River runoff and nitrate loading simulation for the land use changes in the Takasaki River basin in Chiba, Japan

E.D.P. Perera, Y. Iwami, Y. Chida

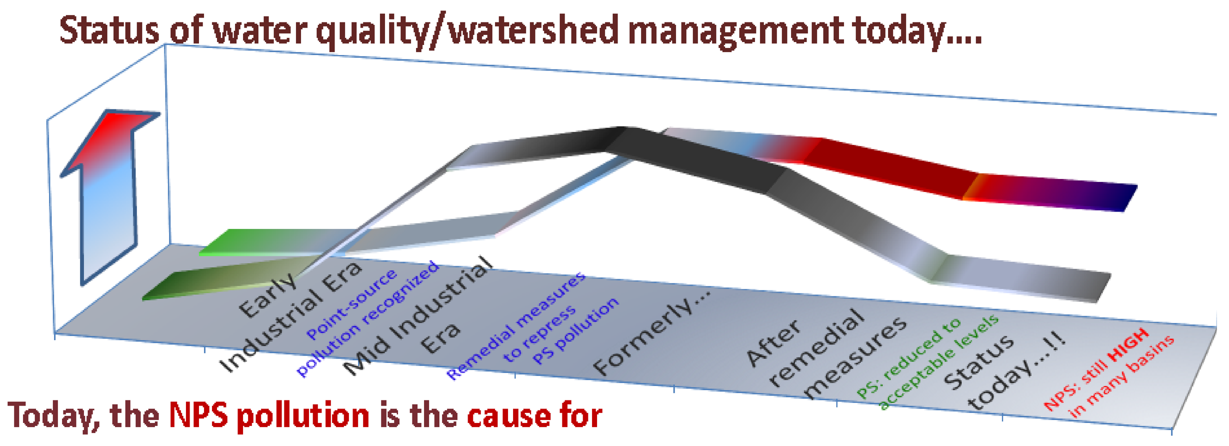
International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO, Public Works Research Institute (PWRI), 1-6, Minamihara, Tsukuba, Ibaraki, Japan. Email: perera55@pwri.go.jp

Abstract: The present study makes an attempt to evaluate the possible impacts of land use changes on hydrologic and nitrate loading responses using a numerical model, available land use, river runoff and nitrogen (N) loading data for a small river basin of 85 km2 named as Takasaki River. The existing land use types in the basin consist of 22.7% forests, 9.0% rice fields, crop lands 33.4%, urban areas 34.1%, and water bodies 0.8%. The nutrient contributions to the river from different Point Sources (PS) and Non-Point Sources (NPS) are accommodated in the developed model. Agricultural areas, forests and urban areas are considered as NPS within the model. N discharges from different land use types have a significant contribution to the river water quality. At this end the updated WEP model is applied to understand the impact of land use changes' contribution to the Takasaki River runoff. A qualitative analysis of the land use changes is conducted by simulating two land use scenarios within the river basin for the period of 5 years. The two scenarios considered are: Scenario -A: 80% crop area converted into urban areas (urbanization), Scenario - B: 80% crops land area is converted to forests (afforestation). The model was executed with the observed rainfall for 2006 to 2010 to check the variation of river runoff and N loading. The obtained results are compared with the simulation results which are obtained under the exiting conditions of the basin for the aforementioned time duration. For the Scenario – A, the 5 year averaged annual water volume passed through the monitoring point has been increased 2.6 % compared to the calculated results of existing condition while for the Scenario – B, same comparison shows a decrement of 0.12 %. The annual averaged N loading for the Scenario – A shows significant increments compared to the natural condition simulation results. The increments are 23.2% and 4.2% in the A and B scenarios respectively.

NPS pollution traits and why suppression is important?

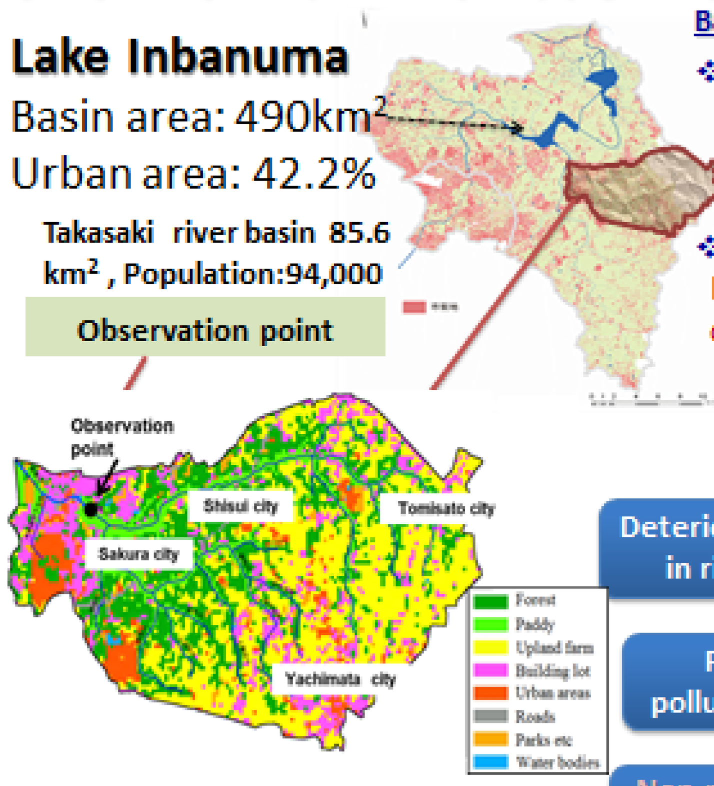
- Extremely difficult to trace, monitor and manage
- NPS pollutants build up on land surfaces mainly during dry weather
  - *Fertilizer applications + Animal waste (Agricultural diffuse sources)*
  - *Atmospheric deposition*
  - *Automotive exhaust/fluid leaks*
- Pollutants are washed-off land surfaces during precipitation events (mainly stormwater runoff; partly subsurface paths via infiltration)
- Stormwater runoff will flow into lakes and streams => accumulation...

Status of water quality/watershed management today....



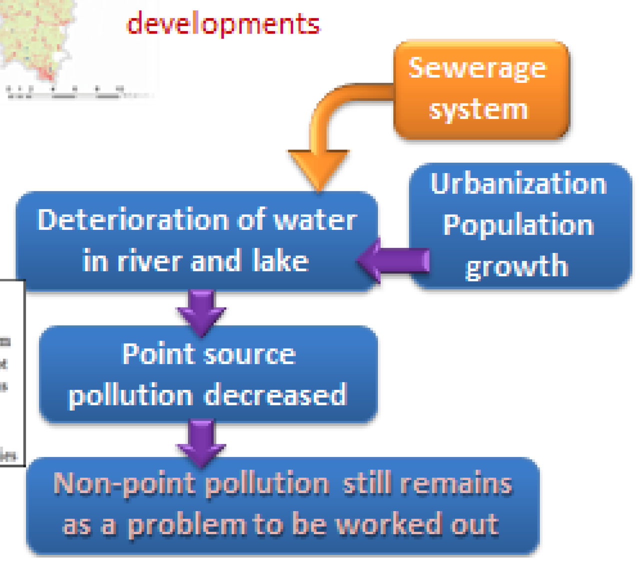
Today, the NPS pollution is the cause for MOST REAMAINING water quality problems in many watersheds...!!!

Overview of river basin and background

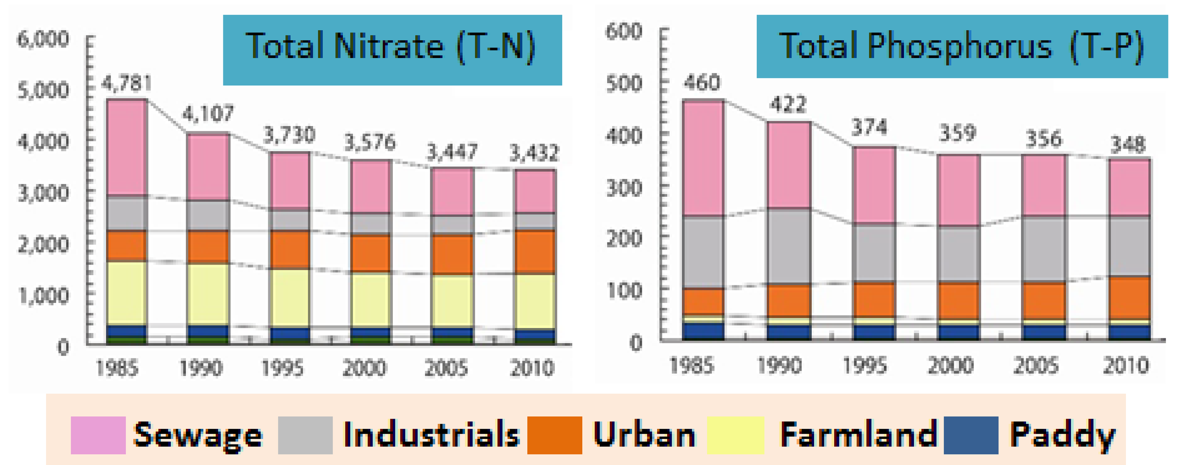


Basin Background

- Both commercial fertilizers and manure are used annually in farmlands for vegetables and fruits and in paddy fields.
- Ongoing urbanization and related land use changes & infrastructure developments



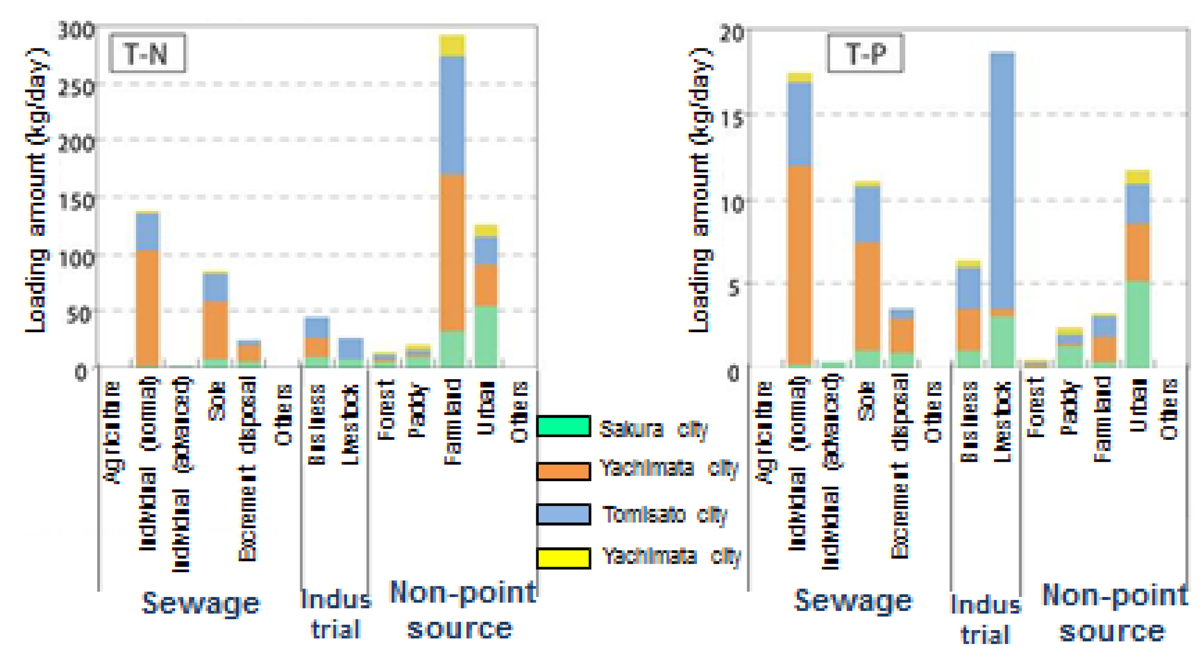
TN & TP loadings by different sources



Point source pollution from **sewage** and **industrials** has **decreased** over the past two decades.

On the other hand, non-point source pollution from **urban** area and **farmland** is not reduced much.

Actual state of water quality in river

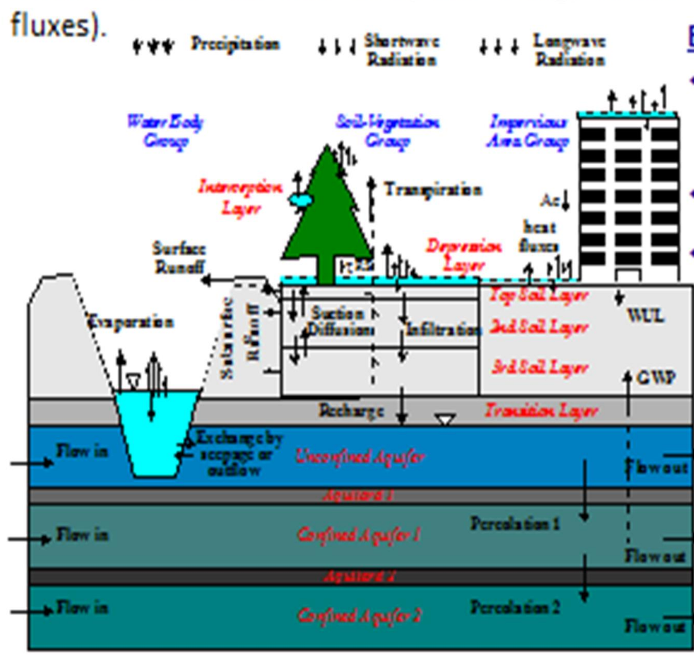


Loading in the Takasaki River basin in 2008.

As of 2008, non-point source pollution affected water quality in river

Physically-based processes simulated in WEP hydrologic model.

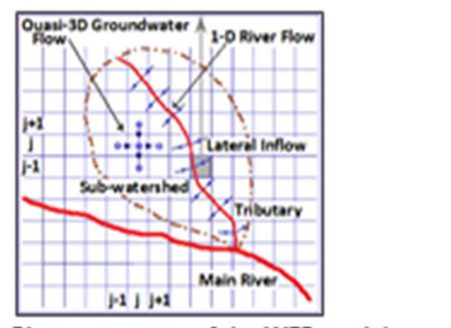
The Water and Energy Processes transfer model is a grid-based distributed parameter hydrological model capable of simultaneous simulation of hydrological (evapo-transpiration, infiltration, surface and subsurface runoff, groundwater flow, surface runoff and river flow) and energy transfer processes (radiation and heat fluxes).



Vertical structure of the WEP model

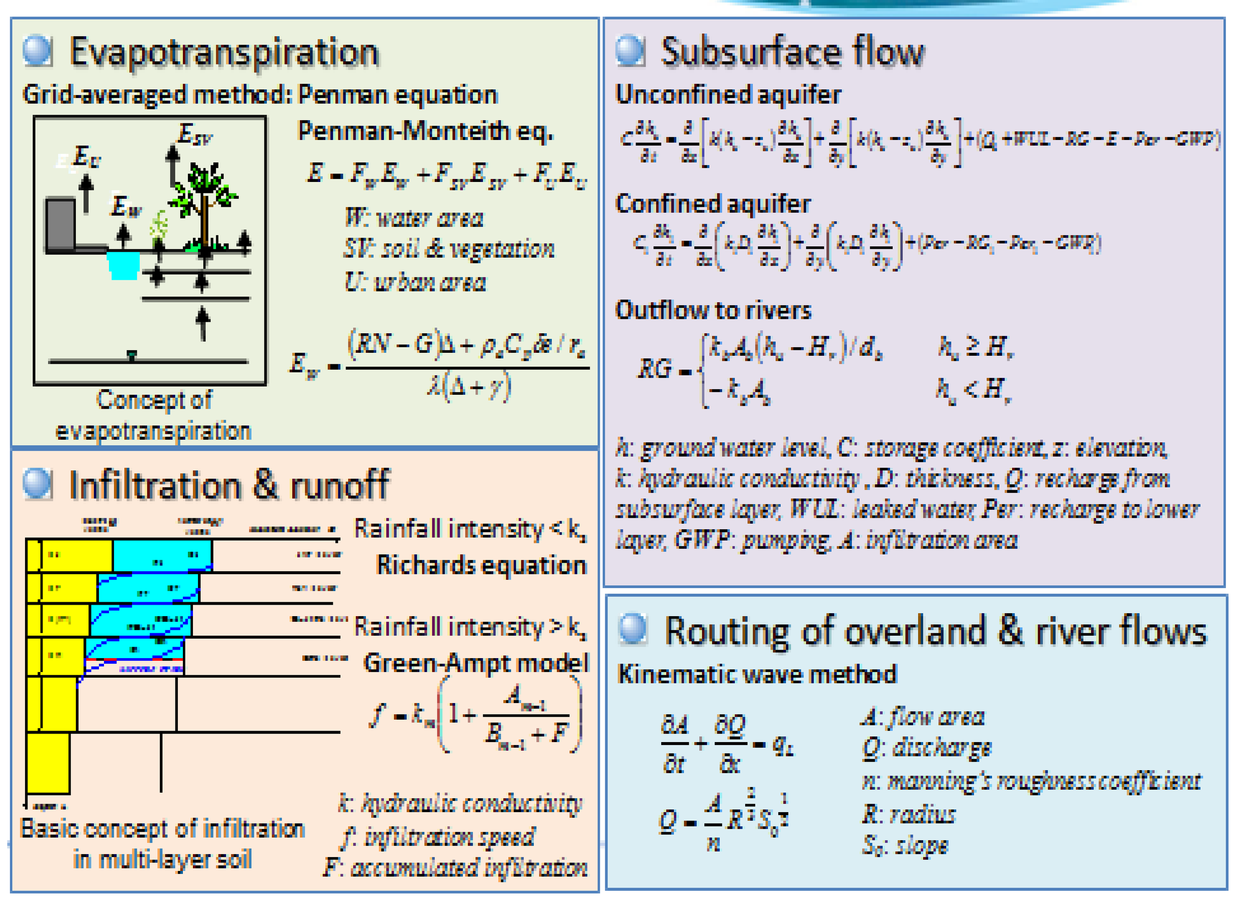
Basin and simulation characteristics

- Land-use: Mainly agricultural (Famlands & paddy 50%), Semi-urbanized (urban area~20%), decreasing area of forests
- Spatial/temporal resolution: 100 m X 100 m grid for simulation
- Time step of 10 min for river flow routing during rainfall periods, and 1-hr for all other hydrological processes

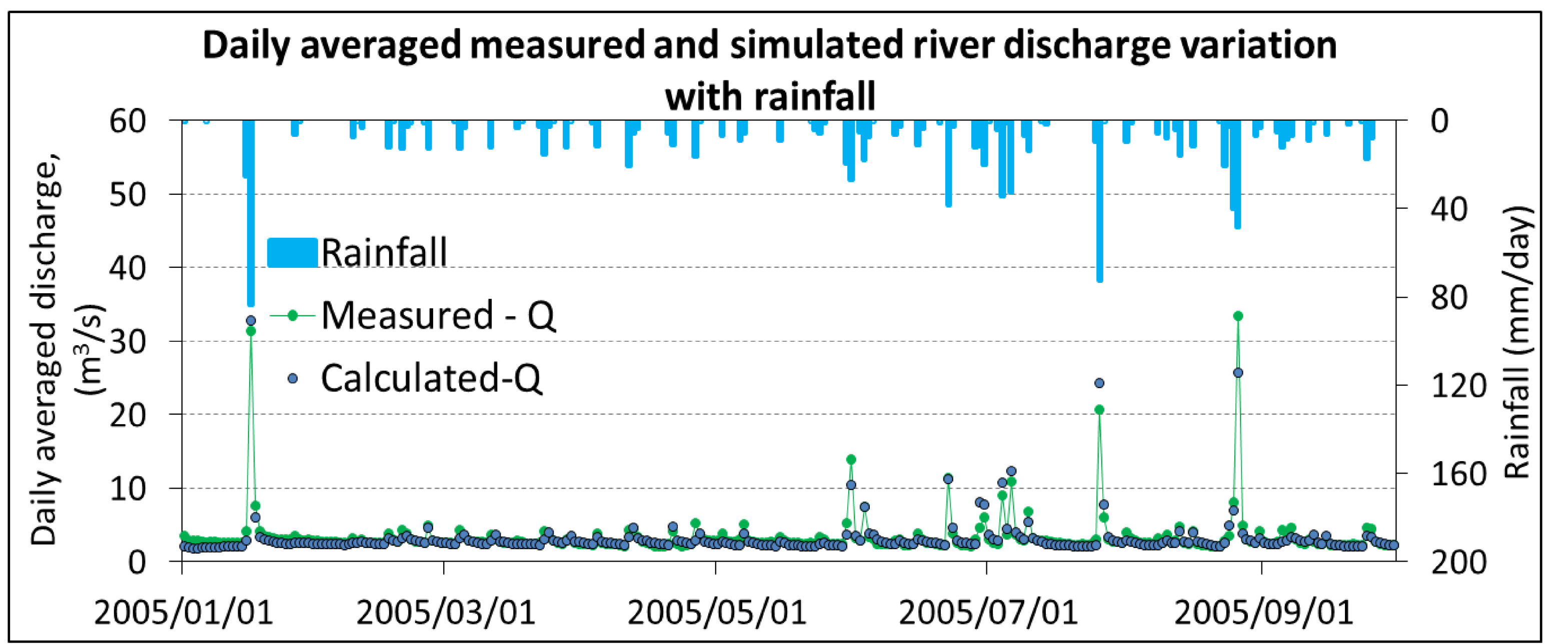


Planar structure of the WEP model

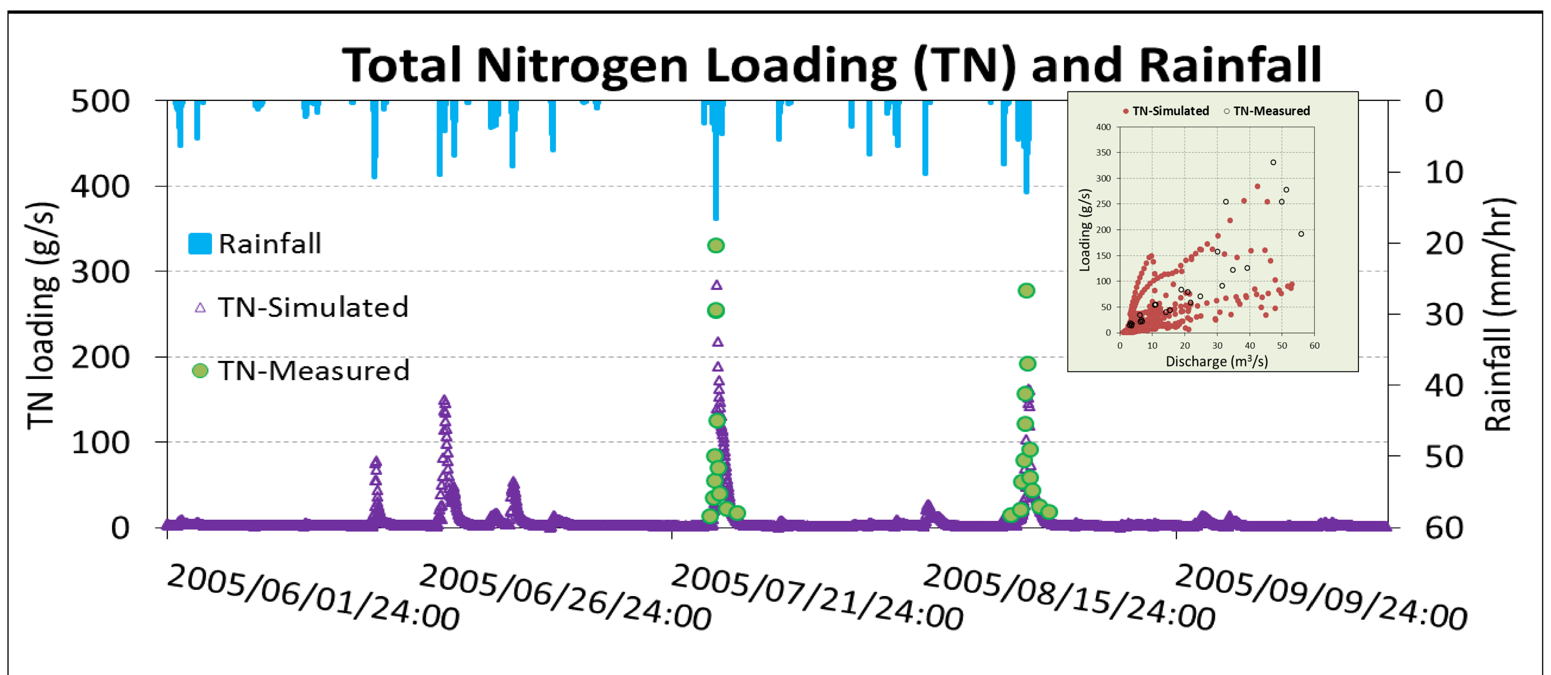
Structure of WEP model



Model Calibration for 2005 River Discharge and TN Data



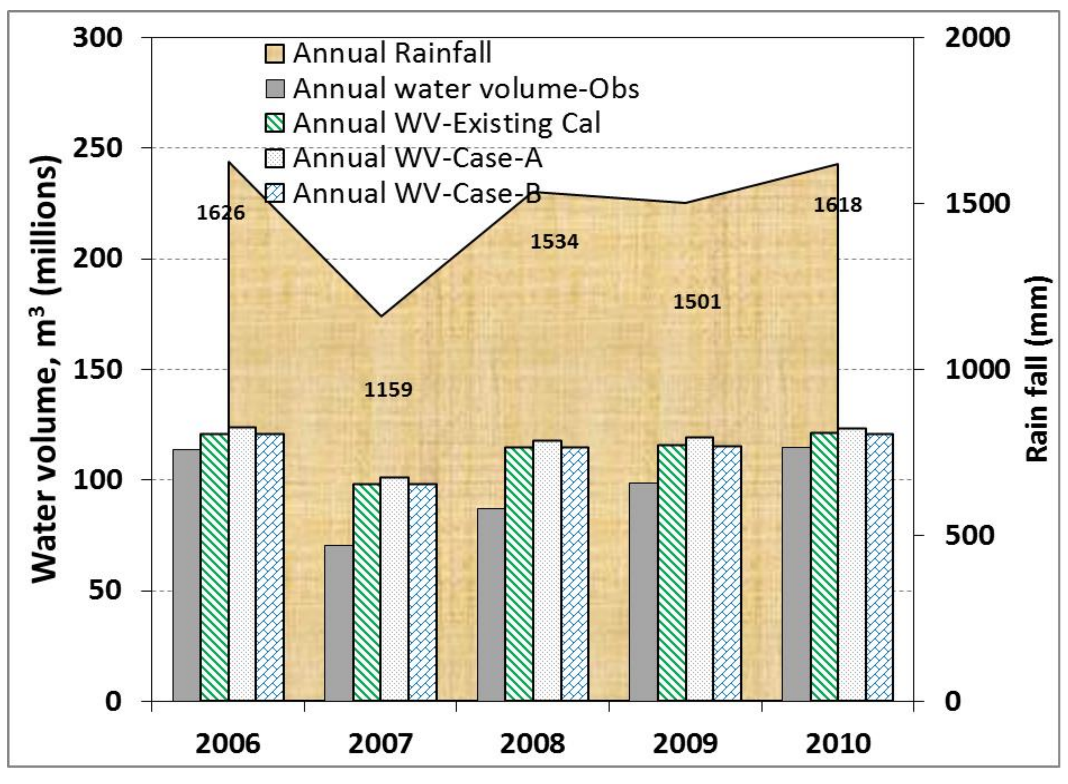
N-S Coff (1.0) =	0.82
RRMSE (0.0) =	0.47
MAE (0.0) =	0.60
RMSE (0.0) =	1.58

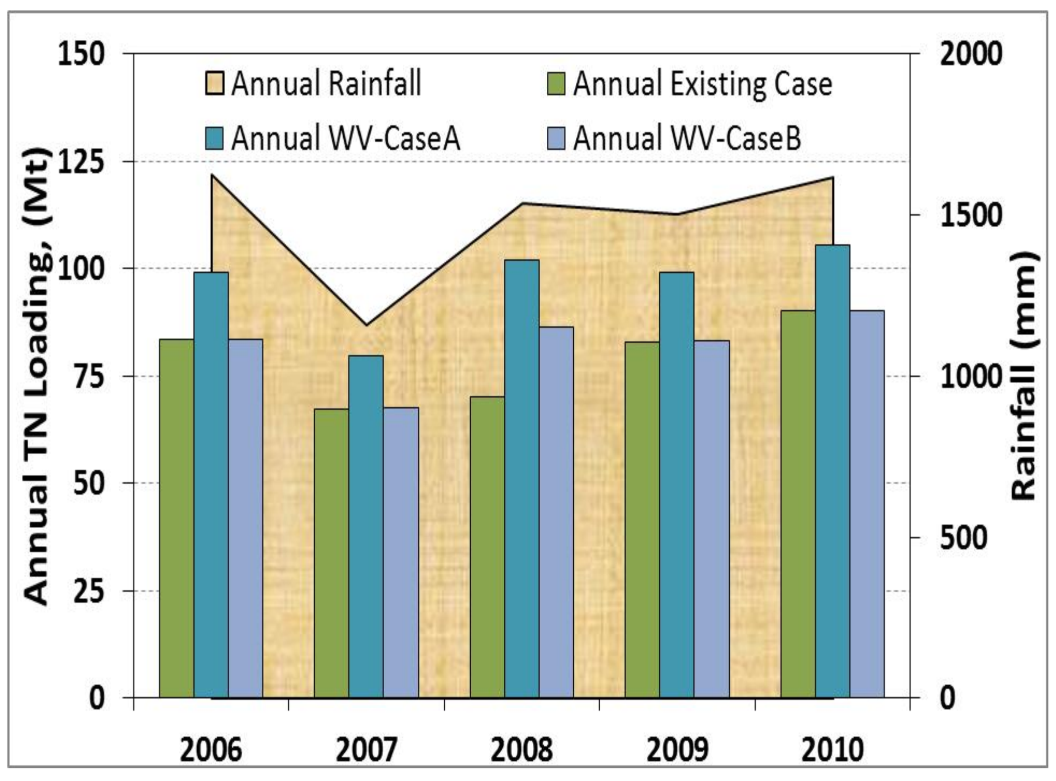


Case A: 80% Crop area is converted into Urban area

Case B: 80% Crop area is converted into Forest

Land use type	Existing		Case A		Case B	
Forest	22.7%	19.3 km^2	22.7%	19.3 km^2	49.4%	42.0 km^2
Crop Lands	33.4%	28.4 km^2	6.7%	5.7 km^2	6.7%	5.7 km^2
Urban/Residential	34.1%	29.0 km^2	60.8%	51.7 km^2	34.1%	29.0 km^2
Rice fields	9%	7.7 km^2	9%	7.7 km^2	9%	7.7 km^2
Water bodies	0.8%	0.7 km^2	0.8%	0.7 km^2	0.8%	0.7 km^2





Case A: Water volume increased 2.6 % and TN increased 23.2%

Case B: Water volume decreased 0.12% and TN increased 4.2%