CWE 2004
Cumulative Watershed Effects Analysis
Klamath National Forest
February 9, 2004

Analysis by Don Elder & Mark Reichert

Quantitative Models for
Surface Erosion, Mass-wasting and ERA/TOC

Introduction:

In March 1998, cumulative watershed effects (CWE) assessment was done on the Westside of the Klamath National Forest. This assessment consisted of three quantitative models (USFS, 1998). These models have been used on the Forest since the late 1980s (USFS, 1990) and were redefined during the Indian Creek CWE assessment (USFS, 1998b). Since 1998, these three models have been used for project-scale analyses. In the years between 1998 and 2004, the models were refined as a result of this process. Additional disturbances from proposed project activities have been added to the Westside CWE run to provide results for the project alternatives. However, the Westside CWE was rapidly becoming outdated relative to recent activities and wildfires, to new information concerning watershed disturbance coefficients and recovery curves, inclusion of activities on private lands, and to improved modeling techniques. This analysis serves to update the 1998 assessment.

Overlays of Forest GIS coverages were used to generate the tabular analysis that accompanies this process paper. Analysis area for quantitative model runs consists of four hundred & nine (409) 7th-field drainages. Of the 409 7th-field analysis drainages, 330 are on the westside of the Forest, 79 are on the eastside. See accompanying Table B for a complete list of analyzed drainages. Table B also includes the 5th-field watershed and 4th-field subbasin associated with 7th-field drainages.

General Assumptions:

The quantitative models used in this assessment consist of two spatially explicit sediment models [mass-wasting and surface erosion models] and a spreadsheet (not spatially explicit) model [ERA/TOC] that serves as a disturbance index. The headings below are from MacDonald (2000) and serve to define general assumptions of the Klamath National Forest CWE assessments.

Issues & resources of primary concern, including location: These models characterize cumulative **watershed** effects, and thus do not address other types of cumulative effects. Primary issue of concern is the aquatic environment and its beneficial users – fish, humans and other aquatic biota. These models seek to define the extent to which watershed disturbances (chiefly roads, fire and harvest) affect natural quantities, qualities and distribution of watershed products – water, sediment and wood. In other words, issues include water quality and quantity characteristics, channel characteristics, riparian vegetation and habitat connectivity.

Spatial scale: Project (site)-specific actions are modeled within the context of 7th-field watersheds (drainages, from 3,000 to 10,000 acres in size). If required, 7th-field watersheds can be aggregated to characterize 6th or 5th-field watersheds.

Temporal scale: Surface erosion model predicts quantities of delivered sediment for the first winter season following the action and is expected to diminish thereafter. Non road-related sediment yields return to near background in three to seven years, depending on local site conditions. Mass-wasting (landslide) model predicts delivered sediment over a decade following the project. High rates of landsliding are typically associated with episodic flood events, which recur every 10 – 20 years. Non road-related sediment yields return to near background in ten to twenty years, depending on local site conditions. Non road-related ERA modeled disturbances recover gradually over forty years.

Since roads are "forever" and do not recover like vegetative disturbance, road-related sedimentation is constant year after year. Positive changes can occur by stormproofing, decommissioning, and administrative decisions that affect use levels.

Magnitude of risk: Quantitative magnitude of risk to beneficial users is not defined. However, the assumption is that as model defined risks increase, the risk to beneficial users also increases. Accelerated sedimentation from mass-wasting and surface erosion threatens natural channel characteristics, biological productivity and water quality of streams. As model values approach "threshold," these adverse impacts become significant and no longer benign.

Level of effort: The three quantitative CWE quantitative models discussed above need to be run in a GIS environment. Unit- and road-specific information about the proposed action needs to be provided to the modelers by project proponents. Information should consider those specific actions listed below. Information must contain recent past actions (post March, 1998), present actions, proposed actions and reasonably foreseeable future actions.

Stochastic element**:** Altering the condition of a land surface is a game played in a stochastic environment – random, but probabilistic. For example, several dry winters might follow the clearing of a hillslope; in which case, high rates of landsliding would not occur. On the other hand, a flood event might occur the winter after; in which case, copious landsliding would occur. These triggering flood events remain essentially unpredictable, but we can define the probability and estimate the ***risk*** of such erosional events. CWE modeling seeks to predict the ***increased risk*** of slope failure and sedimentation from our proposed action – not absolute sedimentation volumes. This concept of ***risk*** combines a statement of probability of an event with an estimation of the resultant magnitude.

Arc/Info coverages:

CWE process described in this document is GIS based. Arc/Info coverages are therefore referenced in closed triangular brackets, <coverage>, for example. Results of this assessment are shown in tables (MS Excel worksheets) contained in the following files (MS Excel workbook): *cwe_sheds_forest_5feb04.xls.* Key coefficients and important assumptions are found in *cwe_coefficients.xls* file. See below for more detailed discussion of the three models used in this assessment.

These coverages extend across the analysis area, which is described under the coverage called <cwe_sheds04>. All coverages are from Forest layers that were "clipped" by analysis boundary. Unless otherwise indicated, coverages extend throughout the analysis area.

[1] **<cwe_sheds04>** - is a polygon coverage containing 409 7th-field drainages. This coverage was not clipped to the Forest administrative boundary and includes drainages that contain small percentages of Forest administered lands. Drainages in & around Scott Valley, Shasta Valley, and within the Cottonwood Creek watershed were excluded on a case-by case basis when they contained no Forest administered lands. Boundary of this coverage defines the 'analysis area' and is stored in a coverage called <**clip**>.

[2] <**rds**> - is a line coverage clipped from the Forest library roads coverage, called <travel_route>. Arcs within this line coverage were attributed from TIS (Transportation Information System) database using an AML (Arc Macro Language) called "rd_cwe.aml." Attributes that were added included: (1) status [e.g., 'EX' for existing, 'DE' for decommissioned], (2) width (road surface width, in feet), (3) road surface material [e.g., native, crushed rock, pit-run rock, asphalt], (4) template [e.g., outsloped, insloped, crowned, flat], and (5) maintenance level [e.g., ML = 1, 2, 3, 4, or 5].

For **classified** (system) roads, 'K' and 'D' values are calculated for individual road segments based on changes in surface type and template. Maintenance level is used as a surrogate for level of use or traffic. Roads with heavy use produce more sediment by surface erosional processes (Reid and Dunne, 1994). Multipliers are employed to integrate use levels. Unspecified roads are assumed (by default) to be native surfaced, flat, and maintenance level 2. County roads were assumed to have 26' width, crushed aggregate surface, crowned and maintenance level 4. State roads were assumed to have 32' width, asphalt surface, crowned and maintenance level 5.

Surface type [modifies 'K']	Value	**Template** [modifies 'D']	Value	**Use** [maintenance level]	Multiplier
native (& unspecified)	"k" soil	unspecified	.29	0 (unspecified)	.5
pit-run aggregate	.10	outsloped	.15	1	.5
crushed aggregate	.02	insloped	.40	2	1
asphalt- pavement	.01	crowned	.40	3	2
chip-seal	.02	flat	.23	4	2
cinders	.05			5	2

[3] <**disturb**> - is a polygon coverage that contains harvest and fire watershed disturbances. This coverage represents a compilation of activities generated from four general sources:

1. Past logging activities on Forest Service (FS) administered lands. Information was obtained from the Forest's managed stands layer (<mgstands>). Previous analyses have used only the plantation layer (regeneration harvest). Incorporation of managed stands layer means that partial cuts were modeled, yielding generally higher CWE values.
2. Past logging activities on private industrial timber lands. Polygons were digitized from DOQ (Digital Ortho-quads) images. Activities were assigned a 'year' and harvest 'impact' based on comparison to adjacent dated and described FS activities. Activity 'years' were lumped into decades.

3. Wildfires with burn intensity mapping. Included are the following wildfires: [1] Hog (1977), [2] 1987 Fires (1987), [3] Dillon (1994), [4] Specimen (1994), [5] East (1999), [6] Bark (2000), [7] Crawford (2001), [8] Jones (2001), [9] Larry (2001), [10] Swillup (2001), [11] Creek (2002), [12] Forks (2002), and [13] Stanza (2002).
4. Recent and present activities on FS and private lands. Table A lists projects/activities that were incorporated. Activities on private lands were added on a project-by-project basis and therefore, include only projects within Beaver Creek, Horse Creek, Doggett Creek and South Fork Scott River areas. Information on these private projects was obtained from THP (Timber Harvest Plan) documents. Planning documents (NEPA & ESA) provided information on FS projects.

Recent and present activities are modeled using a combination of the following parameters:

1. **Silvicultural prescription** - Since silvicultural prescriptions very widely between projects, even between units and alternatives in one project, the CWE impact of proposed silvicultural activities is based on the following table:

CWE Impacts Based on Rx	Basal Area Removed 1/	Silvicultural Prescription [Examples]
HIGH	> 70%	Clear cuts Green tree retention Seed Tree - prep & removal Shelterwood - prep, seed & removal [high quantity removed]
MODERATE	40% – 70%	Overstory removal Group select (heavy) Shelterwood - prep, seed & removal [moderate quantity removed]
LOW	10% - 40%	Commercial thin Group select (light) Single tree select Sanitation Salvage (unit)
NONE	< 10 % live trees	Fire salvage (dead trees) Roadside salvage Pre-commercial thin

1/ General guidelines only; basal area removed can depend on existing stocking levels

2. **Logging system** – see tables in MS Workbook (*cwe_coefficients_9feb04.xls*) for details.
3. **Site preparation** (following logging) - see tables in MS Workbook (*cwe_coefficients_9feb04.xls*) for details.

[4] **<kcrls>** - is a polygon coverage that combines information necessary to run the USLE model. See below for more details. The coverage includes: (1) soil erodibility, (2) conversion factor, (3) runoff factor, and (4) slope-length steepness factor.

[5] **<geo13>** - coverage was created by the combination of four Forest geological layers: (1) bedrock geology, (2) geomorphology, (3) active landslides, (4) inner gorges (of stream channels), combined with a two-slope-class-DEM-generated coverage (<65% slopes & >65% slopes). This coverage divides the landscape into 15 "geomorphic terranes." Polygons are coded 0 (for no data), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 17 - corresponding to the "geomorphic terranes." These terranes exhibit different rates of sediment delivery from mass-wasting processes, as determined by the Salmon Sediment Analysis [de la Fuente & Haessig, 1994] and modified for this analysis, using data from the 1997 Flood. **<geo13>** covers all 7.5' quads that contain any KNF administered lands, and therefore, covers the analysis area - including ``checker board" ownership along the eastern margin. However, polygons with no ``geo13" designation were coded "0" for no data and assigned default coefficients of "geo13" number "8" (see below).

Important caveats:

Information presented here was generated from three CWE models in a GIS environment. Data with different levels of detail were mixed. CWEs were modeled at a 7th-field watershed scale using data with resolution consistent with this scale. Base component information (GIS layers), such geology, roads geomorphology, soils, fire, and harvest, was mapped chiefly at 1:24,000 (7.5 minute quadrangles) or lesser. Harvest-related information used in the 'Current' columns was calculated using both managed stand data (past harvest) and project-scale data (present harvest activities). Effects of the proposed action were modeled in more detail (project-scale information). Future actions were also modeled using project-scale information.

The GIS-based information should serve as the basis for further investigation. Subsequent steps may include (but not be limited to) the following:

[1] Beneficial uses must be clearly identified,

[2] Model-derived results should be validated (based on professional judgment &/or field data); this includes validation or modification of TOC parameters in ERA model,

[3] More detailed field evaluations may be warranted, especially in more sensitive areas (based on data limitations or gaps),

[4] Scale considerations must be evaluated based on specific issues identified for this project. These issues may require analysis at multiple spatial scales. For example, fish habitat issues may necessitate evaluation of effects at intermediate scales (e.g., 7th to 5th field watersheds), while BMPs or action alternative comparisons might be pertinent at local scale (e.g., road segment, units); broader-scale qualitative discussions may be required,

[5] Proposed action should be placed in context with regards to CWE trends (e.g., increasing, decreasing, stable) and potential impacts to beneficial uses for individual watersheds and subbasins,

[6] Some activities were not modeled but need to be considered qualitatively (e.g., mining, grazing, recreation), and

[7] Interpretation and conclusions from this information needs to be discussed; discussion should include how cumulative (watershed) effects affect beneficial uses.

Spatial scale of the processes that affect the beneficial user of concern should define the scale of the assessment (MacDonald, 2000). We model watershed processes that affect aquatic resources; therefore, we need to model at the watershed scale. But what is the appropriate scale or scales? Quantitative results of CWE models are typically reported at the 7th field, but the risk of adverse cumulative effects may manifest itself through multiple 7th field watersheds, aggregated up to the 6th field, 5th field, or larger. In the case of McNeal-Glasgow, an appropriate scale of analysis is the entire South Fork Salmon 5th field watershed. Recent court decisions (e.g., Rothstein III) and proposed ESA consultation direction suggest broader scale (5th field or larger) assessment is needed.

Watershed inference points:

Watersheds are ensembles of hillslopes that interact with stream channels at their bases and transmit fluxes of watershed products - water, sediment, organic debris, and chemicals. When land use increases the magnitude of those fluxes, they accumulate along channel networks. Generally speaking, the larger the proportion of the land surface that is disturbed at any time, and the larger the proportion of the land that is sensitive to disturbances, the larger is the downstream impact. These land-surface and channel changes can: increase runoff and sedimentation, degrade water quality, and alter channel and riparian conditions to make them less favorable for aquatic species and other beneficial uses of water.

Klamath National Forest CWE assessments model these disturbances and land sensitivity. Results fall on a continuum. As disturbances increase (and recover) over time and space, at some point, the **risk** of initiating or contributing to existing adverse cumulative watershed impacts becomes a cause for concern. These model-specific levels are called "**inference points**" (or "thresholds of concern" - TOC) and are used to inform land management decisions. Ecologically, a transition exists from lower to higher risk of adverse effects to beneficial uses – from insignificant to potentially significant. From a management perspective, inference points are intended to represent the center of that transition zone. Inference points do not represent the exact point at which cumulative watershed effects will occur. Rather, they serve as "yellow flag" indicators of increasing susceptibility for significant adverse effects occurring within a watershed.

Modeled CWE levels, relative to defined inference point values, are expressed as "**risk ratios**." These ratios are calculated by dividing accelerated sedimentation and ERA values by an inference point value. For the GEO and USLE models existing levels are shown as 'percent over background,' which is a measure of accelerated sedimentation. For the ERA/TOC model existing disturbance levels are expressed as "equivalent roaded acres" (ERA). Inference point values for each model have been identified at the following levels: (1) USLE (surface erosion) model = 400% over background, (2) GEO (mass-wasting) model = 200% over background, and (3) ERA/TOC model = watersheds TOC value. For example, a watershed with GEO model-estimated sediment delivery from mass wasting of 100% over background would yield a risk ratio of .50 [100% divided by 200%]. Risk ratio values represent a continuum of and serve as indicators of relative watershed condition. Inference point values will need to be reviewed, and either validated or changed. Circumstances warranting change include acquisition of new or more refined information and/or better understanding of watershed processes and interactions.

The inference point values cited above have been used provisionally on the Klamath National Forest since the late 1980s. They played a large role in determining CWE associated with Klamath Plan

AWWCs (Areas with Watershed Concerns) shown in *Record of Decision for the Final Environmental Impact Statement for the Klamath National Forest* (USFS, 1995a). Professional judgment and knowledge of individual watersheds originally established these values, including the 200% and 800% over background inference points. Inference point values were affirmed during the Indian Creek CWE review (USFS, 1998b) and the Westside CWE assessment (USFS, 1998a). Study of the 1997 Flood (de la Fuente and Elder, 1998) showed that watersheds experiencing the greatest flood effects had CWE model values over inference point values.

Watersheds with elevated CWE model numbers near or over these inference point values typically share common characteristics. These include high road densities and/or large areas of wildfire (high/moderate burn intensities) or harvest (high/moderate impact silvicultural prescriptions). These disturbances commonly lie on sensitive landscapes, with respect to geology, landforms and soils. Examples include inner gorges, active landslides and weathered granitic soils. During episodic flood events, these watersheds typically exhibit high rates of landsliding and channel alteration.

Recovery (duration of adverse effects):

Recovery rates described below are typical or "average." Recovery rates are model and activity intensity dependent. For example, surface erosion processes depend on soil (vegetative) cover and therefore recovery is quicker in the USLE model than in the mass wasting model, where recovery depends on reestablishment of (subsurface) hill slope hydrology and root strength, both associated with mature conifer/hardwood stands. Partial cuts recover quicker than regeneration cuts. Actual recovery rates will vary greatly and depend a multitude of parameters that are generally site specific. Some parameters that can affect recovery rates include project characteristics, such as extent, pattern and intensity of disturbance(s) and the physical environment, such as bedrock geology, geomorphology, soils (soil productivity), precipitation, elevation, aspect, slope gradient, and slope position. These site-specific characteristics can interact in complex and sometimes poorly understood ways and can act synergistically or additively. Recovery curves (plots of adverse effects verse time) are typically concave upwards with very steep slopes initially, flattening over time.

Roads do not recover without overt treatments. Benefits (positive CWEs) occur when roads are either decommissioned or stormproofed to Forest standards. See accompanying table for coefficients and Forest standards.

This analysis uses newly developed recovery curves. Mathematical details can be found in the accompanying AMLs (usle.aml, geo.aml, era.aml). Example curves are plotted in accompanying graphs.

In the USLE model, recovery is modeled by the "C" (cover) factor and equation [1]:

[1] $Y = 0.244\ X^{-1.54}$ where Y = "C" factor and X = years since disturbance.

In the GEO model, coefficients stay fixed for 10 years and then recover (linearly) to background values during the next 40 years. Initial coefficient values are shown in MS Workbook (*cwe_coefficients_9feb04.xls*).

In the ERA model, coefficients typically stay fixed for a period of years and then recover to zero in a linear fashion during a subsequent period of time. Both the length of the "flat" section and "slope" section of the curve is dependent on initial ERA coefficient. Initial coefficient values are shown in MS Workbook (*cwe_coefficients_9feb04.xls*).

USLE model - Surface erosion sediment delivery

Methodology & Assumptions:

Model used in this analysis predicts sediment **delivery** to streams from surface erosion. Model generated values were calculated using the Universal Soil Loss Equation [USLE] or Klamath (modified) Universal Soil Loss Equation [KUSLE], defined by the following equation:

A = [.7]*R*LS*D*K*C

where:

A= estimated soil loss (cy/ac/yr)	.7 = converts tons to cubic yards (cy)
R = rainfall/runoff factor	LS = slope-length/slope-steepness factor
D = delivery factor	K = soil erodibility factor (by Soil Map Unit [SMU])
C = cover factor (from disturbance class)	

USLE "estimated soil loss" is calculated in a GIS environment using Arc/Info programming language (Arc Macro Language – "AML"). "AML" (usle.aml) is run on a combined USLE coverage [<usle>]. This overlay was created from the following coverages:

(1) <kcrls> = Forest GIS library layer - integrates the following information:

- Soil erodibility factor ("k") from Forest soils layer, based on 'soil map unit'
- Conversion factor ("c") – converts tons to cubic yards
- Runoff factor ("r") – from formula, r = 10.2*p^2.17, where "p" is maximum 6-hour rainfall with 2-year recurrence interval, in tenth of inch [from NOAA isopluvial mapping of Northern California]
- Slope-length steepness factor ("ls") – 2.50 for slopes less than 35%, 7.32 for slopes greater than 35%. Slope gradients were derived from 30-meter DEMs (digital elevation model) overlain with inner gorge layer.

(2) <disturb> = used to assign "C" factor, based on percent ground cover; includes harvest, fire (wild and prescribed) and road/landing disturbances. See Table A for list of modeled activities. Includes adverse impacts from past, present and future activities and beneficial impacts from road stormproofing and decommissioning.

Delivery coefficients ("D" factor in the USLE equation) were modified for this analysis. Previously, all roads were assigned a "D" factor value of .29; for everything else, "D" factor of .05 was used. For this analysis, roads were given various "D" factor values (ranging from .15 to .40 – see Table above) based on the road template; for everything else, "D" factor of .10 was used. Doubling of general "D" factor value (from .05 to .10) meant that inference point was cut in half – from 800% over background to 400% over background.

Predicted sediment **delivery** is for the first 12 months (year) following project completion. For the surface erosion model, sedimentation rates expressed by the model are realized during a six-hour maximum rainfall with a two-year recurrence interval. In other words, the probability is 50% that a six-hour event will occur in any given year that will produce model-predicted sedimentation rates.

CWE model values are expressed as "**risk ratios**." These ratios are calculated by dividing accelerated sedimentation values by an "**inference point"** value. In the USLE model, accelerated sedimentation is figured as “% over background,” which is calculated from ‘current’ model-estimated sediment delivery [‘Current’ and ‘Current + proposed + future’ columns] less background [‘Background’ column] divided by background values.

"Background" is a watershed's natural sediment **delivery** assuming no disturbance. "Background" includes land with (1) old harvest units, (2) old fire, (3) young fire, low burn intensity, (4) young harvest, low impact prescriptions, and "pristine." In other words, land with disturbances that have fully recovered, disturbances not modeled, and completely undisturbed land. Background should NOT be confused with “baseline,” which is term used in ESA (Endangered Species Act) consultation and is equivalent to “Current” used in this analysis (i.e., existing conditions prior to proposed action).

GEO model - Sediment delivery from mass wasting processes

This model estimates sediment **delivery** to streams from mass wasting and has its empirical base in the Salmon Sub-basin Sediment Analysis [de la Fuente & Haessig, 1994] and uses methodology developed in Amaranthus et al. [1985], the Grider EIS [USFS, 1989] and KNF LRMP [USFS, 1994]. Model estimates sediment delivery using a matrix of coefficients (see below). Sediment **delivery** coefficients are modified from Salmon Sub-basin Sediment Analysis [de la Fuente & Haessig, 1994] and are based on geomorphic terrane and disturbance. Coefficients were modified for this analysis using 1997 Flood information.

GEO Mass-wasting model [Values represent model-estimated sediment delivery in cubic yards / **DECADE**]

Code	Description	Background (undisturbed)	Roads	High impact fire or harvest 1/	Moderate impact fire or harvest 2/
0	unknown	0.25	18.27	2.05	1.15
1	Active Landslides	25.92	753.12	94.64	60.28
2	Toe Zone Dormant Slides	1.89	154.53	5.92	3.91
3	Dormant Landslides	1.89	154.53	5.92	3.91
4	Granitic Mtn. Slopes, Steep Slopes (>65%)	1.00	585.40	10.35	5.68
5	Granitic Mtn. Slopes, Low to Moderate Slopes	0.53	35.13	5.50	3.02
6	Non-Granitic Mtn. Slopes, Steep Slopes (>65%)	1.23	81.84	2.50	1.87
7	Goosenest, gentle slopes	0.05	0.50	0.25	0.15
8	Non-Granitic Mtn. Slopes, Low to Moderate Slopes	0.25	18.27	2.05	1.15
9	Inner Gorge on Unconsoildated Deposits	19.94	308.52	42.51	31.23
10	Inner Gorge on Granitic Slopes	6.36	699.46	109.95	58.16
11	Other Inner Gorge	5.14	168.55	8.79	6.97
12	Debris Basins	1.06	25.00	17.00	9.03
13	Glacial Moraine, Terrace and Fan Deposits	2.17	6.38	5.50	3.84
17	Goosenest, steep slopes	0.50	5.00	2.50	1.50

1/ Includes 'GTR' and equivalent silvicultural prescriptions and high/moderate burn intensity wildfire
2/ Includes partial cuts and other moderate impact silvicultural prescriptions
[Revised 30-Jan-04]

GEO "cubic yard/decade" is calculated in a GIS environment using Arc/Info programming language (Arc Macro Language – "aml"). "Aml" (geo.aml) is run on a combined GEO coverage [<geo>]. This overlay was created from the following coverages:

(1) <geo13> = Clip of Forest library layer <geo_terranes>; contains geomorphic terrane polygons listed in table above,

(2) <disturb> = same coverage used for USLE above, except used to assign sediment delivery coefficient value from table above. For example, a road lying on geo13# = 3 would have a sediment delivery coefficient of 225.05 (cy/ac/10yr).

Predicted sediment delivery is for the first decade following project completion. Coefficients recover to background values in 50 years. For the GEO (mass wasting) model, coefficients predict sedimentation volumes from landsliding for a flood event with a recurrence interval of 10 – 20 years. In other words, probability of attaining sedimentation rates of the magnitude predicted by the coefficients is 1 to 10 through 1 to 20 [i.e., 10% - 5% in any given year].

CWE model values are expressed as "**risk ratios**." These ratios are calculated by dividing accelerated sedimentation by an "**inference point"** value. In the GEO model, accelerated sedimentation is figured as "% over background," which is calculated from 'current' model-estimated sediment delivery ['Current' and 'Current + proposed + future' columns] less background ['Background' column] divided by background values.

"Background" is a watershed's sediment **delivery** assuming no disturbance. "Background" includes land with (1) old harvest units (>50yr), (2) old fire (>50yr), (3) young fire (<50yr), low burn intensity, (4) young harvest (<50yr), low impact prescriptions, and "pristine." In other words, land with disturbances that have fully recovered, disturbances not modeled, and completely undisturbed land. Background should NOT be confused with "baseline," which is term used in ESA (Endangered Species Act) consultation and is equivalent to "Current" used in this analysis (i.e., existing conditions prior to proposed action).

<u>ERA</u> - Disturbance index (ERA/TOC)

The ERA/TOC model provides a simplified accounting system for tracking disturbances that affect watershed processes, in particular, estimates in changes in peak runoff flows influenced by ground-disturbing activities. Unlike the surface erosion (USLE) and mass wasting (GEO) models, ERA/TOC is not intended to be a process-based sediment model. It does, however, provide an indicator of watershed conditions.

This model compares the current [&proposed] level of disturbance within a given watershed (expressed as % ERA) with the theoretical maximum disturbance level acceptable (expressed as % TOC). Some use ERA/TOC as a "run off risk" model which estimates the level of hydrological disturbance or relative risk of increased peak flows and consequent potential for channel alteration and general adverse watershed impacts. To determine ERA, coefficients for disturbance classes [types & ages] are compared to values for roads to calculate the area of road that would produce the same changes in peak flows. This information is used to create a table of Equivalent Roaded Area (ERA) coefficients (see KNF EIS, pg. G-9; notes associated with ERA table).

Elder & Laurent (pers. comm., 1998) developed ERA coefficients for use at the project scale. These coefficients were modified from the Jack/Gray EA (Kilgore & Power, 1998) and used relative values from KNF CWE Analysis Handbook (Van de Water, et al., 1990) and from other literature sources. Coefficients were further modified in February 2002 in a meeting of timber project planners and CWE modelers. Coefficients used in this analysis are shown in 'ERA' worksheet of MS Excel file *cwe_coefficients.xls.*

Coefficients are additive. Coefficients for harvest prescription are added to logging system coefficients, which are added site prep coefficients. For example, a tractor logged GTR harvest unit with tractor piling of slash would have a total ERA coefficient of **.12** (GTR Rx) + **.04** (tractor logging - modified) + **.03** (mastication) = **.19** (total ERA per acre). Helicopter logged commercial thin with hand piling site preparation would have a total ERA coefficient of **.03** (CT Rx) + **.001** (helicopter logging system) + **.001** (hand piling) = **.032** (total ERA per acre).

TOC (threshold of concern) is a measure of watershed sensitivity. TOC is calculated based on channel sensitivity, beneficial uses, soil erodibility, hydrologic response, and slope stability of each watershed. For example, a watershed with sensitive channels, highly productive anadromous streams (high beneficial use), highly erodible soils, high landslide densities &/or high percentage of granitic lands (slope stability), and high percentage of watershed in the "rain-on-snow" zone (~3,500' to 5,000' elevation; hydrologic response) would have a <u>high</u> "watershed sensitivity level" and therefore a <u>low</u> TOC. An ERA/TOC ratio approaching or greater than 1.00 serves as a "yellow flag" indicator of increasing susceptibility for significant adverse cumulative effects occurring within a watershed. Susceptibility of CWE generally increases from low to high as the level of land disturbing activities increase towards or past an ERA/TOC value of 1.00 (USFS, 1988). TOC values for the analysis watersheds were taken from the Klamath National Forest CWE Assessment 2002 (USFS, in prep.). Individual 7^{th}-field drainage TOC values for each parameter are shown in Table B. Evaluating existing condition of benefiting resources in the analysis area should validate these values. Differences with those shown in (NMFS) matrix of pathways and indicators should be explained.

CWE model values are expressed as "**risk ratios**." These ratios are calculated by dividing ERA values by an "**inference point"** value. In the ERA/TOC model, ERA values are divided by the TOC value for each watershed (see Table B for these values and parameters used to calculate them).

<u>CHANGES – 1998 vs. 2004:</u>

Highlights of major changes between the CWE model analyses of 1998 and 2004 are as follows:

- Inclusion of activities on private lands in the following areas: (1) Beaver Creek, (2) Horse Creek, (3) Doggett Creek, (4) areas of lower Scott River, and (5) South Fork Scott River.

- For vegetative disturbances (fire – wild & prescribed and timber harvest activities), development and use of more realistic recovery curves for all three models.

- Modeling of roads as attributed lines using TIS database. Roads are modeled differently depending on status, road surface width, road surfacing material, template, and use (maintenance level).

- Modification of GEO model (mass-wasting) coefficients to reflect information from the 1997 Flood assessment and inclusion of the effects of side-slopes on road prism widths.

- For USLE model, general (non-road) delivery factor was doubled from .05 to .10. This necessitated reducing the inference point from 800% over background to 400% over background.

- Watersheds have changed. Most of the changes consist of splits of formerly large (greater than 10,000 acre) 7^{th} field watersheds into two or three watersheds. A complete list of changes is in the spreadsheet filed at K:/res/gis/supv_office/don/cwe/watersheds.xls.

Conclusions / Further work:

- The differences cited in the section above suggest that "inference points" may need to be adjusted. See summary numbers in the Table below.

MODEL	# drainages	USLE	GEO	ERA
Risk Ratio: => 1.0				
west - number	330	19	26	11
east - number	79	0	0	0
total - number	409	19	26	11
west - % of 330		5.8%	7.9%	3.3%
east - % of 79		0.0%	0.0%	0.0%
total - % of 409		4.6%	6.4%	2.7%
Risk Ratio: .80 to .99				
west - number	330	20	28	5
east - number	79	1	0	0
total - number	409	21	28	5
west - % of 330		6.1%	8.5%	1.5%
east - % of 79		1.3%	0.0%	0.0%
total - % of 409		5.1%	6.8%	1.2%
Risk Ratio: => .80				
west - number	330	39	54	16
east - number	79	1	0	0
total - number	409	40	54	16
west - % of 330		11.8%	16.4%	4.8%
east - % of 79		1.3%	0.0%	0.0%
total - % of 409		9.8%	13.2%	3.9%
1998 Risk Ratio: => 1.0				
west - number	249	35	34	36
west - % of 249		14.1%	13.7%	14.5%

- Recent logging activities and roads on private industrial timber lands need to be captured for the remainder of the "checker-board" ownership areas of the Forest.

- Continue to validate model results. Recovery curves need special emphasis.

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