Arnold Schwarzenegger
Governor

BIOMASS TO ENERGY:

FOREST MANAGEMENT FOR WILDFIRE REDUCTION, ENERGY PRODUCTION, AND OTHER BENEFITS

APPENDIX 6

PIER FINAL PROJECT REPORT

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APPENDIX 6: Cumulative Watershed Effects Analysis for the Biomass to Energy Project

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Notice of Change in Scenario Naming Conventions

Key assumptions, modeling structures and terminology were altered and refined to accommodate new thinking during the course of this study. The reader will observe in the appendices that the scenarios are referred to as "Scenarios 1, 2 and 3" or "S1, S2 and S3."

In both the main text of the Final Report and in the Life Cycle Assessment appendix (Appendix 4), the former Scenario 1 (S1) was renamed to the "Reference Case." Scenario 3 (S3) has been renamed the "Test Scenario." Scenario 2 (S2), focused on the relative contributions and impact of Industrial Private Forestry (IPF) has been eliminated from most of the analyses that make up the entire study. These changes better reflect the focus of the study, which is fundamentally about the landscape level changes in wildfire, habitat, and other dynamics. The modification of terminology do not substantively affect the findings or recommendations of the study.

Cumulative watershed effects (CWE) of the Biomass to Energy (B2E) project were evaluated using the USDA Forest Service Region 5 cumulative watershed effects model and verified using WEPP FuME. WEPP FuME is a web based interface (http://forest.moscowfsl.wsu.edu/fswepp/) that predicts soil erosion associated with fuel management practices (prescribed fire, thinning, and a road network) and compares the result with erosion from wildfire. The Region 5 CWE model is a disturbance-based model where all disturbances are equated to an acre of road or equivalent roaded acre (ERA).

Cumulative effects analysis assesses the impacts of multiple disturbance activities over time and space. Cumulative impacts are impacts that are influenced by multiple activities or causes. A cumulative watershed impact is a cumulative impact that influences or is influenced by the flow of water through a watershed.

In the Northern Sierras the impacts from vegetation management activities are primarily from increased erosion and sediment resulting from decreased soil infiltration, decreased soil cover, bank and fill failures along roads, and altered runoff patterns. MacDonald (2000) argues that the current emphasis on changes in runoff, when analyzing cumulative watershed impacts, is largely unjustified, whereas forest management activities can have relatively large effects on erosion and sediment. Mass wasting can be a potential problem in localized areas in the Sierras. Mass wasting will not be analyzed at this scale of analysis, but would need to be analyzed at the project design and implementation level where necessary.

Watershed impacts are most effectively prevented using Best Management Practices (BMPs) in designing and locating roads and skid trails, maintaining protective vegetation cover, limiting disturbance, water-barring, mulching skid trails, etc (Rice & Berg 1987). MacDonald (1994)

states that the effects of present day management activities on water quality are usually transient and are rarely severe enough to cause significant damage to fish populations. Exceptions to this conclusion would include:

a) unstable areas or areas with highly erodible soils,
b) the combination of management activities with extreme storm events, and
c) downstream deposition areas where there is potential for cumulative effects.

This cumulative effects analysis assumes the implementation of BMPs. Cumulative effects analysis does not prevent the individual impact; BMPs do. Cumulative impacts analysis is done to insure that individually minor impacts, when added together with past, present and reasonably foreseeable future actions, do not become collectively significant.

The Region 5 CWE equivalent roaded acre (ERA) model is a non-specific model for modeling disturbance and recovery. It can be designed to model disturbance and recovery related to sediment and erosion, or can be modified for other disturbance related processes, such as mass wasting. The ERA model equates all disturbance activities to an acre of road and recovers them over some period of time following a recovery curve based on the process being modeled. Modeling of off-site cumulative watershed effects should be based on the individual physical processes involved (Rice & Berg 1987). The Region 5 CWE model can be modified for different processes by changing the ERA coefficients and recovery curves.

Project Area and Parameters

For this analysis 6th order HUC watersheds were used. The HUC 6th watersheds ranged from 2,500 to 46,000 acres in size and averaged 23,000 acres. The project area was divided up into 122 watersheds. ERA coefficients were based on the effect of management activities on erosion and sedimentation. Erosion and sedimentation are the most likely mechanisms for causing a cumulative watershed effect in the Sierras. At this level of analysis sensitive areas, such as highly erodible soils or areas adjacent to streams, were not broken out for separate ERA coefficients and recovery curves.

Disturbance was quantified using the following corporate GIS cover:

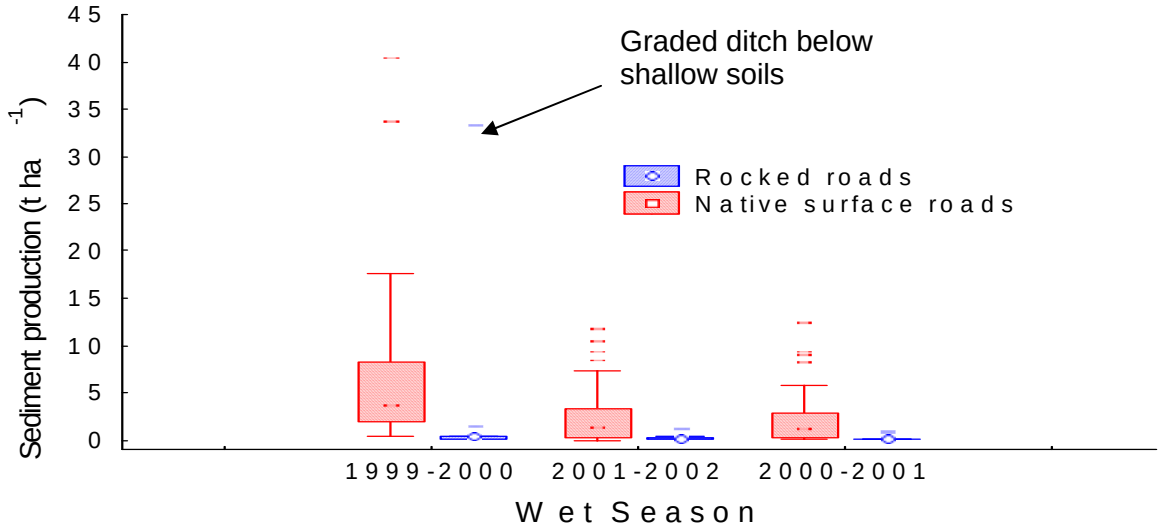
1. FACTS (Forest Service Activity Tracking System). **This is an Oracle data base linked to a GIS spatial data set in SDE of past Forest Service management activities.**
2. State Timber Harvest Plan (THP) Covers. **The CDF currently has 2 of the 4 counties completed for the B2E Project Area (Lassen and Sierra counties). Only about ¼ of the areas was covered by THPs (Ftp site:** ftp.fire.ca.gov**).**
3. Forest Roads Cover. **RSL transportation cover which covers the whole project area.**
4. Fire History. **These covers were obtained from RSL (SDE site).**
5. Burn Severity. **These covers were obtained from RSL (SDE site).**
6. B2E Treatments. **The B2E treatments started in 2006 and went to 2036. For this analysis, only the 2006 to 2026 treatments were used. When a watershed was scheduled for treatment the assumption was made that it would be treated in one year.**

These disturbance covers were analyzed using a cumulative watershed effects model that is written in visual basic. The program reads each treatment and treatment year and, based on the ERA coefficient, recovery curve, and years to recover, computes the ERAs by year for each treatment. It also tracks information about each treatment ERA.

ERA Coefficients and Recovery Curves:

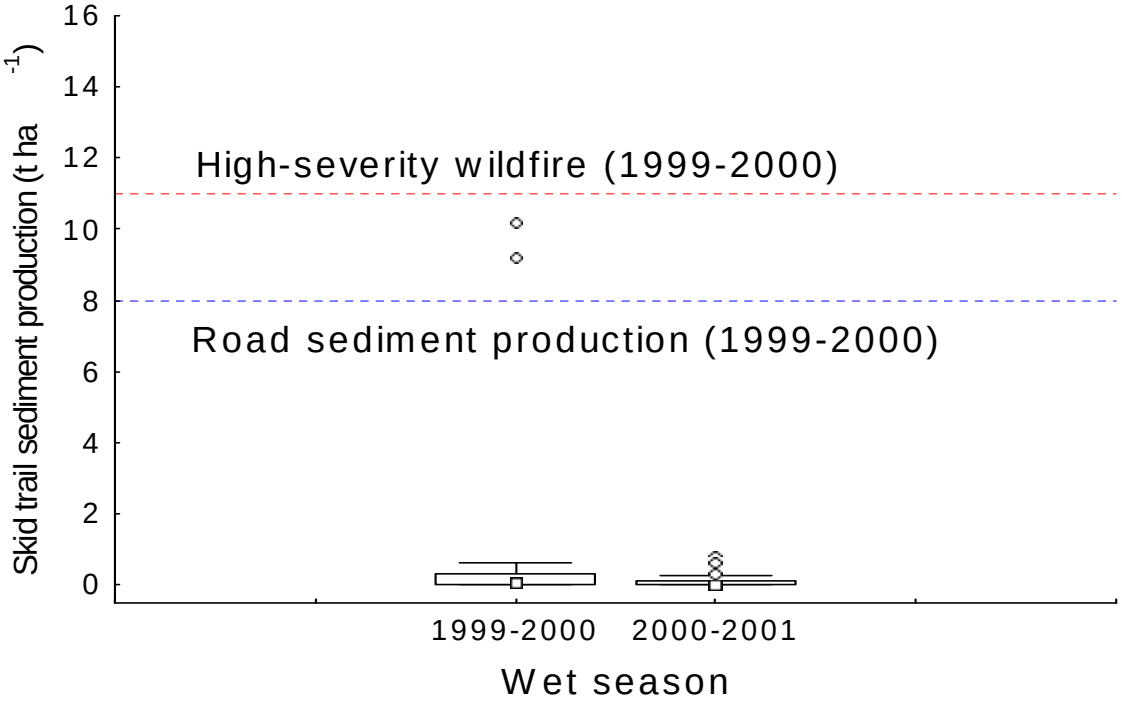
ERA coefficients and recovery curves were based on erosion and sedimentation studies from the American River Study on the Eldorado National Forest. The studies measured erosion rates from wildfire, logging roads, timber harvest, and prescribed fire, using sediment fences on the American, Cosumnes and Yuba River basins. Sediment delivery was also examined. The following figures are taken from a power point presentation on the study by Drew Coe, Eric Chase, Sandra Litschert and Lee MacDonald. The thesis that produced this data is referenced at the end of this report.

Figure 1: Road Surface Erosion by Surface Type, Over Three Wet Seasons



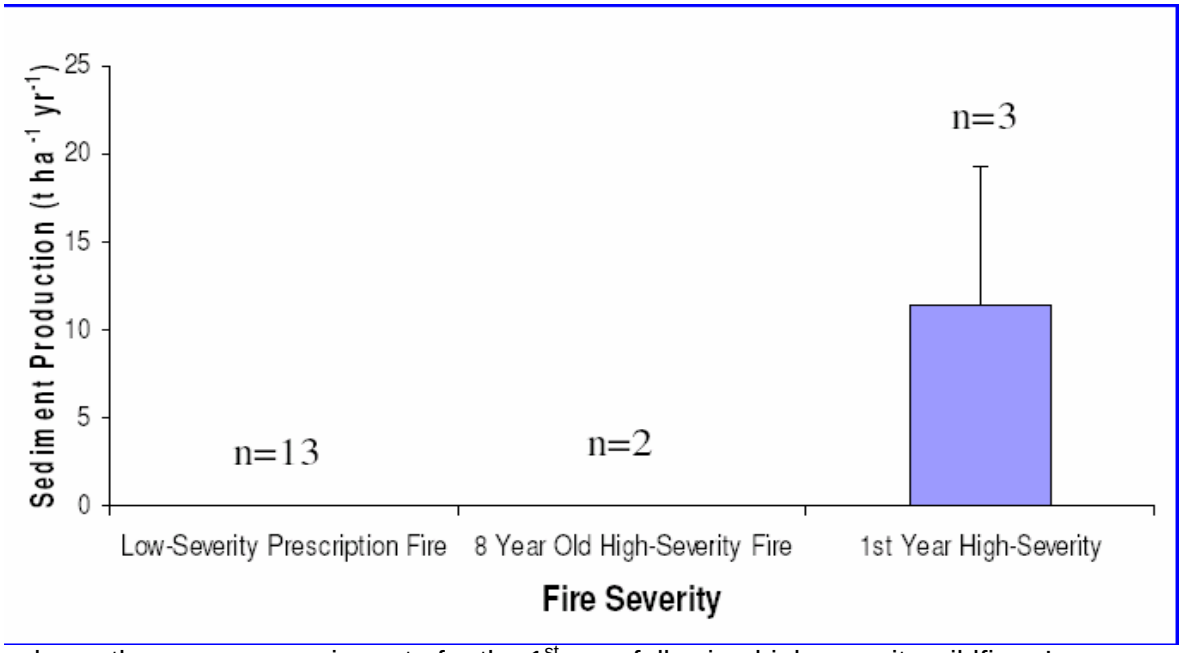
Native surface roads had 10 to 16 times more erosion that rocked roads. The 1999-2000 wet season had higher intensity storms which produced increased erosion. Sediment traveled less than 42m below the drainage outlet for 95% of the road segments.

Figure 2: Erosion from Timber Harvest



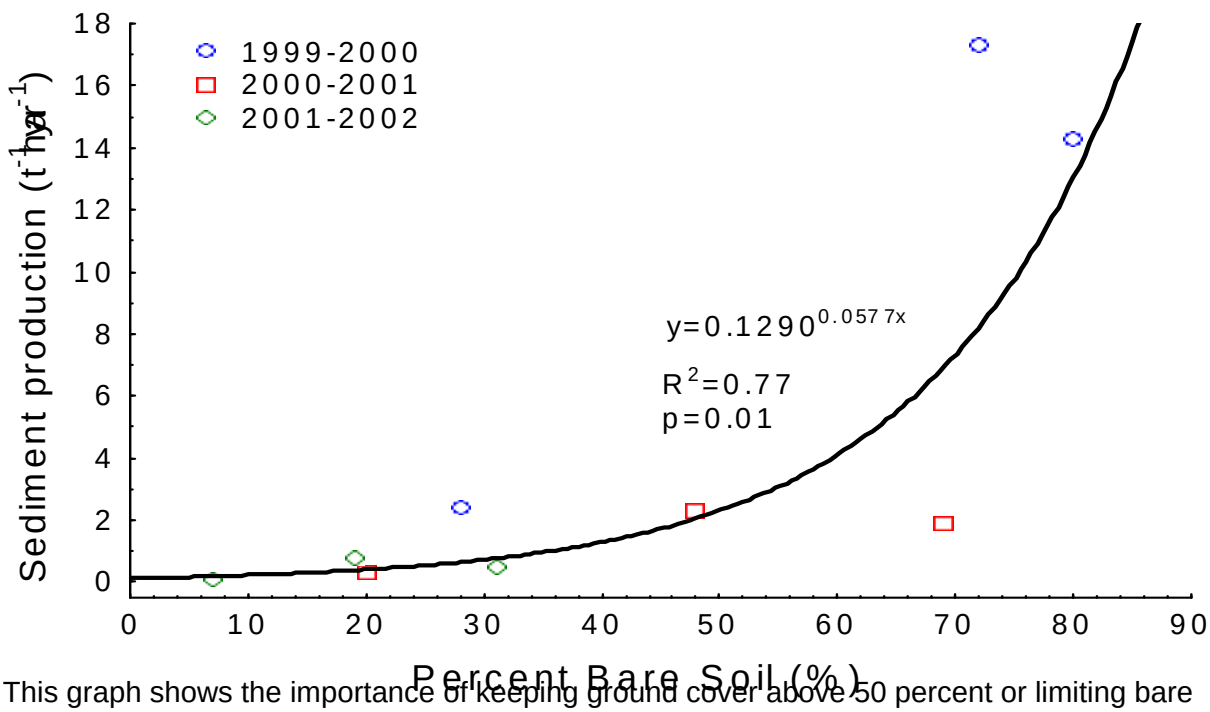
Erosion rates shown in Figure 2 are from skid trails only. Erosion rates from skid trails were 3-5 percent of that produced by roads. Most of the erosion came from 2 out of 36 skid trails measured.

Figure 3: Sediment Production Rates for Prescribe Fire and Wildfire (1999-2000)



This shows the average erosion rate for the 1st year following high-severity wildfire. Low-severity prescribed fire produced almost no erosion.

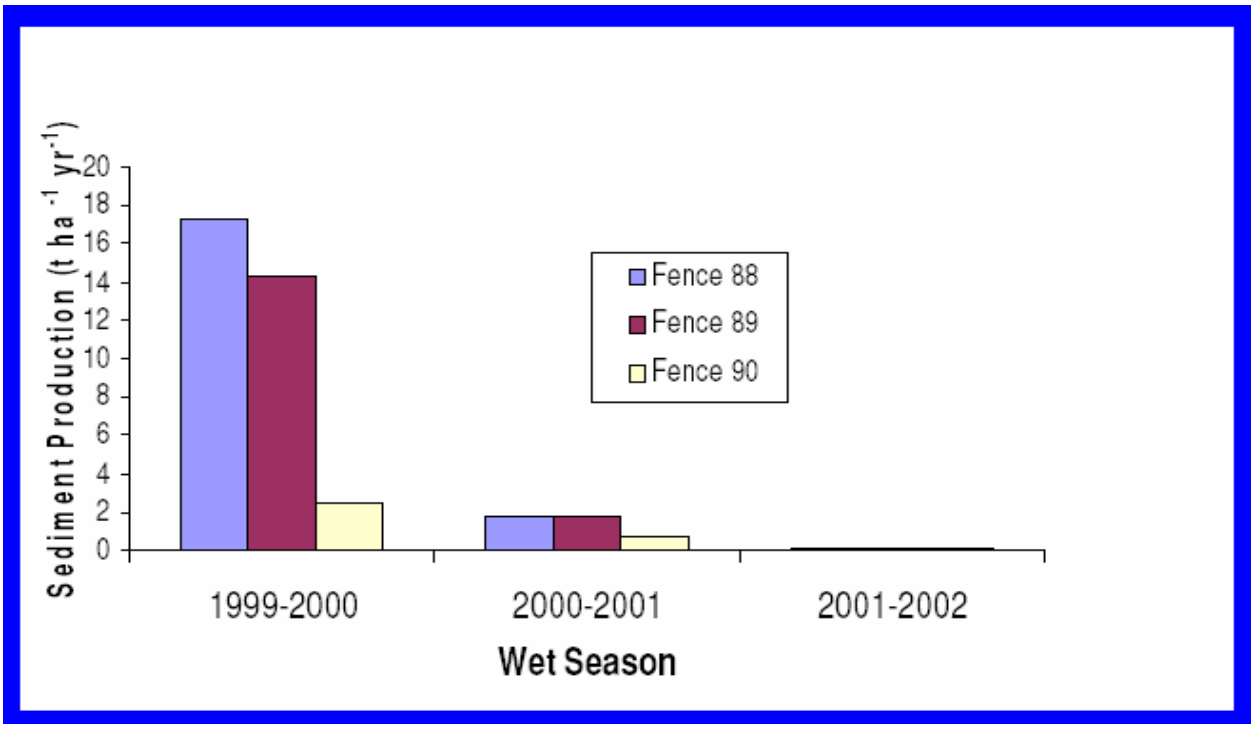
Figure 4: Post-fire Erosion and Ground Cover from Wildfires



This graph shows the importance of keeping ground cover above 50 percent or limiting bare ground to no more than 40-50 percent.

The average erosion rate for prescribed fire was .0098 Tons/ha compared to 10.8 Tons/ha for high severity wildfire.

Figure 5: Erosion Recovery from High-severity Wildfire



Erosion from wildfire recovers quickly and follows a concave curve. This may have been somewhat exaggerated by the higher rainfall intensities during the 1999-2000 wet season, but the pattern would not change.

In summary, erosion and sediment yield for the American River Study are shown in table 1.:

Table 1: Mean Sediment by Treatment (1999-2000) and Proportioned ERA Coefficient.

	Mean Sediment Rates\2		Sample Size (n)		
Disturbance Type	Tons/ha	Kg/M^2		Era Coef\3	Est Pct Skid trails/landings
Roads Dirt	8.80	0.798	17-55*	1.000	N/A
Roads Gravel or Paved	0.90	0.082	10	0.102	N/A
OHV Trails	3.90	0.354	7	0.443	N/A

Minimally disturbed sites	0.01	0.001	3	0.001	N/A
High Severity Wild Fire	11.00	0.998	3	1.250	N/A
Holland soil skid trail	8.20	0.744	2	0.932	N/A
Other skid trails	0.40	0.036	34	0.045	N/A
Skid Trails (Mean)	0.83	0.076	36	0.095	N/A
Prescribed Fire	0.01	0.001	15	0.001	N/A
Thin Unit (estimated\1)	0.13	0.012		0.014	15%
Regeneration Harvest (estimated\1)	0.23	0.021		0.026	27%

\1 Harvest Units estimated from skid trail erosion rates and minimally disturbed rates. 15 percent of thins were assumed to be in skid trails and landings and 26 percent of regeneration harvest were assumed to be in skid trails and landings.

\2 Mean sediment rates taken from the American River Sediment Fence study.

\3 Era Coefficients Dirt roads are set to 1 era per acre and all other ERAs are calculated base on the amount of sediment per acre relative to roads. For example the mean skid trail produces 0.83 Tons/ha or about 1/10 that of dirt roads.

In the American River study, sediment rates were highly skewed, with a few sites producing the majority of the sediment from each land use (Table 1). For roads, a couple of segments, with inadequate road drainage, and road segments that were recently graded, produced a majority of the road sediment. On skid trails most of the erosion came from 2 of 36 segments on the Holland soil type. These outliers probably represent areas where “Bests Management Practices” were not met. The case can be made to ensure the mistake is not repeated and exclude them from the ERA coefficient calculation. I did not exclude the outliers for this analysis but averaged them into the Era coefficient. When assigning ERA coefficients, local knowledge should be also used along with the data.

For this analysis Dirt roads were set to 1 ERA per acre. Every other ERA value was calculated base on the average sediment yield relative to dirt roads sediment yield. For example the average sediment yield on high severity wildfire areas are 11 tons/ha and dirt roads are 8.8 tons/ha. High Severity wildfire would get an ERA coefficient of 11/8.8 or 1.25.

Assigning the Coefficients

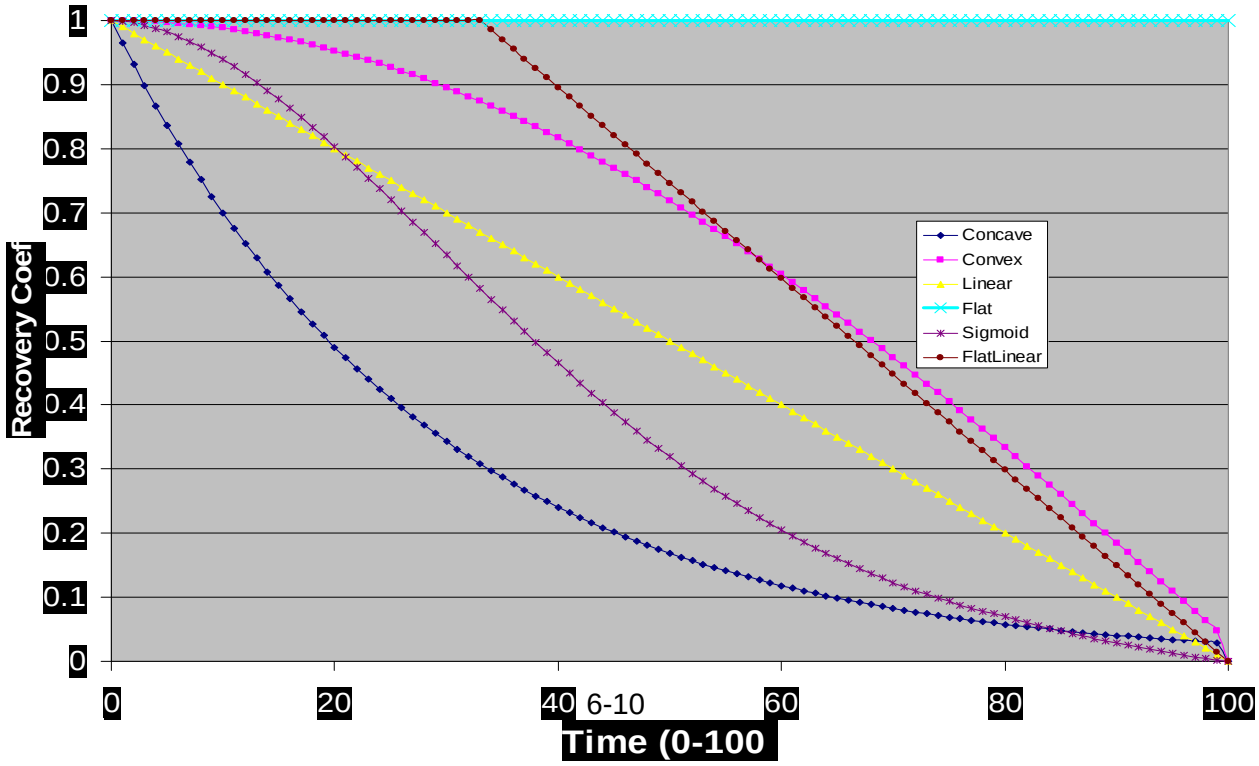
All treatments were assigned an ERA coefficient, a recovery curve, and recovery years based on the American River study, other studies, and local expertise. Sample ERA coefficients used in the analysis are listed in Table 2. The complete ERA coefficient tables are listed in each alternative spreadsheet attached.

Table 2 Era Coefficients

Activity Group	Activity Method	ERA's / Acre	Recovery Yrs	Recovery Curve
Activity Fuels	Broadcast Burn	0.001	3	Concave
Activity Fuels	Machine Pile	0.021	8	Concave
Fuel Treat	Thin From Below, Tractor	0.014	8	Concave
Harvest	Clear Cut Tractor	0.026	10	Concave
Harvest	Thin Tractor	0.014	8	Concave
Road	Gravel	0.22	60	Flat
Road	Dirt	1	60	Flat
Wildfire	High Severity with Salvage	1.4	8	Concave
Wildfire	Moderate Severity	0.3	4	Concave

Different recovery curves can be assigned based on what is being modeled. For example, since an active road does not recover over time, a flat recovery curve would be assigned. Most sediment recovery can be plotted as a concave curve. Recovery curves available for the model are shown in Figure 6. (It is possible to design a custom recovery curve by adding it to the 10RecovCurves table in the access database. The column name is the one that will appear in the dropdown menu when assigning curves. The curves are entered into a table made up of 100 periods. The numbers from 1 to 0 can produce any curve desired. The program interpolates this table for the recovery years chosen).

Figure 6: Built-in Recovery Curves



Watershed Thresholds
We do not know the ERA or disturbance threshold for any given watershed. The thresholds can vary within a watershed based on the intensity and duration of storm events. A very large 100-200 year storm event can exceed the threshold of an undisturbed watershed. A relatively small 1 or 2 year storm event may cause debris slides after a wildfire. The amount and severity of disturbances increase the likelihood of a storm event exceeding the watershed threshold. In Southern California it is common to have debris slides and houses filling up with mud from only from a 1 to 2 year storm event after a wildfire. This would take a much larger storm even with no wildfire. The winter of 2005, a large storm event caused major damage to relatively undisturbed watersheds in the southern California area..

The thresholds of concern can be estimated based on past events. Local knowledge is very important in estimating the threshold of concern. It is usually a conservative estimate based on 30 to 100 year storm events. The threshold values used for this analysis are from the Tahoe and Plumas Forests. The thresholds of concern are listed in the spreadsheets

Modeling
Equivalent Roaded Acres (ERAs) were modeled for B2E alternatives S1, S2 and S3 for years 2004 through 2034. The spreadsheets display risk ration and total ERAs. Risk ration is the percent of ERAs in a watershed divided by the watershed threshold times 100. A risk ration of 100 would mean the watershed is right at the threshold of concern, 80 would be 20 percent below, and 200 would be 100 percent over its threshold of concern. The spreadsheets for each alternative are located with this document.

For modeling simplicity all treatments and wildfires were assumed to occur at 2006, 2016 and 2026.. The 2036 treatments were not modeled. Alternative S1 is a no treatment alternative, S2 treats only private land, and S3 treats both private and National Forest land.

The Vegetation treatments always occurred before the wildfire, except in alternative S1 where not treatments were done. The acres of wildfire were modeled to estimate the expected return interval and fire intensity based on historical data. ERAs were modeled to represent erosion and sedimentation based on results from the American River sediment fence study (Table 1).

Results
Total ERAs (sediment)
Figure 7 shows the total ERAs for all watersheds in the project area by year and alternative. In 2006 and 2026 the treatment alternative S2 produce slightly higher ERAs than the no treatment alternative S1, but in 2016 the S2 treatment alternative produced fewer ERAs. The fires in 2006 and 2026 occurred almost entirely on National Forest land where the 2016 wildfires had more private land with treatments. Treating only private land was not very effective in reducing size and intensity of wildfires.

Alternative S3 included the National Forest fuel treatments as well as the private land. This alternative produced less ERAs that either Alternative S1 or S2. The treatments were effective in reducing the size and intensity of wildfires and thus reduced overall sediment yields as modeled through ERAs.

Figure 8 shows ERAs by Alternative, disturbance type and year. The no treatment alternative has highest wildfire sediment ERAs and Alt S3 and the lowest. In S3 the reduced ERAs from wildfire exceeds the increase in treatment ERAs, a net reduction. Roads were constant in all alternatives.

Cumulative Effects

The analysis shows that with implementing Best Management Practices the biomass and fuel treatments will reduce the overall potential for cumulative effects. This is because the treatments reduce the potential for wildfire.

Table 3 shows the risk ratios by alternative for watersheds there threshold of concern (TOC) for year 2006, 2016 and 2026. The watershed is over the TOC where the risk ration exceeds 100. Alternative S1 has the most watersheds over threshold and by the greatest percent, S2 is next and S3 has the least amount of watershed over threshold by the least percentage. The first decade anternative S1 and the third decade alternates S1 and S2 are about the same. This is because Alternative S2 had very few treatments where the fire occurred.

The treatments by them selves never pushed a watershed over threshold. All the watershed that are over threshold are due to wildfire. In watersheds that do not burn there is more disturbance by the treatments and small increase in sediment but not enough to exceed watersheds thresholds oof concern. This increase is offset by the reduced fire intensity an fire size in watersheds where wildfire occur. Recovery from the effects of wildfire commonly happens in just 2 to 4 years, but the initial effect can be severe if a high intensity rainfall event occurs shortly after the fire. In alternative S3 the number of watershed over threshold drops from 7 to 1 as a result of the fuel treatments. The risk ration of Upper Red Clover Creek drops from 568 to 212 because the fuel treatments reduced the fire intensity.

Figures 9 and 10 compare the watersheds by threshold class for alternatives S1 and S3. The fuel treatments moved a few watersheds from one threshold class to the next higher class, but none of the treatments exceeded the watershed threshold. The B2E modeled wildfires usually moved the watershed well over threshold. No watershed moved over over threshold from the treatments and 8 watersheds moved form over threshold in S1 to under threshold in S3 in years 2006 and 2016.

Figure 11 was added to show the effect of the fuel treatments on a modeled wildfire. Both the size and intensity of the wildfire are reduced by the fuel treatments.

Roads do not change among alternatives or over time. There effect is a constant. In reality some roads may be put to bed and other new ones built. This analysis assumes that the road densities will not change significantly as a result of the treatments.

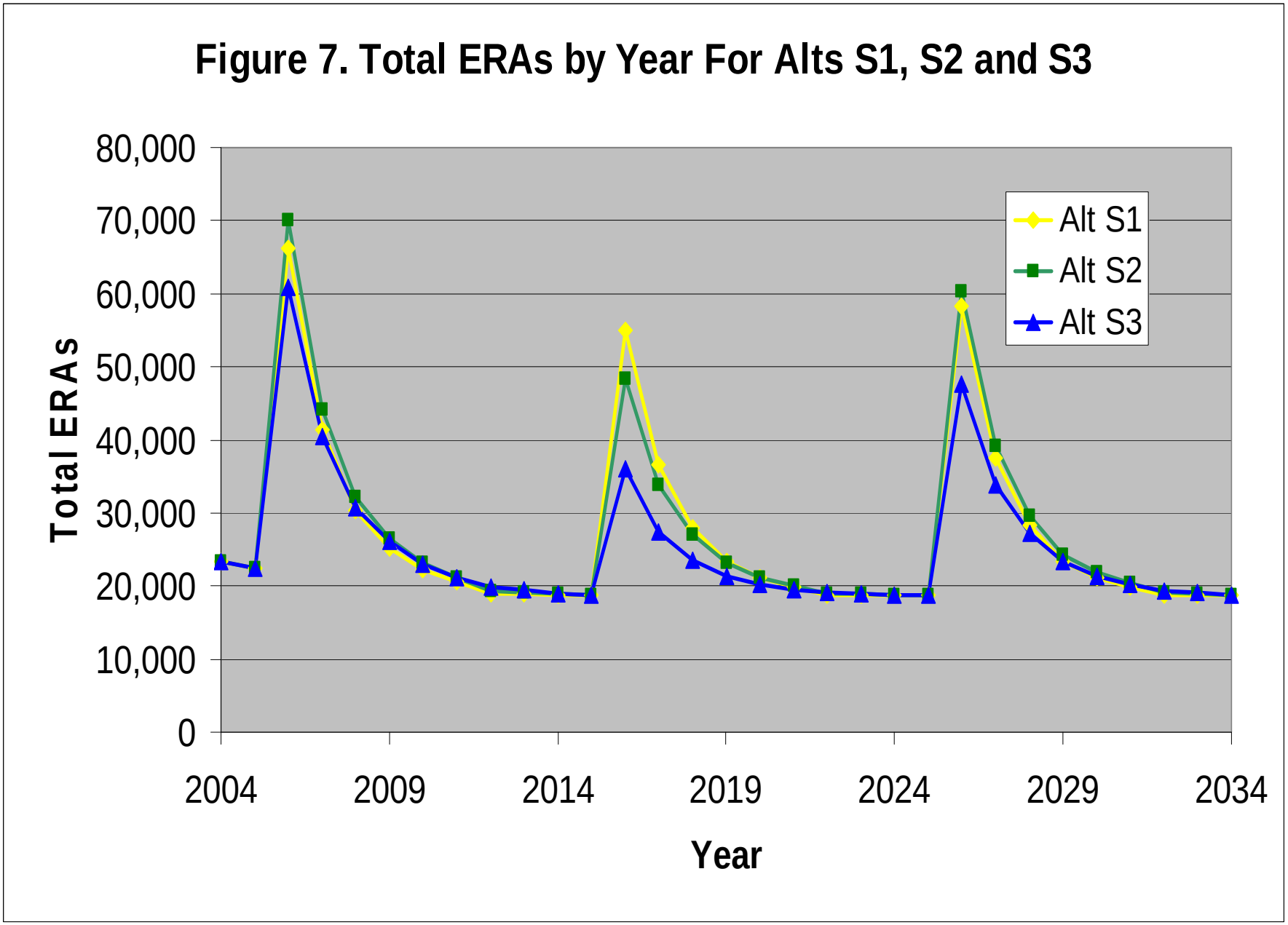


Figure 7. Total ERAs by Year For Alts S1, S2 and S3
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Total ERAs
2004
2009
2014
2019
2024
2029
2034
Year
Alt S1
Alt S2
Alt S3

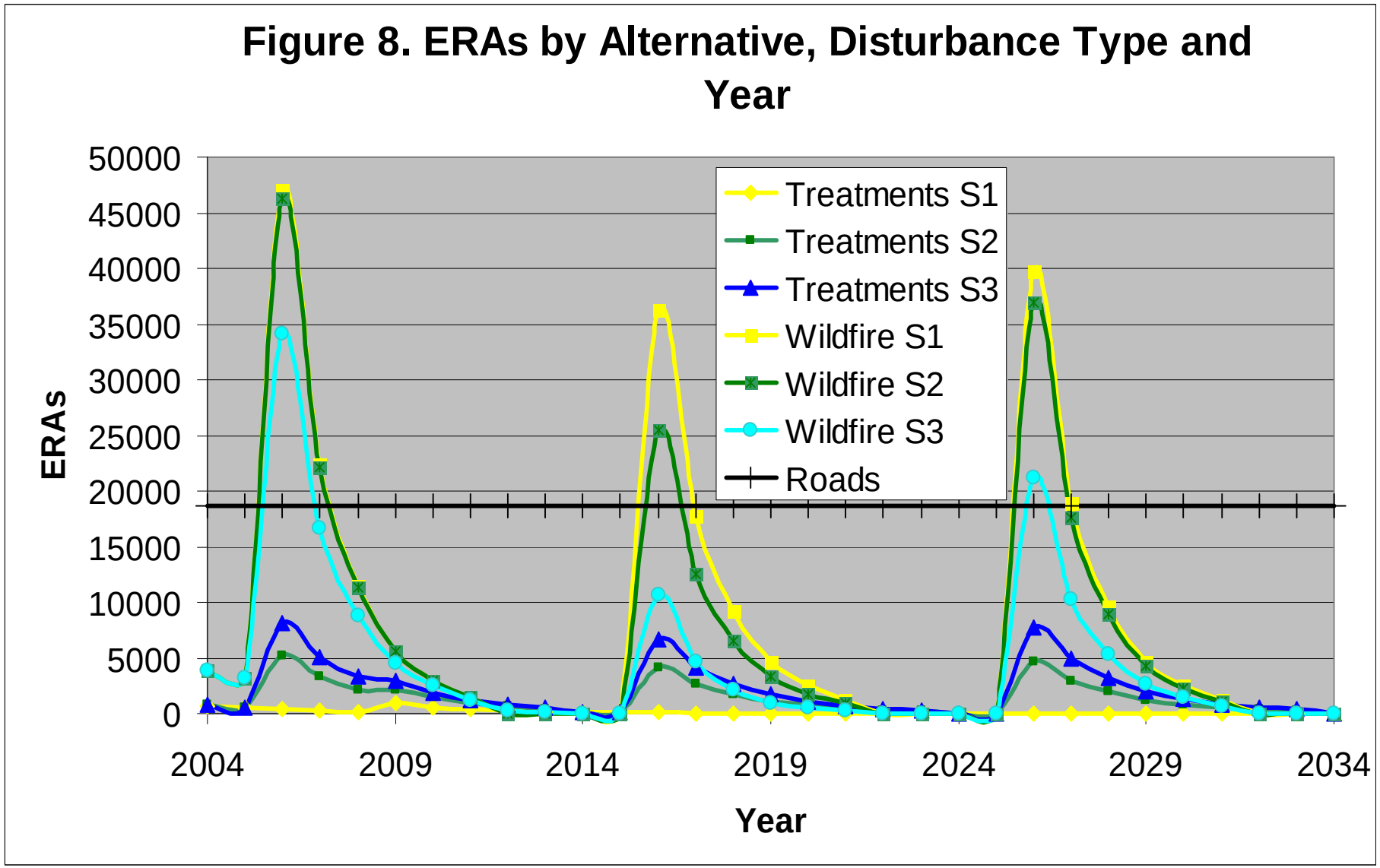


Figure 8. ERAs by Alternative, Disturbance Type and Year
ERAs
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2004
2009
2014
2019
2024
2029
2034
Year
Treatments S1
Treatments S2
Treatments S3
Wildfire S1
Wildfire S2
Wildfire S3
Roads

Table 3: Risk Ratios by Alternative for Watersheds over Threshold Year 2006, 2016 and 2026

	Alt S1			Alt S2			Alt S3		
HUC_NAME	2006	2016	2026	2006	2016	2026	2006	2016	2026
Stoney Creek	490			485			434		
Lower Last Chance Creek	488			487			413		
Clarks Creek	275			271			142		
Mc Clellan Canyon	295			294			218		
Mc Dermott Creek	270			256			190		
Middle Last Chance Creek	258			257			177		
Pineleaf Creek	184			185			87		
Otis Canyon	122			111			35		
Lower Pine Creek	114			115			107		
Upper Red Clover Creek		572			500			216	
Dixie Creek		297			190			49	
Big Grizzly Creek		200			124			74	
Bald Rock Canyon		138			58			38	
Adams Neck		180			160			75	
Wild Yankee Creek		112			72			48	
Last Chance Creek		101			73			42	
Carman Creek			419			392			251
Antelope Creek			267			241			123
Clairville Flat			154			136			69
Seneca			172			178			143

Figure 9: CWE Risk Assessment by Watershed Alt S1 (No treatments) Vs Alt S3 Treat Private and National Forest Land Year 2006

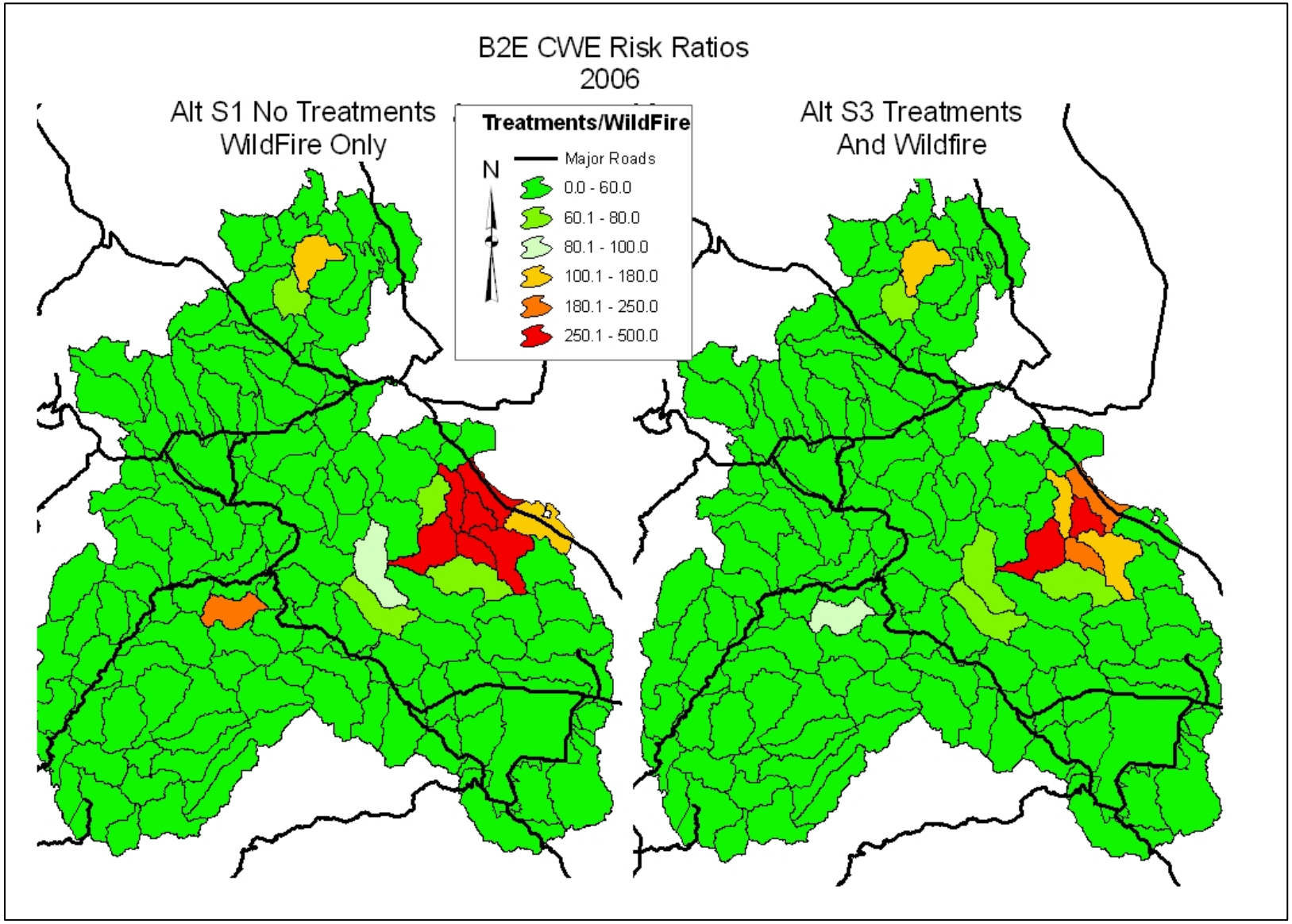


Figure 10: CWE Risk Assessment by Watershed Alt S1 (No treatments) Vs Alt S3 Treat Private and National Forest Land 2016

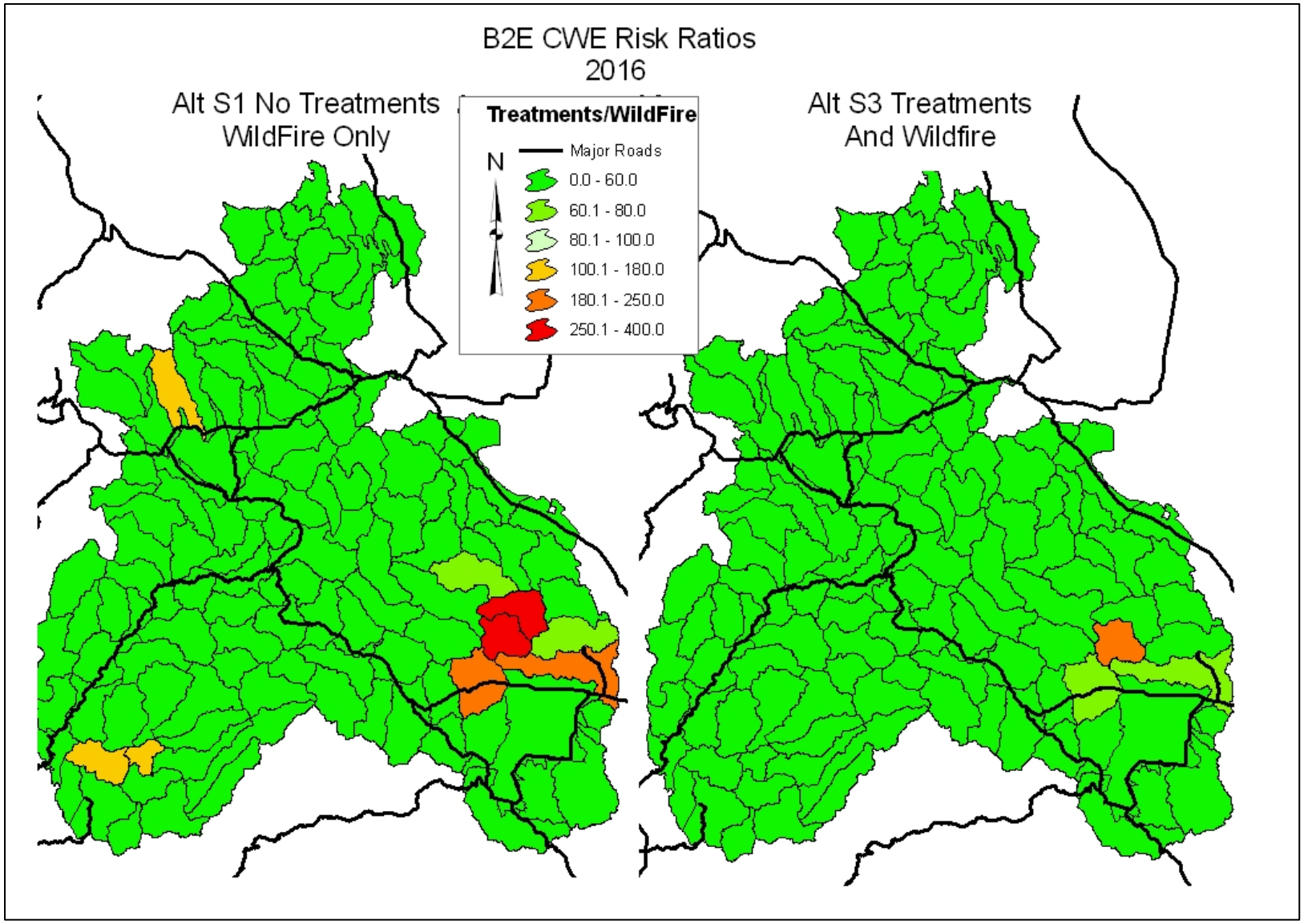
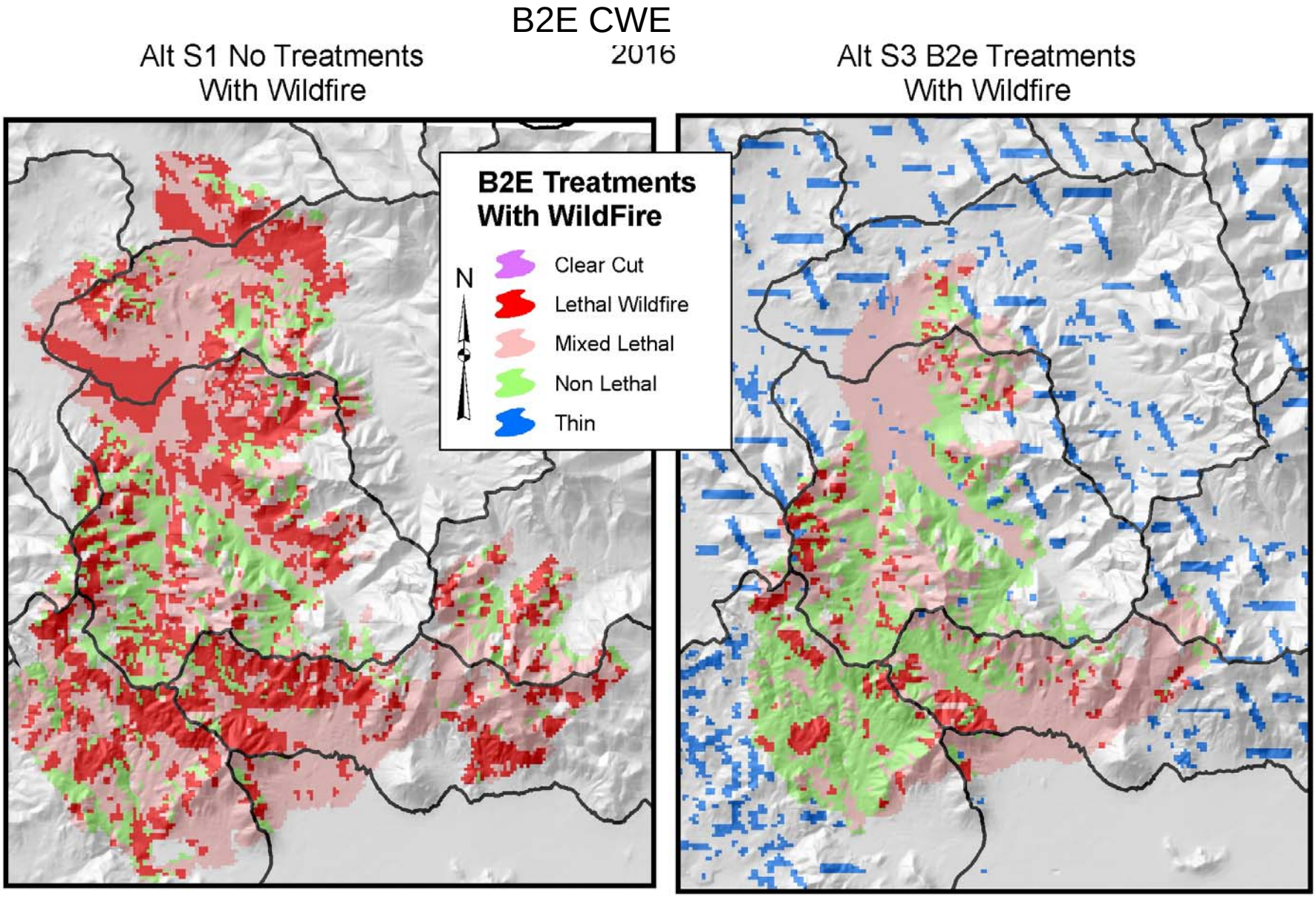


Figure 11: Effects of Treatments on Wildfire Size and Intensity



WEPP FuME

The WEPP FuME (Fuel Management) interface was run for this analysis. WEPP FuME is a web based interface (http://forest.moscowfsl.wsu.edu/fswepp/) that predicts soil erosion associated with fuel management practices (prescribed fire, thinning, and a road network) and compares the result with erosion from wildfire. Erosion plots were taken all over the US for this model. There are also numerous studies to verify the results of the WEPP erosion model and it is quick and easy to run..

The results of a WEPP FuME run are shown in Table 5 below. The model also generates a report with additional information in Appendix 1. To average out the variation in storm intensities the model returns an average sediment yield over a 50 year period.

Table 5. WEPP FuME Output Summary Based on 50 years of Possible Weather

Line	Source of sediment	Sediment delivery in year of disturbance (ton mi^{-2})	Return period of disturbance (y)	"Average" annual hillslope sedimentation (ton mi^{-2} y^{-1})
1	Undisturbed forest		1	0
2	Wildfire	6707.2	100	34
3	Prescribed Fire	108.8	20	5.4
4	Thinning	0	20	0.0
5	Low Access Roads	1.8 to 8.6	1	1.8 to 8.6
6	High Access Roads	6.7 to 12.9	1	6.7 to 12.9

In running WEPP FuME it was assumed that the unit would be treated every 20 years by thinning and burning the generated fuels. The fire return interval from 1900 to 2006 has been around 200 years so this is what I set for the model. Because of the high fuel build up on National Forest land and if global warming continues, that estimate might be conservative. The 200 year return interval was greatly influenced by the suppression success we have had until recently. I assumed that fire suppression would as successful as the last 100 years.

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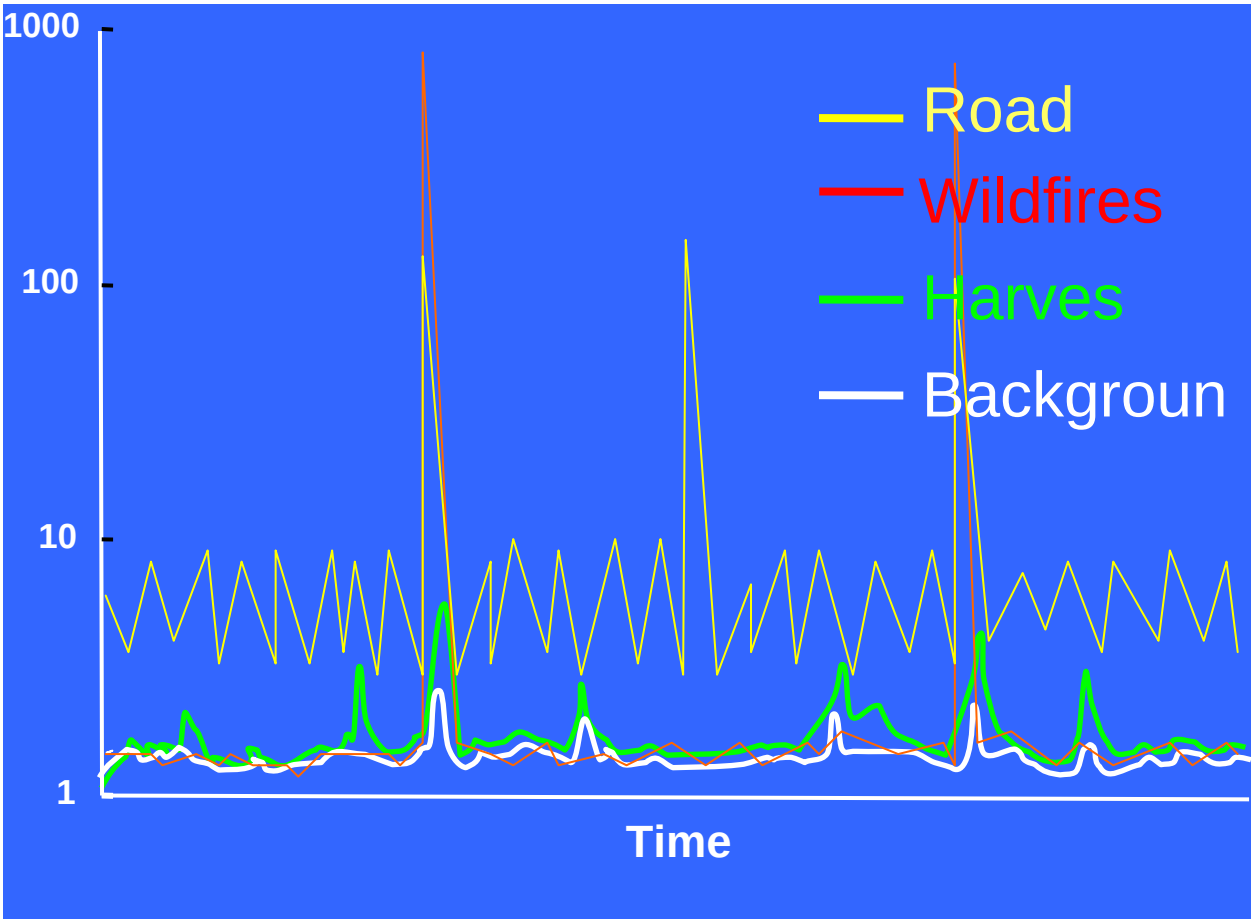
The WEPP FuME results paint a very similar picture to the ERA model. Over the next 50 years, the amount of sedimentation from wildfire will be around 6 times that of the fuel treatments. If the fuel treatments drop the average wildfire sediment yield in half the total average sediment rate will drop from 55 to 42 tons/mi^2/yr

Conclusions

The conclusions based on the R5 sediment ERA analysis match the WEPP FuME web analysis. High intensity wildfires produce the higher risk to increase erosion and sedimentation than the vegetation treatments. Wildfire can produce more erosion per acre than that of a road. Wildfire can burn a lot of acres. Figure 12 is a hypothetical erosion rate over time for roads, wildfire, harvest, and background (no action). Coe 2005 based this on the American River study results.

Note that the scale is exponential: wildfires produce 10 times the sediment produced by the erosion of roads.

Figure 12. Hypothetical Erosion Rates: Wildfires vs. Harvest vs Roads vs Background.



The B2E treatments under Alternative S3 have a low risk of causing a cumulative watershed effect, and have a high potential to reduce the sediment yields over the project area and reduce the potential for cumulative effects from wildfire (a net decrease). For Alternative S2, treat only private land, the conclusions are not as clear. Private land is not uniformly spread throughout the project area and private land treatments would not have an effect on many of the wildfires. This was seen in decade 1 and 3 of the analysis where private land treatments had only minimal effects on wildfire size and intensity because there just weren't many private land treatments in the wildfire area. When doing fuels management in mixed ownership, it is important to have all parties coordinate there treatments.

In the Sierras erosion and sedimentation is the primary process for degrading stream water quality from vegetation management activates. With current Best Management Practices the risk to water quality is low.

These conclusions assume that Best Management Practices are used in the B2E vegetation management activities. It was not assumed that the alternatives would require an increase in road density for these projects. Some roads may be obliterated and other roads built or re-opened, but the total road density would remain about the same.

The biggest shortcoming of this analysis is the lack of local knowledge of the area. Sensitive areas need to be identified for special treatments or BMPs and the thresholds of concern need to be continually evaluated. These site specific analyses should be at the project level, when the treatments are being designed.

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