7 Sediment Sources

Previous work in the Wilson River Basin has identified slope instability, road instability, and runoff from rural roads as the primary sediment sources (E & S Environmental Chemistry, Inc, 2001). For this assessment, slope instability was assessed using topographically based models for landslide susceptibility and runout (Miller and Burnett, 2007a&b; Burnett and Miller, 2007; Benda et al., 2007), calibrated to landslide inventories collected by ODF after the 1996 storms (Robison et al., 1999), results of which are reported below (see Appendix T – Slope Stability Assessment for a detailed analysis). Road instability and runoff were assessed based on detailed road surveys following the "Rapid Watershed Risk and Current Conditions Survey" protocol (Mills et al., 2007), reported below (for a detailed analysis, see Appendix M – ODF Roads Protocol).

7.1 Slope Instability

All analyses in this section are based on overlay of mapped landslide initiation points and runout tracks on 10-m digital elevation models (DEMs). Hence, references to topographic attributes, such as slope gradient, refer to quantities calculated from DEM elevations. DEM-based measures of topography will not generally match field-based measures; they are based on different length scales and involve different resolution of topographic details. The models we use are based on empirical relationships between observed (mapped) landslide and debris flow locations and DEM-derived topographic attributes. This allows us to use a GIS to extrapolate results to areas without mapped landslides and debris flows, but also constrains our resolution of potential landslide and debris flow sites to those that can be identified with the digital data. These results identify potential hazard zones that can be verified through field observations.

7.1.1 Shallow Landslide Susceptibility

7.1.1.1 Methods

All steep slopes within the watershed can potentially generate shallow, rapidly moving landslides. For this assessment, potential landslide-source areas are characterized in terms of susceptibility to landslide initiation. All potential sites are ranked in terms of landslide susceptibility, starting with the least-stable sites and progressing to the most stable, and hazard zones are then defined to encompass a specified proportion of the expected landslide initiation sites (refer to Appendix T – Slope Stability Assessment), starting with the least-stable sites.

Landslide susceptibility is characterized in terms of an empirically calibrated dependence on slope gradient, based on the density (number per unit area) of landslide initiation sites in different slope classes (e.g., 70 – 80% gradient). As

described in Appendix T, other topographic attributes can also be used to define susceptibility, with slope gradient potentially working better for identifying potential landslide sites during high-intensity rainstorms, and a combination of slope and drainage area working better for landslides triggered by long-duration rainstorms. GIS layers provided with this assessment report results based on empirical calibration to both sets of topographic attributes.

Landslide susceptibility can also be defined to include the potential for a landslide, or subsequent debris flow triggered by a landslide, to travel to a Type F (fish-bearing) stream (Appendix T – Slope Stability Assessment). For this case, hazard levels are defined to encompass a specified proportion of the initiation sites for landslides that deliver to Type F streams, and thereby highlight the most likely upslope source areas for debris-flow-delivered sediment and woody debris to fish-bearing streams.

Landslide source areas defined solely on the potential for initiation and delivery do not include, however, any assessment of the potential magnitude of the event. A low-probability, long-runout debris flow may pose a similar hazard as many higher-probability, short-runout debris flows in terms of the cumulative length of channels affected and the volume of sediment and wood incorporated into the deposit. A third GIS coverage was created (refer to Appendix T – Slope Stability Assessment) that used a combination of susceptibility to landslide initiation, probability for debris-flow delivery (to a fish-bearing stream), and runout length to a fish-bearing stream to define hazard levels.

This set of map coverages (based on landslide susceptibility; susceptibility + probability of delivery; and susceptibility + delivery + runout length) provide three slightly different contexts for identifying potential landslide-hazard zones. The appropriate map depends on the intended use. Susceptibility alone identifies landslide-prone areas without reference to channel effects; susceptibility + delivery identifies areas most likely to generate landslides that travel to fish-bearing streams, and susceptibility + delivery + runout highlight source areas in terms of the quantity of wood and sediment (based on relative runout length) they might carry to fish-bearing streams.

7.1.1.2 Results

Map 44 shows three hazard levels based on slope gradient. High hazard zones cover the least stable sites and are set to encompass 50% of the expected landslide occurrences. Moderate hazard zones include progressively more stable sites and are set to include an additional 40% of the expected landslides. Low-hazard zones include the most stable (but still landslide-prone) sites and are set to encompass the remaining 10% of potential landslide sites. All DEM-inferred slopes less than ~30% have zero hazard. These levels are illustrative; hazard

zones based on different proportions of the expected landslide occurrences can be generated using the prop_slope GIS raster coverage (Appendix T – Slope Stability Assessment).

Map 26 shows hazard zones defined using both landslide susceptibility and probability for delivery to a fish-bearing stream. A high hazard is set to encompass 50% of the expected initiation sites for landslides that can trigger debris flows that travel to fish-bearing streams; the moderate hazard zone encompasses an additional 40% of the initiation sites for landslides that deliver, and the low hazard zone encompasses the remaining 10% of these sites. Incorporating the probability for delivery reduces the size of each of these hazard zones, because many landslide-susceptible sites have a low (or zero) estimated probability for delivery.

To incorporate an estimate of debris-flow magnitude, Map 27 shows hazard zones based on landslide susceptibility, probability of delivery, and runout length to a fish-bearing channel. Here, the runout length is used as a measure of the potential magnitude of debris-flow effects. This definition tends to highlight longer-runout debris flows and incorporates many upper headwall areas into a high-hazard zone that fell into moderate or low hazard zones when runout length was not considered. This is the best definition of hazard within the context of potential for debris-flow delivery of sediment and wood to fish-bearing streams.

7.2 Debris Flow-Prone Channels

7.2.1 Methods

The potential for debris-flow runout is based on a cumulative assessment of slope gradient, degree of topographic confinement, and channel-junction angles encountered along any potential debris-flow track. Details of model design, calibration, and validation are given in Appendix T – Slope Stability Assessment.

Susceptibility to debris flows is defined separately for Type N (non-fish-bearing) and type F (fish-bearing) channels. For each case, debris-flow susceptibility is defined in terms of the proportion of debris flow travel length (Type N) or depositional sites (Type F) expected over the entire watershed.

7.2.1.1 Type N Channels

We characterize Type N channels in terms of the relative potential for traversal by a debris flow from upslope that continues to a Type F stream. Susceptibility to debris-flow traversal and delivery to a fish-bearing stream is gauged in terms of the proportion of expected debris-flow track length. Each of four hazard levels are defined to encompass 25% of the expected debris-flow travel length through

Type N channels, starting with the most debris-flow-prone channels in the High category and progressing to the least debris-flow-prone channels in the Low category. Thus, high hazard zones encompass the Type N streams expected to include, on average, 25% of the debris-flow-track length; the high hazard zone plus the next zone encompass the Type N streams expected to include, on average, 50% of the debris-flow-track length, etc.

7.2.1.2 Type F Channels

To assess the potential for debris-flow deposition in these Type F streams, all Type F channels were divided into reaches with relatively uniform gradient and confinement averaging about 100 meters in length (using methods described in Clarke et al. in press). All potential landslide sources for each reach were identified and the probability for landslide initiation and delivery calculated for each source. The product of the probabilities for landslide initiation and delivery defines the probability that each potential source initiated a debris flow that traveled to the reach. Each reach was then assigned the maximum of these debris flow probabilities. Four hazard rankings for Type F streams were then defined to each include 25% of the expected Type F reach length affected by debris flows, starting with the most susceptible sites. Thus, high-hazard zones encompass the Type F channels expected to include, on average, 25% of the debris-flow-depositional sites; the sum of the high and the next hazard zone encompass the Type F channels expected to include, on average, 50% of the debris-flow-depositional sites, and so on.

7.2.1.3 Effects of Debris-Flow Deposits on Type F Channels

When evaluating the role of debris flows on fish-bearing streams, it is important to consider how debris-flow deposits affect channel and habitat morphology. In depositional areas, debris flows can construct levees; build fans at tributary junctions (Dietrich and Dunne 1978); create boulder deposits along fan margins (Benda 1990, Wohl and Pearthree 1991); form ponds at fan constrictions (Everest and Meehan 1981); create wide valley floors (Grant and Swanson 1995); force channel meanders (Benda 1990); and spates of debris flows can lead to widespread channel aggradation and formation of terraces (Roberts and Church 1986, Miller and Benda 2000). In addition, debris flows can incorporate logs and whole trees that have accumulated in small (Type N) channels over decades to centuries and deposit them on fans, valley floors, and at low-order confluences (Hogan Bird et al. 1998, May and Gresswell 2003). Debris flows entering larger rivers with greater transport capacity can be rapidly eroded, potentially forming destructive debris torrents and debris-laden floods (Benda Veldhuisen et al. 2003).

The nature of these effects varies from site to site depending on debris-flow size and composition (e.g., amount of wood and boulders), valley geometry, and the sediment transport capacity of the channel where the debris flow deposits. Regional data on the rate of erosion of debris-flow deposits provides an indication of debris-flow effects on channels as a function of channel size and gradient (Benda 1990, Benda et al. 2003). Using these data and field observations of deposit types (Benda 1990, Grant and Swanson 1995, Hogan Bird et al. 1998, May and Gresswell 2004, Lancaster and Grant 2006, Bigelow Benda et al. 2007), we define four classifications:

Deposit type	Criterion (slope*drainage-area threshold)	Channel effects	Habitat effects
Colluvial (transported soil and debris) deposits, with little to no subsequent fluvial erosion	< 0.13 km^2 (32 acres) and-or drainage area < 3 km^2 (741 ac)	Channel and valley burial; potential sediment and wood source for subsequent long-runout debris flows.	Deposits of sediment and wood modulate runoff through headwater channels, provide habitat for amphibians and invertebrates.
Morphological Significant Deposits	< 0.40 km^2 (99 ac)	Create fans and terraces, log jams, boulder deposits.	Short-term destructive effects: burial of channel habitat, increased fine sediment load, increased bedload with associated loss of pools and increased channel instability. Long-term constructive effects: boulder and wood deposits contribute to channel complexity and formation of pools.
Dilution and rapid erosion of deposit	< 1.0 km^2 (247 ac)	Formation of scouring debris-laden floods	Damage to downstream channel and riparian areas.
Hyper Dilution	> 1.0 km^2. (247 ac)	No major in-stream deposits, minor effects on channel morphology	

7.2.2 Results

7.2.2.1 Type N Channels

All Type N channels with upslope debris-flow sources are potentially debris-flow prone. Map 29 (and discussed in greater detail in Appendix T – Slope Stability Assessment) identifies the Type N channels susceptible to debris flows that continue on to fish-bearing (Type F) streams, using the hazard definitions described in the methods section above. The greatest concentration of high-hazard zones is coincident with areas having a high probability for landslide initiation and delivery (Map 26), particularly in the North Fork Wilson sub-basin. Along any debris-flow-prone Type N stream, the hazard rating tends to increase downstream, reflecting the increasing number of potential debris-flow source areas encompassed in the drainage area to the channel. These hazard ratings rank Type N channels in terms of potential for delivery of any available woody debris to fish-bearing streams.

7.2.2.2 Type F Channels

Debris flows enter fish-bearing streams primarily at confluences with debris-flow-prone Type N channels. These locations are identified in Map 25. Potential debris-flow depositional reaches are scattered discontinuously throughout the channel network, with a spacing between sites that tends to increase with increasing channel size. Channels near the headwaters in debris-flow-prone areas (e.g., North Fork and Jordan Creek subwatersheds) have numerous, closely spaced debris-flow input points with potentially overlapping effects; downstream and in less-debris-flow-prone areas, debris-flow sites are more widely spaced.

7.2.2.3 Debris-Flow Deposit Effects

Colluvial deposits are primarily confined to headwater (Type N) channels (Map 28; note that these deposits may be subject to subsequent erosion by long-runout debris flows). Morphologically significant depositional sites occur through many of the smaller fish-bearing (Type F) streams. Debris flows depositing in these channels can be important sources of large wood, suggesting that protection of upslope sources of wood is particularly important for these channels. Of note in the Wilson River watershed are the extensive reaches with sufficient stream power to generate debris-laden floods. Overlap of debris-flow sources with these reaches, as found along the North Fork Wilson and Jordan Creek, identify channels subject to these destructive flood events.

7.3 Deep-seated Landslides

No active, large deep-seated landslides and earthflows were detected in the Wilson River basin using aerial photography or during the field surveys.

However, an ODF aerial survey in March 2007 revealed numerous incidences of small, deep-seated failures. On March 28, 2007, ODF staff flew a plane (Partenavia) to conduct a coarse scale aerial survey to assess effects of the November 2006 storms within the Wilson watershed. The survey was qualitative in nature, but provided an excellent overview of channel conditions in the Wilson River watershed at the subwatershed scale. Storm effects were concentrated in the Jordan Creek and South Fork subwatersheds, with locally heavy effects elsewhere. This applied to both landslide locations and stream channel effects. Interestingly, a greater number of small deep-seated landslides were noted than were shallow-rapid landslides.

Another type of deep-seated failure common to certain areas in the Wilson River watershed is episodic deep failures that occur on relatively steep, planar slopes during very intense rains. A good example of this type of landsliding occurred in the West Fork of the North Fork Wilson River in early December 2007 following a major rainstorm. The deep-seated slides were 10 meters or more deep and thus they were unlikely affected by historical timber harvest. The volume of sediment released was estimated to range from tens to hundreds of thousands of cubic meters and was sufficient to inundate the channel and valley floor for kilometers below the landslide.

Unfortunately it is difficult to accurately predict where landslides of this type will occur in the future. The ground surface characteristics of these areas prior to failure are not well understood and the most reliable indicators may be below ground and thus not detectable by geoscientists. Thus these types of failures are not covered in this analysis. They should be considered as part of the natural (background) disturbance regime. However, when building new roads or refurbishing old roads in basins known to have had historical deep-seated slides it is recommended that the character of both the subsurface rock (weathered, highly fractured or competent) and surface topography be carefully examined. In geomechanical suspect terrain, road construction that involves significant excavation of hillslope material should be carefully considered. LIDAR may be useful for detecting the hillslope areas with a long history of this type of failure.

The analysis here is limited to larger features since there is no reliable method to detect existing small features or to predict future occurrences of small, deep-seated landslides.

7.3.1 Methods/Background

Two methods are used to predict the likely locations of large deep-seated landslides and earthflows in the Wilson River basin. One uses the Roering and others (2005) model that is based on detecting specific combinations of hillslope gradient and curvature, empirically calibrated to the central Oregon Coast Range.

The other method relies on perturbations in the longitudinal profiles of river valleys. Neither approach indicates the activity level of deep-seated landslides (e.g., active versus dormant). Because large landslides occur relatively infrequently, the majority of such features in a watershed should be old and hence could be viewed as sources of physical heterogeneity in rivers by creating knick points that reduce valley gradient upstream and increase gradients downstream (Grant and Swanson 1995, Cruden and Thomson 1997). Lower-gradient valley segments upstream of large slides can create wide valleys containing more floodplains, side channels, and more sediment and woody debris (Figure 29); the large slide in the Devil's Lake Fork subwatershed is a good example of this. For a more detailed discussion of the methodologies used in this section, refer to Appendix E – Detailed Methodologies.

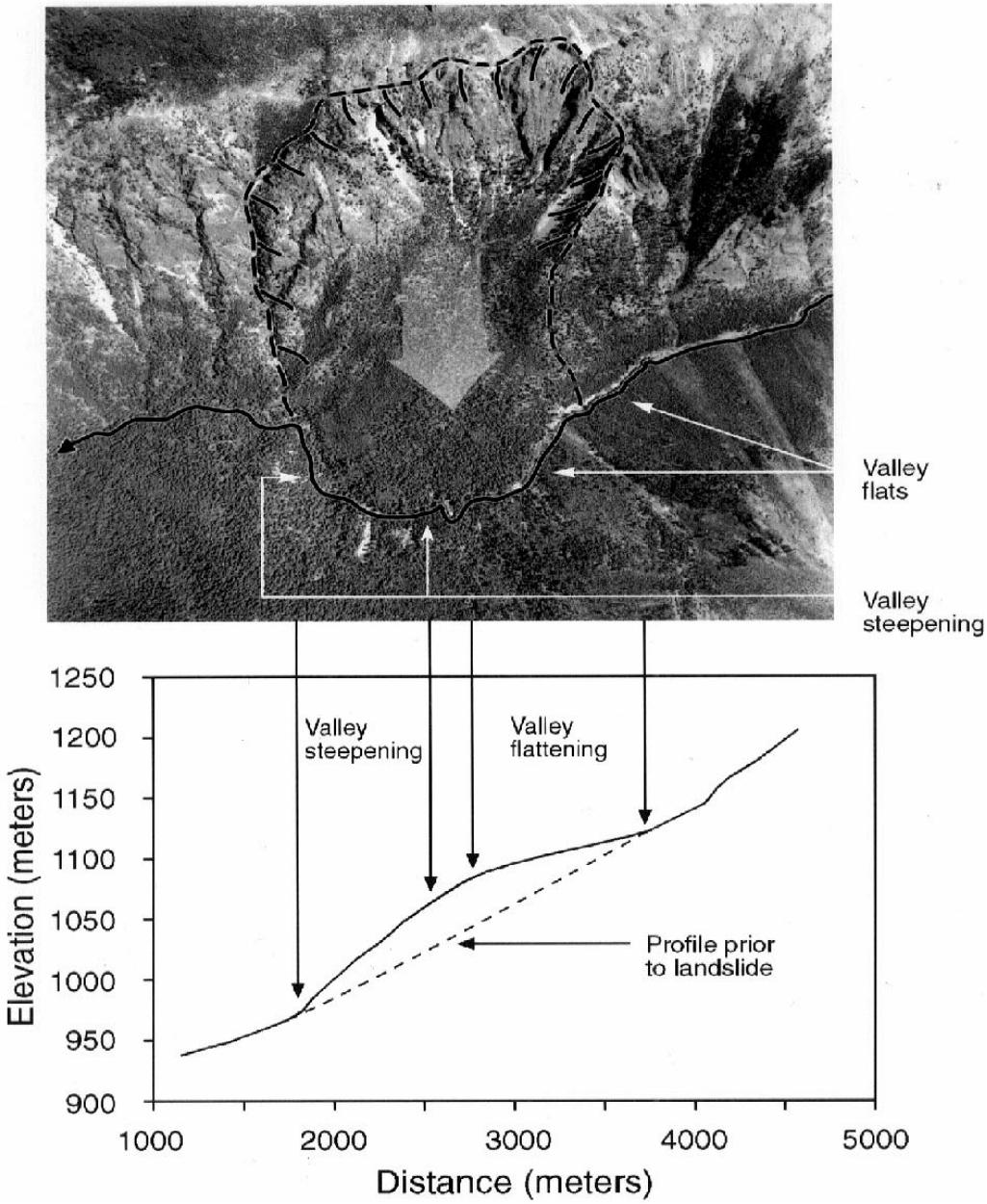


Figure 29. Large, ancient deep-seated landslides can be a source of habitat development and heterogeneity. The landslide depicted here, located in eastern Washington, has resulted in a large bulge in the longitudinal profile of the river. Upstream of the landslide low gradient valleys and channels have created floodplains and lower gradient, meandering channels. Younger deep-seated landslides can pose a threat to aquatic resources through increased erosion and turbidity. Because of the rarity of large landslide events, the majority of such features in a watershed should be old.

7.3.2 Results

Predicted deep-seated terrain using the Roering and others (2005) model is shown in Map 45. Much of the Wilson River watershed is classified as having topography indicative of deep-seated landslides. In particular, a high concentration of such terrain is located in the far eastern portion of the basin. The deep-seated algorithm likely over-predicts the occurrence of deep-seated landslides and earthflows since it does not evaluate the level of activity (i.e., ancient and non active terrain is not differentiated from more recent or active landslides). Additionally, other types of low gradient topography could get included in the deep-seated designation. Finally, due to the algorithm used, this method does not intrinsically demarcate fine scale boundaries of deep-seated landsliding.

The second method produced twelve individual longitudinal profiles of the major channels in the Wilson River watershed (Figure 30). The longitudinal plots that correspond to the locations in Figure 30 are shown in Figure 31 through Figure 34. All but three of the profiles (9) show some type(s) of perturbations in the elevational profiles suggesting that large deep seated failures exist in the watershed and are affecting valley profiles. The highest concentration of elevational perturbations occurs in the eastern portion of the Wilson River watershed (profiles #1 and 2) and they occur in an area predicted by the Roering and others (2005) model to have a high density of terrain indicative of large landslides and earthflows (e.g., Map 45). For example, the upper most perturbation in the profile in #1 (LLID 4540661238739; Lower Wilson River subwatershed) (Figure 31) identifies what appears to be a large ancient failure at that location (Figure 35). Although the large landslide analyses can be used to help screen for occurrences of large failures in the Wilson River watershed, field reconnaissance and detailed field surveys will be required to verify predicted patterns as well as level of activity (e.g., active versus dormant).

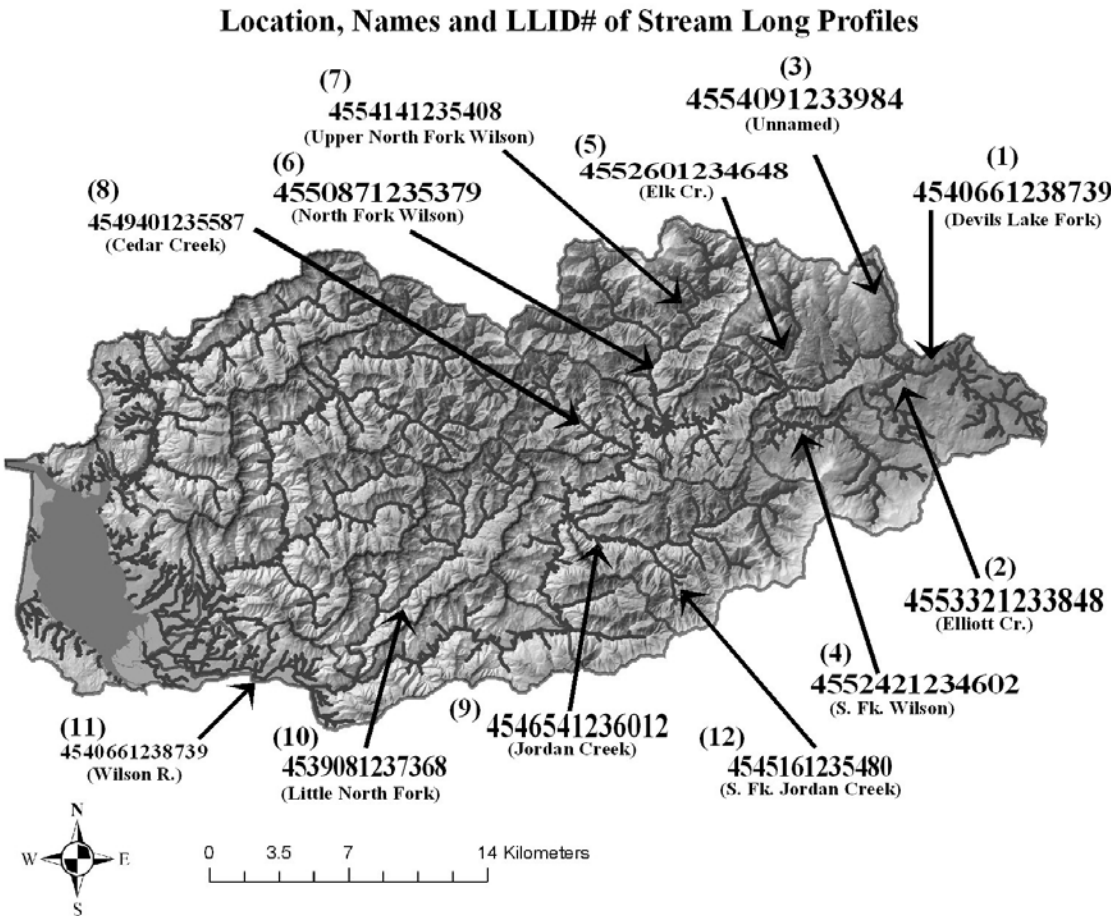


Figure 30. Locations of three principal Tillamook Bay basins (Miami, Kilchis, Wilson) with locations of principal tributaries in the Wilson River watershed where longitudinal profiles were used to search for potential deep-seated landslides.

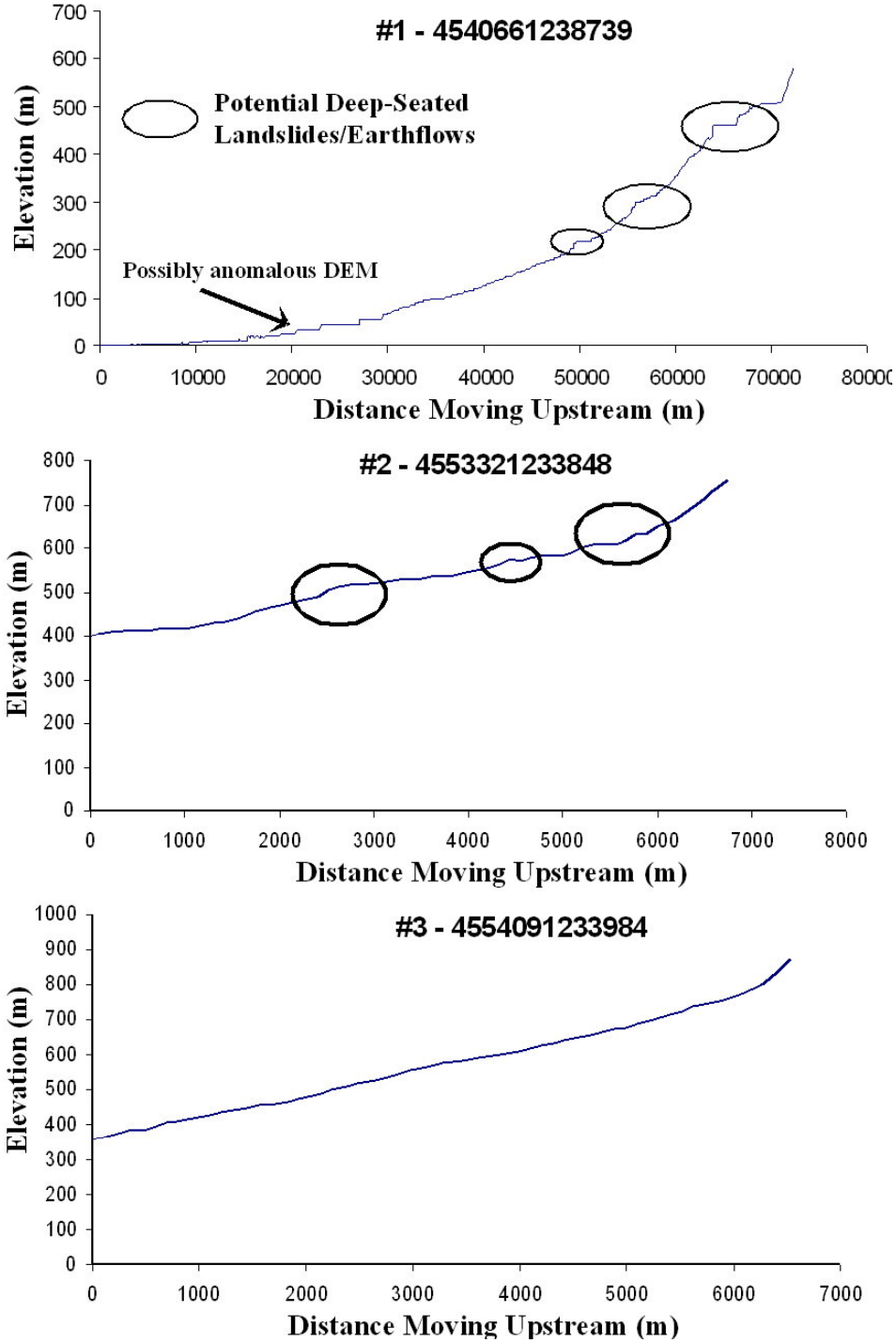


Figure 31. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

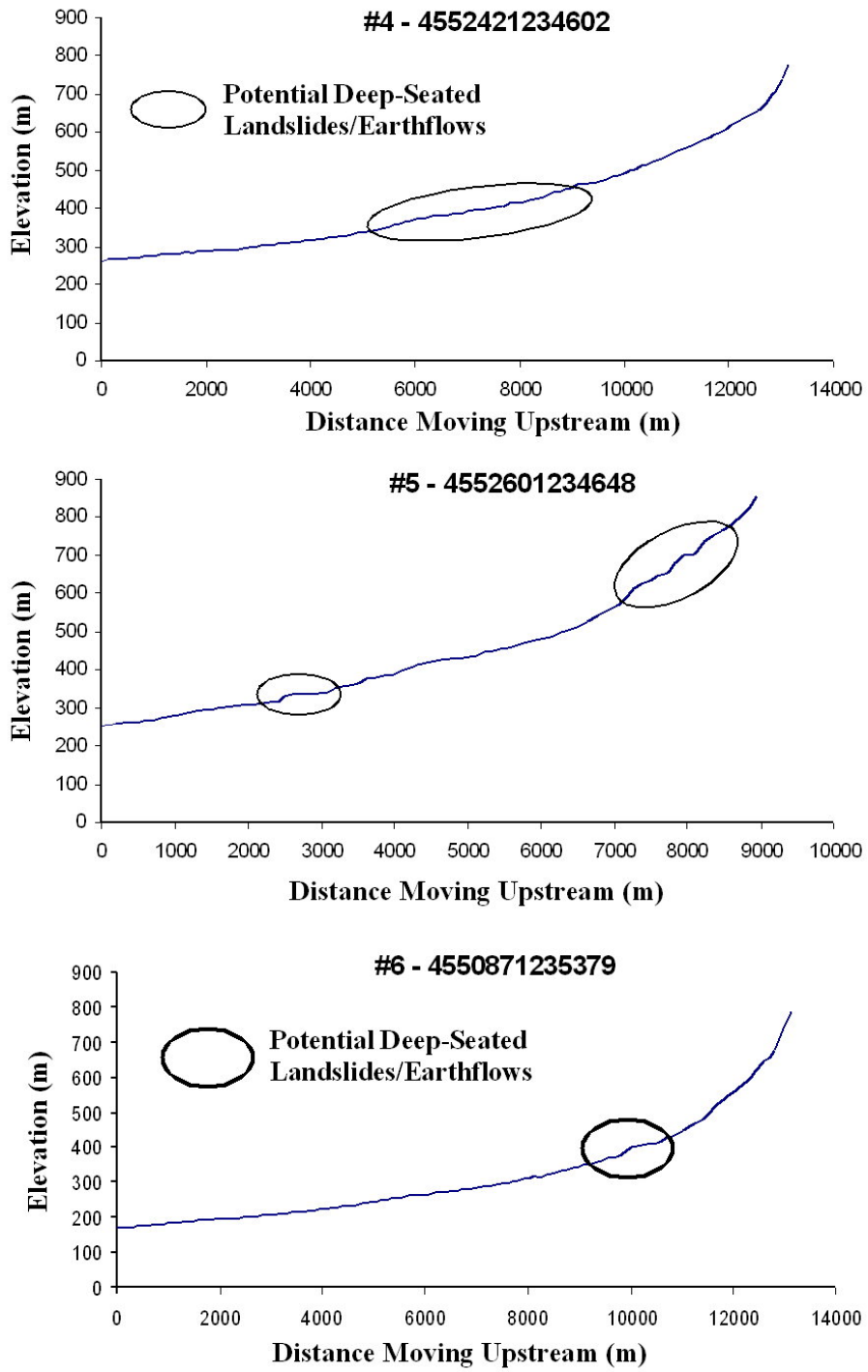


Figure 32. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

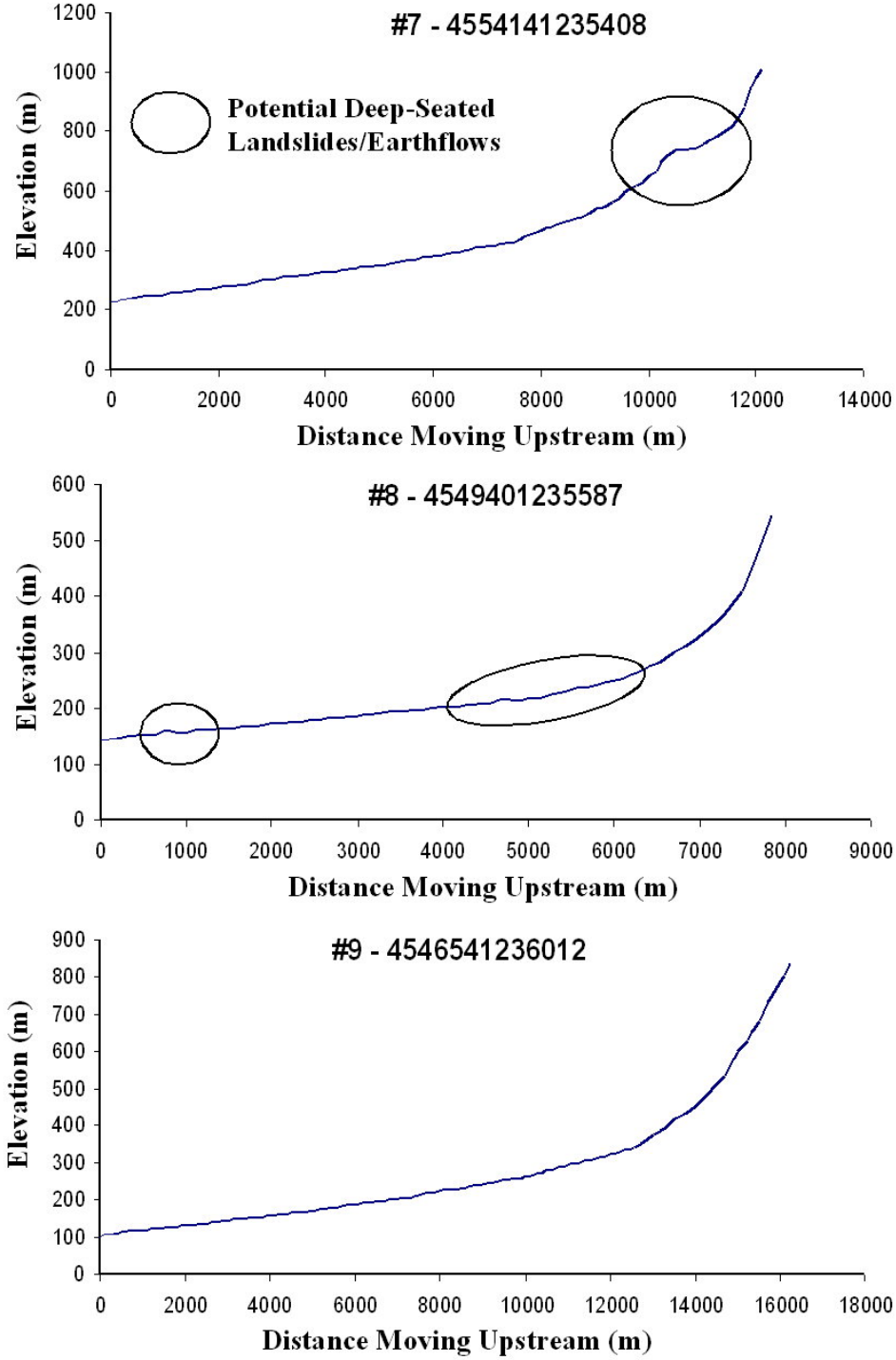


Figure 33. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

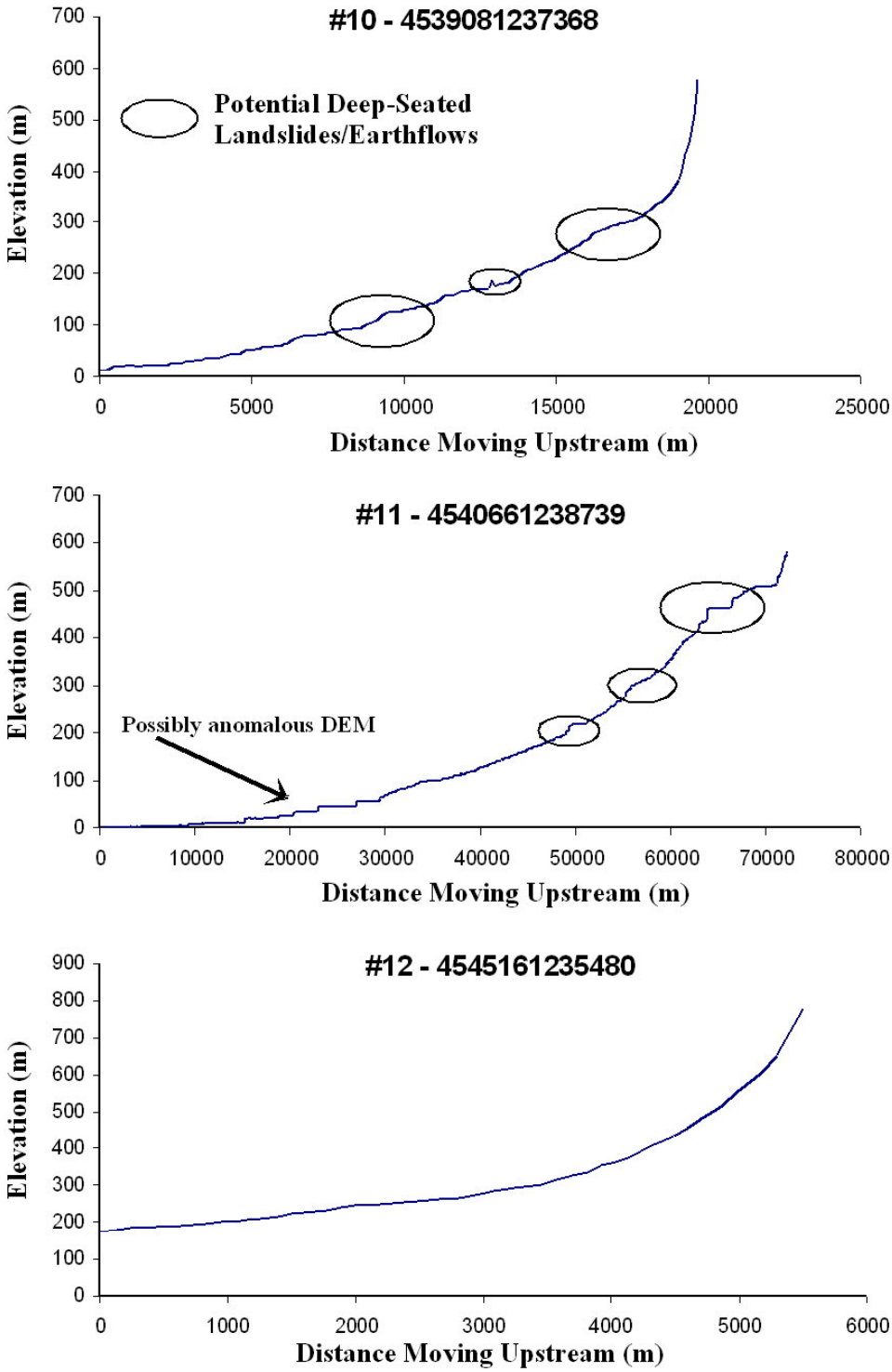


Figure 34. Longitudinal profiles of major tributaries within the Wilson River watershed are used to search for perturbations in the distance-elevation data that can indicate locations of large deep-seated failures and earthflows (refer to Figure 30 for LLID/stream names).

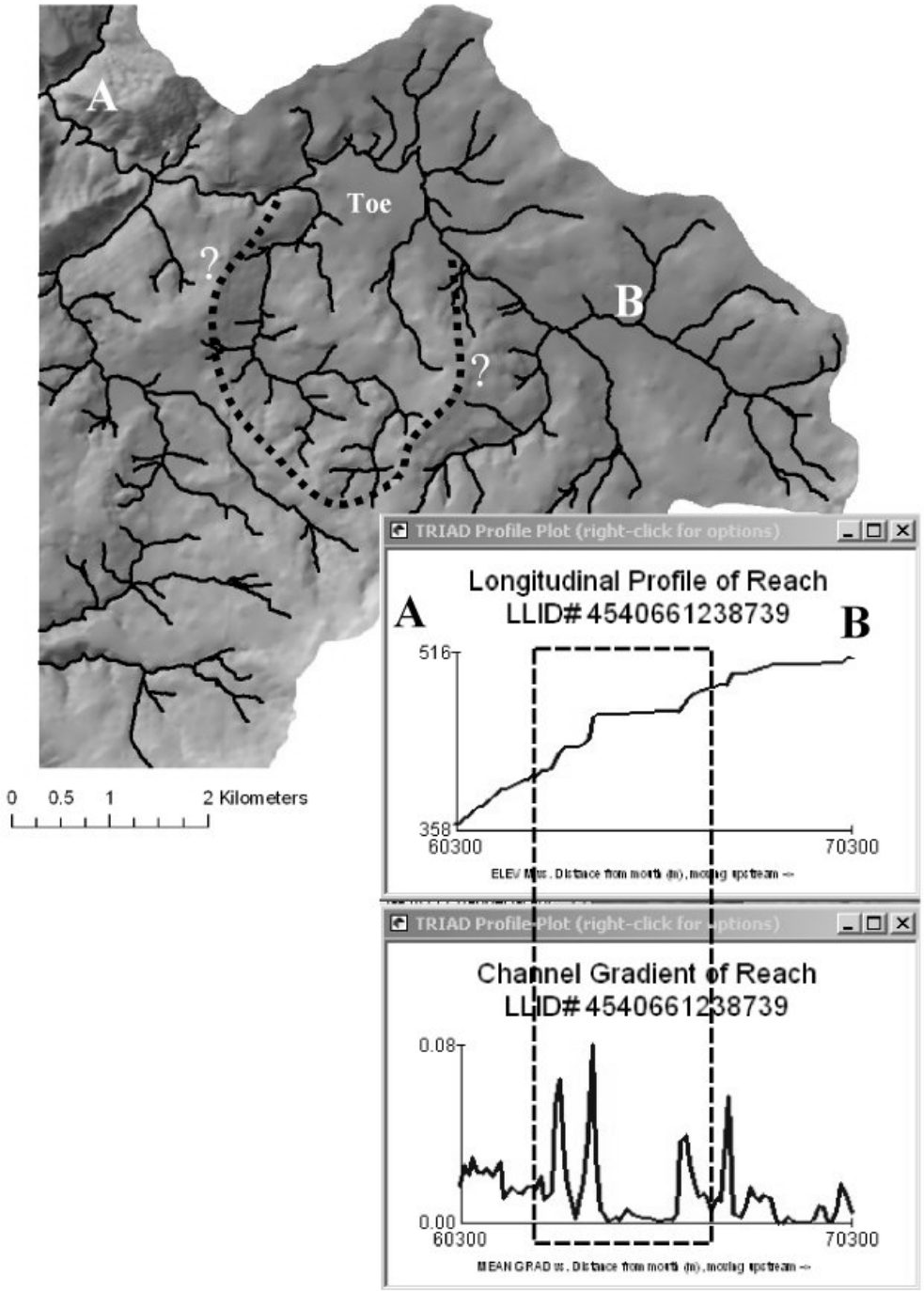


Figure 35. An example from the far eastern corner of the Wilson River basin where an apparent large deep-seated landslide is altering the longitudinal profiles of channel gradients, elevation, and valley widths (refer to Figure 30 for LLID/stream names).

7.4 Road-Related Issues

Roads provide access to a wide variety of activities within the Wilson River watershed. From timber harvesting and log hauling to recreating with Off Highway Vehicles (OHV) and motorcycles, the roads within the watershed are well used and often a busy place.

The Oregon Forest Practices Act of 1971 and the rules governing forest roads that were adopted in 1972 considered the impact of roads on aquatic resources in terms of road location, construction and maintenance (Mills et al. 2007). Since 1972, the body of knowledge regarding the interaction between roads and aquatic resources has grown. Similarly, ODF has continued to research, monitor, and develop Best Management Practices (BMP) for forest roads.

The environmental impact of forest roads are well known and widely documented. Mills and others (2006) and others summarized the environmental effects of forest roads on aquatic resources as:

- Restriction of fish, flow, sediment and debris passage at stream crossing structures;
- Input of sediment in amounts over background;
- Alteration of aquatic habitat from sediment, increased fines in stream sediment, and, for roads adjacent to streams, directly filling and eliminating habitat;
- Change in hydrology and stream flow when roads intercept rainfall and groundwater and alter rate of water delivery to streams.

Even though the effects of roads have been understood by researchers for some time, land managers have generally focused on road density, proximity to streams, and surface material in their assessment of forest road condition. The need to better characterize the current condition of State forest roads led to the development of a road assessment protocol that went beyond calculating road density, proximity to streams, and surface material. The State developed the "Rapid Watershed Risk and Current Condition Survey" (Appendix I) to evaluate the current effect forest roads have on aquatic resources within a particular watershed. The survey categorizes and rates linear features such as drainage system, critical location, prism stability, surface condition, and vegetation along the roadway. At specific point locations the survey categorizes and rates stream crossings, cross drains, and other features as they affect streams and the watershed. The survey allows managers to evaluate current and near-term road conditions as they are likely affected by flood producing storms. Generally, the

survey captures attributes associated with roads and their potential environmental risk. Mills and others (2007) identified the environmental risk factors associated with roads in forested mountainous terrain as:

- Road location in relation to streams or landslide/other serious erosion prone slopes;
- Stream crossing effects on fish passage;
- Washout and diversion risk at stream crossings;
- Percent of road system with hydrologic connection to streams;
- Land area dedicated to roads and not growing forests; and
- General condition rating of the prism, surface, drainage system, and brush/weeds.

Road segment features are rated and attributed with Attention Priority Codes (AP). There are 5 AP codes and are described by Mills and others (2007) as:

- **AP Code 1**: blocks road, prevents drainage, makes the road unsafe to use, or otherwise is causing damage and/or serious erosion that affects water quality. Road-work is required immediately if the issue affects water quality or the road is not intentionally closed.
- **AP Code 2**: significantly restricts road use, or the ability of water to drain across the road, and if left alone will likely get worse over time.
- **AP Code 3**: has a moderate effect on road use, speed, or water flow across the road, but is not an imminent forest practices problem and though it may reduce driving speed, is not a serious safety hazard. Code 3 conditions need maintenance or repair in the future (next few years for inactive roads, sooner for active logging roads).
- **AP Code 4:** is a minor impairment in the function that does not require immediate maintenance or repair.
- **AP Code 5**: indicates perfect working order and there is no effect on the road function as designed nor is there increased erosion.

7.4.1 Survey utility

The survey data are readily available for use by ODF District managers and engineers in terms of identifying specific road segments in need of immediate repair. The survey data may also be used to help prioritize maintenance efforts by

focusing on road segments that are in the most need of maintenance. The data are also useful for longer-term strategies such as prioritizing road hazard reduction activities. A principal use of the survey is to assess overall road conditions and risks when the survey was conducted, for comparison with other road systems or with benchmarks and performance measures.

Maintenance needs are best determined using an Attention Priority Code (especially codes 1 and 2). Stream crossing structure replacement should be based on washout risk, fish passage restriction, and also on attention priority code. Sidecast pullback is evaluated by prism stability and critical location risk level. Road vacating should be based on a combination of factors, especially a large percentage of the road in the more critical locations. Limits on winter road use can be determined by road surfacing and the percent of road hydrologically connected to streams.

In 2006, workers from Duck Creek Associates, Inc. surveyed the Wilson River watershed road and trail system using the Rapid Watershed Risk and Current Condition Survey. The results of that survey are the basis for this assessment.

7.4.2 Roads in the watershed

It is important to understand while reviewing this section of the document that the rapid road risk assessment is a snapshot of current conditions at the time of the survey. Although the survey was completed in 2006 and provides a comprehensive dataset from which to characterize the road system, the survey occurred prior to November 2006 when records indicate that the Wilson River flooded to its greatest extent since recorded history. The storm changed conditions on the ground and ODF managers and engineers are well aware of many of the changes that have occurred. District engineers have documented many washouts caused by the November 2006 storm (refer to Map 54, addressed later in this section), resource specialists have conducted aerial surveys and qualitatively assessed channel and road conditions, and the authors of this document have been on the ground since the storm observing many of the changes the storm produced. The results of those post-storm investigations are qualitative in nature and discussed throughout this document. Nevertheless, the road survey data still represent the best available quantitative assessment of the current road conditions.

7.4.2.1 Methods

All open and blocked roads were surveyed by traveling the road either by vehicle or by foot. An open road is defined as “a road that can now be used safely by trucks and maintenance equipment”. ODF defines a road with a “blocked” status as being “a closed road that cannot be driven by a pick-up because of a tank trap,

boulders or debris on the road, or by vegetation growing on the road. These roads should be routinely inspected if they include any stream crossings or steep fills/sidecast. Construction equipment is required to remove the blockage." They may also be used as trails.

There are many older and difficult to find road prisms in the Wilson River watershed. Most of these older "grown over" roads are covered by 10- 20 inch diameter alders and in some cases conifers. These old road prisms were typically not on the ODF road map layer that was used to locate roads during the survey. Most of these very old (>30 years) blocked roads are difficult to find while surveying and were not included in this survey. The majority of blocked roads included in this survey were easy to locate and find. The distinction is important because the blocked roads included in this survey should not be considered road abandoned prior to the Forest Practices Act of 1971.

7.4.2.2 Road area in the watershed

The 2006 survey found that there were approximately 3 times more open roads than blocked roads in terms of both overall length and area. Total road area was calculated for the entire Wilson River watershed. Road area equals the sum of the prism width, (cut-slope width plus sub-grade width) multiplied by the overall segment length. Less than 2% of the land mass owned by ODF in the Wilson River watershed is covered by roads and unavailable for timber production (Table 27, Map 46).

Table 27. Summary of road data collected in 2006 for ODF lands within the Wilson River watershed.

Road Status	Road Length (in miles)	Area (in acres)	Road Density (miles/sq mile)	Percent of ODF Land Ownership Covered by Roads (area)
Open	432.0	1,053.0	2.8	1.1
Blocked	197.0	406.0	0.9	0.4
Total	**629.0**	**1,459.0**	**3.8**	**1.5**

7.4.3 Hydrologic Connectivity

Hydrologic connectivity occurs when water intercepted by the road prism flows from a road directly to a stream or waterway (Mills et al. 2007). A hydrologically connected road segment may be a source of fine sediment loading to streams if the connected segment is actively eroding. Depending on the location of cross-drains, ditches and culverts, the water flowing over a road can

either end up in a stream or waterway (hydrologic connection) or it can be directed to porous forest soils (not hydrologically connected). Reducing the hydrologic connectivity of forest roads on State lands has been adopted as a State Forest performance measure. Reducing the area of road that is hydrologically connected is critical in terms of protecting the streams and waterways from sediment loading. Forest roads have illustrated hydrologic connectivity percentages as high as 50-75 (Reid and Dunne 1984). Properly designed roads direct sediment to the forest floor rather than allowing sediment loading to streams. Improved design has reduced the percentage of hydrologically connected roads in watersheds from greater than 50% to as low as 15% (Dent et al. 2003 and Bilby et al. 1989).

Table 28. Miles of forest roads that were hydrologically connected in the Wilson River watershed during the 2006 survey. Open and Blocked roads were surveyed within the Wilson; open roads for the Upper Nehalem and Miami River watersheds are reported for comparison purposes.

		Percent of the total number of miles of open road by watershed (length)		
Road Status	Miles of hydrologically connected road	Wilson River	Upper Nehalem	Miami River
Open	68.5	16.0	16.0	20.0
Blocked	20.7	10.0	NA	NA

Table 28 lists the length, area, and relative percentages of open and blocked roads that were hydrologically connected during the 2006 field assessment on the Wilson River watershed. For a regional comparison, the percent of hydrologic connected road segments in two neighboring watersheds are shown. Of the three watersheds, the Wilson River watershed had the lowest percentage of open roads (length) that were connected to the respective stream networks. Approximately 15% of open road length was classified as hydrologically connected. The 15% value is at the lower end of the 15% - 20% connectivity predicted for improved roads (Mills et al. 2007). We also calculated hydrologic connectivity for the Wilson River watershed in terms of road area. Hydrologically connected open roads covered 0.2% (162.5 acres) of ODF lands within the Wilson River watershed, while blocked hydrologically connected roads covered an area of only 0.03% (29.7 acres) (Table 28). Hydrologic connection was spatially distributed throughout the watershed somewhat equally (Maps 47 and 48). The data and subsequent analysis from the 2006 survey strongly suggest that roads in the Wilson River watershed have been improved to limit direct runoff of water from roads to streams.

7.4.4 Critical Locations

Road location remains one of the most important design criteria in terms of affecting aquatic resources. Critical Locations were defined by the Oregon Board of Forestry as locations with inherent risk to resources regardless of construction technique, although construction technique can reduce risk (ODF Forest Practices Technical Note # 7, 2003) Roads that are in critical locations tend to be risk prone for the life of the road. The 2006 field assessment surveyed and categorized road location as stream-associated, slope-associated, or non-critical. A risk factor of highest to negligible is assigned to each risk category. Stream-associated risk factors include (listed according to their relative risk from high to low):

- Canyon Fill - roads located in a steep, narrow, canyons with high cuts and fills that encroach on the stream (highest risk);
- Channel Fill - roads located next to and sometimes encroaching on a stream, yet these roads may be stable (highest risk);
- Stream in Ditch – streams that are routed down a roadside ditch (moderate risk);
- Stream Parallel - roads located within 100 feet of a stream (elevated risk);
- Wetland – roads that intersect or are adjacent to a wetland (elevated risk).

Slope-associated risk factors include (listed according to their relative risk from high to low):

- Cut and Fill Slides – roads with failures of both cut and steep side-cast slopes that are difficult to stabilize (highest risk);
- Fill Slides – roads with side-cast slope failures along segment and illustrate cut-slope failure (highest risk);
- Deep Active Slides – roads located on a deep active slide where the slide is moving the prism (moderate risk);
- Steep Fill – road comprised of side-cast fill placed on natural slopes that are over 65 percent, with a resulting slope of over 75 percent (moderate risk);

- Deep Inactive Slides – roads located through the toe of an old slide (elevated risk);
- Steep Full-bench – road constructed with an effective end haul, or repaired with effective pullback (elevated risk).

Roads that do not receive a critical location designation are considered non-critical, and if well maintained pose negligible risk to aquatic resources

Table 29 lists the critical condition and location of open roads located in the Wilson River watershed. Roads considered non-critical located make up over 80% of the open roads in the Wilson River watershed (Maps 49 and 50). In terms of a comparative percentage, non-critical open roads in the Wilson River watershed are just about mid-way between the percentage of non-critical segments in the Upper Nehalem River (94.4%) and the Miami River watersheds (63%). One trend visible in the data presented in Table 29 is that less than 2% of the open roads within the Wilson River watershed are in the most critical locations. Roads in the Wilson watershed have a higher percentage of high-risk critical locations than the Upper Nehalem watershed but a considerably lower percentage than the Miami watershed. Within the stream associated severity category, roads parallel to the stream made up 7.0% of the overall roads in the Wilson River watershed. The highest risk factor roads related to streams are canyon and channel filled segments. These two categories combined accounted for 0.3% of the open road system length. In the slope-associated severity category, steep fill roads dominated all other types (11.2%). The highest slope-related risk factor on open roads were roads affected by cut and fill slides (0.3%).

Table 29. Critical location of open roads in the Wilson River Watershed. Critical location is expressed as the percent of the total length of open road system; the Nehalem and Miami watershed percentages for critical location are shown as a reference of nearby road conditions.

		Percent of the open road system (length)		
Critical Location Risk	**Risk**	**Wilson**	**Upper Nehalem**	**Miami**
Stream-related				
Canyon fill	Highest	0.1	0.0	4.7
Channel fill	Highest	0.2	0.0	6.1
Stream in ditch	Moderate	0.1	0.0	0.1
Wetland	Elevated	0.0	0.0	0.0
Stream parallel	Elevated	7.0	4.1	4.0
Slope-related				
Cut and fill slides	Highest	0.3	0.0	0.6
Fill slides	Highest	0.8	0.0	4.1
Deep active slides	Moderate	0.1	0.0	0.0
Steep fill	Elevated	11.2	1.2	15.0

Critical Location Risk	Risk	Percent of the open road system (length)		
		Wilson	Upper Nehalem	Miami
Full bench	Elevated	0.0	0.2	2.4
Non critical	Negligible	80.1	94.4	63.0

Surveyors also assessed the critical location for blocked roads. These are roads that tend to go unnoticed by managers because of their relative isolation. The percentage of roads in critical locations is essentially the same for both open and blocked roads (Table 30) and 3.1% of blocked roads were located on cut and fill slides. While roads located parallel to streams were essentially the same for blocked and open roads, we identified nearly 5% less blocked roads located on steep fill than on open roads. In spite of these minor differences, blocked roads generally follow the same pattern in terms of critical condition and location as open roads in the Wilson River watershed.

Table 30. Critical condition and location for blocked roads in the Wilson River watershed.

Critical Location Risk	Risk	Percent of the blocked road system (length)
Stream-Related		
Canyon fill	Highest	0.2
Channel fill	Highest	0.1
Stream in ditch	Highest	0.3
Wetland	Highest	0.1
Stream parallel	Elevated	6.9
Slope-Related		
Cut and fill slides	Highest	3.1
Deep active slides	Highest	0.1
Fill slides	Highest	2.1
Steep fill	Elevated	6.3
Full bench	Elevated	0.0
Non critical	Negligible	80.8

Critical location can be considered alone or in conjunction with hydrologic connectivity. For example, roads classified as stream parallel when considered alone may not pose an immediate risk to the aquatic resource. We considered the spatial distribution of hydrologically connected roads that coincide with critically located roads. A series of spatial queries were run that included intersecting

hydrologically connected roads with an AP of 1, 2, and 3 with critically located roads. A total of 8.6 acres of blocked and critically located roads were hydrologically connected and eroding to streams, whereas, critically located open segments totaled 6.4 acres. Open road area considered under this scenario covered 0.6% of the total open road area, while blocked roads under this scenario covered 2.1% of the total blocked road area. The higher percentage of critically located and connected roads potentially delivering sediment from blocked roads could be a function of maintenance as blocked roads receive less attention and maintenance than open roads.

Table 31. The length and area of sediment loading segments (hydrologically connected and a surface drainage AP of 1, 2, and 3) coincidental to critically located road segments.

Relation	Critical Condition	Road Status	Segment Length (ft.)
Stream-related	Canyon Fill	Blocked	1,434.3
	Channel Fill	Blocked	130.0
	Stream in Ditch	Blocked	1,897.9
	Wetland	Blocked	475.5
	Stream Parallel	Blocked	6,790.0
Slope-related	Cut/fill Slides	Blocked	3,026.0
	Deep Active	Blocked	510.0
	Fill Slides	Blocked	4,589.8
	Steep Fill	Blocked	3,112.0
	Blocked Sub Total		21,965.5
Stream-related	Channel Fill	Open	165.2
	Stream in Ditch	Open	152.5
	Stream Parallel	Open	7,570.0
Slope Related	Fill Slides	Open	49.3
	Steep Fill	Open	5,983.8
	Open Sub Total		**13,920.8**

The survey data collected and presented in this assessment provide a unique characterization of the current conditions in the watershed. However, the key word is “current”. Photographic Plate 18 illustrates how conditions changed in less than one year in the watershed and adds legitimacy to the idea that critically located roads remain risk prone for the life of the road. The photograph was taken approximately 3 months after the record setting November 2006 storm. The green highlighted segment was characterized as being stream parallel, hydrologically connected and not delivering sediment to the stream. After the storm, the road classification changed to a stream parallel “fill slide”, hydrologically connected and delivering sediment directly to the stream.

Therefore, ODF should consider resurveying the roads after a significant storm event (see recommendations).

7.4.5 Prism Stability

Surveyors measured prism stability along all open and blocked road segments in the watershed. The prism was ranked according to Prism Stability Codes (Table 32). Prism ratings categorize the extent to which a landslide or erosion is affecting a road prism. Approximately 10.5% of the open roads have significant blocking by landslides or erosion (Prism Stability Codes 1-3). Blocked roads have nearly 23% in the same categories. Maps 51 and 52 illustrate the spatial distribution of prism stability in the watershed.

Table 32. Prism stability as a percentage of the total open and closed roads by Prism Stability Code. Prism Stability Codes are defined as 1= Landslide Blocking, 2=Landslide Partially Blocking, 3=Severely Eroding, 4=Minor Erosion, 5= No Erosion

Prism Stability Code	Percent of total open road	Prism Stability Code	Percent of total blocked road
1	0.0	1	5.7
2	0.7	2	5.5
3	9.6	3	12.3
4	60.8	4	53.1
5	29.0	5	23.0

7.4.6 Stream Crossings

Road stream crossings present the greatest challenge to road engineers in terms of limiting negative impacts to aquatic resources. Stream crossing structures generally include culverts, fords, and bridges. The greatest challenge at a stream crossing is providing adequate fish passage for both adult and juvenile fish. For a discussion of fish passage see both the fish passage discussion in this chapter (below) and Chapter 9, Fish and Fish Habitat.

7.4.6.1 Condition of stream crossings

Stream crossings were evaluated in terms of the need for maintenance (Table 33). On open roads, stream crossings with AP Codes 1 and 2 (the most seriously degraded crossings) made up just 2.7% of the overall percentage of stream crossings; whereas, 29.4% of the stream crossings on blocked roads are considered in need of attention. Again, the data indicate that the blocked roads that are out of sight of managers may be in greater need of attention than the easily accessed open roads, for culverts still in place need another inspection and may need scheduled repair or removal.

Table 33. The number of stream crossings and the respective Attention Priority (AP) Codes identified and ranked during the pre November 2006 storm field assessment. The percentage of the total for each ranking is also shown.

Stream Crossing AP Codes (Open)										
# AP 1	% of total	# AP 2	% of total	#AP 3	% of total	# AP 4	% of total	# AP 5	% of total	Total # Surveyed
3	0.4	18	2.7	72	10.8	391	58.5	184	27.5	668
Stream Crossing AP Codes (Blocked)										
# AP 1	% of total	# AP 2	% of total	#AP 3	% of total	# AP 4	% of total	# AP 5	% of total	Total # Surveyed
44	17.0	32	12.4	44	17.0	102	39.4	37	14.3	259

At each stream crossing, surveyors examined the opportunity to install a cross drain that would filter most of the drainage currently destined for the stream crossing (Table 34). Approximately 30% of the current stream crossings along open roads could benefit from the installation of additional cross drains. Similar percentages exist for blocked roads; although, 44% of the stream crossings on blocked roads do not need additional filters. On both blocked and open roads, at least 30% of stream crossings have no option for increased filtering.

Table 34. Stream crossing filter opportunities are shown by the relative availability and need.

Filter Opportunities	Number	% of Total	Road Status
Available	206	30.8	Open
Unavailable	252	37.7	Open
Not Needed	210	31.4	Open
Filter Opportunities	**Number**	**% of Total**	**Road Status**
Available	68	26.3	Closed
Unavailable	77	29.7	Closed
Not Needed	114	44.0	Closed

7.4.6.2 Washout Risks

This section discusses stream crossings and sedimentation in terms of washout potential and stream crossing condition. Floods in 2006 and 2007 have shown that washout risk at stream crossings may be the most important road issue facing managers. Mills (2006) describes washout potential occurring when fill material, acting as a dam at a stream crossing, is overtopped causing a dam break flood to

occur. Much like a debris flow, the ensuing flood washes out the structural crossing material and scours out the channel downstream of the road carrying and scattering debris. Diversion occurs when water overtops the fill and diverts down along the road creating deep rills and gullies resulting in significant damage to the road and excess loading of debris to streams and creeks downslope of the diversion.

Surveyors rated every stream crossing in the Wilson River watershed for washout potential and diversion. Crossings were rated as being high, moderate, or low (Table 35, Map 53). Most stream crossings exhibited low washout potential. However, the increase in high potential from 9 to 15.4% on open to blocked roads respectively may be explained by the lack of maintenance on blocked roads. Washed-out roads only occurred along blocked roads; this is because once a washout occurs, the road is considered blocked.

Table 35. Stream crossing washout potential survey data for open and blocked roads.

Open Roads Washout Risk	Number	% of total
Low	313	46.9
Medium	295	44.2
High	60	9.0
Total	**668**	**100**

Blocked Roads Washout Risk	Number	% of total
Low	109	42.1
Medium	41	15.8
High	40	15.4
Washouts	69	26.6
Total	**259**	**100**

7.4.6.3 Inspecting and Servicing Stream Crossings

As discussed previously, stream crossings were rated for washout potential in terms of being Low, Moderate, or High. For the purposes of this analysis, we looked at stream washout potential where crossings were rated as High or Moderate and also had an Attention Priority Code of 1-3. The results for stream crossings that fit these criteria on blocked roads are found in Table 36. These crossings have the ***highest priority for inspection and repair***; these crossings have been out of sight for some time and rarely, if ever, get inspected. Road name and the distance from the start of the road are given. Note: some of these crossings may have had been inspected and repaired after the November 2006 storm.

Table 36. Stream crossings on blocked roads prioritized for inspection and maintenance. These crossings have a High or Moderate washout potential and an Attention Priority Code of 1-3. These crossings are considered a high priority for inspection because these crossing are not routinely visible to managers and may pose significant risks to the Wilson watershed aquatic resources.

RTID	Distance from road start	Road Status	Washout Potential	AP Code	RTID	Distance from road start	Road Status	Washout Potential	AP Code
1-7-11.13	1965	Blocked	H	3	2-8-25.2	4600	Blocked	H	1
1-7-33.3	2720	Blocked	H	3	Arch Cape MI	4970	Blocked	M	1
1-7-7.4	125	Blocked	M	2	Arch Cape MI	5300	Blocked	H	1
1-8-1.2	6690	Blocked	M	3	Arch Cape MI	6500	Blocked	H	1
1-8-10.5	545	Blocked	H	2	BLU CK	3715	Blocked	H	2
1-8-22.4	6770	Blocked	M	3	BLU CK	11855	Blocked	H	3
1-8-25.2	8600	Blocked	H	3	CLIN4.50	2865	Blocked	H	2
1-8-25.2	9805	Blocked	M	3	CLIN5.51	1610	Blocked	M	3
1-8-25.2	10780	Blocked	H	3	CLIN5.51	2740	Blocked	H	2
1-8-25.2	11160	Blocked	M	3	CLIN5.51	3420	Blocked	M	3
1S-8-1.0	3145	Blocked	H	3	CLIN5.51	4700	Blocked	H	3
1S-8-1.1	6895	Blocked	H	2	CLIN5.85A	1655	Blocked	M	2
1S-8-11.411	3155	Blocked	H	2	D FNCE	13245	Blocked	M	1
1S-9-18.2	650	Blocked	M	2	D FNCE	13615	Blocked	H	3
1S-9-18.2	1165	Blocked	M	3	D FNCE	13735	Blocked	M	3
1S-9-18.4	572	Blocked	H	1	D FNCE	14380	Blocked	H	1
2-7-15.3	145	Blocked	H	1	D FNCE	14540	Blocked	M	2
2-7-15.3	240	Blocked	H	2	HOSKINS	1165	Blocked	H	3
2-7-15.31	870	Blocked	H	3	HOSKINS	1665	Blocked	H	2
2-7-15.31	1035	Blocked	H	3	JONES	13880	Blocked	M	2
2-7-15.31	1500	Blocked	H	3	N FK WIL	26820	Blocked	M	3
2-7-22.3	625	Blocked	H	3	OLD CDR	6855	Blocked	H	1
2-7-22.3	930	Blocked	H	3	POLLO	620	Blocked	M	2
2-7-22.3	6435	Blocked	H	3	POLLO	725	Blocked	M	1
2-7-33.1	2400	Blocked	M	3	Powerline1	1890	Blocked	H	3
2-7-33.1	2480	Blocked	M	2	Powerline10	1810	Blocked	H	2
2-7-33.1	2555	Blocked	M	2	Powerline11	960	Blocked	M	3
2-7-33.1	4280	Blocked	M	2	Powerline11	3165	Blocked	M	2
2-8-25.2	2705	Blocked	H	1	ROGERS RD	16480	Blocked	H	3
2-8-25.2	3390	Blocked	H	1	RUSH RD	695	Blocked	H	2
2-8-25.2	1965	Blocked	H	3					

Stream crossings on open roads were also rated using a slightly different criteria than those on blocked roads. Open road stream crossings are considered a high priority for inspection if they had a High washout potential and an Attention Priority Code of 1 or 2 (Table 37).

Table 37. Stream crossings on open roads prioritized for inspection and maintenance. These crossings have a High washout potential and an Attention Priority Code of 1 and 2. These crossings are considered a high priority for inspection.

RTID	Distance from road start	Road status	Washout Potential	AP
2-8-25.1	2,915	OPEN	H	2
7CED2.25	1,240	OPEN	H	2
7CED2.25	2,760	OPEN	H	2
BEN SMITH	9,285	OPEN	H	2
CDR CK	4,750	OPEN	H	2
CDR CK	10,585	OPEN	H	2
CDR CK	12,930	OPEN	H	2
D FNCE	7,615	OPNE	H	1
E ACCESS	3,090	OPEN	H	2
FALL CK	1,275	OPEN	H	2
FALL CK	2,225	OPEN	H	1
KANSAS CK LP	2,830	OPEN	H	2
MILLS_BRDG	5,508	OPEN	H	2
N FK WIL	1,910	OPEN	H	2
N FK WIL	20,270	OPEN	H	1
NF WF	16,300	OPEN	H	2
SFWI	23,215	OPEN	H	2
SFWI1.42	7,455	OPEN	H	2

7.4.6.4 Fish Passage

Fish passage was evaluated at all stream crossings during the winter of 2006. Each crossing was rated in terms of its ability to allow fish to pass. Specifically, we evaluated if stream crossings that crossed fish-bearing streams were a barrier to adult and juvenile fishes, only juveniles, or not a barrier to fish passage. A stream was considered a fish-bearing stream if it had a Type F designation, or if fish were observed. A stream was considered likely to support fish if it did not have a Type F designation, but the stream was less than 10% gradient and had an active channel width of more than 3 feet. Table 38 contains a list of stream crossings determined to be likely or known barriers to fish passage. These stream crossings should be inspected and repaired to allow for full fish passage.

Table 38. Prioritized stream crossings on both open and blocked roads identified as being barriers to fish passage. Shown is the road name, distance from the beginning of the road, the barrier type, and the field determination of whether the stream is known or likely to support fish. **NOTE:** some crossings may have already been inspected and repaired since the November 2006 storm.

Route ID[1]	Road Status	Distance from start of road (in feet)	Barrier Type[2]	Is the Stream Fish Bearing?
JUNO	Open	14,760	AB	Known
BDAM6.45	Open	1,535	FB	Known
BDAM	Open	35,555	FB	Known
SCCK	Open	8,335	FB	Likely
SAD2	Open	3,950	AB	Likely
CLIN	Open	3,225	AB	Likely
SCCK0.53	Blocked	790	AB	Likely
SFWI	Open	24,335	AB	Likely
BDAM	Open	24,400	FB	Likely
BDAM	Open	30,625	AB	Likely
DRCK	Open	24,345	FB	Likely
BDAM	Open	28,550	AB	Likely
LAMT1.37	Open	695	AB	Likely
BDAM	Open	26,270	FB	Likely
IDCK1.56A	Open	2,425	FB	Likely
KILCH LO	Open	7,675	FB	Likely
BDAM	Open	21,025	FB	Likely
POLLO	Blocked	2,950	AB	Likely
1-7-11	Open	4,350	FB	Likely
1S-9-18.2	Blocked	2,600	AB	Likely
N FK WIL	Open	10,415	AB	Likely
SMITH	Open	2,960	FB	Likely
KNS CK	Open	3,860	AB	Likely
BVR	Open	2,580	AB	Likely
MUESL	Open	5,665	AB	Likely
KNS CK	Open	3,165	AB	Likely
1-7-9.2	Open	125	FB	Likely
BDAM	Open	9,715	AB	Likely

[1] Route ID as identified in the ODF roads database.

[2] AB = adult and juvenile barrier; FB = juvenile barrier.

7.4.7 Reducing Hydrologic Connectivity at Stream Crossings

Reducing hydrologic connectivity of roads to streams depends on engineering strategies that effectively divert road surface runoff to the forest floor where it is effectively filtered. Strategically placed cross drains perform this function. Cross drains are most often culverts 18 – 24 inches in size. Surveyors inspected each cross drain along open and blocked roads and assigned an AP Code to each drain

(Table 39). Open roads had a total of 2,491 cross drains of which 3.8% are in need of servicing. Of the 241 blocked road cross drain total, 18% require attention. Cross drains were also surveyed and rated for additional filtering opportunities (Table 39). As with stream crossings, increased filtering can divert runoff to the forest floor thereby limiting sediment loading to streams and creeks. In all, 89% of open road cross drains need no additional filters while 88% of blocked road stream crossings were determined to not need filters, indicating that ODF road planners and engineers have done an excellent job limiting sediment loading from the watershed's roadways.

Table 39. AP Codes for cross drains on open and closed roads.

Cross drains AP Codes (open)										
AP 1	**% of Total**	**AP 2**	**% of Total**	**AP 3**	**% of Total**	**AP 4**	**% of Total**	**AP 5**	**% 0f Total**	**Total**
11	0.4	83	3.4	411	16.5	1,460	58.6	526	21.1	2,491
Cross drains AP Codes (blocked)										
AP 1	**% of Total**	**AP 2**	**% of Total**	**AP 3**	**% of Total**	**AP 4**	**% of Total**	**AP 5**	**% 0f Total**	
18	7.5	25	10.4	43	17.8	128	53.1	27	11.2	243

Table 40. Filter opportunities for cross drains on open and blocked roads.

Cross drains (*open*)	**Number**	**Percent of total**
Available	114	4.6
Unavailable	148	5.9
Not Needed	2,224	89.3
(*blocked*)	**Number**	**Percent of total**
Available	28	11.6
Unavailable	56	23.2
Not Needed	159	66.0

7.4.8 Short-term Risk Analysis

7.4.8.1 Field-verified Sediment Delivery to Streams

The 2006 road assessment data may be queried in various ways to detect where road features interact. For example, in order to determine the spatial distribution and quantity of roads actively delivering sediment to streams we combined four features and queried them based on a specific attribute; hydrologic connectivity, drainage codes 1, 2, and 3, surface condition 1 and 2, and prism stability code 3. The codes are defined below to illustrate why they were queried for interaction

and used additively to determine the extent of roads actively delivering sediment to streams.

Drainage AP 1: surface drainage not controlled; surface water is causing severe erosion of road prism and needs immediate attention; unsafe to drive

Drainage AP 2: surface drainage not controlled; surface water is causing moderate erosion of road or onto steep fill; needs attention in next dry period

Drainage AP 3: surface drainage poorly controlled, potential to cause erosion of road prism or weakness in road surface; needs attention within a year

Surface Condition 1: road surface very deeply rutted or ponded, difficult or impossible driving conditions

Surface Condition 2: road surface rough or rutted (over 6 inches, or with many deep potholes or severe washboards)

Prism Stability 3: serious surface erosion or minor cutbank slump

When these feature attributes were combined and intersected with hydrologic connectivity, we found that 30 miles, or ~5% of the total roads in the Wilson River watershed, are actively delivering sediment to streams. Of those 30 miles, 16 miles, or 53% of the delivering total originates from blocked roads, while 14 miles, or 47% originates from open roads. Recall that 16% of all open and 10% of all blocked roads were hydrologically connected (Table 28). Of note is that approximately 76% of the hydrologically connected blocked roads are actively eroding into streams. In contrast, approximately 3% of the hydrologically connected open roads are actively contributing sediments to streams. Although overall hydrologic connectivity was found to be low on blocked roads, these results indicate that blocked roads are a persistent source of sediment loading in the Wilson River watershed. Hydrologically connected blocked roads need monitoring to reduce their impact on aquatic resources. A list of specific roads and the length of road potentially delivery sediment are listed in Appendix X – List of Priority Inspection Roads.

7.4.8.2 Prism Stability and Delivery of Sediment to Fish-bearing Streams

Prism stability has been rated for all road segments and discussed previously in this analysis. To better understand how prism stability may interact with the probability of landslide delivery to fish-bearing streams, road segments with a Prism Stability Code of 2 (Landslide Partially Blocking) were intersected with the results from the landslide delivery model where landslide delivery potential was considered “High”. The modeled data characterized the probability that a particular 10 meter cell on the landscape would deliver to a fish-bearing stream

during a landslide (Miller and Burnett 2007). The modeled values range from 0-1 where a value of 1 indicates that any debris flow initiated from that 10 meter pixel will reach a fish-bearing stream, and a value of 0.5 indicates that about half the debris flows from that pixel would reach a fish-bearing stream. The following categories were used for the modeled probabilities:

0.0 - .09 = "Low", 0.1 - .49 = "Moderate", and 0.5 – 1.0 = "High".

Logically, if a landslide is partially blocking a road it is probably is actively eroding. If we consider this source of sediment along with a high potential for delivery to a fish-bearing stream, we can pinpoint short term risk to aquatic resource. Thirteen individual segments on eleven individual roads were identified as meeting posing a short term risk. The road segments listed in (Appendix X – List of Priority Inspection Roads) should be monitored to determine if maintenance is required to limit the sediment delivery to fish-bearing streams.

Table 41. Road segments rated with a Prism Stability Code of 2 (landslide partially blocking road) and the modeled high potential delivery to a fish-bearing stream. Segment distances are given in feet from the start (MP 0.0) of the road.

RTID	Segment Starting Distance (feet)	Segment End Distance (feet)
1-8-1.2	4,500	4,700
1-8-22.3	850	1,200
1-8-22.3	4,525	4,725
1-8-22.4	7,265	7,465
1-8-33	2,520	2,800
ARCH CAPE MI	7,600	7,800
ARCH CAPE MI	8,000	8,200
CLIN5.85A	4,435	4,730
DRCK	24,725	25,085
FALL CK	2,125	2,325
N FK WIL	29,220	29,720
RUSH RD	950	1,150
SFWI	25,500	25,700

7.4.9 Long-term Risk Analysis

7.4.9.1 Critical Location and Debris Flow Risk to Fish-bearing Streams

Data were compared from two independent sources; one source was modeled and one source was field derived, to investigate the interaction between road critical location and the landslide delivery potential to a fish-bearing stream. The

modeled data characterized the probability that a particular 10 meter cell on the landscape would deliver to a fish-bearing stream during a landslide (Miller and Burnett 2007). The modeled values range from 0-1 where a value of 1 indicates that any debris flow initiated from that 10 meter pixel will reach a fish-bearing stream, and a value of 0.5 indicates that about half the debris flows from that pixel would reach a fish-bearing stream. Field derived data were collected to describe the extent of critically located roads and have been discussed in detail in earlier sections.

The following categories were used for the modeled probabilities:

0.0 - .09 = "Low", 0.1 - .49 = "Moderate", and 0.5 – 1.0 = "High".

We looked at road segments where the highest slope severity categories (in this case it was limited to Fill Slides) intersected a high potential of landslide delivery to a fish bearing stream. The results are shown in Table 42. These road segments should be field inspected to determine if the fill slides identified in the road survey pose a long-term risk to the aquatic resource.

Table 42. Road segments where field derived high slope severity critical locations were intersected with high modeled landslide delivering potential to a fish bearing stream. Segment distances are given in feet from the start (MP 0.0) of the road. These roads potentially pose a long-term risk to the aquatic resources of the Wilson and should be inspected.

RTID	Segment Starting Distance	Segment End Distance	RTID	Segment Starting Distance	Segment End Distance
1-8-1.2	4,500	4,700	1-8-25.2	16,000	16,400
1-8-1.2	5,650	5,800	1-8-33	2,520	3,890
1-8-1.2	6,250	6,400	ARCH CAPE MI	7,600	7,800
1-8-1.2	7,050	7,500	ARCH CAPE MI	8,000	8,200
1-8-1.2	8,300	8,600	ARCH CAPE MI	8,400	8,600
1-8-1.2	9,000	9,450	KANSAS CK LP	1,900	2,400
1-8-1.21	600	1,180	N FK WIL	29,210	29,720
1-8-1.24	130	300	SFWI	27,030	27,600
1-8-22.4	2,250	2,700	UFAL	25,550	26,780
1-8-22.4	3,665	3,925			

7.4.10 Roads with Higher Long-term Risk

The 2006 field assessment of stream crossings in the Wilson River watershed rated each stream crossing and cross drain for various attributes including but not limited to; washout potential, diversion, and structural integrity. Afterward, the November 2006 flood occurred that significantly altered many stream crossings throughout the watershed. The Tillamook District road engineers' surveyed the storm-affected roads and crossings and produced a "coarse scale" map of impacted areas that was later head-up digitized into GIS (Map 54). ODF engineers tallied 53 sites impacted by the November 2006 storm and rated the impacts as either High or Low.

An analysis was conducted using a combination of critically located road segments that also had at least one stream crossing with a high wash out potential (Table 43). These roads need to be inspected and possibly vacated to limit negative impacts to aquatic resources. We determined that if a road has a Risk Index of 0.50, it would require pulling back steep fill and stream crossings where accessible by equipment. When it is not feasible to get equipment to a particular site, crews could hand construct overflows at high washout risk culverts.

Table 43. Roads rated by a "Risk Index". The index was calculated by finding the product of critically located road segment length and a critical severity category. Critical Severity categories include Highest = 5, High = 3, Moderate = 1, and Elevated = 0.5. The product was then added to a high washout potential rating of 20 for every high washout potential occurrence along a critically located segment. Then for each complete road length the individual segment values were summed and then divided by the total road length to determine the overall Risk Index. The high Risk Indices may indicate the need to vacate a road. **Road segments with a risk index of >0.50 are shown in bold and are the highest priority for inspection.**

RTID	STATUS	(Segment Lengths * Critical Risk Factor + High Washout Potential) (SUMMED)	Total Road Length	Risk Index
2-7-15.31	**BLOCKED**	**6,385**	**1,630**	**3.92**
2-7-22.3	**BLOCKED**	**6,270**	**7,400**	**0.85**
BLU CK	**BLOCKED**	**11,140**	**13,520**	**0.82**
OLD CDR	**BLOCKED**	**8,820**	**14,725**	**0.60**
SFWI2.65	OPEN	2,337.5	7,135	0.33
1S-8-11.4	OPEN	1,135	3,625	0.31
E ACCESS	OPEN	1,857.5	6,140	0.30
2-8-25.1	OPEN	980	4,075	0.24
TILLISON CK	OPEN	2,025	8,595	0.24
NF WF	OPEN	5,647.5	29,235	0.19
KANSAS CK LP	OPEN	1,260	7,310	0.17
SFWI	OPEN	6,425	39,785	0.16

RTID	STATUS	(Segment Lengths * Critical Risk Factor + High Washout Potential) (SUMMED)	Total Road Length	Risk Index
MUESL	OPEN	3,080	19,145	0.16
N FK WIL	OPEN	2,432.5	23,120	0.11

Further analysis was conducted on critically located roads that did not have stream crossings with a High washout potential (Table 44). Interpreting the indices requires professional judgment. As mentioned before Blocked roads with an Index of over 0.5 should be pulled back where feasible. Open roads with an Index between 0.25 and 0.5 should be improved or relocated and those over 0.5 should be vacated.

Table 44. Critically located roads rated by a "Risk Index". The index was calculated by finding the product of critically located road segment length and a critical severity category. Critical Severity categories include Highest = 5, High = 3, Moderate = 1, and Elevated = 0.5. Then for each complete road length the individual segment values were summed and then divided by the total road length to determine the overall Risk Index. The high Risk Indices may indicate the need to vacate a road.

RTID	STATUS	Segment Lengths * Critical Risk Factor (SUMMED)	Total Segment Length	Risk Index
2-7-22.7	BLOCKED	4,625	925	5.00
2-7-15.31	BLOCKED	6,325	1,630	3.88
2-8-24	BLOCKED	5,050	1,310	3.85
1-7-36.31	BLOCKED	12,160	2,335	2.60
1-8-10.5	BLOCKED	5,225	2,375	2.20
1-8-1.21	BLOCKED	7,605	1,180	2.15
1-8-1.24	BLOCKED	1,125	750	1.50
1-8-33	BLOCKED	5,192.5	4,190	1.24
1S-8-1.0	BLOCKED	15,987.5	14,795	1.08
LIL NF	BLOCKED	8,005	7,410	1.08
BLU CK	BLOCKED	26,320	13,520	0.97
2-7-16.2	BLOCKED	1,950	2,280	0.86
2-7-18.2	OPEN	4,987.5	6,040	0.83
1-8-23.2	BLOCKED	1,335	1,655	0.81
2-7-22.3	BLOCKED	23,325	29,600	0.79
1-7-12.1	OPEN	2,512.5	3,200	0.79
1-8-1.24	BLOCKED	1,125	1,500	0.75
1S-8-6.3	BLOCKED	2,550	3,530	0.72
CLIN5.85A	BLOCKED	18,975	26,720	0.71

RTID	STATUS	Segment Lengths * Critical Risk Factor (SUMMED)	Total Segment Length	Risk Index
2-7-15.3	BLOCKED	2,960	4,240	0.70
2-8-25.4	BLOCKED	1,000	1,455	0.69
1-7-36.2	BLOCKED	2,770	4,190	0.66
1S-8-8.7	BLOCKED	1,200	1,910	0.63
1-8-33	BLOCKED	5,192.5	8,380	0.62
2-7-32.4	BLOCKED	2,150	1,760	0.61
1-7-36.3	BLOCKED	4,220	7,315	0.58
N FK WIL	BLOCKED	5,480	9,985	0.55
1-8-1.2	BLOCKED	8,037.5	14,725	0.55
HOSKINS	BLOCKED	2,500	4,605	0.54
1-7-31.11	BLOCKED	1,350	2,500	0.54
2-8-25.1	OPEN	2,200	4,075	0.54
CST RNG LP	OPEN	2,782.5	5,225	0.53
1S-7-10.55	BLOCKED	4,175	4,070	0.51
1-8-36.2	BLOCKED	47.5	95	0.50
N FK WIL SP2	OPEN	255	510	0.50
1S-8-1.2	OPEN	270	540	0.50
W FK WIL SP1	OPEN	185	370	0.50
N FK WIL SP3	OPEN	135	270	0.50
CST RNG LP	BLOCKED	757.5	1,515	0.50
SFWI0.29	OPEN	285	570	0.50

Table 45. Roads identified as having the stream running in the ditch. These roads should be inspected and repaired. Roads determined to have the stream running in the ditch were distributed evenly among open and blocked roads.

Route ID	Segment Distance (in feet) from Road Beginning	Segment Length (feet) in Ditch
1-7-11.13	2,120	895
1-8-21.5	3,545	130
1-8-21.5	2,800	375
2-7-15.3	930	1,040
2-8-26.2	245	140
CDR CK	12,930	470
CLIN	7,600	200
CLIN4.50	2,410	455
GILMR	2,000	315
SFWI	10,595	240
SFWI	29,025	200
Total		**4,460**

7.4.11 Road Findings and Recommendations

This analysis evaluated forest roads in the Wilson River watershed using a survey protocol developed by ODF to rapidly assess the risk roads pose to aquatic resources. The survey, conducted in 2006, found that culverts at stream crossings are one of the most important road features in terms of the need for ongoing inspection and repair. Severe storms in the winter of 2006 and 2007 caused failure at many crossings and illustrated the vulnerable nature of stream crossings. Based on survey data, we found many stream crossings with a high wash-out potential including many on blocked roads that are not routinely inspected. We have identified stream crossings with high washout potential and in need of servicing. These crossings are listed in Tables 36 (on blocked roads) and 37 (on open roads). Managers need to inspect these crossings to determine if the current structure needs to be removed and replaced. Inspection of critical stream crossings should occur during high flow events. Repairs should include removing debris, constructing dips, and constructing berms in the ditch at the lower spot on the stream crossing fill.

Surveyors also rated fish passage at all stream crossings. We found 28 stream crossings that blocked fish passage. Those stream crossings are listed in Table 38 and are in need of inspection and repair.

Hydrologic connection on both open and blocked roads is relatively low. Open roads have a higher percentage of hydrologically connected segments than blocked roads. Managers should evaluate hydrologic connectivity while upgrading and repairing roads. Significant storms may change the hydrologic connectivity of a road. Therefore, monitoring roads after storms to determine hydrologic connectivity is critical.

Considering hydrologic connectivity alone does not tell the complete story of forest roads and sediment delivery to streams. We found that while hydrologic connection of blocked roads was relatively low, the majority of hydrologically connected blocked roads actively loaded sediment to streams. Segments identified as actively loading sediment to streams are identified in Appendix X – List of Priority Inspection Roads. These roads should be inspected and repaired if needed.

The proportion of open roads in higher resource risk critical locations in the Wilson River watershed is similar to other nearby watersheds. The percentage of blocked road segments determined to have cut and fill slides (i.e., high slope severity) was 10 times greater than the percentage of cut and fill slides for open road segments. Blocked roads were determined to have 3 times more of their

total length that contained fill slides than did open roads (Table 30). Table 42 identifies specific road segments that may pose a long-term risk where slope severity intersects with high potential for landslide delivery to fish bearing streams. These road segments should be inspected to determine if maintenance is needed to prevent future delivery to fish-bearing streams.

Open roads in the Wilson River watershed typically have stable prisms. Blocked roads are less stable and pose a greater risk to the aquatic resource. (Table 32). Road segments that are unstable and have a high potential for landslide delivery to fish-bearing streams should be inspected in order to prevent future delivery to fish bearing streams (Section 7.4.9 Long-term Risk Analysis).

In all, the road system has been designed to limit impacts to aquatic resources. Yet, problems persist, especially at stream crossings where wash out potential is high and where fish passage is blocked . The data summarized in this analysis directs managers to road segments that are a high priority for inspection, repair or removal.

7.5 Recreation-Related Issues

7.5.1 Off-Highway Vehicle Trails

7.5.1.1 Methods

During the 2006 road inventory, approximately 42 miles of trails were surveyed by Duck Creek Associates on the basis of the OHV-Designated trail map and field-based convenience sampling. Queries were made to determine which of the surveyed trails segments were hydrologically connected, parallel to streams or exhibiting erosion. For the purpose of this study, trails were determined to be hydrologically connected when water intercepted by the *trail* prism flows down the *trail* directly to a stream, road drainage feature or culvert that flows to a stream (after Mills et al. 2007). A sample of 13 hydrologically connected trails was selected from the Duck Creek Associates inventory and recommendations from ODF staff during field reconnaissance trips. These hydrologically connected trails were assessed for washout risk using 1) trail grade, 2) slope alignment angle, 3) distance to steam/road drain, 4) water drainage off trail, 5) topographic position, and 6) soil texture. Attempts by ODF to prevent or repair problems were also noted.

7.5.1.2 Results

Sedimentation is most acute where eroding trails intersect adjacent streams or road drainage systems linked to streams. Trail intersections that are then indirectly linked to streams should be considered high priority for management actions. ODF estimates that the Wilson River watershed has approximately 150

miles of designated trails but undesignated trails have not been systematically surveyed except where they intersect roads (noted as a "feature" during the Duck Creek Associates road survey; refer to Appendix M – ODF Roads Protocol). Table 46 below indicates that of the trails surveyed (42.7 total miles) by Duck Creek Associates, 2.1% had hydrologic connectivity and 2.1% ran parallel to streams (Map 55). Data were unavailable for determining the percentage of other unsurveyed user-created trails that were connected or parallel to streams and more accurate figures, therefore, were not available. A limitation of method is that it may vastly underestimate the impact of OHV trails because the Duck Creek Associates survey was not a census, but a selection of 28% of designated trails and ~5% of undesignated trails. Undesignated trails are not maintained or repaired and tend to have steep gradients, high erosion, and impaired drainage.

Table 46. Incidence of hydrologically connect trails. The table shows the percentages of trails found during the Duck Creek Associates road survey to be associated with sedimentation risks.

Trails	Total # Feet Surveyed	Total Miles	% of Crossings Surveyed
150* miles of designated OHV trails	225,580	42.7	28.4
Hydrologic Connectivity	16,065	3.1	2.1
Parallel To Streams	17,030	3.2	2.1
Prism AP 1**	0	0.0	0.0
Prism AP 2**	5,020	1.0	0.01
Prism AP 3**	25,130	4.6	3.1

Stream Crossing Washout Potential (N=74)	Rating	# of Crossings	% of Crossings
	High	18	24.3
	Moderate	17	23
	Low	39	52.7

* exact total OHV mileage within the watershed has yet to be confirmed (does not include all user-created trails
** **AP** Attention Priority Code (see Appendix M – ODF Roads Protocol and a discuss in this chapter, section 7.4 Road-Related Issues)

1 – surface drainage not controlled; surface water is causing severe erosion of road prism and needs immediate attention; unsafe to drive
2 – surface drainage not controlled; surface water is causing moderate erosion of road or onto steep fill; needs attention in next dry period
3 – surface drainage poorly controlled, potential to cause erosion of road prism or weakness in road surface; needs attention within a year
4 – road surface is not draining fully, damage not observed, drainage water not flowing into potentially unstable locations
5 – surface drainage is functioning properly

7.5.2 OHV Trail-Stream Intersections Affecting Water Quality

Data from the field assessment of hydrologically connected trails indicate a high likelihood of water quality effect on trail-stream intersections that have had no mitigating trail drainage engineering, bridging, and/or that exhibit trail grade/slope alignment in excess of trail standard maximums. This question cannot be fully answered without a full census of the designated and undesignated trail system. The Duck Creek dataset of designated trails identify hydrologically connected trails, including those that were parallel, and those with prism stability concerns. From the table above only 3.11 miles of sampled trails were found to have Prism Stability Priority Codes of 1-3 and were mostly concentrated in the Devil's Lake Fork and South Fork subwatersheds (Map 56). Almost half of the stream crossings were found to have "high" or "moderate" washout potential. The dataset only recorded hillslope, not slope alignment or trail grade; two important predictors of washout risk. While "hillslope" is a good indicator, to identify washout risk, all three characteristics need to be recorded.

7.5.3 OHV Trail-Road Intersections Affecting Water Quality

The results of Duck Creek Associates road survey provide an indication of the degree to which hydrologically connected trails may be a problem. To further understand the impacts of hydrologically connected trails, 13 hydrologically connected trails (identified during the road survey) were field-surveyed and the results are presented in Table 47. Results indicate that trail-stream and trail-road intersections are very likely to adversely affect water quality due to the predominance of steep grades, fall line slope alignment and poor drainage (see Photographic Plates Photographic Plate 19, Photographic Plate 20, and Photographic Plate 21 for some examples). Trail construction guidelines from the AMA[60] and IMBA[61] recommend trail grades that average 10% and slope alignment that is no greater than half the grade of the sideslope.

The majority of hydrologically connected trails sampled at trail-road and trail stream intersections violated these recommended maximums. For example, 77% of sample trails exhibited an alignment in the 0-22 degree range which means they run directly down the fall line. When trails follow the fall line, water can't be directed off the trail with normal outslope of the tread path or with drainage dips placed at intervals. Rolling grade dips (RGDs) that reverse the trail grade can divert water but the dip needs to be constructed and maintained so that water and eroded material has a place to go to. Sump holes are typically used along

[60] Off Highway Motorcycle & ATV Trails Guidelines for Design, Construction, Maintenance and User Satisfaction 2nd Edition. Joe Wernex American Motorcyclist Association 1994
[61] Trail Solutions: IMBA's Guide to Building Sweet Singletrack. International Mountain Bicycling Association 2006

designated OHV trails to serve this function but rainfall and erosion patterns often make these a short-lived solution.

Many of the worst hydrologically connected trails are undesignated or user-created with no regard for design standards. Furthermore, none of the undesignated trails are maintained as they are not part of ODF's OHV-designated trail system. These undesignated trails have high impacts on water quality and are common enough throughout the watershed to be a concern. Given the quantities of sediment originating from trails indicated by the CSA profiles, sediment delivery is likely across the trail system especially on high-gradient hydrologically connected trails. Designated OHV trails should continue to be given maintenance/correction action priority as they likely receive the most use. However, the undesignated trails identified by the Duck Creek Associates dataset should also be assessed.

Table 47. Washout potential of hydrologically connected trails showing the results of 13 trails assessed using parameters that indicate the degree of washout risk.

Inventory Indicator	Sample Points	Percent
Trail Grade		
0-2%	1	8
3-6%		
7-10%	1	8
11-15%	1	8
16-20%	1	8
21-30%	4	30
>31%	5	38
Slope Alignment Angle (degrees)		
0-22	10	77
23-45		
46-68	3	23
69-90		
Distance to Creek or Road Drainage Features		
Within 25 ft	10	77
Within 26-50 ft	1	8
Within 51-75 ft		
Within >75 ft	2	15
Water Drainage off Trail		
0%	4	30
25%	6	46
50%	1	8
75%	1	8
100%		
Topographic Position		
Valley	5	38
Midslope	5	38
River edge	3	23
Soil Texture		
Sandy Clay Loam	11	85
Clay Loam		
Silty Clay	2	15
Sandy Loam		
Loam		
Silt Loam		

An additional OHV trail problem included Table 47 results are the predominance of trails within 25 feet of streams or road drains that also have poor drainage. Soil texture also presents a picture of trails that are easily eroded, don't absorb water very well and compact readily – not good characteristics for sustainable trails.

7.5.4 Hydrologically Connected Trails

The Road Survey conducted by Duck Creek Associates assessed approximately 28% of the total trail system (of an estimated 150 miles) and found that 7.3% was hydrologically connected (Map 55). Because the exact number of OHV trails in the basin are unknown, this may not be a representative sample of the whole designated and undesignated trail network.

7.5.5 Trail Erosion Condition

While ODF is undertaking a program of trail realignment and drainage construction, many of the trails are on legacy routes – logging skid roads and firebreaks – that are steep, fall-line and without drainage structures. This makes the high use levels produce active erosion conditions on most trail surfaces (Map 56). The field assessment of trails found more highly eroding, hydrologically connected trails than were identified by the Duck Creek Associates survey, suggesting a greater degree of erosion than previously indicated.

7.5.6 Recreational Trail Network and Streams

Preliminary results from the Duck Creek Associates database (summarized in Table 46) show that 3.1 miles of the 42.7 DCA-surveyed miles of trails are located parallel to streams. ODF estimates that there are 150 miles of OHV trails in the basin. Using this estimate, we can extrapolate to the entire basin and surmise that about 10 miles of designated trails are hydrologically connected. However, it is yet to be calculated as a percentage because of the total user-defined, designated AND undesignated trail length as it is still unknown.

7.5.7 Recreational Trail Washout Risk

Trail impact studies indicate that rainfall intensity and slope gradient are key factors explaining variations in soil loss on trails[62]. Two additional key indicators of washout potential are slope alignment and the length of trail following the fall line. Field data within the Wilson-Trails geodatabase does not contain these indicators so they were included in the field assessment of a sample of 13 hydrologically connected trails. During the field surveys of an additional seven

[62] Wilson and Seney. 1994. Mountain Research and Development, Vol. 14, No 1, 1994, pp77-88. Erosional Impacts of Hikers, Horses, Motorcycles and Off-Road Bicycles on Mountain Trails in Montana.

(7) hydrologically connected OHV trails, trail segments were quantified using cross-sectional area to estimate soil loss from the tread at the sample point since trail creation. Accurate and precise cross-sectional area measures require different procedures based on the type of trail, relationship to terrain and erosion. The cross-sectional area surveys differentiate between historical soil loss episodes (legacy road washouts), more recent recreation-related erosion and washouts.

7.5.7.1 Methods

Oregon Department of Forestry OHV maps, district recreation staff advice and survey records from the Wilson-Trails geodatabase were used to identify a small sample of hydrologically connected trails to measure washout risk and soil loss. The size of the watershed, the number of trail miles, and limitations on fieldwork did not allow for a statistically representative sample or a census of all trails in the watershed. The convenience sample was drawn from the trail system to represent potential washout sites based on a representative set of designated trails around the watershed and of each kind of use, including 1) Motorcycle (MC), 2) Motorcycle/Quad (MC/Q) and four-wheel drive (4WD).

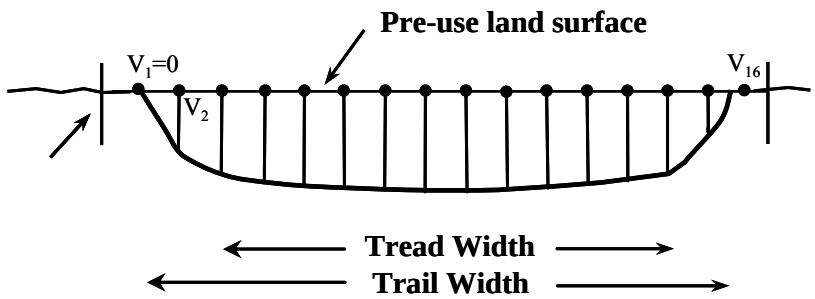
Upon locating the target hydrologically connected trail segment, a GPS device was used to document each trail's location and the length of hydrologically connected trail was determined by ground inspection. The assessment followed trail monitoring standards developed by Marion[63] and were modified to measure just the length of trail with hydrological connectivity. Trail conditions were assessed using point sampling procedures, and included measurement of trail length, width, and soil loss since trail creation using a cross-sectional area procedure. Trail condition measurements were taken at transects spaced at fixed intervals along each sample section of trail. Vertical measurements taken at 0.3 foot intervals along each trail transect were recorded on a field datasheet, and then the cross-sectional area was calculated using Microsoft Excel spreadsheet formulas. The number of transects for each trail was dictated by the length of the hydrologically connected section (normally, the number is proportional to the trail's full length).

Sample point locations were measured at intervals. At each sample point, string-line transect were established perpendicular to the trail tread as illustrated in Figure 36 and Photographic Plate 22 and Photographic Plate 23. The tread width was defined by boundaries at the edge of the obvious wear pattern (vegetation loss, soil exposure) capturing about 95% of all trail traffic. Trail width was

[63] Trail Monitoring Manual – Daniel Boone National Forest Dr. Jeff Marion, USDI, US Geological Survey, Patuxent Wildlife Research Center, Virginia Tech/Department of Forestry (0342) Blacksburg, VA 24061.

assessed only across the bottom of the eroded tread, excluding the steep sides that are not actively impacted by tires. The key characteristic of OHV wear and tear is that travel patterns on active trails can be all the way across the available tread path and beyond depending on the individual (speed, skills, momentum). Measures were taken to avoid including historical wear that had previously incised a trail (old skid road or wear episode) by not including recently undisturbed organic surfaces or re-vegetated edges or old cutbanks.

Figure 36. Cross-sectional area diagram illustrating measurement procedures. (from Marion, 2004)



Vertical distances from the string line down to the trail tread provided the trail depth measures. Trail condition measures were calculated for each trail and for all trails combined, including area of disturbance, cross-sectional area, and mean trail width, depth, and cross-sectional area (Table 48). The "area of disturbance" is an estimate of the land area intensively disturbed by OHV traffic, and was calculated by multiplying trail length by mean trail width. cross-sectional area volume, an estimate of aggregate soil loss (cross-sectional area ft^3), was calculated by multiplying mean cross-sectional area (converted to ft^2) first by sample segment then by total trail length (See Table 49).

Table 48. Description of trail impact indicators and calculation methods.

Variable	Description
Trail Length	Length of informal trail, summed to obtain an aggregate measure for each study area.
Tread Width	Width of tread that captures about 95% of all traffic. Assessed at sample points along each informal trail and averaged for each trail to obtain mean trail width.
Trail Width	Width of trail, including tread and trail-sides up to pre-use land

Variable	Description
	surface. Assessed at sample points along each informal trail and averaged for each trail to obtain mean trail width. Mean trail width for study areas was calculated as the area of disturbance for each trail divided by total length.
Area of Disturbance	The mean trail width times the trail length.
CSA	The cross sectional area from the pre-use land surface to the tread surface. Assessed at sample points along each informal trail and averaged for each trail to obtain mean cross-sectional area. Mean cross-sectional area for study areas was calculated as area of disturbance times mean trail depth
CSA Volume	The mean cross-sectional area for a trail times trail length – an estimate of the total volume of soil lost from a trail.
Mean Trail Depth	Calculated by dividing mean cross-sectional area by mean trail width.

7.5.7.2 Results

Seven sample segments of trail were measured for mean trail width and length to provide estimates of soil disturbance (area in ft^2) shown in Table 49 below. This was then multiplied by the trail length (from OHV map data) and then summed across all types indicating an average disturbance area of 2 acres per mile of trail.

Table 49. OHV erosion quantities (area) along hydrologically connected (HC) trails showings erosion quantities (area) for select OHV trails.

Sample HC Trail Segment	Sample HC Trail Length (ft.)	Mean Trail Width (ft.)	Sample HC Trail Area of Disturbance (ft^2)	Total Trail Length (ft.)	Total Trail Area of Disturbance (ft^2)
1. Quarry #44	225	8.4	1,890	1,742	14,633
2. Military #43	475	8.5	4,038	10,560	234,766
3. Beaver Dam MP 5 (renegade)	240	6.1	1,464	2,640	16,104
4. Cobmaster #66 drop off	200	5.9	1,180	200	1,180
5. Firebreak Five #14	520	17.1	8,892	9,504	162,518
6. University Fire Power #10	1,300	14.4	18,720	6,336	91,238
7. Highway Access #80	910	6.5	5,915	910	5,915
Totals:	3,870		42,099	31,892	526,354
Sample HC length is 12 % of total trail length (6 miles)			**Totals in Acres**		12.1
			Acres/Mile		2.0

Seven sample segments of trail were measured for mean cross-sectional area, mean trail depth and length to provide estimates of soil disturbance (volume in ft^3) shown in Table 53 below. The estimate of soil erosion volume per mile was also derived for each sample trail. Volumes were totaled across all types indicating a combined disturbance volume of 22,893 cubic feet over a combined sample trail length of 3,870 feet. This results in a combined total of 1,157 cubic yards of soil loss extrapolated to estimate volume per mile of trail. It is suspected that the variability of the trail conditions makes extrapolation beyond the sample length difficult to do especially across different types of trail. However, this indicates that hydrologically connected OHV trails are a significant source of sediment, especially considering the year round nature of use and the back log of repair and closure facing ODF staff. Where ODF has placed and maintained drainage features on designated trails, the sediment is diverted to the forest, but on unmaintained hydrologically connected trails, sediment can flow down to drainages (stream and/or road drainage systems).

Table 50. OHV Erosion Volume along hydrologically connected trails. This table shows erosion quantities (volume) for select OHV tails (based upon mean cross-sectional area [CSA] measures).

Hydrologically Connected Sample Trail Segment	Mean Trail Depth* (in)	Mean Trail Width (in)	Mean CSA (in^2)	Trail Erosion Volume		
				Length(ft)	(ft^3)	(ft^3/mi)
1. Quarry #44	8.3	100.5	832	225	1,300	30,507
2. Military #43	4.5	102	461	475	1,520	16,896
3. Beaver Dam MP 5 (renegade)	3.6	73.5	264	240	432	9,504
4. Cobmaster #66 drop off	4.5	70.5	320	200	440	11,616
5. Firebreak Five #14	9.2	205.5	1,886	520	6,812	69,168
6. University Fire Power #10	6.8	173	1,182	1,300	10,660	43,296
7. Highway Access #80	3.5	79	269	910	1,729	10,032
Totals:				3,870	22,893	31,241
			Totals in yards^3		848	1,157/mile

* Mean trail depth for all vertical measurements. NOT the average of profile mean trail depth.

ft^3 = length x Mean cross-sectional area

ft^3 /mile = (5,280/Length) X ft^3

The average trail depth was also calculated per sample segment.
CSA Volume: The mean CSA for a trail times trail length – an estimate of the total volume of soil lost from a trail.
e.g., Quarry Trail: 225 x 12 = 2700 (trail length in inches) x 832 = 2,246,400 (in^3) x .0005787 = 1,300 ft^3 for estimated erosion volume in cu ft. Expressed in volume of soil loss per mile as (1300 x 5280)/225 = 30,507 ft^3/mi.

Erosion associated with old road/skid trails was effectively accounted for by not measuring early era incision profiles (explained, previously, in the methodology). It would be helpful in future trail assessments, however, to differentiate between trails on old logging roads/skids and those newer ones that have been established by users or by ODF. Trails 1, 2, 3, 4 and 7 in table 51 are sample segments of trails established by users or ODF and recorded a combined soil loss total of 515 cubic yards per mile.

Table 51 below summarizes two other measures of trail condition that are associated with sedimentation and washout risk: fall-line slope alignment and the presence of secondary or braided trails. The presence of secondary or braided trails indicates problems in the trail section itself that could be from other factors (e.g., rutting or obstacles). They are, however, intuitively related. No statistical tests were performed to determine if these two factors were significantly related.

The ODF trail layer did not include braided trail length which could multiply the mileage of actual trail on the ground by a factor of seven[64]. Future trail mapping should include the length of secondary or braided trail sections associated with the main route.

Table 51. OHV sample of hydrologically connected trail braiding and fall-line showing the percent fall-line and the number of secondary tails associated with the select OHV tails (secondary trails indicate problems).

Hydrologically Connected Sample Trail Segment	Secondary Trails (#)	% of Trail Direct Ascent (Fall Line)
1. Quarry #44	13	22.0
2. Military #43	14	26.0
3. Beaver Dam MP 5 (renegade)	6	100.0
4. Cobmaster #66 drop off	4	87.5
5. Firebreak Five #14	5	91.0
6. University Fire Power #10	6	85.0
7. Highway Access #80	3	58.0
Total	51	

[64] The total number fo secondary trails across the 7 assessed trails was 51 (a bit over 7 times). Therefore, this is a rough indicator of the degree of braiding among these 7 samples segments. However, not enough trail segments were able to be measured to make an estimate for the entire system.

7.5.8 Overall Condition of OHV Trails

Fieldwork and database inventory analysis results indicate that OHV trails in the watershed exhibit a variety of conditions that are having low to severe impacts on water quality. Although the total number of miles of all trails (both designated and undesignated) in the forest is unknown (see the Data Gaps and Limitations section, below), data from the Duck Creek Associates road survey, combined with data in the OHV trails database, indicate that at least 22% of the currently-used OHV trail system in the forest could be user-created[65]. Such undesignated trails are currently not managed by ODF and, therefore, are more likely to be negatively impacting water quality.

Field surveys of the OHV trails found that designated OHV trails also are contributing to water quality problems either directly at road or stream intersections or indirectly by contributing sediment to hydrologically connected drainage systems. Of the 42 trail miles assessed by Duck Creek Associates, 28% were found to be at risk of sedimentation. Extrapolated to the entire watershed, this would indicate that as much as 41 miles of the 150 designated OHV trail miles pose a sedimentation risk. Of the hydrologically connected trail segments that were assessed in the field, extremely high levels of disturbance and erosion were noted with an average soil loss of 2 acres and 1,157 cubic yards of soil loss per mile. Additionally, all the soil loss resulted from relatively recent activities as the cross-sectional area measures were taken only on the active tread wear area. For reference, a 4 foot wide motorcycle trail should only have a disturbed area of 0.485 acres/mile, a 6 foot wide motorcycle/quad trail should have a disturbed area of 0.728 acres/mile and a 10 foot wide four-wheel drive trail should have a disturbed area of 1.214 acres/mile. The Firebreak Five four-wheel drive trail ("FB5" in the Duck Creek Associates road assessment GIS layer), on the other hand, a ridgetop boundary road located between the Little North Fork and Middle Wilson subwatersheds, had a footprint of 3.74 acres/mile. In order to calculate an annual estimate of soil loss, yearly monitoring would be required.

7.5.8.1 Data Gaps and Limitations

Off-highway vehicle trails, both designated and undesignated, in the Wilson River watershed are not accurately mapped or, in the case of the undesignated trails, not mapped at all. ODF has a GIS layer representing trails mapped over the last 15 years, but staff stated it is not up to date and only covers main routes, not all the myriad of user-created trails, braiding and "play" areas. An accurate calculation of the total number of miles of OHV trails currently utilized,

[65] Estimate derived from the DCA road survey showing that 36 points in the Forest Grove and 56 points in the Tillamook districts had trail/road crossings that could not be accounted for in the ODF OHV trail database (92 of 413; 22.3%).

therefore, is not possible and field assessments conducted for this watershed analysis were only able to provide a rough estimate.

7.5.8.2 Recommendations

- Management of the system is being hampered by a lack of accurate and up-to-date inventory data. Therefore, we recommend an immediate and full inventory of the OHV trail system with a particular focus on the undesignated trails.

- The inventory should include a trail census, sample sites and permanent monitoring points where erosion quantity and rate data can be calculated. In order to get an accurate system-wide estimate of erosion, trail impact measures (e.g., cross-sectional area profiles) should be taken at intervals along the length of the trail.

- Because data from the detailed road assessment indicate that hydrologically connected sections are most likely to impact water quality, the inventory strategy should place priority on hydrologically connected trails and trail segments.

- Additionally, for each type of trail (e.g., motorcycle, motorcycle/quad, four-wheel drive), ODF should develop acceptable targets for average maximum soil loss (ft^3/mile) and disturbed area (acres/mile). These targets could then be used as indicators of overall trail "health" and sustainability.

7.5.9 High Priority Trail Segments

Trail design guidelines and impact studies indicate that certain key characteristics create the highest potential for washouts and erosion problems. Duck Creek Associates trail survey data revealed that almost half of the designated OHV trails had moderate to high stream crossing washout potential. An additional field erosion assessment sample (representing all OHV types) found that a majority of trail segments were exhibiting key washout risk indicators. For example, 77% of trails segments surveyed ran down the fall line and 84% had trail grades in excess of 11 degrees.

Recreation staff and volunteers have taken on and accomplished a massive amount of work dealing with a trail system that included many ill-sited legacy roads and trails used by an increasing number of OHV users. The problem trails focused on in this report are those near streams and while ODF has managed to divert and or bridge all of the designated trail/stream crossings, the field work indicated much work still to be done on user created trails. Steep gradient trails on steep slopes following the fall-line are very problematic, regardless of how

many rolling grade dips are placed. Rolling grade dips that are placed on problem trail sections are not as effective as rolling grade dips designed into new trails. ODF has placed drainage features on much of the designated trail system and water is effectively diverted off trail to deposit into the forest. Where trails are hydrologically connected, sump holes can be effective in trapping sediment, but without maintenance they become filled and overflow. It is good start, but Rerouting the trail away from road drains and streams or off the steep side slope is a better long-term solution.

7.5.9.1 Data Gaps and Limitations

A lack of geographic data in the OHV trail inventory database resulted in difficulties in identifying the geographic locations of problem trail segments. Field assessments conducted for this watershed analysis, however, provided insight into the trail characteristics that are causes for concern within the Wilson River watershed (discussed in greater detail in the Recommendations section, below). Additionally, the ODF OHV trail inventory database provided good baseline data on site conditions but lacked numerical measures useful for determining specific site priority (also discussed in greater detail, below).

7.5.9.2 Recommendations

- The following core washout risk indicators should be used to determine priority for corrective action for problem trail segments. The trail:
    - is hydrologically connected,
    - follows the fall line (low slope alignment angle),
    - has gradients in excess of 12%,
    - lacks proper drainage of water from the trail surface,
    - exhibits active erosion and delivery of sediments to the drainage, and
    - is located on unusually erosion-prone soils located on steep slopes.
- Any hydrologically connected trail segment in the watershed that exhibit the above attributes should receive the highest priority for corrective

action (closure and rerouting) as they are generally difficult to drain, maintain, and prevent erosion[66].

- There are a number of trails that are not yet designated but have been identified as "proposed" for inclusion. We recommend that the washout risk indicators listed above be used to screen proposed trails or segments of trails from becoming designated until the trail is rerouted or upgraded.

7.5.10 High Priority Dispersed Camping Sites

7.5.10.1 Data Gaps and Limitations

The ODF inventory of dispersed camping sites provided a good baseline for data in site conditions but lacked numerical measures useful for determining site-specific priorities. Data were instead used to provide direction on setting priority based on site conditions.

7.5.10.2 Recommendations

7.5.10.1.1 Highest Priority for Upgrade or Closure

- To reduce impacts to riparian vegetation, water quality, and tree vigor, any campsite currently located within 25 feet of the water should be removed or set back to at least 25 feet from the water because it is in violation of ODF Administrative rules for campsite proximity to streams. A more conservative approach would be to use tree length (100 feet) but people are naturally drawn to water and availability of flat ground is limited. Appendix W – List of Priority Dispersed Recreation Sites for Upgrade or Closure lists these sites and they are identified on Map 43.

- In addition, 62% of sites exhibited moderate to very high overall impact ratings and should also be high priority for action as these sites exhibit an array of problems impacting water quality and the achievement of properly functioning local riparian conditions.

- Sites documented during the Duck Creek Associates road survey that exhibited moderate to very high impacts and complete vegetation loss of over 1,000 square feet are on the Forest Grove District (FG088, FG101, FG060, FG073, FG092, and FG100; as labeled in the Duck Creek Associates road survey GIS layer). Two sites exhibited impacts that covered 10,000 square feet (FG029, FG039) and exhibited severe soil exposure and compaction. These campsites should be a high priority for

[66] Except for those short trail sections with built-in grade reversals and/or sediment traps that isolate runoff.

remediation as they all exhibited heavy OHV use, sedimentation and canopy impacts.

7.5.10.1.2 Actions to Address Impacts

- While Leave No Trace[67] and other common mitigation guidelines for campsites on federal land recommend a 100-200 foot set back. However, it is recommended to set back all campsite boundaries to 50 feet from streams because of the impracticality of buffering at a greater distance on the narrow streamside benches typical of this watershed.
- Restrict vehicle access to sites within the inner riparian zone (inner riparian zone) by making these sites "walk-in" only.
- Block and revegetate dispersed sites that are currently used by OHVs for circuit riding.
- Remove or reroute access roads and trails that run down the fall line.
- Remove or upgrade eroding trails that link the campground to the water.
- For the summer season (e.g., high use season), place portable toilets at the most popular sites.
- Institute a dispersed camp permit and fee program to:
    - hold users accountable for damage
    - inform users of best practices, and
    - help pay for site maintenance, mitigation and restoration.

The emphasis on removing vehicle access and pit riding by OHVs from campsites results from these problems being present in all of the high impact campsites. Setting back the edge of the campsite from the water adds a measure of prevention and buffers impacts from the stream edge.

7.5.11 Future Inventory and Monitoring

The dispersed campsite inventory undertaken by ODF provided a good baseline for data on the general conditions and locations of dispersed campsites in the watershed. The sample of sites reassessed for this analysis indicated that many of

[67] Leave No Trace guidelines can be found online at www.lnt.org.

the impacts reported by ODF were underestimated and/or were subjective measures that lack numeric values (refer to Table 26).

7.5.11.1 Recommendations

- Use a set of metrics for future inventory and monitoring that provides more accurate and quantifiable data. We recommend that the USFS campsite monitoring protocol[68] be used.
- Update the current ODF dispersed campsite inventory form. The metrics listed in Table 52 could be added and adjusted for greater utility in future monitoring and assessment projects.

Table 52. Recommended ODF dispersed campsite inventory form changes. Note: the presence of a question mark indicates that the inclusion of this field's measurement/metric is open ended.

Form field	Measure/Metric	Changes
Site Characteristics	ODF index *? = open ended*	Recommended upgrade
site code GPS	FG### or TL### lat, long, altitude	
Dimensions Number of access roads Forest canopy surface type logging landing or draft road multiple campsites fire pits Trail access? name/type Water access? Distance in ft Water body name Access (social) Trails Site improvements effectiveness comments	In feet (XbyY) # open/closed veg type ? ? ? ? ? ? ? ? ? ?	***DA 0,1,2,3 & Sq feet Mgt or social % closed FGI see below* Active landing/road # # actual distance in feet # ineffective, partially effective, effective
Photos & Reservations of access	?	
Site Use Info. day use or overnight use target shooting swimming fishing pit riding other	Check all that apply	Rename "OHV use" & add type (4wd, mc, quad)
Human Impacts Litter/garbage	Check all that apply	

[68] Recreation Site Monitoring Procedures and Protocols: David Cole, Aldo Leopold Wilderness Research Institute.

Form field	Measure/Metric	Changes
Road damage Dumping Fire hazards human waste erosion soil compaction water quality issue vehicle damage streamside damage tree damage firewood gathering number of affected trees		Access road damage Sediment delivery to stream Regular or OHV Impacts <25 ft of stream TD**+ damaged and undamaged tree count within campsite
Comments *other impacts, largest impact* *Overall impact*	Low, mod, high, very high	Use total score from adding FGI + TD + DA

*Frissell Ground Cover Impact **(FGI)**	1 – Ground vegetation flattened but not permanently injured	2 - Ground vegetation worn away in activity center	3 – Ground vegetation lost on most of the site	4 – Bare mineral soil widespread, exposed roots	5 – Soil erosion obvious, trees reduced in vigor or dead
Tree Damage **(TD)	0 – No more than 3 severely damaged trees.	1 – 4 to 10 severely damaged trees.		2 – More than 10 severely damaged trees.	
***Disturbed Area **(DA)**	0 – No more than 25 m^2 (0-250 ft^2).	1 – 26 to 100 m^2 (251 – 1,000 ft^2).	2 – 100 m^2 to 1,000 m^2 (1,000 ft^2 to 10,000).	3 – More than 1,000 m^2 (more than 10,000 ft^2).	

- Future monitoring protocol to address tree damage could include additional data gathering to produce better accuracy and enhance long term monitoring of impacts on riparian vegetation. If time and staff are available, additional data on tree damage could be gathered by census of trees within the site boundary to account for existing density, % damaged and severity of damage. Below is a USFS example of monitoring protocols for this level of data collection for campsites (Glidden 2005)[69]

[69] Glidden, N. 2005. Impact Indicators and Methodology for Wilderness Campsite Inventory and Monitoring Unpublished report from Dixie National Forest, US Forest Service. May 2005 (provided by Jeffery Marion, Virginia Tech).

If long term LW recruitment impacts from dispersed camping become a concern, species data should also be collected.

Marion and Cole (1996)[70] recommend all trees within the boundaries of the campsite area be censused according to these criteria. Trees <4.6 feet (<140 cm) tall but at least 0.5 years old should be counted as tree reproduction. Trees >4.6 feet (>140 cm) tall be classified and counted as either damaged by humans (e.g., nails, broken branches, trunk scars) or undamaged by humans. Felled trees (tree stumps) should also be counted.

Table 53. Example of USFS Tree Damage Monitoring Protocol.

Damage	Categorical Rating	Numerical Rating	Notes
Tree Impacts or mutilations	Percent Tree Damage (On-site)	(0-5%, 6-25%, 26-50%, 51-75%, 76-100%)	Determine the percentage of trees within the site's boundary that have visual damage that can attributed to human use and record the appropriate attribute choice on the data sheet or in the GPS.
	Percent Tree Damage (Site related)	(0-5%, 6-25%, 26-50%, 51-75%, 76-100%)	Determine the percentage of trees in and around the site that have visual damage that can attributed to human use of the site and record the appropriate attribute choice on the data sheet or in the GPS.
	Number of Damaged Trees (On-site)	(No trees, No damage, broken branches/1-2 scarred tree, 3-7 scarred trees, >7 scarred trees/# of trees) or (Number of damaged trees)	Determine the amount of trees within the site's boundary that have visual damage that can attributed to human use and record the appropriate attribute choice or number on the data sheet or in the GPS.
	Number of Damaged Trees (Site related)	(No trees, No damage, broken branches/1-2 scarred tree, 3-7 scarred trees, >7 scarred trees/# of trees) or (Number of damaged	Determine the amount of trees in and around the site that have visual damage that can attributed to human use of the site and record the appropriate attribute choice or number on the

[70] Marion, J. and D. Cole. 1996. Spatial and temporal variation in soil and vegetation impacts on campsites. *Ecological Applications,* 6(2):520-530.

Damage	Categorical Rating	Numerical Rating	Notes
		trees)	data sheet or in the GPS.
	Number of Damaged Trees and Severity of Damage.	(Number of trees damaged in each classification: Slight, Bad, Felled)	Determine the amount of trees within the site's boundary that have visual damage that can attributed to human use and record the number of trees in each category of damage on the data sheet or in the GPS.
	Percent Canopy Cover (Rapid Inventory)	(0-25%, 26-50%, 51-75%, 76-100%)	Estimate percent cover by mentally "lumping" the canopy cover on the site into one part of the site and record the appropriate attribute range on the data sheet or in the GPS. Note: Remote sensing may be used in some cases to determine canopy cover of a site.

7.5.12 Effectiveness of Recent (post-1994) Recreation Site Upgrades

ODF recreation staff have undertaken the monumentous job of trying to mitigate years of unrestricted and damaging recreational impacts while not having adequate or comprehensive inventories of the areas needing attention. Districts have enlisted volunteers, secured grants and in-kind services and developed considerable capacity to manage the heavy demand placed on the forest by recreation users and events. Heavy year-round use, too many events, and eroding trails and sites, however, still outstrip ODF's capacity to effectively manage and mitigate impacts to the watershed.

7.5.12.1 General Recommendations

- Drastically reduce the event schedule until the trail system is better mapped, mitigated and under control.
- Close the forest completely to OHV use in the winter.
- For OHV events, stop using trails that exhibit the washout risk indicators identified by this analysis (refer to section 7.5.8 Overall Condition of OHV Trails and 7.5.9 High Priority Trail Segments, above).

- Introduce a minimum annual number of hours OHV clubs must volunteer on trail work before they can hold an event, preferably on the route they wish to use.

- Introduce and enforce an event bond to repair and upgrade failing trails.

7.5.12.2 OHV site upgrades

Key staging areas such as Rogers camp, Brown's camp and Jordan Creek have been successfully upgraded within the campsite or day-use area boundaries. However, outside those boundaries, efforts to mitigate impacts have been much less effective, not consistent and not monitored or maintained. ODF staff and volunteers have undertaken repair work on a variety of different sites often using differing techniques. Results have been mixed and many mitigation attempts have been ineffective at stopping or reducing the worst impacts.

7.5.12.1.1 Recommendations

- Step up enforcement, trail patrol and signage efforts to help educate OHV users about appropriate behavior, trail etiquette and places to ride.

- Close or treat satellite staging areas with the same site hardening and delineation techniques used at the main OHV sites.

7.5.12.3 OHV Trail System upgrades

A significant proportion of the trail system is built on legacy pre- and post-fire logging roads, skids trails and fire breaks. These were all placed during a period of forest management where environmental (Forest Practices Act) standards were undeveloped or absent. Future use of the network for OHV recreation was not anticipated but OHV users have "adopted" this network and continue to do so today, long after the roads were closed. Mitigation of eroding trails, poor drainage areas and inappropriate location cannot realistically be carried out until the trail system is rationalized back to a more manageable level. Some upgrades of popular designated trail segments are progressing but the work load is not currently matched by the staffing capacity. Undesignated trails receive the least attention but still get heavily used and may be seriously impacting water quality.

OHV use is increasing in spite of higher gas prices and travel distances, meaning increased and sustained OHV use can be expected across the watershed. Furthermore, club membership is dropping leading to fewer opportunities for young and new users to learn appropriate behaviors and to be involved in volunteerism.

7.5.12.1.1 Recommendations

- Place a moratorium on new trail construction until the existing system is inventoried, upgraded and reduced to a more manageable size.
- Institute a monitoring program to assess the effectiveness of upgrade projects and the rate of degradation.
- Institute a "Closed Unless Posted Open" policy for trails to limit the use of unrestrained riding through the forest and on undesignated trails or in riparian areas.

7.5.12.4 Dispersed campsite upgrades

ODF Recreation staff have attempted site improvement at 22% (n=43) of the sites to mitigate or prevent user impacts. Of those sites, 44% were rated by ODF recreation technicians as effective, 37% as partially effective and 18% as ineffective. During the site improvement survey, an ODF technician suggested a range of management actions useful in guiding future efforts. Improper vehicle access and pit riding by OHVs, however, remain the two biggest factors in failed improvements. Persistent re-entry and unblocking of closed access trails requires more robust measures to be effective. OHVs were consistently listed as factors associated with site upgrades that were rated as ineffective or partially effective, and, therefore, OHV access should be targeted.

An example of recent progress on a larger scale addressing this issue is the Wilson River Vehicle Management Plan (ODF Internal draft 2/2007). ODF staff recommend a number of actions based on the Wilson River Corridor Dispersed campsite inventory. The strategy chosen by ODF, however, appeared to be the least aggressive option, which past experience and this analysis have shown to be ineffective.

Recreation management principles caution that whatever conditions are tolerated will become the normally accepted mode of operation. Dispersed campsite impacts that have occurred across the watershed for the last two decades may have set up an expectation among users that ODF accepts the high impacts and poor conditions. Allowing this expectation to continue makes future recreation site upgrade/mitigation work less likely to succeed and be appreciated or respected by users.

7.5.12.1.1 Recommendations

- Overhaul and tighten the dispersed camping rules on the forest to better announce and enforce impact-related regulations.
- Develop an overnight camping fee permit to obtain user data, revenue and establish a "point of sale" opportunity for an education program to

inform dispersed campers of appropriate behaviors including OHV use, waste disposal, firewood selection and live tree protection.

- Apply trenches, boulders, root wads and fences (in combination) to more effectively block OHV and other vehicles from going beyond access blockades. A series of campsites along Cedar Creek have successfully received this kind of robust and effective upgrade (see Photographic Plate 24 for an example of an effective barrier). The target sites for this action are listed below in Table 54.

Table 54. High priority dispersed camping sites recommended for upgrade or closure based on ODF-recorded human impact ratings of "High/Very High" (n=62).

Site Code	Human Impact Comments	Overall Impact
TL008	Largest impact: pit riding.	Very High
TL016	Largest impacts: garbage, access road next to stream with no buffer.	Very High
TL019	Largest impact: stream running through site, carrying sediment and garbage directly into W. Fork Wilson River.	Very High
TL032	Largest impacts: heavy use, garbage dumping, and unmanaged OHV trail.	Very High
TL033	Largest impact: dumping of large items.	Very High
TL040	Largest impact: campsite on cliff over stream with no buffer.	Very High
TL050	Largest impacts: heavy use, vehicular erosion and rutting, and unnecessary road network.	Very High
TL051	Largest impacts: draft road to Wilson River, fire ring under high water mark, heavy use, vehicular erosion and rutting, and unnecessary road network.	Very High
TL052	Largest impacts: hazard trees, heavy use, vehicular erosion and rutting, and unnecessary road network.	Very High
TL061	Largest impacts: road to site crosses small stream and also provides unsecured access to the back of the forestry center. In addition, severe tree damage.	Very High
TL067	Largest impact: heavily rutted road with direct sediment drainage into river. Also, heavy use as a party spot with lots of garbage.	Very High
TL068	Largest impact: heavily rutted road with direct sediment drainage into river. Also, heavy use as a party spot with lots of garbage.	Very High
TL069	Largest impact: water traveling down road, pooling in camp site, and draining with sediment directly into river. Heavy use site.	Very High
TL070	Largest impacts: no buffer to stream, garbage. Safety issue: fire ring only a few feet from cliff being undercut by stream.	Very High
TL071	Largest impact: small stream running through campsite carrying sediment.	Very High
TL072	Largest impact: no buffer to stream.	Very High
TL076	Largest impact: 2 fire rings directly next to stream.	Very High

Site Code	Human Impact Comments	Overall Impact
TL077	Largest impacts: lots of garbage, no buffer to stream, heavy use.	Very High
TL081	Largest impact: no buffer on steep bank to stream and waterfall.	Very High
TL092	Largest impacts: garbage, human waste, tree damage, OHV riding, little buffer to creek.	Very High
TL104	Highest impact: erosion and severe rutted condition of access roads.	Very High
TL105	VERY HIGH IMPACT: 4wd tracks crossing creeks in at least 3 places. Road drainage not functioning. Deeply rutted meadow and unmanaged OHV access to forest. High volume of garbage.	Very High
TL117	Highest impact: fire rings under high water mark; camping right next to active salmon spawning stream. Also, plenty of garbage.	Very High
TL119	Largest impacts: heavy use, no buffer to stream, damaged trees, garbage.	Very High
TL128	Largest impacts: major access road rutting from vehicle traffic.	Very High
TL147	VERY HIGH IMPACT: severe rutting from vehicle traffic. Extensive section of road and campsite were flooded. Draft road provides OHV access to river bed.	Very High
TL148	Largest impact: access road and campsite on cliff edge above stream with no buffer. Also, can park on stream's edge because of draft road.	Very High
TL150	Largest impact: campsite on cliff's edge over stream at end of draft road. Safety concern.	Very High
TL126	Largest impacts: close proximity to stream and garbage.	High
FG029		High
FG039	largest impact = user created trails and mud pits	High
FG053		High
FG070		High
FG073	Largest impact = motorized user-created trail network	High
FG074	Lots of user created motorized trails surrounding the site.	High
FG092	Lots of garbage. Heavy amounts of tree damage. A little streamside erosion occurring.	High
FG101	Ax marks in trees. Many user created hiking and OHV trails on North side of site	High
TL009	Largest impact: pit riding.	High
TL011	Highest impact: fire ring under high water mark.	High
TL012	Highest impact: easy vehicle access to stream on legacy draft road.	High
TL024	Largest impact: 2 OHV access paths.	High
TL030	Largest impact: < 25 ft. from stream, heavy use.	High
TL039	Largest impact: heavy use.	High
TL041	Largest impacts: damaged trees, garbage, draft road access to streamside.	High
TL046	Largest impacts: unnecessary road network.	High
TL049	Largest impacts: heavy use, vehicular erosion and rutting, and unnecessary road network.	High
TL054	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High

Site Code	Human Impact Comments	Overall Impact
TL055	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL056	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL057	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL058	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL059	Largest impacts: unnecessary road network, vehicular erosion and rutting.	High
TL060	Largest impacts: garbage, access to 2 unmanaged motorcycle trails up the creek drainages.	High
TL087	Largest impacts: garbage, vehicular rutting.	High
TL096	Highest impact: heavy use and close proximity to stream.	High
TL097	Largest impact: heavy use, close proximity to stream, and OHV trails.	High
TL101	Largest impact: garbage and highly rutted condition of access road.	High
TL103	Largest impacts: unbuffered access to stream and garbage.	High
TL107	Largest impact: access to multiple unmanaged OHV trails.	High
TL112	Fire hazard: nearby slash piles. Largest impact: pit riding.	High
TL139	Other impacts: large amount of spray-paint graffiti on trees and boulders, as well as carved graffiti on trees.	High
TL156	Largest impacts: no buffer to stream, damaged trees.	High