Forest Hydrology for Climate Adaptation

Rolf Gersonde
Watershed Management Division
Seattle Public Utilities
Forest Hydrology

Objectives

• Regulate run-off from forested watersheds

• Improve in-stream habitat for fish

• Tree water status to increase resistance to disturbances

• Forest productivity and habitat functions
Water Cycle Regulation

- Peak Flow
- Base Flow
- Water Quantity

STORMWATER DISCHARGES FROM VARIOUS LAND COVERS

waterencyclopedia.com and waterontheweb.org
Water Cycle Regulation

- Peak Flow
- Base Flow
- Water Quantity
Regulating total Run-off:
Effect of Forest Cover on Hydrology

- Watershed yield
- Peak-flows
- Hydrologic regulation
Reducing Canopy Cover Increases Annual Stream Flow

Modified after Bosch and Hewlett 1982, JoH
Forest Cover Removal and Increase in Peak Flows

Changes in peak flow above bankfull discharge in relation to forest removal by harvesting, fire, or insects in North America, adapted from Plamondon (1993, 2002).
Difference in Runoff between Treated and Untreated Catchments - Recovery of Hydrologic Regulation

Short-term increase in Total Runoff
Long-term deficit in Runoff

Perry and Jones
Ecohydrology 2016
Managing Peak Flows: Forest Management Effects

• **Hill slope flow** routing to streams

• **Culvert Sizing** for Peak Flow Events

• **Rain-on-Snow Events**
Hillslope Flow Routing with Road Drainage
Perched Culvert Undersized for Peak Flow Events
Increased Culvert Sizing for Future Peak Flow Events

100%
120%
140%

2000 2040 2080

100yr Peak Flow Event
Rain-on-Snow
Increased Winter Precip.

Adjusting Culvert Size to Projected Peak Flow Increase
Rain-on-Snow Event

SNOWFALL

Wet, Windy Warm, Storm
(Atmospheric River)

Rain-snow transition

Snow-line

Snowcover exposed to warm, windy weather = Melt

Rain-on-Snow event produces Larger AREA contributing overland runoff to stream
Freezing Level Elevation during Winter Storms:

Past storm data

Rain Zone <1500 ft elevation
Transition Zone 1500 – 3000 ft
Snow Zone > 3000 ft elevation

Frequency (Nov 1993 - Mar 2017)
Freezing Level Elevation during Winter Storms:

Past storm data, +3°C temperature during storms
Freezing Level Elevation during Winter Storms:

Past storm data, +3°C temperature during storms

Snow Zone >4900 ft elevation
Larger Transition Zone

Frequency (Nov 1993 - Mar 2017)
Managing Base Flows:
Hydrologic Effects of Stand Age and Structure

- Younger trees transpire more water
- Fewer trees transpire less water
Water Use of Young and Old Riparian DF/WH Forests

Moore et al. 2004, Tree Physiology
Nisqually Community Forest VELMA modeling

Bob McKane¹, Brad Barnhart¹, Jonathan Halama¹, Paul Pettus¹, Allen Brookes¹,
Kevin Djang³, Joe Ebersole¹, Greg Blair¹, Justin Hall⁴,
Joe Kane³, Paula Swedeën⁶, Laurie Benson⁷

¹ U.S. Environmental Protection Agency
² Nisqually National Wildlife Refuge
³ U.S. Fish and Wildlife Service
⁴ U.S. Forest Service
⁵ Outdoor Research
⁶ University of Washington
⁷ Washington State University

Young Forest
Higher Transpiration

Old Forest
Lower Transpiration

Lower soil moisture and drainage

Lower streamflow (summer/fall)

Higher soil moisture and drainage

Higher streamflow (summer/fall)
Watershed 10, HJ Andrews, OR
- 0.1 km² headwater catchment
- 450 year-old conifer forest
- Clearcut in 1975
- Stream discharge data 1969-present

Forest age effect turned OFF

Streamflow, mm/day


450 year-old forest → Clearcut 1975

Observed
Modeled
Watershed 10, HJ Andrews, OR
- 0.1 km² headwater catchment
- 450 year-old conifer forest
- Clearcut in 1975
- Stream discharge data 1969-present

Forest age effect turned **ON**

Streamflow, mm/day

3.8x more low flow with age effect

450 year-old forest → Clearcut 1975
Baseflow for different Forest Landscape Age using the VELMA Model

Simulated September Minimum Flow
Average for 2006-2014

Mashel Forest Landscape Age

- Actual: 6 cfs
- 40 yr: 2 cfs
- 100 yr: 11 cfs

Longer Rotation Age has 2-5 times greater Base Flow
Effect of Canopy Cover on Hydrologic Processes
Streamflow responses to alternative forest practices
(Tolt Watershed, VELMA Model)

20 to 60% higher summer low flows with thinning
(≈50-190 more cfs)
Climatic Exposure
Effects of Topography and Aspect

- Evapotranspiration
  - Radiation
  - Temperature
  - Wind

- Topographic Position
  - Soil Depth
  - Water Flow

- Snow Cover
  - Growing Season
  - Water Supply
  - Climate Exposure

- Soil Type
  - Water
  - Nutrients
Topographic Position Index

Greater Climate Exposure on Ridges and Upper Slopes with shallow soil and less available water

Topographic Position Index
Jenness Ent. 2006 ArcView Extension

- 1, 2, 3 - Canyons and Drainages
- 4 - Valleys
- 5, 6 - Plains and Slopes
- 7 - Upper Slopes
- 8, 9, 10 - Ridges
Reference Evapotranspiration Model
using Solar Radiation and Temperature (elevation)
for the months of June – July – August, 30 m Resolution

Greater Evaporative Demand
on South-facing Slopes
Climatic Exposure Model
using ref. Evapotranspiration, Topographic Position, Snow Cover, and Soil

Identify Sites with high and Low climate exposure to prioritize adaptive management
Adaptation Strategies for Forest Hydrology

• *Older forest* for hydrologic regulation and reduced transpiration
• Adjust *culvert size* to future peak flow events
Adaptation Strategies for Forest Hydrology

• **Lower stand density** for reduced transpiration and resource competition
• Regenerate trees in **canopy gaps** to reduce water stress
Adaptation Strategies for Forest Hydrology

- **Canopy gaps** to increase snow accumulation and limit snow-on-rain events
- **Mixed-species stands** and **variable canopy** for resilient water cycle regulation
Adaptation Strategies for Forest Hydrology

- **Group Selection Regeneration System** for:
  - Snow retention in canopy gaps
  - Regeneration in gaps to reduce moisture stress
  - Regenerating mixed species
  - Matrix thinning to reduce transpiration and interception
  - Dispersed opening to reduce effects of Rain-on-Snow

Rolf.Gersonde@seattle.gov