Forest Practices Technical Note Number 8

Version 1.0

Installation and Maintenance of Cross Drainage Systems on Forest Roads

June 20, 2003

Objective

Technical notes are written to help resource professionals, in this case engineers and foresters responsible for road design or maintenance. This note provides technical guidance on recent road drainage rule revisions. Effective road drainage controls runoff waters and directs these waters to locations where they have little or no effect on water quality. This note does not provide information on stream crossing structures. Forest Practices Technical Notes 4 and 5 provide guidance on stream crossing structures.

Resource Issues

A Forest Practices Advisory Committee (FPAC) was assembled in 1999 to review existing forest practices and make recommendations to effectively protect salmon habitat and water quality. After review of the scientific and monitoring data, the FPAC made the following recommendations to improve drainage of forest roads:

1. ***Better clarify the objectives of the road drainage rules so that the risk of sediment delivery to waters of the state from new roads is minimized, and***
2. ***require additional cross drainage installation as a maintenance requirement prior to an operation when current road condition and a proposed use will impair water quality.***

Effective road drainage is necessary to protect the road prism from damage, to keep the road surface stable, and to allow efficient forest management. Good drainage for resource protection also helps ensure a stable, effective forest road. Proper drainage allows full use of forest roads and reduces maintenance and repair costs. Based on the results of recent Rule Compliance; Wet Season Road Use; Storm Impacts and Landslides of 1996; and Road Sediment monitoring projects, it is important to pay special attention to drainage if the following situations are encountered:

- Near stream crossings and in wetlands;
- On roads that are parallel to and very close to streams;
- On roads where use is changing from inactive to active timber haul;
- When reconstructing old roads, especially sidecast constructed roads on slopes steeper than 60%; and
- On existing roads where gullies have developed in the ditch or at culvert outlets.

Forest Practice Rules

The Board of Forestry adopted revised rules that were effective on January 1, 2003. The rule for road design (for new and reconstructed roads) has been clarified. There is now a clear priority for locating cross-drainage structures. The substance of this rule has not been changed, as shown below. The road maintenance (for older roads) rules have been modified, with a new requirement to install additional drainage where needed to protect water quality (see page 12 of this Note).

OAR 629-625-0330
Drainage

(1) The purpose of this rule is to provide a drainage system on new and reconstructed roads that minimizes alteration of stream channels and the risk of sediment delivery to waters of the state. Drainage structures should be located based on the priority listed below. When there is a conflict between the requirements of sections (2) through (6) of this rule, the lowest numbered section takes precedence, and the later-numbered and conflicting section shall not be implemented.

(2) Operators shall not concentrate road drainage water into headwalls, slide areas, high landslide hazard locations, or steep erodible fillslopes.

(3) Operators shall not divert water from stream channels into roadside ditches.

(4) Operators shall install dips, water bars, or cross drainage culverts above and away from stream crossings so that road drainage water may be filtered before entering waters of the state.

(5) Operators shall provide drainage when roads cross or expose springs, seeps, or wet areas.

(6) Operators shall provide a drainage system using grade reversals, surface sloping, ditches, culverts and/or waterbars as necessary to minimize development of gully erosion of the road prism or slopes below the road.

DRAINAGE SYSTEM FOR NEW AND RECONSTRUCTED ROADS

The road drainage rule now provides a specific order for locating road drainage structures. Where there are conflicts, use the following priority order for placing drainage structures.

A. Do not collect drainage and discharge it on steep slopes, headwalls, and active and recently active landslide areas, since additional water can trigger landslide movement. **This may require routing drainage to stream channels.**
B. Place stream crossing structures at all stream channels, so streams are never running in a ditch.
C. Provide a cross drainage structure for filtering immediately upstream from stream crossings to allow muddy runoff to seep into the forest floor.
D. When wet areas are crossed, provide drainage to keep water from affecting the road surface.
E. The **last** item is to slope the road so that the need for cross drains is reduced and to place essential cross drains on the rest of the road at a spacing that will prevent gully formation (either in the ditch, or below the cross-drain).

Road reconstruction includes any road re-location, widening, or replacement of stream crossing structures. It does not include removal of brush, bank slough, or the addition of or replacement of cross drainage structures alone. The road design rules, including 629-625-330, apply directly only to the road segments under reconstruction and to new construction. However, if existing road drainage is inadequate, the department may direct drainage repairs on all portions of the road under OAR 629-625-600 (9), as described later in this Technical Note.

A. Road drainage and landslides

SCIENCE AND MONITORING

Robison and others (1999) and other studies have found that road drainage waters directed onto landslide prone locations increases the risk of landslides. Since landslides can cause very large inputs of sediment, it is a priority to reduce landslide occurrence. Locations where added water is most likely to increase landslide occurrence include high landslide hazard locations, especially headwalls; existing landslide deposits; and steep fillslopes. Each of these terms is defined below.

TERMINOLOGY

Headwalls are steep, concave slopes that do not contain stream channels. The headwalls of greatest concern meet the high landslide hazard slope steepness criteria (see below). However, concentration of drainage to any headwall steeper than around 60 percent can also trigger landslides.

Slide areas include all active and recently active landslide deposits. There are two common slope forms for slide areas: 1) an upper scarp, main body, and toe (Figure 1) or 2) multiple scarps and hummocks (Figure 2). Some slides may pre-date the age of the stand of trees currently on the site. The fact that the trees are straight does not necessarily imply the landslide is inactive.

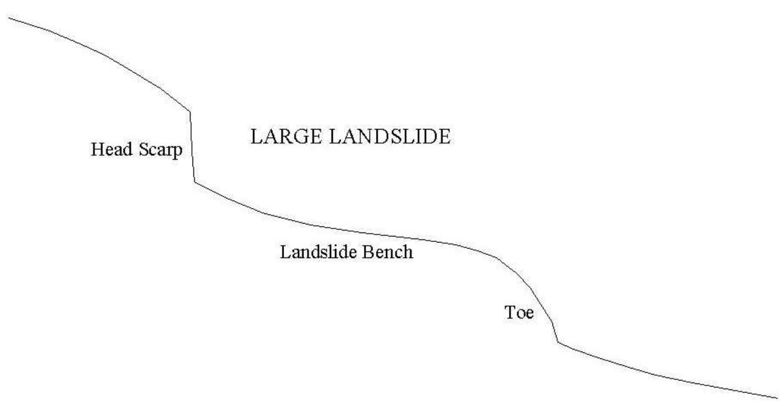

Figure 1. Shape of deep-seated landslide; scale on order of 50 to 1000 feet.

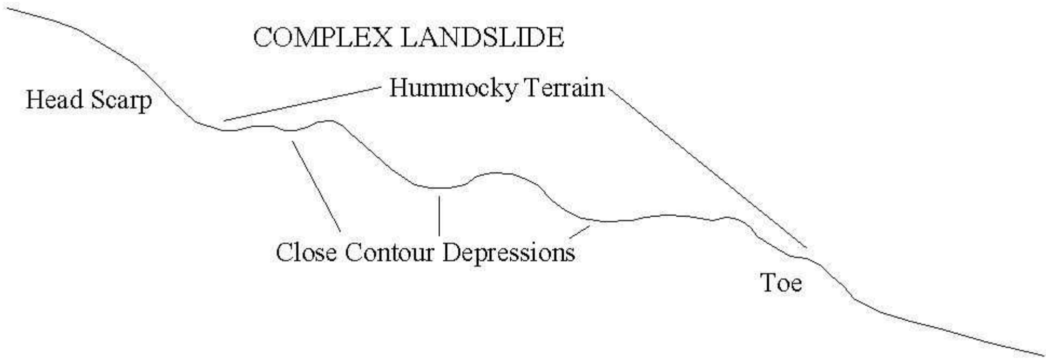

Figure 2. Common ground features of complex landslides; scale on order of thousands of feet.

Steep erodible fillslopes include any fills of mostly soil and over 2 feet thick on slopes over 60 percent, or over 50 percent if soils are wet (springs or seeps during the wet season) or within 100 feet of streams.

High landslide hazard locations are defined by OAR 629-600-0100 (31) as specific sites that are subject to initiation of a shallow, rapidly moving landslide. The specific criteria for determination of these sites is found in 629-623-0100 (3) as

(a) The presence, as measured on site, of any slope in western Oregon (excluding competent rock outcrops) steeper than 80 percent, except in the Tyee Core Area, where it is any slope steeper than 75 percent; or
(b) The presence, as measured on site, of any headwall or draw in western Oregon steeper than 70 percent, except in the Tyee Core Area, where it is any headwall or draw steeper than 65 percent.
(c) Notwithstanding the slopes specified in (a) or (b) above, field identification of atypical conditions by a geotechnical specialist may be used to develop site specific slope steepness thresholds for any part of the state where the hazard is equivalent to (a) or (b) above. The State Forester shall make the final determination of equivalent hazard.

For more information on high landslide hazard locations, see Forest Practices Technical Note #2.

Concentration of road drainage means collecting drainage from one location and directing it to a location where it had not flown to prior to road construction. A serious example of improper drainage concentration is a ditch that carries water from one headwall and discharges water to another headwall. Another example is a ditch that carries water from off of an active or recently active landslide and discharges water onto an active or recently active landslide.

IMPLEMENTATION

Most landslide prone locations can be identified during field reconnaissance during road layout. Use of an accurate clinometer and observation of slope form looking for headwalls (visibly concave steep slopes), scarps (local, very steep slopes) and hummocky (irregular) terrain are the tools needed to identify potentially unstable terrain.

Drainage structures should not be located to discharge onto headwalls, except in cases where drainage water can be directed onto headwalls that have previously failed and are scoured to rock. When roads are constructed across continuous high landslide hazard locations, cross drains should be placed so that drainage flows to convex or uniform slopes near each spur ridge. For existing landslides, cross drainage should be placed just above the location before the road begins to enter the existing landslide area.

B. Avoiding diversion of stream channels

SCIENCE AND MONITORING

Ditches normally have finer soil material than do stream bed and banks, thus are more easily eroded. When stream flows are diverted onto these more erodible materials, increased erosion is almost certain. In addition, research and monitoring have also shown that sediments are also easily eroded from road surface. ODF monitoring turbidity in streams increased in proportion to the flow observed in ditches. When streams are diverted into ditches, there is no opportunity to filter sediments to the forest floor (see Section C of this Technical Note).

TERMINOLOGY

Stream channels have defined bed and banks, meaning that there has been sorting of material by flow. Streambeds contain less fine soil particles than surrounding soils.

A ***gully*** is a trench of at least 6 inches in depth carved into soil, rock or fill by runoff and not located in a channel, in a location where eroded material can be deposited into waters of the state. Gullies are distinguished from stream channels by the lack of sorting of materials. Gullies are formed by infrequent rainfall events or redirection of surface drainage, and disappear over time if drainage is re-directed.

IMPLEMENTATION

This rule is very simple, always place a culvert at stream crossing locations. Never use a roadside ditch to connect two stream channels. Limited excavation further from the road can be acceptable in cases where small streams come together at the crossing.

C. Cross drains for filtering

SCIENCE AND MONITORING

The forest floor can usually absorb large amounts of water, and can be used to greatly reduce the potential for muddy runoff entering streams. In western Oregon, undisturbed forest soils can often absorb over 10 inches of water per hour. When muddy runoff waters are directed to these soils, water flows into the ground, leaving the road-generated sediment on the forest floor. Research has shown that sediment plumes typically extend from about 5 feet to 130 feet below cross drain culverts (except when gullies form, which often extend to stream channels).

The distance muddy runoff water travels increases with road grade and spacing to the next cross drainage structure.

The recently completed wet season road use monitoring study found that, after rainfall, the factor that had the greatest effect on turbidity was the length of road delivering to streams. This appears to have been a more significant factor than surfacing durability.

IMPLEMENTATION

Drainage waters must be directed onto undisturbed soils. Cross drains need to be installed as close to stream crossings as possible and allow between 15 and 200 feet of ground filtering between the outlet of the cross drain and the high water level of the stream, as measured from the stream (Figure 4). The distance depends in part on the slope of the ground below the drain discharge, the road grade and the distance to the next culvert up the road (see Table 1).

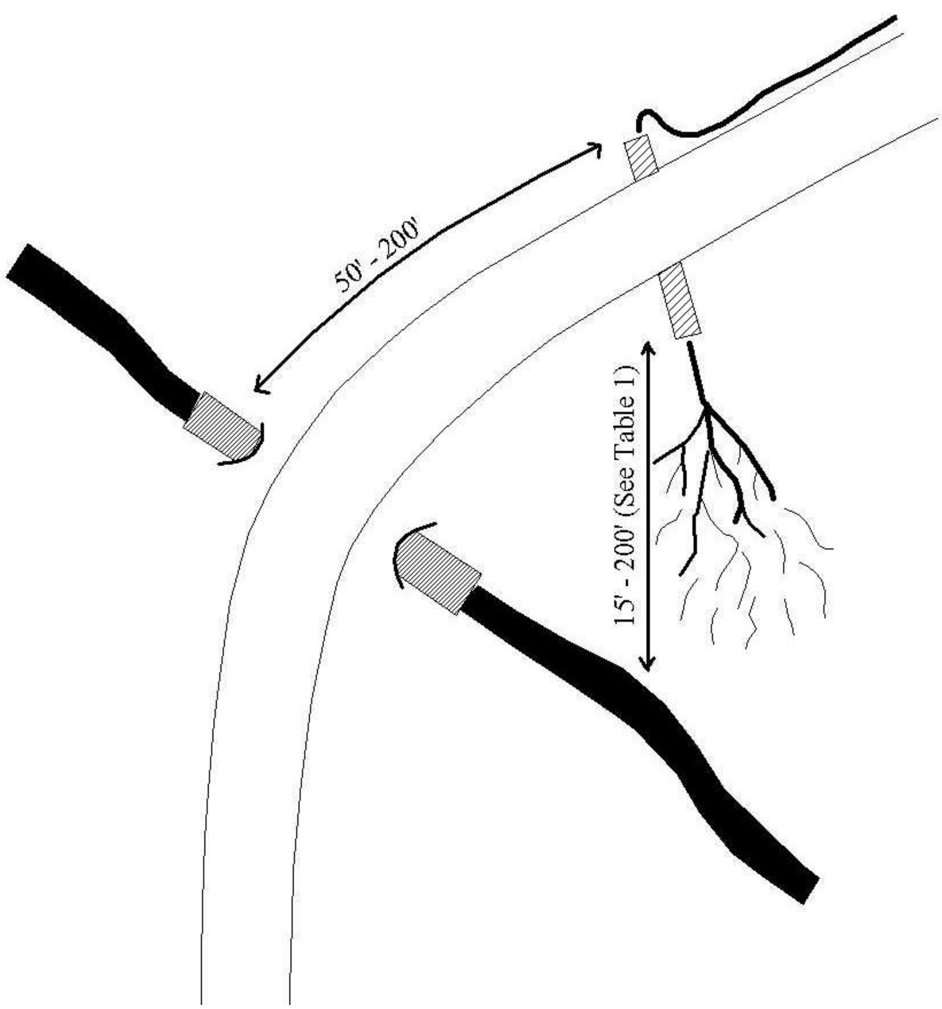

Figure 4. Installation of cross-drains above stream crossings to effectively filter muddy runoff.

Table 1. Suggested distances for filtering

Road grade	Distance to next cross-drain up road under 300 feet	300-600 feet	over 600 feet
0 to 5 %	15 ft	30 ft	50 ft
6 to 12 %	30 ft	60 ft	100 ft
13 to 19 %	50 ft	100 ft	150 ft
over 20 %	60 ft	120 ft	200 ft

Cross drains should be 50 to 200 feet from the stream crossing, as measured along the road (Figure 4). For effective filtering, soils must not have been disturbed by logging equipment, should include no fill, and slope steepness should be less than 60 percent, if possible. For continuous high landslide hazard locations, or sections of steep fill too long for half rounds, ditch flow may need to discharge directly into streams. Also, if soils are disturbed, additional filtering distance is required.

D. Drainage of wet areas

SCIENCE AND MONITORING

Water saturation on the road surface greatly reduces the strength of that surface. This results in erosion of the surface, and also results in a road that may not be driveable. In most cases, there are many solutions for drainage of a wet surface.

TERMINOLOGY

Springs flow from a single location for all or most of the year, and have a significant flow at some time of the year.

Seeps flow from multiple locations, each seep has little flow volume.

Wet areas are locations where soil is saturated or nearly saturated during periods when the road is used.

IMPLEMENTATION

If flows are high, a culvert should be installed at the location of the spring or seeps, so that the potential for ditch erosion, and movement of surface fines from the road is eliminated. As a rule of thumb, high flow is considered to be that which fills a 5-gallon bucket in a minute.

Soil fill should not be placed directly on wet areas since it will become soft and lead to an unstable surface. For areas with moderately wet soils, a free-draining gravel at the base of the fill can be used in most cases. If the flow is significant or soils are very soft or unstable, a perforated culvert or a French drain (gravel wrapped in geotextile) may also be needed. Geotextiles placed on top of wet areas can effectively separate wet soils from the road surface materials if the geotextiles are not damaged during construction or use.

E. Road drainage system

SCIENCE AND MONITORING

Monitoring of road drainage systems has found that most landowners in western Oregon use a crowned surface for permanent roads. Most temporary roads have limited surface shaping. Waterbars are generally installed on temporary roads after use. There is little research on the suitability of outsloping for permanent roads. Outsloped roads are not considered suitable for road grades exceeding 8% unless the road is rocked and not used when snow or ice are present.

E (1). SELECTING A DRAINAGE SYSTEM

A drainage system includes surface sloping and structures to direct water away from the road prism. There are many drainage system components and options available for almost every road, and any road can and usually should use different drainage systems as conditions change. The choice of appropriate drainage systems depends on whether the road is permanent or temporary, season of use, haul volume, local climate, soil and rock conditions, and landowner needs. The following section discusses advantages and disadvantages of the major drainage systems.

Surface shape: Permanent roads must have one of three shapes: crowned, outsloped or insloped. Use of multiple shapes on the same road is also acceptable. Temporary roads may be constructed with little surface slope as long as cross ditches or other structures are installed prior to periods when rainfall or snowmelt can be expected. Temporary roads must have drainage structures installed at all stream crossings, and also on all road segments over 1000 feet in length that do not have grade reversals.

TERMINOLOGY

Crowned roads provide the best drainage for roads with high traffic use, or for roads that are used during the wet season.

Insloping of road is usually only appropriate for short stretches where the slope below the road is potentially unstable.

Outsloped roads are best on lower use roads with gradients under 8 percent. They should be augmented with waterbars or other drainage structures if there is potential for any traffic (including unauthorized) or if they are used on pitches steeper than 8 percent. Waterbars should also be installed or reinstalled to filter water next to all stream crossings prior to each wet season.

E (2). Cross-drainage structures

SCIENCE AND MONITORING

Soil properties and road grade have a major influence on ditch erosion and potential for gullies to develop (Arnold, 1957). ODF monitoring found that culverts comprise about 35 percent of the cross drainage structures use on forest roads in western Oregon. Waterbars and ditch-outs each make up about 15 percent the cross drainage structures used in western Oregon. Many roads also had non-engineered drainage features (water flowing across the road without any structure). ODF monitoring also found that roads with steeper grades (over 9 percent) often had fewer cross drains than less steep roads, with spacing exceeding that recommended to reduce ditch erosion.

IMPLEMENTATION

The location and installation of cross-drainage structures is the final element of drainage, and recognizes there are many ways to drain a road. Local experience is important here. First, look for opportunities that do not require the use of structures across the road. Use of ditch-outs as roads cross ridges is very effective, as are grade reversals. Cross drains must be placed more frequently as road grades get steeper and in more erodible materials, like decomposed granite. The culvert spacing guidelines in Table 2 are based on Arnold (1957) but have been simplified to consider only two soil types, normal and erodible. Most soils are considered normal. Erodible soils include decomposed granitics in southwest Oregon, volcanic ash in eastern Oregon, and any soils with natural gullies or a history of surface erosion problems at that location.

Table 2. Typical minimum culvert spacing for erosion control

Culverts draining to forest floor		
Road Grade	**Normal Soils**	**Erodible Soils**
0 to 1 % dry season	1500 feet	1000 feet
*0 to 1 % wet season**	*300 feet*	*300 feet*
2 to 5 %	1000 feet	700 feet
6 to 12 %	700 feet	400 feet
13 to 19 %	400 feet	250 feet
over 20 %	250 feet	150 feet

** water ponds on flat grades so extra drainage is needed for roads used during wet periods*

Table 2 is applicable for effective, well-maintained structures only. If waterbars are used, they should be installed at closer spacing, since waterbars can be easily damaged if filled with sediment by traffic (authorized or unauthorized). Note that the lengths in Table 2 are typical, and should always be adjusted to make sense for local conditions. If another local criteria effectively works to keep sediment out of streams, it should be used instead of the criteria in Table 2.

Standard drainage structures

Culverts are usually metal or plastic, with a standard recommended diameter of 18 inches. Culverts are the drainage structure of choice for high volume roads in western Oregon that are used during the wet season. Culverts are typically galvanized steel or heavy plastic. Plastic relief culverts are easier to install, have a longer life expectancy, and are less likely to be damaged by maintenance activities, but are flammable.

Ditches are inboard trenches large enough to carry the highest expected flow, taking into account likely erosion and growth of vegetation. They carry water between drainage structures on crowned roads and are usually at least 2 feet wide and 1 foot deep.

Waterbars are diagonal berms made by cutting and filling across the road. Waterbars are very effective on roads with low speed and light traffic volume. They are best installed or reinstalled after active timber hauling operations, as they require periodic rebuilding.

Dips are fairly gentle grade reversals of the road surface. The lowest point of the dip must be lower in elevation that rise further down the road. They are generally not useable for wet season use roads (especially for high volume). On gentle road grades rolling dips allow moderate vehicle speeds. For steep grades, dips slow traffic greatly, so not usually chosen for mainlines in steep terrain.

Cross-ditches are appropriate only on roads with no traffic. They must be removed prior to use by traffic. They are very effective at getting water across the road, though are subject to vandalism by persons wishing to have vehicular access. Cross ditches do not normally require maintenance unless they have been vandalized or otherwise removed.

Ditch-outs are short ditches installed at or near ridgelines near where roads cross the ridge. They are very low cost, and should be installed at every ridge crossing if drainage would not naturally flow off the road.

Grade reversals are high points in the road. Design using grade reversals reduces the number of other cross-drains needed.

Alternative drainage structures

Rubber flap water diverters are constructed with "sheets" of heavy flexible rubber or plastic (usually industrial conveyor belting) attached to timbers. The timbers are buried in the road surface, so that the flexible material extends out (about 3 inches) and can deflect water off the road. They are installed at an angle across the road, similar to waterbars. Roads must be outsloped for rubber water diverters to work.

French drains are used to drain wet areas. These are usually made by ditching through the wet area and back filling with clean gravel (usually river rock). Geotextiles are placed in the ditch and wrapped around the rock if soil is fine (mostly silt, clay or muck). If anticipated flows are high, a perforated pipe is also installed in the middle of the drainage gravel. Design, installation technique and long term maintenance are all very important when considering French drains. Equipment operators can ruin an expensive French drain during routine maintenance if they are not aware where these are located.

Discouraged drainage structures

Open top culverts easily plug, and are difficult or impossible to clean.

Small diameter (under 15 inch) ***culverts*** plug very easily.

ROAD DRAINAGE IMPROVEMENT ON ACTIVE ROADS

MAINTENANCE RULE CHANGE

OAR 629-625-600(9) Where needed to protect water quality, as directed by the State Forester, operators shall place additional cross drainage structures on existing active roads within their ownership prior to hauling to meet the requirements of OAR 629-625-0330.

PROTECTING WATER QUALITY

Road drainage must be improved when there is the likelihood of substantial sediment delivery if the drainage system is not upgraded. Inspection of road drainage on inactive roads prior to active road use is essential. Evidence of potential sediment delivery include the following conditions:

ROAD USE CHANGING - LIKELY SEDIMENT DELIVERY

- No cross drain structure (for filtering) within 200 feet of a stream crossing
- Streams running in roadside ditches

ROAD USE NOT CHANGING - LIKELY SEDIMENT DELIVERY ON ANY ROAD

- When gullies (over 100 feet in length) exist in a ditch, or below a cross drain
- Surface drainage waters flow into cracks on the outside edge of the road
- When more than 30 percent of the road system draining directly to streams or into gullies (a goal for a superior road is 15 percent)

REPAIRS FOR OLDER ROADS

When repairing older roads, streams running down ditches need to be put back into the original channel. Other common repairs are adding cross drains for filtering above stream crossings, and installing new cross-drains where gullies have formed in the ditch or at culvert outlets. In general, the information on drainage of new roads as described earlier in this Technical Note are also appropriate for maintenance of older roads. Use any technique that efficiently fixes the problem.

Sources of Additional Information

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Oregon Department of Forestry Field Offices

For more information about the Oregon Forest Practices Act or the Forest Practice Rules, please contact your local Oregon Department of Forestry office which can be found at http://www.oregon.gov/ODF/Working/Pages/FindAForester.aspx *or the headquarters office at 2600 State Street, Salem, Oregon 97310. 503-945-7200.*