Hydrologic and Sedimentation Effects of Open and Closed Roads

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Debates are raging in recent years over the benefits of road closure. Road closure is an increasingly common practice to achieve a variety of management goals including improvement of aquatic and terrestrial ecosystems, and reduction of casual human effects on forest environments. As with road construction, however, there are some major hydrologic considerations that must be considered.

The construction and use of a road severely disturbs the soil, increasing runoff rates, reducing subsurface water flows, and altering shallow groundwater equilibrium. Unfortunately, information needed to understand road prism effects on surface and subsurface hydrology is limited.

In a recent study in the Western Cascades in Oregon, Wemple (1994) found that roads can have a significant effect on the surface hydrologic response of small watersheds. Nearly 60% of the road network in Wemple's study drains to streams and gullies, and is therefore hydrologically integrated with the stream network. Field observations suggest that roadside ditches and gullies function as effective surface flow paths, which substantially increase drainage density during storm events. Times to peak are faster, and peak runoff rates are greater in the water shed with the greater road density. Results of this study suggest that addressing and mitigating the integration of roads with streams may be an effective first step toward watershed restoration.

The differences in infiltration rates has led to the practices of road ripping and subsoiling to break up impermeable layers. Observations of road ripping suggest that it reduces runoff and erosion, but the reason may be more due to increased roughness than to increased hydraulic conductivity. If that is the case, ripping could be more detrimental to steep road sections than retaining the current surface, because the probability of mass failure or channelization leading to gullying are increased. In one study, we found that ripping had little effect beyond increasing surface roughness on two different soils. The high-silt soil tended to form a surface seal during the first rainfall following ripping, and the disturbed gramtic soil collapsed during the first rainfall after ripping, both leading to runoff rates similar to those before ripping.

Road prisms, active or abandoned, can be an ongoing source of sediment if the runoff is concentrated in ditches or channels. In areas of concentrated flow, the potential to create gullies is great. If no maintenance can be done on culverts, road closure design must address self-maintaining designs of alternative structures. This requires determining an appropriate channel shaping for culvert removals and water bars to minimize erosion of the banks and surfaces, as well as appropriate outsloping or ditch relief cross drainage to minimize the effect of disused roads on the hydrologic system. Any activity that can distribute the runoff from roads onto a broader area will generally decrease sedimentation problems.

In most steep forests, there is a major amount of the runoff from the forest that moves down slope through the soil. Roads may intersect or block such flow paths through excavation and compaction. Spring lines at the base of road cut embankments are symptomatic of such flow disruption. This sub-surface flow is then available to cause instability, or increased erosion when a storm or snowmelt occurs, because the soils in the vicinity of the seep area will be saturated, weak, easily detached, and will have low to no infiltration, leading to greater local runoff and erosion.

If a road is totally recontoured, the subsoil compaction during construction and removal, may still be present This will lead to localized seeps that may be the source of a landslide, or lead to gully formation. The photograph shows are contoured road across an earth flow that has adequately addressed any surface run of or erosion, but may lead to groundwater-driven problems in the future.

Recontoured road which will successfully eliminate surface hydrologic and erosion problems, but which may lead to slope failure or gullying because of a major seepage line along the base of the former cutslope some 3 m. below the surface.

One of the most frequent reasons presented for road closure is that sedimentation will be decreased from the watershed. Construction-generated sediment and traffic-induced sediment can be quite high. Traffic has been attributed as the major cause of sediment from a road, once the road has been built. In the absence of traffic, however, high sedimentation rates decrease dramatically. On an annual scale, it has been found that one year following road construction and logging, sediment yields had decreased from over 200 tons/km^2/yr to 8 tons/km^2/yr in Idaho Batholith granitic parent material. Individuals contemplating road abandonment should consider if the reduced sediment yields without traffic are sufficiently low to protect forest resources before embarking on expensive earthworks. Comparison needs to be made between the increase in sedimentation from the road abandonment activities and the existing sedimentation rates. We are currently collecting sedimentation data from low-use roads in the Oregon Coast range.

Once sediment leaves a road, it may or may not end up in a water course. Numerous guidelines have been developed for different forests recommending minimum buffer areas between roads and streams. The safe distance varies from a few feet to a few hundred feet depending on the climate, the topography, and the length of road contributing to the runoff. The WEPP model has shown itself to be particularly useful in predicting site-specific safe distances between roads and streams, and we are embarking on such a study. Distances from streams are also important to consider during any major road closure activity. Major disturbance from recontouring can result in severe sedimentation if the road is adjacent to a live stream, but will have minimal effect if there is an adequate buffer strip. If there is an adequate distance between a disused road and a live stream, however, it may not be necessary to carry out any major activities beyond culvert removal and outsloping.

Culverts will have a finite life, and any culverts that are abandoned will eventually fail. Some may fail because of deterioration and collapse, and others will have inlets blocked by coarse woody debris or sediment. Culvert blockage increases risks of

catastrophic failures from gullying or road fill collapse. Generally, if roads are no longer needed, physically removing a culvert, or hydrologically removing flow to the culvert by diverting concentrated surface flows along cutslopes with waterbars is practiced.

If a watershed has a history of disturbance, and of past sedimentation, the closing or removing of roads may have minimal effect on sediment leaving the watershed for many years. Frequently, sediment eroded from disturbed upland areas, like roads, may be deposited in the lower gradient streams draining the watershed. A reduction in upland erosion may simply mean that the stream draining the watershed is now able to transport some of the excess sediment that has been deposited in the channel in past years. If downstream sediment is a concern, then analysis of the main streams draining the watershed is recommended.

In summary, the construction of the current Forest Service road network required significant engineering input. A similar level of engineering consideration must be given to its removal.

Reference

Wemple, B.C. 1994. Hydrologic integration of forest roads with stream networks in two basins, Western Cascades, Oregon. MS Thesis, Oregon State University, Eugene.

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