhat in Burdwan, West Bengal.

HEC HMS Interface

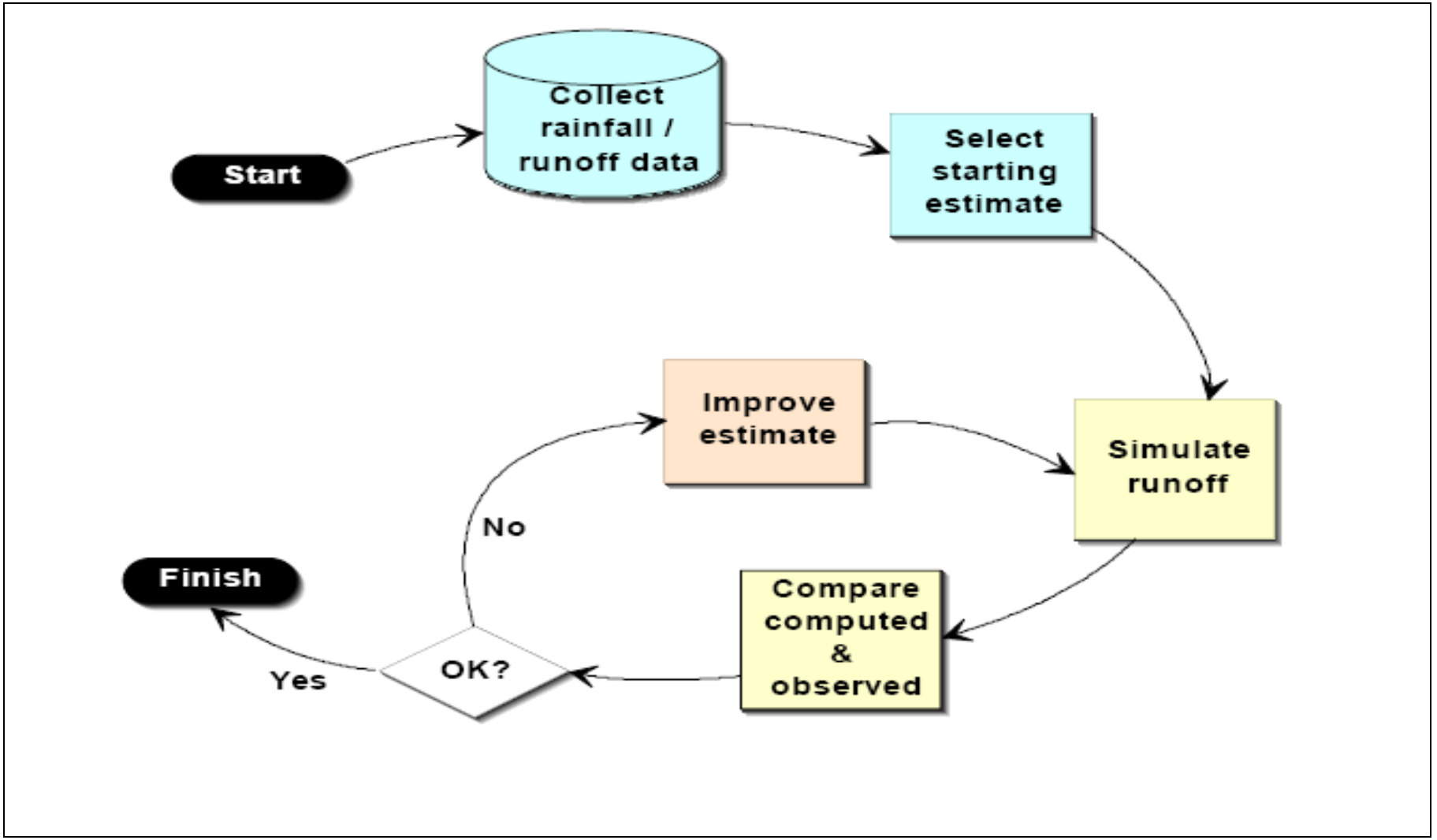


Model calibration

- Calibration is the process of adjusting the model parameter values until model simulated results match historical data

- Calibration allows us to correct errors and thus ensures our accuracy. A well calibrated model will give us a much better scope of properly utilizing the model

Calibration procedure



Input parameters & agencies

- Precipitation in mm from IMD, Kolkata
- Discharge in cumecs from CWC, Asansol
- Soil data from NATMO,NBSSLUP thematic maps
- Topographical information from SOI, Kolkata
- Futuristic statistical precipitation data from IITM, Pune obtained from on Hadley centre for climate prediction and research, UK.

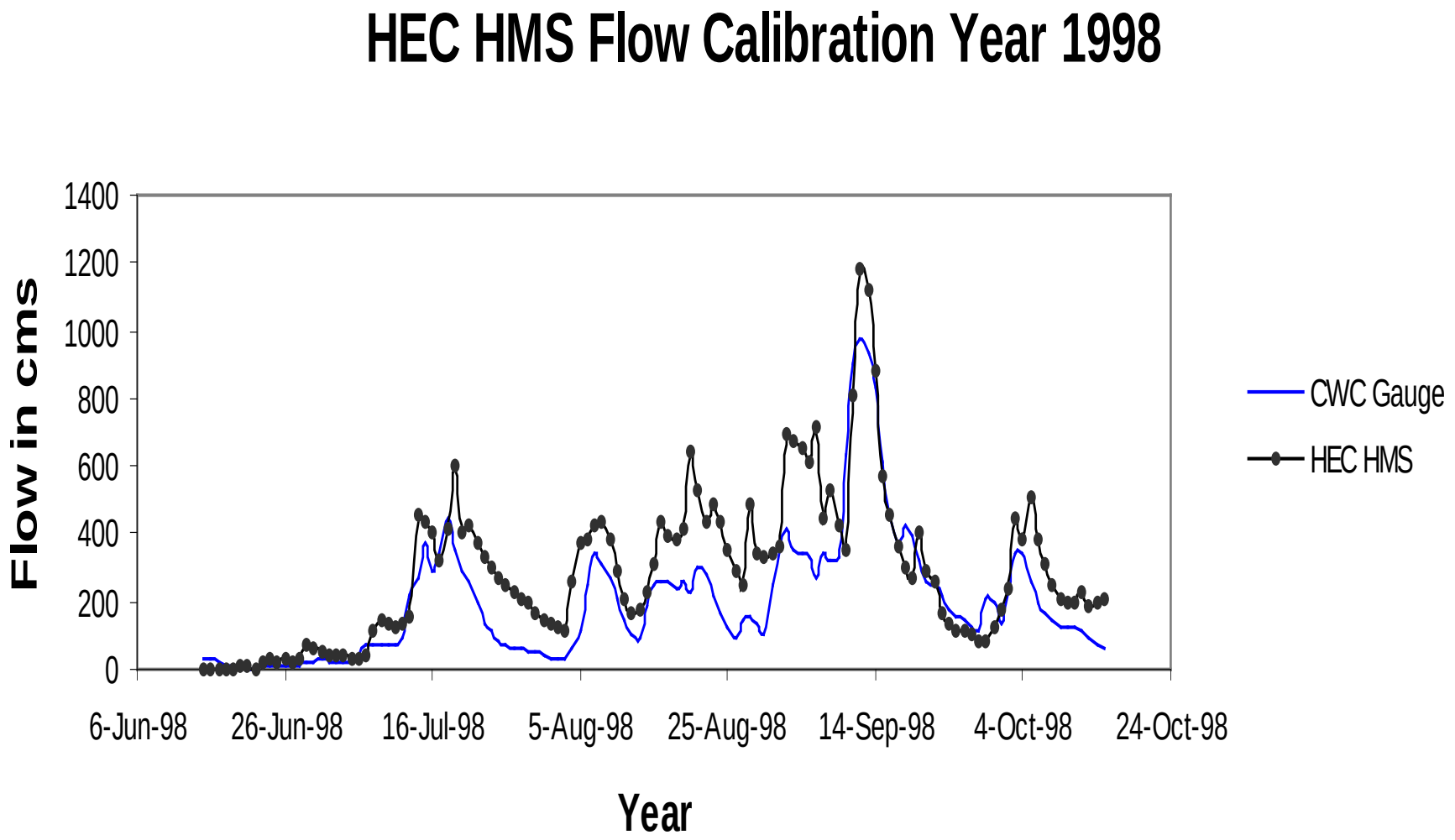
Results of Calibration

Coefficient of correlation

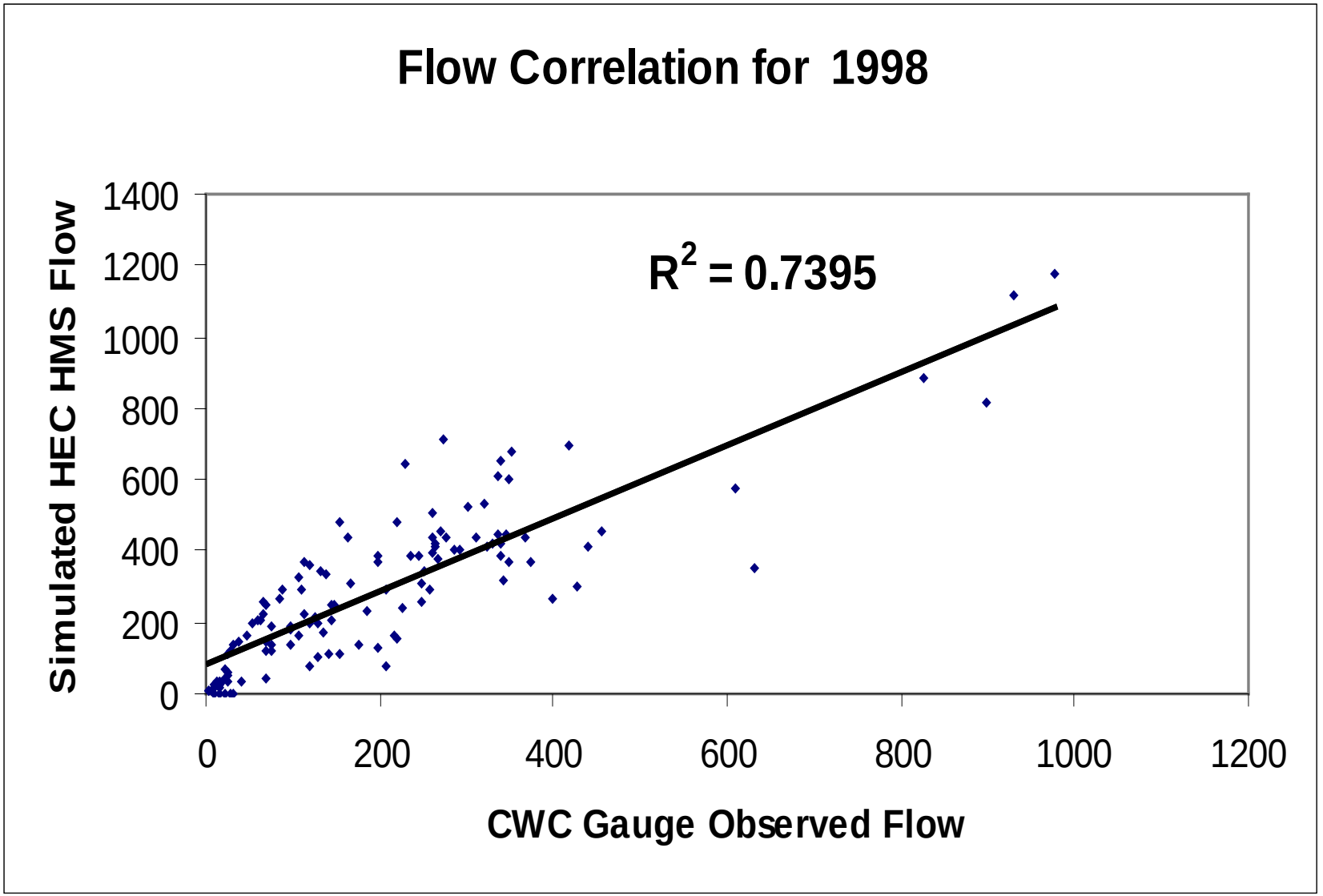
- The statistical goodness-of-fit used was the coefficient of correlation (R^2), which explains how much the measured values are explained by the simulated values indicating the strength of correlation between the two variables.

- If the value for R^2 is zero or close to zero, the model's prediction capability is poor and unacceptable. If the values are close or equal to one, the model prediction is considered perfect.

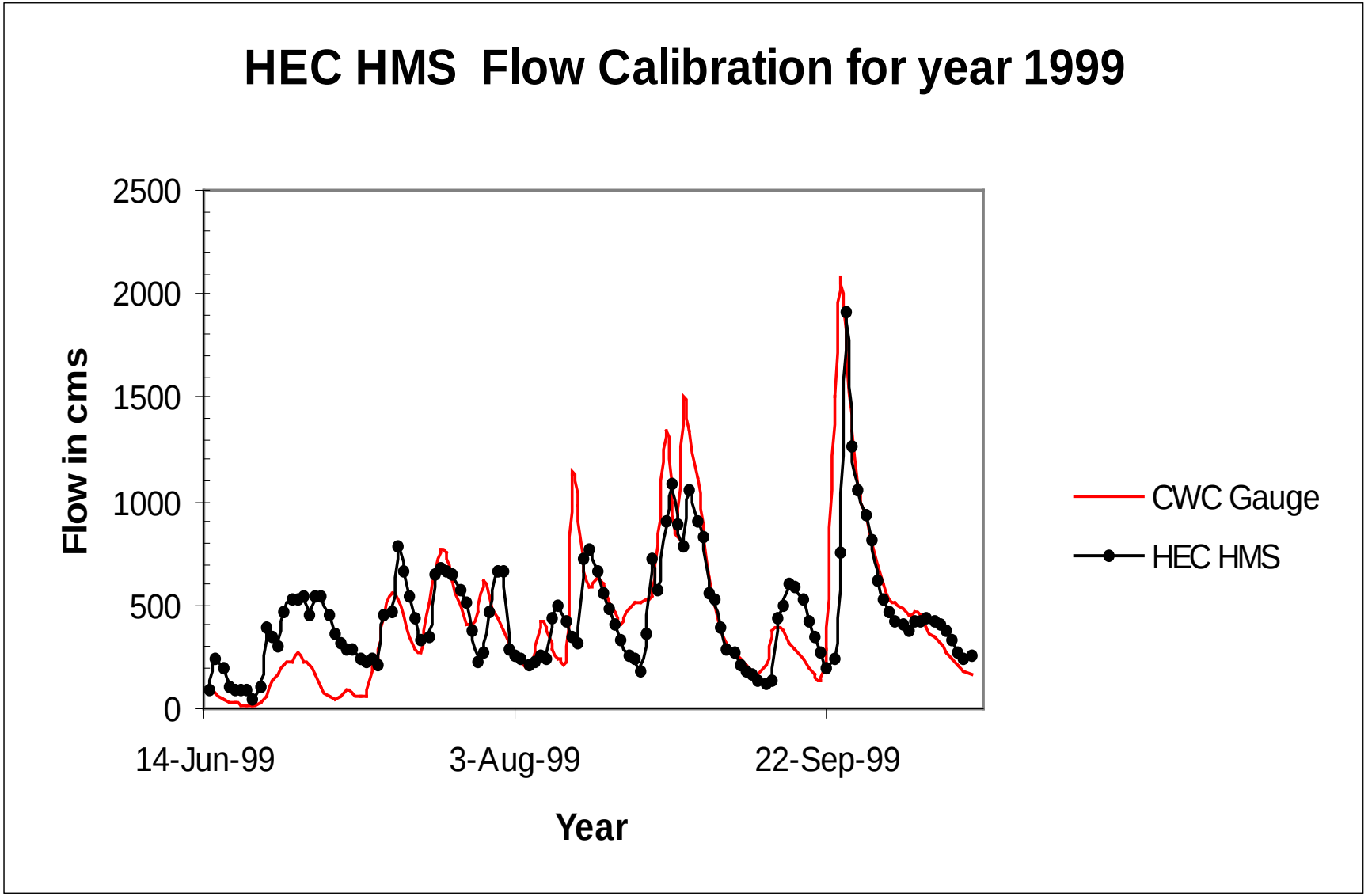
Jamtara calibration for the year 1998



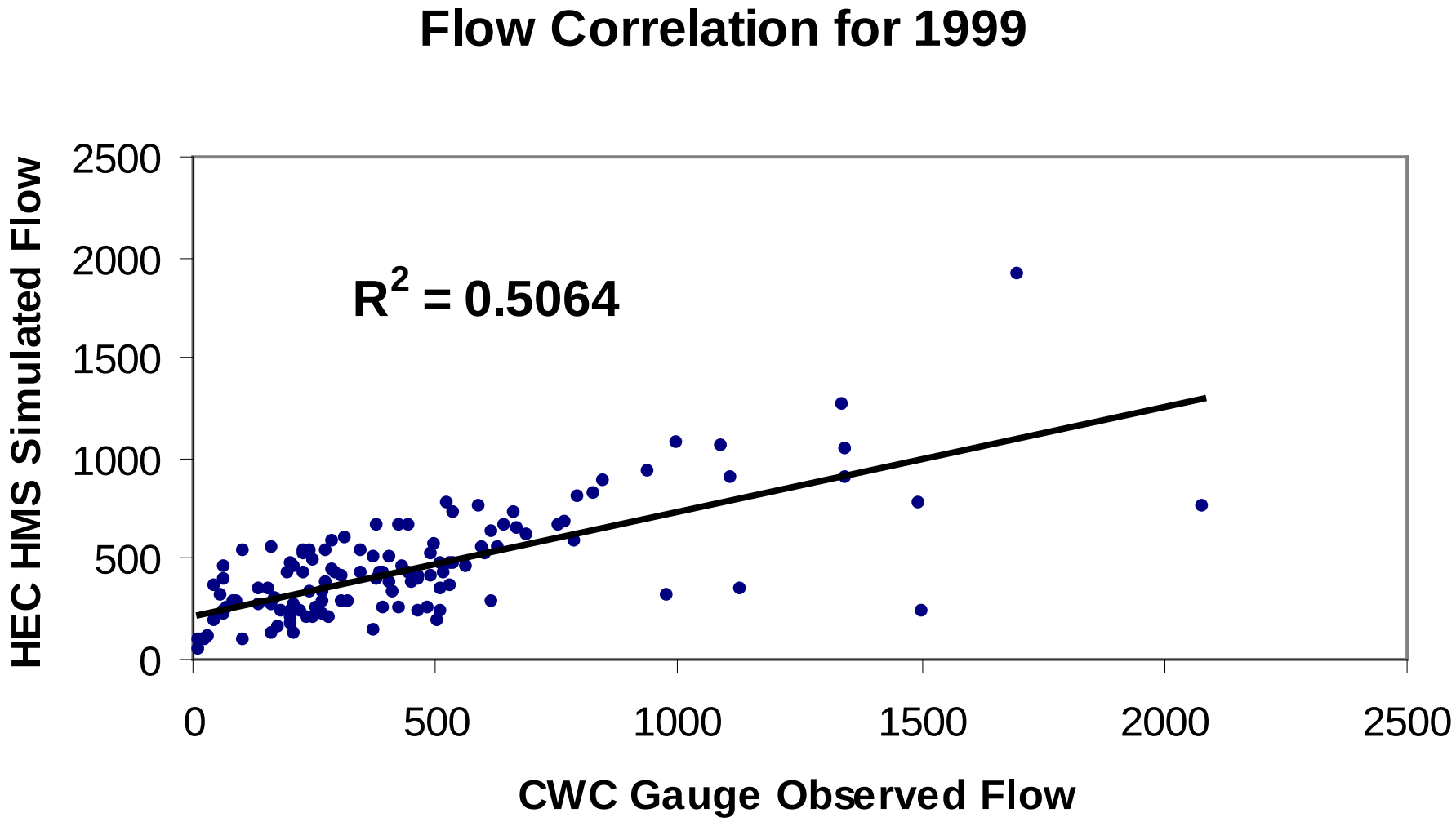
Jamtara calibration for the year 1998



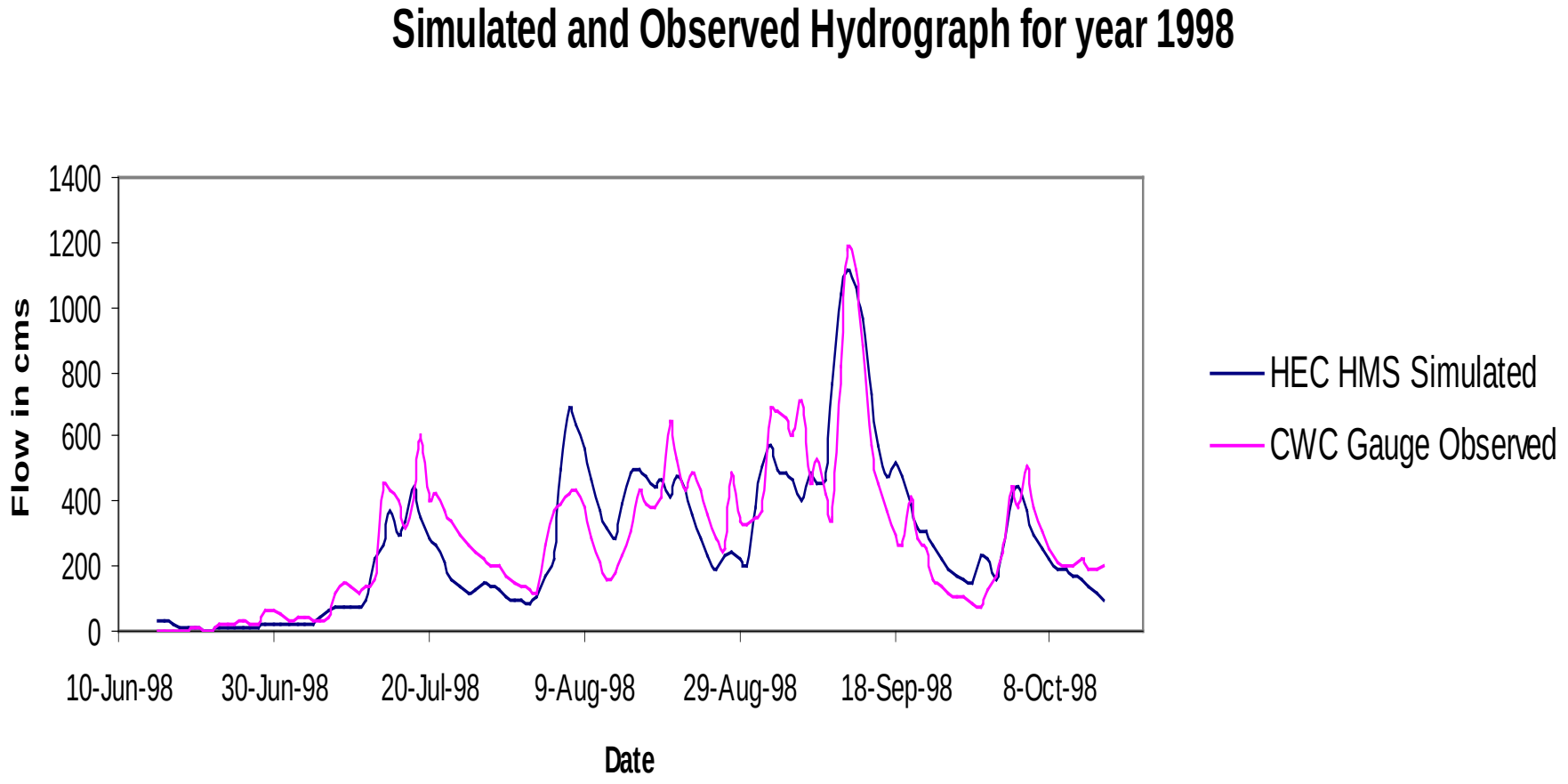
Jamtara calibration for the year 1999



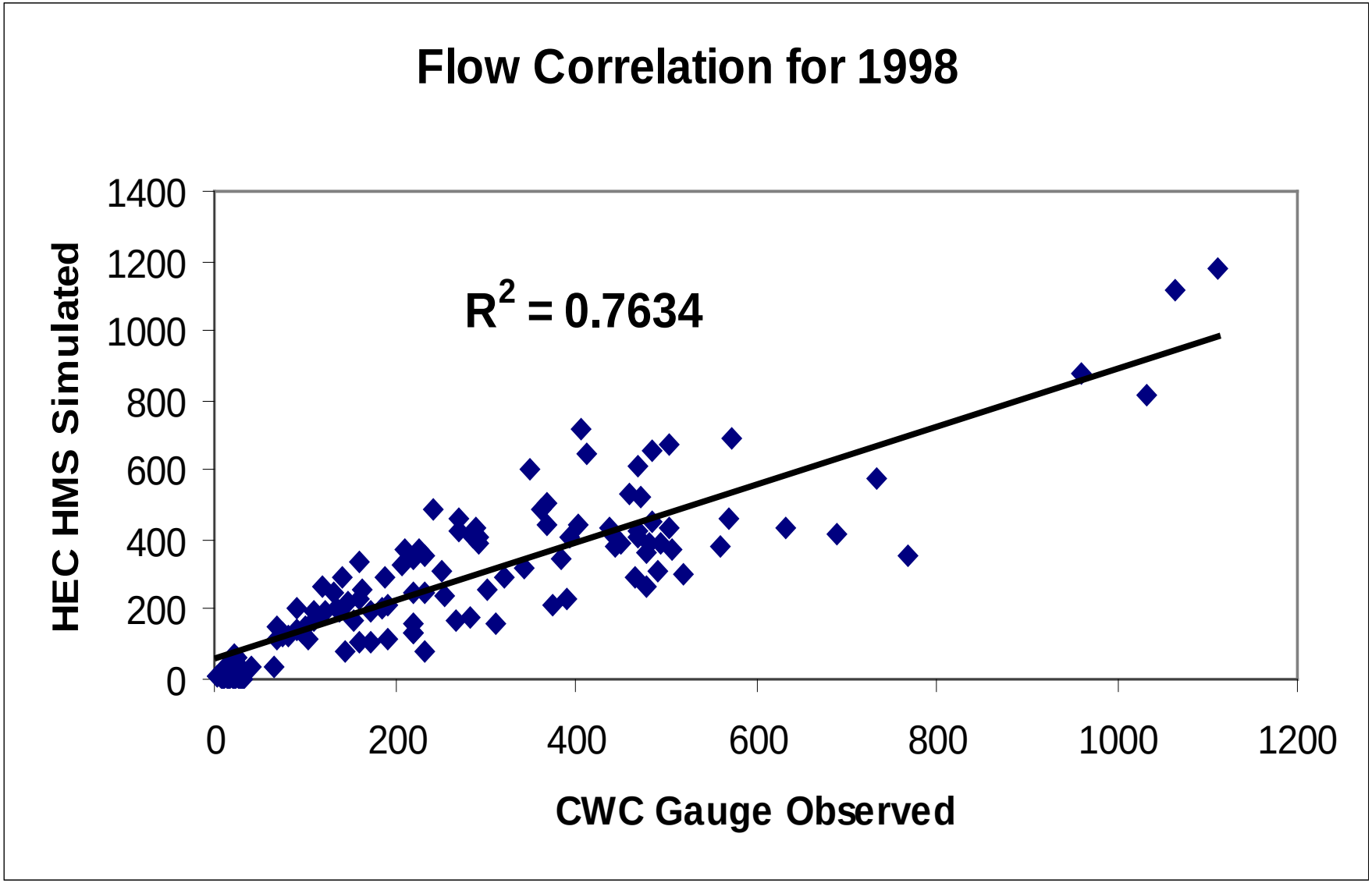
Jamtara calibration for the year 1999



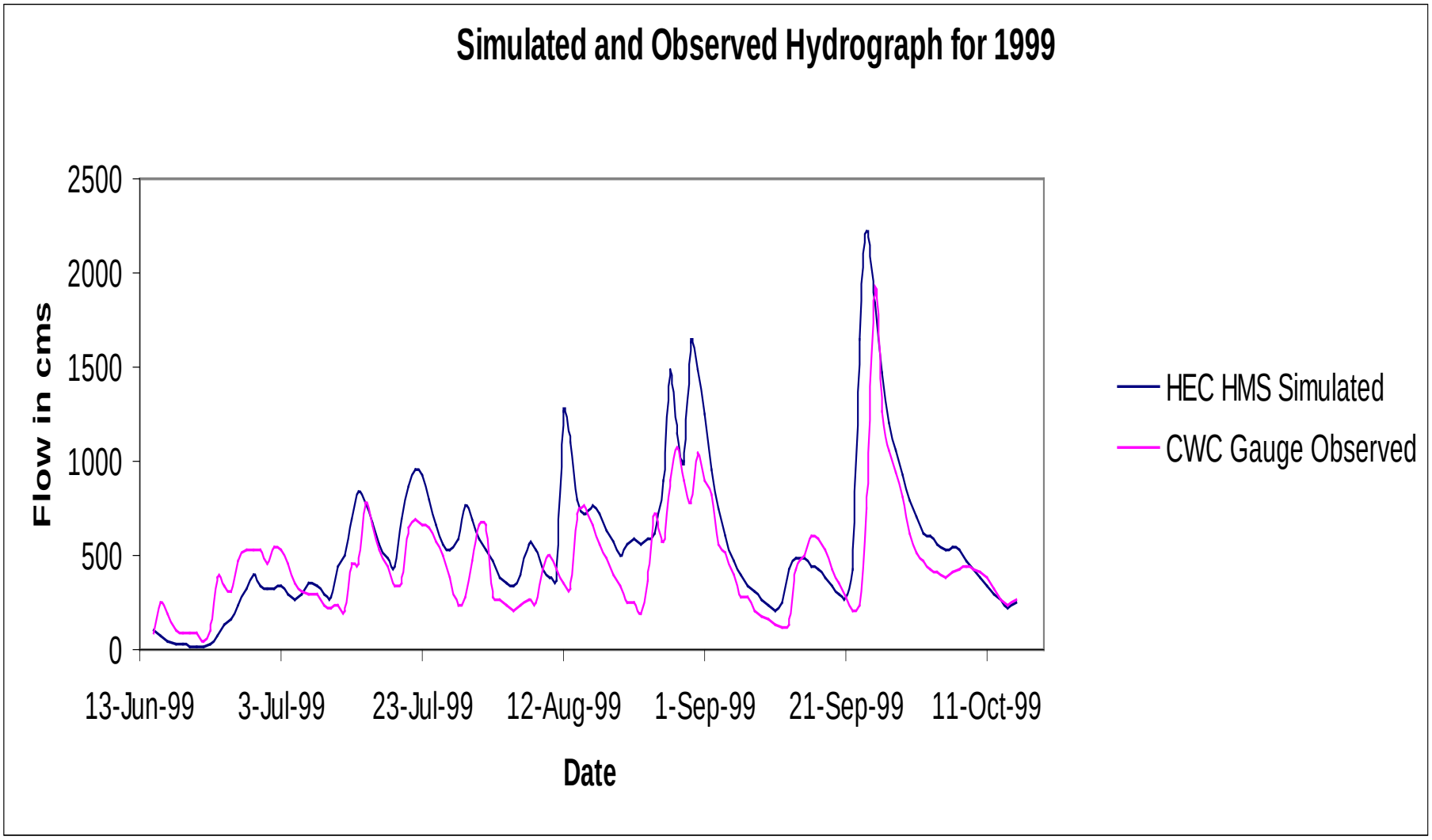
Natunhat calibration for the year 1998



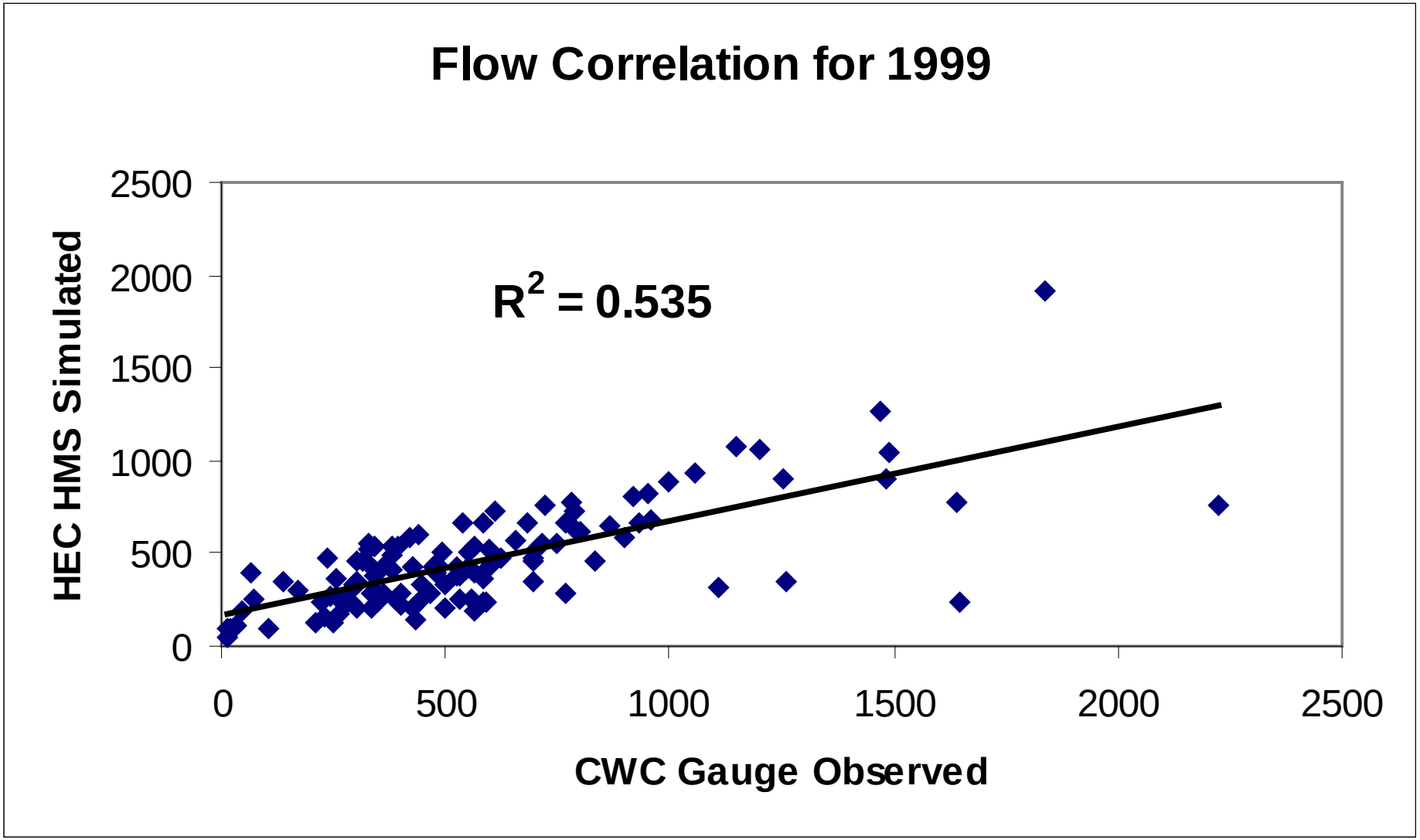
Natunhat calibration for the year 1998



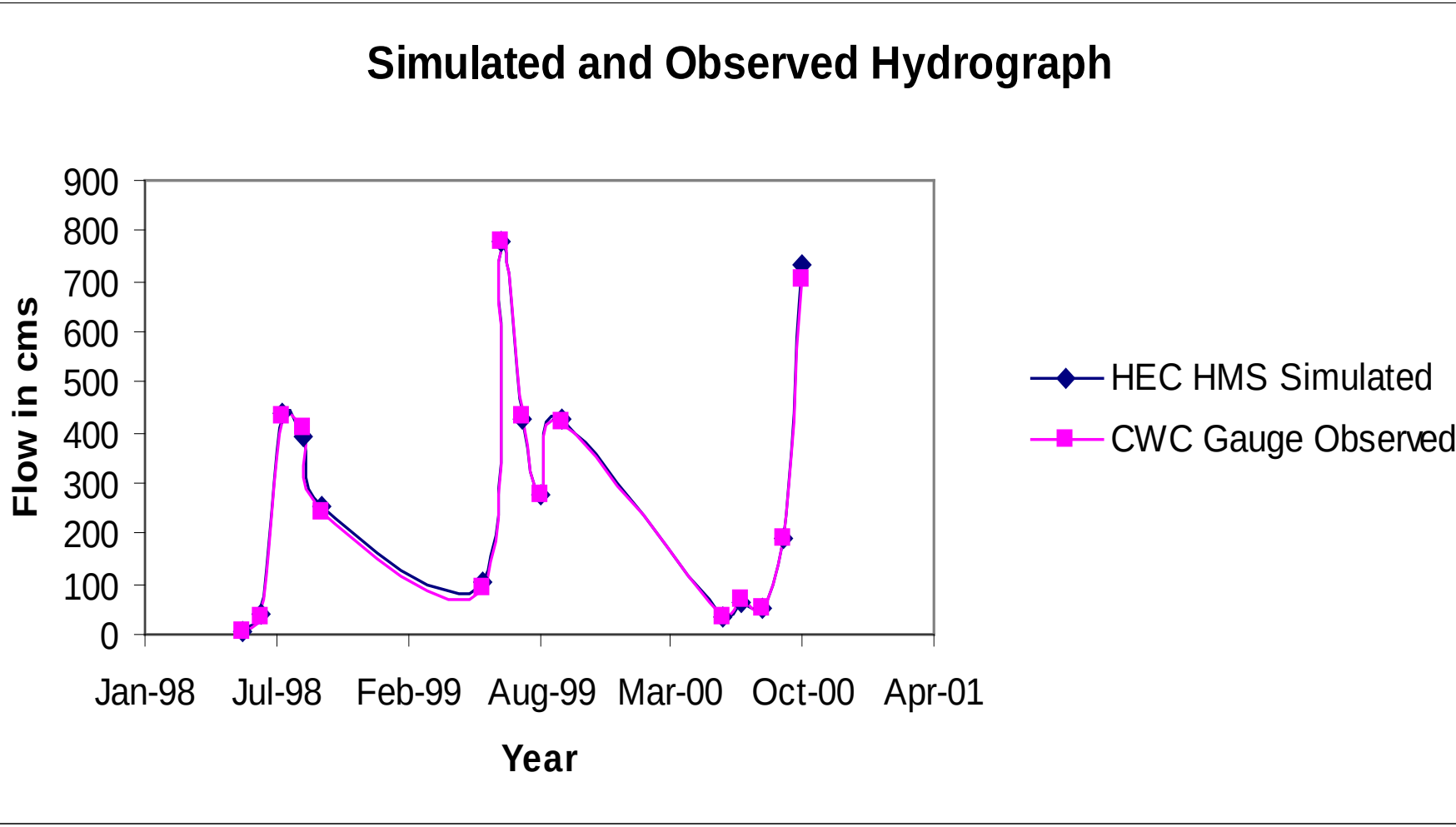
Natunhat calibration for the year 1999



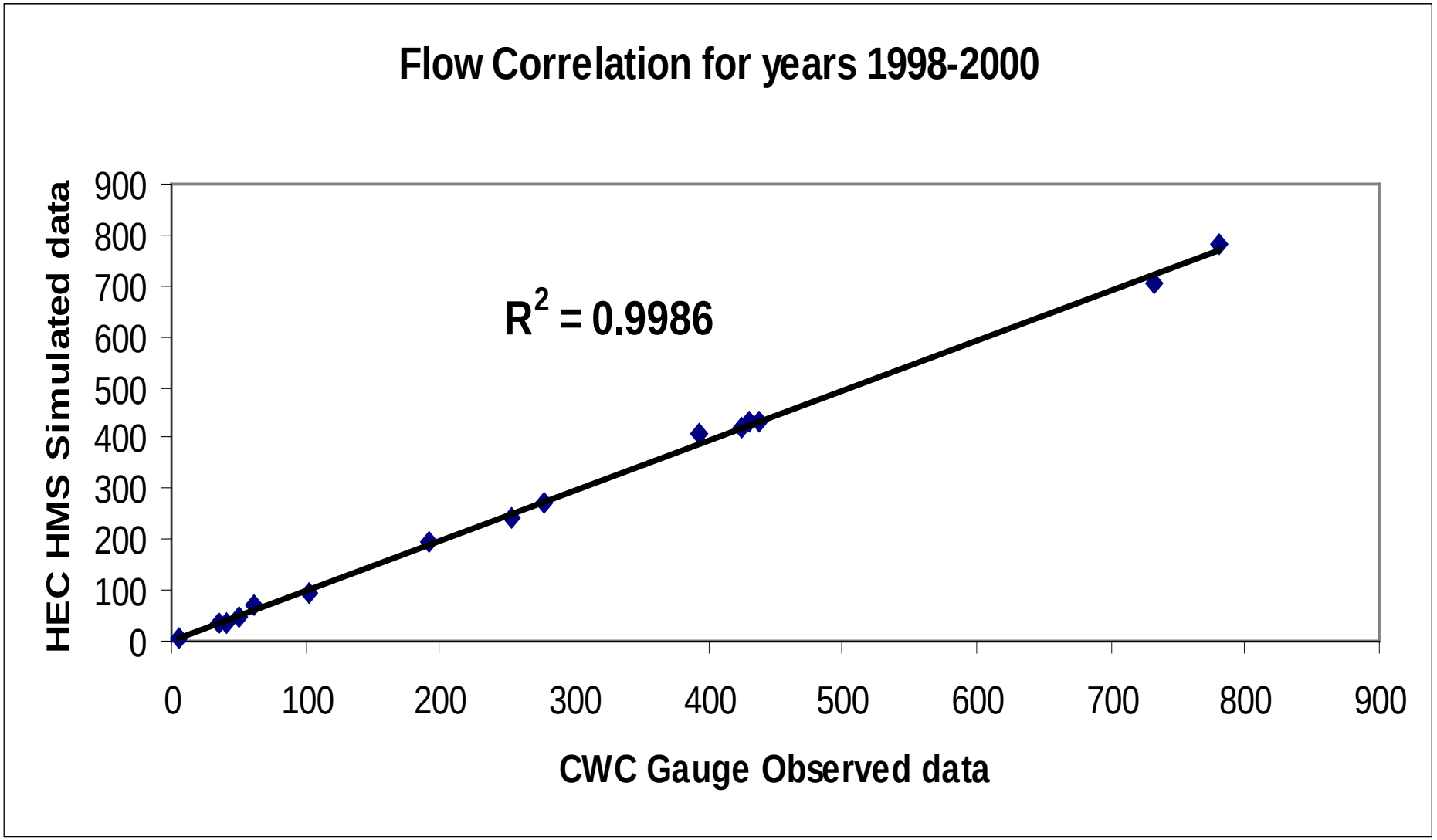
Natunhat calibration for the year 1999



Natunhat calibration for the year 1998-2000



Natunhat calibration for the year 1998-2000



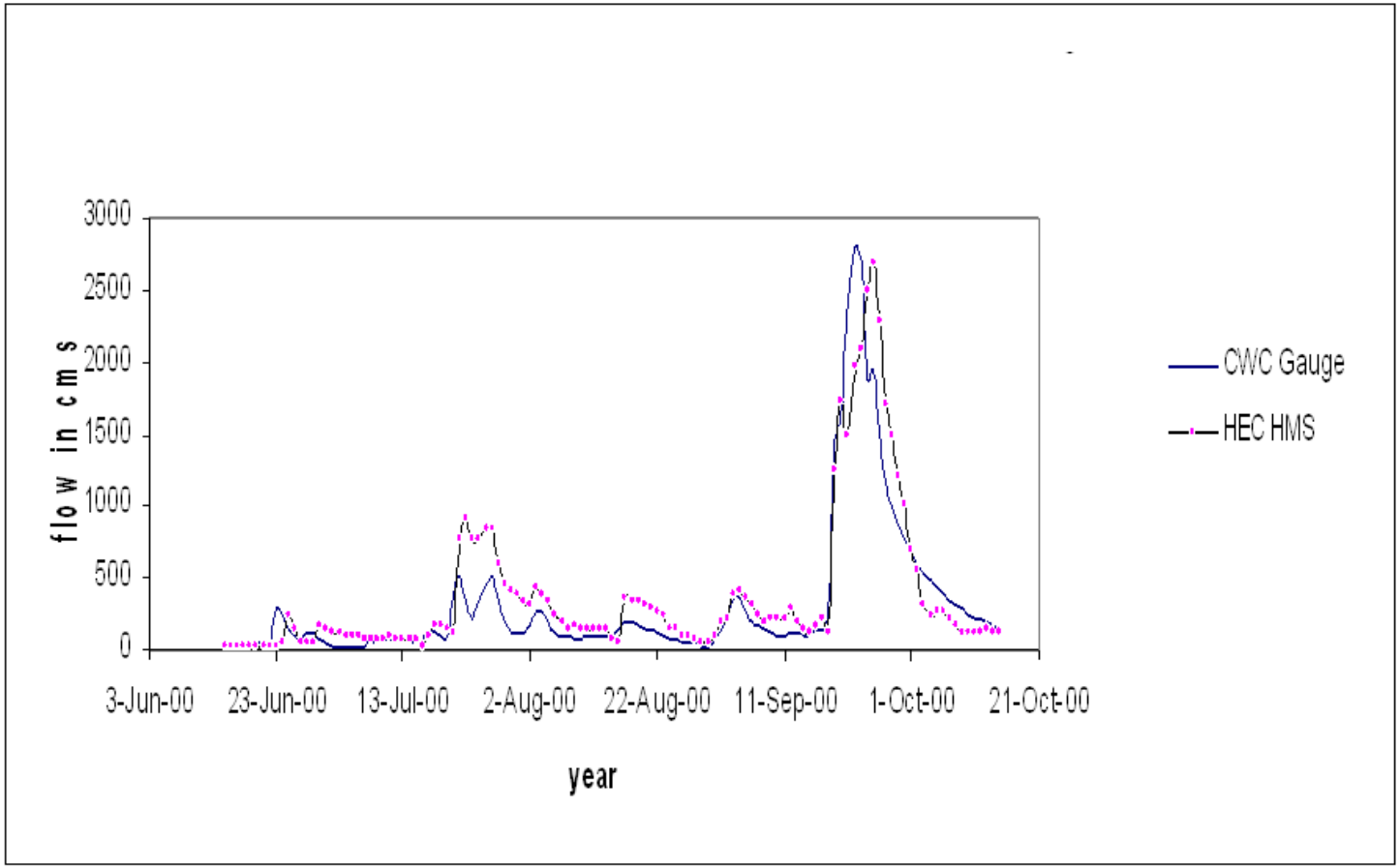
Model validation

- Model validation was performed for the annual and monthly stream flows of the Jamtara & Natunhat sub-basins. The site was selected based on the availability of measured flow data.

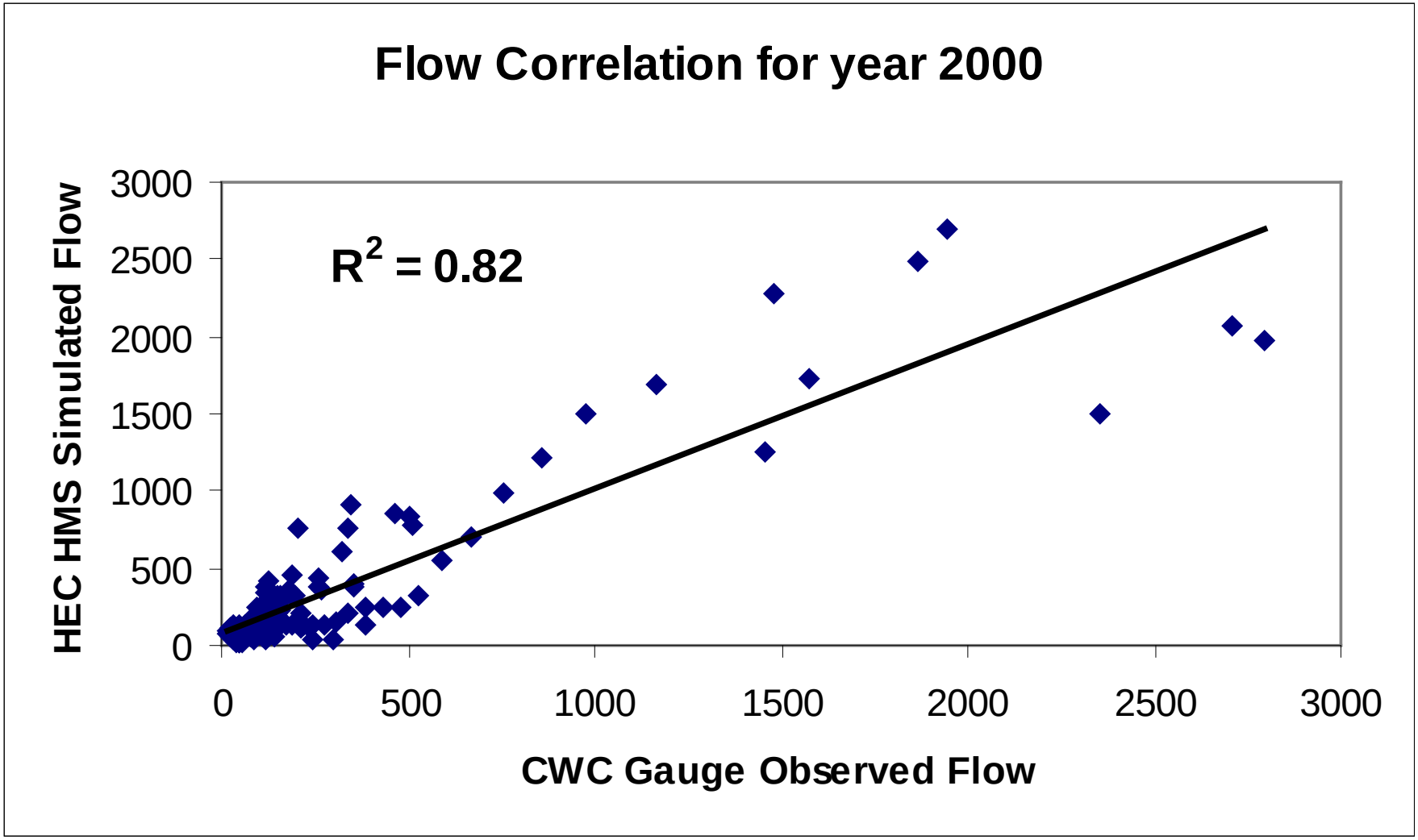
- In the validation process, the model run was made with input parameters set during the calibration process without any change and the results were compared with observed data from the year 2000 were used for calibration.

Results of Validation Study

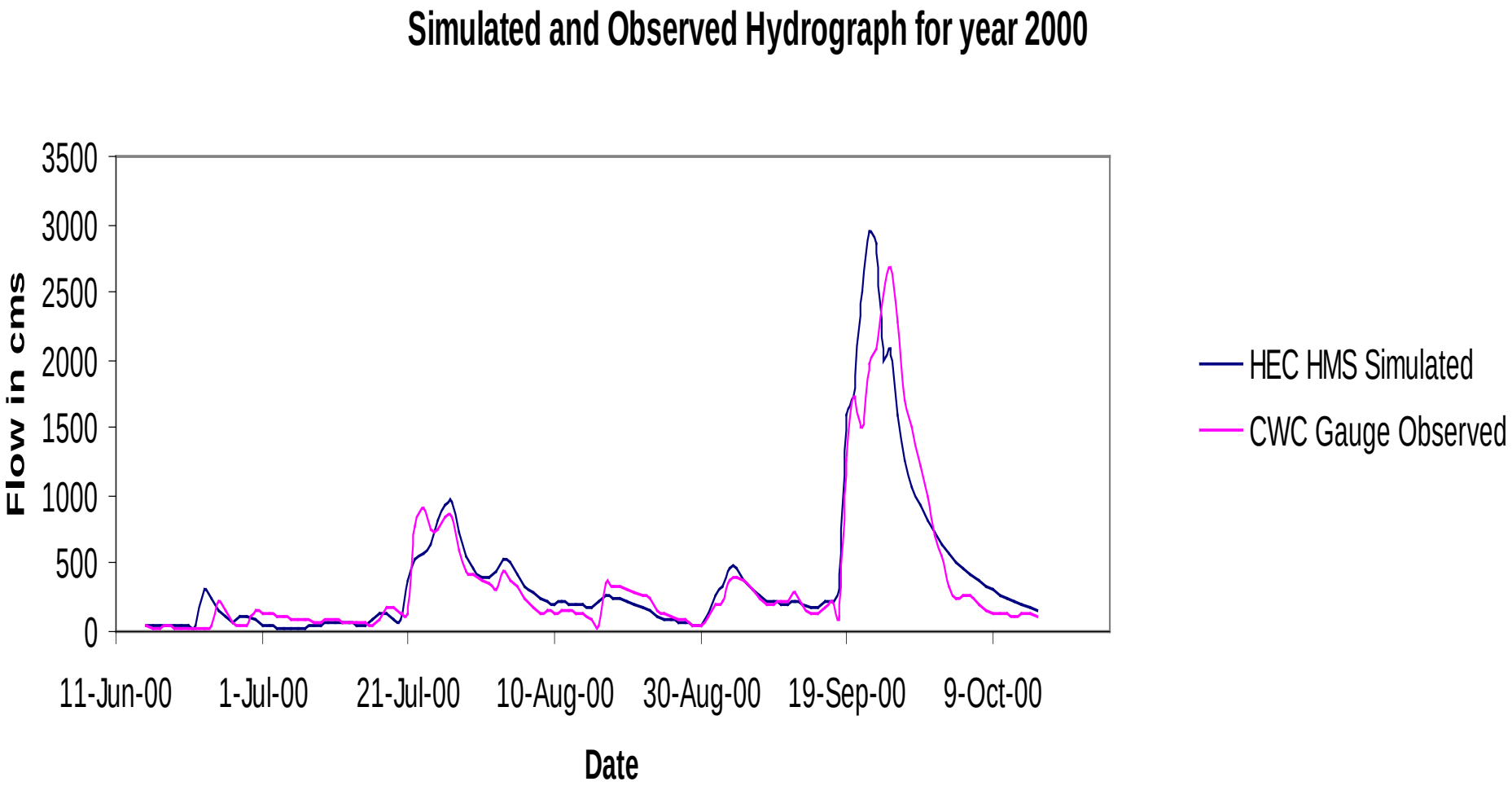
Flow validation over Jamtara for the year 2000



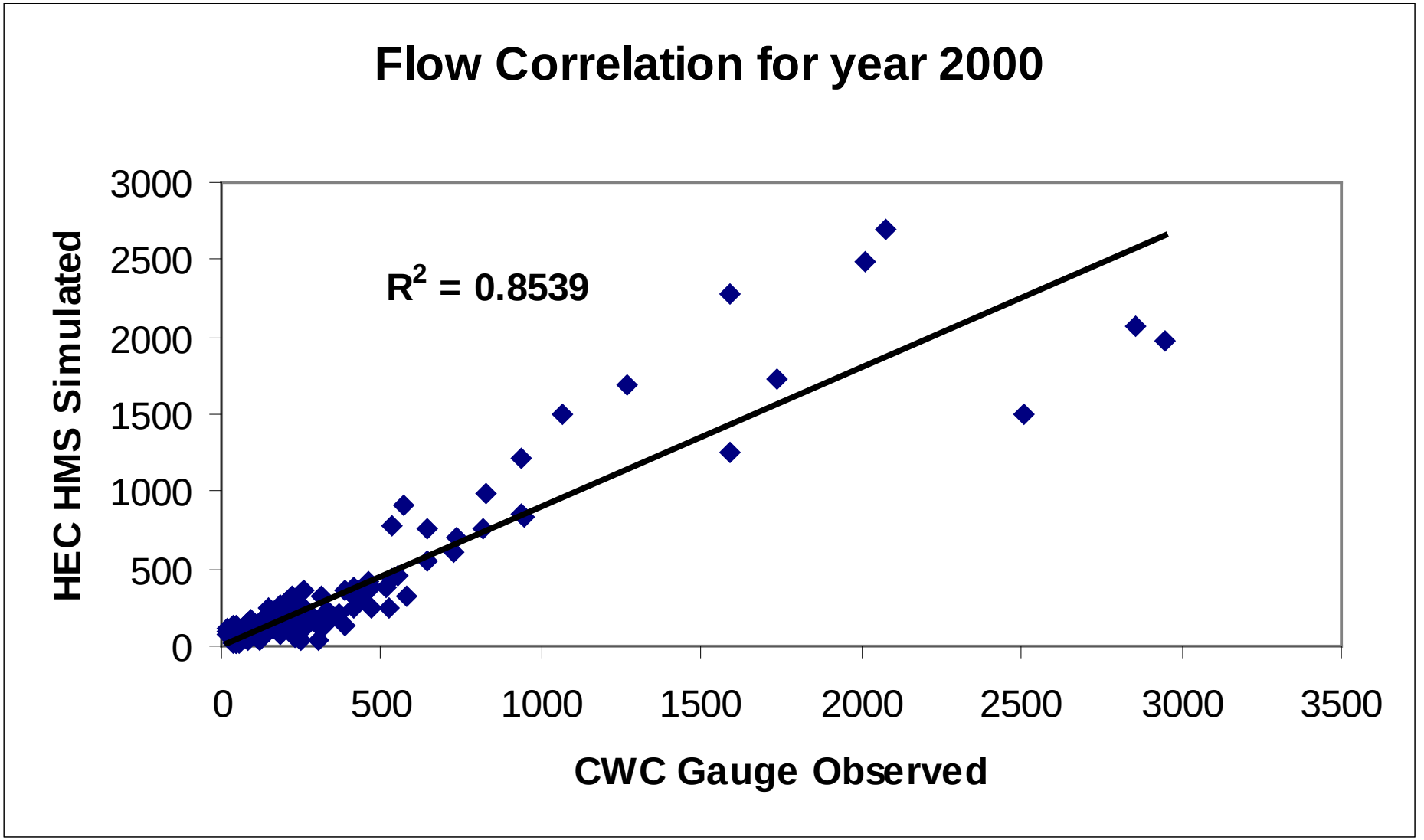
Flow validation over Jamtara for the year 2000



Flow validation over Natunhat for the year 2000

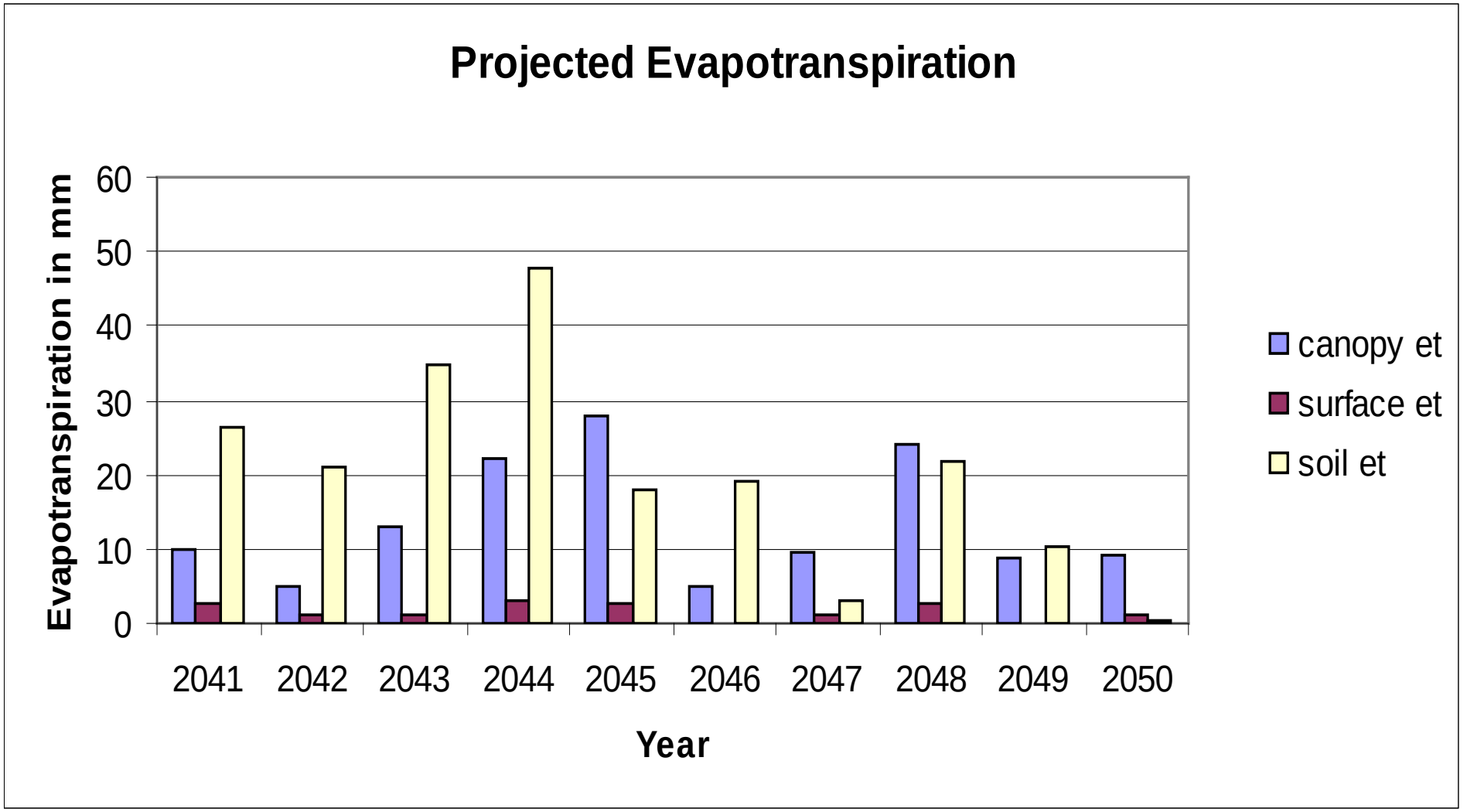


Flow validation over Natunhat for the year 2000

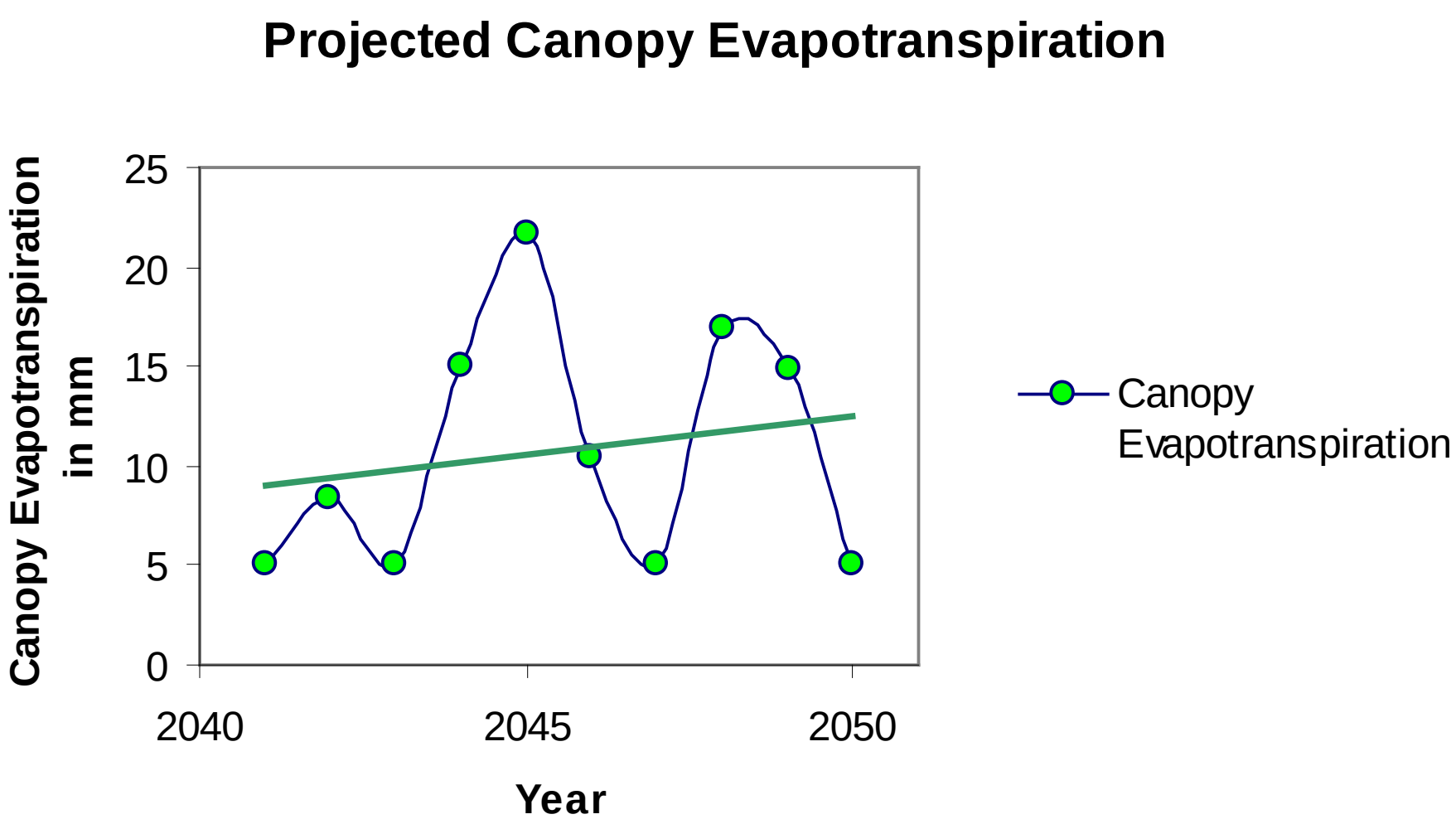


Projected Results for the years 2042-2050

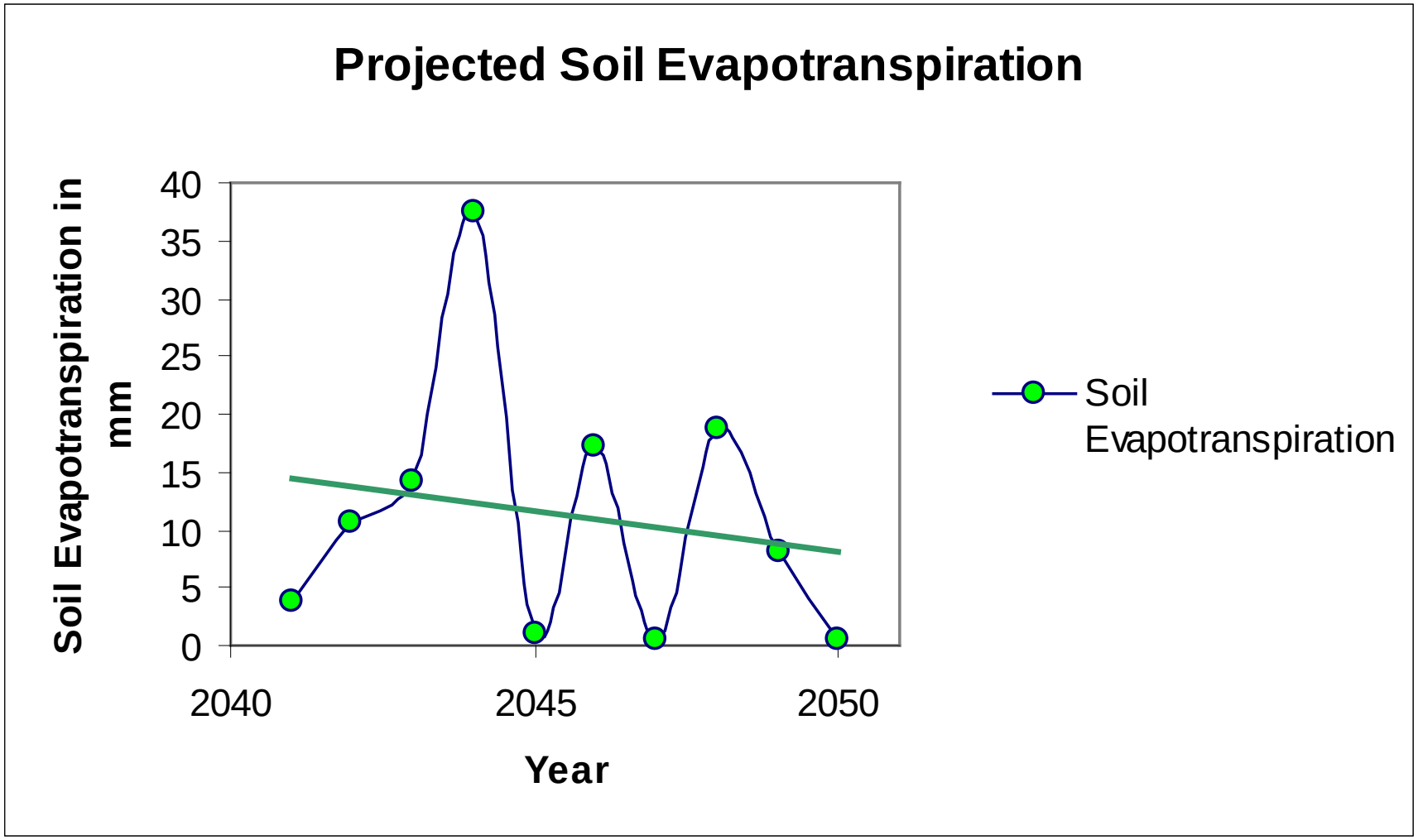
Projections for Jamtara during the years 2042-2050



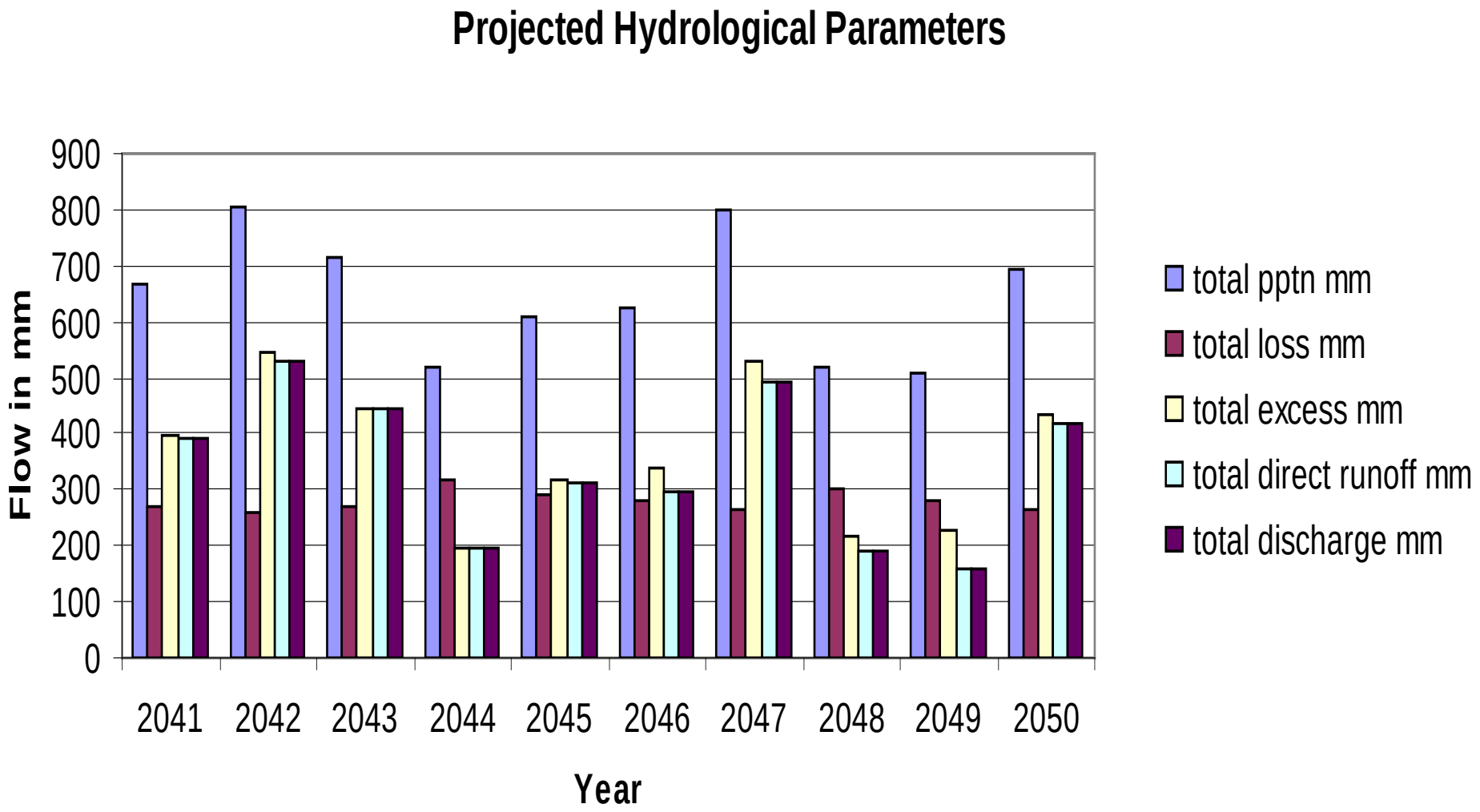
Projections for Natunhat during the years 2042-2050



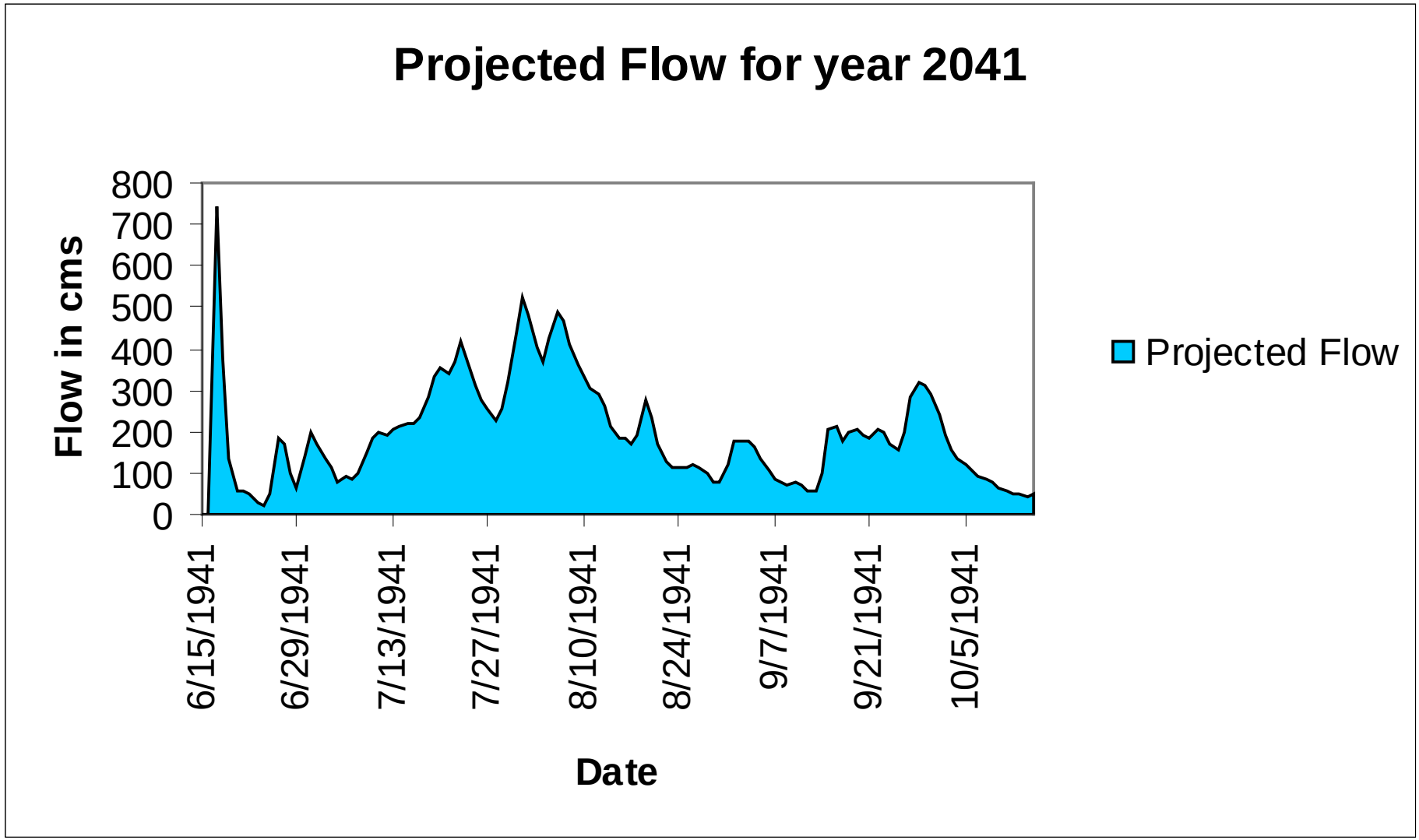
Projections for Natunhat during the years 2042-2050



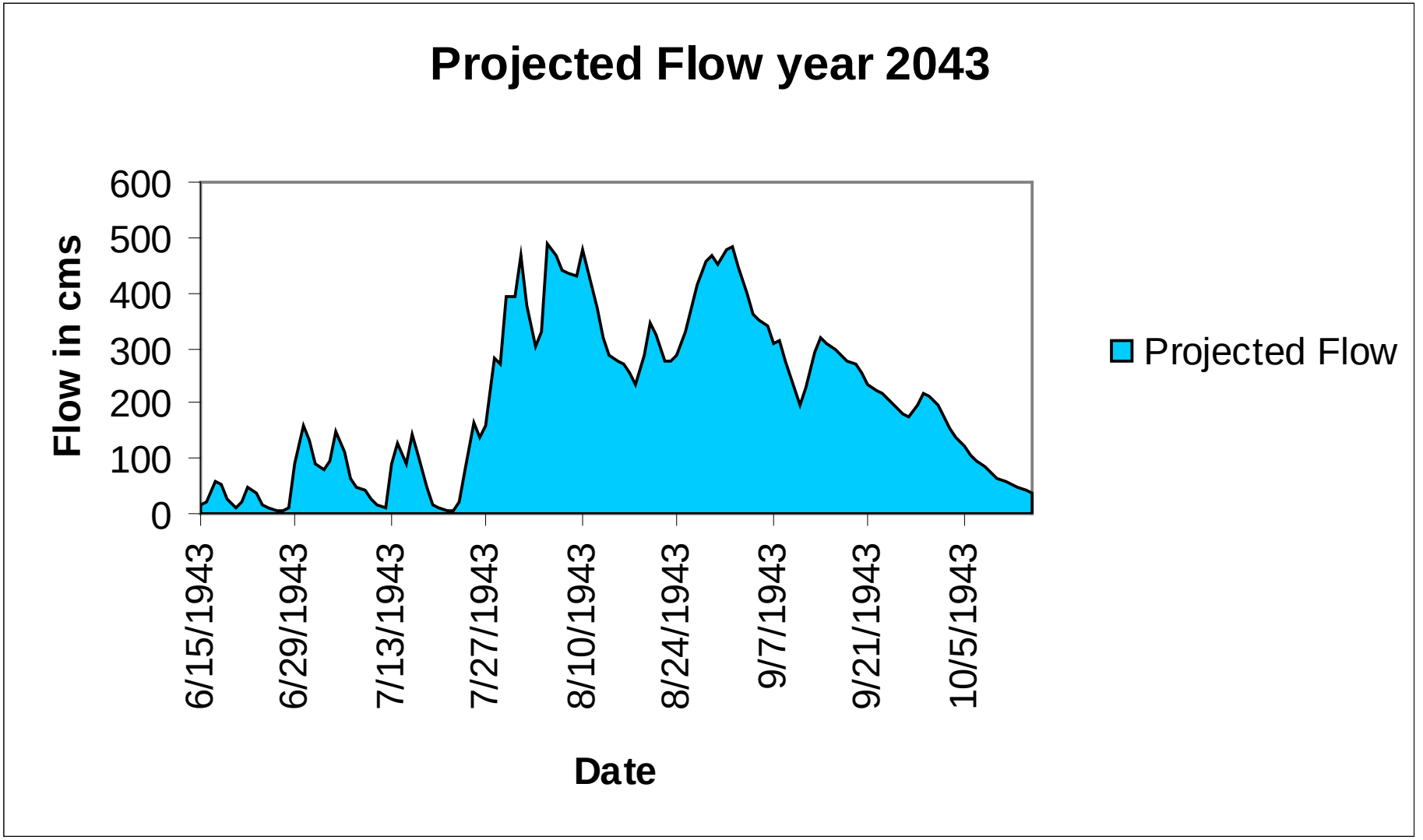
Projections for Jamtara during the years 2042-2050



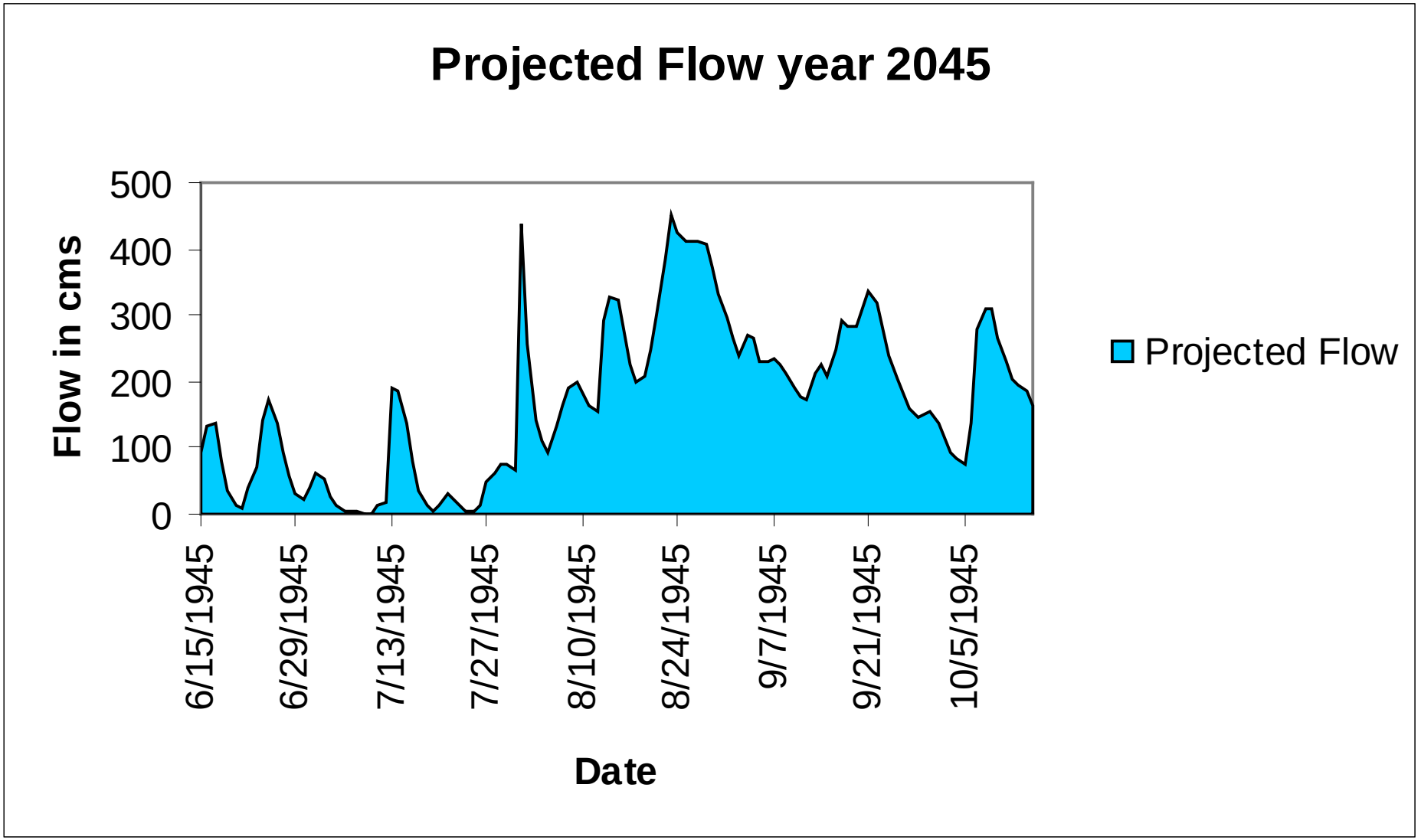
Projection for Natunhat during the year 2041



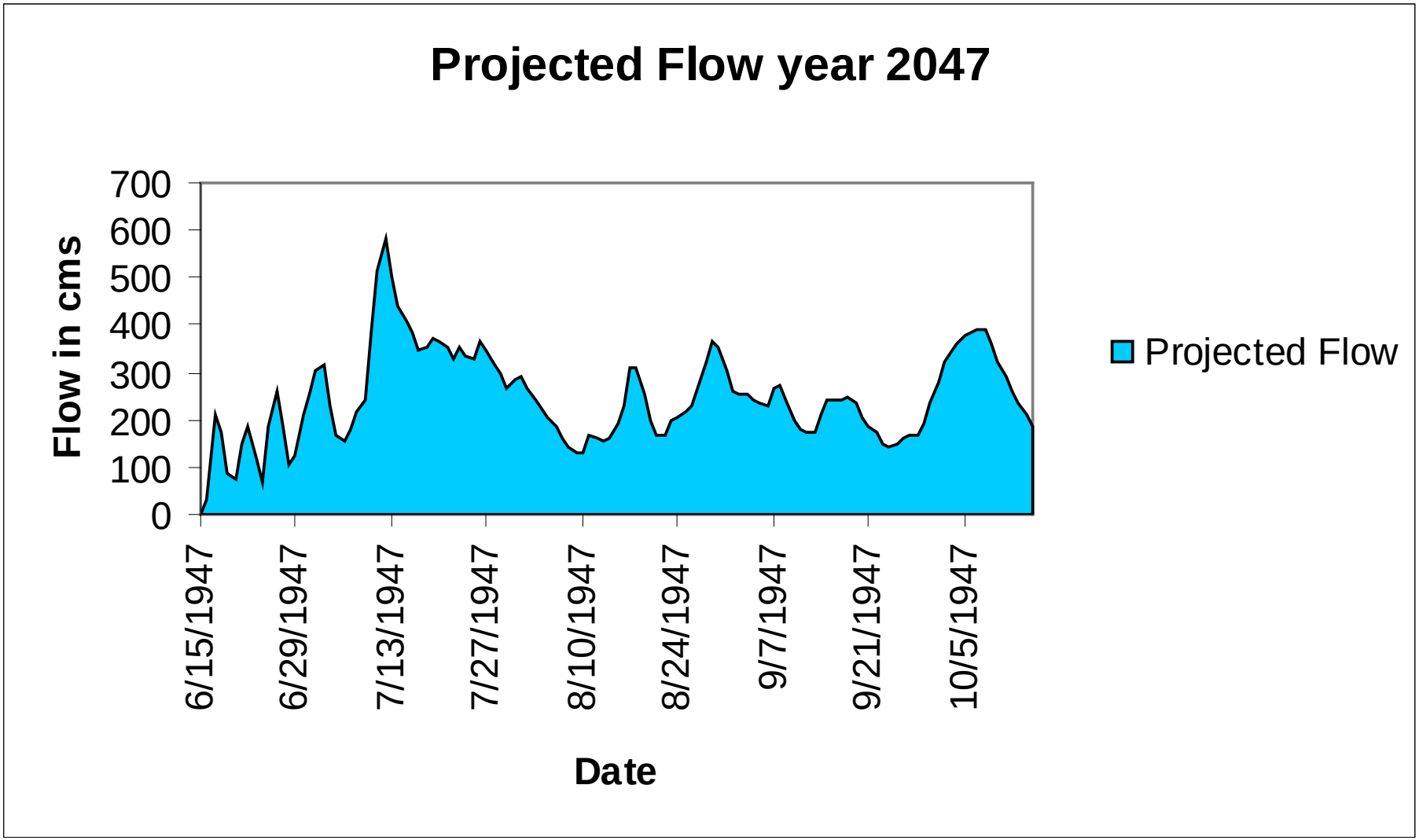
Projection for Natunhat during the year 2043



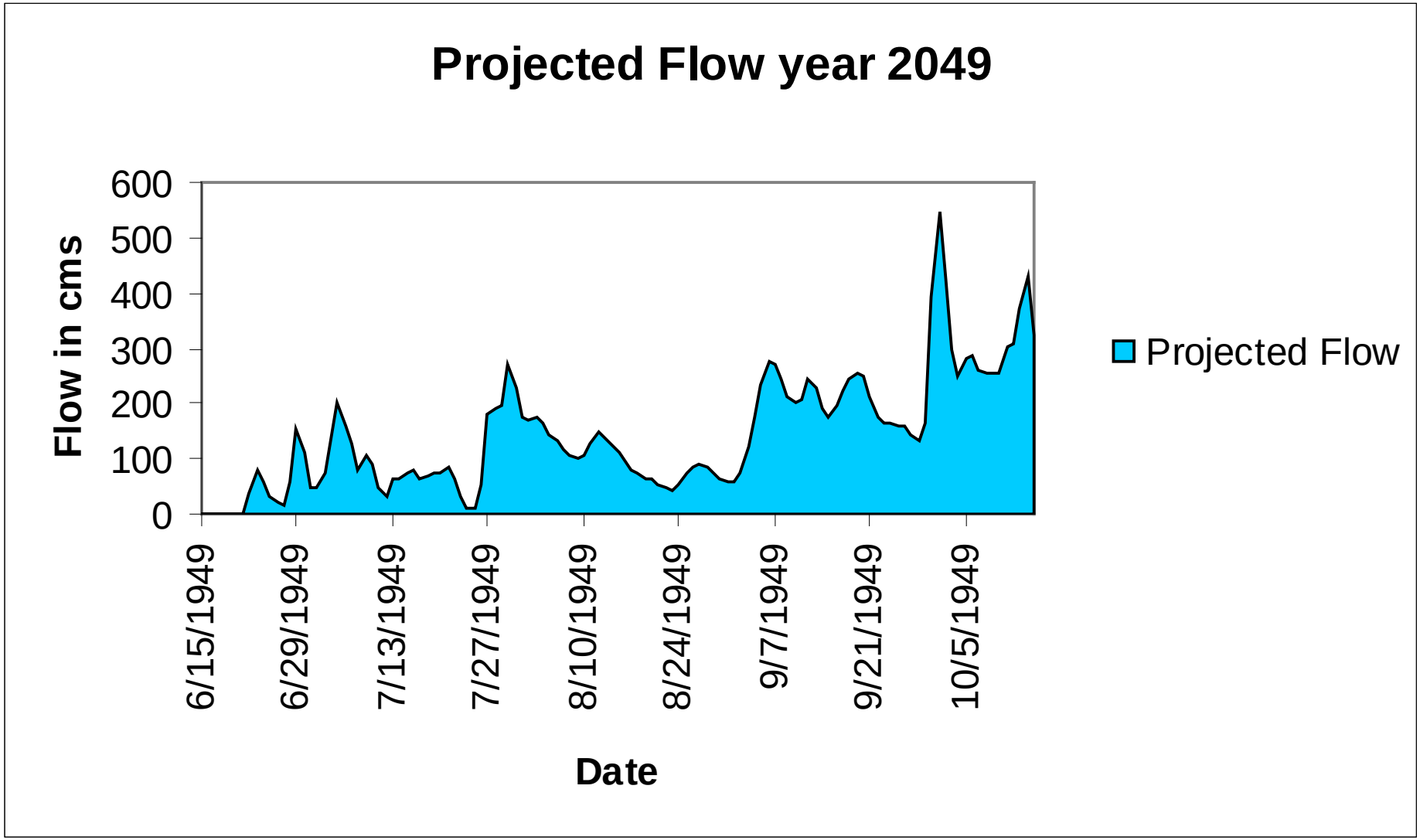
Projection for Natunhat during the year 2045



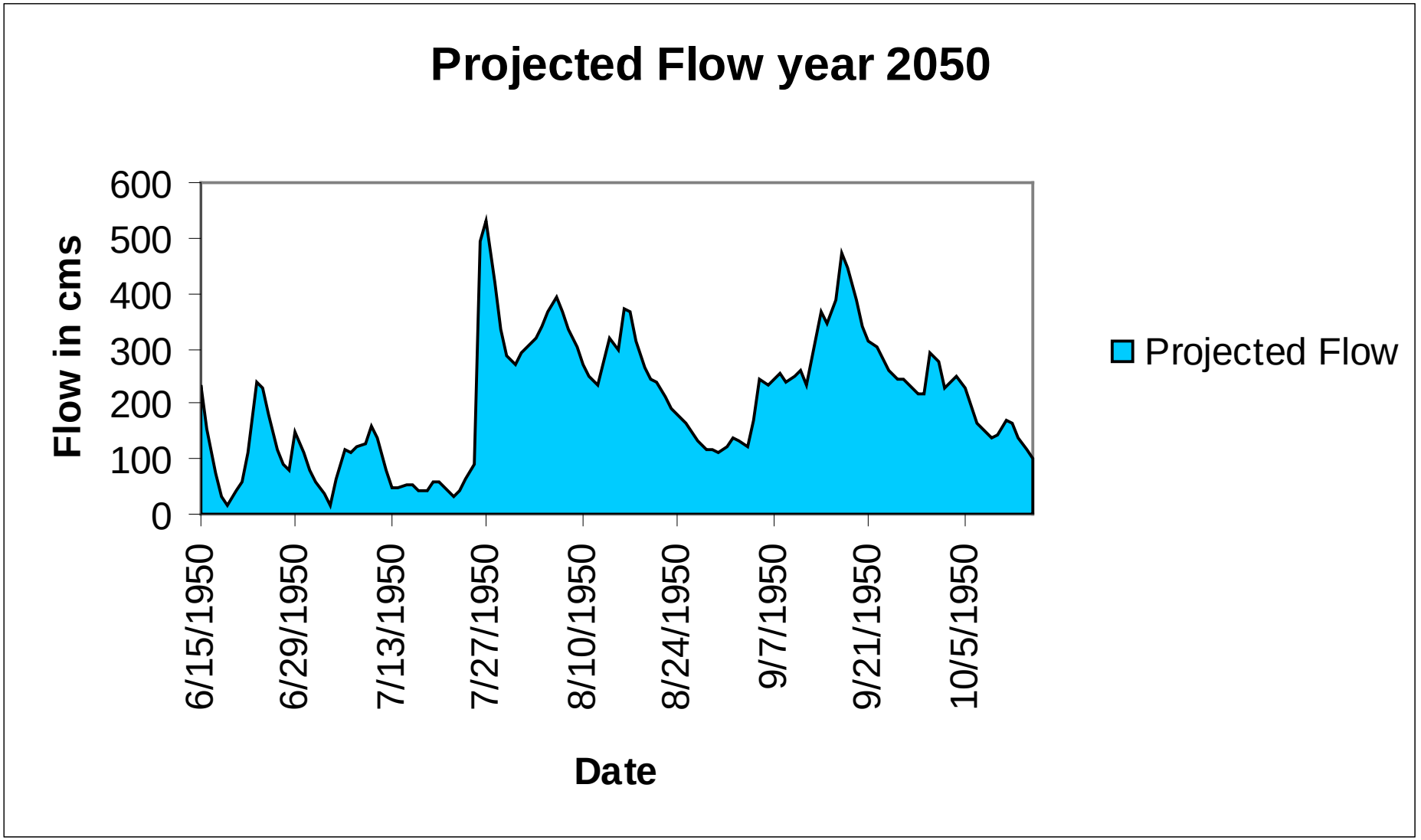
Projection for Natunhat during the year 2047



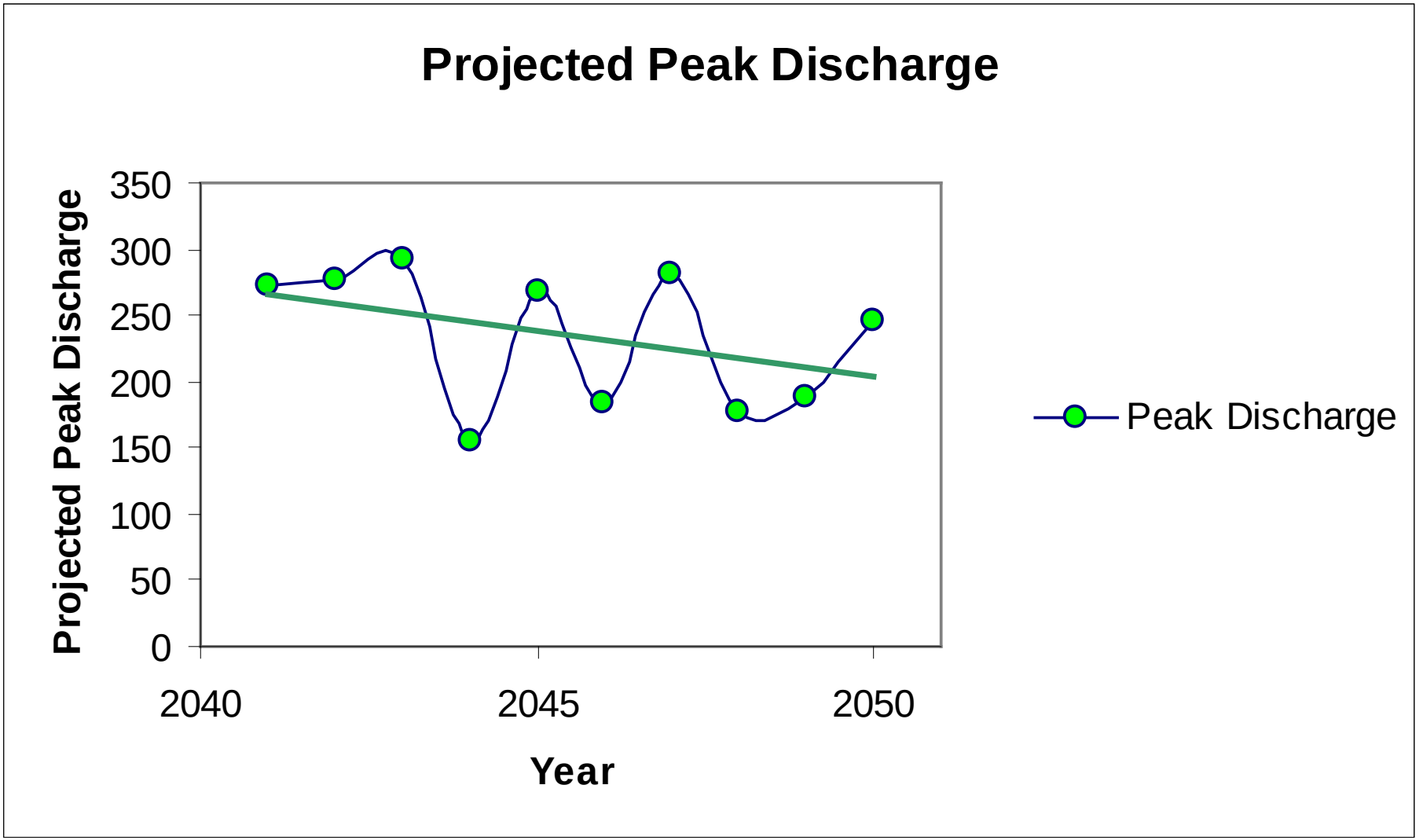
Projection for Natunhat during the year 2049



Projection for Natunhat during the year 2050



Projection for Natunhat during the years 2042-2050



Observations

- It was observed that precipitation, discharge, excess and direct runoff decrease while losses increase over the mentioned time frame.

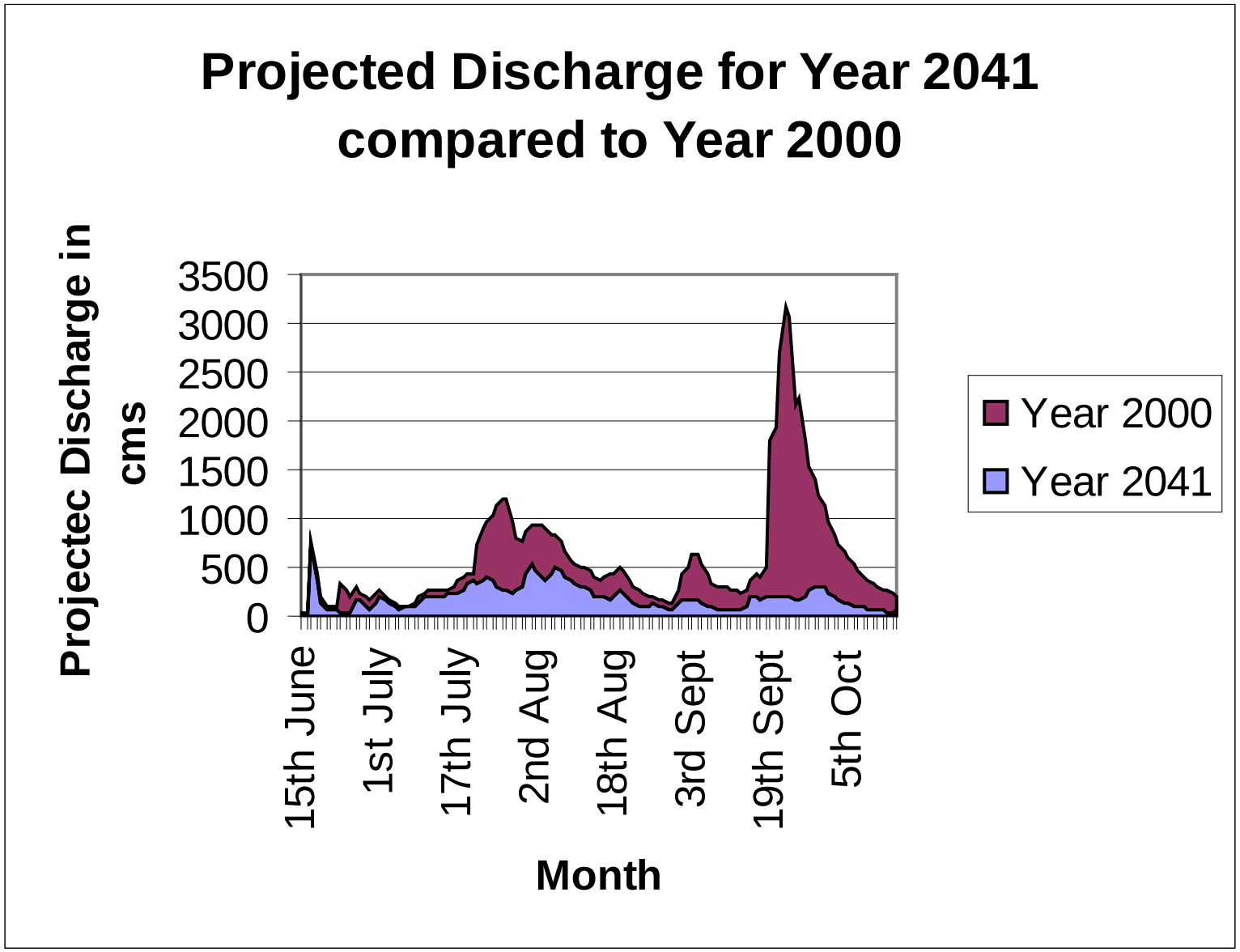
- Soil parameters such as canopy evapotranspiration are seen to increase. The soil evapotranspiration and surface evapotranspiration are seen to display a decreasing trend from the year 2041-2050.

Projected discharge comparison at Natunhat 1/2

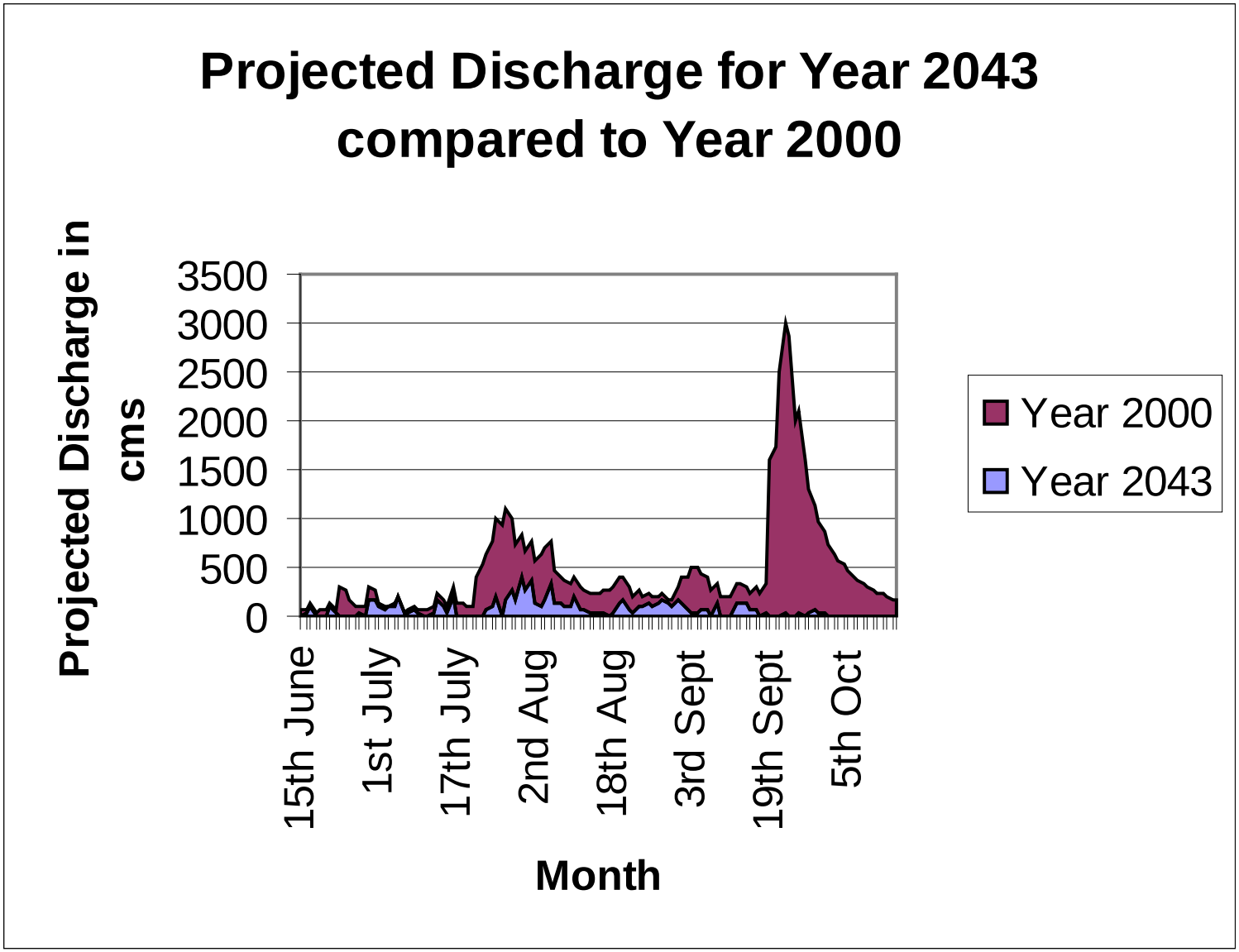
- The runoff simulated for the current climate year 2000, was compared with results for the warmer climate, simulated towards the year 2050.

- In the following figs we see a comparison of projected discharge of years 2041,43,45,47 and 2049 with respect to baseline year 2000 (wherein no climate change has occurred and is under present precipitation regime).

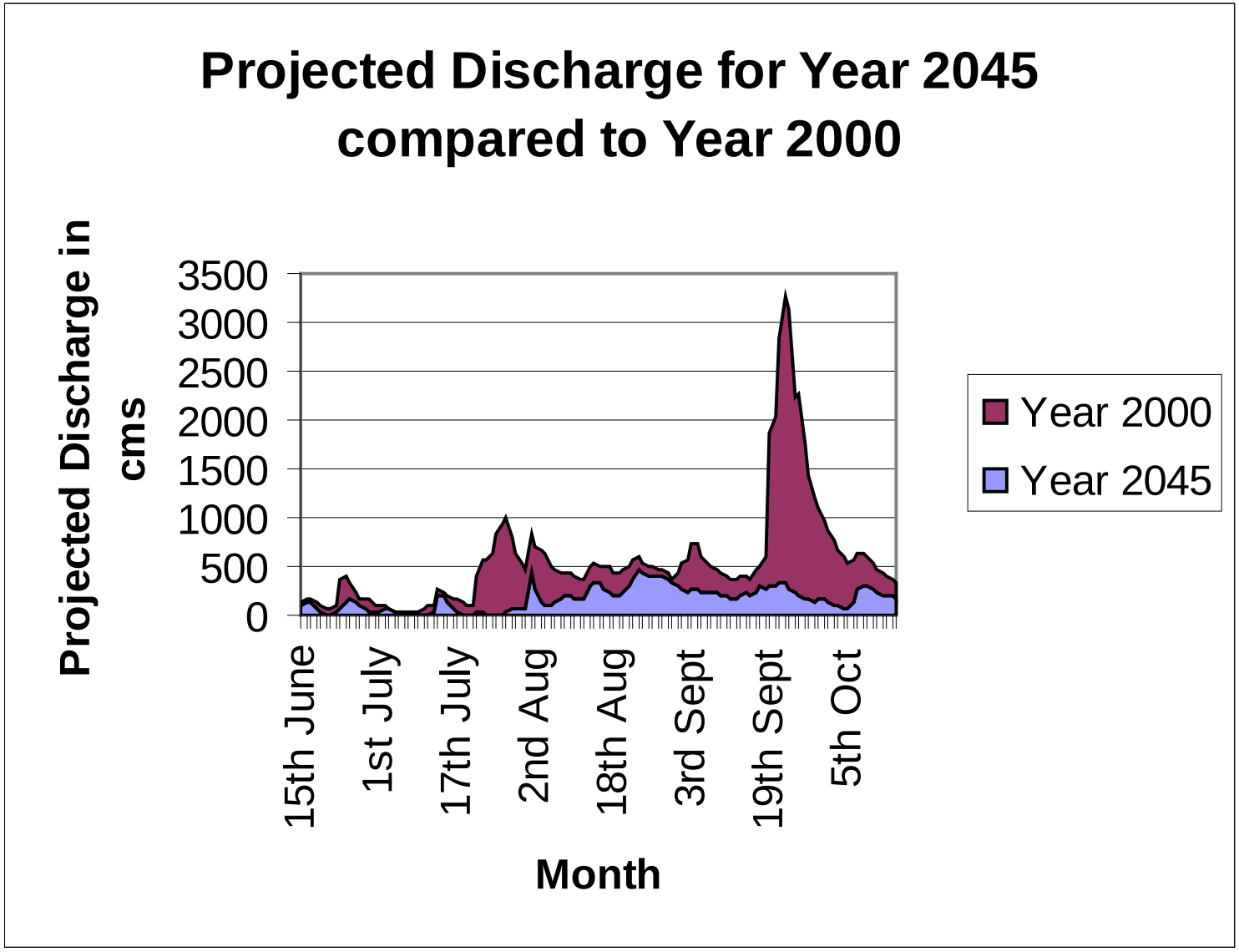
Projected discharge comparison at Natunhat



Projected discharge comparison at Natunhat



Projected discharge comparison at Natunhat



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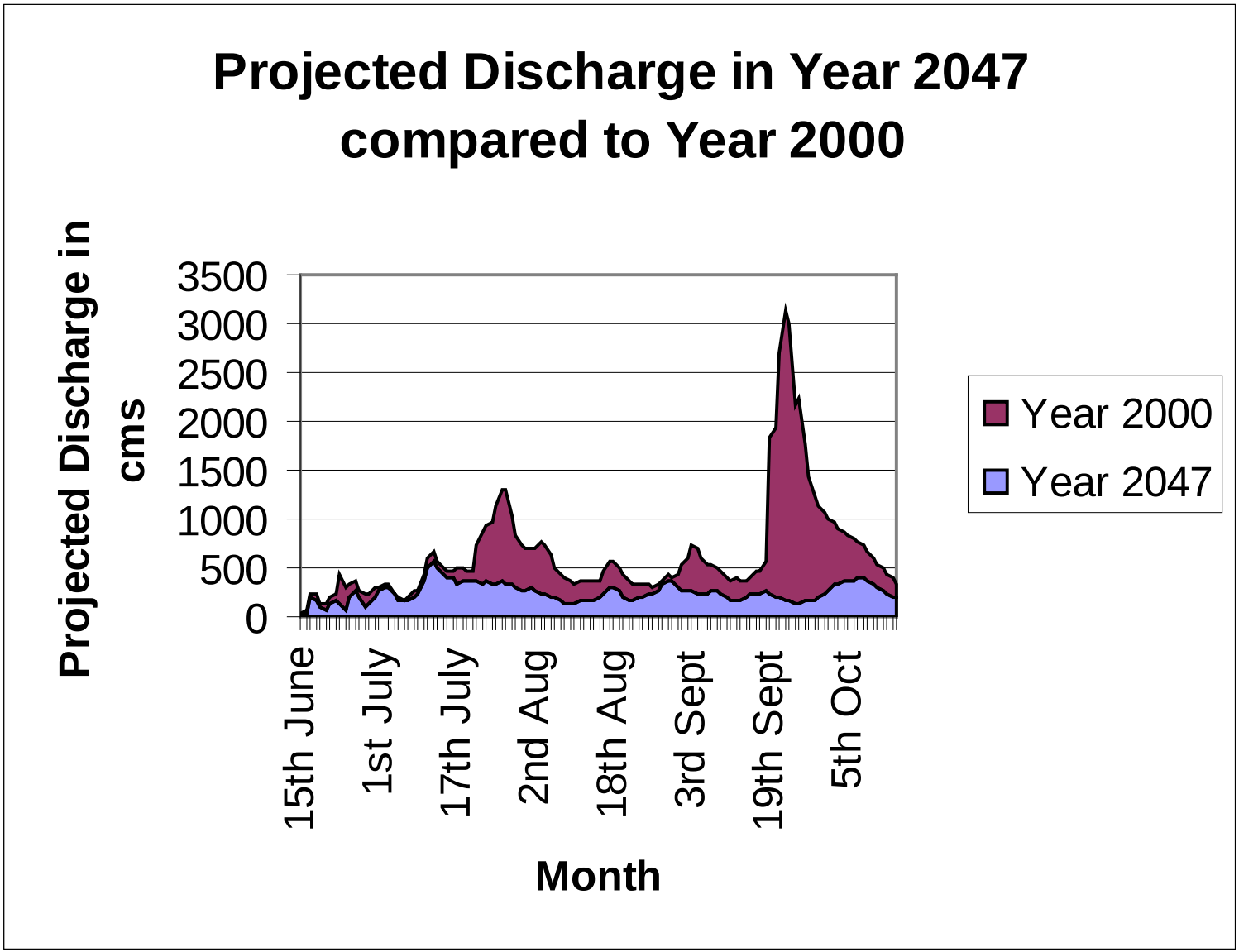
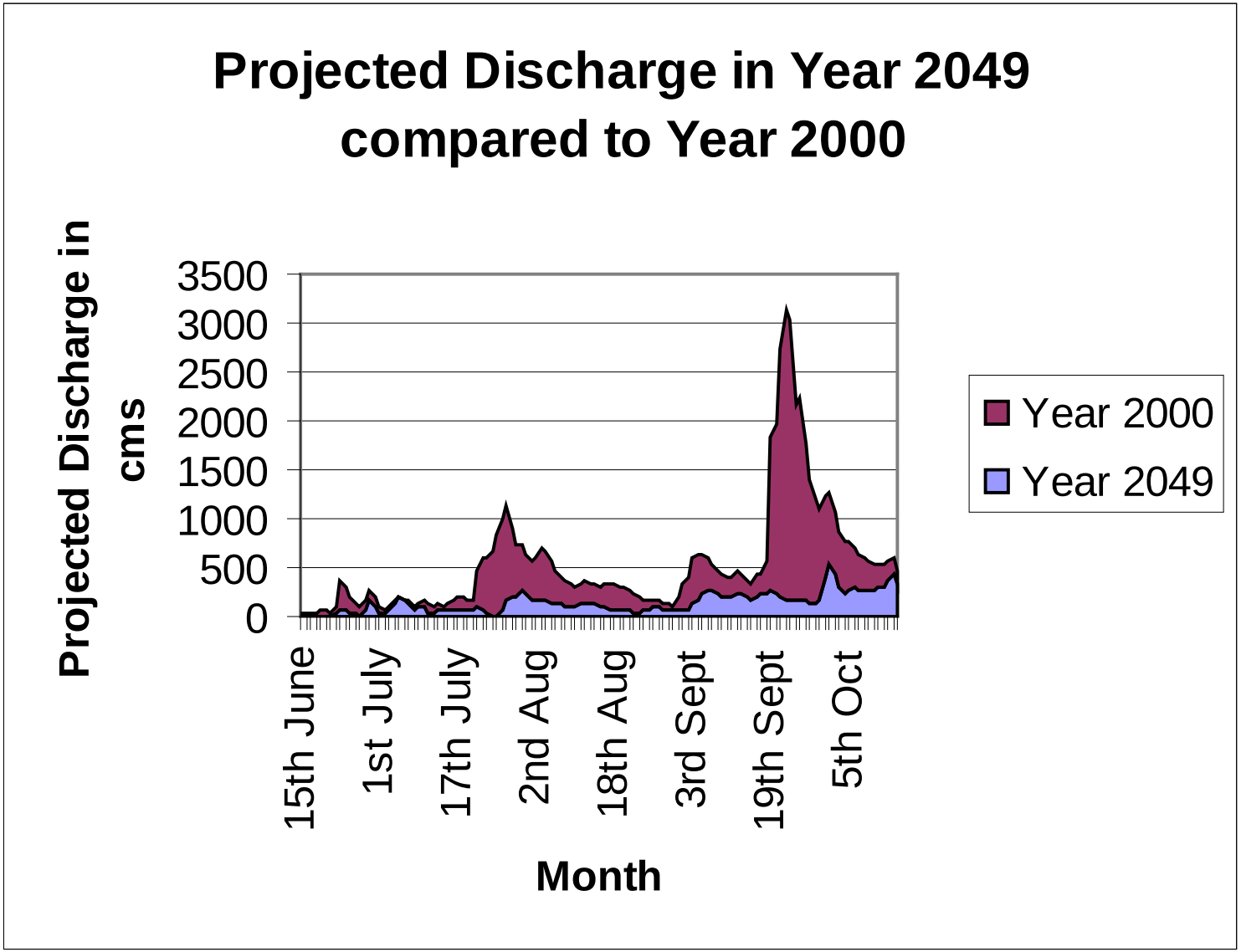


Projected discharge comparison at Natunhat



Projected discharge comparison at Natunhat 2/2

- Here the least effect of climate change is seen in year 2047 (37.50% less discharge as compared to discharge for year 2000)

- In 2043 we see the maximum effect of climate change where projected discharge is 82.24% less than baseline discharge

- This may be attributed to the effects of climate change such as shifts in spatial rainfall patterns, increase in average annual temperature and less annual precipitation per basin average area.

Conclusion of part II

- A detailed study involving the application of a very well calibrated HEC HMS model ($R^2 = 0.85$) was carried out over the Ajay River spanning Jharkhand and West Bengal. The sub basins chosen for the work were Jamtara sub basin (Jharkhand) and Natunhat sub basin (West Bengal).

- Projected data obtained from Hadley Centre, UK through IITM, Pune was used to obtain projected parameters for future water availability of the Ajay River over the chosen area from the year 2041-2050.

Conclusion of part II

- It was observed that precipitation, discharge, excess and direct runoff decrease while losses increase over the mentioned time frame.

- Soil parameters such as canopy evapotranspiration are seen to increase. The soil evapotranspiration and surface evapotranspiration are seen to display a decreasing trend from the year 2041-2050.

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- **Arnold, J. G., Williams, J. R., Srinivasan, R. and King, K. W (1994)** Soil and Water Assessment Tool, Use's Manual, USDA, Agriculture Research Service, Grassland, Soil and Water Research Laboratory, 808 East Blackland Road Temple, TX 76502.

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- **Tripathi M P; Panda R K and Raghuwanshi N S (1999a)** Runoff estimation from a small watershed using SWAT model. Hydrological Modelling, Proceeding of International Conference on Water, Environment, Ecology, Socio-Economics and Health Engineering, held at Seoul, Korea from October 18 to 21, 1999, pp 143–152

- **USACE (2000a)** Hydrologic Modeling System HEC-HMS. Technical Reference Manual, US Army Corps of Engineers, Hydrologic Engineering Center

Publications

International Publications 1/4

- Sujana Dhar and Asis Mazumdar.,(2009) **Hydrological Modeling of the Kangsabati River under Changed Climate Scenario: Case Study in India,** Hydrological Processes, John Wiley & Sons. Accepted for publication.

- Sujana Dhar and Asis Mazumdar.,(2008) **Hydrological Modeling of Natunhat Watershed , West Bengal of the Ajay River Catchment under Changed Climate Scenario** , International Journal of Ecological Economics and Statistics, Princeton University, USA. Accepted for publication.

- Sujana Dhar and Asis Mazumdar (2009). **Impacts of Climate Change under the Threat of Global Warming for an Agricultural Watershed of the Kangsabati River.** Proc. of EnviroEnergy 2009 & World Academy of Science, Engineering and Technology.

International Publications 2/4

- Sujana Dhar and Asis Mazumdar (2009). **Climate Change and its impact on the Kangsabati Basin using the SWAT Model.** Proc. of Water, Energy, Environment and Society. New Delhi 2009

- Sujana Dhar and Asis Mazumdar (2009). **Asssessment of the Impacts of Climate Change over the Kangsabati River using Hydrological Modeling**. Proc. Climate Change Conference.Pune 2009

- Sujana Dhar and Asis Mazumdar (2008). **Simulation of the SMA Parameters for the Ajay River for Future Water Availability Scenario.** Proc. International Convention On Water Resources Development And Management. Pilani 2008

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Thank you