Little Fall Creek / Hills Creek

Watershed Analysis

February 1997

Weyerhaeuser

Glossary of Terms

active channel The bed, banks, and floodplain of a stream subject to modifications by streamflows. Geometrically synonymous with the bankfull channel.

aggradation A disequilibrium stream channel process that raises the elevation of a reach of an active stream channel by depositing bedload.

alluvial Describing material, usually sediment, deposited by a stream or running water.

anadromous fishes Fish that spend the adult phase of their life cycle in salt water and move up fresh water streams and rivers to spawn.

andesite A dark to medium-colored, fine-grained extrusive rock. Rocks are generally hard and resistant to erosion but are often mixed with less resistant materials.

avulsion The process by which a channel changes course by a sudden diversion. The periodicity of avulsion is controlled by the rate of topographic change, fluctuations in discharge and occurrence of triggering events.

bankfull The cross-sectional elevation of the channel corresponding to the top of the floodplain.

basalt A dark-colored, fine-grained igneous (extrusive) rock. Rocks are generally hard and resistant to erosion but are often mixed with less resistant materials.

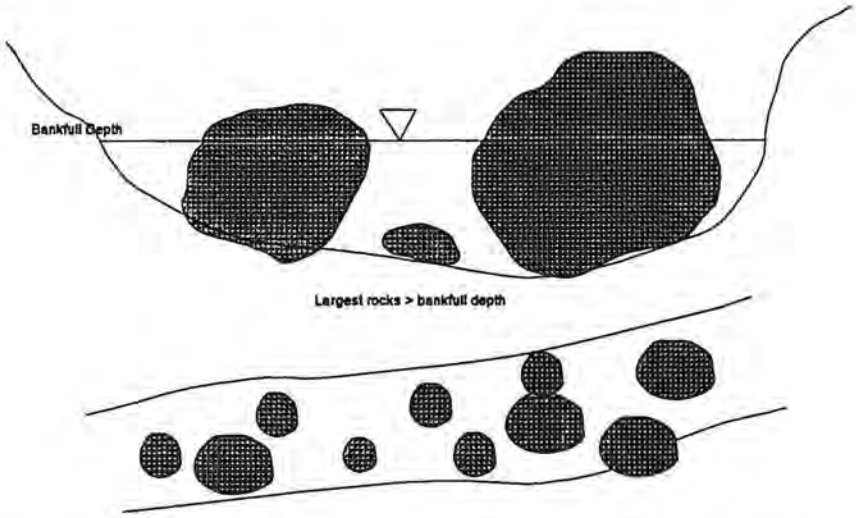
base level The elevation below which a reach of a stream cannot degrade its bed.

bed roughness The frictional resistance to flow in a river or stream system.

bedload mobility The material transported along the floor of a flowing fluid by rolling, sliding or saltation.

cascades A series of small closely spaced waterfalls or steep rapids (channel gradient usually 8-20%). Largest rock in the channel exceeds bankfull depth. Infrequent, small pools (<1 channel width per pool). Low in-channel storage of sediment (high transport relative to supply).

Illustration:



channel migration zone The area that streams have recently occupied (in the last few years or, less often, decades), and would reasonably be expected to occupy again in the near future.

colluvium A deposit of rock fragments and soil material accumulated within depressions or at the base of steep slopes as the result of gravitational action.

confinement The relative ratio of bankfull (active) channel width to valley width where the valley margins may be defined by hillslopes or terrace scarps. This ratio, when assessed in the context of stream gradient, provides a qualitative index of available shear stress as a function of water surface elevation in the channel.

Low confinement (LC) = VW > 4 CW
Moderate confinement (MC) = 2 CW < VW < 4 CW
Tight Confinement (TC) = VW < 2 CW.

Example: Channels with wide floodplains (LC) may shift laterally over the valley bottom, changing course or pattern in response to disturbance but channels confined by bedrock valley walls (TC) can only respond by bedrock modification or channel armoring

dam-break flood (DBF): A dam break flood (DBF) occurs when a natural constriction or dam in a stream channel fails and causes a downstream surge of water and debris caused by the sudden breaching of an impoundment in a stream channel; a form of debris torrent. These dams can be caused by rockfall into a channel, a small slope movement blocking a

channel, the deposit of a debris flow, or a debris jam, beaver activity, or a number of other natural mechanisms, and can cause a flood up to two orders of magnitude larger than normal storm runoff floods. These mass wasting events are unusual in that they initiate in areas of generally low slopes, unlike most mass wasting events. These extreme hyperconcentrated (water > sediment) floods can occur in 1st through 6th order valleys, in both natural and managed landscapes.

debris flood (debris-laden flood) A peak flow event comprised of large volumes of organic debris that can scour and erode the bed and banks of the stream. The woody material can be a component of the waning surge of an upstream debris flow. Distinguished from debris flows and dam break floods by the lack of viscous flow.

debris torrent (DT) Debris flow or dam-break flood, undifferentiated. The effects of debris flow and dam-break floods can appear superficially similar (particularly on air-photos), although the two processes differ in initiation, composition, and travel characteristics. This term is used when it is not possible to distinguish between the two, either because of poor resolution on air-photos or inconclusive evidence in the field.

deep-seated failure Landslide involving deep regolith, weathered rock, and/or bedrock, as well as surficial (pedogenic) soil. As used here, deep-seated landslides commonly include large (acres to hundreds of acres) slope features, associated with geologic materials and structures. In watershed analysis, they are divided into:

- **large-persistent deep-seated failures (LPD)** Commonly slump-earthflows involving large areas of hillside; found in natural and managed landscapes, recognizable over long periods of time, and almost always predate land use. These occur due to climatic changes (periods of high rainfall) or events such as strong earthquakes, geologic weakness, or channel incision. These large persistent deep seated slides appear to have been active at some time in the past, however, they do not appear to have moved on the large scale for many years, perhaps centuries.
- **small-sporadic deep-seated failures (SSD)** Commonly smaller slumps that can be triggered at irregular intervals (by storms or earth movement), and can weather to the point where they are indiscernible.

degradation A disequilibrium stream channel process that lowers the elevation of a reach of an active stream via incision.

dike Long, thin intrusive igneous rock units that cuts across the structure of adjacent rocks.

Illustration:

earthflow: Deep-seated landslide of broken soil and rock, dominated by slow movement (flow-like); produce linear areas of hummocky, disjointed terrain. Earthflow activity is favored in deep, cohesive soil, clay-rich bedrock, or slumped material, and is largely controlled by seasonal (or longer) fluctuations of pore-water pressure.

ephemeral stream A stream that flows only briefly in direct response to rainfall or snowmelt. Its streambed remains above the groundwater table.

extrusive A type of igneous rock that has been erupted onto the surface of the earth. Extrusive rocks include lava flows (which are often composed of basalt and andesite) and pyroclastic material such as volcanic ash.

floodplain The area immediately adjacent to the channel being constructed by the river in the present climate and flooded at high discharge. The level of the floodplain is commonly inferred to be the level of the bankfull stage and is commonly misinterpreted as being coincident with low stream terraces.

flotation load The portion of mobile particles, usually woody debris, in a stream that remain suspended in the water column due to low specific gravities relative to water. A type of suspended load.

geomorphic General shape or features of the landscape.

headwall A steep, wall-like cliff at the back of a hollow or hillslope depression. In reference to slope stability, the term refers to the stability of the entire hollow or depression.

hydrologic maturity Condition of a forest stand in which hydrologic processes operate as they do in a mature or old-growth forest. In particular, snow accumulation is typically lower in thick, dense forest (at middle and lower elevations) than in openings, due to

interstorm melt of snow caught in the canopy; and snowmelt is slower, due to decreased wind-aided flux of sensible and latent heat.

intermittent stream A stream that flows during part of the year. Its water is derived from rainfall, snowmelt, or occasional groundwater discharge into the stream channel.

intrusive A type of igneous formed by the injection of magma (molten rock) into pre-existing rock.

iteroparous Capable of repeated reproduction (characteristic of most fishes)

landslide Any mass-movement process characterized by downslope transport of soil and rock, under gravitational forces, by sliding or deformation within a discrete failure zone. Also used to refer to the resultant landform. In common usage, can also include other forms of mass wasting not involving sliding (rockfall, etc.)

large woody debris (LWD) recruitment Large woody debris delivered by the fall of streamside trees, or delivery from upstream sources by stream transport.

longitudinal profile A topographic profile along a valley or stream

mafic Said of an igneous rock composed chiefly of dark, ferromagnesian minerals (iron and magnesium rich minerals).

mass wasting General term for dislodgment and downslope transport of soil and rock under direct gravitational forces (i.e., without major action of water, wind, or ice); mass movement. In watershed analysis, this class of erosion processes is divided into three categories: shallow-rapid landslides, deep-seated failures, and debris torrents.

migration Any mass movement from one habitat to another with characteristic regularity in time according to stages of life history.

peak flow event Maximum instantaneous stream discharge during runoff, commonly caused by an individual rainstorm, rain-on-snow, or spring snowmelt.

perennial stream A stream that flows continuously as a result of surface runoff and influx of groundwater.

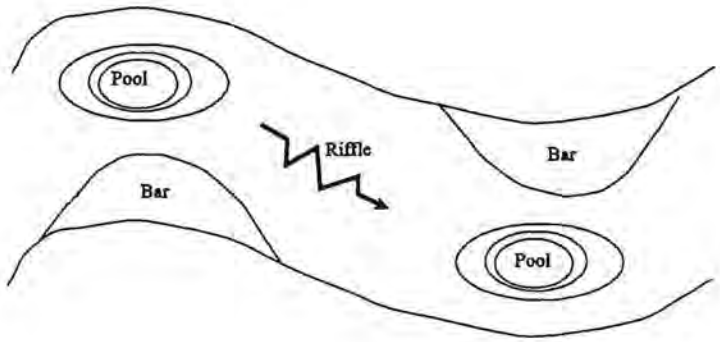
piedmont A plain that slopes away from the base of a mountainous escarpment.

plane-bed channel A channel that lacks well-defined bedforms and are characterized by long stretches of relatively planar channel bed that may be punctuated by occasional channel spanning rapids. Channel gradient is commonly between 1 and 3%, and can have a wide range of confinement (LC to TC). Additions of large woody debris may provide sufficient flow convergence and divergence to cause pool development and transform the

channel to a forced pool-riffle morphology. Rapid aggradation (sediment deposition) can change the channel to a braided morphology.

pool-riffle channel A channel with an undulating bed that defines a sequence of bars, pools and riffles. Channel gradient is commonly between 1 and 3%, and generally unconfined. Regular spacing of pools at 5-7 channel widths per pool. Maximum diameter of substrate much less than bankfull depth. Low relative transport capacity makes them particularly sensitive to changes in sediment supply and discharge.

Illustration:



potamodromous A type of fish migration which occurs wholly in freshwater.

Quaternary The second period of the Cenozoic era, following the Tertiary; also, the corresponding system of rocks. It began 1.6 million years ago and extends to the present.

Rain-on-snow zone Area (generally defined as an elevation zone) where it is common for snowpacks to be partially or completely melted during rainstorms several times during the winter.

riparian function Activity relating to the LWD recruitment and stream-shading functions provided by riparian vegetation.

riparian zone Area surrounding a stream, in which ecosystem processes are within the influence of stream processes.

saltation The process of particle transport in stream channels via bouncing along the stream bed. Particle position thus alternates between suspension in the flow and short-term resting on the channel bed.

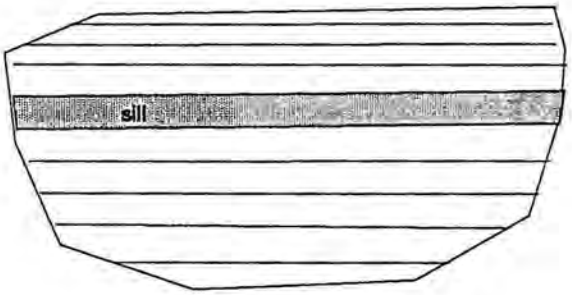
semelparous Capable of one reproduction (characteristic of salmon).

shallow-rapid landslide (SR): Landslide produced by failure of the soil mantle (typically to a depth of one or two meters, sometimes including some weathered bedrock), on a

steep slope. The debris moves quickly (commonly building up and developing into a debris torrent), leaving an elongate, spoon-shaped scar. Shallow-rapid landslides typically occur in this basin on steep, concave slopes where thin soil and/or decomposed rock overlie a more cohesive bedrock. These features are also known as debris slides, debris avalanches, or planar failures and occur within the soil, rarely incorporating bedrock. Soil thickness is typically small compared to the length of the landslide. The material of the slide moves rapidly down slope along a surface that is roughly parallel to the ground surface. This mass wasting type includes road fill failures. The debris commonly breaks apart to form a debris avalanche and, depending on the location, can deliver sediment to streams and damage roads. Fill failures lead to shallow rapid failures, and when in young (<20 year) conifer stands that do not have adequate buttressing strength. These shallow rapid failures can propagate down the steep slopes and when the accumulated mass enters a stream channel and combines with great amounts of water, the resulting slurry can turn into a highly destructive debris torrent. Debris torrents scour the channels of the steeper slopes, and then deposit huge amounts of fine and coarse sediment onto the lower gradient slopes within the stream channels, providing an instantaneous, and long term sediment source. Shallow-rapid landslides not associated with roading, most often occur in convergent topography on steep slopes in areas where topography or bedrock structure concentrates drainage such as in swales or draws. The main factor contributing to the occurrence of these types of slides are slope, saturation of soil and loss of root strength. Forest practices can effect these factors and influence the occurrence of shallow-rapid landslides.

sill An igneous intrusion that parallels the planar structure of the surrounding rock (like a dike but dikes can bisect rock but a sill has to parallel the planes of the rock into which it is intruded).

Illustration:



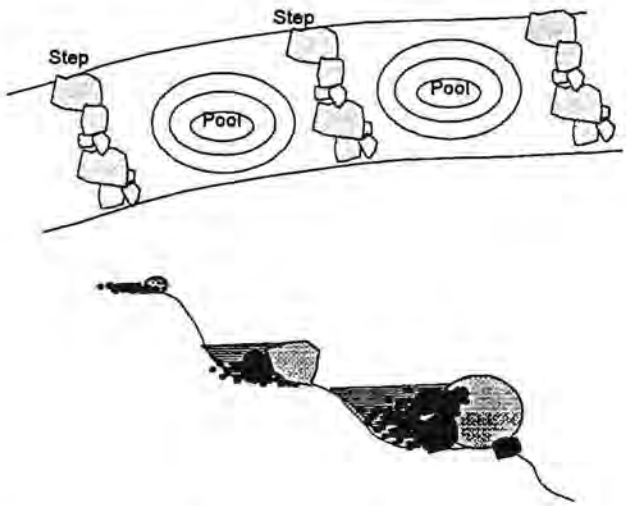
slump: Deep, rotational landslide, generally producing coherent movement (back-rotation) of blocks over a concave failure surface. Typically, slumps are triggered by increased pore-water pressure in mechanically weak materials (deep soil or clay-rich rock).

slump-earthflow: Landslide exhibiting characteristics of both slumps and earthflows; typically the upper part moves by slump (rotation of blocks), while the lower portion moves by flow (hummocky terrain).

snow-water equivalent (SWE) Amount of liquid water (expressed as depth) derived by melting a snowpack.

step-pool channels A series of steps separating pools. The steps may be composed of LWD or accumulations of sediment. A regular spacing of pools at 1-4 channel widths per pool. Heterogeneous bed mixture. Low sediment supply, high discharge.

Illustration:



strath An extensive terrace-like remnant of a broad valley floor that has undergone dissection, e.g. a river terrace along a valley wall or incised bedrock.

stream power The power available to transport bedload. It consists of those variables (such as discharge and gradient) that, if increased, favor bedload transport and fluvial degradation.

stream terrace A relatively flat surface adjacent to a stream or river that represents an abandoned floodplain (low terraces are frequently confused with the floodplain). Terrace surfaces can rise one to tens of meters above the active channel bed.

step-pool channel Channels characterized by large particles (boulders or woody debris) organized into discrete channel spanning accumulations that form a series of steps separating pools. Longitudinal gradients are typically 4 to 8 percent.

Tertiary The first period of the Cenozoic era (after the Cretaceous of the Mesozoic era and before the Quaternary), thought to have covered the span of time between 65 million and 2 million years ago; also, the corresponding system of rocks.

toe The downslope edge of a landslide or slump.

Little Fall Creek / Hills Creek

Watershed Analysis

PART I

Section B

Causal Mechanism Reports
and
Prescriptions

May 1997

Weyerhaeuser

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INTRODUCTION

The prescriptions included in the watershed analysis report were developed by the prescription team to address triggering mechanisms having the potential to adversely affect fish and water resources in the Little Fall Creek/Hills Creek Watershed Administrative Unit (WAU) of Lane County, Oregon.

The Little Fall Creek/Hills Creek WAU consists of 8 sub-basins (52,235 acres) tributary to the Willamette River. The watershed is primarily forestland owned by Weyerhaeuser (60%), Willamette National Forest (12%), BLM (10%), Willamette Industries (4.5%) and other private landowners (13.3%).

The Watershed Synthesis portion of this document has described watershed characteristics and resource sensitivities (watershed *analysis*). This section addresses prescriptions, which are watershed *management* techniques.

LITTLE FALL CREEK / HILLS CREEK TEAM MEMBERS

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Start Date: November 1996

Initiated by: Weyerhaeuser Company
Completion Date: May 1997

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MANAGEMENT SUMMARY

Overview

Management prescriptions have been prepared to address all triggering mechanisms identified in the Causal Mechanism Reports. In most cases, we have developed several alternatives to match prescriptions to the site. The specific prescription call will be made by the appropriate land manager in the field. Our intent is to maintain landowner flexibility to integrate protective and/or preventative measures into management activities.

Note that prescriptions have been developed only for forestland. We have not addressed resource sensitivities and triggering mechanisms resulting from non-forestry activities. Note also that while Willamette Industries participated in this watershed analysis, the prescriptions were written for Weyerhaeuser forestlands.

The key sensitivities for the Little Fall Creek/Hills Creek Watershed are:

1. In-Stream Structure (lack of large woody debris to provide high quality habitat)
2. Fine Sediment (naturally high background rates and management related inputs primarily from roads)

Prescriptions, implementation, and associated resources are focused on these key sensitivities. We have prepared two maps to aid in implementation (see **Map RX1** *Prescription Sensitivities*

and **Map RX2** *Prescription Summary, Road Maintenance*; both maps are located in Prescription Documents section).

Monitoring has been designed to evaluate effectiveness of these management techniques. In addition, monitoring and future evaluations will be used to periodically check overall "health" of the watershed, including areas that are currently in the desired state and not identified as resource sensitivities (e.g. to ensure that stream temperatures stay within acceptable ranges).

Triggers have been established to re-open the process if the prescriptions do not yield the desired results. Trigger parameters originate in the mid and long-term trends tracked in the monitoring process. Due to natural variability and slow rates of change, some parameters must be tracked for a minimum of five years before a trend can be established.

The team believes that, over time, these prescriptions will protect water quality and fish habitat. Thus, we expect continuous improvement in fish habitat and water quality in this watershed.

KEY SENSITIVITIES

1. Large Woody Debris (LWD)

Resource Objective:	Re-establish LWD recruitment potential by developing self-sustaining riparian areas that support large conifer for recruitment to the stream channel.
Prescription: Description:	• Manage riparian areas to provide a long-term source of coniferous large woody debris. ◊ Focus riparian enhancement work where the need and potential for success are greatest (e.g. hardwood dominated riparian stands occupying sites that would or previously did support conifers). • The Oregon Forest Practices Act, including the 1994 stream protection rules, is the basis for prescriptions.
Objective:	• Increase conifer LWD in streams.
Monitoring:	Site Specific: • Monitor the effectiveness of any stream enhancement projects in the Little Fall Creek / Hills Creek Watershed that may be placed as a result of this watershed analysis or from projects outside of this analysis. • Where applicable, use ODF&W fish survey information as an indicator of habitat improvement. Broad Scale: • Repeat photo assessment of LWD recruitment potential on fish-bearing streams using watershed methodology at ten year intervals. Evaluate this after twenty years for effectiveness and adjust as necessary.

Trigger for Prescription Review:	• Long-term trend for LWD/pools is decreasing (from watershed analysis stream habitat protocol) without a catastrophic natural event that would explain the trend. • Long-term trend for LWD recruitment potential is flat or decreasing (from watershed analysis stream habitat protocol) without a catastrophic natural event that would explain the trend.
Situation / Prognosis:	• Large conifer for current recruitment is less than optimum. Currently 50% of the WAU has low riparian recruitment potential. However, many areas are stocked with young conifer, or mixed conifer and hardwood stands, providing good long-term recruitment potential. • Pools created by LWD are considered low in the anadromous migration corridor of Little Fall Creek. • Short-term increases in LWD would require active placement or a catastrophic natural event (i.e. Columbus Day storm). • We expect an increase in LWD input to the system. Significant increase due to natural input is not expected for several decades (50 to 100+ years).
Overall/long-term measures of success:	• Higher density of large resident fish. • Improved complexity (pool and cover) for summer rearing habitat used by salmonids.

2. Fine Sediment

Resource Objective:	Maintain high quality instream habitat for aquatic biota. Minimize contamination of spawning gravels by fine sediments.
Prescription: Description	• Reduce fine sediment generated by management activities. Priority areas for improvements focus on roads. ◊ The Weyerhaeuser Road Maintenance Manual forms the basis for prescriptions (see Prescription Documents section).
Objective	• Minimize sediment generated by management activities. • Prevent sediment generated by management activities from entering streams.
Monitoring:	Site Specific: • Re-do the road inventory and sediment model for the watershed in 10 years. Broad Scale: • Track location and reasons for culvert failures. • Incorporate into GIS the location and reason, if known, of any mass wasting failure that delivers.

Trigger for Prescription Review:	• Fine sediment levels trending upward over 10 year period from original road inventory sediment predictions.
Situation / Prognosis:	• Fine sediment levels are naturally high in this WAU due to high clay content soils, particularly in the Hills Creek area. • Turbid run-off is common in Hills Creek, due to the smectite soils, independent of management activities. • Management-generated sediment entering streams is expected to be decreasing.
Overall/long-term measures of success:	• Reduced fine sediment contamination of spawning gravels.

IMPLEMENTATION

Prescription implementation will begin in May, 1997.

There is a process in place in the region to review upcoming harvest activities for prescription sensitivities. Any potential watershed issues are communicated through this process to the appropriate field personnel prior to the start of activity.

Map RX1 (*Prescription Sensitivities*) and Map RX2 (*Prescription Summary, Road Maintenance*) are two maps that have been developed to aid in the implementation of prescriptions in this watershed.

The Region plans to conduct annual reviews of watershed management. These reviews will provide:

- Documentation of prescription activities carried out during the previous year (e.g. brief description of activities).
- Documentation of monitoring results, if any, from the previous year.
- Planning and coordination of prescription activities for the coming year.

Little Falls Creek / Hills Creek Watershed reviews are targeted for June of each year (starting June 1998).

WATERSHED CHARACTERISTICS SUMMARY

Watershed Administrative Unit: Little Fall Creek/Hills Creek

Drainage System:	Middle Fork Willamette tributary to Willamette
Location:	Hills River Mile 195 of Middle Fork Willamette Little Fall Creek RM 3.5 of Fall Creek (which enters Middle Fork Willamette at RM 198.5)
Basin Area:	52,235 acres (81.6 square miles)
Climate:	Mainly rain, snow at elevation
Mean Annual Precipitation:	40" in lowlands, up to 90" uplands
Elevation Range:	540' - 4200'
Geology:	Diverse assemblage of Tertiary age volcanic rocks that have undergone little structural deformation. Lithologies include tuffs, breccias, andesites, and basalts. Quaternary alluvium fills the valleys.
Sub-basin Stream Density (mi/mi^2)	average 5.42
Sub-basin Road Density (mi/mi^2)	avg 3.97 mi/mi^2
Vegetation (dominant)	2nd growth Douglas fir
Vegetation (sub-dominant)	Hemlock, red alder
Land Use:	Forest management, agriculture, rural residences
Major Land Owners:	Weyerhaeuser Company, Willamette National Forest, BLM, Willamette Industries and other private landowners
Water Supplies:	No public
Salmonid Resources:	Anadromous: Chinook salmon (spring), Steelhead (summer and winter) Resident: Rainbow trout, Coastal cutthroat trout, Mountain whitefish

Mass Wasting Resource Sensitivity A1:

Road-related failures in steep, concave slopes; high mass wasting hazard potential.

CAUSAL MECHANISM REPORT

Situation Summary:

Road-related shallow rapid landslides (SR), debris torrents ([DT], including also debris flows [DF] and potentially dam break floods [DBF]) and small sporadic deep-seated landslides (SSD) in mass wasting map unit (MWMU) 1 are delivering coarse and fine sediment through steep gradient channels (GMU 4, 5 and 6) to lower gradient channels (GMU 1, 2 and 3). The primary concerns for fish habitat include:

- temporary fining of substrate from fine sediment deposition, primarily in GMU 3 and 4, reducing habitat complexity;
- temporary accumulations of fine sediment in low velocity areas reducing availability of rearing habitat in GMU 2 and lower gradient reaches of GMU 4 and 5;
- temporary and local channel aggradation and pool filling by coarse sediment, reducing habitat complexity in GMU 2, 3, and 5;
- sediment scour and fill from debris torrents resulting in reduced habitat complexity;
- turbidity during and following storm-flow events that can:
  - temporarily degrade water quality,
  - impact salmonids' ability to feed,
  - cause gill abrasion affecting respiration (extreme or chronic increases);
- removal of in-channel large woody debris by debris torrents (DT, DF, and DBF), resulting in loss of sediment storage and sorting, and removal of pool-forming steps;
- potential loss of fish populations by debris torrent scour, where those populations are isolated by barriers. Currently the existence of isolated populations is unknown in the WAU.

Note: The extent of sediment deposition would be significantly increased if the quantity of in-channel large woody debris (LWD) increases over time. Increased LWD would improve fish habitat by increasing the availability of spawning gravel, pool habitat and cover. However, if sediment sources are not controlled, storage from LWD could result in excess fine and coarse sediment storage, degrading the habitat.

Triggering Mechanisms:

The following factors lead to the generation and delivery of sediment from road-related landslides in MWMU 1:

Natural characteristics:

- Steep slopes (≥40% by the DEM), held up by relatively resistant basalts and andesites (field-measured slopes are commonly steeper).

- Concave slopes, headwalls and bedrock hollows to concentrate shallow ground water, increasing pore water pressure to destabilize slopes.
- Occurrence of large storms, routing large quantities of shallow ground water to unstable slopes.
- Clay-rich, unstable soils formed from weathered volcanics (breccias, volcaniclastics, interbedded volcanic sediments).
- In some cases, shallow ground water seeps may be reducing slope stability by increasing pore-water pressure.

Contributing management-related characteristics:

- Sidecast road and landing construction that oversteepens and overweights slopes. This accounts for 88% of the road-related landslides in this MWMU.
- Oversteepening of cutbanks on steep, unstable slopes. This accounts for 7% of the road-related landslides in this MWMU.
- Filling of road ditches by cutbank ravel or talus diverts drainage to tread and then to steep, unstable draws.
- Insufficient culvert size or blocking of culverts with woody debris, cutbank ravel or road sediment, diverting drainage to the tread and unstable fill slopes.

Maps:

Map A2 delineates the mass wasting map unit for this situation, MWMU 1. The specific areas of concern are subject to field verification, and consist of moderately steep (≥40% DEM slopes) concave slopes and headwalls.

Map A1 shows the locations of specific landslides.

Additional Comments:

Sidecast Failures:

Sixty-nine of 84 landslides (82%) identified in this MWMU are road-related. Of these, 61 (88% of 69, or 73% of 84) are associated with sidecast road or landing fill. More detailed information on these landslides is available from the landslide inventory (Appendix A).

Channel Observations:

The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs. See the Channel Assessment (Appendix E) for further observations.

Location GMU	Affected Fish	Observations
All GMUs	All anadromous and resident fish	• Turbidity observed during and following high flow events
GMUs 2,4 and 5	Anadromous fish in GMUs 2 and 4 and resident fish in all	• Storage of fine sediment at channel margins • Fine sediment accumulation in backwater areas • Some filling of gravel and cobble interstices

Management Objective:

Minimize road related failures on steep concave slopes (MWMU 1) from existing roads or landings that can deliver sediment to streams. Avoid road related failures from new roads/reconstruction and landings on steep concave slopes that can deliver sediment to streams.

PRESCRIPTION

Existing roads:

- Inventory and evaluate existing roads and landings. Review roads on a three year rotation for:
  - Evidence of potential side cast failure,
  - Cut bank stability and drainage issues,
  - Effectiveness of drainage,
  - Type of construction (standards, age, likelihood of organic debris in fills).
- When orphan roads from previous harvest are encountered, identify any issues and address when management activities are going on in the area.
- Where road evaluation indicates a potential for failure, evaluate, correct on a priority basis (imminence and resource impact) and document corrective action. Corrective actions could include:
  - Consultation with Geologist on high risk sites,
  - Pull-back sidecast,
  - Revegetating exposed slopes,
  - Cutbank stabilization,
  - Drainage controls such as relief pipes or road flaps to prevent direct drainage onto sidecast,
  - Subsequent adjacent harvest prescriptions (leave tree locations, and/or full suspension over unstable sidecast, for example).
- Ensure continued training for appropriate personnel in identifying road slope stability processes.
- Do not increase the loading on existing sidecast areas with management activities.

New Roads:

- Evaluate alternative logging systems or unit layout to avoid road and/or landing construction in high risk areas of MWMU 1. If roading is unavoidable or alternatives create a higher risk to the resource, then:
  - No sidecast road construction on concave slopes greater than 50% where failure could deliver sediment to stream,
  - Engineer drainage with culvert spacing and location to route additional water away from headwall,
  - Review new roads during the first winter after construction for potential cutbank seepage and to establish a maintenance schedule for any obvious problem areas.

Justification for Prescription:

For existing roads we will use a combination of inspection and corrective action to prevent road-related failures associated with sidecast, oversteepened cutbanks and inadequate road drainage. The Springfield Operating Area targets a three year cycle for field inspection of the area's road network, with identified high risk areas inspected more frequently. The results of the road inspection are incorporated into the prioritization of road maintenance activities.

Orphan roads are abandoned roads from previous harvest (generally more than 40 years ago), often not detectable with aerial photography. These roads are usually discovered when field personnel are out on the ground preparing for upcoming management activities. Potential problems identified with these old roads will be corrected during site preparation after harvest activities.

Continued training for operations personnel will ensure that evidence of potential failures will be recognized when they are present. This training includes personnel doing the road inspections and also people who are on the ground prior to planned management activities. The GIS maps included in the Mass Wasting module are useful for identifying where these steep, concave slopes are likely to be found in the watershed, but field verification is required to identify the specific sites. The burden for identifying the high risk areas falls on the field personnel. With training and the use of technical support when needed, we believe these areas can be identified and appropriate precautions utilized.

In most cases, evaluating alternative logging systems or unit layout will help to avoid new road construction in high risk areas of MWMU 1. The natural characteristic of the triggering mechanism is typically located mid slope, allowing for the water concentration that triggers the failures. Ridgetop to ridgetop harvest units, where feasible, would avoid mid slope road construction.

New road construction will have drainage engineered, with culvert locations and spacing, to route additional water away from headwalls. Sidecast road construction will not be allowed on slopes greater that 50%. All but one of the 29 landslides in MWMU 1 for which field slopes were measured occurred on slopes exceeding 50%. The one exception occurred on a 47% slope.

Monitoring:

The location of future failures will be mapped and given to the GIS for incorporation in the landslide inventory. If known, include date and reason for failure. This data will be evaluated at 10 year intervals to determine if the prescriptions are effective at minimizing failures from old roads and avoiding failures associated with new road construction.

Mass Wasting Resource Sensitivity A2:

Road-related failures in inner gorges, LPD-prone terrain, and very steep planar or convex slopes; moderate mass wasting hazard potential.

CAUSAL MECHANISM REPORT

Situation Summary:

Road-related shallow rapid landslides (SR), debris torrents ([DT], including also debris flows [DF] and dam break floods [DBF]) and small sporadic deep-seated landslides (SSD) in MWMU 2, 3 and 4 are delivering coarse and fine sediment through steep gradient channels (GMU 4, 5 and 6) to lower gradient channels (GMU 1, 2 and 3). The primary concerns for fish habitat include:

- temporary fining of substrate from fine sediment deposition, primarily in GMU 3 and 4, reducing habitat complexity;
- temporary accumulations of fine sediment in low velocity areas reducing availability of rearing habitat in GMU 2 and lower gradient reaches of GMU 4 and 5;
- temporary and local channel aggradation and pool filling by coarse sediment, reducing habitat complexity in GMU 2, 3, and 5;
- sediment scour and fill from debris torrents resulting in reduced habitat complexity;
- turbidity during and following storm-flow events that can:
  - temporarily degrade water quality,
  - impact salmonids' ability to feed,
  - cause gill abrasion affecting respiration (extreme or chronic increases);
- removal of in-channel large woody debris by debris torrents, resulting in loss of sediment storage and sorting, and removal of pool-forming steps;
- potential loss of fish populations by debris torrent scour, where those populations are isolated by barriers. Currently the existence of isolated populations is unknown in the WAU.

Note: The extent of sediment deposition would be significantly increased if the quantity of in-channel large woody debris (LWD) increases over time. Increased LWD would improve fish habitat by increasing the availability of spawning gravel, pool habitat and cover. However, if sediment sources are not controlled, storage from LWD could result in excess fine and coarse sediment storage, degrading the habitat.

Triggering Mechanisms:

The following factors lead to the generation and delivery of sediment from road-related landslides in MWMU 2, 3 and 4:

Natural characteristics:

- Steep slopes in MWMU 2 and 4 (≥40% by the DEM in MWMU 2, ≥60% in MWMU 4), held up by relatively resistant basalts and andesites (field-measured slopes are commonly steeper).

- Concave slopes, headwalls and bedrock hollows in MWMU 2 and 3 to concentrate shallow ground water, increasing pore water pressure to destabilize slopes.
- Clay-rich, rapidly creeping soils in MWMU 3 that are unstable in themselves, and also increase perching of shallow groundwater, elevating pore-water pressure, further decreasing stability.
- Occurrence of large storms, routing large quantities of shallow ground water to unstable slopes.
- Close proximity and direct sediment routing to streams, especially in inner gorges (MWMU 2).

Contributing management-related characteristics:

- Sidecast road and landing construction that oversteepens and overweights slopes. This accounts for 72% of the road-related landslides in these MWMU (87% of the road-related landslides in MWMU 2 and 4).
- Oversteepening of cutbanks in clay-rich, rapidly creeping soils. This accounts for 14% of the road-related landslides in these MWMU, primarily in MWMU 3 in LPD-prone terrain (91% of the road-related landslides in MWMU 3).
- Filling of road ditches by cutbank creep or rapid failure, diverting drainage to unstable fillslopes and draws.
- Insufficient culvert size or blocking of culverts with debris, road sediment or debris torrent deposits, causing a DBF (debris torrents primarily triggered by roads upslope [see also Causal Mechanism Report Summary for Mass Wasting Resource Sensitivity A1]).

Maps:

Map A2 delineates the MWMU for this situation, 2, 3 and 4. The specific areas of concern are subject to field verification, and consist of the following:

- MWMU 2. Moderately steep (≥40% by DEM), slopes on inner gorges within the MWMU 2 polygons on Map A2.
- MWMU 3. Moderate slopes (≥30% by DEM) within the MWMU 3 polygons on Map A2.
- MWMU 4. Very Steep (≥60% by DEM) planar and convex slopes within the MWMU 4 polygons on map A2.

Map A1 shows the locations of specific landslides.

Additional Comments:

Sidecast Failures:

Fifty-eight of 181 landslides (49%) in these MWMU are road-related. Of these, 42 (72% of 58, or 23% of 181) are associated with sidecast road or landing fill. More detailed information on these landslides is available from the landslide inventory (Appendix A).

Channel Observations:

The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs. See the Channel Assessment (Appendix E) for further observations.

Location GMU	Affected Fish	Observations
All GMUs	All anadromous and resident fish	• Turbidity observed during and following high flow events
GMUs 2,4 and 5	Anadromous fish in GMUs 2 and 4 and resident fish in all	• Storage of fine sediment at channel margins • Fine sediment accumulation in backwater areas • Some filling of gravel and cobble interstices

Management Objective:

Minimize road related failures in inner gorges, LPD-prone terrain and very steep planar slopes (MWMUs 2, 3 and 4), from existing roads or landings that could deliver sediment to streams. Avoid road related failures from new roads/reconstruction and landings in these MWMUs that could deliver sediment to streams.

PRESCRIPTION

Existing Roads:

- Inventory and evaluate existing roads and landings. Review roads on a three year rotation for:
  - Evidence of potential sidecast failure,
  - Cutbank stability and drainage issues,
  - Effectiveness of drainage,
  - Type of construction (standards, age, likelihood of organic debris in fills).
- When orphan roads from previous harvest are encountered, identify any issues and address when management activities are going on in the area.
- Where road evaluation indicates a potential for failure, evaluate, correct on a priority basis (MWMU 4 [60%+ slopes] and MWMU 2 [inner gorges] are higher risk areas than MWMU 3 [LPD-prone terrain]) and document corrective action. Corrective actions could include:
  - Consultation with Geologist on high risk sites,
  - Pull-back sidecast,
  - Revegetating exposed slopes,
  - Cutbank stabilization,
  - Drainage controls such as relief pipes or road flaps to prevent direct drainage onto sidecast,
  - Subsequent adjacent harvest prescriptions (leave tree location, full suspension, no cut or partial cut areas, for example).
- Ensure continued training for appropriate personnel in identifying road slope stability processes.
  - Do not increase the loading on existing sidecast areas with management activities where failure would cause sediment delivery to stream.

New Roads:

- Evaluate alternative road placement options in high risk areas of MWMUs 2 and 4.
  - No sidecast road construction on slopes greater than 55% where a failure would deliver sediment to stream.
  - Engineer drainage with culvert spacing and location to route surface water away from sensitive areas.
- Review new road construction during the first winter after construction for potential cutbank seepage and to establish maintenance schedule for obvious problem areas.

Justification for Prescription:

For existing roads we will use a combination of inspection and corrective action to prevent road-related failures associated with sidecast, oversteepened cutbanks and inadequate road drainage. The Springfield Operating Area targets a three year cycle for field inspection of the area's road network, with identified high risk areas inspected more frequently. The results of the road inspection are incorporated into the prioritization of road maintenance activities.

Orphan roads are abandoned roads from previous harvest (generally more than 40 years ago), often not detectable with aerial photography. These roads are usually discovered when field personnel are out on the ground preparing for upcoming management activities. Potential problems identified with these old roads are typically corrected during site preparation after harvest activities.

Continued training for operations personnel will ensure that evidence of potential failures will be recognized when they are present. This training includes personnel doing the road inspections and also people who are on the ground prior to planned management activities. The GIS maps included in the Mass Wasting module are useful for identifying where these inner gorges, LPD-prone terrain and very steep planar slopes are likely to be found in the watershed, but field verification is required to identify the specific sites. The burden for identifying the high risk areas falls on the field personnel. With training and the use of technical support when needed, we believe these areas can be identified and appropriate precautions utilized.

In most cases, evaluating alternative logging systems or unit layout will help to avoid new road construction in high risk areas of MWMU 2 and 4.

New road construction will have drainage engineered, with culvert locations and spacing, to route additional water away from sensitive areas. Sidecast road construction will not be allowed on slopes greater that 55%. Of the 14 landslides in MWMU 2 and 4 for which field slopes were measured, 12 occurred on slopes of 55% or greater. The two exceptions are a dam-break flood, which occurred in the channel itself as opposed to on the slope, and a shallow rapid landslide, which initiated on a 40% slope.

Typically, roads are built in the summer when weather conditions may not show how the road has impacted drainage. Reviewing new roads the first winter after construction should show any areas that may need additional relief culverts to route cutbank seepage onto the forest floor.

Monitoring:

The location of future failures will be mapped and given to the GIS for incorporation in the landslide inventory. If known, include date and reason for failure. This data will be evaluated at 10 year intervals to determine if the prescriptions are effective at minimizing failures from old roads and avoiding failures associated with new road construction.

Mass Wasting Resource Sensitivity A3:

Non-road-related failures in steep, concave slopes and inner gorges; moderate mass wasting hazard potential.

CAUSAL MECHANISM REPORT

Situation Summary:

Shallow rapid landslides (SR), debris flows (DF), debris torrents (DT) and small sporadic deep-seated landslides (SSD) in MWMU 1 and 2 are delivering coarse and fine sediment through steep gradient channels (GMU 4, 5 and 6) to lower gradient channels (GMU 1, 2, and 3). The primary concerns for fish habitat include:

- temporary fining of substrate from fine sediment deposition, primarily in GMU 3 and 4, reducing habitat complexity;
- temporary accumulations of fine sediment in low velocity areas reducing availability of rearing habitat in GMU 2 and lower gradient reaches of GMU 4 and 5;
- temporary and local channel aggradation and pool filling by coarse sediment, reducing habitat complexity in GMU 2, 3, and 5;
- sediment scour and fill from debris torrents resulting in reduced habitat complexity;
- turbidity during and following storm-flow events that can:
  - temporarily degrade water quality,
  - impact salmonids' ability to feed,
  - cause gill abrasion affecting respiration (extreme or chronic increases);
- removal of in-channel large woody debris by debris torrents (DT, DF, and DBF), resulting in loss of sediment storage and sorting, and removal of pool-forming steps;
- potential loss of fish populations by debris torrent scour, where those populations are isolated by barriers. Currently the existence of isolated populations is unknown in the WAU.

Note: The extent of sediment deposition would be significantly increased if the quantity of in-channel large woody debris (LWD) increases over time. Increased LWD would improve fish habitat by increasing the availability of spawning gravel, pool habitat and cover. However, if sediment sources are not controlled, storage from LWD could result in excess fine and coarse sediment storage, degrading the habitat.

Triggering Mechanisms:

The following factors lead to the generation and delivery of sediment from non-road-related landslides in MWMU 1 and 2:

Natural characteristics:

- Steep slopes (≥40% by the DEM), held up by relatively resistant basalts and andesites (field-measured slopes are commonly steeper).
- Concave slopes, headwalls and bedrock hollows to concentrate shallow ground water, increasing pore water pressure to destabilize slopes.
- Occurrence of large storms, routing large quantities of shallow ground water to unstable slopes.
- Clay-rich, unstable soils formed from weathered volcanics (breccias, volcaniclastics, interbedded volcanic sediments).
- In some cases, shallow ground water seeps may be reducing slope stability by increasing pore-water pressure.
- Close proximity and direct sediment routing to streams, especially in inner gorges (MWMU 2).

Contributing management-related characteristics:

Eighteen out of 23 non-road-related landslides (78%), for which applicable stand age data is available within these MWMU, probably occurred within 20 years of harvest. This suggests that in most cases the slope stability was reduced by harvest, possibly associated with:

- reduction in root strength (Burroughs and Thomas 1977, Krogstad 1996, Ziemer 1981), and/or
- increases in shallow subsurface pore-water pressure following removal of vegetation during harvest.

Maps:

Map A2 delineates the mass wasting map units for this situation, MWMU 1 and 2. The specific areas of concern are subject to field verification, and consist of the following:

- MWMU 1. Moderately steep (>40% field-observed slopes) concave slopes and headwalls within the MWMU 1 polygons on Map A2.
- MWMU 2. Moderately steep (≥40% by DEM), slopes on inner gorges within the MWMU 2 polygons on Map A2.

Map A1 shows the locations of specific landslides.

Additional Comments:

In-unit Failures:

The following table lists the non-road-related landslides associated with MWMU 1 and 2 for which applicable stand age data is available. Large deep-seated landslides have not been listed, because of greater ambiguity in their initiation date.

Table CMA1 Non road-related landslides associated with MWMU 1 and 2 for which applicable stand age data is available.

Landslide Number	Slide Type	Slope Type	Position	DEM Slope (%)	Estimated Years Since Harvest	Estimated Delivered Volume (m^3)
135	SR	Planar	Ridge	85	33	6,552
105	SSD	Concave	Stream Adjacent	25	25	5,879
123	SR	Concave	Ridge	55	12	5,205
96	DF	Concave	Midslope	65	8	1,834
75	SR	Concave	Stream Adjacent	65	28	1,808
127	SR	Concave	Midslope	75	7	1,301
87	SR	Concave	Midslope	45	16	1,130
98	DF	Concave	Midslope	55	8	459
118	DF	Concave	Midslope	85	6	306
114	DF	Concave	Midslope	65	12	306
46	SR	Concave	Midslope	85	12	228
76	DT	Concave	Midslope	85	28	226
77	DT	Concave	Midslope	75	25	226
97	DF	Concave	Midslope	45	8	153
221	LPD	Convex	Midslope	65	7	55
200	SR	Concave	Stream Adjacent	45	7	32
217	DF	Planar	Midslope	55	7	17
40	SR	Concave	Midslope	35	2	0
258	SR	Concave	Midslope	85	3	0
204	SR	Planar	Midslope	55	1	0
45	SR	Concave	Midslope	85	5	0
44	SR	Concave	Midslope	85	5	0
101	SR	Concave	Midslope	75	5	0

Channel Observations:

The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs. See the Channel Assessment (Appendix E) for further observations

Location GMU	Example Stream Segments	Observations
All GMUs	All anadromous and resident fish	• Turbidity observed during and following high flow events
GMUs 2,4 and 5	Anadromous fish in GMUs 2 and 4 and resident fish in all	• Storage of fine sediment at channel margins • Fine sediment accumulation in backwater areas • Some filling of gravel and cobble interstices

Management Objective:

Minimize in-unit landslides and their adverse effects due to management related activities on steep concave slopes and inner gorges (MWMUs 1 and 2) that could deliver sediment to streams.

PRESCRIPTION

- Ensure continued training for appropriate field personnel in identifying topographical/ geological features that accompany areas of high risk. Utilize a geologist or qualified slope stability specialist when risk is indeterminate.
- Consider alternative harvest plans when operating in high risk areas. These may include:
  - Partial cut, selective cut or no cut areas,
  - Redesigning harvest boundaries,
  - Suspension logging,
  - Falling and yarding away from unstable areas,
  - Longer greenup timeframes between adjacent harvest units.,
  - Loading leave trees in downslope draws from likely landslide areas to help arrest a failure and/or provide LWD to channel if a failure does occur.
- Use harvest and forest management techniques that avoid concentrating flow in MWMU 1. For example:
  - Yard away from headwall areas.
  - Downhill skyline corridors should not use a fan pattern when that pattern will result in flow concentration to steep concave slopes.
  - Evaluate placing leave trees in unstable areas if the site is suitable (i.e., wind-firm, safe, operationally feasible).
  - Evaluate retaining understory vegetation, particularly big-leaf maple or alder. The trade off for this may be the difficulty of establishing conifer regeneration, which may supply more root strength stability over the long-term.
- Evaluate the adequacy of the riparian area protection plan to protect the identified inner-gorge area to the slope break. In areas that current practices do not adequately protect the inner-gorge area to the slope break, adjust the unit layout and harvest plan considering:
  - Use leave tree placement in riparian areas to provide additional root strength in unstable inner-gorge areas. Include an evaluation for wind firmness when planning leave tree placement.
  - Enhanced regeneration (i.e., higher density, older stock) of sensitive inner-gorge areas after harvesting to enhance root strength over time.
  - Use harvesting methods that do not disturb the identified inner-gorge areas.
  - Leave additional trees a minimum of 20 feet beyond the slope break to protect unstable areas.
- Adapt management prescriptions for Mass Wasting in response to any newly acquired knowledge/understanding of triggering mechanisms.

Justification for Prescription:

Training provided to field personnel will improve their ability to recognize and evaluate areas vulnerable to disturbance and prone to failure. This training also gives them the ability to know when conditions or planned management activities warrant the use of geotechnical support. Features which are typical of steep concave slopes or sites prone to inner gorge failures can be identified as units are being laid out for harvesting activities. The field engineer can use these features and evidence of current or past failure to evaluate the potential for future failure. As we

gather more data and refine the triggering mechanisms, we will continue to incorporate this learning into our management activities.

Grouping leave trees downslope (in draws) from potential slide areas will have several functions. If a slide occurs, these trees will help to dissipate energy. If the slide has sufficient force to uproot the trees, this then becomes a large woody debris contribution to the streambed and helps minimize the distance the slide moves down channel. (Note that in unmanaged watersheds this sequence is many times a contributor of LWD to the stream.) Grouping leave trees in or adjacent to riparian trees is also preferred operationally.

Techniques that can result in concentrating flow will be avoided in areas of suspected risk. These areas may be especially susceptible to artificial concentrations of surface or sub-surface run-off.

Current riparian zone protection may encompass the identified inner gorge areas. If the current riparian protection is not adequate, additional leave trees to protect the slope break may be needed since the break itself is where many failures are initiated.

Harvest unit layout must be evaluated with the sensitive high risk areas in mind. Windthrow is a risk, depending on the location of leave trees in relation to terrain and other surrounding timber. In the case of the inner gorge areas, windthrown trees can result in soil disturbance and create an additional sediment source to the stream. The field engineers must use their experience to weigh the trade-offs regarding leave tree selection. Harvesting methods and layout can be adapted to avoid soil disturbance impacts to these areas.

Monitoring:

The location of future failures will be mapped and given to the GIS for incorporation in the landslide inventory. If known, include date and reason for failure. This data will be evaluated at 10 year intervals to determine if the prescriptions are effective at minimizing failures from old roads and avoiding failures associated with new road construction.

Surface Erosion Resource Sensitivity B1:

Dirt roads / abandoned roads.

CAUSAL MECHANISM REPORT

Situation Summary:

Surface erosion from dirt roads has the potential to deliver significant fines to the stream system. Frequently dirt roads are vegetated but subsurface flow and runoff is diverted to the compacted tread, causing concentrated flows to create gullies. Deliveries to the stream system may occur, causing localized pool-filling and increased turbidity to downstream segments.

Fine sediment can deposit in and affect smaller, lower gradient stream channels where stream power is low relative to input volumes and less able to flush sediment deposits. In addition, localized deposits of sediment in reaches with spawning gravels have the potential for impacts in larger tributary channels where anadromous fish spawn. Resident fish and rearing juvenile anadromous fish are affected if pool filling occurs. Impacts from increased turbidity are present in all reaches regardless of stream size.

- One sensitivity in the fish-bearing segments is localized deposition of sand sized fine sediment which could potentially contaminate spawning gravels of salmonids and reduce rearing areas by filling pools. The following areas would be sensitive if inputs are large: GMUs 1 and 2 for reducing habitat complexity and possible intrusion into spawning gravels; GMU 2 and lower gradient reaches of 4 and 5 for rearing habitat.
- A second sensitivity is turbidity during storm events. Depending on duration and severity, high turbidity conditions can:
  - potentially degrade water quality,
  - impact salmonids' ability to feed,
  - under extreme levels cause gill abrasion affecting respiration, particularly of juvenile fish.

Observations:

The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs.

Location GMU	Affected Fish	Observations
All GMUs	All anadromous and resident fish	• Turbidity observed during and following high flow events
GMUs 2,4 and 5	Anadromous fish in GMUs 2 and 4 and resident fish in all	• Storage of fine sediment at channel margins • Fine sediment accumulation in backwater areas • Some filling of gravel and cobble interstices

Triggering Mechanisms:

- Old dirt roads dating from the first timber harvesting done in the watershed are still evident on the landscape. Those roads built in areas with shallow A horizons and/or impeded internal drainage are prone to surface erosion. Subsurface flow and runoff is diverted to the compacted tread, where erosion causes gullies to develop.
- Frequently after roads are abandoned there is no access for maintenance vehicles and drainage problems easily develop. Road and ditch drainage can concentrate flows and be a source for erosion. Sidecast on roads and landings that have not been pulled back can fail. Exposed soils erode easily off cutslopes and the road running surface.
- When harvesting on gentle ground with ground-based equipment, dirt roads are constructed into a unit. After the harvest is completed, if the road is not closed, recreational vehicles can potentially gain access to the road and compact the surface. During rainy weather, long tread flow-paths develop on these roads which do not have relief drainage. Frequently subsurface flows are intercepted by the tread flow-path and runoff concentrates in the tread, eroding the road surface and delivering fine sediment to drainage systems.
- Recently built dirt roads are potentially very high fine sediment deliverers until the tread surface and cutslope becomes armored and/or ditchouts are used to divert flow. If roads are driven on, armoring is removed.

Example Sites:

Road #
Old dirt roads off the 100 Road in the upper headwaters of the Cedar sub-basin—gullies.
U.S.F.S. 427--abandoned road fill failure.
Harvest unit off the 100 Road at the 130 Road in Cedar sub-basin--long-tread flow path.

Location:

Refer to Map CMB1.

Additional Comments:

- When roads are abandoned (obliterated) the road should not require any future maintenance. Maintenance guidelines should refer to active roads. Road abandonment guidelines should focus on the road drainage (e.g., ditches, culverts, crown, dips, waterbars, insloping, outsloping) and the protection of public resources. Blockage and closure of the road can be done using tank traps, rip rap, root wads, logs or slash. Road and ditch drainage should be routed to create the most natural and/or non-erosive drainage pattern. This may require removal of culverts since drainage structures not removed will eventually fail. Non-driveable waterbars and dips can be constructed to disperse runoff and minimize erosion. Sidecast on roads and landings that have a potential of failing should be pulled back. Exposed soils should be revegetated at the appropriate time of the year. The running surface of the forest road should be ripped to create a softer seed bed for germination of vegetation.

Photographs:

PHOTO CMB1. Photo of a gully in the tread of an abandoned road in the headwaters of Cedar Creek/Hills Creek drainage.

Management Objective:

Minimize sediment delivery to streams from dirt roads / abandoned roads.

PRESCRIPTION

Dirt Roads:

- Cultivate temporary logging roads after use (put to bed).
- Maintain roads to Weyerhaeuser Road Maintenance Manual guidelines (see Prescription Documents section).
- Restrict general access to dirt roads on Weyerhaeuser ownership.
  - Logging roads that will be reused will be blocked and waterbarred to restrict access during wet weather.

- Newly constructed roads that winter over before being rocked will be stabilized using practices outlined in the Weyerhaeuser Road Maintenance Manual (see Prescription Documents section).
- Maintain drainage integrity on closed dirt roads by continuing to educate all users to ensure dirt roads will not be used during periods of wet weather when damage would occur. This may include specific language in contracts or signs at barriers blocking access to the road.

Abandoned or Orphan Roads:

- When orphan roads from previous harvest are encountered, identify any contributing or potentially contributing sediment issues and address when management activities are going on in the area.
- When abandoning a road, follow Oregon Department of Forestry standards to meet the Oregon Forest Practices Act.

Justification for Prescriptions:

The *Willamette Timberlands Road Maintenance Manual* (last updated January 1997) was designed by a cross-functional group of Weyerhaeuser operating personnel specifically to improve maintenance practices. Objectives included reducing erosion and minimizing sediment delivery to stream channels.

The *Manual* includes practices drawn from prescriptions specified in the four previous watershed analyses conducted on our land (Upper Mohawk, Lower McKenzie southside, Lower McKenzie northside and the Upper Siuslaw Watersheds), as well as from adaptive trials conducted in the Willamette Region. We feel these practices generally minimize sediment delivery and they will be actively updated as we try new procedures and evaluate effectiveness.

Traffic on dirt roads in wet weather creates ruts that channel water, cause erosion, and allow sediment delivery to streams. Most erosion control efforts will be ineffective if traffic is not limited. We will manage this by putting to bed and blocking roads not needed for access, and closing with gates or other means roads that must be retained for access.

We currently have language in all of our contracts regarding dirt roads. Hunters are informed of our policies regarding dirt roads. No matter what is done, there is the possibility of vandalism and damage occurring from opening our gates during hunting season. Our intent is to educate the people who may be visiting our lands on the importance of maintaining the integrity of these roads and their drainage.

Orphan roads are abandoned roads from previous harvest (generally more than 40 years ago), often not detectable with aerial photography. These roads are usually discovered when field personnel are on the ground preparing for upcoming management activities. These old roads are typically ripped, pulled and planted during site preparation after harvest activities.

Monitoring:

N/A

Surface Erosion Resource Sensitivity B2:

Long ditch infeed lengths.

CAUSAL MECHANISM REPORT

Situation Summary:

Long ditch infeed lengths on logging roads with few relief drains are delivering fine sediment directly and indirectly to fish-bearing streams. Many roads do not have relief drains, ditchouts or sediment catch basins to capture runoff and/or redirect flow to filter through the forest floor. This is primarily a situation which results in increased turbidity throughout the WAU and localized pool filling in fish-bearing waters.

Fine sediment can deposit in and affect smaller, lower gradient stream channels where stream power is low relative to input volumes and less able to flush sediment deposits. However, localized deposits of sediment in reaches with spawning gravels have the potential for impacts in larger tributary channels where anadromous fish spawn. Resident fish and rearing juvenile anadromous fish are affected if pool filling occurs. Impacts from increased turbidity are present in all reaches regardless of stream size.

- One sensitivity in the fish-bearing segments is localized deposition of sand sized fine sediment which could potentially contaminate spawning gravels of salmonids and reduce rearing areas by filling pools. The following areas would be sensitive if inputs are large: GMUs 1 and 2 for reducing habitat complexity and possible intrusion into spawning gravels; GMU 2 and lower gradient reaches of 4 and 5 for rearing habitat.
- A second sensitivity is turbidity during storm events. Depending on duration and severity, high turbidity conditions can:
  - potentially degrade water quality,
  - impact salmonids' ability to feed,
  - under extreme levels cause gill abrasion affecting respiration, particularly of juvenile fish.

Observations:

The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs.

Location GMU	Affected Fish	Observations
All GMUs	All anadromous and resident fish	• Turbidity observed during and following high flow events
GMUs 2,4 and 5	Anadromous fish in GMUs 2 and 4 and resident fish in all	• Storage of fine sediment at channel margins • Fine sediment accumulation in backwater areas • Some filling of gravel and cobble interstices

Triggering Mechanisms:

The following factors lead to the generation and delivery of potentially large quantities of sediment from long infeed lengths:

- Because of the many miles of midslope road with light haul traffic, these roads have a potential for high cumulative sediment yield to the stream system. More frequent drainage relief is especially important on midslope roads with long infeed length ditchlines draining directly to stream crossings or lower elevation road ditchlines.
- Much of the runoff and fine sediment generated on the road tread and ditchline is delivered directly to a live stream channel by the road ditch. Many roads do not have adequate drainage along ditchlines since few relief drainage structures have been installed. More relief drains, ditchouts or sediment catch basins would capture runoff and/or direct flow to filter through the forest floor.
- Tread runoff generally delivers half to the fillslope and half to the cutslope with crowned or insloped and outsloped roads. Because of the lack of a crowned surface on the tread of the road, the tread is delivering much of its runoff from the tread to the ditchline.
- Steep grades with long-infeed lengths cause ditchlines to downcut. Sediment deposited in the ditchline easily erodes with rain storms and delivers fine sediment to the stream system.
- Long ditch infeed lengths can concentrate flows which increase the potential for cutslope slump block failures as the toe of the cutslope is cut away by ditchline flow.
- Sparsely vegetated cutslopes generate large volumes of fine sediment in localized areas. This is particularly evident in large persistent deep-seated landslide areas and regions of well weathered, deep clay soils and clay substrates. Concentrated flows of ditchline water from long infeed lengths pick up enough velocity to downcut the ditchline and scour the ditchline of vegetation.
- Heavy traffic, where present, greatly increases the quantity of fine sediment that is potentially eroded from the tread, enters the ditchline and delivers to the stream.

Example Sites:

The following list of roads and road segments provides examples of this road situation from the road inventory.

Road #	Segment #	Length Miles	Fine Sediment Yield Tonnes/Year Light Haul
LFC 7080	943	0.25	10
LFC 6000	733	0.39	6
HCR 370	106	0.18	6
LFC 7000	802	0.58	5

Prioritization:

1. Long ditch infeed lengths on steeper gradient roads delivering directly to fish-bearing waters.
   - Long ditch infeed lengths on steep heavy haul road segments (mainline roads) delivering directly to fish-bearing waters.
   - Long ditch infeed lengths on steep moderate haul road segments (primary/secondary roads) delivering directly to fish-bearing waters
   - Long ditch infeed lengths on steep light haul road segments (spur roads) delivering directly to fish-bearing waters.
2. Long ditch infeed lengths on all other road segments delivering to live stream drainages.

Additional Comments:

Road drainage should include consideration of the following factors:

1. The type of drainage (i.e., fish passage).
2. The adequate capacity of culverts (culvert sizing).
3. The right quantity of culverts to reduce the concentration of flow.
4. The correct locations of cross drains to divert flow to a forest floor.
5. Road surface waters from the tread should be prevented from flowing onto unprotected fills or into flowing waters using inslope or outslope surfaces.

Photographs:

PHOTO CMB2. Flow diverted into ditchline with a long infeed length along Hills Creek mainline.

Management Objective:

Minimize fine sediment delivery to streams resulting from long ditch in-feed lengths on forest roads.

PRESCRIPTION

New Roads

- Follow Weyerhaeuser Road Maintenance Manual guidelines for culvert placement on new road construction (see Prescription Documents section).

Existing Roads

- Prioritize areas for road drainage improvements considering:
  - Upcoming winter hauling activities,
  - Subsurface flow in LPD-prone terrain,
  - Known road segments potentially delivering sediment to streams,
  - Road erosion assessment from watershed road inventory.
- High priority road segments will be upgraded as resources permit. Upgrading may include:
  - Installing additional culverts for cross drainage and spacing,
  - Targeting ditch relief 150 to 200 feet prior to stream crossing when topography allows,
  - Road crowning,
  - Ditches will be pulled only when necessary and will be reseeded afterward when appropriate,
  - Cutslope revegetation efforts will target the segment between the last ditch relief culvert and the stream crossing.
- Maintain forest roads following the guidelines outlined in the Weyerhaeuser Road Maintenance Manual (see Prescription Documents section).

Justification for Prescription:

The *Willamette Timberlands Road Maintenance Manual* (last updated January 1997) was designed by a cross-functional group of Weyerhaeuser operating personnel specifically to improve maintenance practices. Objectives included reducing erosion and minimizing sediment delivery to stream channels.

The *Manual* includes practices drawn from prescriptions specified in the four previous watershed analyses conducted on our land (Upper Mohawk, Lower McKenzie southside, Lower McKenzie northside and the Upper Siuslaw Watershed), as well as from adaptive trials conducted in the Willamette Region. We feel these practices generally minimize sediment delivery and they will be actively updated as we try new procedures and evaluate effectiveness.

The *Manual* includes current road construction standards which outline drainage requirements, including maximum relief culvert spacing by road gradient classes and designing culverts for a 50-year flood with a minimum 24" culvert in definite draws. The *Manual* recognizes the impact soil types have on sediment generation. Targeting 150 feet for a relief drain before crossing a live stream will divert the sediment out onto the forest floor, keeping it out of the channel.

The level of hauling activity is a major factor in sediment generation from forestry roads. We will identify roads with upcoming winter haul activity and place a priority on them for drainage upgrading.

Monitoring:

N/A

Surface Erosion Resource Sensitivity B3:

Stream adjacent roads.

CAUSAL MECHANISM REPORT

Situation Summary:

Erosion from stream adjacent road segments is delivering significant fine sediment to the stream channels. When the stream adjacent road is a mainline with heavy haul traffic or a secondary road with moderate traffic, fine sediment is primarily generated from the tread. Cutslopes may also deliver fine sediment, but fillslopes are generally well vegetated and filter fine sediment through the forest floor. Stream adjacent mainlines with low gradients and long infeed lengths may pond water and allow some fine grained particles to settle out.

Fine sediment can deposit in and affect smaller, lower gradient stream channels where stream power is low relative to input volumes and less able to flush sediment deposits. However, localized deposits of sediment in reaches with spawning gravels have the potential for impacts in larger tributary channels where anadromous fish spawn. Resident fish and rearing juvenile anadromous fish are affected if pool filling occurs. Impacts from increased turbidity are present in all reaches regardless of stream size.

- One sensitivity in the fish-bearing segments is localized deposition of sand sized fine sediment which could potentially contaminate spawning gravels of salmonids and reduce rearing areas by filling pools. The following areas would be sensitive if inputs are large: GMUs 1 and 2 for reducing habitat complexity and possible intrusion into spawning gravels; GMU 2 and lower gradient reaches of 4 and 5 for rearing habitat.
- A second sensitivity is turbidity during storm events. Depending on duration and severity, high turbidity conditions can:
  - potentially degrade water quality,
  - impact salmonids' ability to feed,
  - under extreme levels cause gill abrasion affecting respiration, particularly of juvenile fish.

Observations:
The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs.

Location GMU	Affected Fish	Observations
All GMUs	All anadromous and resident fish	• Turbidity observed during and following high flow events
GMUs 2,4 and 5	Anadromous fish in GMUs 2 and 4 and resident fish in all	• Storage of fine sediment at channel margins • Fine sediment accumulation in backwater areas • Some filling of gravel and cobble interstices

Triggering Mechanisms:

The following factors lead to the generation and delivery of fine sediment from stream adjacent roads:

- The close proximity of roads to a stream channel creates situations where road drainage flows into the channel either directly or indirectly. This is especially true where relief drainage structures have not been installed for long distances along the road to route road runoff to wider areas of forest floor between the road and the channel.
- Because of the lack of available land between the road and the stream for receiving runoff, even if relief drainages are available to route runoff away from the channel, fine sediment is not able to filter through the forest floor. Extra measures should be taken to route runoff away from the stream onto a forest floor or land surface, which may filter the fine sediment, and, where feasible, to install sediment catch basins to filter sediments.
- Some ditchlines are periodically cleaned and left unvegetated. The lack of vegetation allows erosion of the ditchline and transport of road sediment.
- Heavy traffic greatly increases the quantity of sediment eroded from the tread of the road. In many cases erosion of the road tread occurs from ruts which have developed from truck tires during haul.
- Where roads cross fish-bearing stream channels, most, if not all, runoff and fine sediment generated on the road prism is delivered directly to the stream channel. Long tread flow-paths and long infeed lengths along the ditchline generate and deliver fines from the cutslope and tread.
- In some situations grades frequently drain from both directions of the road to a live stream crossing, causing fine sediment to be delivered directly into fish-bearing waters.
- Fillslopes frequently mimic the high delivery conditions of ditchlines because a significant road running length is close to the stream and drainage enters the fillslope area and delivers directly to the stream channel.
- Fill material that is placed stream adjacent along forest roads is bare and unvegetated and easily erodes with heavy rainfall. Removed fill and end haul material should be placed in a stable location that will not erode and deliver to the stream network.

Example Sites:

During heavy haul, road segments in close proximity to streams in the WAU are delivering some of the higher volumes of sediment to the stream system.

Road #	Segment #	Length Miles	Fine Sediment Yield Tonnes/Year Heavy Haul
LFC M/L	507	1.03	112
LFC M/L	405	0.44	47
LFC M/L	494	0.30	39
LFC M/L	401	0.20	25
LFC M/L	404	0.22	24
LFC M/L	478	0.17	19

Prioritization:

1. Heavy haul on stream adjacent roads on road crossing segments at fish bearing streams.
2. Heavy haul on stream adjacent roads on all other segments.
3. Moderate and light haul on stream adjacent roads on road crossing segments at fish bearing streams.
4. Moderate and light haul on stream adjacent roads on all other segments.

Location:

Refer to Map CMB1.

Photographs:

PHOTO CMB3. Photo taken during winter of 1996 along the Little Fall Creek Mainline Road. The road was under a heavy haul traffic situation.

Management Objective:

Minimize sediment delivery from streamside roads.

PRESCRIPTION

Prioritize areas for resource allocations based on volume of sediment delivery projected to make it to the stream. Recognize that the areas of emphasis will change based on the amount of activity the different road segments are supporting from various management activities.

- Where economically practicable, use high quality rock on streamside roads. Where high quality rock is not available, use other management techniques to minimize sediment generated (i.e., seasonal activities road maintenance techniques).

- Consider installing sediment catch basin, ditchline diversions and/or cross drains prior to live stream crossings to filter sediments.
- Use soil stabilization techniques such as grass seeding, mulching and matting on unvegetated cut slopes between the last ditch culvert and the stream crossing where there is evidence of siltation.
- Use methods to divert travel surface run-off such as diversion flaps, rolling dips, crowning and road sloping, water barring, regular road maintenance and berms.
- Avoid regular road maintenance activities during periods of heavy rainfall.
- Maintain established vegetation in ditch lines and at the bottom of cut slopes where it does not interfere with normal ditch function.
- Consider adding a lift of rock (2"-6") to selected streamside road segments prior to active hauling.
- Consider use of geotextile barriers to control sediment delivery from streamside roads.
- Maintain roads to *Weyerhaeuser Road Maintenance Manual* guidelines with special emphasis on areas with potential for delivery (see Prescription Documents section).
- Restrict access to forestry and dirt roads where appropriate to minimize delivery of sediments to streams and meet current ODF Standards.
- Maintain ongoing training for company and contract road maintenance operators as needed to ensure compliance with road maintenance expectations.
- Avoid placement of waste piles from end haul construction along stream-adjacent roads where there is potential of delivering sediment to the stream.
- Vegetate existing waste piles along stream-adjacent roads that can deliver sediment to the stream.

Justification for Prescriptions:

The level of hauling activity determines the quantity of sediment eroded from the tread of the road. Identifying roads with upcoming hauling activity and prioritizing these road segments for improvement using the criteria outlined in this causal mechanism will allow us to get the most benefit for the resources allocated.

Streamside roads have a higher probability of delivering sediment to the stream because of their proximity and the lack of permeable forest floor before reaching the channel. The prescriptions for this causal mechanism list a host of possible activities to minimize sediment delivery to the stream. The land managers have many options to choose from to cover the various situations that may be encountered. Some will work better in specific areas than others.

An additional lift of rock along streamside roads can be effective in reducing the amount of fines that can be pumped to the road surface and carried to the stream. This may be very effective where there is a limited window of heavy traffic and a definite streamside sediment problem. Using high quality rock will prevent the surface from breaking down with use and introducing additional sediment to the tread.

Monitoring:

N/A

Surface Erosion Resource Sensitivity B4:

Diversion of subsurface flow of water into forest road ditchline.

CAUSAL MECHANISM REPORT

Situation Summary:

Near-surface ground water is intercepted by the road prism and is being concentrated in ditchlines. This increases the potential for fine sediment to be introduced to the channel from the cutslope and tread of the road. This is primarily a situation which results in increased turbidity throughout the WAU and localized pool filling in fish-bearing waters.

Fine sediment can deposit in and affect smaller, lower gradient stream channels where stream power is low relative to input volumes and less able to flush sediment deposits. However, localized deposits of sediment in reaches with spawning gravels have the potential for impacts in larger tributary channels where anadromous fish spawn. Resident fish and rearing juvenile anadromous fish are affected if pool filling occurs. Impacts from increased turbidity are present in all reaches regardless of stream size.

- One sensitivity in the fish-bearing segments is localized deposition of sand sized fine sediment which could potentially contaminate spawning gravels of salmonids and reduce rearing areas by filling pools. The following areas would be sensitive if inputs are large: GMUs 1 and 2 for reducing habitat complexity and possible intrusion into spawning gravels; GMU 2 and lower gradient reaches of 4 and 5 for rearing habitat.
- A second sensitivity is turbidity during storm events. Depending on duration and severity, high turbidity conditions can:
  - potentially degrade water quality,
  - impact salmonids' ability to feed,
  - under extreme levels cause gill abrasion affecting respiration, particularly of juvenile fish.

Observations:

The following table lists several observations of fine sediment in channels. Observations of fine sediment in the channel are the result of both natural background inputs and management-related inputs.

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Triggering Mechanism:

The following factors lead to the generation and delivery of fine sediment from ditchlines that intercept and concentrate flow from subsurface flows:

- In areas where the geologic parent materials have weathered to deep clay soils, subsurface flows are shallow and are easily intercepted by road ditchlines.
- When roads are built with long ditch infeed lengths, flows of water are diverted from springs and seeps, and concentrate in the ditchline during runoff. The erosive power of the water in the ditchline has the potential to downcut the ditch, producing fine sediment which may deliver to live streams.
- Sparsely vegetated cutslopes ravel into the ditchline during the dry season and erode through sheetwash during heavy runoff. Cutslopes with no vegetation deliver larger volumes of fine sediment to stream systems.

Example Sites:

The following list of roads and road segments provides examples of this road situation from the road inventory.

Road #	Segment #	Length Miles	Fine Sediment Yield Tonnes/Year Light Haul
18-1-73 BLM	Cedar Creek	--	--
HCR 100	326	0.10	0.1
HCR 100	331	0.13	3.0
HCR 353	244	0.03	1.5
LFC 3100	625	0.10	5.5

Prioritization:

1. Those road segments found within large persistent deep-seated landslide areas within areas of deep clay soils.
2. Other road segments identified as having drainage diverted to the ditchline with a long ditch infeed length.

Management Objective:

Minimize the effects of the interception of subsurface flow in deeply weathered clays which erodes ditchlines and delivers fine sediment to streams.

PRESCRIPTION

In areas where these conditions are known to exist:

- Where possible, avoid building new roads

In areas where there are existing roads or new construction is unavoidable:

- Slow drainage in ditch to avoid down cutting. Consider:
  - Putting non-erodible material in ditch to slow the flow,
  - Installing culverts for cross drainage,
  - Vegetating cut slope where possible.
- New construction in LPD-prone terrain will be reviewed during the first winter after construction for potential cut bank seepage and to establish maintenance schedule for any obvious problem areas.
- Utilize flatter grades and minimize cuts when building new road.

Justification for Prescriptions:

The prescriptions written are a mix of prevention and mitigation. While the field engineers can often identify areas likely to have subsurface drainage, (hummocky ground, light brown or gray soil colors and by the vegetation present), these areas can not always be identified in advance, especially seeps and springs, or totally avoided with new road construction.

Typically, roads are built in the summer when weather conditions may not show how the road has impacted drainage. Reviewing new roads the first winter after construction should show any areas that may need additional relief culverts to route cutbank seepage onto the forest floor.

Monitoring:

N/A