Roads in the River: Encroachment, Implications, and Solutions

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In recent years, forest road management issues have focused more frequently on roads within riparian areas. This includes every aspect of managing existing roads, from prioritizing aquatic habitat restoration, to understanding risks and watershed health, to road location, storm damage repair, and road maintenance. Current direction and changes in priority (i.e., Northwest Forest Plan, Aquatic Conservation Strategy), suggest a change in the way that encroachment problems are approached. Watershed analysis and management under the Aquatic Conservation Strategy (ACS) imply an understanding of processes, cause and effect, and managing (reducing or eliminating) hazards in priority areas such as Key Watersheds, riparian areas, and areas adjacent to important aquatic species habitat. Traditional standards of practice, such as bank hardening and revetment construction, can be very effective for protecting infrastructure, but are increasingly viewed as being incompatible with aquatic resource objectives. These techniques are now closely scrutinized, and approaching such problems in the traditional mode invites controversy. Designs and solutions should reflect this change of attitude. Questions now being asked at the planning and design phase include: What do we know about natural conditions, active processes, and the range of natural variability? Can the design at a site emulate local processes or a designated reference condition? Looking at analysis at several scales often provides insights. Examples from the Olympic National Forest, Washington, illustrate these considerations and some of the links between site conditions, physical processes, and the resulting design solutions.

Keywords: *road management, channel geomorphology, aquatic habitat, stream channel, bank hardening*

Introduction

Lands administered by the USDA Forest Service contain considerable areas of steep, mountainous terrain that present a challenge for road managers and designers. Within the steepest and most dissected terrain, the flattest and most stable locations are often along lower valley slopes and in valley bottoms adjacent to streams. Further complicating the situation, the valleys in mountainous regions are often narrow, making road and stream interactions more likely. From a road management perspective, these same valley bottom areas are usually the preferred locations for the most important or highest standard roads. While these areas are preferred for road location, they create conditions where roads are most closely connected to the stream network.

In the past decade, land managers for the Forest Service and other resource agencies have become increasingly concerned with these road-stream interactions in both the long-term and short-term management of the transportation network. Both the Aquatic Conservation Strategy in the Northwest Forest Plan (USDA and USDI 1994), and the National Road Management Policy (USDA FS 1999; Federal Register 2001) address these issues and provide guidelines and direction for management. Such policies suggest that a better understanding of physical conditions and geomorphic processes will result in better management and better decision making. This concept applies to land management at the watershed or larger scale as well as design and implementation decisions at the site or project scale.

Roads in the River Margin

This presentation focuses on problems associated with roads located in and along channel margins. Road washouts and other problems range from simple encroachment to more complex encroachment in an active or changing landscape (Figures 1 and 2). Complex encroachment problems often require a more comprehensive assessment and more complicated or creative design solutions. Site assessments confined to the immediate washout area are often inadequate for determining the best solutions. They may fail to address causal mechanisms, processes that operate at a larger scale, trends, or off-site and long-term impacts. Problems in the most complex or sensitive environments are more likely to encourage solutions that rely on avoidance of the problem.

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Figure 1. An example of simple encroachment: Site assessment may be limited to the area at and immediately adjacent to the site. Designs solutions may be limited to the immediate washout area.

Figure 2. Encroachment within an active landscape: North Fork of Calawah River, Forest Road 2923. Assessment included evolving or active slope processes at washout.

Figure 3: The Dosewallips washout. The photos are taken from the 2610 road at the downstream end of the washout, looking upstream. In the left hand photo (a) , the line of coarse rocks near mid-channel indicates the approximate location of the former toe of the road fill. The bank on the right (b) is 20 to 30 m high. The washout is approximately 100 meters long. Photo (a), D. Cenderelli; photo (b), T.E. Davis.

Three examples from the Olympic National Forest are offered to illustrate several of these points. The discussion closes with some thoughts on revetment designs and project development for solutions that are more consistent with natural resource objectives.

CASE EXAMPLE 1: THE DOSEWALLIPS RIVER WASHOUT

In January 2002, a 100-m section of Forest Road 2610 was washed out by the Dosewallips River (Figure 3). The Dosewallips is a key watershed, a high priority for restoration, protection, and recovery of aquatic species. The watershed has high-value fisheries including a threatened stock of Chinook salmon (*Oncorhynchus tschawytscha*). The watershed upstream of the washout has had minimal timber harvest and has a low road density. The headwaters are within Olympic National Park. The primary road use is recreation traffic; both the national park and the national forest maintain campgrounds beyond the washout, and the national park has trailheads accessing a system of trails into the backcountry.

The Environmental Assessment (EA) following the washout considered a range of alternatives. Initially, the preferred alternative was to re-establish the road in its former location. The design was developed concurrently with the EA and the assessment of potential impacts. Early in the process, several assumptions were made that suggested this was a reasonable course of action. These assumptions included the following: (1) the road had been in this location for 80 years or more; (2) salmon habitat within the main channel adjacent to the washout is rather marginal (coarse, steep, and uniform); and (3) overall salmonid habitat in the upper watershed is of high quality and is functioning naturally.

Because of the high ecological values in the watershed, and questions raised during public review of the draft EA, it became evident that a more detailed analysis was needed. An intermediate level (reach) assessment was conducted in order to better describe the potential long-term and off-site impacts to fish habitat and listed fish stocks (Cenderelli et al. 2003). The reach assessment consisted of a more comprehensive evaluation than the EA, focusing on the following factors:

- Temporal assessment, evaluating change over time using historic air photos dating from 1939
- Geomorphic characterization of the river channel extending upstream and downstream of the washout.
- Hydrologic characterization including flood history and response.
- Characterization of the channel bed sediments
- Characterization of sediment sources, terraces and sources of spawning gravels
- Assessment and characterization of aquatic habitat.

Geomorphic Setting

The unique nature of the washout area was not fully appreciated prior to the reach assessment. The washout is located in an area where the river is incised into a series of glacial outwash and fluvial terraces; four distinct terrace sets were identified and mapped. This section of river was designated the Terrace Transition section. Figure 4 shows the Terrace Transition and adjacent geomorphic types. Table 1 displays some of the characteristics.

The Terrace Transition section and the link to the high quality habitat in the Alluvial Unconfined response reach downstream are important associations in this part of the watershed. A similar association was not found in the upper watershed. Although it is limited to slightly more than one meander wavelength, only about 850 m long, the Terrace Transition section supplies a substantial amount of high quality spawning-sized gravels to areas immediately downstream. The long-term trend has been toward increasing erosion from the bend at the washout, and decreasing erosion at the other high bank in the upper meander bend. Revetment construction would eliminate the source of spawning gravels in the lower bend.

Additional findings from the reach assessment included:

1. Temporal and spatial variability is more significant than initially assumed.
2. The long-term trend in river planform is toward expansion at the downstream meander bend and increasing bank erosion at the washout.
3. The recommended mitigation should emulate the natural processes and links that would be diminished by revetment construction. Encouraging meander development and associated bank erosion with log (large woody debris, LWD) complexes is an appropriate mitigation, although it will not compensate for eliminating the high bank as a source of spawning gravel.

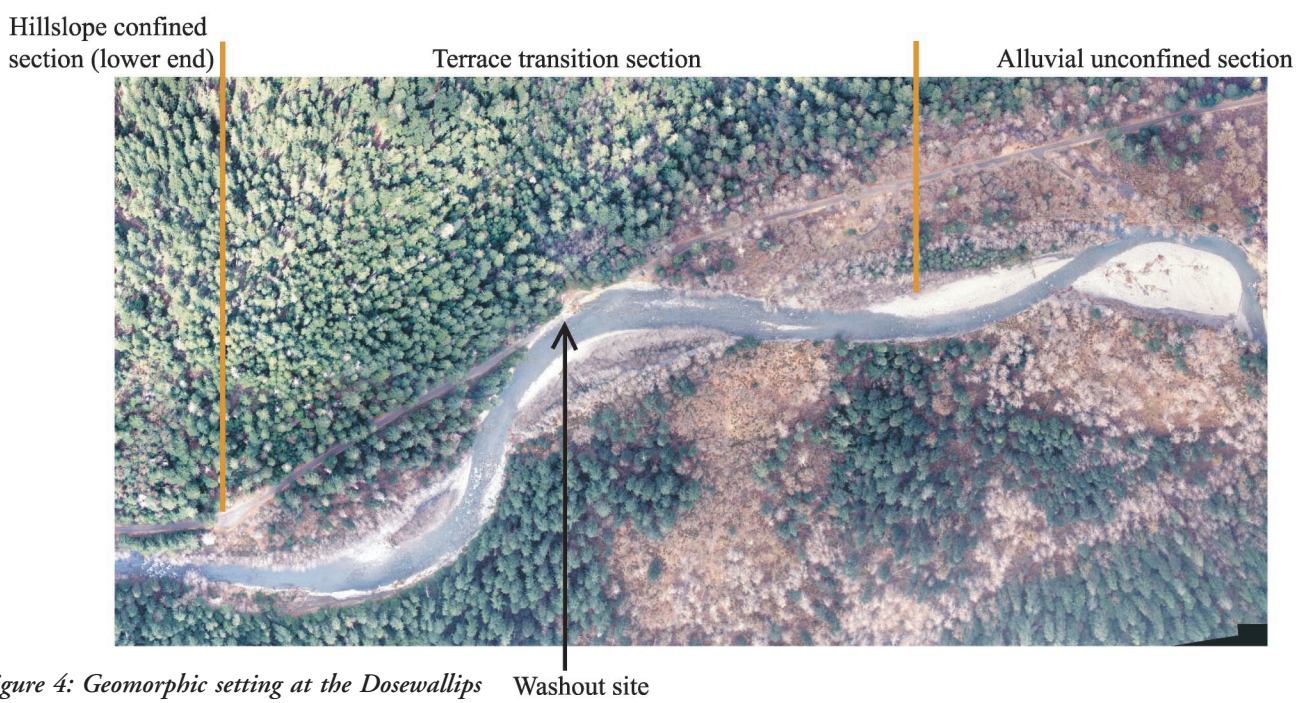

Figure 4: Geomorphic setting at the Dosewallips washout site. Upstream is to the left of the photo.

Table 1: Dosewallips River, characteristics of designated channel geomorphic units.

	Hillslope Confined	Terrace Transition	Alluvial Unconfined
Gradient	2% to 4%	< 1% to 2%	< 1%
Confinement	Confined	Moderate confinement	Unconfined
Bed material	Boulders and bedrock	Cobble and gravel	Gravel
SPF*	Transport	Transport (supply)	Response
Comments	Hard, dominated by non-deformable bed and banks	High sediment supply from adjacent banks; hillslope interaction high	Frequent split channels and abundant wood (log jams); Habitat value is high
Rosgen Class	B1 and B2	F3 to F4	C4

**SPF: Sediment processing function (Montgomery and Buffington 1993)*

Summary of the Dosewallips Example

- Initial assumptions were based on a limited scope, site level assessment.
- An intermediate level or reach assessment was needed to accurately describe potential impacts on fish and fish habitat.
- The relationship between upstream (sediment poor), the washout area (high sediment and spawning gravel supply), and the downstream response reach is more important than conditions at the washout site. The aquatic habitat immediately adjacent to the washout is considered rather marginal.
- Because the original preferred alternative would create substantial adverse impacts at the reach scale, to a resource that is very limited in the watershed (Chinook salmon spawning habitat), it is not consistent with Aquatic Conservation Strategy objectives.

CASE EXAMPLE 2: THE UPPER DUNGENESS RIVER, FOREST ROAD 2860

The 2860 Road is an example of simple encroachment, as compared to the setting of the Dosewallips washout. The valley bottom is narrow, but is the only suitable location for a road through this area. The road has been in this location for over 40 years. The channel is steep, coarse and predicted to be rather insensitive to change. The washout site is shown in Figure 5.

Similar to the Dosewallips, the Dungeness is a high value watershed with regard to fisheries, water quality, and watershed restoration. This section of the river supports populations of four species of Pacific salmon. Bull trout (*Salvelinus confluentus*) also occur, and along with the local Chinook salmon population are federally listed as threatened species. It is a popular recreation area, so reducing access is controversial. Significant channel attributes at the washout site are shown in Table 2.

Figure 5: The Upper Dungeness River at the 2860 Road washout. Boulders in mid-channel and the constriction formed by the road encourage accumulation of logs and diversion of flow along the toe of the fill. This has been a chronic problem area.

Table 2: Upper Dungeness channel geomorphic unit characteristics.

Type	Hillslope Confined
Gradient	2% to 4%
Confinement	confined
Bed material	boulders and bedrock
SPF*	transport
Comments	hard, dominated by non-deformable bed and banks
Rosgen Class	B1 and B2

**SPF: Sediment processing function (Montgomery and Buffington 1993)*

High quality Chinook spawning habitat is concentrated 1200 m downstream of the washout, in the area around East Crossing Campground. The channel in this area is a lower gradient unconfined alluvial channel type, classified as Rosgen channel class C3 (Rosgen 1994). It is the first response reach (Montgomery and Buffington 1993) downstream of the washout.

In previous years this road segment was treated with a traditional approach, meaning that washouts and erosion were repaired by armoring the bank. The coarse, steep nature of the hillslope-confined channel adjacent to the site suggested limited need for concern about impacts on aquatic habitat; the need for access dominated the decision-making processes. Site assessment limited to the washout area did not provide information that was compelling enough to change the management of the road. Ultimately, however, it was larger scale considerations and concern for watershed values that governed the decision process. The final decision was to decommission the road and campground and provide alternate access to trails and recreation opportunities in the upper watershed.

The proximity to high-value aquatic habitat, watershed-scale values, and the character of the stream channel through the stream-adjacent road segment directly influenced the design of the decommissioning. An intensive level of road decommissioning was done where the road was most directly connected to the river (Figure 6). In locations where the connection to the river was not as strong, or the impact was interpreted as low, the intensity of decommissioning was reduced.

Summary of the Dungeness River Example

- The final decision (decommissioning) was based on factors well beyond the site scale, including watershed values and linkages to downstream habitat conditions.
- Interdisciplinary and interagency involvement throughout the project was a key to success, as was extensive contract oversight.
- The final design included high and intermediate levels of road decommissioning and was based on identified risk, site conditions, and interpreted channel sensitivity.

Case Example 3: The Walter Creek revetment, Road 2350, Milepost 9.95

In this example, the repair contract was awarded as a traditional riprap revetment following a simple site investigation. However, during construction, problems were encountered and the project could not be built as designed. Because the problem surfaced during the construction phase, a solution was needed quickly. An interdisciplinary group, including design and construction engineers, a fisheries biologist, the construction contractor and the equipment operator, developed a preliminary solution on-site. The site was quickly re-surveyed and the new design was accomplished the following day. In this example assessment was limited to the immediate washout area.

Figure 6: High intensity decommissioned section through former washout; roadway and all associated fill have been removed. Straw mulch indicates former road and area disturbed by excavation. Two of the log complexes placed for structure and stabilization can be seen on the left. Note the lower intensity of treatment at the far (upstream) end.

The solution involved lowering the fill and installing internal reinforcement (reinforced soil slope) to steepen the slope and reduce encroachment. Figure 7 shows this phase during construction.

Figure 7: Construction at Walter Creek. Note the installation of geotextile fabric reinforcement through steepened section of the revetment.

Structure was added along the channel margin, including logs keyed into existing boulders but not into the revetment. The structures were designed to reduce erosional forces on the revetment, but ultimately provided complexity to the channel. The use of logs embedded into the foundation or footprint of the road was avoided because of a concern for decaying logs compromising long-term performance. The slope above the riprap was covered with a turf

Figure 8: Walter Creek Revetment, Rd 2350 milepost 9.95 - photo of completed project.

reinforcement mat, filled with topsoil and planted. The completed project is shown in Figure 8.

Summary of Case Examples

The preceding examples show a range of sites and conditions. They involve changes in approach that span the project development process from assessment to implementation. The list below provides a summary.

- All of the projects started out as conventional riprap revetments.
- All began with assumptions made from a limited (site) level assessment
- All changed substantially and none were implemented as initially envisioned; Walter Creek has been implemented as a riprap revetment although it is not a traditional design.
- The Dosewallips is a complex site in an evolving environment. Potential solutions are complex, expensive, and extend well beyond the limits of the washout. The assessment was comprehensive.
- The Dungeness, by comparison, is a relatively simple encroachment problem involving a more limited assessment, though still extending well beyond site boundaries. The solution was based on issues and values beyond the site level.
- Walter Creek is a much more straightforward example. It involves site level assessment only, and the solution is limited to the washout area. Nevertheless, the design incorporates features not typically found in conventional revetments.

Table 3: Conceptual elements useful for evaluating bank protection designs.

Variable	Habitat Components	Traditional Revetment Designs
Texture	rough	smooth
Variability	high	low/uniform
Hydraulic efficiency	inefficient	efficient
Structure	complex (messy)	simple (neat)
Overall impression	soft	hard

Design Solutions: Some Thoughts on Non-traditional Approaches

Traditional solutions such as riprap revetments are effective techniques that have stood the test of time and should not be abandoned. Design methods such as those developed by the Corps of Engineers (USACoE 1991), the Federal Highways Administration (USDOT FHA 1989) are appropriate starting points for projects involving riprap. However, natural resource professionals and regulatory agencies are calling for more creative solutions that minimize adverse impacts on the stream environment. With this in mind, consider the range of conditions within the variables listed in Table 3.

Several variables in Table 3 are often an objective of, or are affected by, bank protection measures. These variables highlight some key differences between desirable aquatic habitat conditions and traditional riprap design objectives. Column 2 lists conditions with respect to these variables that are often associated with high quality aquatic habitat. It is often rough, highly variable, hydraulically inefficient and structurally complex. These are also components that perform important energy dissipation functions within streams. Column 3 suggests that traditional engineering designs favor opposing conditions with respect to these variables; they tend toward efficiency, uniformity, and predictablility. The stream environment is dynamic and variable, while analysis and design necessitates simplifying assumptions. Incorporating elements that increase variability and turbulence also increases uncertainty, risk, and cost. In the search for more compatible designs, the challenge is to develop an integrated approach that seeks the best compromise between engineering efficiency and natural habitat values.

A Contemporary Design Example: The Big Quilcene Revetment

The Big Quilcene Revetment, shown in Figure 9, offers a fine example of a non-traditional, or some would say a more contemporary, bank hardening design using riprap. Rootwads and short rock spurs have been incorporated along the toe, and soil bioengineering techniques using brush layers and jute matting were used in the upper

Figure 9: Big Quilcene River revetment just upstream of Highway 101. Note the irregular shaped rock toe incorporating rootwads and built to a limited height with brush layers installed above.

section. These techniques are intended to soften some of the effects of riprapped banks, and increase hydraulic roughness.

In this example the height of the rock armor (H) is somewhat lower than recommended in traditional designs. Many newer designs set the top of the rock to the height of lower discharges such as the predicted 20-year recurrence interval flood (Q_{20}), or even lower. Because shear stresses or erosional forces are concentrated near the channel bed, and drop off rapidly toward the water surface, the top of the structure need not be as hard or be designed to resist the maximum shear stress. Closer to the surface, soil bioengineering, plantings, or other soft techniques can be used (USDA NRCS 1992). Designers must be careful to recognize the uncertainty involved in predicting flood height, and therefore the risk involved when basing rock height (H) on lower flow levels.

Conclusions

In many instances, traditional approaches based on simplifying assumptions or a limited scope of analysis have been costly. At complex sites such as the Dosewallips washout, this approach has led to complete redesigns and repeating several steps of the environmental assessment phase or National Environmental Policy Act (NEPA) analysis. Conducting design concurrent with NEPA analysis is risky at these sites.

Many streambank protection projects are still approached in a traditional mode, which is to replace and fortify what was previously there. Approaches for treating road encroachment problems have changed in the last decade, particularly for natural resources management and regulatory agencies. There is an increased emphasis on understanding physical and biological processes and finding solutions that are consistent with the range of natural conditions. Road management in this environment is not business as usual, and assessments and designs should reflect this. Road management agencies, highway departments, and the consultants that often work for them do not necessarily have this philosophy.

The scale of the assessment will often have to be expanded beyond the immediate project area in order to determine the best solutions. Design and on the ground implementation should maximize the use of available structure. Many improved designs use the same components that provide stability in undisturbed stream analogs or nearby reference conditions.

Early interdisciplinary or interagency involvement is valuable, and in some cases is essential, at any phase of these projects. The degree of involvement is directly related to site complexity and to larger scale issues such as watershed values. Involving regulatory agencies after designs have been completed, or only after a problem has been encountered during construction is asking for trouble.

Manuals such as Washington State's Integrated Streambank Protection Guidelines (WDFW et al. 2002) and the Federal Interagency Working Group's Stream Corridor Restoration Manual (FIWG 1998) provide excellent guidance for road management and design along stream and river margins. These guides address habitat impacts, and attempt to integrate an understanding of changes in channel processes into road management and design.

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