Summary Report Describing the Preparation of Hydrologic Data Bases for Pacific Northwest HUC4 Watersheds Used to Identify Basin Hydrologic Type and Quantify Temperature Sensitivity.

Alan F. Hamlet
Department of Civil and Environmental Engineering
University of Washington

For The Climate Leadership Initiative
Institute for a Sustainable Environment
University of Oregon
7/19/2007

Introduction

Based on some existing macro-scale hydrologic simulations for the Pacific Northwest (PNW) from 1916-2003 (described by Hamlet and Lettenmaier 2005, 2006; Hamlet et al. 2005, 2006), a set of hydrologic data bases summarizing the basin average water balance for moderate sized watersheds in OR, ID, WA and BC for different regional temperature regimes was produced for this project. The primary products to be produced from this information were a map showing the classification of each watershed at the Hydrologic Unit Code 4 (HUC4) level according to hydrologic type (rain dominant, mixed rain and snow, or snowmelt dominant), and a set of data bases quantifying the hydrologic sensitivity of each watershed to various levels of warming for a constant precipitation regime.

This effort follows a similar study (Sept, 2006) for the UO Climate Leadership Initiative providing the same kinds of information for the 61 Washington State Water Resources Inventory Areas (WRIAs).

Description of Hydrologic Simulations

Four hydrologic simulations were used to produce the water balance summaries in each watershed as shown in Table 1. All of the runs use identical “observed” historical precipitation, but each has a different temperature regime.

Table 1 Description of Temperature Regimes in the Hydrologic Model Runs

Temperature Regime Used in the Hydrologic Simulation	**Description**
“Pivot_1915”	The temperatures in this hydrologic model run are consistent with conditions in the early 20th Century. Monthly temperature trends are removed from the data (pivoting around 1915), but decadal and interannual variability of temperarute are much like the historic record. Temperatures in the early part of the record are much like those in the

	observations, but temperatures in the latter parts of the 20th century are colder than actually occurred.
"Pivot_1950"	The temperatures in this hydrologic model run are consistent with conditions in the mid 20th Century. Monthly temperature trends are removed from the data (pivoting around 1950), but decadal and interannual variability of temperature are much like the historic record. Temperatures in the early part of the record are warmer than those in the observations, and temperatures in the latter part of the 20th century are cooler than those in the observations.
"Pivot_2003"	The temperatures in this hydrologic model run are consistent with conditions in the late 20th Century. Monthly temperature trends are removed from the data (pivoting around 2003), but decadal and interannual variability of temperature are much like the historic record. Temperatures in the early part of the record are warmer than those in the observations, but temperatures in the latter part of the 20th century are much like those in the observations.
"Pivot_2000_plus2C"	In this run temperatures are first detrended to create a temperature regime consistent with the late 20th century (as above), and an additional 2 degrees C is then added to the data in a monthly pattern shown in Figure 1 (based on four GCM simulations reported by Snover et al. 2003). This is a simple climate change scenario showing the effects of a 2 C warming coupled with observed precipitation.

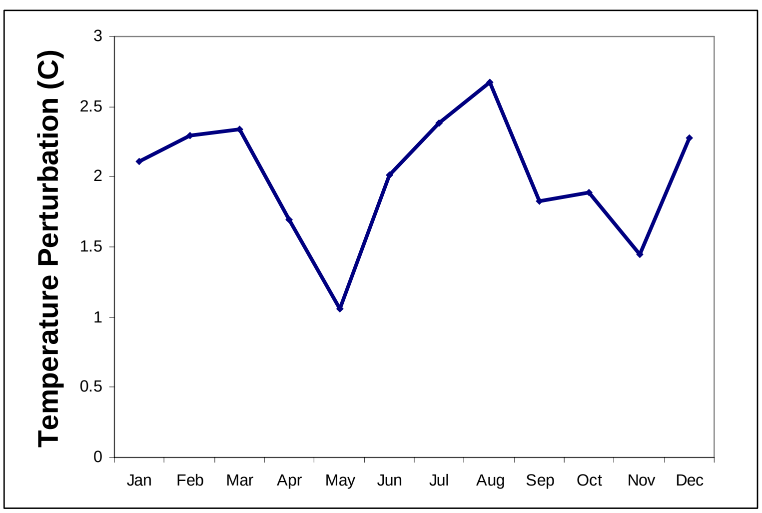

Figure 1 Monthly Pattern of Temperature Increases Used for the Pivot_2000_plus2c Scenario

Watershed Definition and ID Numbers

The watersheds examined in this study are delineated according to level 4 of the HUC basin classification system in OR, WA, ID and BC. Each basin is identified by a unique 8 digit number (except in BC where the basins are listed by a name). A listing of the basins used in this study and their HUC4 ID number is available at:

ftp://ftp.hydro.washington.edu/pub/hamleaf/huc4_climate_change/data_bases/HUCnames.txt

Water Balance Summaries

For each river channel location, a long term water balance summary under natural conditions (monthly values of precipitation, snow water equivalent (SWE), runoff, soil moisture, and evapotranspiration (ET) expressed as an average depth over the watershed) was produced for each hydrologic model run (temperature regime) and each basin defined above. SWE and soil moisture are given as first of month values, the other variables are monthly totals. Table 3 shows a mass balance summary for watershed huc4_16010102 for the 1950 temperature regime.

Table 3 Basin average water balance summary for huc4_16010102 for the 1950 temperature regime (units mm)

	Precipitation	SWE	Runoff	Soil Moist	ET
Oct	45.5	0.9	14.9	233.3	13.6
Nov	66.7	6.7	12.1	245.5	11.0
Dec	82.8	49.6	10.0	247.0	8.5
Jan	83.6	121.5	9.4	238.2	8.6
Feb	70.3	197.0	8.2	229.0	10.5
Mar	61.5	255.0	13.7	221.6	19.5
Apr	52.3	271.2	57.1	232.6	24.5
May	58.2	136.2	66.7	336.8	43.9
Jun	40.3	21.9	30.4	398.8	85.0
Jul	28.0	1.2	17.4	342.7	91.0
Aug	30.9	0.0	13.7	265.0	50.2
Sep	38.0	0.0	13.3	233.3	24.8

Defining the Hydrologic Basin Type of each Watershed

In the course of examining the sensitivity of streamflow timing shifts it was found that a robust metric that can be used for classifying the hydrologic basin type for each watershed is the long term average of the peak SWE (in whatever month it occurs) divided by the long term average of total cool season (Oct-Mar) precipitation. These values were calculated for each watershed and temperature regime (Figure 1). A value of this metric between 0.1 and 0.4 identifies mixed rain and snow (transient) watersheds that are relatively sensitive to warming. Values below 0.1 are classified as rain dominant, values higher than 0.4 are classified as snow dominant. These thresholds are somewhat arbitrary, but were found to work well in identifying the most sensitive basins to warming. Figure 2 shows the classification of all the watersheds included in the study for the 1950 temperature regime. Figure 3 shows a map of the same information with greater geographic detail for OR.

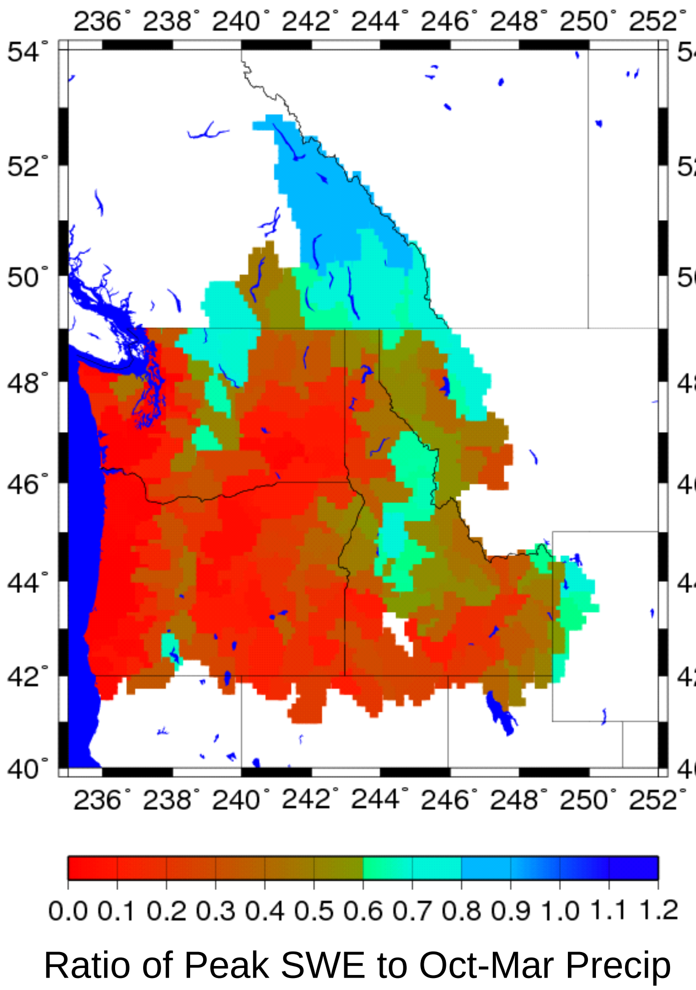

Figure 1 Fraction of Oct-Mar precipitation stored as peak SWE from the simulated water balance summaries for each HUC4 watershed for the 1950 temperature regime.

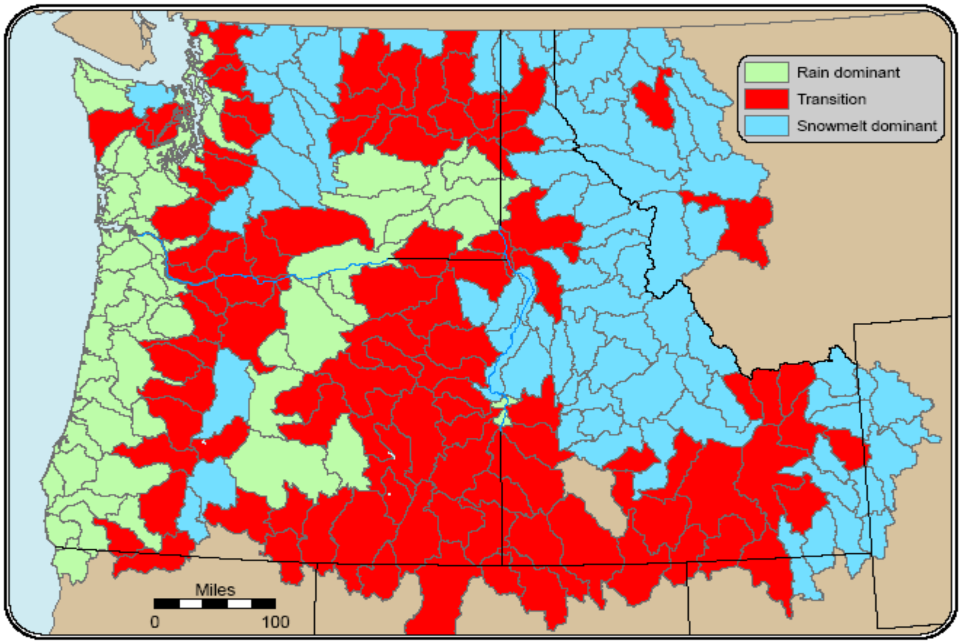

Figure 2 Hydrologic classification of the Pacific Northwest HUC4 watersheds (green = rain dominant, red = transient snow, blue = snow dominant) based on the fraction of Oct-Mar precipitation stored in the peak SWE for the 1950 temperature regime (see text).

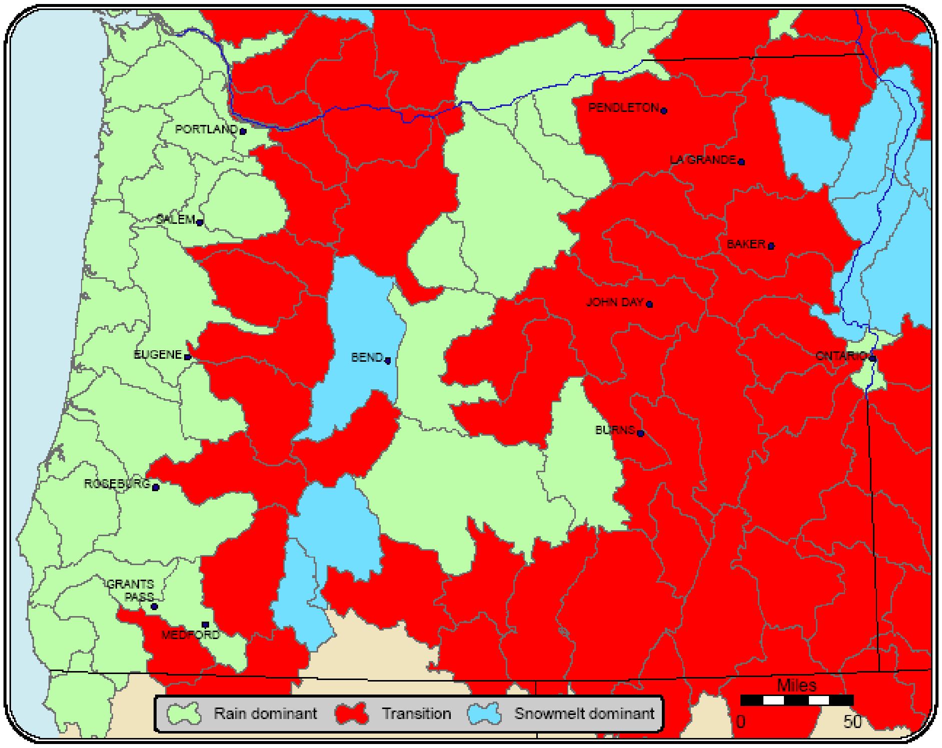

Figure 3 Same as Figure 2 but showing more geographic detail in OR.

Hydrologic Data Bases and Excel Spreadsheets to Display the Changes in Hydrologic Variables

For a more detailed examination of the sensitivity of each watershed, a set of data bases have been constructed for each hydrologic variable (e.g. SWE). The files are called **huc4_runoff_data_base**, **huc4_soilmoist_data_base**, **huc4_swe_data_base**, and **huc4_et_data_base**. Each file contains one record (row) per watershed and 49 fields (columns) as described in Table 4.

Table 4 Description of Data Fields in Summary Data Base Files

Field Position in Each Record	Description	Example
1	watershed ID String	"huc4_16010102"
2-13	Oct-mar values for pivot_1915 temperatures	number
14-25	Oct-mar values for pivot_1950 temperatures	number
26-37	Oct-mar values for pivot_2003 temperatures	number
38-49	Oct-mar values for pivot_2000_plus2C temperatures	number

An additional file called **huc4_frac_precip_as_snow_1950** stores the fraction of Oct-Mar precip stored as peak SWE for each WRIA for the 1950 temperature regime only.

The data base files are archived at:
ftp://ftp.hydro.washington.edu/pub/hamleaf/huc4_climate_change/data_bases/

A plotting spreadsheet (huc4_runoff_data_base.xls) to display plots of changes in monthly average runoff for each watershed is provided as a template. To use the spreadsheet, the appropriate data base (e.g. for SWE) is pasted into the worksheet called huc4_runoff_data_base. The other worksheets compare data for different temperature regimes. An ID string (e.g. "huc4_16010102") is entered in cell B3 of each of these worksheets and the plot will update to show the changes in runoff for this watershed. The worksheet "Plot 1915 vs 2003" shows the change in the seasonal timing of runoff associated with temperature changes that have already occurred in the 20^{th} century, and the worksheet "Plot 1950 vs plus2c" shows the changes in the seasonal timing of runoff between 1950 and estimates of temperature increases for the mid 21^{st} century. This spreadsheet can be used as a template to make similar plots of other hydrologic variables as well, since the primary data bases all have the same file format.

Another spreadsheet (huc4_hydrologic_classification.xls) classifies each watershed as 1 (rain dominant), 2 (transient), or 3 (snowmelt dominant) according to the value the fraction of precip as SWE in the data file (Figure 2).

The spreadsheets are archived at:
ftp://ftp.hydro.washington.edu/pub/hamleaf/huc4_climate_change/spreadsheets/
Water balance summaries for each watershed and hydrologic model run are available at:
ftp://ftp.hydro.washington.edu/pub/hamleaf/huc4_climate_change/

Archived Figures
Several versions of the basin classification maps are available at:
ftp://ftp.hydro.washington.edu/pub/hamleaf/huc4_climate_change/figures/

References
Hamlet A.F., Lettenmaier D.P., 2005: Production of temporally consistent gridded precipitation and temperature fields for the continental U.S., J. of Hydrometeorology, 6 (3): 330-336

Hamlet A.F., Mote P.W, Clark M.P., Lettenmaier D.P., 2005: Effects of temperature and precipitation variability on snowpack trends in the western U.S., J. of Climate, 18 (21): 4545-4561

Hamlet A.F., Mote P.W, Clark M.P., Lettenmaier D.P., 2006: 20th Century Trends in Runoff, Evapotranspiration, and Soil Moisture in the Western U.S., J. of Climate (accepted)

Hamlet, A.F., Lettenmaier, D.P., 2006: Effects of 20th century warming and climate variability on flood risk in the western U.S., Water Res.Research (in review)

Snover, A.K., Hamlet, A.F., Lettenmaier, D.P., 2003: Climate Change Scenarios for Water Planning Studies, BAMS, 84 (11):1513-1518