DEPARTMENT OF ECOLOGY

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Subject GIS Analysis, Yakima River Suspended Sediment TMDL Evaluation

GIS Objectives and Scope

The overall objective of the Yakima River Suspended Sediment TMDL Evaluation Phase 1 was to provide a revised assessment of where the most severe suspended sediment and persistent pesticide problems are located within the Yakima basin, and which sub-basins have the greatest likelihood of damaging fish resources. (Joy and Patterson, 1994)

The specific GIS objective was to use landscape analysis to estimate source-area erosion from irrigated areas based on readily available techniques and data. The project area for this analysis included the entire Yakima River watershed, although the primary focus was on irrigated cropland.

Approach

Historically, furrow irrigation has proven to be the irrigation practice which causes the greatest surface erosion. Therefore, to assess the worst-case erosion problems, the focus was on this method of water delivery. The approach taken was to calculate furrow erosion based on an erosion modeling technique which had been adapted to the farming and irrigation practices used in the study area. Fortunately, the U.S. Soil Conservation Services had developed such a method. Unfortunately, this method was not easily automated with GIS tools.

Three data sets were required for the furrow erosion analysis. These were land-surface slope, land cover (crop type), and the soil erodibility factor. By solving for furrow erosion only (not erosion caused by other water delivery systems) the maximum erosion load was identified. This helped identify priority areas for more detailed analysis.

Once these data were assembled, the erosion model was solved on an acre-by-acre basis for approximately 18% of the Yakima Watershed which was classified as having a cropland, orchard, pasture, vineyard, grove, nursery, and ornamental horticultural land cover.

This calculated erosion was then compared with the soil tolerance value to identify which areas were most at risk from loss of soil productivity due to surface erosion.

Data Processing

All spatial data manipulation and analysis was done with ARC/INFO version 6.1.1 standard functions and GRID module. Primarily the GRID Module was used to manage all model input information and erosion calculations. GRID uses a cell-based (also called gridded, raster, or image) data model to manage geo-spatial information. It includes the grid-algebra tools which were used for analysis and modeling. Due to the enhanced handling of large raster images, all graphic output was done with ARC/INFO 7.0.2.

Sources of Information

Land Cover

The USGS 1:250,000 scale Land Use / Land Cover information was used as the land cover information source. The information was derived primarily from NASA high-altitude aerial photography. Other information such as land use maps and field surveys were also included. The feature polygons are homogenous with a minimum size of 10 acres.

These data were developed during the mid 1970s and is very outdated in many urban areas. The USGS, however, verified the accuracy of agricultural land use in the Yakima Valley as part of the USGS 1987-1991 Yakima NAQWA project. (Joy and Patterson, 1994, p19)

The two main land cover classes used were: 1) Cropland / Pasture class, and 2) Orchard / Groves / Vineyards / Nurseries / Ornamental Horticultural Areas class. Unfortunately, further subclassifications such as the split between cropland and pasture, or the split between irrigated and non-irrigated cropland, are not available with this data set. Figure 1 shows the land use and land cover for the project area.

Land Surface Slope

USGS 1:24,000 scale digital elevation data were used as the source information for calculating slope angles. A statewide data set processed by Washington Department of Natural Resources (WDNR) was used, since the data had been processed into a continuous data set, and smoothed to remove most anomalous values. (WDNR, no date)

The WDNR data consisted of a grid of quarter-acre cells (104.355ft/side), with elevation values truncated to the nearest whole number. These data were re-sampled using cubic convolution (weighted-distance average of the nearest 16 cells) to form a 1-acre cell size (208.71 ft/side) elevation grid. Land surface slope was then calculated from this re-sampled elevation grid using a moving 3-cell-by-3-cell computation window. Slope is calculated for the center cell by calculating the difference in elevation between it and the surrounding cells. The maximum difference in elevation is then divided by the cell size and reported as the percent slope for the center cell.

Edit plots of slope values (see Fig. 2) and simulated hill-shade (see Fig. 3) show a pattern of noise in the data. These are indicated by horizontal banding which terminates at 7.5 minute quadrangle boundaries. This problem is mostly apparent in flat areas south and east of Toppenish and in the Granger Drain areas. Commonly different sections of a USGS digital data set will contain errors within a tile.

Another error noted was discontinuity across quadrangle boundaries. These errors, typically called edge-matching errors, occur when tiles of data are joined together to form a large, continuous data set. The WDNR elevation data were processed with a data-smoothing algorithm to remove such areas, but apparently this processing was not completely effective.

Soils

The U.S. Soil Conservation Service 1:250,000 State Soil Geographic Data Base (STATSGO) was used as the data source for soil erosion potential. STATSGO data was compiled by generalizing more detailed soils survey maps. (SCS, 1991). Each STATSGO map-unit polygon contains 1 to many components (up to 21), each of which may be associated with 1 to many profile layers. Both the component and layer tables contain soil attribute information. This complex relationship between map-units, components, and layers is designed to maintain source information detail, while providing a manageable statewide data base. It is up to the user to select the appropriate method or statistic to assign any given soil attribute to the mapping unit.

The Soil Erodibility Factor (also known as the K-factor), reported in tons/acre/year, was a required input parameter for this erosion modeling. Two aggregation methods were used to provide this factor for each of the 229 soil polygons within the project area. One method assigned the erodibility factor based on the K-Factor value of the predominant soil component, i.e., the component with the largest area. The other approach was to calculate an area-weighted soil erodibility factor based on all components within the mapping unit polygon. These weighted data, shown in Figure 4, were used in the final erosion calculations.

An area-weighted Soil Tolerance Factor (also known as the T-factor), reported in tons/acre/year, was also calculated from STATSGO layer 1 information and added to the soils polygon coverage. This was used to calculate the erosion/tolerance ratio as an indicator of those soils at risk for loss of production due to surface erosion.

Quality Control

Standard procedures for creation and management of GIS data were established to ensure consistent modeling results. All analysis windows (the spatial extent of the analysis) were set to the 1-acre digital elevation grid which covered the entire Yakima River watershed. All newly generated grid GIS data sets were established with the same cell size, and used the same point of origin. This ensured registration of analysis grids.

A shaded-relief hill slope plot was compared with 1:100,000 scale streams and lakes for verifying registration of the elevation grid. No errors were found but noise in the data was observed. No correction was applied.

Edit plots were made of the WRIA boundary, STATSGO soils, and Land Use grids; and these were compared to the source vector data to ensure consistency. No errors were found.

Data Analysis

Furrow erosion was estimated from the Furrow Erosion Nomograph State of Washington, January 1985, developed by W. Weller and H. Krauss of the U.S. Soil Conservation Service, Yakima Office (Weller, 1985). This is a revised model from the one developed in SCS (SCS, 1978). Equations for the nomograph were unavailable, therefore a tabular look-up-table was developed by solving the nomograph for a series of conditions found within the project area. These values are listed in the table below.

Model Parameter	**Values used in look-up-table**
Slope Percentage	<=1, 2, 5, 8, 12, =>15
Area-weighted Soil Erodibility Factor (k-factor)	0, .05, .10, .15, .20, .25, .30, .35, .40, .45, .50, .55
Land Cover	Cropland / Pasture Class, Orchard / Groves / Vineyards / Nurseries / Ornamental Horticultural Areas Class

Slope and Soil Erodibility grid data sets were reclassified into the class intervals shown above. These were then used as the input to the erosion calculation.

Furrow erosion was calculated on a 1-acre, cell-by-cell basis for the project area. The ARC/INFO GRID software selected land cover, soil erodibility factor, and slope percentage values and looked-up the resulting furrow erosion through as series of selection steps. Furrow erosion in tons/acre/1000 ft of furrow was reported.

Results

The spatial distribution of calculated furrow erosion rates is shown in Figure 6. Several views of the resulting erosion output were prepared with different remap tables (a look-up table to assign calculated erosion to a map shading symbol). These were used to compare calculated erosion with results from the earlier investigation.

There is general agreement between this erosion analysis and the erosion rates described by SCS 1978 report. There are however certain areas where differences were noted. The differences observed along the valley edges appear to be caused by higher calculated erosion rates from those areas with higher surface slopes. These areas comprise the foothills and terraces along the valley edges where steeper topographic relief occurs. Most of these areas do not use furrow irrigation and therefore would not have been included if reliable irrigation information had been available for the project area. Figure 6 shows the calculated erosion rates in tons/acre/1000 ft of furrow.

The ratio of calculated furrow erosion over soil tolerance factor showed several areas which were at risk for lost soil productivity. In this analysis, the higher the ratio, the greater the risk of lost soil productivity. The areas with high ratios are shown in Figure 7.

Conclusions and Recommendations

This erosion analysis would have been more informative if better land cover and water-use information was available. The fact that cropland and pasture were combined into the same cover class is a major pitfall in the analysis. These two cover classes have widely differing erosion potential. This lumping of land cover surely masked valuable details of the erosion analysis. The calculated erosion rates are based on values for *cropland* land cover, and therefore should represent the <u>worst case erosion areas.</u>

The Phase 2 sediment modeling and analysis will require more refined source information. Sub-watershed or irrigation district-level erosion, sediment transport, and BMP efficacy analysis will require that the following data requirements be met.

Data with the appropriate spatial precision and granularity will be required for sub-watershed or irrigation district-level analysis. Typically data mapped at 1:24,000 scale would offer appropriate spatial accuracy for these analyses. Such data, if properly managed within a GIS system, will preserve the source accuracy 40 ft.

The size of the mapping unit (or image classification unit) should be equal to, or smaller than, the size of the hydrologic response units used in modeling. This granularity will be required to evaluate effects of farm-field applied BMPs.

The University of Washington-led Washington GAP (WaGAP) analysis project has much to contribute to this project. The classified image and image-to-land cover classification approach being developed will provide useful land cover information. While the land-cover polygons being developed by WaGAP will be too large for sub-watershed modeling, the image and the spectral classification information will be useful for land cover delineation on a sub-watershed level. For this image information to be useful field image classification and verification will be required. Depending on the size of the analysis area, this could be a major task.

For sub-watershed modeling, 1:24,000 scale hydrography data will be required. Unfortunately, WDNR has not completed the 1:24,000 hydrography in the lower Yakima Watershed. It is scheduled to be completed as part of the Data96 Project, but the completion data is unknown. Ecology, as a participant, will receive a license for this data upon completion, but may request partial sets in the interim. Ecology will likely be responsible for verification and editing required to ensure correct stream-routing. This step is required since irrigation canals crossing natural stream courses complicate networking capabilities within the GIS analytical tools.

A detailed soil survey such as the SCS Soil Survey Geographic Data Base (SSURGO) would be the appropriate soil inventory for the Phase 2 analysis. The SCS recommends SSURGO for defining erosion areas and developing erosion control practices. (SCS, 1991).

Irrigation location and type is another critical information gap. Phase 2 modeling will require detailed information regarding water delivery systems. These will need to be defined as polygons (or Arc/Info version 7 regions) of water delivery detailed by amount and irrigation method. Information provided by Ecology's Water Resources Program will probably not be a useful information source.

If sediment routing and sediment delivery ratios are to be calculated, then channel morphology (width, depth, slope, roughness) will be required for each stream segment in the routing analysis. These will need to be assigned as attributes of the GIS stream segments.

A Best Management Practice inventory will need to be completed or updated. How this will best be addressed in GIS is not clear at this time.

Several edge-matching errors and ripple-banding were observed in the WDNR digital elevation data. These problems must be resolved if the Agricultural Non-Point Source Model (AGNPS) is used. AGNPS makes extensive use of elevation data in the calculation of slope-length, drainage network, and hill slope. The edge-matching errors will produce erroneous hill slopes and drainage paths. These errors will be much more significant on the scale of an irrigation district.

References

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer, 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey, Professional Paper 964, Reston, VA. 28 pgs.

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U.S. Soil Conservation Service, 1991. State Soil Geographic Data Base (STATSGO) Data Users Guide. SCS Miscellaneous Publication No. 1492, 88 pgs.

U.S. Soil Conservation Service, 1978. Yakima Cooperative River Basin Study, Draft, December 1978. USDA Soil Conservation Service, Spokane, WA.

Wa. Dept. of Natural Resources, (no date). Development of a Single Statewide Elevation Surface. Wa. Dept. of Natural Resources, Division of Information Management, Olympia, WA. 3 pgs.

Weller, W., H. Krauss, 1985. Furrow Erosion Nomograph State of Washington. 1 pg.

Appendix A.
GIS Data set names and descriptions

Name	Data Type	Description	Workspace
erosion	Grid	Calculated Erosion grid based on SCS Nomograph calculations	$YAK
kfact-rc	Grid	STATSGO k-factor grid (kfact-1a) reclassified into classes used in erosion modeling	$YAK
kfact1a	Grid	STATSGO 1-acre cell size soil erodibility factor (k-fact)	$YAK
yak-slope1a	Grid	1-acre cell slope grid derived from digital elevation model grid	$YAK
slope-rc	Grid	Slope grid reclassified into classes used in erosion modeling	$YAK
yak-dem1a	Grid	1-acre cell digital elevation model resampled form state wide grid	$TMP2
yak-lulc1a	Grid	1-acre cell land use land cover grid, produced from polygon coverage	$TMP2
yak-lulc	Polygon Coverage	Land Use / Land Cover clipped from statewide USGS GIRAS coverage	$TMP2
yak-sgo2	Polygon Coverage	Yakima STATSGO soils coverage clipped from statewide coverage and with summary attributes added for soil erodibility and soil tolerance factors	$YAK
yak-shade1a	Grid	Hillshade calculated from DEM	$TMP2
yak-str100	Arc Coverage	1:100000 streams from Washington Rivers Information System	$TMP2

Ecology GIS Network file system paths:
Path $YAK = /net/sunserv/home/jtooley/projects/yakima
Path $TMP2 = /net/eils1/usr2/yakima/tooley

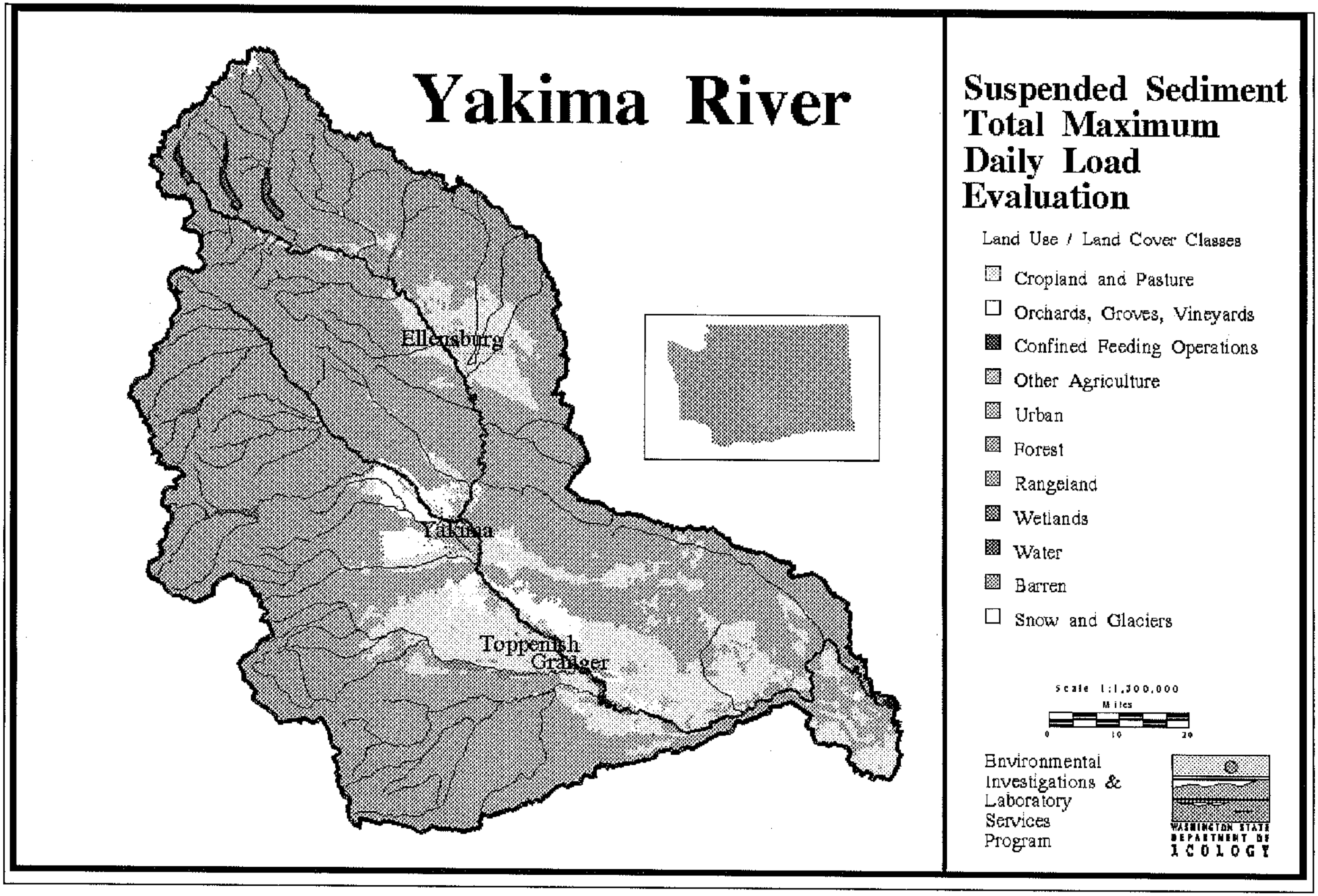

Figure 1. USGS Land Use / Land Cover

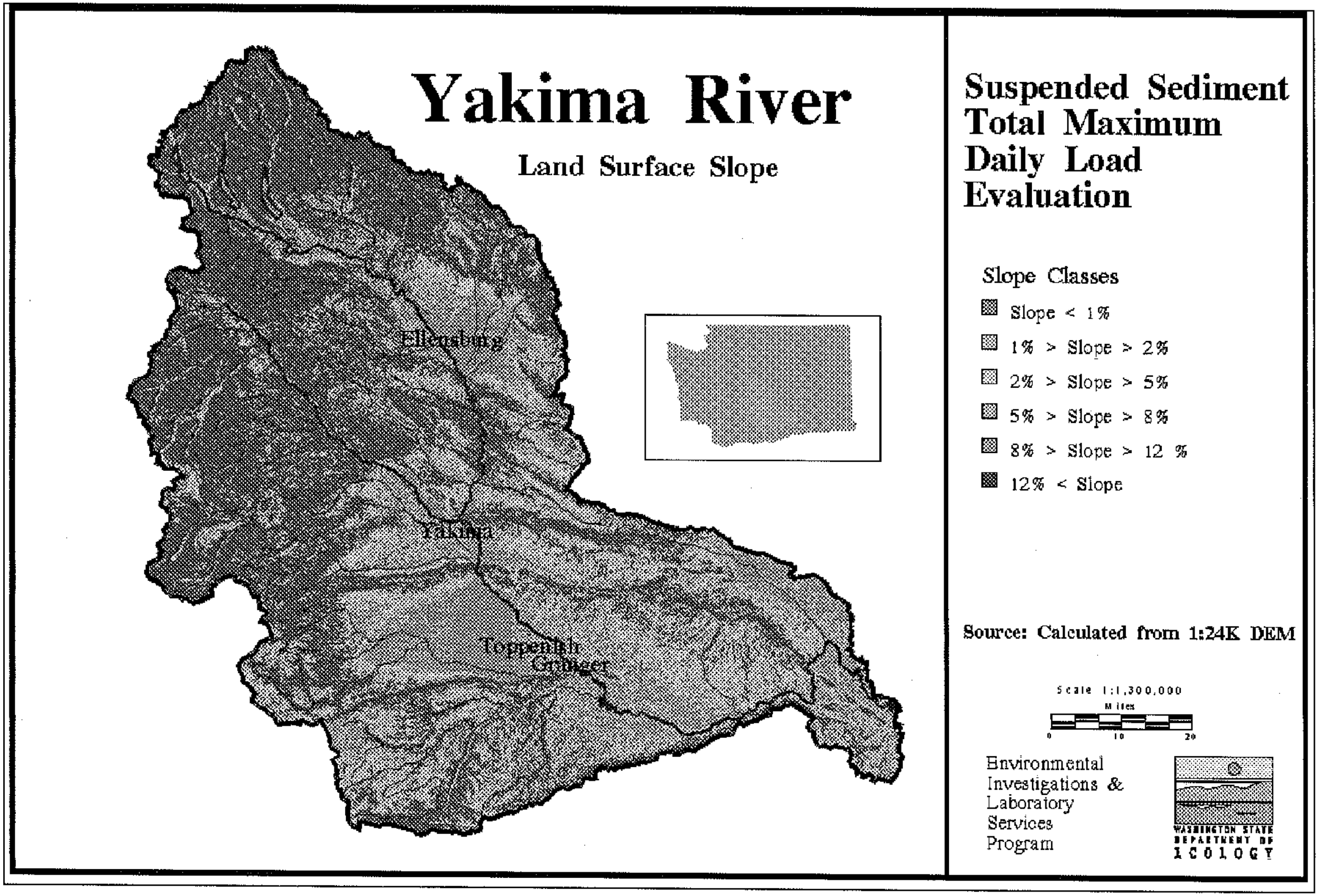

Figure 2. Land Surface Slope

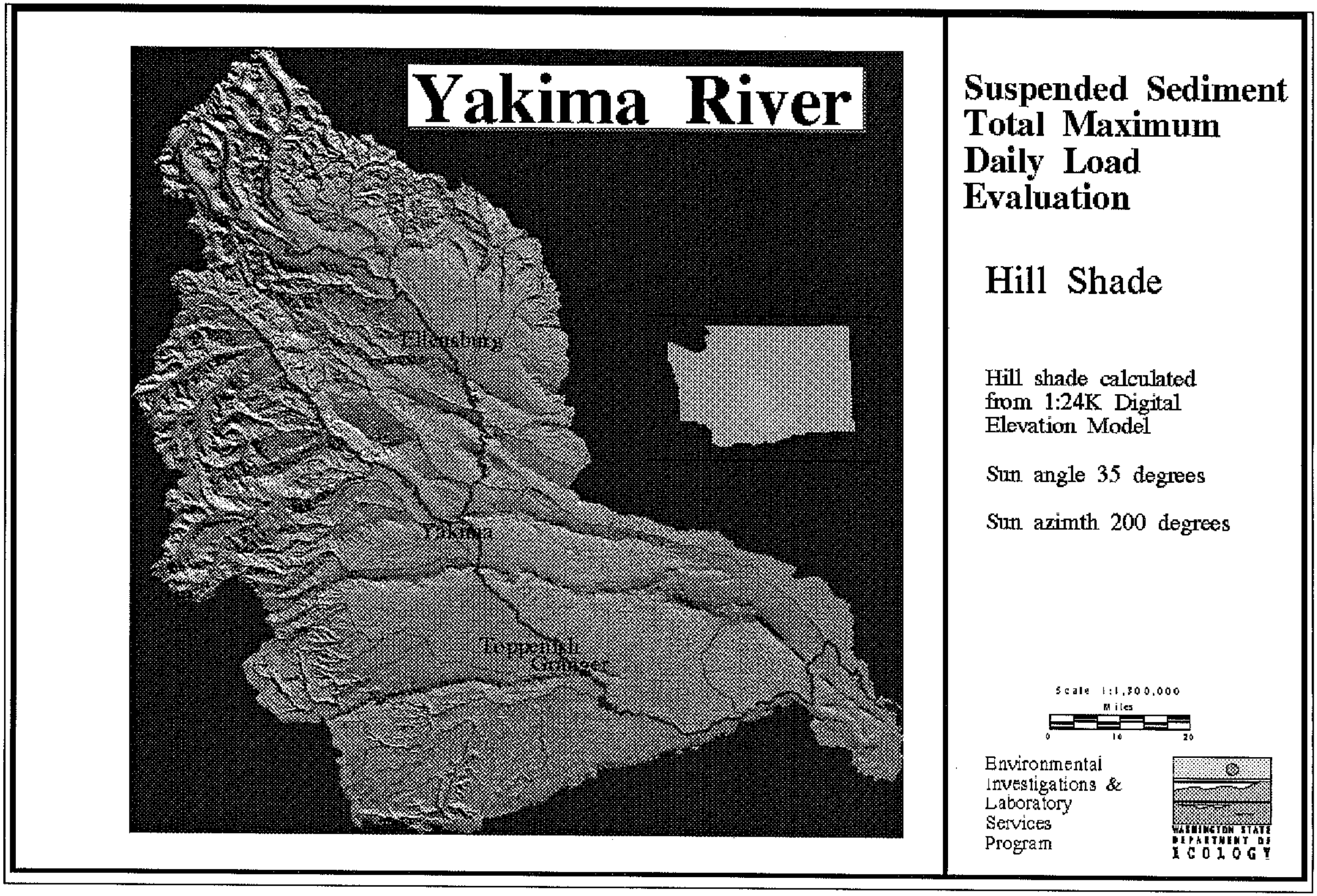

Figure 3 Simulated Hill Shading

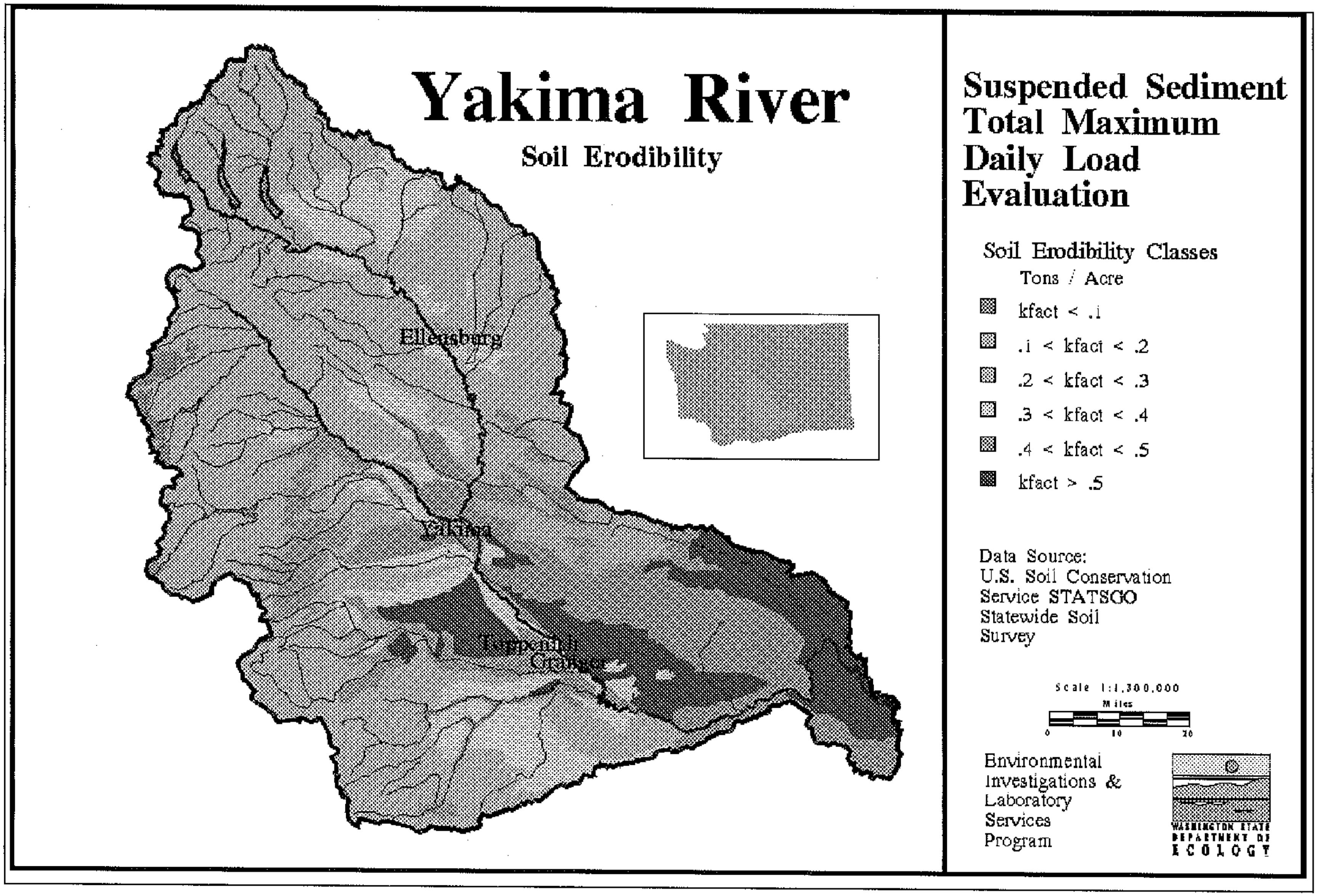

Figure 4 Soil Erodibility Factor

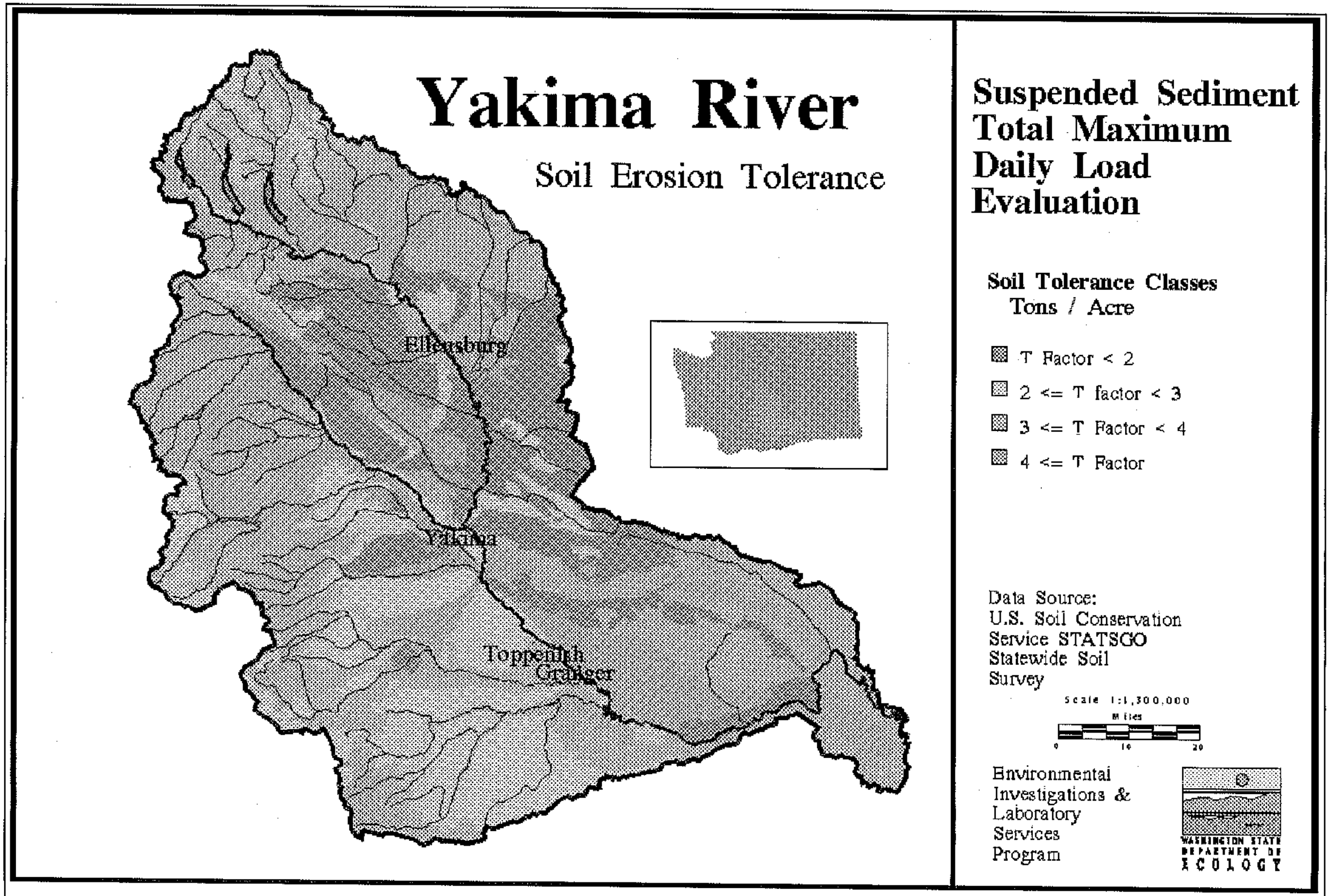

Figure 5. Soil Tolerance Factor

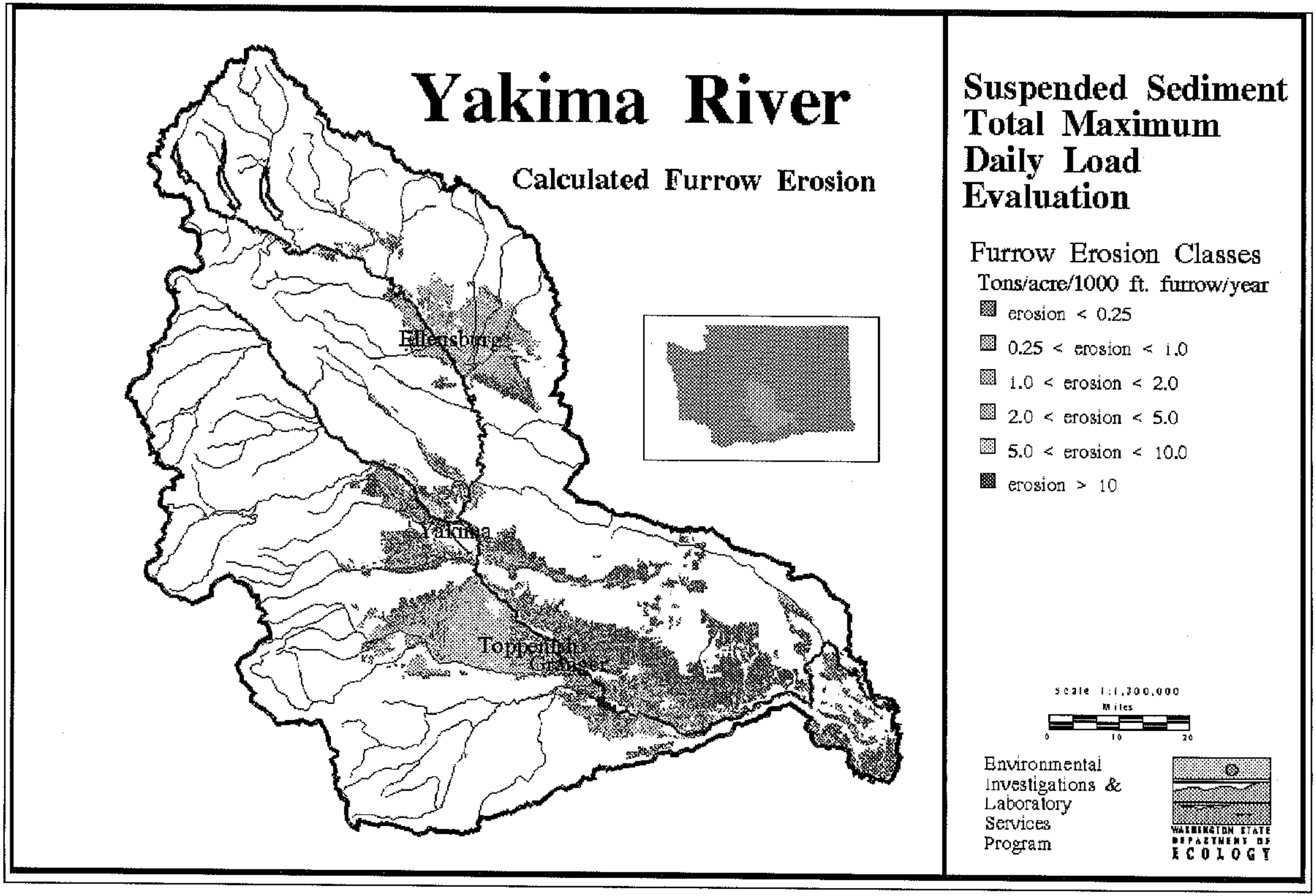

Figure 6. Calculated Furrow Erosion Yakima Watershed

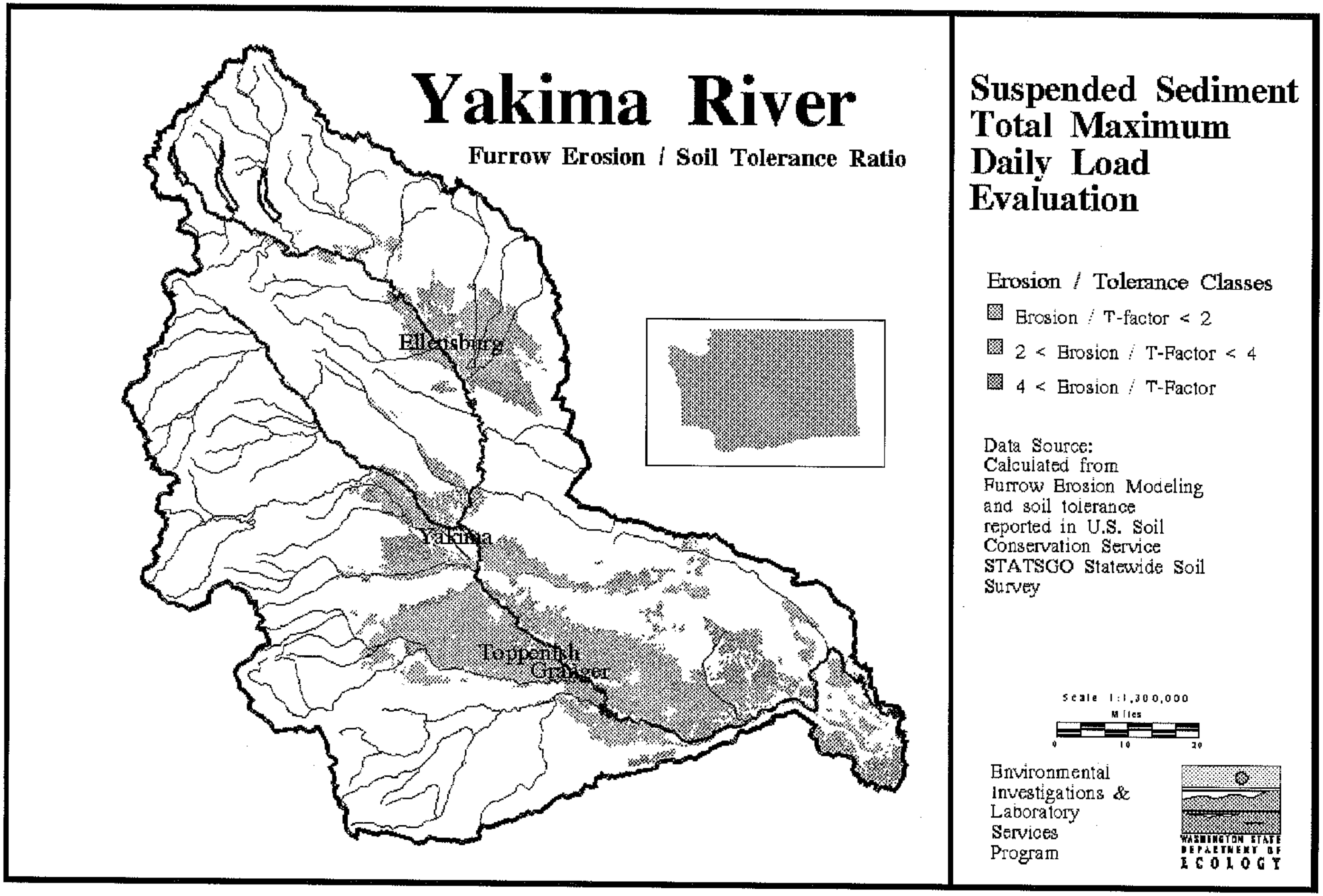

Figure 7 Calculated Furrow Erosion - Soil Erosion Tolerance Ratio, Yakima Watershed