DOCUMENT 2

Review of Dubé et al. 2010 to Inform IRST literature review on roads package

For 21 August 2024 IRST meeting

IRST member review

Task

<u>ROADS PACKAGE</u>: New deadline -- 12 August 5:00pm

- Please **read**:
    - 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. https://www.dnr.wa.gov/publications/fp_cmer_08_801.pdf
- In the body of an email, **identify knowledge gaps you believe exist from the Dubé et al. (2010) article**. This information will help INR search for studies during the 2010-2024 timeframe.
- **Provide us with key words/search terms** INR should consider as part of its initial literature search, particularly as it relates to identified knowledge gaps.
- **Attach any relevant articles, studies, or information, and if possible, place citations or URL links, in the body of your email**.

Responses

IRST member 1

There is a tremendous amount of information in this report, and while I didn't find any "gaps" in the approach, analysis, or presentation of results, I did see some things that we will need to work on before launching our own project.

Hydrologic connectivity AND sediment?

The CMER project was designed to quantify both the degree of hydrologic connectivity *and* the amount of sediment delivered to water bodies in the sampled areas. I know that the AMPC indicated they would be satisfied with a report like Dube et al 2010, and I believe they said sediment delivery was acceptable to measure but secondary to their interest, but adding sediment delivery complicates the monitoring effort considerably. We will need to review the WARSEM model and potential equivalents, and the data collection and analysts will be more costly. So, are we going to do sediment too?

Sample size

The Dube study design ultimately settled on a sampling unit of 4 sq mi, and 60 units spread among 3 geographic areas. Apportionment per area was based on % of private forestland in each area.

Total sample reflected 1.7% of private forestland. We should try to learn how much this cost. Another approach would be to aim for a certain percent coverage in each of Oregons 2 regions - east and west - then figure out how many samples / what cost that would entail.

Metrics and Performance Measures
CMER had pre-ordained the use of two metrics and associated performance measures (Table 1). RLEN for hydrologic connectivity and RSED for sediment. These seem fine to me. But we need to decide if the performance metrics for these 2 parameters are what we want to use in Oregon. Might require AMPC input. Also, newly constructed roads had their own metric (subjective - "virtually none").

Separate project for Small Private Forest landowners?
The Dube et al. study relied on voluntary participation of landowners, including access permission. Those that did participate had to estimate the degree of road use in the year preceding field measurements, and the degree to which sampled roads on their ownership met current standards. Lack of participation weakened conclusions on small private roads. Do we want to tackle large and small industrial landowners separately. If so, how?

Field measurement bias among surveyors
This was a significant issue, and the authors offered several ways to address. Importantly, they suggest some time be spent on how re- measurements of same sample units years apart for trend assessment will be done. There are cost and other implications from this issue we will need to consider.

Remeasurement interval
The Dube study was designed to have the sample units remeasured at 5-yr intervals to establish trends. Is this an appropriate interval? Also, the degree that roads were deemed up to standard was relatively high in the sampled units at time of first sampling. If all roads meet the "fully in compliance" with new standards by the second visit, do they need further sampling?

IRST member 2

Identify knowledge gaps you believe exist from the Dubé et al. (2010) article. This information will help INR search for studies during 2010-2024.

- *Sampling of new roads was limited in Dubé***.** *This may be a knowledge gap.*
- *Are the road types and rock sources and rock "quality" in Dubé applicable for estimating sediment yields in Oregon?*
- *As discussed previously, there was limited sampling of small landowners. This is a gap*.

Provide us with key words/search terms

- *Sediment delivery; forest roads; hydrologic connectivity; road surface erosion; road network; runoff*

Attach any relevant articles, studies, or information, and if possible, place citations or URL links, in the body of your email.

- *There have been numerous studies of forest roads in the western U.S. since 2010 that should be included in a literature review.*

- *Examining work by B. Sugden, K. Bladon, M. Reiter are a few authors that should be examined in a literature search.*
- *A few examples of peer-review publications to include are:*
    - Review paper in the Journal Forests: https://www.mdpi.com/1999-4907/11/11/1201/pdf
    - Reiter et al. about the Deschutes Watershed: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.2009.00323.x
    - Arismendi et al about the Trask River Watershed Study https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016WR020198
    - Rachels et al: https://www.sciencedirect.com/science/article/abs/pii/S0378112720301572

IRST member 3

The Dubé et al. (2010) paper provides a foundation to inventory forest roads in Washington state to determine their potential to contribute to sediment production and delivery to streams. This report describes methods for monitoring that tracks road attributes over time, with the goal of quantifying reduced road drainage connectivity to streams. To this end, Dubé et al. (2010) identifies the types of roads/hydrology configurations that will be identified, and the potential for each type to contribute sediments to waterways. A variety of data metrics were to be collected at each of the sampled road segments in order to determine potential sediment load and content. The paper includes a discussion of sample size selection and potential analysis that focuses on simple linear regression that links road system characteristics with road standards.

The population of interest in the Dubé et al. (2010) report are all forest practices rules-regulated (FFR) timberlands within the state. Based on GIS analysis, the authors clearly identify the area in different timber region of interest (Coastal Spruce, East of Crest, West of Crest). They also describe the random selection process for sample identification.

Six areas of further exploration beyond the Dubé et al. (2010) paper are related to: 1) definition of hydrologic connectivity, 2) scope of the project, 3) sample selection process; 4) metrics inventoried, 5) analysis, and; 6) models.

Hydrologic Connectivity: A clear definition of hydrologic connectivity was not presented in the Dubé et al. 2010 paper. Nor is a clear definition of this term present in the Oregon Forest Accord document. Rather, references are made to other documents. More information about how hydrologic connectivity is defined would help IRST frame the type of research that needs to be designed and completed.

Scope: The fundamental goal of the Dubé et al. 2010 paper was an inventory of hydrologic connectivity of all FFR roads in Washington. The hydrologic connectivity that is being inventoried here appears to be founded on proximity to stream channels as well as road characteristics. However, it may be that road features such as slope confer connection differently during low compared to high precipitation events. Climate is changing, and an anticipated (and already experienced) change is the intensity of winter storm events is under way. Expanding the scope of the inventory to understand hydrologic connectivity during different types of storm events would help in tracking road/hydrology connection in Oregon over time. As the frequency and intensity of peak events change in the future, so too may the vulnerability of roads. Additional research that could inform the IRST in considerations of seasonal storm event intensity and how that changes aspects of hydrologic connectivity for roads would be useful.

Sample selection: the sample unit identification process is based on the random selection of land ownership section blocks. Within each selected section block, roads are defined and surveyed. While this provides a terrestrial perspective of the available roads, it is not necessarily linked to rivers. For example, it is possible that only roads in headwater areas could be selected in one block, or only roads along a river mainstem in another. Rivers are not randomly distributed across landscapes, and roads tend to follow rivers. Additional survey designs of roads that link roads specifically to rivers and river characteristics (e.g., stream order, available stream kilometers, drainage area, etc) would be informative.

Metrics inventoried: the metrics described in the Dubé et al. (2010) paper are road specific, but are quite general. Other road/hydrologic connectivity survey methods would be useful to review to ensure that the correct data is being collected. This may be particularly relevant if connectivity with different storm events is considered.

Analysis: the analysis that is described is simplistic in nature. This allows for simple trend detection which is the goal of the Dubé paper. If differences in precipitation regimes or storm events is considered, additional analysis, and likely modeling, will be necessary. Additional examples of road/hydrology connection under different precipitation events would be useful.

Sediment models: A model to predict sediment production is prudent at the scale of a state-level inventory, as was demonstrated by Dubé et al. (2010). The sediment delivery model WARSEM was used in the Dubé et al. (2010) paper because the products from this model are closely related to the Road Surface Erosion Module calculations in the Washington Watershed Analysis Manual that was used to develop FFR performance targets for sediment delivery. To determine if WARSEM is useful in Oregon, it would be useful to know if forest roads in Oregon have sediment delivery performance targets, and upon what model those targets were based.

Possible Key Words for a literature search:
Forest roads, hydrologic connectivity, storm events, road/stream sampling, road/sediment models

IRST member 4

When developing the RFP and evaluating proposals for monitoring hydrologic connectivity, the following highlights considerations such as key differences between the AMPC objectives and those of Dube, elements in Dube that are useful in meeting the AMPC objectives, and gaps that would need to be filled.

Objectives:

1. Dube objectives were to determine if the road characteristics that affect runoff and sediment delivery to streams are improving through time as RMAP are implemented between 2001 and 2016; and to determine the extent to which roads on lands subject to WDNR forest practice rules meet the FFR performance targets. These objectives appear to differ in substance from the final AMPC questions posed to the IRST for hydrologic connectivity:

1.What is the status of hydrologic connectivity of roads? The AMPC secondary questions address (a&b) small/large private ownership class and eastern/western Oregon; and (c) what other factors affect hydrologic connectivity

2. What is the trend of hydrologic connectivity of roads

3. Determine Rule Effectiveness.

a. In the long term, to what extent are road rules associated with hydrologic disconnection effective at achieving biological goals and objectives?

Objective 1.1– Forest practices near streams minimize sediment delivery (Based on the full reading of the HCP BGOs - do we want to address this in relation to roads as a "forest practice"? If so, then we need to list the road rules related to achieving this objective to enable design of a sampling strategy around this and determine how these might compare to Table 3. "Data Collected on Delivering Road Segments" from Dube.)

Objective 1.3 – Road runoff directly to streams is minimized (We need to decide if this is the only BGO that we're considering and list the road rules around this to enable design of a sampling strategy).

2. Unless we include the HCP BGO 1.1, the direct relevance to our task of the sediment modeling conducted by Dube isn't clear.

Performance Metrics/Targets:

1. Dube et al. evaluated the performance metrics of miles of delivering road/miles of stream and tons of delivered sediment/year/miles of stream. The AMPC has not provided us with performance metrics or targets. Do we want to use the metrics/targets in Dube? Do we need to develop a different set of metrics? If so, should these be developed before moving forward with a RFP (or whatever our next step will be)?

2. Dube et al. identified issues with obtaining accurate estimates of stream miles, which is a critical component in calculating results for their metrics. Given the high-resolution stream layer available for private forest lands in Oregon, is this likely to present a similar problem?

Sampling Frame:

1. Dube inventoried numerous characteristics of forest roads in a total of 60 random four-square-mile sample units across the state between 2006 and 2008, five to seven years after the forest practice rules were adopted.

2. Given the differences in objectives and ownership patterns between the two studies, is a block sampling design appropriate to address the AMPC questions? The checkerboard federal/private ownership, particularly in southwestern Oregon, would limit the areas that could provide four-square mile sample units dominated by private lands. Also as cited in Dube "Although many small forest landowners were willing to cooperate, any one uncooperative landowner resulted in rejection of the entire quarter section for that unit. The end result is that, despite the relatively high number of participating small forest landowners, small forest parcels make up less than five percent of the sampled area." Could reducing the block size or using a point sampling frame that better targets the connection between roads and streams be a reasonable alternative?

3. If a point sampling approach is more desirable, then what metric would be used? One possibility is to determine what percentage of drainage/crossing features that could be hydrologically connected actually are connected. Could the criteria from Dube et al. 2004 (Appendix A, p3) help identify the denominator? "The model assumes that road segments that drain to the forest floor over 200 feet away from a stream or water body do not deliver sediment. This is based on studies of travel distances of sediment downslope of culvert outfalls by Trimble and Sartz (1957), Haupt (1959), Haupt and Kidd (1965), Swift (1985), Megahan and Ketcheson (1996), and Brake et al. (1997)."

4. Within the next three to four years, large landowners through FRIA will submit to ODF a complete map of roads that could be overlaid on the FERNS high-resolution stream network to provide a point sampling frame. Using these maps may have implications for the start of any monitoring.

5. Consistent with Dube's recommendations, the sampling would likely need to be stratified by large and small landowners.

Data collection:

1. Dube et al. relied on field methods for collecting data. Is this necessary? Would this require field data collection during runoff events? Or, could the following assumptions from Dube be helpful if a modeling approach is used: "Table A-9 was further simplified to provide the Road Delivery Factors used in the model (Table A-10). The model provides for 3 delivery categories: delivery directly to the stream (100% of eroded sediment is delivered); drainage structure is located within 100 feet of a stream (35% of sediment is delivered); or drainage structure is between 100 and 200 feet from a stream (10% of sediment is delivered). Roads farther than 200 feet from a stream are assumed not to deliver sediment to streams unless a gully exists between the road and the stream channel that allows for transport of sediment from the road to the stream." See also p 41 in Dube et al "Road drainage connectivity was assessed by assigning each road segment into one of six delivery categories: No delivery (no data was collected on these segments); Drains directly into stream channel/typed wetland; Drains directly into stream channel/typed wetland via a gully; 35% delivery to a stream/typed wetland; 10% delivery to a stream/typed wetland; No evidence of delivery, but road parallels within 20 feet of a stream/wetland"

2. If a field sampling approach is selected, then definitely need to include a component for assessing observer variability.

3. Might we consider a remote sensing approach to identify roads with LiDAR imagery given that this is available for much of the state or will be shortly?

4. Dube "The study is designed to resample the same units in each sampling event and to use paired t-test analyses to assess change (Raines et al. 2005)." Samples would be auto-correlated and the approach could lead to bias. Need to discuss.

5. Dube sampled "non-drivable roads". How will we deal with these? Including these will add substantially to the sample cost and may not be necessary given the State-led abandoned roads inventory that will be conducted.

6. Reporting on traffic levels is not required in Oregon, but most sediment comes from wet weather hauling (e.g., van Meerveld et al. 2014). Do we want to consider traffic levels, and if so, how?

7. Do we focus only on the pre-PFA existing road network or include roads constructed under the newly adopted road standards? If the latter, then do we stratify by age of the road to ensure an adequate sample size for newly constructed roads.

Modeling:

1. If modeling hydrologic connectivity only from digital data, what index or metric should be used?

2. Should we rely on WARSEM or another model if modeling sediment delivery?

Possible Keywords:

Hydrologic connectivity; Index of Hydrologic Connectivity; modeling/measuring hydrologic connectivity; road-stream connections

A few fairly recent citations:

Alvis, A. D., Luce, C. H., & Istanbulluoglu, E. (2022). How does traffic affect erosion of unpaved forest roads?. Environmental Reviews, 31(1), 182-194.

Al-Chokhachy et al. 2016. Linkages between unpaved forest roads and streambed sediment: why context matters in directing road restoration. Restoration Ecology.

van Meerveld, H. J., E. J. Baird, and W. C. Floyd (2014), Controls on sediment production from an unpaved resource road in a Pacific maritime watershed, Water Resour. Res., 50, 4803–4820, doi:10.1002/2013WR014605.

Yu, Z., Zhao, Q., Liu, Y., Yu, J., Wang, A., & Ding, S. (2024). Soil erosion associated with roads—A global review and statistical analysis. Land Degradation & Development, 35(11), 3509-3522.

Yu, Z., Zhao, Q., Liu, Y., Yu, J., Wang, A., & Ding, S. (2024). Soil erosion associated with roads—A global review and statistical analysis. Land Degradation & Development, 35(11), 3509-3522.

Hernani, H., & Fedra, L. (2019). Application of LiDAR DEM Metrics to Estimate Road-stream Sediment Connectivity in Alberta Eastslopes Salmonid Habitats.

Benda, L., James, C., Miller, D., & Andras, K. (2019). Road erosion and delivery index (READI): A model for evaluating unpaved road erosion and stream sediment delivery. JAWRA Journal of the American Water Resources Association, 55(2), 459-484.

Dangle, C. L., Bolding, M. C., Aust, W. M., Barrett, S. M., & Schilling, E. B. (2019). Best management practices influence modeled erosion rates at forest haul road stream crossings in Virginia. JAWRA Journal of the American Water Resources Association, 55(5), 1169-1182.

White, R. A. (2010). Accuracy of forest road and stream channel characteristics derived from LiDAR in forested mountain conditions. California Polytechnic State University.

Sosa-Pérez, G., & MacDonald, L. H. (2017). Reductions in road sediment production and road-stream connectivity from two decommissioning treatments. Forest Ecology and Management, 398, 116-129.

Surfleet, C. G., & Marks, S. J. (2021). Hydrologic and suspended sediment effects of forest roads using field and DHSVM modelling studies. Forest Ecology and Management, 499, 119632.

Kastridis, A. (2020). Impact of forest roads on hydrological processes. Forests, 11(11), 1201.