SCOPE OF WORK

Project Title

Effectiveness of Road Rules in Reducing Hydrologic Connectivity and Significant Sediment Discharge (EMC-2015-004) – Statistical Review

Project PI

USFS Pacific Southwest Research Station

Introduction and Background Information

The project titled "Effectiveness of Road Rules in Reducing Hydrologic Connectivity and Significant Sediment Discharge" (Road Rules Effectiveness Monitoring) proposes to monitor changes in key indicators of forest road performance that result from the implementation of the "Road Rules, 2013 Rule Package" (Road Rules). Roads can alter hydrologic and geomorphic processes in ways that can adversely impact aquatic ecosystems (Luce and Wemple, 2001). As such, an evaluation of the effectiveness of the Road Rules is vital to assessing the overall effectiveness of the California Forest Practice Rules in protecting aquatic resources.

This proposal is part of a tiered effort (Figure 1) to evaluate the effectiveness of the Road Rules, with a primary focus on evaluating the efficacy of the Road Rules in reducing surface erosion-related water quality impacts across a range of recurrence interval storm events. Road Rule effectiveness for reducing mass wasting and watercourse crossing failures will be evaluated separately using a Large Event (i.e., high recurrence interval, post-mortem) monitoring approach. In addition, we will also propose to implement a number of research effectiveness monitoring studies to more rigorously quantify the effectiveness of the Road Rules in reducing sedimentary impacts relative to narrative or numeric State water quality objectives (i.e., validation monitoring). For example, a research-level road effectiveness monitoring study might directly quantify sediment discharge on a treated connected road segment to determine if the implementation of the Road Rules resulted in a less than significant sediment discharge.

The primary EMC critical question to be addressed with EMC-2015-004 is:

- Theme 3—Road and WLPZ sediment

  Are the FPRs and associated regulations effective in: (a) reducing or minimizing management-related generation of sediment and delivery to watercourse

channels; (b) reducing generation and sediment delivery to watercourse channels when timber operations implement the Road Rules 2013 measures; and (c) reducing the effects of large storms on landslides as related to roads, watercourse crossings and landings.

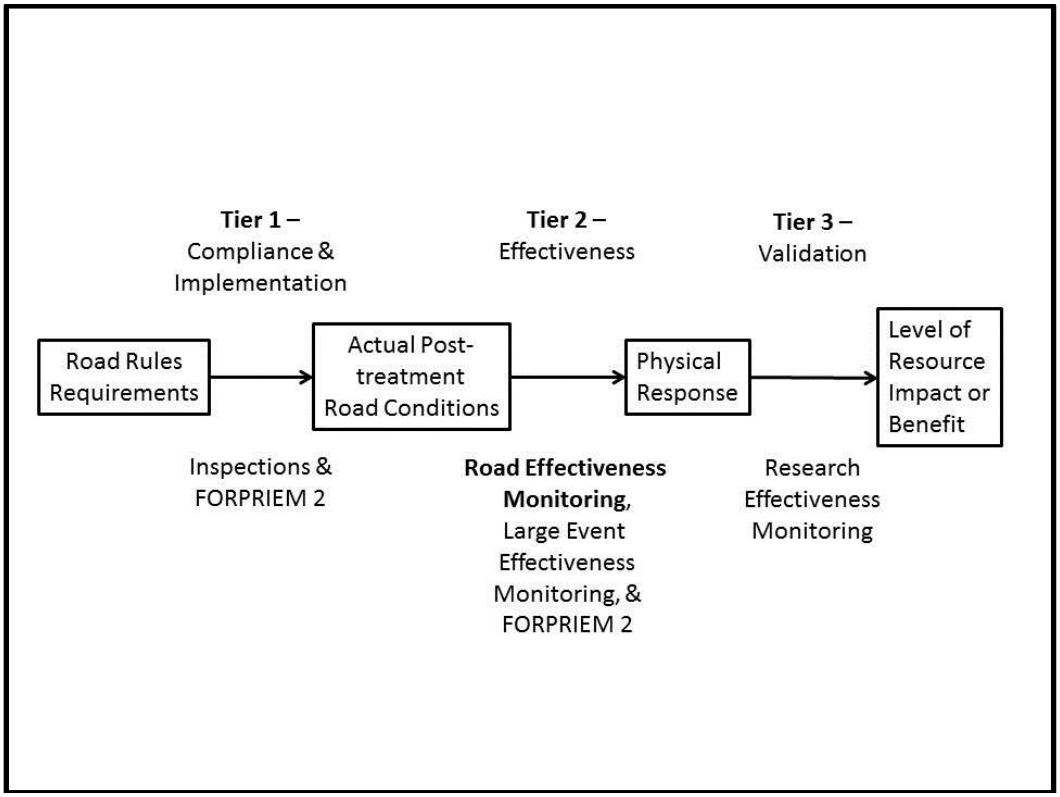

Figure 1. Schematic of a suggested tiered monitoring approach to address the Road Rules (adapted from Veldhuisen et al., 2000 and Raines et al., 2005)

Regulatory

The Road Rules, 2013 rule package (Road Rules) was approved by the California State Board of Forestry and Fire Protection (BOF) in January, 2014, and became effective on January 1, 2015. While the Road Rules have many procedural and operational requirements, the Road Rules generally rely on performance standards to achieve the desired outcome of avoiding or reducing significant adverse impacts to aquatic resources (see 14 CCR § 923 [943, 936] (b)). A major theme of the rule package is to prevent or reduce "Significant Sediment Discharges" from existing and planned roads. Significant Sediment Discharges are defined[1] as:

> *Soil erosion that is currently, or, as determined based upon visible physical condition, may be in the future, discharged to watercourse or lakes in quantities*

[1] Forest Practice Rule definitions are found in 14 CCR § 895.1.

that violate Water Quality Requirements or result in significant individual or cumulative adverse impacts to the beneficial uses of water. One indicator of a Significant Sediment Discharge is a visible increase in turbidity to receiving Class I, II, III, or IV waters.

In turn, "Water Quality Requirements" are defined as:

A water quality objective (narrative or numeric), prohibition, TMDL implementation plan, policy, or other requirement contained in a water quality control plan adopted by the Regional Board and approved by the State Water Board.

Under the Road Rules, the first step in eliminating or reducing Significant Sediment Discharges and complying with water quality regulations is to identify "Significant Existing or Potential Erosion Sites", which are defined as:

A location where soil erosion is currently, or there are visible physical conditions to indicate soil erosion may be in the future, discharged to watercourses or lakes in quantities that violate Water Quality Requirements or result in significant individual or cumulative adverse impacts to the beneficial uses of water.

Once the Significant Existing or Potential Erosion Sites are identified, the rule language in 14 CCR § 923.1 [943.1, 936.1] (e) (1, 2, and 3) requires the RPF to submit an inventory of Significant Existing or Potential Erosion Sites along with a description of feasible treatment(s) to mitigate significant adverse impacts from roads and/or landings.

Treatments for Significant Existing or Potential Erosion Sites focus on "hydrologic disconnection", which is defined as:

The removal of direct routes of drainage or overland flow of road runoff to a watercourse or lake.

If Significant Existing or Potential Erosion Sites cannot be hydrologically disconnected, 14 CCR § 923.5 [943.5, 936.5] (i) requires the use of erosion control measures to prevent Significant Sediment Discharges:

Where logging road and landing surfaces, road approaches, inside ditches and drainage structures cannot be hydrologically disconnected, and where there is existing or the potential for significant sediment discharge, necessary and feasible treatments to prevent the discharge shall be described in the plan.

Altogether, the Road Rules require a stepwise process to identify and treat erosion sources that pose a risk to aquatic resources, and this process is illustrated in Figure 2.

In the context of this study, effectiveness of the Road Rules will be assessed based upon the degree to which roads/landings are disconnected from the watercourse network after implementation of the rules.[2] Changes in the controlling variables or conditions that drive sediment production will be assessed for hydrologically connected road segments so that the relative magnitude of sediment delivery can be estimated.

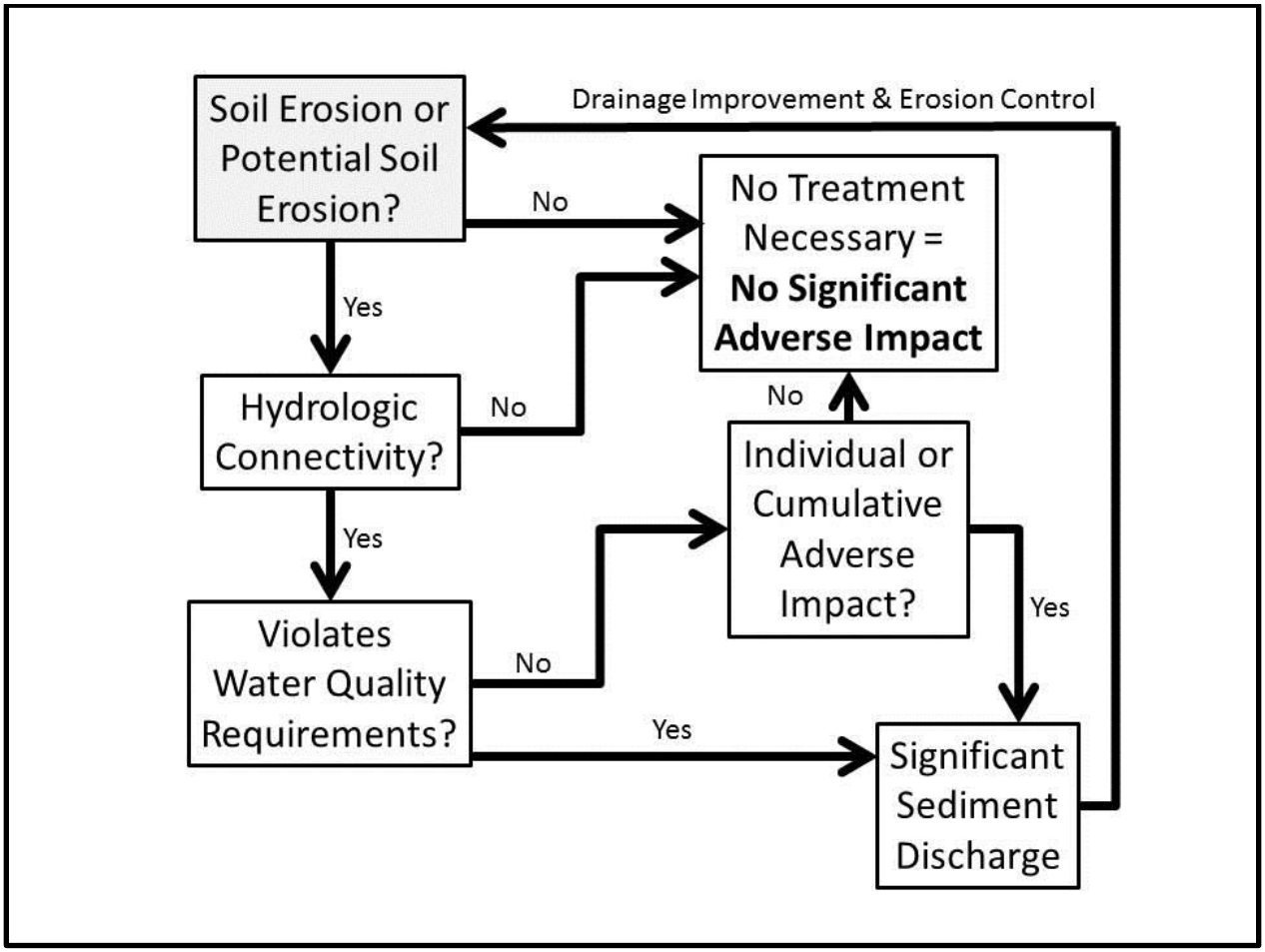

Figure 2. The stepwise process for avoiding or reducing significant adverse impacts to aquatic resources as required by the Road Rules.

Technical

A monitoring methodology for evaluating the effectiveness of the Road Rules should account for the important factors controlling road sediment production and delivery. Road erosion is the result of the interaction between erosive forces, such as rainfall intensity and runoff energy, and the availability of erodible sediment (Reid and Dunne,

[2] Guidance on how to achieve hydrologic disconnection is provided in Technical Rule Addendum No. 5 and in Weaver et al. 2014.

1984; Luce and Black, 1999; Ziegler et al., 2000). Road design plays an important role on runoff erosivity because sediment transport capacity is proportional to road drainage spacing (Luce and Black, 1999) and the shape and width of the road tread can influence runoff patterns (Burroughs and King, 1989). Factors that influence erodibility include native soil characteristics, aggregate quality, road gradient, road age, grading, and vehicle traffic rates (Megahan, 1974; Burroughs and King, 1989, Luce and Black, 2001a; Ziegler et al., 2000; Reid and Dunne, 1984; Luce and Black, 2001b; Megahan et al., 2001).

The likelihood of resource damage from road-generated sediment is not only related to the magnitude of road erosion and runoff, but also the degree of linkage between road sediment sources and the watercourse network. According to the Road Rules, road sediment that is not delivered to the watercourse network does not constitute a significant adverse impact to aquatic resources. Therefore, the extent to which the Road Rules are effective in preventing resource impacts is largely dependent on road connectivity, or hydrologic connectivity, to the watercourse network.

General Monitoring Approach

This monitoring proposal will address how effective the Road Rules are at decreasing the magnitude of erosion, runoff, and sediment delivery at the road segment and plan scale.[3] Uncertainty regarding the effectiveness of the Road Rules can be addressed by posing the following general monitoring questions:

General Monitoring Question 1: How many of the THPs are already in compliance with the road rule package (statewide and by region)?

General Monitoring Question 2: Have road attributes that affect surficial sediment production (i.e., surface erosion) and delivery improved after implementation of the Road Rules?

Since the connectivity and erosion potential of the connected road segment controls the potential for significant sediment discharge and rule compliance, these questions can be addressed through the development of the following specific monitoring questions:

[3] Some data on previous road rule requirements and their effectiveness exist from past monitoring work conducted as part of the Hillslope Monitoring Program (Cafferata and Munn, 2002). For example, 85% of gullies recorded on randomly located road transects and 70% of rills documented were judged to be caused by road drainage feature problems. Highly erodible surface material and steep road gradient were also frequently cited causes of rilling (see Table 11). Data collected from the FORPRIEM monitoring program (Brandow and Cafferata,2014) may be able to be used to beta test some of the parameters being considered for Road Condition Monitoring.

Specific Monitoring Question 1: Has the length/area/percentage of roads draining to watercourses decreased after the implementation of the Road Rules?

Specific Monitoring Question 2: Have the road attributes affecting surface erosion for connected road segments improved since the implementation of the Road Rules?

These specific monitoring questions allow us to generate some initial testable hypotheses such as:

> **H_o** 1: No reduction in road drainage connectivity to streams has occurred since implementation of the Road Rules.[4]
>
> **H_A** 1: Road drainage connectivity has been reduced after implementation of the Road Rules.
>
> **H_o** 2: No improvement in road attributes that affect sediment production for connected road segments has occurred since implementation of the Road Rules.
>
> **H_A** 2: Improvement in road attributes that affect sediment production for connected road segments has occurred since the implementation of the Road Rules.

Testing these hypotheses requires collecting road information at the THP/plan scale for hydrologically connected road segments. We will attempt to collect information on the conditions (i.e., variables) that drive sediment production and delivery pre- and post-Road Rule implementation.

The preliminary list of proposed monitoring variables is listed below (Table 1). Arrows indicate the dependence of sediment production and sediment delivery on increases in each road attribute (e.g., sediment production goes up as road length increases). These data can be used to test the null hypotheses presented in the preceding section. Changes in hydrologic connectivity can be measured pre- and post-treatments (Figure 3) to determine if there is significant reduction in road-to-watercourse linkage. Attributes influencing the relative magnitude of sediment delivery for connected road segments will also be tracked (Figure 4). If present, connected erosion features will be characterized and quantified using techniques similar to those from the Battle Creek Task Force Report (2011). For instance, the presence of rilling, gullying, or mass wasting will be noted and delivered sediment volume will be estimated.

Additionally, the data can be integrated into a single metric of sediment production through the use of models (e.g., SEDMODL2, Road:WEPP, GRAIP Lite). The benefit of

[4] Hydrologic disconnection has been required for areas governed by the Anadromous Salmonid Protection Rules since 1 January, 2010.

modeling sediment production is that it incorporates the suite of interacting practices used to decrease road sediment production (e.g., road rocking and improved drainage). The disadvantage of modeling sediment production is that the absolute values of model outputs can be taken out of context. As such, it is suggested that modeled outputs be presented in a relative fashion, such as a percentage increase or decrease in sediment production relative to pre-implementation.

Table 1. List of independent variables that control sediment production and delivery from roads. Arrows indicate the dependence of sediment production or delivery on increases in each road attribute.

Independent Variable	Sediment Production	Sediment Delivery
Road length	↑	↑
Road slope	↑	↑
Road width	↑	↑
Road drainage configuration (e.g., road shape - crowned, insloped, or outsloped)	↕	↕
Road surface (e.g., depth, hardness, breakdown components)	↓	↓
Wet weather traffic	↑	↑
Presence of erosion features (e.g., gullies) or ruts	↑	↑
Ditch length	↑	↑
Ditch width	↑	↑
Ditch condition	↕	↕
Soil type/erodibility	↕	↕
Drainage outlet condition	↕	↕
Cutslope height	↑	↑
Cutslope angle	↑	↑
Cutslope cover	↓	↓
Fill height	↑	↑
Fill cover	↓	↓
Distance from watercourse	↓	↓
Hillslope angle	↑	↑
Number of stream crossings	↑	↑
Road length connected to stream	↑	↑
Length of rocked road connected to stream)	↓	↓
Length of road abandoned/deactivated	↓	↓
Filter strip condition	↕	↕
Road construction quality/compaction	↕	↕
Watercourse Class	↕	↕

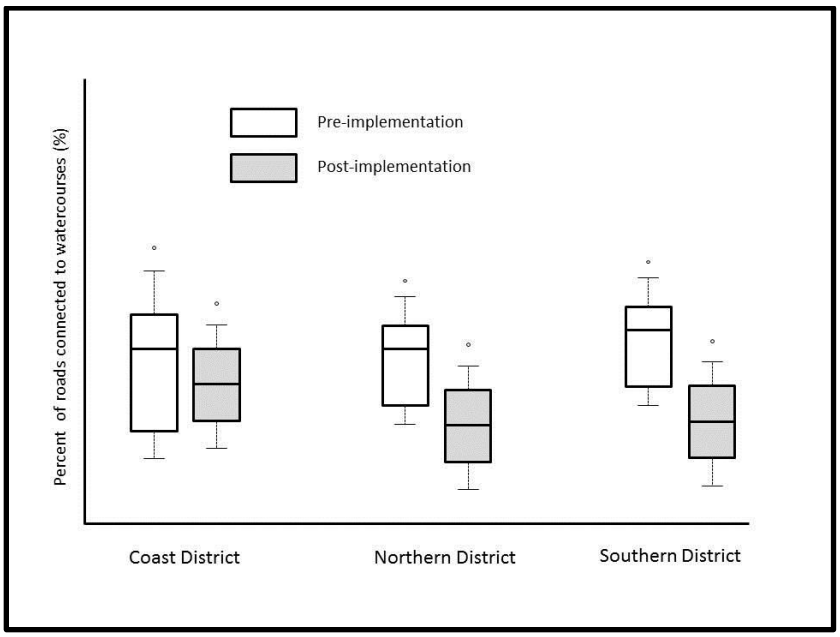

Figure 3. Hypothetical change in hydrologic connectivity for Timber Harvesting Plans by Forest Practice District pre- and post-implementation of the Road Rules. Reducing the length of connected roads decreases the likelihood for significant sediment discharges.

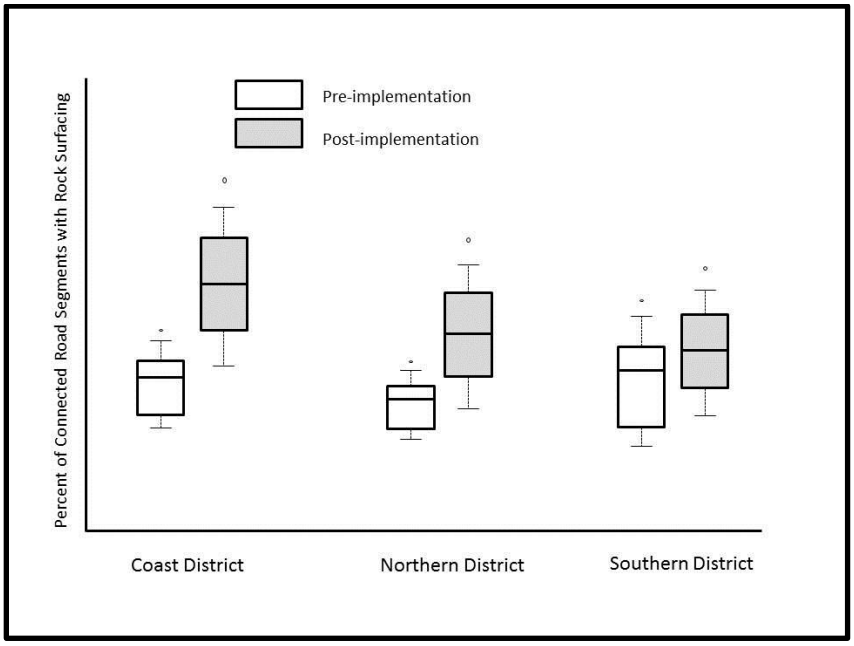

Figure 4. Hypothetical change in the percent of hydrologically connected road length with rock surfacing. An increase in the percent of connected road segments with rock surfacing will result in a lower likelihood of significant sediment discharge.

Goal of the Statistical Review

Sampling will be performed pre- and post-treatment at the THP/plan scale. Sampling protocols and other statistical considerations will be formalized in the study design following consultation with a statistician. THPs and other types of harvesting documents (i.e., NTMPs, MTHPs, PTHPs) will be selected using a stratified random approach similar to that proposed for FORPRIEM ver. 2.0. Ideally, a contractor with earth science expertise could be hired to collect the field data, analyze the data, and produce preliminary and final reports.

A preliminary methodology for a stratified random sample of completed THPs and NTMP-NTOs to better test the FPRs on a larger percentage of higher erosion risk sites has been developed by the CAL FIRE GIS Program in Santa Rosa (Program Manager Suzanne Lang). The following ArcGIS layers have been beta tested to assess relative erosion risk:

- 10 m DEM slope (index for shallow landsliding).
- Deep seated landslide susceptibility layer (Wills et al. 2011).
- E-EHR (surface erosion hazard) [note incomplete soil survey data in Calaveras and Humboldt counties at this time] (program currently available from CAL FIRE GIS Program, Santa Rosa).
- Drainage density (National Hydrology Dataset).

A preliminary algorithm has been tested to combine these parameters for a composite score (Table 2), similar to that used by McKittrick (1994) to rate erosion potential for super planning watersheds in California.

After a stratification sampling scheme is developed for higher risk plans, the ArcGIS THP layer and a randomization scheme will be used to select the appropriate number of plans in each risk category (high, medium, and low)—allowing an adequate relationship to the total plan population to be generated. **Statistical review is needed to (1) refine this stratified random sample design, and (2) develop a final the sampling plan. Statistical review is required by the EMC prior to finalizing the Road Rules Effectiveness Monitoring sampling plan**

Contract Tasks

This contract will inform the BOF, CAL FIRE, and the EMC determine how we can most effectively realize the following benefits of an appropriate statistical design. Specific tasks include:

1. Determination of sample sizes needed to characterize a parameter population for a specified degree of uncertainty, and procedures for estimating differences and necessary sample sizes.

2. Review of proposed sampling design with respect to variables measured and locations for sampling, thereby minimizing costs while achieving stated goals.

3. Ability to assess the precision of the estimates in a statistically defensible manner.

4. Analytical testing and estimation procedures that ensure efficient use of data collected and provide an estimate of precision for valid conclusions.

Deliverables

The contractor will perform tasks that include:

1. Produce a final draft technical report for review and concurrence by the Department and production of a final draft report that incorporates the Department's comments.

2. A presentation on the project to the State Board of Forestry and Fire Protection's EMC.

3. Conduct all project administration relating to invoices.

The final report will describe the findings and conclusions from the specified investigations. The EMC will review the report, summarize its conclusions, and use the results to finalize the sampling plan that will allow data collection and analyses for Road Rules Effectiveness Monitoring to proceed in a timely manner.

Timeframe

Finished products ready for Department and EMC review will be produced beginning in February 2017, and finalized and fully disseminated by June 30, 2017.

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