Prediction of Effects of Changing Precipitation Extremes on Urban Water Quality

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EPA STAR Extreme Events Kick-off Meeting

Outline

- Research questions and objectives
- Selection of Study Sites
- General overview of the DHSVM model
- Framework of integrated DHSVM-WQ model
- Pilot case study site: Mercer Creek basin
- Short-term goals

Research Questions

How has and will the physical-chemical quality of urban streams change in a warming climate?

- How will changes in precipitation and temperature extremes affect urban water quality?

- What interactions might there be between changing land cover and climate extremes as they affect urban water quality?

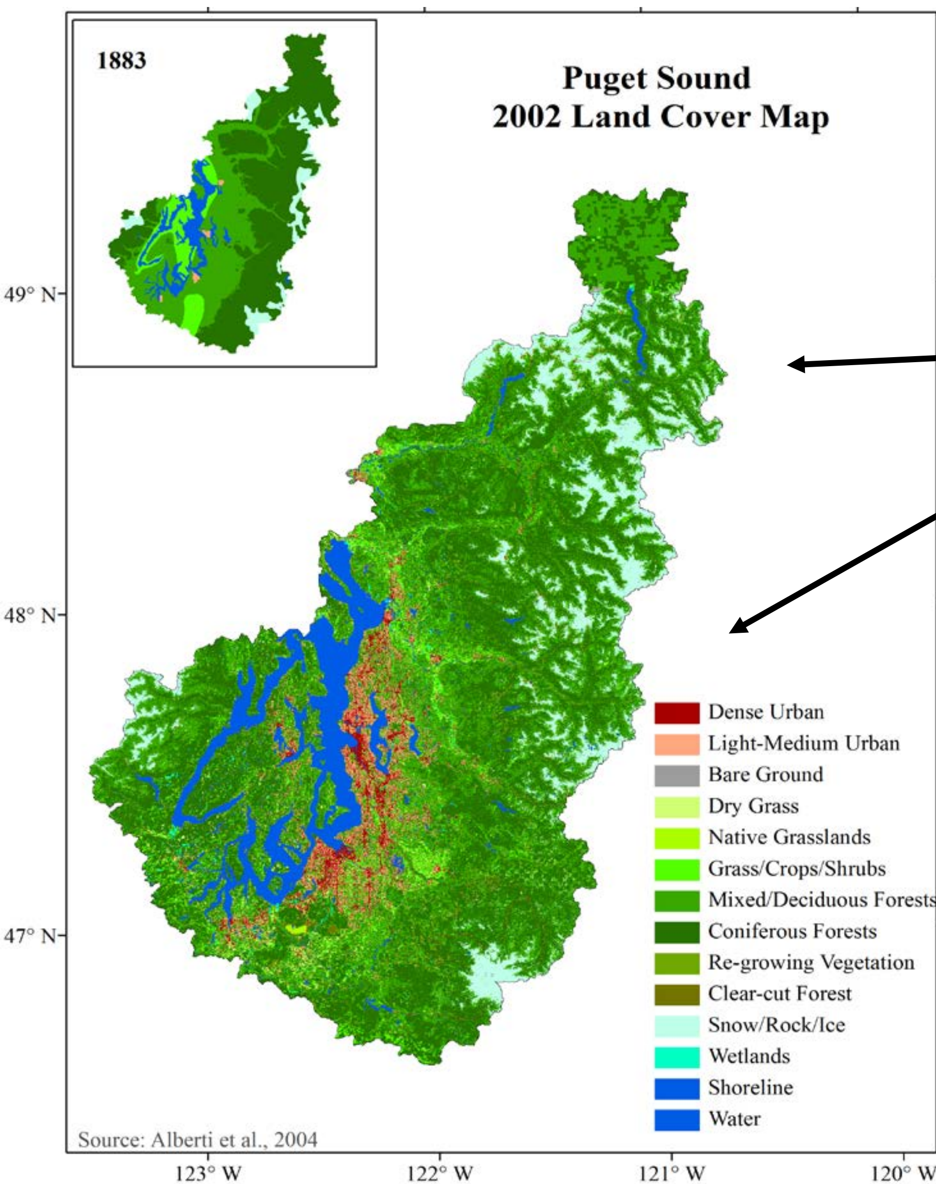
- To what extent can land cover policies mitigate the effects of climate change in urban areas?

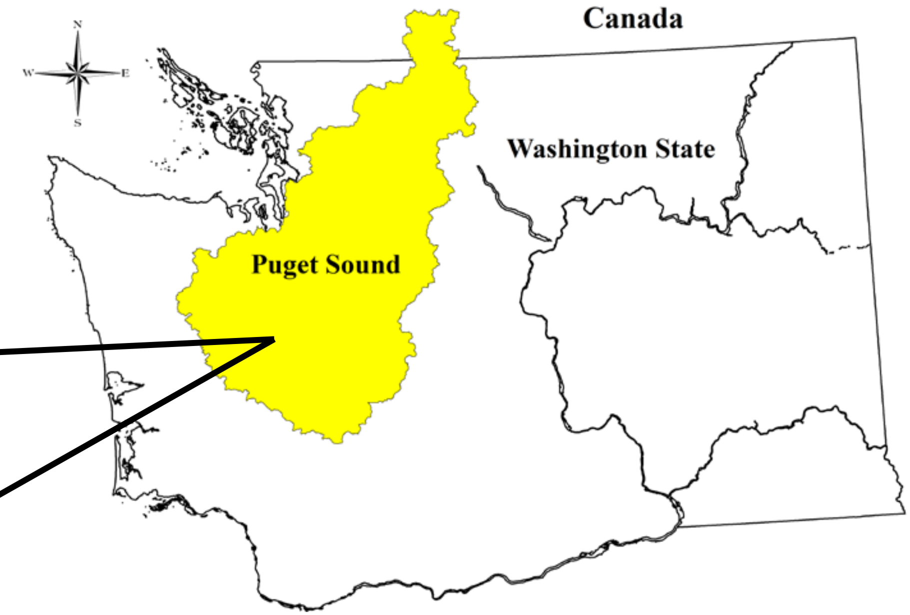
Research Objectives

- Integrate a system of the Distributed Hydrology Soil Vegetation Model (DHSVM) hydrology model, urban water quality models, and dynamical and statistical downscaling methods to provide a framework for predicting the effects of changing climate extremes on urban water quality at regional scales.

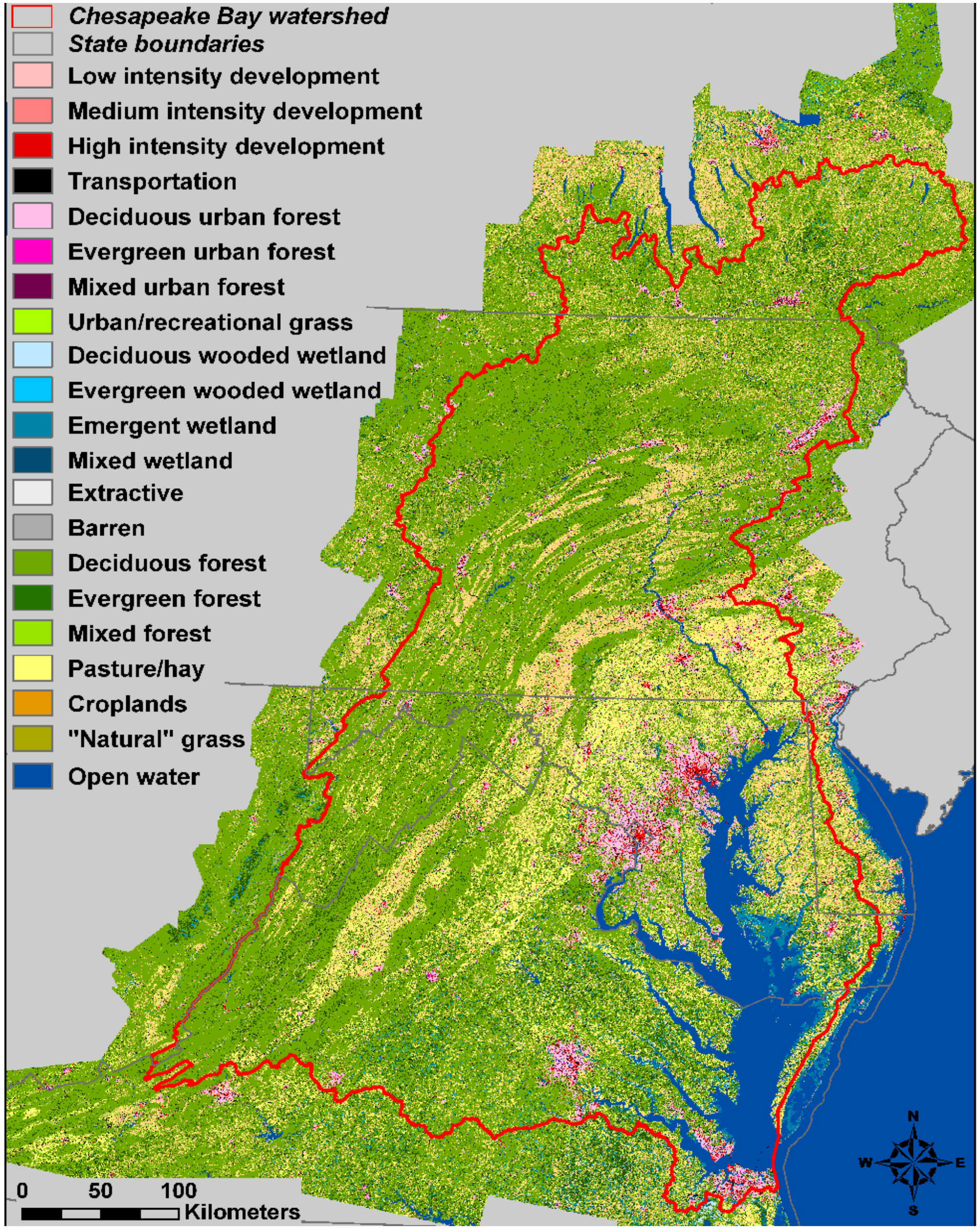
- Demonstrate application of the framework to assess the implications of 2007 IPCC AR4 climate change scenarios (and AR5 scenarios as they become available) on water quality for the next half century at the scale of large urban regions.

Case Study Site: Puget Sound Basin





The Puget Sound basin is selected as one of our case study sites. The basin has a drainage area of about 40,000 km^2, of which about ¼ is urban or partially urbanized.



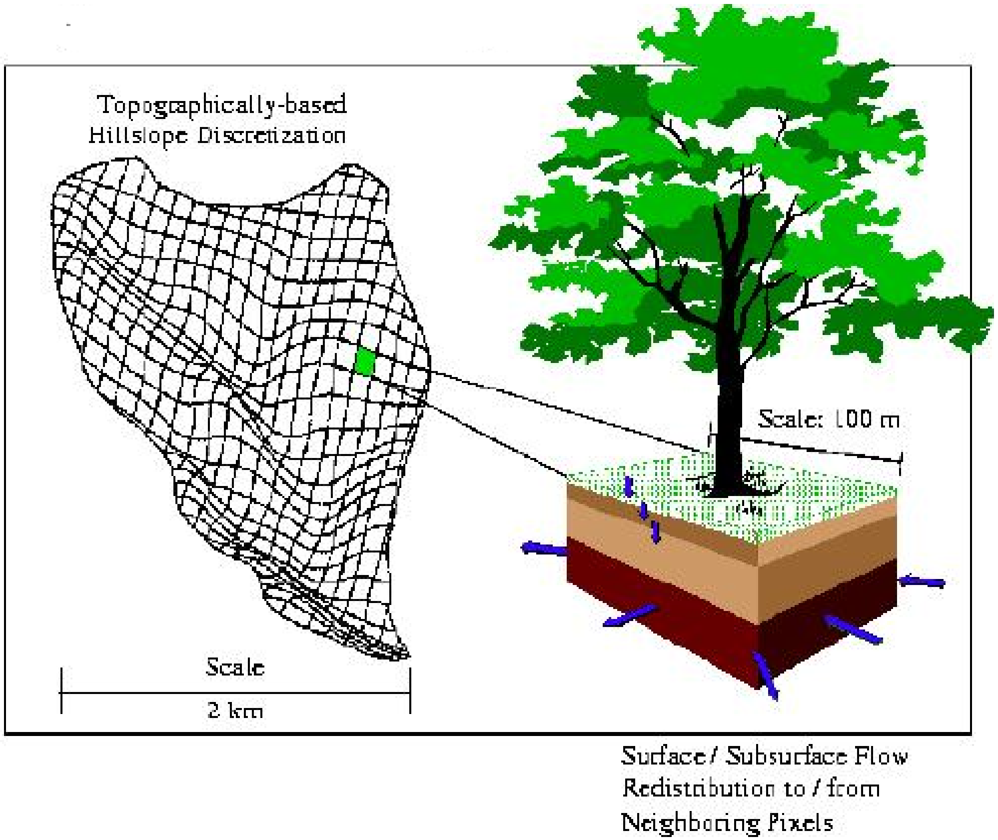
Chesapeake Bay 2000 Land Cover

Comparable Sites

We will select two or three more case study sites of size roughly similar to the urbanized/partially urbanized portion of the Puget Sound basin, such as Chesapeake Bay, for assessment of the changing climate & land cover impact on regional water quality.

(Image source: Woods Hole Research Center)

Distributed Hydrology Soil Vegetation Model (DHSVM)

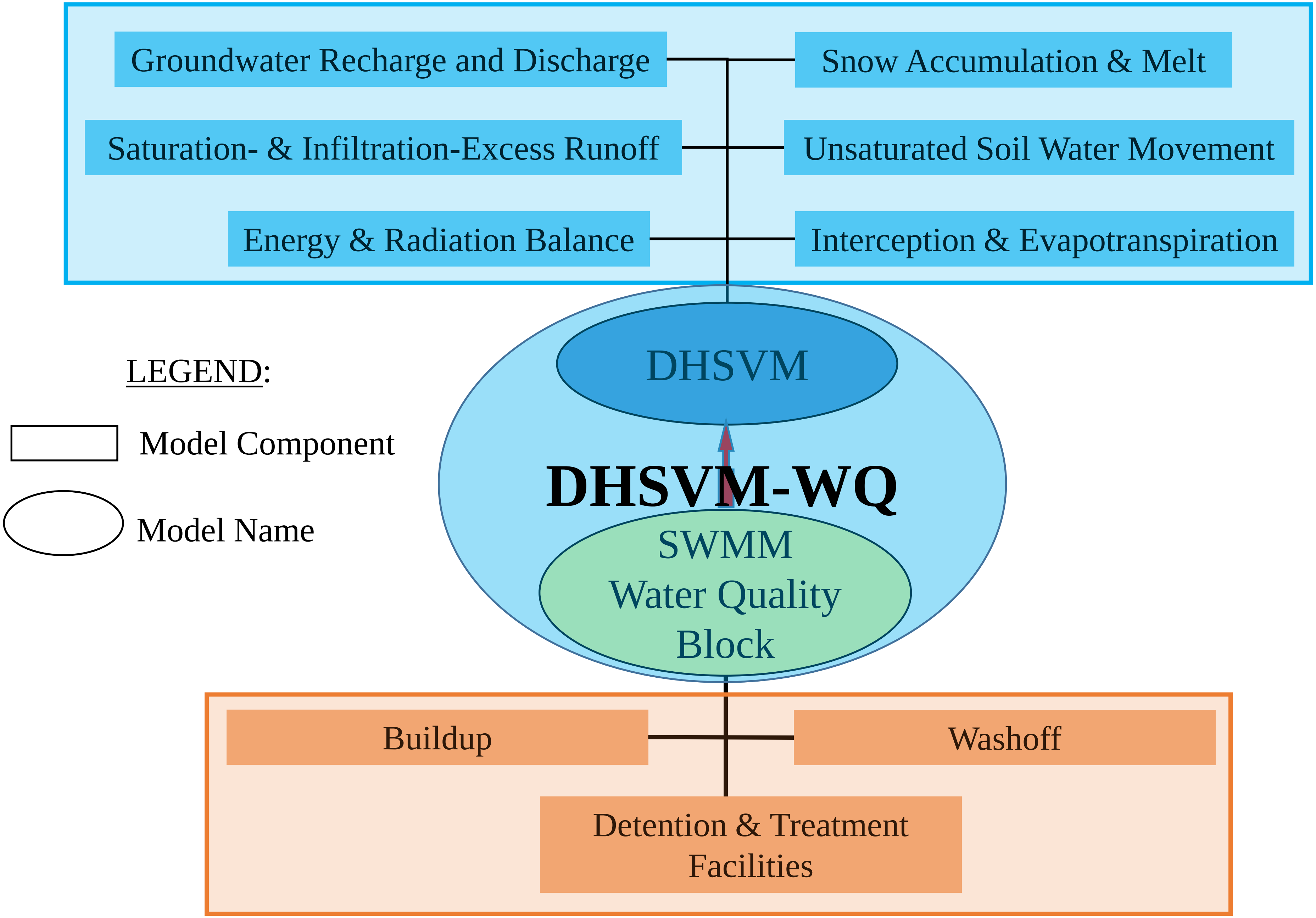


<u>DHSVM features:</u>

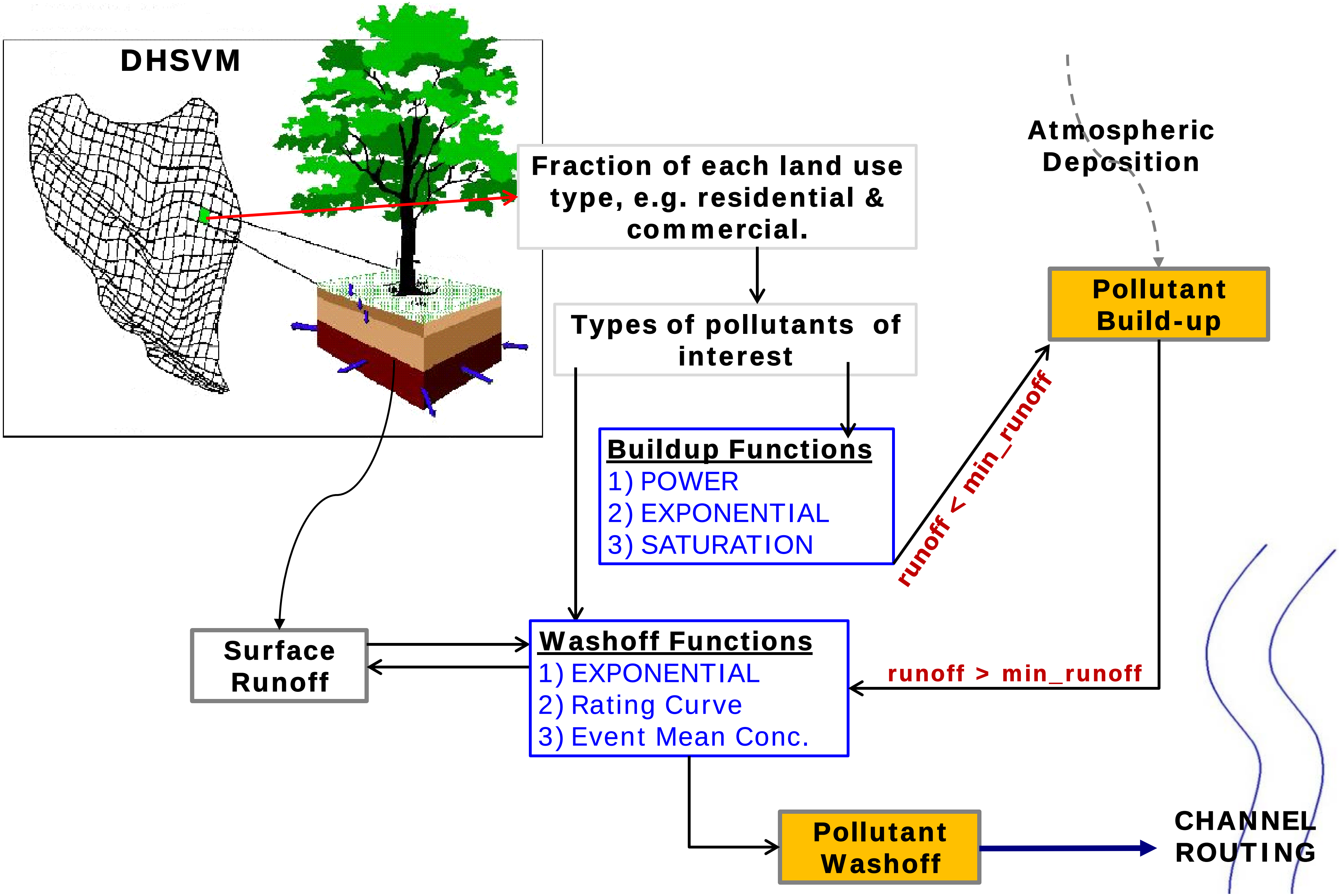
- Physically based, spatially distributed hydrologic model
- Grid based (DEM)
- Two layer canopy for vegetation
- Simultaneously solves energy and water balance

DHSVM has been applied predominantly to mountainous watersheds at high spatial resolutions (10m – 150m) for watersheds of up to 10^4 km^2 and at sub-daily timescales.

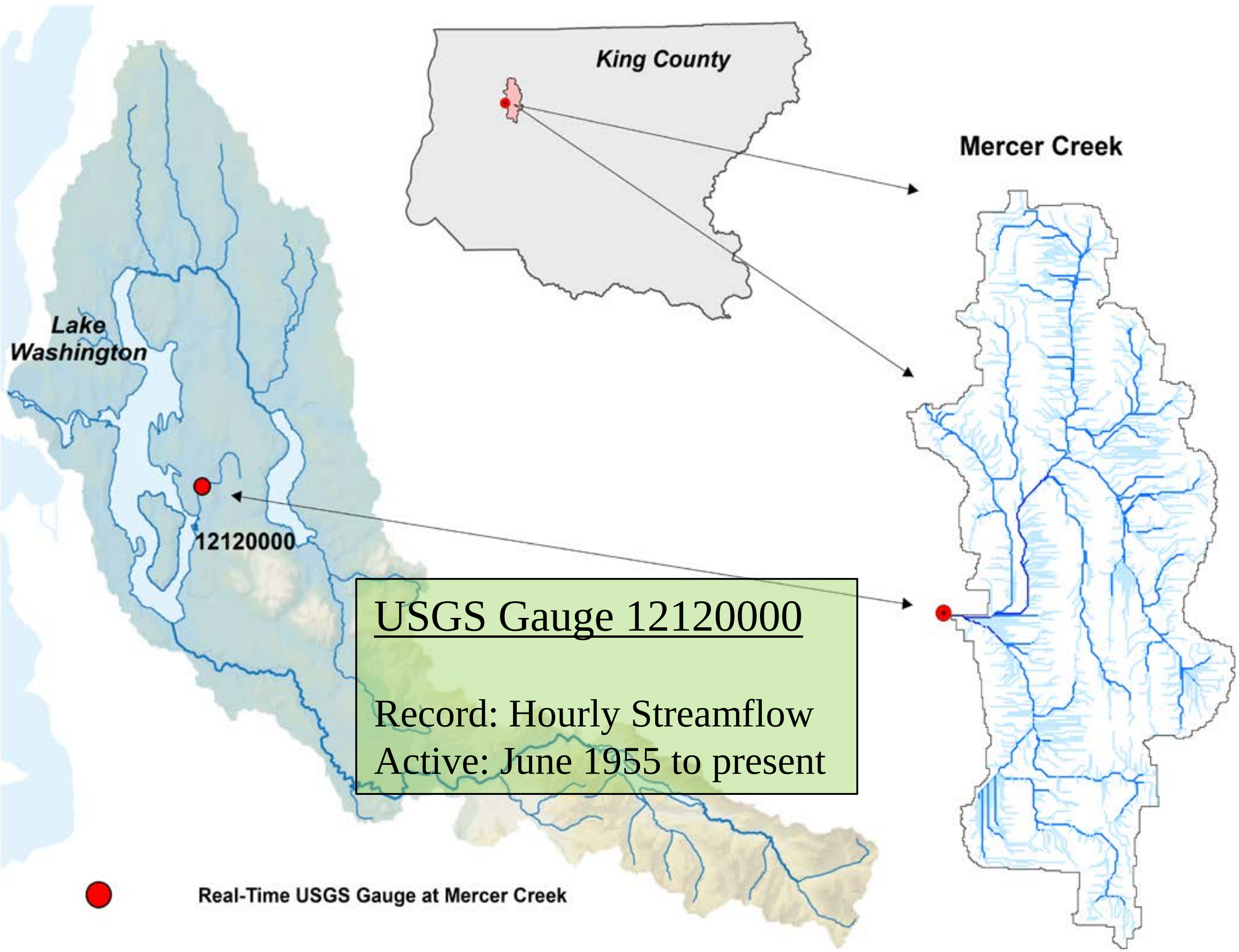
Integration of EPA-SWMM Water Quality Module into DHSVM



DHSVM-WQ Work Flow



Pilot Case Study: USGS Gauge 12120000 Mercer Creek near Bellevue, WA



Mercer Creek Basin

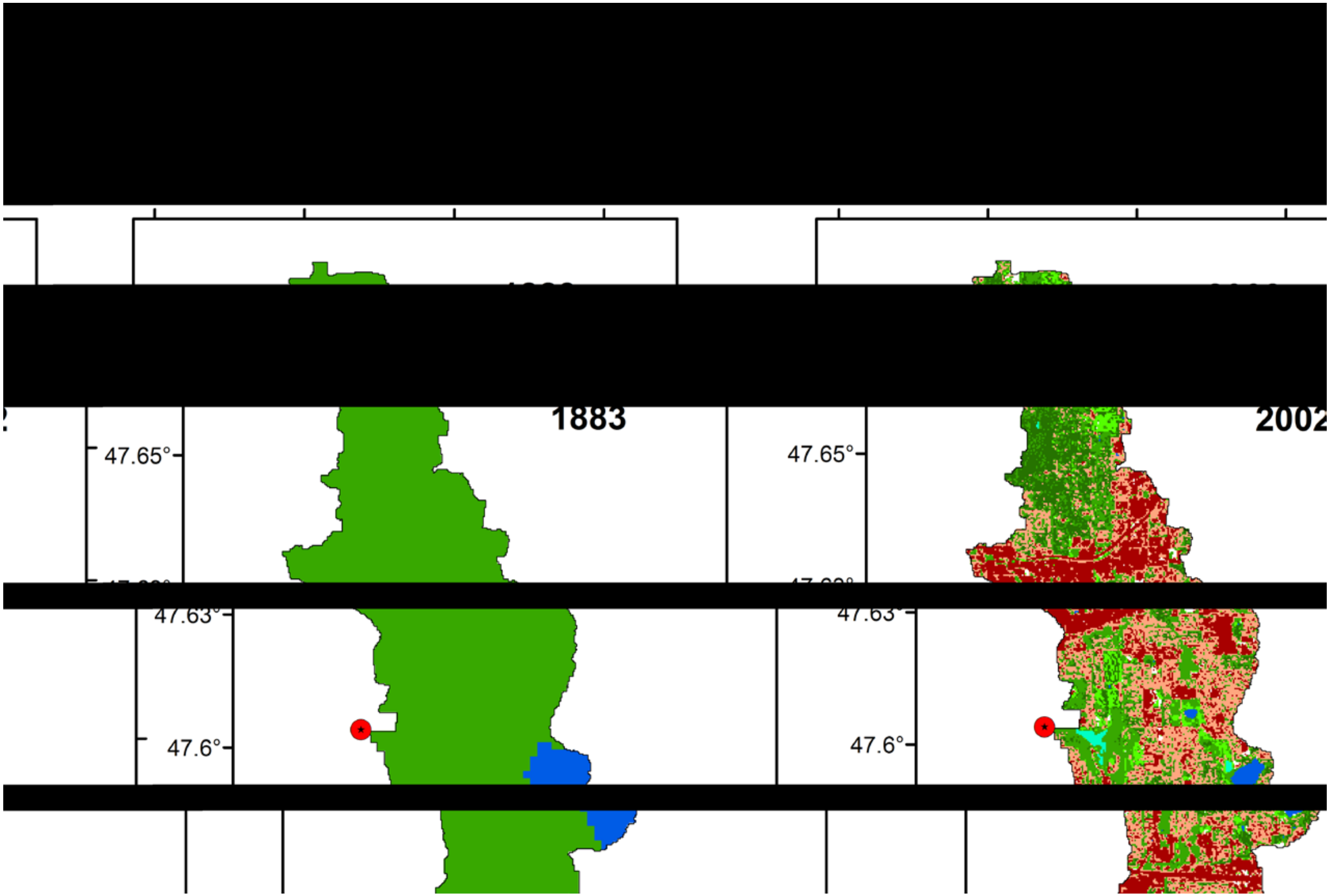
Basin Area:
12 mi^2

Location:
Bellevue, King County

Receiving Water:
Lake Washington

Dominant Land Use:
Residential (47%)

A Century of Land Cover Change in Mercer Creek near Bellevue, WA

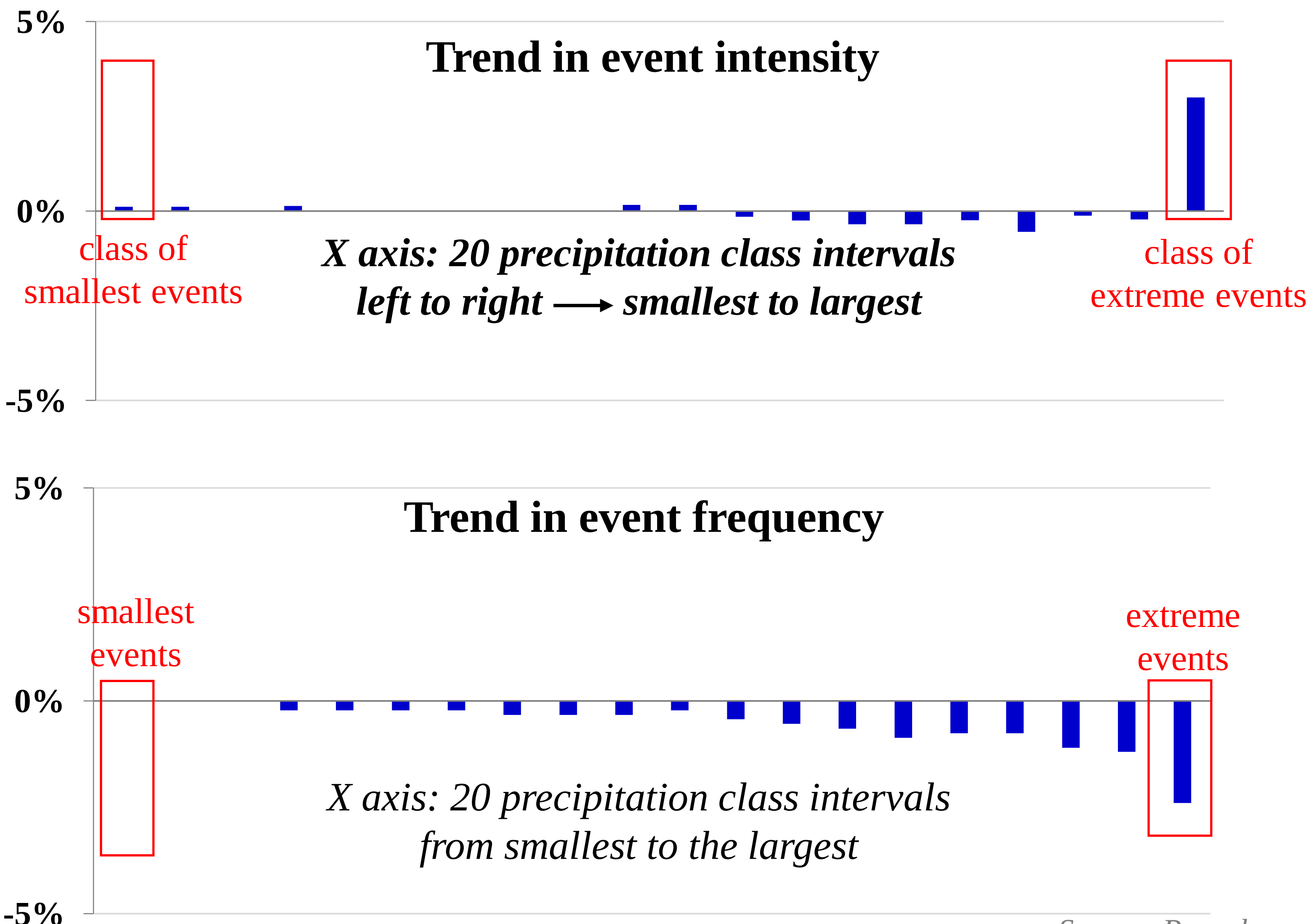


Urbanization: Land Cover Change in Mercer Creek, WA

Land Use	**Percentage**	
	1883	2002
Dense Urban	0.0%	24.1%
Light-Medium Urban	0.0%	33.1%
Grass/Crops/Shrubs	0.0%	4.6%
Mixed Forests	95.9%	22.5%
Coniferous Forests	0.0%	13.3%
Wetlands	0.0%	0.5%
Water	4.1%	0.9%

The Mercer basin has undergone rapid urbanization in the past century, and serves as an ideal site for assessment of urban landscape change effect on hydrological processes and urban water quality.

59-Year Precipitation Trend in WA from 1949 to 2007



Source: Rosenberg et al. (2010)

Precipitation event analysis from 1949 to 2007, WA

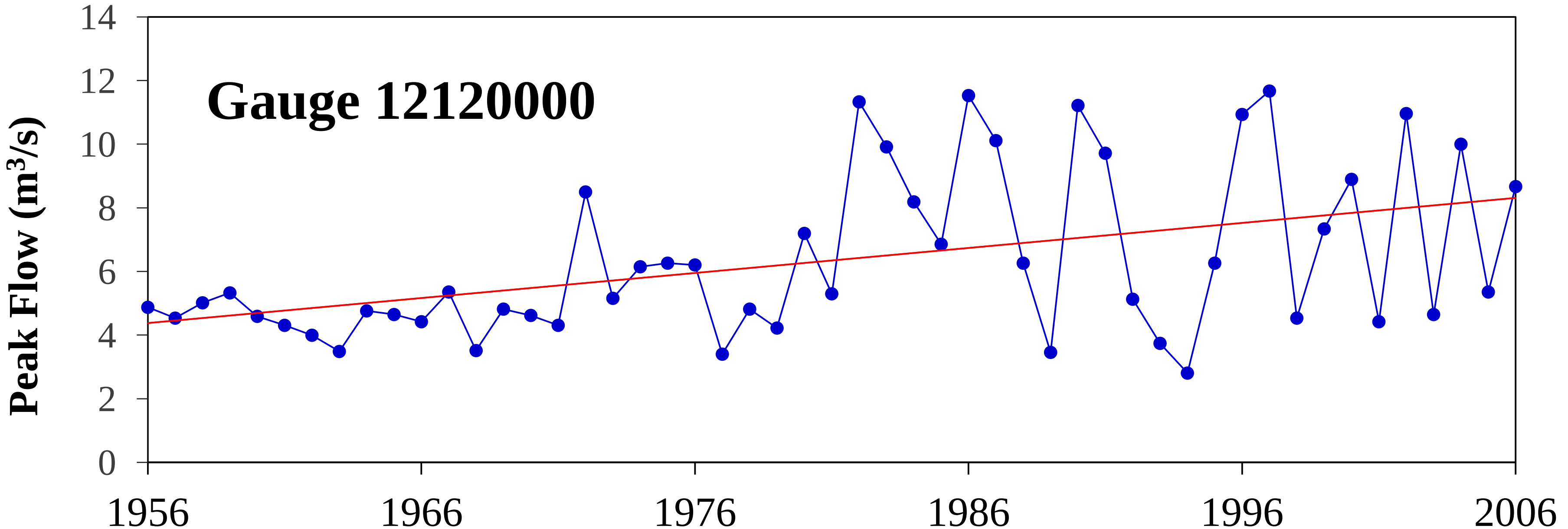
	SeaTac
Average annual number of events	154.5
Average annual precipitation	970 mm
Trend in annual precipitation	-8.90%
… due to trend in event frequency	-9.30%
… due to trend in event intensity	0.40%
Trend in annual median event intensity	4.60%
Trend in annual maximum event intensity	39%

Over 59 years, there is a **NEGATIVE** trend in event frequency for all magnitudes of events, and a **NEGATIVE** trend in precipitation intensity for most class intervals.

However, there is a dramatic **INCREASING** trend in the intensity of extreme events, causing the cumulative trend for intensity to be slightly positive.

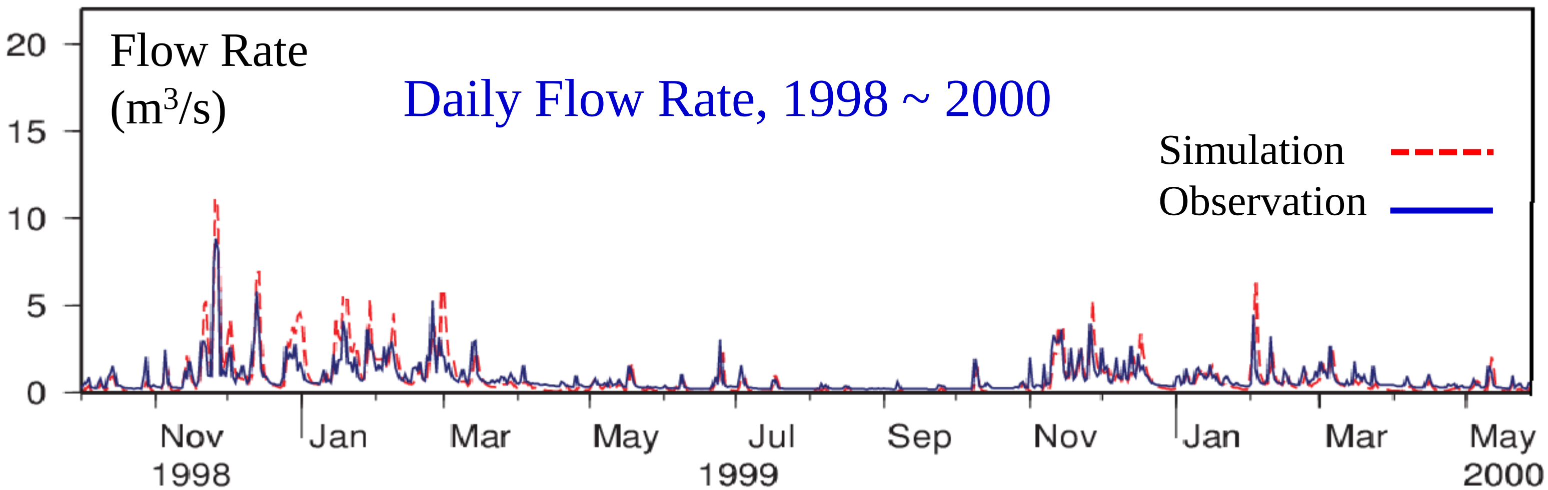
Source: Rosenberg et al. (2010)

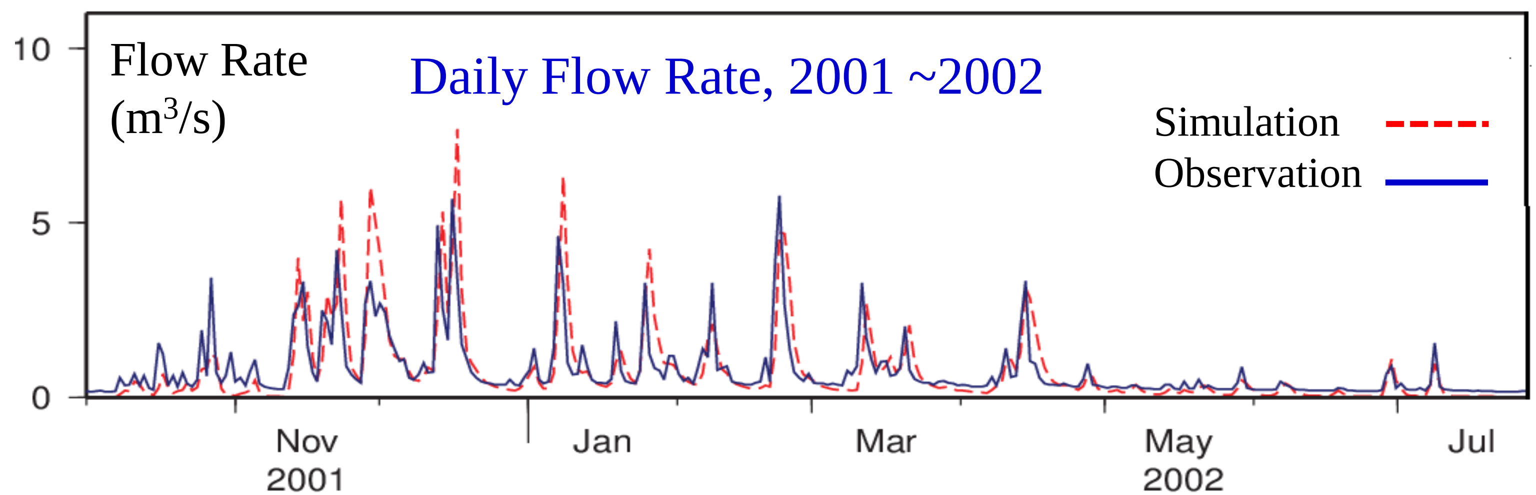
Increasing Trend of Annual Peak Flow at Mercer Creek, 1956 ~ 2006



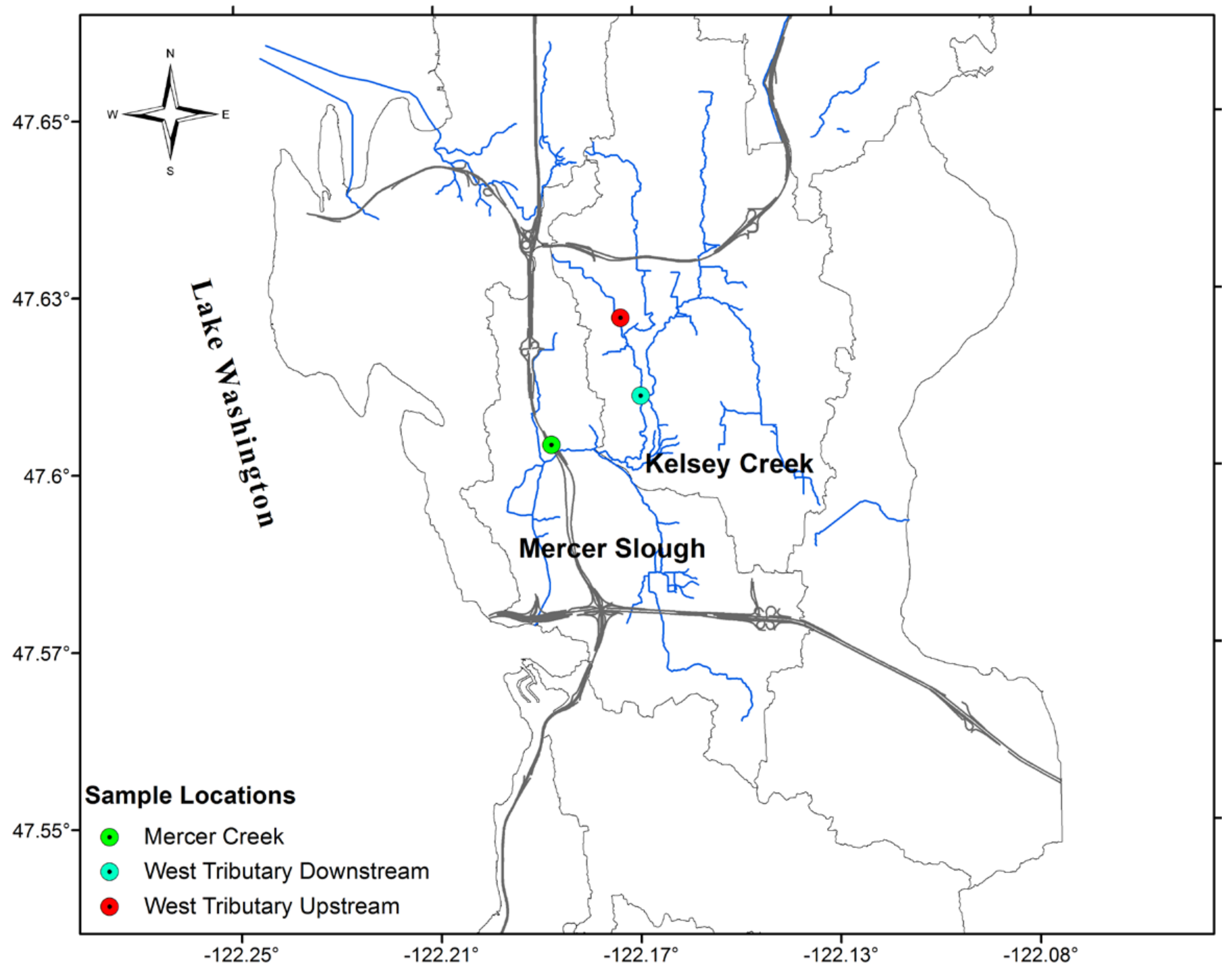
Changing land cover, precipitation pattern and temperature could contributed to the increasing annual maximum flow. Which factor is dominant? To what extent the water quality has been and will be impacted?

Current Climate Evaluation of DHSVM Performance in Mercer 12120000

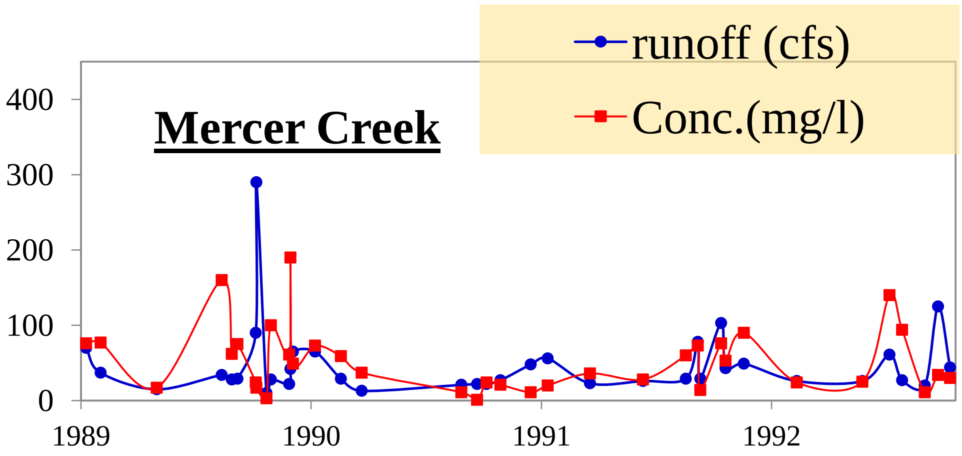


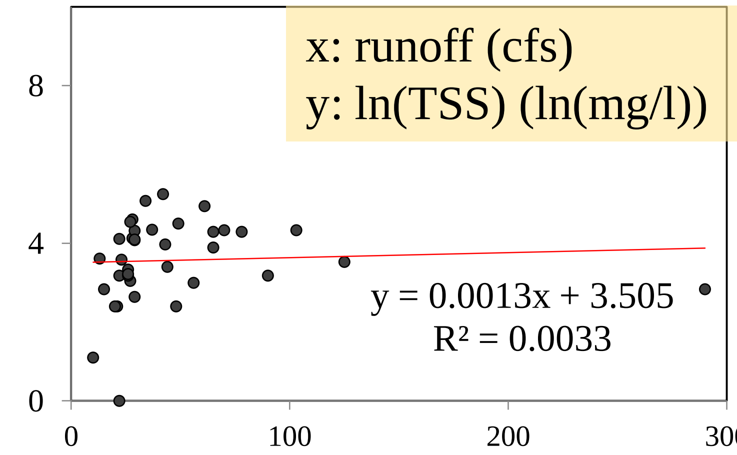


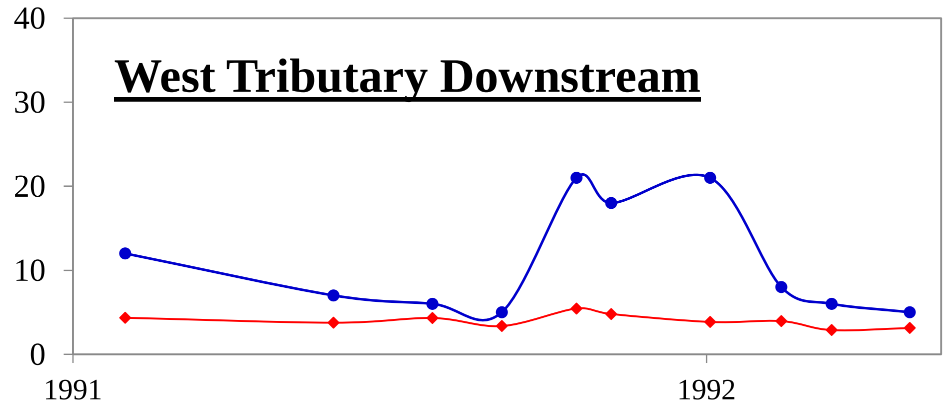
Water Quality Sample Locations at Mercer Creek

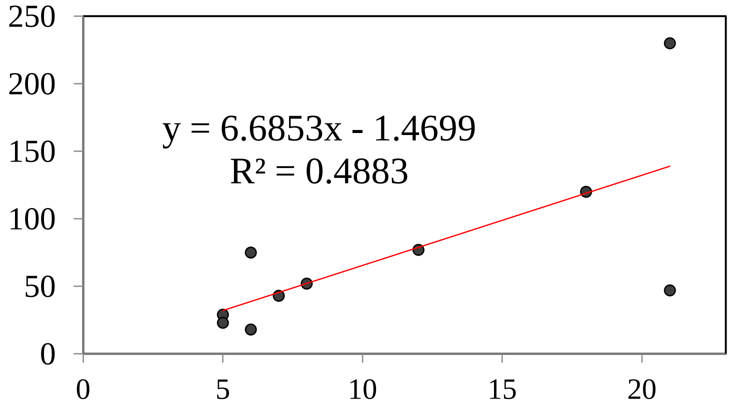


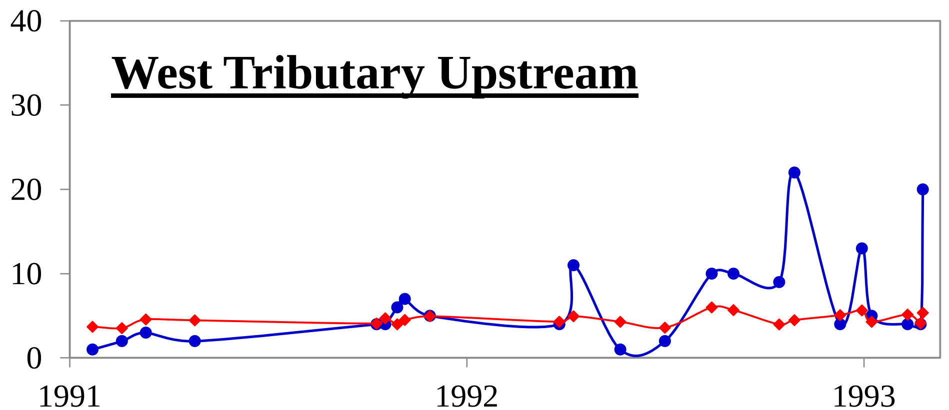
Observed TSS Conc. Vs. Flow

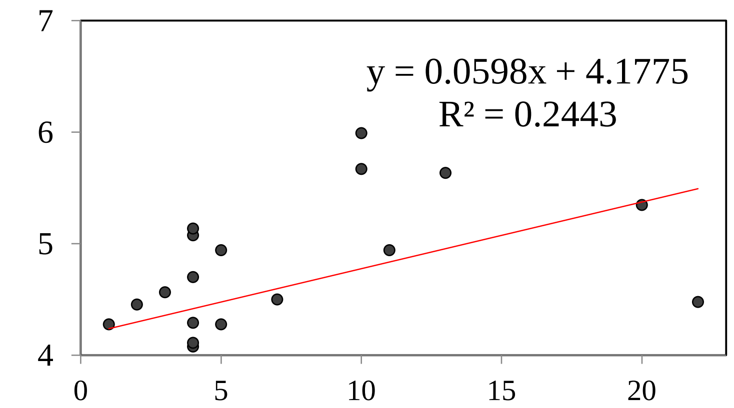




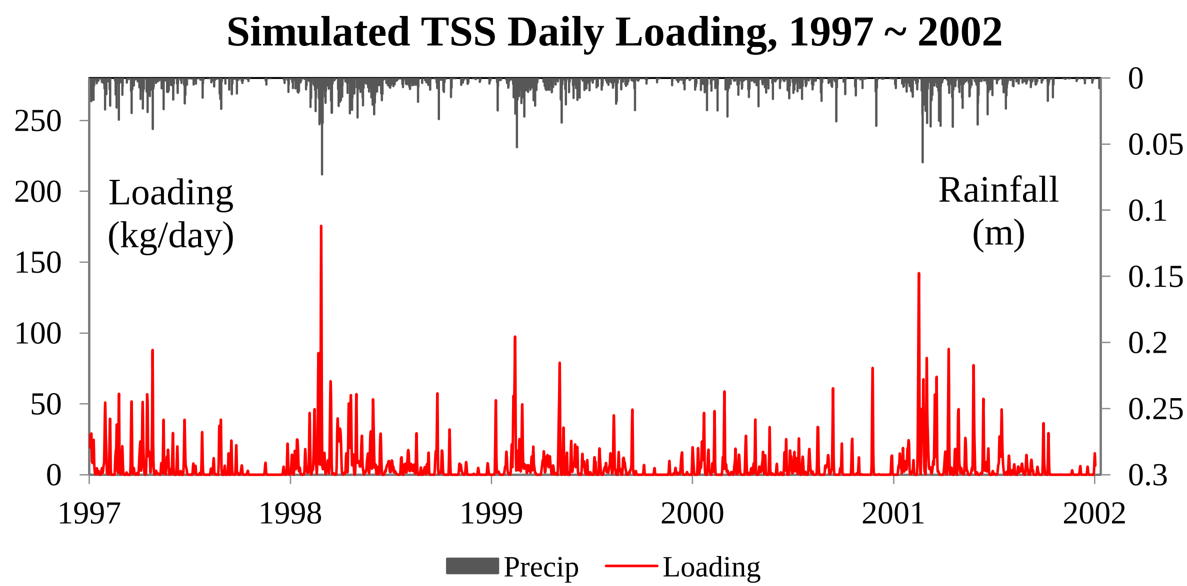


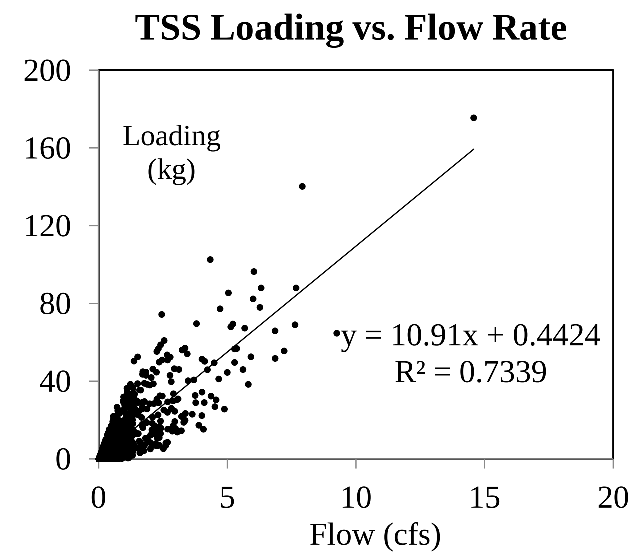


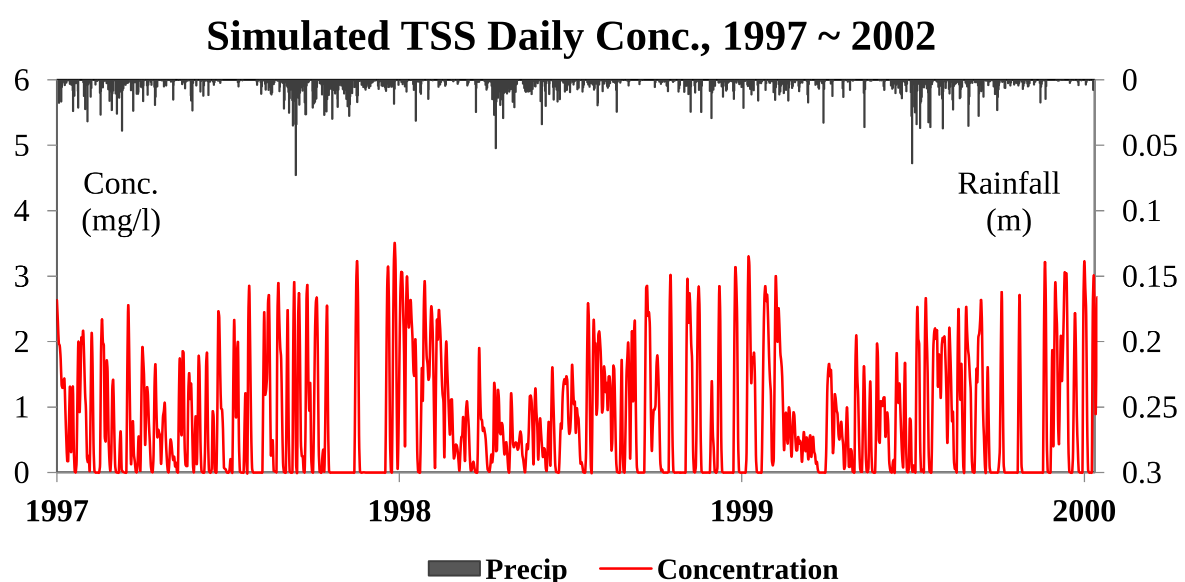


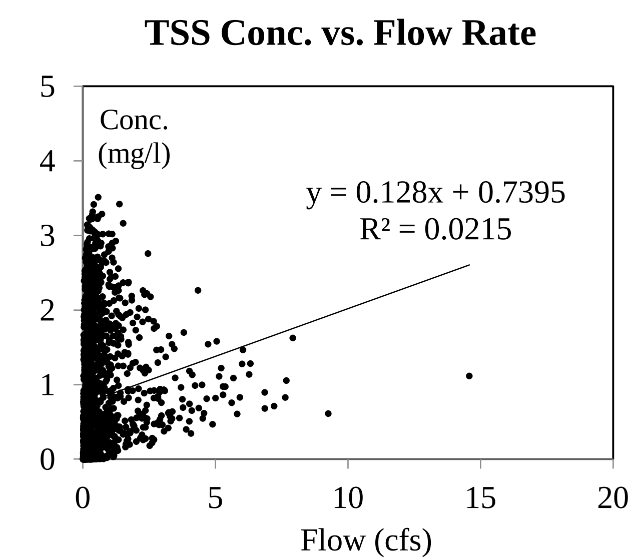


Trial Simulation Results in Mercer 12120000



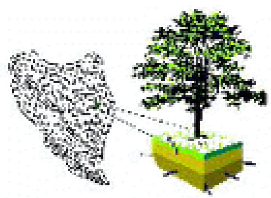






Short-Term Goals

- Incorporate the RBM10 particle tracking-based stream temperature model (Yearsley, 2009) into the DHSVM-WQ model
- Test, evaluate and calibrate the DHSVM-WQ model with observations at Mercer Creek
- Prepare the model input for the Puget Sound Basin.



HYDRO | MODELS | DHSVM | CODE

Distributed Hydrology Soil Vegetation Model

DOCUMENTATION | TOOLS | CONTACTS | PUBLICATIONS

Updates and Bug Fixes

- ***DHSVM 3.1.1 Version Update Released Feb 13, 2013***
  List of Program Updates in DHSVM v3.1.1 (txt)
- ***DHSVM 3.1 Bug Fix Update Released Jan 17, 2013***
  List of bug fixes (txt)

Code & Tutorial Downloads

Date	Descriptio
2/11/2013	Tutorial Package for DHSVM 3.1.1 (.tar.gz
2/11/2013	Full-version DHSVM 3.1.1 Tutorial (.pdf)
1/15/2013	Source code & Test Site Data for DHSVM
12/2012	Full-version DHSVM 3.1 tutorial (.pdf)
12/2012	Short-version DHSVM tutorial for running
12/2012	DHSVM 3.1 Test Site Information (.pdf)
----	Source code & Test Site Data for DHSVM
----	Source code & Test Site Data for DHSVM

Support

DHSVM is a research model and as such is continuously under c
code is available to interested parties, but be advised that no t
made.

DHSVM User Listserve allows subscribers to ask questions, shar

- DHSVM is well documented on the website, including tutorial, source code, training database, relevant publications, new releases and updates.

  http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/index.shtml

- Great user support from DHSVM LISTSERV community

  https://mailman2.u.washington.edu/mailman/listinfo/dhsvm-users

Acknowledgement

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  City of Bellevue, Washington Utilities Department

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nature climate change

Vulnerability of US and European electricity supply to climate change

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In the United States and Europe, at present 91% and 78% (ref. 1) of the total electricity is produced by thermoelectric (nuclear and fossil-fuelled) power plants, which directly depend on the availability and temperature of water resources for cooling. During recent warm, dry summers several thermoelectric power plants in Europe and the southeastern United States were forced to reduce production owing to cooling-water scarcity[2–4]. Here we show that thermoelectric power in Europe and the United States is vulnerable to climate change owing to the combined impacts of lower summer river flows and higher river water temperatures. Using a physically based hydrological and water temperature modelling framework in combination with an electricity production model, we show a summer average decrease in capacity of power plants of 6.3–19% in Europe and 4.4–16% in the United States depending on cooling system type and climate scenario for 2031–2060. In addition, probabilities of extreme (>90%) reductions in thermoelectric power production will on average increase by a factor of three. Considering the increase in future electricity demand, there is a strong need for improved climate adaptation strategies in the thermoelectric power sector to assure future energy security.

between environmental standards of receiving waters and economic consequences of reduced electricity production. Owing to the long lifetime of thermoelectric power plants and magnitude of investments, it is important for the electricity sector to have realistic projections of both water availability and water temperature to be able to anticipate and adapt to changes in cooling-water availability. Although several previous large-scale modelling assessments have been made that evaluate the impact of climate change on freshwater availability on continental and global scales[10–12], most of these studies focus on monthly or annual mean estimates of river flow, and ignore changes in water temperature. Shorter-term (for example, daily) estimates are required to address impacts on aquatic ecosystems and water users, such as thermoelectric power.

We used a physically based hydrological and water temperature modelling framework (Supplementary Section S1) to produce a multi-model ensemble of daily river flow and water temperature projections for Europe and the US over the twenty-first century. We evaluated the modelling estimates using observed daily river flow and water temperatures, which showed an overall realistic representation of observed conditions for the historical period 1971–2000 (Supplementary Sec-