GRAIP/WARSEM
Detailed Implementation Plan
Parameterization Experiment

Objectives and Expected Significance

The purpose of the GRAIP/WARSEM Delivery Analysis is to determine hydraulic connectivity relationships between road drainage diversions and distance to streams as a function of the drain type for western Washington (i.e., diagram equivalent to Figure 1 for Idaho). The analysis will combine existing data from the CMER Road Sub-Basin Project (Dubé et al. 2010) with data from additional road surveys to be conducted in the ongoing Road Prescription-Scale Effectiveness Study area.

The potential for sediment delivery is highly variable across the landscape due to hydrologic, topographic, and vegetative influences. Quantifying the likelihood of sediment delivery from a road drainage feature is critical for informing meaningful choices of best management practices (BMPs). In addition, this information is important for the development of our model because the probability of delivery directly affects modeled estimates of sedimentation in streams.

Background and Motivation

The Washington Road Surface Erosion Model (WARSEM; Dubé et al., 2004) is an empirical modeling tool used to estimate the amount of sediment contributed to streams from road-related surface erosion. An early Rule Tool Project for CMER, WARSEM was developed by utilizing all relevant road surface erosion research to update parameters in the Surface Erosion Module for Conducting Watershed Analysis (Washington Forest Practices Board, 1997). Because of known limitations in the model and data available to develop it, WARSEM is most effectively used as a tool to compare areas or track changes in sediment-contributing factors rather than as a quantitative estimate of sediment loading.

What is the Road Sub-Basin Project? The Road Sub-Basin Project is a “Status and Trends” Project for CMER. The first sample, completed in 2010 (Dubé et al., 2010), surveyed 70 randomly selected, four-square-mile blocks across Washington state. The field survey involved identifying and mapping drainage structures and diversions along forest roads. For each structure or diversion, the surveyors collected numerous observations and measurements and assigned delivery categories. These efforts were consistent with the data needed to implement WARSEM, and the modeled results (i.e., estimates of sediment volumes delivered to streams) were presented in the final report. The Adaptive Management Program's intent is to conduct a second sample to validate decreasing sediment delivery as landowners implement BMPs. The results of the Road Prescription-Scale Effectiveness Monitoring Project, including this parameterization experiment, will lead to refined quantification of BMP effects on sediment delivery in WARSEM.

What is GRAIP (and how does it relate to WARSEM)? GRAIP stands for Geomorphic Road Analysis and Inventory Package (Black et al. 2012). Similar to WARSEM in its basic goals, it was developed as a US Forest Service tool for mapping the hydro-geomorphic risks of roads including sediment production, sediment delivery, landsliding, and gully formation. A large dataset of GRAIP inventory data has been collected throughout the western US that was used to construct generalized sediment delivery curves (e.g., Figure 1). These relationships have informed our understanding about road sediment delivery sensitivities and are applied in the more generalized GRAIP_Lite model (Nelson et al., 2022).

This parameterization experiment aims to evaluate the degree to which the distance of a forest road from a stream affects the probability that sediment from a road drainage structure (e.g., cross-drain culvert) or other diversion (e.g., outsloped tread) will reach the stream. Several factors in addition to absolute distance may influence the results and will be evaluated as covariates. The length of road draining to the drainage structure and total drainage area of that road segment are closely related and have been shown to strongly influence the probability of delivery (e.g., Croke and Mockler, 2001; Montgomery, 1994; Nelson et al., 2022). For example, related work shows that the drainage feature type and contributing length of road affects the probability of delivery to the channel network for a large Idaho dataset (Luce et al., 2014; Figure 1). Other factors, such as hillslope gradient, did not strongly influence the Luce et al. (2014) results; however, deeper soil horizons, particularly greater accumulation of the humus layer, is likely to cause western Washington results to differ from those observed in Idaho. In addition to contributing road length, contributing drainage area, and hillslope gradient below the drainage structure, ditch line gradient and lithology (e.g., siltstone versus volcanic as used in the Major Experiment) are factors that will be evaluated as potential covariates.

Emphasis will be placed on data collection along high-traffic roads, including near-stream roads, to understand less obvious drainage and shorter infiltration distances. The high-traffic results will be evaluated as a subset because large volumes of fine sediment produced by high-traffic road segments may travel farther than is generally observed in other circumstances. This is partially because high-traffic roads are wider and, for a given length of road, contribute more water to a cross-drain culvert. Transport distances are shorter for smaller contributing road lengths, which is relevant to the use of crowning, outsloping, or conveyor-belt structures to reduce the area of road tread contributing to stream crossings.

For this analysis, we will use a sediment delivery survey developed in a manner that facilitates comparisons with pre-existing datasets such as Luce et al. (2014) which was collected using the GRAIP methodology (Black et al., 2012). We will augment our dataset with the Washington Road Sub-Basin Scale Effectiveness Monitoring First Sampling Event (2006-2008) dataset (Dubé et al., 2010) which was collected using the WARSEM methodology (Dubé et al., 2004).

These results will help landowners identify those segments of HTNS (high-traffic, near-stream) roads that cannot be disconnected from the channel network with just the installation of drainage structures (i.e., usually cross-drain culverts in western Washington) and focus the use of tread and ditch line BMP on those road segments with the most critical need. The data will also inform future landscape-scale modeling efforts (see the Expected Results Section in the Study Design).

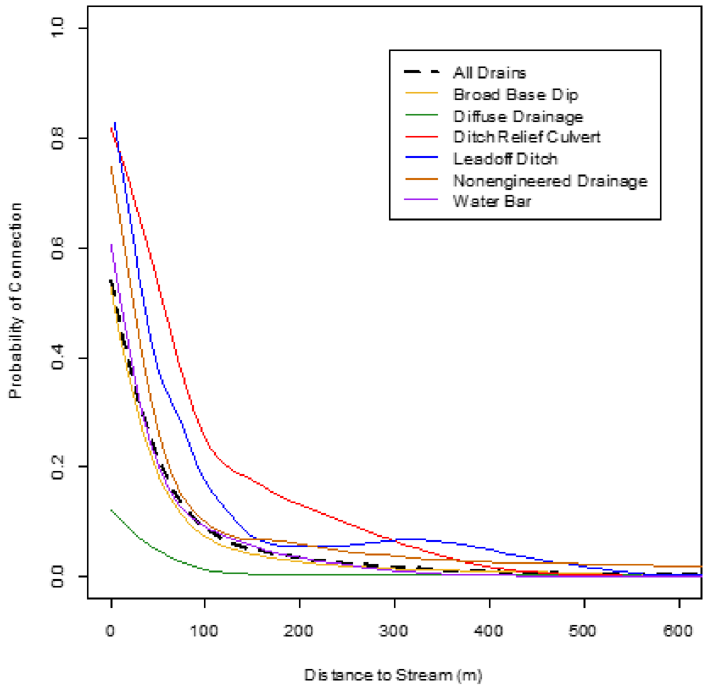

Figure 1. Probability of hydraulic connection in the middle Fork of the Payette River, Idaho. Each line depicts the probability of stream connection as a function of stream distance for each road drainage type (Luce et al. 2014).

Data Acquisition

Field data acquisition will occur during the late winter/early spring of 2025 over a six-week period. Efforts will be focused on two items: 1) Collecting new sediment delivery data in a modified GRAIP protocol along HTNS roads; and 2) Verifying WARSEM-protocol Road Sub-Basin Scale data (Dubé et al. 2010) along selected road segments and adding specific transport/delivery data to those drainage points in 5 of the sample blocks. During the summer of 2025, the field data will be supplemented by extracting information from 20 of the Road Sub-Basin sample blocks. These efforts are described in detail below.

Details of Field Effort and Protocol

New Data: Modified GRAIP Protocol

1. New sediment delivery data will be collected on HTNS roads.
2. The goal is to document the sediment delivery distance and several, potentially important, covariates associated with sediment delivery.
3. Approximately 4 weeks of data collection by a 2-person crew will occur on:
    a. The Fossil Creek Mainline adjacent to Grays River between the 2- and 5-mile;
    b. The South Fork Toutle Mainline 4100 Rd between the 4- and 10-mile markers in the Volcanic Province;
    c. The 1000 Rd, an old railroad grade adjacent to Green River, a tributary to the North Fork of the Toutle River in the Volcanic Province; and
    d. The Melbourne A-Line between the 2- and 7-mile markers in the Siltstone Province.
4. Data will be collected to describe the distance traveled by water and sediment below the drain points. The salient conditions of the hillslope and the road segment associated with each drain

point will also be described. Data will be recorded on a tablet computer with GPS and a LIDAR hillshade background for reference.

a. Drain point information
    i. GPS location or field-measured distance to a reference GPS point
    ii. Drain point type (ditch relief, stream crossing, leadoff ditch [AKA ditchout], other)
    iii. Gully presence or absence (y/n)
    iv. Topographic shape (concave, convex or planar) below the point
    v. Hillslope slope gradient below point (%), with clinometer or range finder
    vi. Stream connection (y/n)
    vii. Slope distance (feet) below the drain point outlet to the end of sediment deposit or evidence of road water (distance measured with a range finder or a string box)
b. Road segment information
    i. Length of ditch contributing to this drain point (one side, or both sides), acquired by GPSing upper point(s) or using other field measurement
    ii. Cutslope height (categories are 0’, 2.5’, 5’, 10’ and 25’), calibrated visual estimate
    iii. Presence of extended fill (y/n), and if so, depth
    iv. Road slope (%), clinometer or range finder

Existing Data: QA/QC+ of Selected Road Sub-Basin Drain Points

1. Selected Road Sub-Basin drain points will be revisited.
2. One goal is to verify the original data. We think most data will be valid but there could be some errors; and we understand that there may be real differences between 2006 and 2024 (e.g., actual gully erosion below a drain point could have extended in the intervening years, or a new cross-drain culvert may have been added).
3. Another goal is to collect GRAIP-style delivery data at points where Road Sub-Basin data collection noted circumstances of marginal delivery (e.g., Road Sub-Basin found field evidence of water and sediment movement from the drain point to a location quite close to the stream and assigned a category of delivery, whereas GRAIP wants the actual distance from the drain point to the end of evidence).
4. Approximately 2 weeks of data collection in W034, W039, W053, W030 and S003, Road Sub-Basin sites near our Major Experiment Sites.
5. Specific drain points will be selected for the following reasons: 1) Emphasis on mainline roads; 2) Checking any points with data that appear suspect; 3) Focusing on points of marginal delivery calls, particularly when the drain points are quite close to the stream; 4) Add drain points that lie between 2) and 3) on 1) to maximize our field efficiency.
6. The original information will be verified or refuted, and two specific pieces of information will be added:
    a. The actual road slope (%), by clinometer or range finder will be taken (original in categories).
    b. Slope distance (feet) below the drain point outlet to the end of sediment deposit or evidence of road water. Distance measured with a range finder or a string box.

Equipment

1. Computer Tablet
2. GPS/Booster

3. Range Finder and/or String Box
4. Clinometer

Extraction of Road Sub-Basin Data

1. Summarize pertinent data from the 20 Road Sub-Basin sites in SW Washington (proximal to the Major Experiment)
    a. Derive directly from tabular data
        i. Road gradient
        ii. Road contributing length
        iii. Drainage type
    b. Establish delivery categories, into Yes/No from %'s in WARSEM schema
    c. Use GIS Tools
        i. Watershed area
        ii. Hillslope gradient
        iii. Topographic shape (convergent/planar/divergent)
        iv. Total distance to stream

Analysis

Sediment delivery probability curves based on distance from the road to a stream will be created for each drainage type (see Figure 1 above). Other potentially significant factors will be statistically evaluated as co-variates. These factors include our field measurements, the extracted and GIS-derived information from Road Sub-Basin, and basic GIS layers such as geology and precipitation.

References

Black, T. A., R. M. Cissel and C. Luce, 2012. The Geomorphic Roads Analysis and Inventory Package (GRAIP) Volume 1: data collection method. RMRS-GTR-280 Rep., 115 pp, USDA Forest Service, Rocky Mountain Research Station, Boise, ID.

Croke, J. and S. Mockler, 2001. Gully initiation and road-to-stream linkage in a forested catchment, southeastern Australia. Earth Surface Processes and Landforms, 26(2), 205–217. https://doi.org/10.1002/1096-9837(200102)26:2<205::AID-ESP168>3.0.CO;2-G

Dubé, K., W. Megahan and M. McCalmon, 2004. Washington Road Surface Erosion Model, Manual and Appendices. For: Cooperative Monitoring, Evaluation and Research (CMER) Committee, Adaptive Management Program of the Forests & Fish Habitat Conservation Plan, Washington State. 56 p. Appendices A-E.

Dubé, K., A. Shelly, J. Black and K. Kuzis. 2010. Washington road sub-basin scale effectiveness monitoring first sampling event (2006-2008) report. Cooperative Monitoring, Evaluation and Research Report CMER 08-801. Washington Department of Natural Resources. Olympia, Washington.

Luce, C. H., T. A. Black, R. Cissel and N. Nelson, 2014. Assessing Controls on Sediment Delivery from Forest Roads, Presentation at International Union of Forestry Research Organizations (IUFRO) World Congress, Oct. 5-11 2014, Salt Lake City, UT.

MacDonald, L.H. and D.B. Coe, 2008, November. Road sediment production and delivery: processes and management. In Proceedings of the first world landslide forum, international programme on landslides and international strategy for disaster reduction (pp. 381-384). Tokyo, Japan: United Nations University.

Montgomery, D. R., 1994. Road surface drainage, channel initiation, and slope instability. Water Resources Research, 30(6), 1925–1932.

Nelson, N., Luce, C. H. and T. Black, 2022. GRAIP_Lite: A System for Road Impact Assessment. 145 pp, USDA Forest Service, Rocky Mountain Research Station, Boise, ID.

Washington Forest Practices Board, 1997. Standard methodology for conducting watershed analysis under Chapter 222-22 WAC. Version 5.0. Department of Natural Resources Forest Practices Division, Olympia, WA.