Incorporating Climate Change in Estimates of the 100-year Flood for Forest Road Management: Methodology and Applications to the Olympic National Forest

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Objective:
A partnership between the Olympic National Forest and Park was formed to assess the impacts of climate change on federal and to incorporate climate change projections in management practices. Road management and culvert design are key components to management in the Olympic Peninsula.

Comparing Methodologies:

Current Statistical Approach
Managers on the Olympic Peninsula use the $Q_{100}$ (peak flow with estimated 100-year return interval) as a key design parameter. Current estimates are based on USGS regressions (http://water.usgs.gov/osw/streamstats/) using annual precipitation and basin area as explanatory variables. Note that temperature and seasonal precipitation are not used as an explanatory variable.

USGS regression and spatial application:
Region 1: $Q_{100}=0.745A^{0.922}P^{1.26}$

Physically Based Approach
A physically-based hydrologic model, the Variable Infiltration Capacity (VIC) model, incorporates a fully integrated snow model. The model explicitly addresses warmer temperatures, wetter winters, changing antecedent snow, and rising freezing levels in estimating daily runoff. Fitted GEV probability distributions are then used to estimate $Q_{100}$.

VIC schematic:

Sensitivity Maps:
The maps to the right show the ratio of the future-to-historical 100-year flood estimated by USGS (left) and VIC (right) models. The USGS model shows low sensitivity of $Q_{100}$ to changes in annual precipitation alone, and little spatial variability. The VIC model results indicate a greater sensitivity of $Q_{100}$ to warmer temperatures (changes in snow) and increases in winter precipitation.

Comparing Results and Potential Applications:

VIC model is physically-based:
- Simulates effects of snow accumulation and melt (rain on snow) and changing freezing levels on flood risk.
- Simulates antecedent conditions (soil moisture, snow) and their effects on extreme events

VIC captures temporal and spatial variability of T and P from climate model scenarios

VIC model responds explicitly to future warming and projected increases in winter precipitation.

USGS regression only incorporates increasing annual precipitation and does not respond to projected warmer temperatures or changing seasonality of precipitation in the future scenario.

$Q_{100}$ was estimated using the USGS regression equations and the VIC model at a spatial scale of ~30 km$^2$. Inputs to these two models were generated from historical gridded meteorological data sets and estimates of future conditions for the 2040s from downscaled GCM scenarios.