Wet Weather Road Use

Forest Practices Technical Note Number 9

Version 1.0

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 the wet weather road use rule (629-625-0700) and on the many options available for protecting water quality when roads are used during wet weather periods.

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 recommendation: ***The forest practice rules should be modified to more specifically address wet-weather hauling. This should include development of two criteria, probably in rule form, to:***
1) Address road use in wet weather to ensure that durable surfacing or other effective methods are used on road segments that can deliver sediment to streams; and
2) Require operators to cease heavy truck traffic on roads when the road surface is breaking down (only for segments that are delivering sediment to streams).

Prior to 2003, wet weather road use had not been directly addressed in the forest practice rules, although maintenance of a stable surface has been required for a long time. Research and monitoring show that wet weather road use can influence water quality, especially turbidity. Monitoring also indicates that the effects of wet weather road use can be reduced through the use of durable surfacing. Durable surfacing also allows much greater flexibility for use of forest roads (much longer periods of active use). In addition, effective road drainage can reduce road maintenance costs, and also reduce surfacing needs for roads. Finally, a gravel surface also reduces erosion potential for roads that are not currently being used for heavy truck traffic.

Forest Practice Rules: The Board of Forestry adopted the wet weather road use rule that follows. The effective date is January 1, 2003. Rule administration does not change until after the summer of 2003, to allow necessary road repairs prior to changing rule enforcement standards.

629-625-0700

Wet Weather Road Use

(1) The purpose of this rule is to reduce delivery of fine sediment to streams caused by the use of forest roads during wet periods that may adversely affect downstream water quality in Type F or Type D streams.

(2) Operators shall use durable surfacing or other effective measures that resist deep rutting or development of a layer of mud on top of the road surface on road segments that drain directly to streams on active roads that will be used for log hauling during wet periods.

(3) Operators shall cease active road use where the surface is deeply rutted or covered by a layer of mud and where runoff from that road segment is causing a visible increase in the turbidity of Type F or Type D streams as measured above and below the effects of the road.

Science and Monitoring

Turbidity is a measure of water discoloration. Turbidity is generally related to suspended or dissolved fine materials in the water. The greater the turbidity, the less light that travels through the water (increasing discoloration). Turbidity is usually measured as nephelometric turbidity units (NTUs). An NTU of about 3 is barely visible in a 1-quart jar. Studies have shown that high levels of turbidity can affect fish by reducing growth rates, causing stress, impairing homing instincts, and reducing feeding rates. Increased delivery of fine sediment to streams can smother redds (locations where fish have deposited eggs). Low-level turbidity effects on aquatic life are unclear. Turbidity may have the greatest effect on drinking water and its treatment.

Wet season road use can be the most significant forest practice-associated source of chronic turbidity and fine sediment in streams. The department has just completed its study of turbidity associated with wet season road use. Results from this monitoring project indicate that: 1) the length of roadside ditch draining to streams; 2) traffic levels; and 3) the percent of fines in gravel surfacing all can affect the turbidity increase associated with wet season road use (Robben and others, 2003). The use of quality aggregate (gravel) road surfacing produces only 6 to 25 percent of the fine sediment produced by roads rocked with poor quality aggregate (Folz, 1996).

Terminology

Active roads (OAR 629-600-0100 (3)) are roads currently being used or maintained for the purpose of removing commercial forest products (log truck traffic).

Deeply rutted means ruts that prevent water from draining off the road surface.

Durable surfacing is any material of sufficient thickness, strength, and lack of fines to resist rutting and breaking down during wet weather road use.

Fines include all materials that pass through a number 200 sieve (all clay, silt). They may also include fine sand particles (Passing a number 40 sieve).

A ***layer of mud*** is sometimes referred to as muck or slop.

A ***road segment*** is the length of road draining to a specific location (usually to a cross drain or stream crossing). See **Figure 1**.

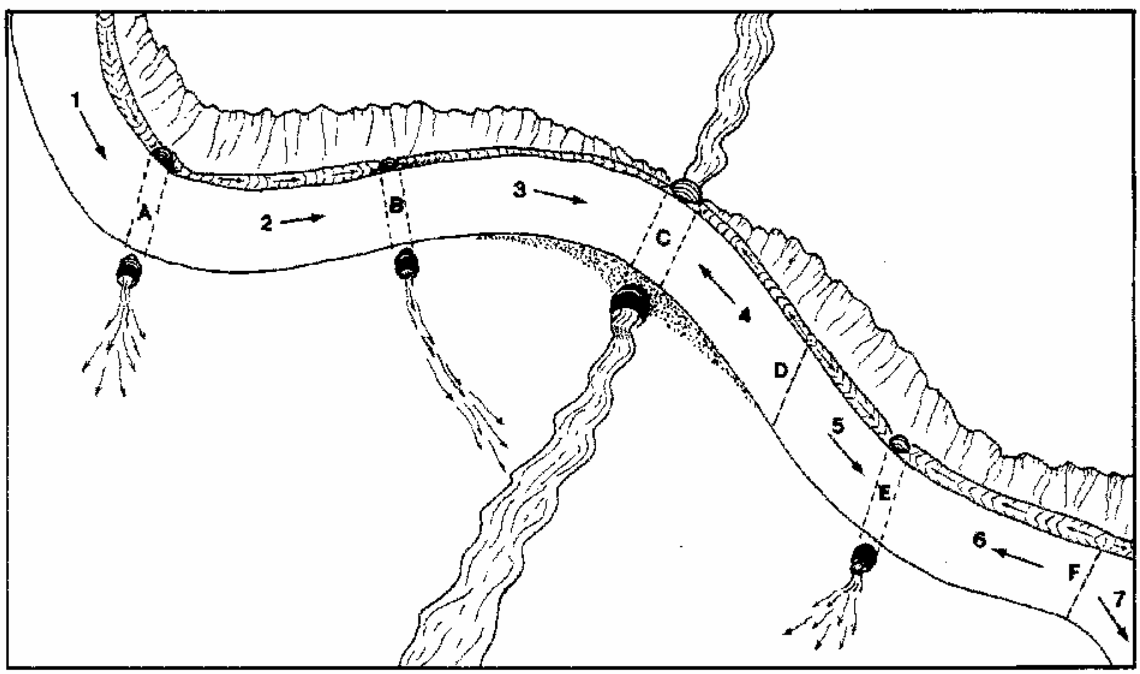

Figure 1. Road segments (numbered 1-7) and drainage features. Segments 3 and 4 drain directly to the stream. Segment 2 may deliver some sediment to the stream.

Wet weather, also called wet periods, includes that time of year when rainfall or thawing normally occurs. In western Oregon, this includes the period from October through April. Wet periods with sufficient rain to result in deep rutting after heavy truck use are also considered wet weather, and also include periods of snowmelt.

Aggregate Surfacing, Road Use and Turbidity in Streams

This section describes the relationship(s) between wet weather road use and stream turbidity, and is based on the limited science and monitoring information available now. Future monitoring and research is likely to modify this current understanding.

There are three primary sources of fine sediment directly associated with wet weather road use:

1. Fines contained in the gravel aggregate as placed on the road;
2. Fines produced from the breakdown of the gravel aggregate from crushing under heavy tire loading and from weathering; and
3. Pumping of fines from the subgrade (soil) through the aggregate.

When the aggregate surfacing is wet, vibrations from heavy traffic can move fine material up through the aggregate to the top of the road. Once fines reach the surface, they remain there until there is enough water from rain or melting snow to wash them down or off the road. As rut depth increases, the aggregate becomes increasingly wet. This reduces aggregate strength and also concentrates drainage water in the ruts, allowing the fines to be carried in runoff flowing down the ruts.

Fines are easily suspended in water, thus creating local turbidity. However, turbid water flowing down the road surface or in ditches may not enter streams. Some material resettles on the road surface or in ditches, to be moved again in later storms. Other sediment settles on the forest floor as drainage water flows into porous soils. Fines in drainage waters that discharge into or very close to streams is, therefore, the principal water quality issue.

The most effective aggregate surfacing design is usually thought to include:

A) A depth of aggregate that prevents rutting in the subgrade and the associated pumping of fines, or a geotextile barrier to prevent pumping;
B) Just enough fines to seal the road surface and reduce water entry into the aggregate and subgrade; and
C) Use of a rock source that is strong and not weathered.

Durable surfacing design includes an effective cross drainage system. Whether crowned, insloped or outsloped, the surface shape should get water off the road quickly. To minimize sediment delivery to streams, cross drains should be placed above all stream crossings unless there is an undisturbed area between the end of the ditch and the stream. Additional information on road drainage is found in Forest Practices Technical Note # 8. Durable surfacing is required only on road segments that deliver to streams used for hauling during wet weather. Therefore, locations needing durable surfacing can be reduced by adding cross-drainage structures that allow filtering of sediments before runoff reaches streams (see Figure 1).

Design for a Durable Surfacing

Durable surfacing includes:

- crushed hard rock with limited fines
- hard pit run rock with limited fines
- may include a lower quality base rock
- rock must be deep enough to prevent pumping, typically 10 inches or more, depending on subgrade strength and traffic
- may be pavement, as the landowners' choice, as pavement is not required by rule
- where soils are very soft, geotextiles can minimize pumping and reduce aggregate needs

Durable surfacing is not:

- sandstone or other sedimentary rock or decomposed granite type rocks (except sometimes as a base)
- weathered rock (sometimes ok as a base)
- muddy rock (over 20 percent passing # 40 sieve or 12 percent passing a # 200 sieve)

Production of durable surfacing requires locating a good source of accessible rock and thoughtful development of that rock source. When buying from commercial sources, the same considerations apply. Rock sources can vary from a large, developed quarry to a road cut.

Hard rock versus soft rock**:** The geologic history of the rock has a big influence on its hardness. In Oregon, the best rock is often volcanic, especially intrusive rock. Lava-flow rock is also usually hard. Oregon's common sedimentary rocks (sandstone and mudstone) breakdown rapidly under traffic unless they have been reformed by heat and pressure as sometimes in the South Coast Georegion. Normal sedimentary rock will not produce a durable surfacing, but may produce a usable base course.

The Unified Rock Classification System (Williamson, 1984) provides a simple method or evaluating rock suitability. Two elements in this classification system are fairly easily used by non-geologists, and are very useful in evaluating rock strength. First is the degree of weathering, determined mostly by changes in rock color. Degree of weathering is classified as:
Visually fresh rock (***VFS***) - has the uniform color typical of that rock;
Stained state rock (***STS***) - has been discolored by oxidation or other processes, but cannot be impacted by finger pressure;
Partly decomposed rock (***PDS***) can be broken into gravel sized particles; and
Completely decomposed rock (***CDS***) can be remolded by hand into soil.

The other important element is rock strength. Rock strength can be estimated using the round end of a ballpeen hammer, and is classified as:
Rebound quality (***RQ***), the strongest rock, where the hammer has no effect on the rock;
Pit quality (***PQ***) where hammering results in a shallow rough pit;

Dent quality (***DQ***) rock is indicated by a dent under the point of impact; and
Crater quality rock (***CQ***) fails when hit by the hammer.

Figure 2 illustrates rock strength based on hammer impacts (from Williamson and Kuhn, 1987).

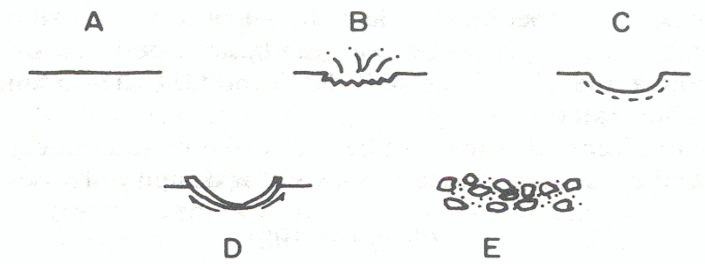

Figure 2. Reaction to impact of ballpeen hammer. A) Rebound quality, no reaction; B) Pit quality, rough pit; C) Dent quality, smooth depression; D) Crater quality, depression with upthrust material around perimeter; E) Moldable quality, crumbles with finger pressure.

The strength estimate provides the best indication of durable surfacing, while the degree of weathering can be used to evaluate rock quality as it varies in the rock source area. Rebound quality rock (***RQ***) must be blasted, and often produces sharp and angular rock that is hard on tires and difficult to compact. Pit quality (***PQ***) rock also usually needs blasting, and usually produces a durable surfacing. Dent quality (***DQ***) rock is marginal as a surface course, but can provide a good base course, while Crater quality (***CQ)*** rock cannot make a durable surfacing. Note that partly decomposed rock with hard rock fragments can sometimes make the best pit-run rock. Completely decomposed rock should only be used as a source of fines if rock production otherwise does not provide enough plastic fine material (about 10 to 12 % of the aggregate overall).

Rock quarry or pit development: Thoughtful development is required to make full use of available rock. Rock weathering should be evaluated over the entire quarry and correlated with strength so that only consistent quality rock is produced. A given quarry often produces several qualities of aggregate. The best aggregate should be used as durable surfacing around stream crossings. Screening and or mixing of aggregate can be used to increase or decrease the percentage of fines in the aggregate. Lower quality rock can be used as a base course, or on road segments that do not deliver sediment to streams. Rock sources that produce "arrow-heads," although unusual, are also a concern and can usually be identified by breaking the rock with a hammer, or early in the crushing process. Once identified, such sources are not recommended for surface course material.

Testing for Durable Surfacing

Gradation and fines: The most important (and relatively simple) test for surfacing durability is the gradation test. Gradation shows the distribution of different sized particles in the aggregate. Some fines are needed for binding. However, too many fines lowers aggregate strength and will quickly wash out of the aggregate. Monitoring found a correlation between turbidity and the percentage of material passing the # 200 sieve. Statistically significant increases in turbidity were found if material passing the # 200 sieve is as low as 6.5 percent. However, this is too few fines to effectively bind the surfacing material in many cases. Therefore, it is recommended that between 8 and 12 percent of the aggregate pass the # 200 sieve, and between 14 and 20 percent pass the # 40 sieve. The higher values are recommended for steep gradient roads, and for a surface coarse where a well-drained base aggregate is used. Gradation can also be used to determine if the material is well graded or gap graded. Gap graded materials do not pack well, so they are much harder to keep in place on the road and will have lower strength as a road surfacing. A clean gravel (little or no fines) can be used as a base rock or as a cap rock over gravel with too many fines.

Resistance to wear and weathering: Tests of the aggregate in the stockpile can provide additional information about durability for road surfacing (Table 1). The two tests that appear most usable for this are the LA Abrasion Test and the Oregon Air Degradation test. ODF monitoring found lower turbidities when the LA Abrasion Test found a rock breakdown of less than 17 percent. Note that these tests are not perfect, and careful evaluation of the rock weathering and durability at the quarry site combined with gradation testing may be sufficient.

Table 1. Evaluation of Aggregate Testing Results

Test	Highest Quality	Marginal Quality*
LA Abrasion	Under 17 % weight loss	30 % weight loss
Oregon Air TM-208	under 20 % loss	30 % max. loss
AASHTO T-210 (fines)	45 % durability	30 % minimum
Sand Equivalent	35-45 %	30 % minimum

***** no alternative source in reasonable proximity***

Application of Durable Surfacing

Important considerations for ensuring a durable surfacing include the strength of the subgrade, anticipated wet season truck traffic, and ability to accept ceasing haul for short periods of time. Segmenting the road by similar sub-grade conditions is important. For subgrades that contain mostly fines, compaction and moisture levels are critical, since some of the aggregate that is placed on a wet or soft subgrade may mix with the weaker material and provide little or no strength. Some landowners choose to let a newly constructed road sit for one season prior to rocking.

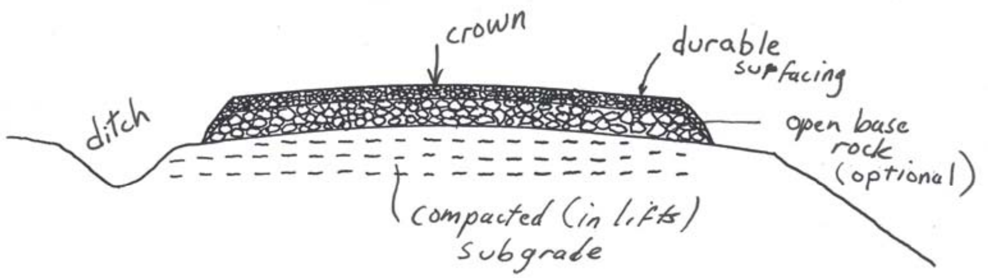

Figure 3. Well-designed durable surfacing

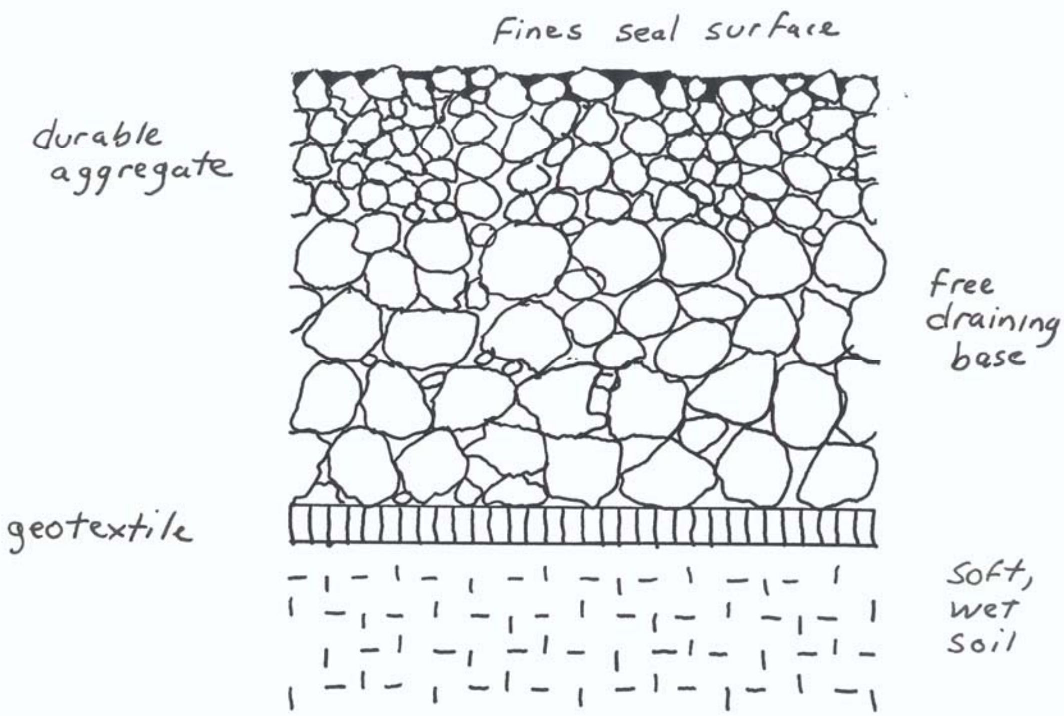

Figure 4. Use of geotextile over soft, wet soil

Subgrade preparation: Effective compaction of the subgrade is very important, especially for soils that are not rocky. Fine-grained soils should be compacted with a sheepsfoot-type roller. During compaction, shape the road surface to drain according to the design (crown, inslope or outslope) as in Figure 3. For effective compaction, the soil should be moist, not wet or very dry. Geotextiles are recommended in cases where soils never dry sufficiently for compaction.

Geotextile use: Geotextiles are appropriate and can save rock in certain cases. They are most useful where roads are located in wetlands or on wet silt or clay soils (Figure 4). A good geotextile must have sufficient ***strength*** to provide reinforcement, have openings that improve ***drainage*** and still provide for ***separation*** to keep the subgrade materials from pumping into the surfacing. When the subgrade can be effectively compacted and drained, there is probably no need for a geotextile.

Depth of aggregate: Necessary aggregate depth depends on: 1) the strength of the subgrade; 2) the number of heavy trucks that will use the road during wet weather; 3) the durability of the aggregate; and 4) whether a geotextile is used. A base course is also an option for most roads. The minimum aggregate depth (for rocky subgrade) should be six inches. Table 2 shows suggested depths of quality aggregate recommended for a durable surface. The depths shown in Table 2 are the total depths of aggregate. If a base course is used, depth includes the base plus the surface layer.

Table 2. Depth of aggregate (including base, if used)

Subgrade	Depth without geotextile	Depth with effective geotextile
Wetland	36"	18"
Wet clay or silt	24"	16"
Well drained clay or silt	14"	10"
Typical drained forest soil	10"	*
Rocky or full-bench	6"	*

***** *geotextile use adds little and not recommended*

For heavy use (over 10 trucks per day), or for added assurance of hauling during very wet periods, add 2 inches additional aggregate.

Base course: A base course usually lowers cost, and can improve drainage. Base rock should have fewer fines than the surface course, since drainage is a very important function of the base. The base course can be softer rock (even sandstone), as long as it contains relatively few fines. A 4-inch layer of durable aggregate can be used as the surface course above a base on a new road, or as the surface course over older, marginally rocked roads. Note that use of a base makes grading difficult if deep ruts or potholes are allowed to develop. Use of a base does allow use of more fine material in the surface layer, since a proper base course provides superior drainage. A sufficient base prevents rutting, even during heavy wet season traffic. Wet weather heavy use roads in the ODF Astoria District often require no grading during the winter months.

Aggregate placement: Rock the road prior to fall rains. Place aggregate when the subgrade is either dry or slightly moist. Ruts should not form during gravel truck use. Taper placement of the durable surfacing (best aggregate) just above the filtering cross-drainage structures (culvert A and grade break D in Figure 1). The road surface should be graded as per the design surface shape (same as the subgrade). Finer, well-graded aggregate should be compacted with a vibratory roller until deflection is not visible. Oversized aggregate can be compacted in place with a grid roller if the rock material has a fracture pattern that produces angular rocks but does not produce "arrow-heads."

Use of asphalt pavement: Nothing in the rules requires forest roads to be paved. However, landowners should consider paving mainline roads in some circumstances. For example, in areas where durable aggregate is scarce and expensive, over the long term, paving can be a lower cost alternative. Another example is in a municipal watershed and where a mainline runs right next to the stream near the water intake.

Road Use Management

Determining when to repair roads and/or cease use is the landowners' and operators' responsibility. They should not rely on forest practices foresters to inform them when either roadwork or ceasing use is needed.

Inspections are most appropriate during the first rainstorm (over one half inch in a day) after any dry period, or after 1-2 inches of rain over a 3-day period. Evaluate the condition of the surface, and most importantly, where sediment delivery to streams is occurring. Determine if additional drainage or rock will be needed. As for sediment filters such as hay bales, use these only if all else fails, as re-grading the surface and proper cross drain location will be more effective. If the road has a well-maintained durable surface and proper cross drainage, visible turbidity increases in Type F or D streams will be rare, and in many cases may never occur, **except during rapid thawing periods.**

Maintenance of durable surfacing: Grading is required prior to deep ruts forming. Shape the surface frequently during wet weather road use to remove ruts and keep water flowing as per the designed road surface slope. Spot rocking on road segments that drain to streams should use only durable surfacing. If the surface is muddy, very clean (fewer fines) aggregate is appropriate. It is much better to add rock during periods when the subgrade is not saturated. **When grading ditches, do not pull dirty rock onto the road surface.** Aggregate breaks down from heavy truck use. As a rule of thumb, 1 inch of replacement aggregate is needed for every 3-6 MMBF (depending on rock durability) hauled over the road.

Thawing periods: After a few days of sub-freezing temperatures, the depth of frozen ground usually penetrates below the road surfacing. Frozen soil thaws from the surface down, and this restricts drainage and greatly lowers the strength of both the surfacing and the subgrade. Heavy truck traffic during thaw periods often causes failure of the entire road surfacing, resulting in very costly damage and possibly very high stream turbidity as well. The most important time to **cease heavy truck traffic** is, therefore, during a rapid thaw period after a deep freeze. Repair of roads that have been used during a rapid thaw may require waiting a week or longer, until the road has drained, and rocking the road with the same depth of rock required for a previously un-rocked road.

Summary

Identify roads planned for winter haul by early summer. Then, evaluate existing surfacing durability, and identify road segments draining to streams without durable surfacing. Upgrade these roads well ahead of fall rains with a combination of additional cross drainage structures to reduce road drainage to streams, and rocking of those segments that still drain to streams. Use the best rock, well-graded aggregate from a hard rock source, on those road segments that drain to streams. Screen this rock if it contains too many fines. The aggregate must be deep enough to prevent breakdown of the subgrade and pumping. Compact the subgrade of unsurfaced roads prior to first rocking if possible, and consider geotextiles for a very wet subgrade. Inspect wet weather use roads frequently, and spot rock with clean, durable surfacing as needed. Cease use when turbidity changes are observed in Type F or D streams (especially important during rapid thaws).

Sources of Additional Information

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