APPENDIX ?: LAND USE AND ANTHROPOGENIC CHANGES TO HABITAT-FORMING PROCESSES IN THE COLUMBIA RIVER BASIN

OVERVIEW

Goal:
Evaluate deviations of current habitat-forming processes from their historical rates or conditions, using spatially explicit analyses.

Products:

1. For each candidate habitat factor (listed in Table 1), maps of (i) historical rates or conditions, (ii) current rates or conditions, and (iii) ratios of current rates or conditions to historical rates or conditions.

Approach:
Our general approach to assessing root causes of habitat degradation by directly analyzing land use changes to habitat-forming processes is based on two well-founded assumptions: (1) salmon are adapted to local habitat conditions, and (2) habitat conditions vary in space and time as a function of landscape processes (as such as soil erosion or riparian functions) (Beechie and Bolton 1999). In combination these two statements imply that sustainable restoration of salmon habitat must focus on restoring processes that create and maintain ecosystems that support salmon. Such restoration actions should ultimately restore the range of habitat conditions that historically sustained abundant and diverse salmon populations.

To analyze deviations from natural conditions for each process and identify where restoration actions are likely to benefit salmon, we estimate (1) historical rates of each process, (2) current rates of each process, and (3) the change in rate (Beechie and Bolton 1999). In our analyses we use coarse resolution data and process-based assessment approaches to identify locations where habitat-forming processes have likely been significantly altered by land uses (Beechie et al. 2002, 2003). We analyze a suite of candidate limiting factors (Table 1) that can be grouped into (1) processes that form and sustain aquatic habitats, and (2) habitat conditions created by those processes (Figure 1). We recognize that dominant processes forming stream habitats vary by ecoregion (Beechie et al. 2003), so we use analyses tailored separately to the relatively dry interior Columbia River basin and the wetter lower Columbia River to assess deviations from historical rates or conditions. In some respects the analyses are similar to those of ICBEMP (Quigley and Abelbide1997) and Skagit Watershed Council (1998), and will to the extent possible rely on results of the ICBEMP analyses or their derivatives (many of which have been peer-reviewed and published in scientific journals). Where possible, we use fine resolution aerial photograph or field data to assess potential errors in coarse resolution analyses.

SURFACE EROSION ON NON-FORESTED LANDS

Overview
Erosion on non-forested lands of the Columbia River basin is dominated by surface erosion and gullying processes, with relatively little contribution from mass wasting. Spatial variation in surface erosion rate is governed by several natural factors including hillslope angle, soil erosivity, rainfall intensity, and vegetation cover. Agricultural practices typically increase surface erosion by reducing vegetation cover and exposing more of the soil surface to rainfall impact and overland flow. The following analysis uses the long-standing universal soil equation as the basic model for estimating changes in surface erosion on non-forested lands as a function of conversion from grass or shrub cover to agriculture. It is necessarily a coarse resolution analysis (in order to have similar data quality across the entire basin), relying on geospatial datasets from ICBEMP and USGS to run the model. Results are summarized in an index of change in surface erosion rate for each HUC6 within the basin.

Products:
1. Map of historical sediment supply ratings at HUC6 resolution
2. Map of current sediment supply ratings at HUC6 resolution
3. Map of difference between current and historical (divide historical by current to get percent increase in sediment supply rating) at HUC6 resolution

Approach and Methods:
The equation at the basis of our approach is the Universal Soil Loss Equation (Wischmeier and Smith 1978), updated as the Revised USLE (Renard 1996):

$$A = RKLSCP$$

where,
A is the soil loss per unit area,
R is the rainfall and runoff factor,
K is the soil erodibility factor,
L is the slope factor,
S is the slope steepness factor,
C is the cover factor (also called the cropping practice factor),
and P is the support practice factor (representing conservation tillage practices).

Accounting for those values that are held constant for both historical and current estimates of sediment production within a grid cell (R), that do not vary spatially (L), or that we cannot estimate with sufficient detail (P) an index of erosion (E) is

$$E = K_p I_{slope} C$$

Where,
K_p is the soil erodibility weighting factor,
I_{slope} is an index of the change in erosion rate as a function of slope,

C is the weighting factor for vegetation cover.

Because all values except C are constant for a given cell in both the current and historical estimates, the ratio of $(E)_{ag}/(E)_{natveg}$ is an index of the change in erosion rate for a grid cell. Values are summarized at the HUC6 level by averaging all cells within each HUC6 to generate maps of mean sediment supply ratings for historical conditions, current conditions, and the ratio of current/historical.

The general steps in the procedure are:

1. Assign erosion weighting factors from Table 2 to each data layer (soil, slope, vegetation) for historical and current conditions.
2. Multiply the factors together to get an erosion rate index for both current and historical conditions.
3. Divide historical erosion rate index (E_{hist}) by current erosion rate index (E_{curr}) to get a rating of change in erosion rate index (ΔE). The analysis will only show changes in non-forest areas given these ratings (see Table 3 for vegetation classes that are considered non-forest).

To estimate E we required values for K_p, I_{slope}, and C. Because we do not have K values for individual soils in the ICBEMP soils layer (we have the percentage of soils with K>0.37 in each soil type polygon), we used a weighting factor for K_p that is a function of the percentage of soils with K greater than 0.37 (Table 2).

Values of I_{slope} are calculated as a function of grid cell slope (from the 10m DEM) using the equation

$$I_{slope} = 3.41(S^2) + 0.93(S),$$

which we derived (using the USLE) to analyze sensitivity of erosion rate to hillslope gradient (m/m) (Figure 2). Normative parameters for the sensitivity analysis were R = 25 (an intermediate value for interior rangelands from Figure 2-15 in Renard et al. 1996), K = 0.37 (arbitrary value based on the ICBEMP), L = 72 (length of standard slope from Wischmeier and Smith 1978), S = slope of grid cell, LS = ((L/72.6)^0.5) * (65.41*((SIN(S))^2) + (4.56*SIN(S)) + 0.065) (a non-linear function of L and S based on Wischmeier and Smith 1978, p. 13), C = 0.01, (value for 80% grass cover from Dunne and Leopold 1978, p 529), and P = 1.

Weighting factors for vegetation cover (C) were selected from various sources as indicated in Table 1. These factors are chosen to represent average relative changes in erosion under various cover types, and are not intended to predict actual erosion rates. Note that we did not have sufficient detail on erosion control practices to incorporate a value of P into the analysis. Literature on the subject indicates that erosion control practices (e.g., no–till seeding, strip cropping) can in some cases substantially reduce erosion rates (e.g., Wischmeier and Smith 1978, Ebbert and Roe 1998 [USGS Fact Sheet FS-069-98]).

Final ratings for current and historical conditions (for each grid cell) were derived by multiplying the three weighting factors together as in the RUSLE. Examples of erosion rating combining all of these factors are shown in Table 4. Values were summarized at HUC6 resolution by first calculating the ratio of current/historical rate for each grid cell, then calculating the area-weighted average ratio for each HUC6.

Results

As one would expect from the structure of the model, the highest erosion ratings for historical conditions in two test basins (Yakima and Grande Ronde) are found in HUC6s with steeper hillslopes and greater area in shrublands (Figures 3, 4). Current sediment supply ratings (Figures 5, 6) and the change in ratings from historical conditions (Figures 7, 8) are driven predominantly by the location of agricultural land uses. Changes in sediment supply ratings are highest where historical grasslands (which had relatively low surface erosion rates) have been converted to agricultural land uses. Across the entire analysis area, the largest changes are concentrated in the Palou