Evaluation of Forest Road Scenarios Using Field Measurements and the Distributive Hydrology Soil Vegetation Model (DHSVM)

South Fork of Caspar Creek

California Board of Forestry
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Christopher Surfleet, PhD
Field Measurements

16 Road Flumes:

- 6 - Runoff, Turbidity, Suspended Sediment Measurement (RTS)
- 10 - Crest Stage Gauges

Measured road runoff from November 2018 – March 2019

22 Road Runoff events

Turbidity and Stage
- Above/below Class I watercourse crossing.
- Above/below Class II watercourse crossing.
Runoff,
Turbidity,
Suspended
Sediment
Measurement
Site 16

Site 12

Runoff,
Turbidity,
Suspended
Sediment
Measurement
Site 16

Site 4
## Total Suspended Sediment Load by Road Surface Type

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>This Study</th>
<th>Barrett et al. 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock</td>
<td>0.01 – 0.85 kg/m²/yr</td>
<td>0.02 – 0.8 kg/m²/yr</td>
</tr>
<tr>
<td>Native</td>
<td>17.8 – 41.0 kg/m²/yr</td>
<td>0.1 – 4.5 kg/m²/yr</td>
</tr>
</tbody>
</table>

Reid and Dunne (1984) 130 X for heavily used roads  
Megahan and Kidd (1972) 750 X for newly constructed roads  
Coe (2006) 3-4X for recently graded compared to ungraded
Prediction of Suspended Sediment Load ($\log_{10} \text{SSL}$)

**Predictors**

- Peak flow (from road storm runoff)  
  Adj. $R^2 = 0.80$

- Maximum turbidity $^{1/3}$

Prediction improved by addition of:
- Cutslope cover  
  Adj. $R^2 = 0.84$

- or

- Road surface type  
  Adj. $R^2 = 0.86$

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**Road Site 17 Select Storms**

- Runoff Depth (ft)
- Turbidity (NTU)

2/12/2019, 2/15/2019, 2/18/2019
Road dimensions and Precipitation to Predict Suspended Sediment Load (SSL) or Peak Flow

Log Suspended Sediment Load (kg) =

(+) Length x Slope$^2$
(+) Road surface type (native or rocked)
(-) Cutslope area
(+) Storm Precipitation Total.

Adj $R^2 = 0.81$
Distributed hydrology-soil-vegetation model (DHSVM)

- Physically based hydrologic model that represents the effects of
  - Topography
  - Soil
  - Vegetation
- Solves the energy and water balance at each grid cell at each timestep

Calibration and Uncertainty

Monte Carlo 10,000 Simulations 2015-2018 hydrologic years

Result is a range of model outputs that provide reasonable models

DHSVM Road Modelling

- Road interception model
- Road overland flow to sink points
- Calibration based on trial and error adjustments of road length, width, infiltration rate, cutslope height.
Road Scenarios Modelling

- All models used 2015-2019 Climate

<table>
<thead>
<tr>
<th>Road Network</th>
<th>Road Scenario</th>
<th>Min. Length m (ft)</th>
<th>Max. Length m (ft)</th>
<th>Average Length m (ft)</th>
<th>Road Density m/ha (mi/ mi²)</th>
<th>Percent Road* Length within 60 m of watercourses (200 ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 CFPR Roads</td>
<td>2018</td>
<td>8 (26)</td>
<td>19 (62)</td>
<td>14 (45)</td>
<td>42.3 (6.8)</td>
<td>13% (3%*)</td>
</tr>
<tr>
<td>Pre-2010 Roads**</td>
<td>2018</td>
<td>14 (46)</td>
<td>39 (128)</td>
<td>27 (87)</td>
<td>42.3 (6.8)</td>
<td>13% (3%*)</td>
</tr>
<tr>
<td>Pre-1974 CFPR Road Rules</td>
<td>Pre-1974</td>
<td>6 (20)</td>
<td>23 (76)</td>
<td>17 (57)</td>
<td>45.7 (7.3)</td>
<td>58%</td>
</tr>
<tr>
<td>Pre-1974 Pre-2010 Roads**</td>
<td>Pre-1974</td>
<td>14 (46)</td>
<td>35 (115)</td>
<td>24 (92)</td>
<td>45.7 (7.3)</td>
<td>58%</td>
</tr>
<tr>
<td>Pre-1974 Pre-1973 CFPRs</td>
<td>Pre-1974</td>
<td>186 (610)</td>
<td>317 (1040)</td>
<td>237 (780)</td>
<td>45.7 (7.3)</td>
<td>58%</td>
</tr>
</tbody>
</table>
Drone view of Ziemer watershed post-harvest (photo credit Ryan McGrath, June 2018)
Suspended Sediment Load Predicted by Simulated Runoff

Log storm sediment load (kg) = \(2.42 + 0.0483 \times \text{low peak flows} - 1.804 \times \text{surface type}\)

Log storm sediment load (kg) = \(2.33 + 0.0342 \times \text{median peak flows} - 1.773 \times \text{surface type}\)

Log storm sediment load (kg) = \(2.25 + 0.0256 \times \text{high peak flows} - 1.724 \times \text{surface type}\)

Coefficient p values = 0.03 to <0.0001; adj. \(R^2 = 0.65\) to 0.78
## Road Suspended Sediment Load by Scenario

<table>
<thead>
<tr>
<th>Forest Vegetation and Road Network</th>
<th>Road Scenario</th>
<th>South Fork Caspar Mean Annual Road Only SSL kg/ha/yr</th>
<th>Ziemer Mean Annual Road Only SSL kg/ha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-harvest Veg. 2018 Roads</td>
<td>2018 CFPR</td>
<td>22.9 – 35.1</td>
<td>0</td>
</tr>
<tr>
<td>Post-harvest Veg. 2018 Roads</td>
<td>Pre-2010 CFPR</td>
<td>52.8 – 85.8</td>
<td>0</td>
</tr>
<tr>
<td>Post-harvest Veg. Pre-1974 Roads</td>
<td>2018 CFPR</td>
<td>346.9 – 469.4</td>
<td>20.8 – 28.2</td>
</tr>
<tr>
<td>Post-harvest Veg. Pre-1974 Roads</td>
<td>Pre-2010 CFPR</td>
<td>409.6 – 594.3</td>
<td>24.6 – 35.7</td>
</tr>
<tr>
<td>Post-harvest Veg. Pre-1974 Roads</td>
<td>Pre-1973 CFPR</td>
<td>954.8 – 2158.2</td>
<td>57.3 – 129.5</td>
</tr>
</tbody>
</table>

### Graphs

- **SFC Median SSL**
  - Lewis et al., 1998
  - 1475 kg/ha/yr

- **Ziemer Median SSL**
  - CFPR 2018
  - Pre-2010 CFPR
  - Pre-1973 CFPR
Peak Flow Changes

<table>
<thead>
<tr>
<th>Road Network</th>
<th>Scenario</th>
<th>South Fork Caspar Peak Flow Increase</th>
<th>Ziemer Peak Flow Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Roads</td>
<td>No roads</td>
<td>1.5% - 11%</td>
<td>2.6% - 17.6%</td>
</tr>
<tr>
<td>2018</td>
<td>2018 CFPR</td>
<td>2.7% - 12.6%</td>
<td>2.6% - 18.0%</td>
</tr>
<tr>
<td>2018</td>
<td>Pre-2010 CFPR</td>
<td>2.7% - 12.6%</td>
<td>2.4% - 18.1%</td>
</tr>
<tr>
<td>Pre-1974</td>
<td>2018 CFPR</td>
<td>1% - 35%</td>
<td>5% - 40%</td>
</tr>
<tr>
<td>Pre-1974</td>
<td>Pre-2010 CFPR</td>
<td>1% - 40%</td>
<td>5% - 53%</td>
</tr>
<tr>
<td>Pre-1974</td>
<td>Pre-1973 CFPR</td>
<td>15% - 46%</td>
<td>5% - 87%</td>
</tr>
</tbody>
</table>

Ziemer Harvesting 2018
Conclusions

• Suspended sediment load was best predicted by the peak flow and the maximum turbidity of road runoff events.

• The statistical model was improved by including measures of soil cover:
  • road surface type (rocked or native)
  • cutslope cover percentage

• Suspended sediment load was best predicted with only road dimensions (no runoff or turbidity) by:
  • Road length x slope²
  • Road surface type (rock or native)
  • Road cutslope height
    (indicates proximity to hillslope drainage was important)
Conclusions (Continued)

• Peak flows and suspended sediment loads were estimated to increase following forest harvest.

• The peak flow increases were larger for the Ziemer watershed. Due to higher harvest level.

• The South Fork Caspar Creek 2018 road network was very effective in reducing peak flow and suspended sediment impacts.

• A road network with a high proportion of streamside roads, even with hydrologic disconnection practices, will still contribute to cumulative watershed impacts.
Acknowledgements

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Questions ?