Generally, the ecological benefits of protecting more inventoried roadless areas from development and roading include:

Physical Resources
- Conserving water, soil, and air resources
- Protecting aquatic ecosystems
- Ensuring that community drinking water sources are protected
- Protecting overall watershed health

Forest Health
- May reduce the occurrence of human-caused fires
- May reduce the spread of some damaging insects and diseases

Biological Diversity
- Increasing habitat protection
- Protecting areas from additional landscape fragmentation and further loss of connectivity
- Maintaining and/or enhancing native plant and animal communities and reducing opportunities for the spread of nonnative invasive species
- Increasing the protection of a diversity of habitats from low to high elevations
- Conserving habitat for threatened, endangered, proposed, and sensitive species (TEPS)
- Providing important habitat for populations of wide ranging animals that need large areas
- with low human activity levels

Physical Resources

Water, soil, and air resources have measurable characteristics that operate within naturally variable ranges of values. Water yield, timing, and quality, soil erosion, air quality, and other characteristics can vary widely, even in undisturbed situations. Land management practices, such as roading, timber harvest, **prescribed burning**, and other similar activities, can affect these values, and their variability. Sometimes the effects are within natural ranges; sometimes they are not. The most common effects of road construction and timber harvest activities on water, soil, and air resources are loss of ground cover vegetation, soil erosion and compaction, loss of soil productivity, increased potential for landslides, reduced transpiration (use of water by plants), increased water runoff, reduced water quality, and reduced air quality. In this analysis, the specific characteristics discussed are water quantity and timing, water quality, drinking water source areas, channel morphology, soil loss and sedimentation, site productivity, landslides, and air resources. Effects of fire on watersheds are discussed in the Forest Health and Fire Ecology section.

Roads have long been recognized as the primary human-caused source of soil and water disturbances in forested environments (Patric 1976; Egan and others 1996). Most impacts occur during initial road construction and then gradually decrease as roadside vegetation is reestablished and disturbed soil surfaces stabilize. Effects such as landslides persist when a road permanently undercuts unstable soils or landforms, or when roads are continually disturbed by road maintenance. Periodic maintenance activities can cause some of the impacts to briefly, but repeatedly, recur. Areas of particular concern are the road surface and associated drainage structures such as ditches and water crossings (bridges, culverts, and fords). Poorly maintained roads can result in greater impacts as surface water is diverted, culverts plug, and other road design characteristics are compromised. Lack of maintenance commonly has detrimental effects on water, soil, and air resources. Insufficient maintenance funding is a key reason for the lack of adequate road maintenance (USDA Forest Service 2000h).

Temporary road construction has most of the same effects as permanent road construction, but generally for a shorter term and for a more limited physical extent. Long-term effects can occur if temporary roads receive extended use, and they are not decommissioned. Generation of sediment within timber harvest units is most strongly related to roading and associated facilities (**skid roads and trails**, log landings, etc.) that are needed to remove logs, as opposed to tree cutting (Anderson and others 1976). Skid roads and trails, log landings, and similar disturbances within the sale area are the main cause of soil erosion and can contribute up to 90% of the sediment generated by timber sale activity (Patric 1976; Swift 1988).

Until recently, poorly managed timber harvest activities have been a major source of sediment from a timber sale area (Stone and others 1979; Martin and Hornbeck 1994). Generally, monitoring has shown compliance rates for implementing best management practices to be between 85% and 98%, with compliance rates increasing over time as awareness and training programs take effect (Stuart 1996, State of Oregon 1999, State of Montana 1998, Phillips and others 2000). Results vary between States and ownerships, with Federal lands and large forest industry entities showing highest compliance, but small non-industrial landowners with little access to professional forestry assistance falling behind. A recent report from Oregon found overall compliance rates of 98% to 99% across all ownership classes (State of Oregon 1999), while a study in Maine reported only 34% of best management practices with compliance rates grater than 80% (State of Montana 1998, University of Maine 1996).

Although, best management practices do not completely eliminate water quality impacts, they do reduce impacts to acceptable levels. “Best management practices may not be completely effective, but they do provide a level of protection that the states and the Environmental Protection Agency judged sufficient to meet the goals of the Clean Water Act” (Ice and others 1997). “Audit results showed that 96 percent of the individual practices audited were effective in protecting soil and water resources” (State of Montana 1998). “When used, the forestry BMPs work well” (University of Maine 1996). Concern remains in some aspects of BMP compliance, however. For example, reports from Montana and Oregon both cited below average compliance rates with road maintenance, road drainage, and temporary crossings (State of Montana 1998, University of Maine 1996, State of Oregon 1999). These aspects of best management practices compliance may require additional education and compliance reviews. Although some excellent work is under way on assessing the effectiveness of best management practices, additional work is need is this area (Seyedbagheri 1996).

Currently, all Forest Service permanent and temporary roads needed for timber sales are designed and constructed using water, soil, and air best management practices that meet or exceed those required by individual States under Environmental Protection Agency

(EPA) direction. Current road design and management criteria incorporate the latest knowledge and experience, resulting in fewer effects such as surface erosion, landslides, sedimentation, and dust emissions, on water, soil, and air resources. Proper design and construction of new roads and maintenance of existing and new roads can limit but not eliminate these effects (USDA Forest Service 2000h).

Water Quantity and Timing

Affected Environment

Water flowing from NFS lands comprises about 14% of the total annual average water yield in the United States. This contribution is roughly 3% in the East and 33% in the West (Sedell and others 2000).

Roads affect the quantity and timing of stream flow by intercepting, concentrating, and diverting runoff (Furniss and others 1991; USDA Forest Service 2000h). They can indirectly affect annual flow volume, since they replace trees that use water. Water otherwise used by trees would become available for runoff or entry into the soil.

Water Quantity – Most experts concur that the relative effects of individual timber harvesting and roading activities on flooding decreases as watershed size increases. The extra flow generated in smaller watersheds becomes less evident as it joins flows from other watersheds and continues downstream (Anderson and others 1976; Stone and others 1979; Hewlett and Doss 1984; Thomas and Megahan 1998; Ziemer 1998; Elliot in press). Similarly, numerous harvest units and roads in multiple sub-watersheds of a larger watershed generally do not yield proportional increases in floods. Additional water from smaller units enters the main stream at different times. This action desynchronizes the flows, moderating net flow increases.

Effects of land uses, such as timber harvest and roading, are more evident during small and moderate storm events but are less important in large storm events (Hewlett 1982; Bosch and Hewlett 1982). Large runoff events are generally the result of large volume or extended periods of precipitation or snowmelt runoff that exceed the capacity of the soil to hold additional water (Lull and Reinhart 1972; Swanston 1991). This is true regardless of land use practices.

Timber harvests can cause an increase in total annual water yield, whereas roads are unlikely to have a similar effect, mainly because harvests tend to cover more area than roads (USDA Forest Service 2000h). Changes in total annual water yield would most likely be detected where there is abundant moisture to begin with, and where the soil has less ability to absorb additional water such as in the coastal forests of California, Oregon, Washington, and Alaska (Regions 5, 6, and 10) (Harr 1983; Kattelmann and others 1983; Ziemer 1987). Studies in Eastern forests indicate that at least 20% to 25% of the **basal area** in a given watershed must be removed to produce detectable increases in annual flow (Douglass 1967; Hornbeck and others 1993).

Changes in total annual water yield are generally less detectable in the drier climates of the Interior West and Southwest where additional water is quickly used by the remaining plants or is lost through evaporation (Schmidt and Solomon 1983). Harvest levels on NFS lands in the Southern and Eastern regions (Regions 8 and 9) are generally too small to generate measurable change (Hornbeck and others 1993; Lull and Reinhardt 1972). Water-yield returning to normal levels is in direct proportion to how quickly the site revegetates. Regrowth in the East and in humid parts of the West is rapid, and flows return to normal levels in 6 to 10 years after harvest. Slower growth in drier parts of the country may extend the recovery period to at least twice as long (Stone and others 1979).

Runoff Timing – Timing of water runoff (how quickly a watershed generates runoff and the time it takes for that water to work its way downstream) can change as roads and related drainage structures intercept, collect, and divert water. This accelerates water delivery to the stream, more water becomes storm runoff, which increases the potential for runoff peaks to occur earlier, be of greater magnitude, and recede more quickly than in unroaded watersheds (Wemple and others 1996).

Vegetation cover removal through timber harvest can also change flow timing. In conifer forests where the majority of precipitation is in the form of snowfall, such as in the Intermountain West, openings in the forest canopy can capture more snow and deliver it earlier during spring runoff (Leaf 1975; Troendle and King 1985; Troendle and King 1987). In rain-dominated Western conifer forests, flows from harvested areas are greater toward the end of the summer dry period than are flows from uncut forests, but the flow difference is minimal once soils are resaturated by fall rains (Ziemer 1998). Harvesting hardwood forests and areas that receive the majority of precipitation from rainfall delivers more water in the late summer or early fall. This pattern can supplement low flows during these times and can be beneficial to fish and other aquatic organisms during water-stress periods (Anderson and others 1976; Stone and others 1979; Swank and others 1988; Kochenderfer and Hornbeck 1999).

Changes in water timing are most likely to occur in areas with large amounts of timber harvest and roading since these activities have the highest potential to alter natural hydrologic processes. Areas with greater variability in seasonal precipitation and runoff, such as the arid and semi-arid portions of the West, would be more sensitive to changes in flow timing than areas with more even rates of precipitation and runoff such as the humid portions of California, Oregon, and Washington, and the Eastern United States. Changes in the magnitude of flood peaks and seasonal low flows are more evident in drier climates (Neary and Hornbeck 1994). The Northern, Intermountain, and Pacific Northwest Regions, respectively (Regions 1, 4, and drier portions of 6) are most likely to experience early runoff during any given storm, since they have relatively high planned harvest levels and are located in drier climates. Even though the Alaskan region (Region 10) has the largest volume of **scheduled timber harvest** in inventoried roadless areas, its yearlong precipitation would make any potential changes in runoff peaks or timing difficult to detect.

The USDA publication, "Forest Service Roads: A Synthesis of Scientific Information," (2000h) summarizes most of the effects of roading and timber harvests on hydrologic regimes.

Collectively, these studies suggest that the effect of roads on basin stream flow is generally smaller than the effect of forest cutting, primarily because the area occupied by roads is much smaller than that occupied by harvest operations. Generally, hydrologic recovery after road building takes much longer than after forest harvest because roads modify physical hydrologic pathways but harvesting principally affects evapotranspiration processes.

Alternative 1 – No Action

NFS lands data shows 1,160 miles of planned roads through 2004 for both timber harvest (623 miles) and other activities (537 miles). Forests also plan to offer 1.1 BBF (billion board feet) of timber during this same period. Region 10 accounts for the largest portion of the timber offer (49%), followed by Region 4 (18%), and Regions 6 and 1 (8% each). Region 10 also plans to build the most roads (31%), followed by Region 4 (23%), Region 1 (12%), and Region 2 (11%).

Roads and timber harvest activities would be designed and implemented to meet all applicable best management practices and timber sale contract requirements, since adherence to these principles is important to maintaining optimal water yield and timing from the disturbed area. However, since best management practices and sale requirements are designed for specific maximum storm/runoff events, storms or runoff that exceed these parameters have some risk of causing on-site or downstream effects.

Average annual water yields would most likely increase where annual precipitation is abundant (although difficult to detect), such as the coastal portions of Regions 5 and 6 and on the Tongass National Forest. Annual water-yield volumes would not be likely to change in the drier portions of the Interior West, even where harvests will be heaviest, or in the East, where harvest volumes and roading are modest.

Regions 1 and 4 would be the most likely to experience increases in flood flows, especially where harvest units or roads are located in small headwater areas and also during small and moderate storm events in late summer.

Alternative 2

This alternative would eliminate roughly 75% of planned road construction (867 miles) and about 73% of the planned timber offer (840 MMBF [million board feet]) in inventoried roadless areas through the year 2004. The remaining 25% of road miles are exempt from the prohibitions for a variety of reasons. The reduction in road miles would reduce disturbance the most in humid areas with high stream densities that require the most drainage structures and crossings such as the wetter parts of Regions 5 and 6 and Regions 8, 9, and 10.

Reductions in timber offer would be dramatic in Region 10 with a 95% drop (512 MMBF), followed by Regions 4 (134 MMBF) and Region 9 (39 MMBF). Compared to Alternative 1, flood flow changes in Regions 4 and 1 would be much less likely due to lowered timber harvests. Detecting changes in flood flows, especially larger flow events, would be less likely in other parts of the country. Average annual water yields, even in humid parts of the country, would be closer to those found in undisturbed forests due to the reduced timber harvest.

Alternative 3

The effects of this alternative on water quantity and timing would be similar to those under Alternative 2. Reductions in roading are the same, but elimination of all offered timber, except for stewardship purposes, drops the offer levels approximately 85%, and virtually eliminates harvests in Region 10, which has little opportunity for stewardship harvests. Flood flows and average annual water yields would be closer to undisturbed levels than those under Alternative 2, and would likely be at undisturbed levels in Region 10.

Alternative 4

Under this alternative, there would be the same drop in road construction as that under Alternatives 2 and 3, but with elimination of timber offered for commodity and stewardship purposes. Water quantity and timing, flood flows and average annual water yields would be the closest to undisturbed levels under this alternative. A slightly increased probability of large fires could increase flood flows and change runoff timing from burned areas.

Water Quality and Drinking Water Source Areas

Affected Environment

Road construction and timber harvest can result in measurable reductions of water quality by introducing sediment and nutrients, causing abnormal temperature fluctuations, and through the indirect effects from human use. Site preparation activities (mechanical, hand treatment, fire, etc.) following timber sales to prepare the area for either natural or artificial regeneration can also have effects on water quality although the extent and severity of these activities on NFS lands has decreased with the reduction in harvest levels and intensity of harvests. Some pollutants are from road construction and maintenance equipment, or are brought into the watershed through public road use.

Temperature – Road construction and timber harvest may cause water temperature to change where groundwater is intercepted and brought to the surface, where the stream channel shape is wider or shallower, or where loss of tree cover in riparian areas reduces shading (Hornbeck and Leak 1992). Temperatures may rise sharply in exposed areas and some of those elevated temperatures may then return to normal levels as water re-enters shaded areas downstream or receives cool inflow from other streams or groundwater (Pierce and others 1993). Smaller or shallower streams are generally more susceptible to temperature fluctuations than larger or deeper streams (Chamberlin and others 1991).

Nutrients – Roading and timber harvest may indirectly affect water quality by increasing the release of certain nutrients from the decomposition of timber harvest byproducts (leaves, branches, and other organic matter). Nutrients, such as nitrogen, phosphorous, potassium, and calcium may increase in stream water following timber management activities. Nitrogen generally shows the most abrupt changes. Tree cutting has less effect than subsequent site preparation activities that are used to expedite regeneration (Hornbeck and Leak 1992). Elevated nutrient levels in streamflow usually return to normal in 1 to 4 years (Chamberlin and others 1991).

The EPA delegates the responsibility to implement the Clean Water Act to the States and Tribes. The Forest Service works closely with States and Tribes to assure Agency management practices comply with their requirements. Per agreements with many States, the Forest Service is the designated water-quality management agency for NFS lands. These agreements include specific procedures to apply if water quality problems are discovered.

Section 303(d) of the Clean Water Act requires States to evaluate water quality in light of State water-quality standards, report those stream segments that are impaired, and require development of a **total maximum daily load** of pollutants. Many States have identified impaired stream segments on NFS lands, and they are working with the Forest Service to determine how to reduce pollutant impacts and meet total maximum daily load requirements. On NFS lands, many of the recognized impairments are from sediment, temperature, nutrients, and similar pollutants (U.S. Environmental Protection Agency 1997).

Figure 3-15 identifies **major watersheds** with impaired waters that also contain inventoried roadless areas on NFS lands. The percentage of impaired stream miles within the watersheds is noted, but this does not imply that the impairments were the result of activities on NFS lands within the watersheds. The impaired stream miles listed below may come from any ownership within the watershed. Of the 533 watersheds with impaired waters, 356 (67%) have between 1% and 10% impairment, 146 (27%) have between 11% and 25% impairment, and 31 (6%) have larger than a 25% impairment. The map shows watersheds with water quality concerns and provides a basis for evaluating the likelihood of impact by implementing additional land management activities.

Drinking Water Source Areas – There are more than 2,000 major watersheds in the United States and Puerto Rico. Of these watersheds, 914 contain some NFS lands, and 661 of those contain inventoried roadless areas. Stepping this number down farther, 354 (55%) are source areas that provide water to facilities that treat and distribute drinking water to the public (U.S. Environmental Protection Agency 1997; Sedell and others 2000.) No data exist for Alaska, Hawaii, or Puerto Rico). About 150 of the source watersheds in Figure 3-16 have some use restrictions, such as the watersheds that service Santa Fe, New Mexico; Portland, Oregon; and Seattle, Washington. Most others provide a wide range of multiple uses. All watersheds that provide public drinking water will be delineated, assessed for risks, and reported to the EPA by May 2003. This action is required by the 1996 amendments to the Safe Drinking Water Act (U.S. Environmental Protection Agency 1997).

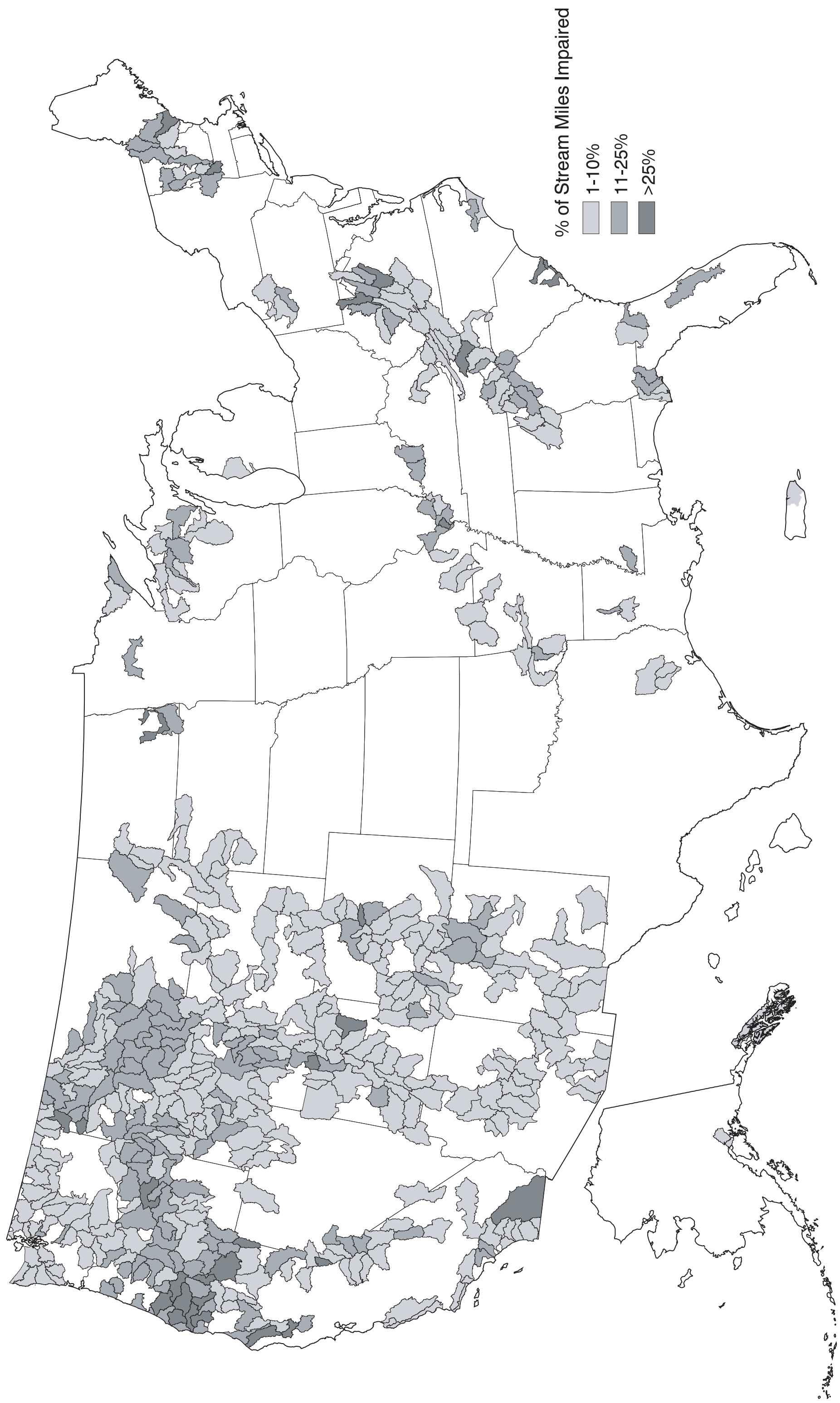

Figure 3-15. Impaired watersheds that contain inventoried roadless areas.
(Roadless Database 2000; U.S. Environmental Protection Agency 1997)

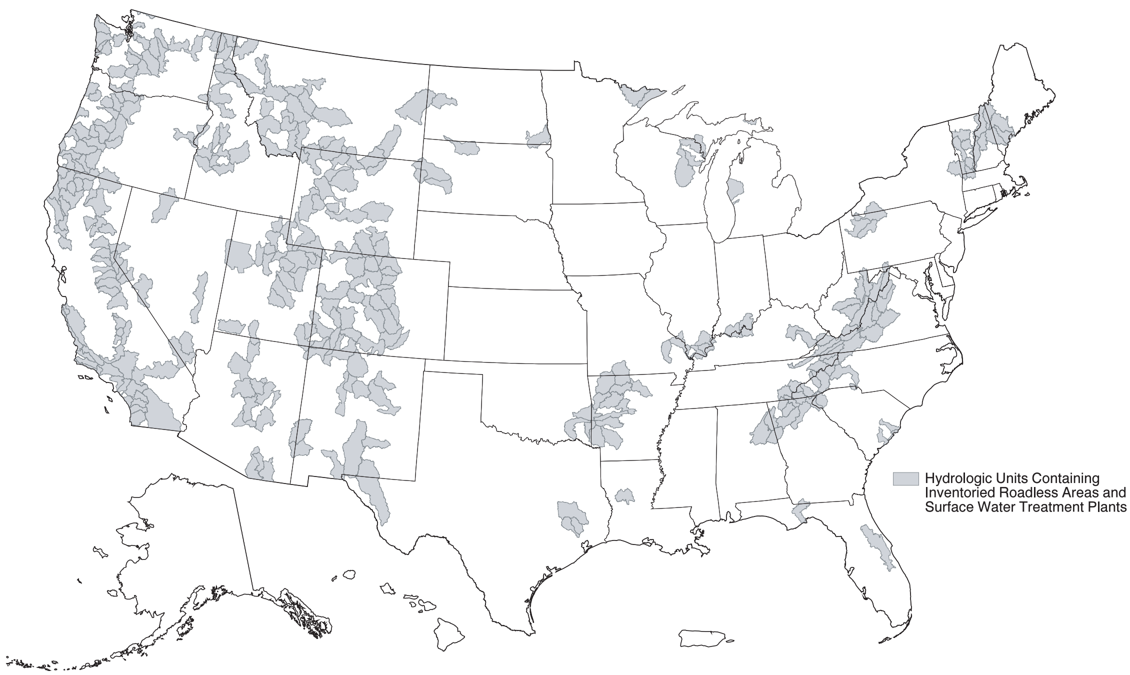

Figure 3-16. Watersheds containing drinking water source areas within inventoried roadless areas on National Forest System lands.
(Roadless Database 2000; U.S. Environmental Protection Agency 1997)

Alternative 1 – No Action

This alternative has the highest levels of timber offer and roading and therefore, has the highest probability of changes to water quality compared to the other alternatives. Although these ground-disturbing activities are closely monitored and use best management practices, the highest likelihood of water quality impacts is in the less frequent but higher volume precipitation and runoff events. In Regions 5, 6, and 10, and the wetter parts of Regions 1 and 4, high runoff can be caused by rain-on-snow events and large storms that sweep in off the Pacific Ocean. The harvest and roading levels in Regions 10, 4, and 1, and in several coastal forests in Regions 5 and 6, are most subject to these events and thus, have a high probability of impacting water quality.

In the drier parts of the Intermountain West and Southwest, rapid spring snowmelt runoff and intense spring and summer thunderstorms produce the most runoff and elevated flood peaks. High-risk seasons in the East are infrequent rain-on-snow events in the late winter and early spring, violent thunderstorms in the late spring to early fall, and precipitation from tropical storms and hurricanes along the Gulf Coast and the Atlantic Seaboard. The highest likelihood of changes to water quality occurs in these key regions during periods of high risk of erosion and runoff. Adding miles to the already under-maintained miles of NFS roads would increase the probability of additional water quality impacts.

Road construction, reconstruction, maintenance, and timber harvest activities affect watersheds. There is particular concern for watersheds that serve as drinking water source areas. Roads tend to contribute sediment, while timber harvest contributes sediment and nutrients. Due to the high level of roading and timber harvest, the greatest likelihood of impacts to watersheds that are drinking water sources is in New Hampshire (White Mountains), Virginia, West Virginia, Georgia, Tennessee, North Carolina (Appalachian Mountains), Oregon and Washington (Cascades), Idaho, western Montana, western Wyoming; the Sierras, and California (northern coast).

The most common concern with impaired waters in forested lands is that sediment loads, nutrients, or temperature changes might further degrade water quality. Timber harvest operations and roading can affect these water quality parameters, especially during high runoff events. Based on the planned roading and timber offer levels, the highest likelihood of water quality impacts is in the forests of Vermont and New Hampshire, Virginia and West Virginia, north Georgia, Idaho and western Montana, eastern and southwest Oregon, and coastal northern California.

Alternative 2

The elimination of about 75% of the planned roading, and the associated 73% reduction in timber offer would have an effect on water quality, particularly in regions and areas highlighted in Alternative 1. Lower roading and timber offer levels would reduce concerns for increased sediment and nutrients in drinking water source watersheds. Concerns for sediment, nutrients, and temperature in watersheds with identified impaired water quality requiring total maximum daily loads would also be reduced. Under this alternative, there would be fewer new road miles needing periodic maintenance.

Alternative 3

This alternative would have the same reductions in roading as under Alternative 2, but it would further reduce the likelihood of logging impacts by allowing only stewardship harvests. Even though Region 10 has little opportunity for stewardship harvest, the region reports that 52 miles of road construction and reconstruction are tied to non-timber activities and would likely remain open, causing some concern for water quality. Similarly, Region 1 would offer only 20% of its planned volume but would still construct or reconstruct 72 miles (52%) of planned roads.

Alternative 4

This alternative would eliminate timber offered for commodity and stewardship purposes. Reductions in roading are the same as those under Alternatives 2 and 3. The incremental reduction in harvest would have fewer effects compared to those under Alternative 3. A slightly increased probability of large fires could affect the quality of water from burned areas.

Channel Morphology

Affected Environment

Roading and vegetation management have the potential to change stream channel morphology (structure and form). Unaltered streams normally exist in a state of **dynamic equilibrium** where stream shape (slope, width, depth, sinuosity) adjusts to incremental changes in sediment and water inputs but retains the same general shape over time (Lane 1955; Heede 1980). Sizable changes in sediment and water inputs can throw the channel out of equilibrium, causing it to adjust to a different form with different functions and values (DeBano and Schmidt 1989a,b; LaFayette and DeBano 1990; Furniss and others 1991; Rosgen 1996).

Stream systems or segments can exhibit vertical instability (down cutting or filling of the channel) or lateral instability (increases or decreases in stream width). Large additions of sediment or decreased flow of water can reduce a stream's ability to transport sediment, causing the channel to aggrade (fill). Sediment inputs from landslides or reductions in water flow can cause these changes. Reducing normal sediment loads or increasing the flow in a stream can increase sediment transport and cause the channel to degrade (cut into its bed or banks). Increasing flow into a channel from road ditch placement or when timber harvests decrease evapotranspiration can cause these changes.

Placing roads in floodplains near streams can confine streams, change the shape of the stream, increase the channel slope, and cause the stream to erode into its bed and banks. Recovery may take decades. Many streams are still adjusting to changes caused long ago. For example, changes in the elevation of a streambed may cause gully formation that continues to erode productive landscapes. Changes in riparian vegetation from strong, deep-rooted species (such as willow or alder) to weak, shallow-rooted species (such as Kentucky bluegrass), or loss of large woody materials can destabilize streambeds and banks. Recovery from stream channel alteration is possible. For example, a 12-year moratorium on sediment-producing activities on the South Fork Salmon River in Idaho resulted in a sizable improvement in channel condition (Chamberlin and others 1991).

Alternative 1 – No Action

Increased water runoff generated from timber harvest areas and road surfaces, and increased sedimentation from road construction, reconstruction, and maintenance are highest in this alternative. Channel degradation from increased erosion or aggradation from increased sediment deposition is a function of each local situation. Channel degradation is most likely in upper watersheds having steeper slopes and more runoff energy, but it can also occur where slopes are more moderate. Sediment from these upper watersheds may be deposited in downstream channels with flatter slopes, commonly in downstream water supply reservoirs or on lands managed by other entities. Due to the planned levels of roading and timber offer, Regions 10, 4, and 1 have the highest potential for stream channel adjustments. However, the roading planned for Region 2, and some local harvests in mountainous country in the East, hold similar concerns.

Alternative 2

The reduction in roading and timber offer provides a generally proportionate reduction in the likelihood of changes in stream channel morphology as outlined under Alternative 1. Opportunities to alter flow or sedimentation are reduced the most in Regions 10, 4, 1, and 2, and in the other specific areas as mentioned above.

Alternative 3

While the reduction in roading is the same as under Alternative 2, the further reduction in timber offer, except for stewardship activities, under this alternative provides additional benefits in terms of conserving stream channel integrity closer to undisturbed conditions. Since Region 10 has little opportunity for stewardship harvest, both roading and harvest levels would be at their minimum levels under this alternative.

Alternative 4

Elimination of timber offered for commodity and stewardship purposes, coupled with the roading reductions, provides the most benefits in terms of minimal likelihood of changes to stream channel morphology. Channels would remain closest to undisturbed conditions under this alternative. A slightly increased probability of large fires could cause changes to channel morphology on-site and downstream.

Soil Loss, Sedimentation, and Site Productivity

Affected Environment

Road construction, reconstruction, and maintenance may cause or accelerate surface erosion and initiate landslide events. General surface erosion caused by water washing over the soil produces mostly fine sediment (sand, silt, clay, gravels), while landslides produce sediment of all sizes including boulders and large organic materials such as trees and root wads. Permanent and temporary road construction and reconstruction can cause increased risk of surface erosion and landslides, but this varies widely and depends on local site characteristics. The planned mileage of permanent and temporary road construction and reconstruction provides the best estimate of effects from erosion and sedimentation.

The greatest concern for soil loss and sedimentation lies in areas where land management activities, such as roading and timber harvest, occur in conjunction with high precipitation, steep slopes, soils prone to surface erosion, and terrain susceptible to landslides. NFS lands with these characteristics include:

- New England highlands of Vermont and New Hampshire,
- Central and Southern Appalachians,
- Central Rockies in Colorado,
- Coastal forests in California and Oregon,
- Sierra Nevada Mountains of California,
- Forests in the Cascade Range of Oregon and Washington,

- Central and northern Idaho and western Montana,
- High elevation portions of Nevada, Utah, and Wyoming, and
- Coastal areas on the Tongass National Forest in Alaska.

These areas are illustrated in Figure 3-17.

Land occupied by roads is essentially lost to long-term production of vegetation unless the road is allowed to revegetate. This is also true for skid roads, skid trails, and landings associated with a timber harvest unit. The amount of land occupied by these roads, trails, and landings varies due to terrain and logging systems used. Western skyline and helicopter logging uses about 2% of the sale area, while careful tractor skidding in the East uses from 4% to 5% (USDA Forest Service 2000h).

Regions 10, 4, 6, and 1 would offer the most timber for harvest in inventoried roadless areas. Region 10 plans to leave most new roads open (85%), while all other regions plan to close half or more of the new roads. Loss of productivity from accelerated erosion and compaction during timber harvest would affect these same regions, especially Regions 10 and 4.

Alternative 1 – No Action

Under this alternative, the planned offer of 1.1 BBF of timber and construction and reconstruction of 1,160 miles of road poses the greatest potential for soil loss, sedimentation, and lost soil productivity compared to the other alternatives. Regions 10, 4, 1, and 2 plan the most road construction and reconstruction. Region 10 plans to offer the most timber volume (49% of the national total) and roading (31% of the national total) in inventoried roadless areas. As in the discussion on water quality, the greatest risks occur during the largest precipitation and runoff events. These events may exceed the design standards of the road, timber harvest, and related best management practices. Application of best management practices and timber-sale-contract requirements are generally effective in handling normal precipitation and runoff.

Alternative 2

The approximately 75% reduction in roading and associated 73% decrease in timber offer from inventoried roadless areas would proportionately decrease the risk of soil loss, sedimentation, and soil productivity compared to that under Alternative 1. The greatest benefits would occur in the Regions 10, 4, 1, and 2, respectively, based largely on reduced road construction mileage.

Alternative 3

While the reduction in roading is the same as under Alternative 2, this alternative further reduces impacts from timber harvesting except for stewardship harvests. This would provide added benefits by reducing the likelihood of soil loss, sedimentation, and lowered site productivity.

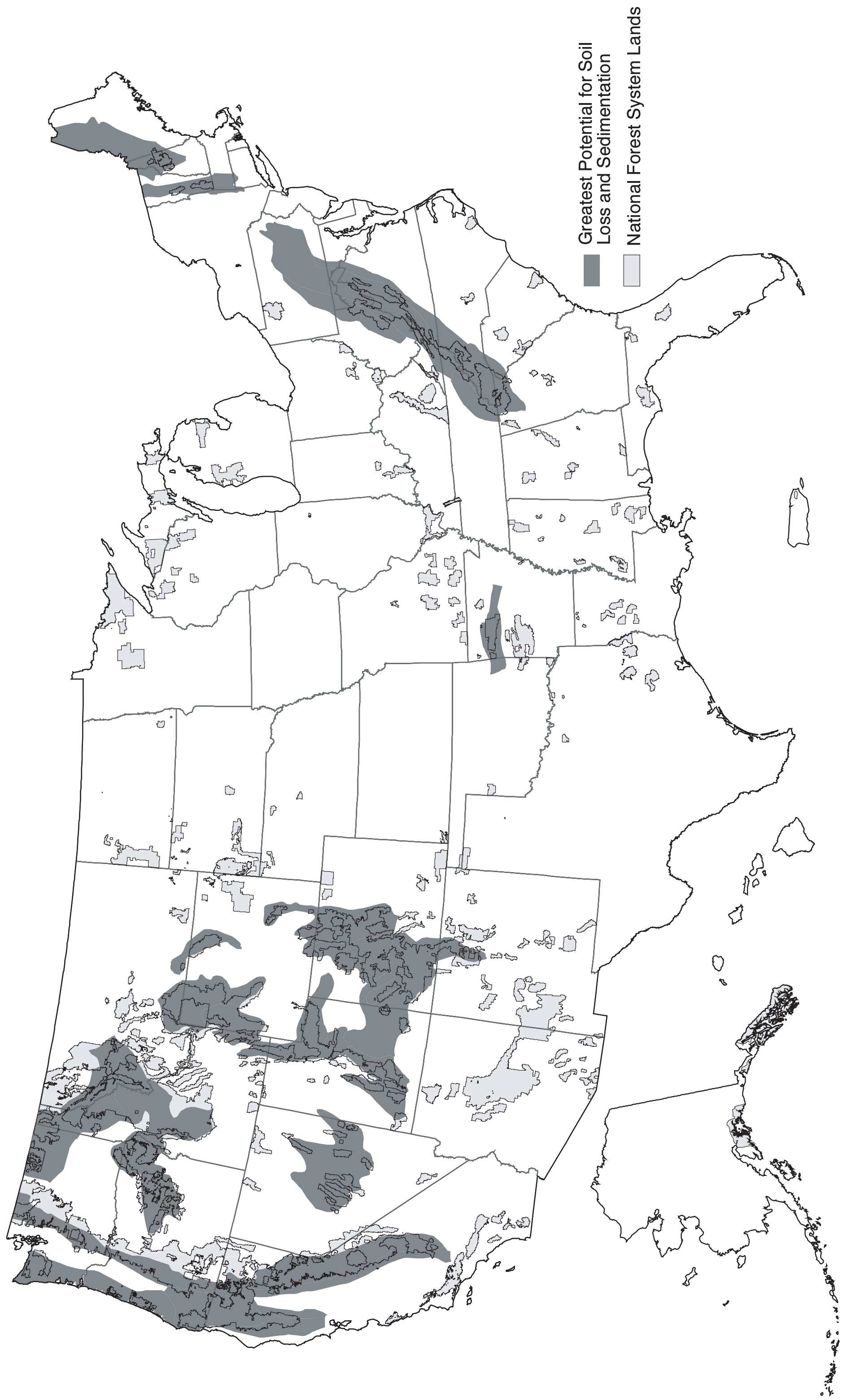

Figure 3-17. Areas with greatest soil loss and sedimentation potential. No data exist for Alaska, Hawaii, or Puerto Rico.

(Roadless Database 2000; Bailey 1995)

Alternative 4

This alternative offers the least risk and the most benefit in terms of preventing soil loss, sedimentation, and soil productivity from timber harvest and road construction activities. The benefits are slightly increased over Alternative 3 based on the elimination of timber offered for commodity and stewardship purposes. However, additional potential exists for negative effects due to slightly increased risk of large fires that can cause substantial erosion, sedimentation, and landslides, both on-site and downstream.

Landslides

Affected Environment

Landslides (the rapid downslope movement of soil, rock, water, and vegetation including mudflows, slumps, and debris flows) not only affect physical and biological watershed characteristics but can also threaten human life and safety. Landslides are recognized, particularly in many parts of Western forests, as a key source of sediment. Chamberlin and others (1991) stated that, "It is usually impossible to harvest unstable hillsides without increasing mass movements, however, except perhaps when careful selective logging with helicopter yarding can be done."

Even a high level of care cannot guarantee avoidance of landslides because loss of root strength will increase risk until roots from new vegetation can provide stability (Ziemer 1981; Robison and others 1999). Figure 3-18 highlights specific areas of concern where land-disturbing activities, such as road construction or timber harvest, have the potential to reactivate historic landslides or initiate new ones. While all regions have some areas of high landslide potential, certain locations deserve special attention. Land-disturbing activities are more likely to occur in the West than in the East, increasing the potential for landslide events. Table 3-9 lists the inventoried roadless acreage with high landslide susceptibility in some key States.

In the West, areas of special concern include:
Steep slopes in Southeast Alaska,
Southwest corner and northeast and central mountains of Oregon,
Portions of eastern Washington,
Central and southeastern mountains of Idaho,
Portions of the mountains of western Montana,
Western edge and northwest corner of Wyoming,
Central and northeast Utah,
Large portions of central and western Colorado,
Northern New Mexico, and
North coastal, north central, and south coastal California.

While landslides are a natural process in these areas, extensive research and other investigations in the West have closely associated land management activities, particularly roading and timber harvest, with accelerated incidence of landslides by several orders of magnitude (Swanston 1974; Anderson and others 1976; Swanston and

Swanson 1976; Sidle and others 1985; Swanston 1991). Landslides were the principal source of erosion related to timber harvesting in some parts of the West, even though these slides occupy a small percentage of the land (Rice and Lewis 1991).

The winters of 1995 and 1996 offered unique opportunities to study landslides in the West. Severe storms in November of 1995 and February of 1996 triggered thousands of landslides throughout California, Oregon, Washington, Idaho, and Montana. A number of studies examined the relationship of land management activities to landslides. A joint study by the Forest Service and Bureau of Land Management in Oregon and Washington found that of 1290 slides reviewed in 41 sub-watersheds, 52% were related to roads, 31% to timber harvest, and 17% in undisturbed forest (USDA Forest Service and USDI Bureau of Land Management 1996). An evaluation of landslides initiated by the Siuslaw National Forest found that roads were the source of 41% of the slides, harvest units less than 20 years old were the source of 36%, while natural forest accounted for the remaining 23% (USDA Forest Service 1997e).

The Pacific Rivers Council funded an aerial reconnaissance to evaluate landslides in Oregon and southern Washington in 1966. Of the 651 landslides in their inventory, 36% of the slides were related to roads, 71% to harvest units less than 15 years old, and 6% to natural forest conditions[6] (Weaver and Hagans 1996). The Oregon Department of Forestry did an intense ground survey of 506 landslides and found that most slides were located in existing forest stands and relatively few were caused by active or old roads, although slides from roads were larger than those in other settings (Robison and others 1999). Other studies on the Clearwater National Forest in Idaho (McClelland and others 1997) and the Mt. Hood National Forest in Oregon (DeRoo and others 1998) found that roads and timber harvest were major causes of landslides.

As an example of the variability in regional landslide susceptibility, two studies of landslide activity in basalt formations on the west side of the Payette National Forest following 1997 storms showed marked contrast to the much-studied landslide-prone granitic formations in the Idaho batholith on the east side of the same forest. An evaluation of 483 landslides by Dixon and Wasniewski (1998) revealed that 86% of the slides (mostly small) originated in areas not affected by management activities, such as roading or timber management, although one third of the large slides were management related. They further found that only 15% were in forested areas, with the rest in grasslands and shrublands. Lesch and Shinn (1997) studied 31 landslides and found that none were directly related to management activities, such as roads, timber harvest, mining, or grazing, but originated in unmanaged settings.

Large or dramatic landslide events in the Eastern forests are rare but do occur (Patric 1976). In the Southern region, the Southern Appalachian Mountains have some areas of high susceptibility, particularly in eastern Tennessee, north Georgia, western North Carolina, and southwest Virginia. In the Eastern region, the mountains of eastern West Virginia and the mountains in central New Hampshire also have high landslide potential.

[6] Percentages sum to more than 100% since some landslides are related to both roads and harvest units.

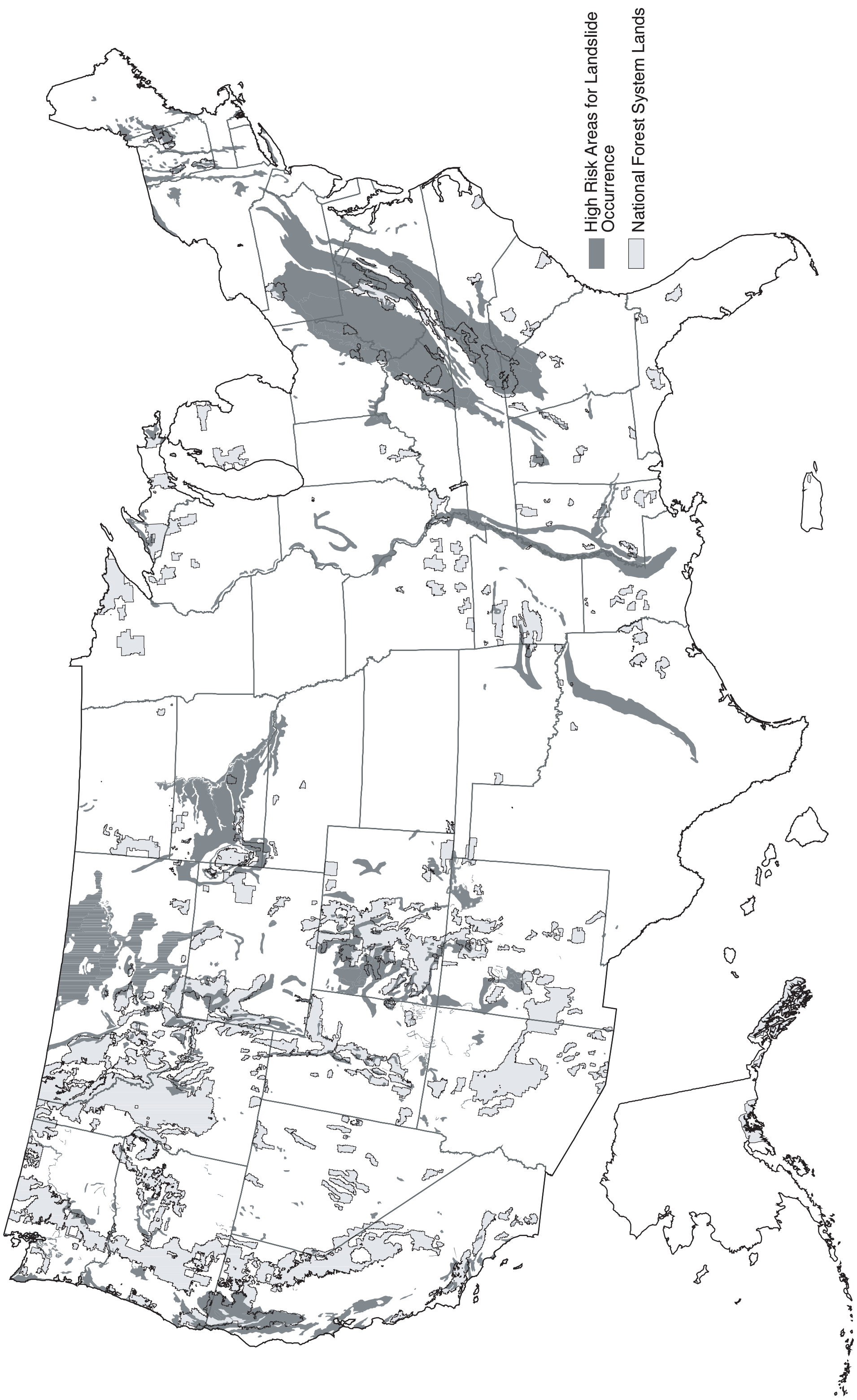

Figure 3-18. Generalized landslide susceptibility map for inventoried roadless areas. No data exist for Hawaii or Puerto Rico.

(Roadless Database 2000; Radbruch-Hall and others 1982)

Table 3-9. States with more than 100,000 acres of inventoried roadless areas, with high landslide susceptibility.

State	Total inventoried roadless area acres (thousands)	Inventoried roadless area acres with high susceptibility (thousands)	Inventoried roadless areas with high susceptibility (%)
Alaska	14,779	1,595	11
Colorado	4,433	1,295	29
Montana	6,397	975	15
California	4,416	789	18
Wyoming	3,257	693	21
Utah	4,013	534	13
Virginia	394	316	80
Idaho	9,322	294	3
North Carolina	172	148	86
Oregon	1,965	143	7
New Hampshire	235	139	59
West Virginia	202	102	50

(Roadless Database 2000; Radbruch-Hall and others 1982)

The likelihood of accelerating landslide incidence due to land management activities appears substantially different in the Eastern and Western parts of the country.

Evaluations of Eastern landslides indicate that the cause is generally extreme precipitation events, such as hurricanes or intense summer convectional storms, where precipitation far exceeds the soil's capacity to absorb and transmit moisture. In these cases, land use has less effect on landslide initiation compared to the West (Anderson and others 1976, Eschner and Patric 1982; Neary and others 1986; USDA Forest Service 2000h; Kochenderfer 2000). Small and localized slumps and other mass movements occur in the East and South, commonly because of improper road drainage (blocked or undersized culverts), which forces water onto unstable road-fill slopes (Burns 2000b; Carlson 2000; Edgerton 2000).

Alternative 1 – No Action

Of the four alternatives considered, Alternative 1 has the greatest probability of landslides, with particular concern in Regions 10, 4, 1, and 2 and with local concerns in the coastal forests of Oregon, Washington, and northern California. While modern road construction and maintenance practices are much better than those used 10 to 30 years ago, special caution is warranted in areas with high landslide potential.

Alternative 2

The reduction in timber harvest and roading under this alternative provides benefits through reduced probability of landslide events. Regions 10, 4, 1, and 2, respectively, stand to benefit most from these reductions in probability with particular emphasis on Region 10 since that region has extensive landslide susceptibility, yet plans the most timber harvesting and roading under Alternative 1.

Alternative 3

This alternative shares the same reductions in roading as Alternative 2 but has small additional benefits from a further reduction in timber harvesting and associated landslide susceptibility.

Alternative 4

The elimination of timber harvesting under this alternative would provide some incremental reduction of landslide potential compared to that under Alternative 3. Risk from roading is unchanged from Alternatives 2 and 3. However, the increased likelihood of severe **wildland fires** increases the probability of landslides in highly susceptible areas.

Air Resources

Affected Environment

Air Quality – Good air quality is necessary to attain and sustain healthy and vital ecosystems. Clean, fresh air is an attribute that visitors to NFS lands highly value. People especially enjoy viewing the scenery, being able to clearly see distant vistas, and knowing that these values are protected, even if they personally never experience them.

The authorities for air resource management on NFS lands include the National Forest Management Act, the Clean Air Act, and the Wilderness Act. A key focus of the Clean Air Act is on **Class I areas**.[7] There are 163 designated Class I areas for air quality protection in the nation. The Forest Service manages 88 of these areas, the National Park Service manages 49, the U.S. Fish and Wildlife Service manages 21, and American Indian Tribes manage five. All management activities on NFS lands must consider air quality related values for all Class I areas managed by any agency, not just those on NFS lands. Table 3-10 displays regions and forests with the highest likelihood of effects in Class I areas due to their proximity to inventoried roadless areas. Figure 3-19 displays Class I areas managed by the USDA Forest Service, other agencies, and Tribes.

Congress required that the air pollution sensitive resources in these areas, especially visibility, be protected from degradation due to air pollution (Malm 2000). Congress established a national goal to prevent visibility impairment and improve visibility in all Class I areas. Regulations issued by the EPA in 1999 specified that States must work closely with Federal land managers to establish strategies by 2004 to reduce to a natural level the regional haze that now affects virtually all Class I areas.

Atmospheric emissions from road construction and use include particulate matter consisting of suspended fine (<2.5 microns in diameter) and larger coarse soils, nitrogen,

[7]National Forest Wilderness Areas, National Parks, or National Wildlife Refuges greater than 5,000 acres in size, designated before establishment to the Clean Air Act Amendments of 1977. Class I areas can also include lands designated by Tribes or States. These areas serve as benchmarks for monitoring changes in air quality over adjacent lands.

Table 3-10. Inventoried roadless areas near Class I air quality areas.

Region	Forest or Grassland
Northern (1)	Flathead, Lewis & Clark, Lolo, Nez Perce, Clearwater, Little Missouri NG
Rocky Mountain (2)	All forests in Colorado, plus Bridger-Teton, Shoshone, Buffalo Gap NG
Southwestern (3)	Prescott, Tonto, Gila, Santa Fe
Intermountain (4)	Humbolt-Toiyabe, Dixie, Fishlake, Sawtooth
Pacific Southwest (5)	Six Rivers, Shasta-Trinity, Lassen, Mendocino, all forests in the Sierra-Nevada range, Los Padres, Angeles, Cleveland, San Bernardino
Pacific Northwest (6)	Mt. Baker-Snoqualmie, Gifford Pinchot, Siskiyou, Umpqua, Winema, Willamette, Deschutes
Southern (8)	Cherokee, Pisgah-Nantahala, George Washington-Jefferson
Eastern (9)	Monongahela, White Mountain
Alaska (10)	There are no Class I areas in proximity to inventoried roadless areas on the Chugach or Tongass National Forests.

(Roadless Database 2000)

and volatile organic compounds from gasoline engines, and soot from diesel engines. These pollutants contribute to visibility reduction. Nitrogen oxides form nitrates and ammonium deposits that contribute to soil and water acidification and leaching. Nitrogen oxides and certain volatile organics can react in the atmosphere to form ozone and other oxidants. At certain levels, ozone is phytotoxic and presents a human health risk. Oxidants are essential factors in the chemistry that creates acidification. Ozone, fine particles, and nitrogen dioxide are criteria pollutants and therefore, States must keep them at or below the critical levels established by the National Ambient Air Quality Standards.

In addition to protection of Class I areas, the Forest Service is required under Section 176 of the Clean Air Act to assure that its actions will not cause or contribute to violations of the air quality standards or increase the frequency or severity of existing violations. Any inventoried roadless areas near **non-attainment areas** may need to consider impacts on those areas.

Mechanical or other fuel treatment before prescribed burning in areas with large fuel accumulations is an important aspect of meeting air quality standards. The direct removal of fuel reduces potential site emissions and indirectly reduces fuel consumption and hence, pollutants. Emissions generated during prescribed burning in untreated forests could exceed standards, a particularly critical concern in inventoried roadless areas adjacent to Class I areas or non-attainment areas.

Global Climate Change/Carbon Sequestration – Sommers (1996) defines global climate change "… as being both physical (e.g., global warming) and chemical (e.g., acid deposition and atmospheric CO2 concentration). According to Gates (1993), "The world

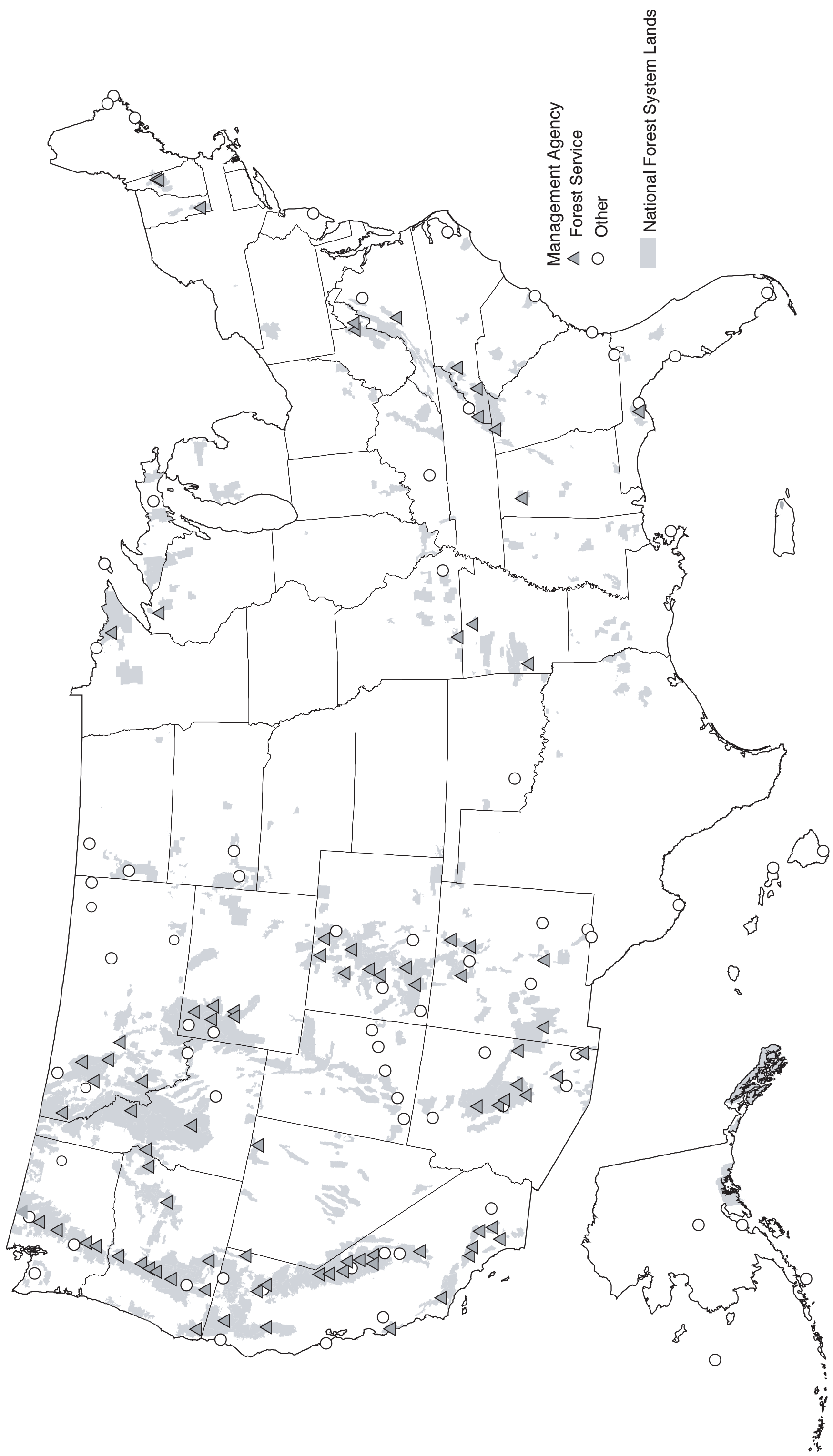

Figure 3-19. Class I air quality protection areas. No data exist for Alaska, Hawaii, or Puerto Rico.

(Roadless Database 2000; USDI, National Park Service 1994)

has been warming for over 100 years and may warm in the future at a rate unprecedented in human existence, as a direct result of industry, forest destruction, and agriculture. These activities result in the accumulation of greenhouse gasses, including carbon dioxide, nitrous oxide, methane, ozone, chlorofluorocarbons, and others. These compounds, along with water vapor, are transparent to sunlight but absorb infrared heat. Their presence in the atmosphere reduces the loss of heat from the earth's surface to outer space – the greenhouse effect - thereby making the world warmer." While estimates vary among researchers, recent data show increases in average temperatures of 0.6 °C over the past 130 years, with seven of the 10 warmest years on record occurring in the 1980s and 1990s (Gates 1993).

Carbon sequestration is the combination of carbon into materials that prevent it from being released back into the atmosphere, either in the short (a few years) or the long term (tens or hundreds of years). Carbon can be sequestered in plant materials (trees), in wood products (paper and lumber), in landfills (waste materials), and commonly in the soil and the organic litter on the soil surface. The rate of buildup varies considerably by temperature, moisture, and productivity of the site with some areas able to sequester large volumes of carbon for many years, while others sequester very little and quickly lose what little is present (Birdsey 1996). Rising use of fossil **fuels** and plants for food, shelter, and energy have released huge quantities of carbon into the atmosphere, accelerating global warming.

Carbon sequestration counters global warming through capture and long-term sequestration of carbon. Carbon sequestration serves as an offset to the carbon added to the atmosphere through burning of fossil fuels, forest clearing for agriculture, and similar actions. Currently, the rate of carbon release to the atmosphere far outstrips carbon sequestration. The size of the gap between gain and release grows wider each year largely due to the burning of fossil fuels.

Forests and forest management can play a role in addressing climate change. In accounting for the location of carbon in forest ecosystems, studies indicate that 61% resides in the soil, 8% in the forest floor (litter and humus), 1% in the understory, and 29% in the trees themselves. Of the carbon in trees, 50% is in the trunks (boles), 17% in roots, 3% in foliage, and the remaining 30% in other parts like branches, twigs, bark, etc. (Birdsey 1996; Birdsey and Heath 1997).

Forests can be managed to maximize carbon accumulation (sink enhancement) and minimize carbon loss (emission reduction). Some of the following strategies are of particular interest in managing NFS lands and several have relevance to management of inventoried roadless areas:

- Increase the area of forest lands, particularly by stocking currently unstocked lands;
- Increase the stocking levels of currently understocked lands;
- Thin or perform other activities to increase growth rates of overstocked and stagnant stands (mechanical, fire, etc.); and
- Reduce releases from wildland fire, particularly severe, stand-replacing fires (Sampson and Clark 1996).

The literature contains considerable discussion concerning timber harvest levels and the amount of time a stand of trees is allowed to grow before final harvest (rotation length). Several general themes emerge from this discussion:

- To maintain current carbon storage rates, letting existing stands grow while providing protection from loses is a reasonable strategy (Row 1996);
- Twenty to thirty-five percent of the forest biomass ends up in long-term storage after harvest (wood products, landfills, etc.), while the remainder is released to the atmosphere (loss in soils, decomposition of litter, twigs, leaves, etc). Reducing harvest level can cause a short-term increase in the amount of carbon stored in forests because volume is retained on site and releases of carbon into the atmosphere during removal of biomass and wood processing are avoided (Heath and Birdsey 1993; Heath and others 1996; Birdsey and others 2000); and
- To increase carbon storage over the long term, a continuous cycle of harvest, efficient use of biomass, and regrowth of young, vigorous trees on highly productive lands can sequester more carbon than letting existing stands grow without harvesting (Row 1996). Conversely, removal of mature or old-growth stands to begin such cycles can produce the opposite effect: net carbon emissions will ensue for many decades following the initial stand harvest. Harvest of mature forest followed by reforestation does not appear to offer net carbon sequestration benefits (Shulze and others 2000)

In discussing the effects of harvest levels, climate change and carbon sequestration, Birdsey and others (2000) conclude that, “Forestry activities that directly or indirectly result in emissions reductions may play an important role in the ability of the United States to meet its international commitments to reduce greenhouse gasses.” While this may be true at the national scale, across all ownerships, the delivery of forest products from NFS lands today is a relatively small part of the national totals. For example, NFS lands provided approximately 5% of the harvest across all ownerships in the nation in 1996. Projections show national forests are planning to offer from 3 to 4 BBF of timber each year from 2000 through 2004. Of that total, planned timber offer from inventoried roadless areas is about 220 MMBF, between 5% and 7% of the projected total NFS offer, or about 0.3% of the planned annual national harvest from all ownerships. Road construction and reconstruction related to timber operations will have little effect compared to the removal of timber. Thus, the planned annual timber offer and road construction and reconstruction from inventoried roadless areas is a very small fraction when compared with the projected annual harvest in the United States.

Forests in the United States currently serve as a carbon sink; they absorb more carbon than they release (USDA Forest Service 2000e). Growth of forests in the United States, in general, has exceeded removal (through timber harvest) since about 1952. This is enough to offset 25% of United States emissions for the same period (Birdsey and Heath 1997).

Sizable reductions in timber harvest over the past 10 to 15 years from Federal lands, particularly lands managed by the Forest Service, will likely result in more sequestered carbon on those lands for several future decades. This is especially notable in the Pacific Northwest but also holds true for other regions. This increase in stored carbon will likely be offset, however, by compensating increases in harvest on other lands, most notably private (industrial and non-industrial) lands, primarily in the South, and increased harvest and imports, largely from Canada (U.S. Environmental Protection Agency 1995). Thus, on a global scale, the planned offer and road construction and reconstruction from inventoried roadless areas is insignificant. None of the alternatives will have a measurable impact on global climate change, carbon sequestration, or related concerns.

Alternative 1 – No Action

Effects on air quality resources in Alternative 1 are mixed. Emissions from road construction, reconstruction, and use would present a small but chronic air pollution impact, particularly where inventoried roadless areas are adjacent to Class I areas. Smoke particles are small and can travel great distances once they are in the atmosphere. Increasing access into inventoried roadless areas would likely facilitate additional prescribed burning to treat hazardous **fuels** and for other resource management purposes. Although smoke generated from these burns may affect Class I areas, the smoke events from prescribed burns are more predictable and manageable (compared to wildland fires) due to adherence to strict burning guidelines. The increased access may result in additional human-caused fires, particularly at the wildland-urban interface. In non-attainment areas, increased access and use may require mitigation measures.

Alternative 2

This alternative would prohibit roughly 75% of future roading and the associated 73% decrease in timber offer in inventoried roadless areas, thus concentrating the expected increased public use on existing roads. This could increase vehicle emissions and dust along existing roads rather than dispersing them along the larger network of roads as under Alternative 1. Concentrating emissions on existing roads could increase impacts where these roads are in or near non-attainment areas. This alternative would eliminate most emissions from the new roads adjacent to Class I areas.

Alternative 3

Timber harvest and hazardous fuel treatments that could be accomplished without road access would still proceed under this alternative. Smoke from prescribed and wildland fire would likely be similar to that under Alternative 2. Impacts from road-generated emissions would be the same as under Alternative 2.

Alternative 4

There would be a slight increased risk of large wildland fires, particularly in the dry pine and fir types in the Intermountain West, and the large quantities of smoke they generate under this alternative. The effects from road emissions are the same as under Alternative 2.

Effects of Social and Economic Mitigation on Water, Soil, and Air Resources

These exceptions would increase the number of miles allowed to go forward from 293 to 358 (662 miles with the Tongass National Forest **exemption**) for Alternatives 2, 3, and 4. The effects of road construction associated with these exceptions would be similar to those previously described under Alternative 1. The beneficial effects related to the prohibition on road construction under Alternatives 2, 3, and 4 would therefore, be somewhat less than previously described.

It is impossible to predict the amount or location of road reconstruction that would be excepted for reasons of public health and safety. Realignment or upgrade of roads would likely result in additional ground disturbance, but it is unlikely that the environmental effects of such reconstruction would substantially expand the area affected beyond that of the original construction, especially given the current emphasis on environmentally sensitive design and use of best management practices. Such reconstruction could, however, result in changes in the kinds and amount of human uses in an area. Provided that conservation of other roadless characteristics is given strong emphasis in the project design and mitigation, this reconstruction would not be likely to result in additional substantial long-term ecological changes.

Estimates indicate that few miles of road construction would be excepted for Federal Aid Highway projects over the next 5 years in inventoried roadless areas. There is no reason to anticipate a substantial increase in the future. Only one 6-mile project is currently planned on the Chugach National Forest. While this project may have local effects on the characteristics and values associated with the affected inventoried roadless area, this limited level of activity would not result in a substantial change in the overall environmental effects of the alternatives.

Six national forests and grasslands in five regions have identified 59 miles of road tied to 21 projects during the 2000 through 2004 time frame related to the exploration or production of leasable mineral materials such as oil and gas, coal, phosphate, and geothermal energy. Regions most affected by this additional mileage are: Region 2 (38 miles) and Region 9 (12 miles). Environmental effects of these road miles, should they be built, are the same as effects for other roads in similar terrain. There is no certainty whether exploration activities conducted through access provided by these roads will eventually lead to development and production of **mineral resources**. If development does take place, effects on water, soil, and air resources can be substantial at the development site and around related facilities. Considerable literature exists addressing these effects (Nelson and others 1991; FISRWG 1998). However, these development activities are subject to stringent environmental analysis, mitigation, monitoring, and evaluation measures at the local level before, during, and after project implementation.

Potential near future geothermal development activity associated with inventoried roadless areas appears limited. Only one forest anticipated lease applications in the next 5 years, with three miles of associated temporary road construction. Although the magnitude of effects from geothermal exploration and development would be dependent on a variety of factors, impacts from such activities do not currently appear to pose substantial or widespread risks to water, soil, or air resources.

Oil and gas exploration and development activity within inventoried roadless areas is anticipated on four national forests in the next 5 years, with an estimated 34 miles of road construction for leasing and possible development. The demand for these resources is increasing nationally and may indicate additional interest in this kind of activity within inventoried roadless areas on these four forests and other NFS lands. The associated road systems would likely account for a substantial portion of potential environmental effects. Other effects of these activities would be determined by the location and size of areas disturbed, the duration of the activity, mitigation measures used for environmental protection including containment of toxic materials used in the drilling process, the type and effectiveness of site reclamation, and the overall level of exploration and development activity within an area.

One national forest identified 17 miles of roads associated with five coal exploration and leasing projects with possible eventual development of underground mining operations. Another national forest identified 5 miles of road with five phosphate leasing and permitting activities with potential for surface mining activities. The coal developments are anticipated to be subsurface and therefore, the environmental impact would involve few disruptions to surface resources and inventoried roadless values except as associated with roads. However, subsurface mining can disrupt surface water quality through release of acid waters from openings and runoff from tailing piles. The proposed expansion of phosphate mining is an open pit operation and therefore, poses higher risks to water quantity and drinking water source areas, channel morphology, soil loss, sedimentation, and soil productivity.

Environmentally, application of the social and economic mitigation measures to the prohibition alternatives would diminish the potential beneficial effects of a prohibition on road construction and reconstruction, given the greater amount of area disturbed and the kinds of activities enabled. Depending on a variety of factors, leasable mining activities supported by road access would potentially have detrimental effects to water, soil, and air resources. However, at current levels of activity and given the application of best management practices, the potential extent of these activities and their impacts do not appear to be widespread, and it is unlikely that most effects would extend much beyond local levels. Decisions on whether to permit such activities, and if so, what environmental mitigation measures would be required, would be made using current planning and decision-making processes. Overall, even with application of these measures, Alternatives 2, 3, and 4 would still provide important benefits relative to water, soil, and air resources.

Other Indirect and Cumulative Effects on Water, Soil, and Air Resources

The following analysis evaluates the incremental cumulative effects of reasonably foreseeable actions on water, soil, and air resource parameters as described earlier in this section. This analysis looks at three spatial scales: 1) inventoried roadless areas, 2) NFS lands, and 3) nationally. Some effects are detected most easily within the bounds of the inventoried roadless area. Other effects will continue off the inventoried roadless area into the general NFS lands area. Still other effects will be detectable off the forest on other ownerships. Effects are for short-term (2000 to 2004) and long-term (2020, 2040) periods.

Many inventoried roadless areas either are in the headwaters of stream systems or are immediately downslope of relatively undisturbed areas such as Wilderness Areas. This is particularly true in the West. In these geographic positions, inventoried roadless areas have special value because they produce high quality water on that site or deliver that water for downstream users. Even though other uses within the watershed and other ownerships downstream may degrade the quality of water once it leaves the roadless area, it may have particular value on-site, such as habitat for fish, a source of clean water for irrigation, or a key recreational resource. Where inventoried roadless areas are surrounded by roaded areas, a more typical situation in many parts of the East, the healthy landscapes provided by inventoried roadless areas may provide an oasis within otherwise heavily used watersheds.

Unlike water and soil resources, air resources are not confined to watershed boundaries. Activities that affect air resources can travel to the area of concern from long distances, from either within the forest or grassland, or from many miles outside the area. Pollutants, such as dust or smoke, generated within an inventoried roadless area may travel scores or hundreds of miles outside the local area depending on wind speed, direction, and other parameters. Equally important is the impact of pollutants (smoke, dust, chemicals, etc.) generated outside of inventoried roadless areas that reduce air, water, and soil quality on Forest Service lands. Air quality on Forest Service lands may be compromised to the point that needed land treatments, like prescribed fire, cannot be undertaken.

At watershed scales that include lands managed by the National Forest System and many other land ownerships, a wide variety of land uses over many decades have dramatically altered natural processes in most watersheds in terms of water, soil, and air resources. Growing populations and the related desire for goods and services has fueled the following activities:

- Construction, maintenance, and use of transportation facilities have occurred across the nation. These include private, local, County, State, and Federal highways, and airports, railroads, and other transportation infrastructure;
- Traditional agricultural activity, such as grazing of domestic livestock and row cropping, and rapidly expanding enterprises, such as large-scale poultry and hog management;
- Timber management, fueled largely by increased demand for housing and paper products;
- Construction and operation of hydrologic modifications, such as dams and levees (nationwide), and water withdrawals for irrigation and other uses (largely in the West);
- Industrial expansion, primarily in the East, but also accelerating in some Western locations such as Denver, Salt Lake City, Phoenix, Boise, and Albuquerque;
- Elimination or reduction of natural fire cycles (most dramatic in the West); and
- Urbanization and sub-urbanization across the nation.

These activities and the effects they have on water, soil, and air parameters very often make it difficult to detect incremental changes or effects from NFS actions since activities by others have already altered these resources.

Water and Soil Resources – Under Alternative 1, incremental changes in flow timing and flood flows will most likely be detectable in and possibly downstream from inventoried roadless areas in the arid and semi-arid portions of Regions 1 and 4. Changes in average annual water yield will be most likely within inventoried roadless areas and downstream on other national forest lands in high precipitation zones in Regions 5, 6, and 10. No incremental measurable changes are expected beyond the forest boundary due to the compounding effects of flow from other land uses.

Incremental changes in water quality for Alternative 1 would most likely be detected within inventoried roadless areas and possibly downstream into other lands within the forest but should not be detectible off NFS lands because of the interaction of pollutants coming from other ownerships and land uses. Regions 10, 4, and 1 are most likely to experience water quality effects, largely from timber harvest levels and associated road construction and reconstruction. The probability of affecting drinking water source areas is directly dependent on the proximity of the individual land-disturbing activity to the withdrawal point for the water supply.

Incremental changes in channel morphology for Alternative 1 are most likely where activities occur in inventoried roadless areas and possibly on downstream national forest lands. Increased road crossings and sediment additions from road construction and re-routing of drainage along roads is the highest concern, particularly in Regions 10, 4, 2, and 1 since they project the most road activity. Incremental changes in channel morphology off national forests are unlikely.

Losses of soil and site productivity are most likely at the individual inventoried roadless area level but not beyond. Some sediment increases generated from activities in inventoried roadless areas may remain detectible at the national forest level but will rarely be detectible beyond the forest boundary because of sediment additions from other land ownerships and land uses. Regions 10, 4, 2, and 1 are the most likely to experience localized sediment increases, due largely to planned road activity.

Within inventoried roadless areas, landslide activity is most likely to increase in high-risk geologic formations in Regions 10, 4, 2, and 1. Some landslide debris may be detectible downstream on the national forest but is unlikely to be detectible beyond NSF lands.

No increased incidence of fire activity in general or large fires in particular is expected. No increases in on-site or downstream effects are expected. No increases in BAER activity are expected.

Water and Soil Resources, Alternatives 2 and 3 – Decreased levels of road construction and reconstruction and related timber harvest reduce the number of opportunities to affect many of the parameters analyzed in this section. Where these activities do occur, they will affect these parameters in the same manner and extent as described for Alternative 1, relative to the timber offer and the number of road construction and reconstruction miles planned for the alternative.

Water and Soil Resources, Alternative 4 – The elimination of timber offered for commodity or stewardship purposes further reduces the likelihood of effects on water and soil resources described for Alternatives 1, 2, and 3. However, some slight chance exists for increases in large fire activity in inventoried roadless areas. Should additional large fires occur, some additional effects might be detectible within the burned area for all of the water and soil parameters. Some incremental effects may be detectible downstream from the burned area onto other lands on the national forests and grasslands, primarily from accelerated soil loss, landslide activity (where applicable) and resultant changes to sediment yields, channel morphology, and water quality. Loss of vegetative cover may also elevate water yields and flood flows downstream off national forests and grasslands onto other ownerships. Increased BAER activity would be needed to minimize the effects on on-site and downstream resources, health, safety, and property.

Air Resources, Alternative 1 – Impacts on air quality from road construction, use, and timber sale activity would be detectable in inventoried roadless areas and adjacent national forests and grasslands. Poor air quality entering some Class I areas from non-national forests lands may make identification of effects difficult. Incremental additions to global climate change and carbon sequestration would not be detectable.

Air Resources, Alternative 2 – Substantial reductions in road construction and reconstruction and related timber harvest will result in reduced opportunities for an incremental change to air quality beyond the NFS lands level. Emissions from outside sources will make it difficult to detect impacts from the activities in inventoried roadless areas. Incremental additions to global climate change and carbon sequestration would not be detectable.

Air Resources, Alternative 3 – Further reduction in timber harvest levels decrease the likelihood of activities in inventoried roadless areas producing detectible impacts to air quality in inventoried roadless areas, on the surrounding national forest, or off the forest or grassland. Incremental additions to global climate change and carbon sequestration would not be detectable.

Air Resources, Alternative 4 – The slightly increased likelihood of large fires elevates the probability of smoke from wildland fires affecting air resources on-site in inventoried roadless areas as well as in the surrounding forest and off NFS lands. Incremental additions to global climate change and carbon sequestration would not be detectable.

Forest Health and Fire Ecology

Approximately one-third (747 million acres) of the total land area of the United States is covered by forest vegetation (USDA Forest Service 1999j). National forests account for 147 million acres of those forested lands. Forest health is the perceived condition of these forests based on age, **structure**, **composition**, function, vigor, level of insects or disease,