COMPENDIUM OF FORESTRY BEST MANAGEMENT PRACTICES FOR CONTROLLING NONPOINT SOURCE POLLUTION IN NORTH AMERICA

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SEPTEMBER 2009

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NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT

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by
Erik Schilling, Ph.D.
NCASI Southern Regional Center
Newberry, Florida

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For more information about this research, contact:

Dr. Erik B. Schilling
Senior Research Scientist
NCASI Southern Regional Center
402 SW 140th Terrace
Newberry, FL 32669
(352) 331-1745, ext. 248
eschilling@ncasi.org

Dr. T. Bently Wigley
Program Manager
NCASI Eastern Wildlife Program
P. O. Box 340317
Clemson, SC 29634-0317
(864) 656-0840
bwigley@ncasi.org

Dr. George G. Ice
Principal Scientist
NCASI West Coast Center
P. O. Box 458
Corvallis, OR 97339
(541) 752-8801, ext. 230
gice@ncasi.org

Dr. Alan A. Lucier
Senior Vice President
NCASI Headquarters
P.O. Box 13318
Research Triangle Park, NC 27709-3318
(919) 941-6403
alucier@ncasi.org

For information about NCASI publications, contact:

Publications Coordinator
NCASI
P.O. Box 13318
Research Triangle Park, NC 27709-3318
(919) 941-6400
publications@ncasi.org

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PRESIDENT'S NOTE

Forestry best management practices (BMPs) are guidelines and prescriptions for protecting water resources in managed forests. BMPs are science-based and very effective in most circumstances.

Forest certification programs in North America recognize water resource protection as an important aspect of sustainable forest management. As a result, certification programs include requirements to implement BMPs and encourage their use.

This report addresses questions about forestry BMPs that have been raised by NCASI members and other stakeholders in forest certification programs. How and why do BMPs vary among jurisdictions? How do states and provinces determine whether BMPs have been implemented?

To address these questions, NCASI reviewed BMPs that are recommended or required by 44 U.S. states and 10 Canadian provinces. NCASI also reviewed efforts by states and provinces to monitor BMP implementation rates.

A key finding is that BMPs throughout North America are based on a common set of science-based principles. Variation in BMPs among jurisdictions is attributable to efforts by states and provinces to apply general principles to their own circumstances.

There is substantial variation in BMP monitoring objectives and methods among jurisdictions. High rates of BMP implementation have been documented in jurisdictions that have made substantial investments in BMP education and monitoring. Some jurisdictions have determined that forestry is a minor source of water quality problems and are reluctant to allocate scarce resources to monitoring implementation of forestry BMPs.

Ronald A. Yeske

September 2009

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MOT DU PRÉSIDENT

Les meilleures pratiques d'aménagement forestier (MPAF) consistent en un ensemble de lignes directrices et de mesures destinées à protéger les ressources en eau dans les forêts aménagées. Les MPAF sont des pratiques à fondement scientifique très efficaces dans la plupart des situations.

Dans les programmes de certification forestière en Amérique du Nord, la protection des ressources en eau représente un aspect important d'un aménagement forestier durable. C'est pourquoi ces programmes comportent des exigences de mise en œuvre des MPAF et en préconisent l'utilisation.

Le présent rapport aborde des questions sur les MPAF soulevées par des membres de NCASI et d'autres parties prenantes relativement aux programmes de certification forestière. Quelles sont les différences entre les MPAF des diverses juridictions, et pourquoi sont-elles différentes? Dans les provinces et dans les États américains, comment détermine-t-on s'il y a eu mise en œuvre ou non des MPAF?

Pour répondre à ces questions, NCASI a examiné les MPAF recommandées ou exigées par 10 provinces canadiennes et 44 États américains. NCASI a aussi étudié de quelle façon les provinces et les États suivent la progression de mise en œuvre des MPAF.

L'étude a révélé entre autres que toutes les MPAF d'Amérique du Nord reposent sur un ensemble commun de principes à fondement scientifique. Les différences entre les MPAF des diverses juridictions sont attribuables à la façon dont les provinces et les États appliquent les principes généraux pour tenir compte de leur propre situation.

Il existe d'importantes différences dans les objectifs et méthodes de suivi des MPAF entre les juridictions. NCASI constate que les juridictions qui ont investi massivement dans l'éducation et le suivi des MPAF affichent un pourcentage plus élevé de mise en œuvre des MPAF. Par contre, certaines juridictions estiment que la foresterie n'est qu'une source mineure du problème de qualité de l'eau et hésitent donc à allouer des ressources déjà limitées dans le suivi de la mise en œuvre des MPAF.

Ronald A. Yeske

Septembre 2009

COMPENDIUM OF FORESTRY BEST MANAGEMENT PRACTICES FOR CONTROLLING NONPOINT SOURCE POLLUTION IN NORTH AMERICA

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ABSTRACT

Federal laws in the United States and Canada have established national goals and legal frameworks for controlling point and nonpoint sources of water pollution. In both countries, federal authorities collaborate with state/provincial authorities to achieve national goals.

By law and tradition, states and provinces have leading roles in controlling water quality problems associated with nonpoint sources (NPS) of water pollution. In most jurisdictions, forest management is a minor source of NPS pollution compared to other land uses but can nevertheless cause important impacts on water resources if implemented without control and mitigation measures. States and provinces have therefore developed management guidelines and prescriptions for controlling sources of NPS pollution associated with forest management activities. In this report, we refer to such guidelines and prescriptions as best management practices (BMPs) while recognizing that many states and provinces use other terms.

This report documents differences and similarities in forestry BMPs among jurisdictions. The differences are attributable to variability among jurisdictions in legal, political, and socioeconomic factors as well as climate, soils, topography, and aquatic biota. Similarities are attributable to the fact that forestry BMPs are based on a substantial body of research that has 1) identified the most important causes of NPS pollution in managed forests and 2) demonstrated the effectiveness of NPS control and mitigation measures that are embodied in BMPs.

Several overarching themes are apparent in forestry NPS programs in all jurisdictions: 1) minimizing soil compaction and the extent of bare soils; 2) separating exposed soils from surface waters; 3) separating fertilizer and herbicide applications from surface waters; 4) inhibiting hydraulic connections between bare ground and surface waters; 5) providing forested buffers around watercourses; and 6) designing stable roads and watercourse crossings.

Several important aspects of forestry NPS programs vary substantially among jurisdictions. For example, there is substantial variation among jurisdictions in streamside buffer widths, criteria for establishing those widths, and management restrictions within buffers. As with overall NPS program design, variability in riparian buffer BMPs is attributable to efforts by states and provinces to apply general principles to their own circumstances.

Several jurisdictions have made substantial investments in monitoring BMP implementation and have used monitoring results to identify problems and document improvement over time. Assessments of BMP implementation rates across jurisdictions are impeded by major differences among jurisdictions in factors such as monitoring objectives and methods. In many jurisdictions, agencies responsible for controlling NPS pollution are reluctant to direct scarce resources to monitoring forestry BMPs because forestry is a minor concern relative to other NPS categories.

KEYWORDS

best management practices, compliance, fertilizers, forest practices rules, harvesting implementation, monitoring, nonpoint source pollution, pesticides, reforestation, riparian forests, roads, stream classification, stream crossings, streamside management zones, waste disposal, water quality

RELATED NCASI PUBLICATIONS

The use of watershed-level studies in examining the hydrologic and water quality impacts of forestry practices in Canada: A literature review. (Forthcoming).

Canadian watershed handbook of control and mitigation measures for silvicultural operations. (April 2009).

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Technical Bulletin No. 672. (July 1994). *Forests as nonpoint sources of pollution and effectiveness of best management practices.*

COMPENDIUM
DES MEILLEURES PRATIQUES D'AMÉNAGEMENT FORESTIER POUR CONTRÔLER LA POLLUTION DIFFUSE EN AMÉRIQUE DU NORD

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RÉSUMÉ

Dans leurs lois, le Canada et les États-Unis ont fixé des objectifs nationaux et établi le cadre légal pour contrôler les sources ponctuelles et les sources diffuses de pollution de l'eau. Pour atteindre ces objectifs nationaux, les autorités fédérales des deux pays collaborent avec les autorités provinciales et celles des États américains.

Selon la loi et la tradition, les provinces et les États sont responsables du contrôle des problèmes de qualité de l'eau causés par des sources de pollution diffuse. Dans la plupart des juridictions, les activités d'aménagement forestier constituent une source mineure de pollution diffuse comparativement à d'autres utilisation du territoire mais peuvent néanmoins avoir un impact important sur les ressources en eau si ces activités sont mises en œuvre sans mesures de contrôle et d'atténuation. Les provinces et les États ont donc élaboré un ensemble de mesures et de lignes directrices pour contrôler les sources de pollution diffuse associées aux activités d'aménagement forestier. Dans le présent rapport, nous faisons allusion à ces mesures et à ces lignes directrices lorsque nous parlons des meilleures pratiques d'aménagement forestier (MPAF), tout en reconnaissant que bon nombre de provinces et d'États emploient d'autres termes.

Le présent rapport documente les différences et les similarités entre les MPAF des différentes juridictions. Les différences sont attribuables à des variations dans les facteurs socio-économiques, politiques et légaux de chaque juridiction ainsi que dans les types de climat, de sol, de topographie et de biote aquatique. Les similarités sont attribuables au fait que les MPAF reposent sur de nombreux travaux de recherche qui ont 1) identifié les principales causes de pollution diffuse dans les forêts aménagées et 2) démontré l'efficacité des mesures de contrôle et d'atténuation des sources diffuses incluses dans les MPAF.

Plusieurs principes fondamentaux constituent la base de tous les programmes de contrôle et d'atténuation de la pollution diffuse en forêt et ce, dans toutes les juridictions : 1) réduire le tassement des sols et l'étendue des sols dénudés; 2) ne pas mettre les sols dénudés en contact avec des eaux de surface; 3) appliquer les fertilisants et les herbicides loin des eaux de surface; 4) bloquer les liaisons hydrauliques entre les sols dénudés et les eaux de surface; 5) établir des zones tampons boisées autour des cours d'eau; et 6) concevoir des chemins forestiers et des traverses de cours d'eau qui soient stables.

Par contre, certains éléments importants présentent de grandes différences dans ces programmes. Par exemple, les exigences en matière de largeur des bandes riveraines, les critères pour établir ces largeurs et les restrictions en matière d'aménagement à l'intérieur de ces bandes varient considérablement entre les juridictions. Tout comme dans la conception globale des programmes de contrôle et d'atténuation de la pollution diffuse, les différences dans les MPAF en matière de bandes riveraines sont attribuables à la façon dont les provinces et les États appliquent les principes généraux pour tenir compte de leur propre situation.

Plusieurs juridictions ont investi massivement dans le suivi de la mise en œuvre des MPAF et ont utilisé les résultats de ce suivi pour identifier les problèmes et documenter les améliorations à apporter au fil du temps. L'évaluation du pourcentage de mise en œuvre des MPAF dans l'ensemble

des juridictions est difficile en raison des grandes différences trouvées dans les juridictions pour des éléments comme les objectifs et les méthodes de suivi. Dans bon nombre de juridictions, les organismes chargés de contrôler la pollution diffuse hésitent à allouer des ressources déjà limitées dans le suivi de la mise en œuvre des MPAF parce que les activités d'aménagement forestier constituent une source mineure de pollution diffuse comparativement à d'autres sources de pollution diffuse.

MOTS CLÉS

bandes riveraines, chemins, classification des cours d'eau, conformité, élimination des déchets, fertilisants, forêts riveraines, meilleures pratiques d'aménagement, pesticides, pollution diffuse, qualité de l'eau, reboisement, récolte, règles de pratiques forestières, suivi, traverses de cours d'eau

AUTRES PUBLICATIONS DE NCASI DANS CE DOMAINE

The use of watershed-level studies in examining the hydrologic and water quality impacts of forestry practices in Canada: A literature review. (ce document sera publié sous peu).

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1.0 INTRODUCTION

Federal laws in the United States and Canada have established national goals and legal frameworks for controlling point and nonpoint sources of water pollution. In both countries, federal authorities collaborate with state/provincial authorities to achieve national goals.

By law and tradition, states and provinces have leading roles in controlling water quality problems associated with nonpoint sources (NPS) of water pollution. In most jurisdictions, forest management is a minor source of NPS pollution compared to other land uses (Binkley and Brown 1993; Wear and Greis 2002) but can nevertheless cause important impacts on water resources if implemented without control and mitigation measures (Ice and Stednick 2004). States and provinces have therefore developed management guidelines and prescriptions for controlling sources of NPS pollution associated with forest management activities. In this report, we refer to such guidelines and prescriptions as best management practices (BMPs) while recognizing that many states and provinces use other terms.

This report addresses two recurring questions about forestry BMPs for water quality protection in North America. How and why do BMPs vary among jurisdictions? How do states and provinces determine whether BMPs have been implemented? To address these questions, NCASI reviewed BMPs that are recommended or required by 44 U.S. states and 10 Canadian provinces. NCASI also reviewed methods used by states and provinces to assess BMP implementation and summarized results of implementation surveys.

2.0 SOUTHEASTERN STATES

2.1 Introduction

In the years following enactment of the Clean Water Act in 1972, best management practices (BMPs) have been developed and approved as the primary mechanism for controlling NPS pollution from forestry operations in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. In this context, a BMP is "...a practice or combination of practices considered by a State [or authorized Tribe] to be the most effective means (including technological, economic and institutional considerations) of preventing or reducing the amount of pollution by nonpoint sources to a level compatible with water quality goals" (40 CFR 130.2(Q)).

Kentucky has mandated the use of its forestry BMPs through the Kentucky Forest Conservation Act (KFCA, KRS 149.330-355). All other states in the region have enacted non-regulatory BMP programs that are backed up by regulatory authority to stop "bad actors" when they ignore BMPs and cause damage to water resources (NCASI 1994b; TN DOF 2003). Forestry BMPs in some states (e.g., Florida, North Carolina and Virginia) are sometimes called "quasi-regulatory" because these states have defined explicitly the legal implications of non-compliance with certain aspects of BMPs.

This section provides information about southeastern state recommendations or requirements for streamside management zones (SMZs), stream crossings, forest roads and other major BMP elements. It also provides information about approaches used by the southeastern states to assess BMP implementation and compliance.

2.2 BMPs

2.2.1 *Streamside Management Zones*

Streamside managements zones (SMZs) are among the most widely recognized forestry BMPs in the Southeast. Stated simply, SMZs are strips of land adjacent to streams in which management practices that may impact water quality are modified or restricted.

As in other parts of North America, stream classification has an important role in SMZ guidelines in the Southeast. Most states in the region recognize three main classes of streams: perennial streams that flow year-round; intermittent streams that flow several months of the year; and ephemeral streams that flow at the surface occasionally, typically in response to storm events. Perennial and intermittent streams have discernible stream channels. Ephemeral streams often lack distinct stream banks and often do not appear on topographic maps (Meyer and Wallace 2001).

Streams may also be classified by stream order, which involves assigning a number based on a stream's location within a stream network (Stanford 1996). Headwater streams are the uppermost streams in the network and are often classified as zero-order (no defined channel) or first-order (first defined channel). Second-order streams are formed when two first-order stream channels combine; a combination of two second-order streams indicates a third-order stream, and so on. Increasing stream order, therefore, typically reflects an increase in stream size.

BMPs in all southeastern states recommend or require use of SMZs (AL FC 1999; AR FC 2002; FL DOF 2008; GA FC 1999; LA DAF Undated; MS FC 2000; NC DFR 2006; Stringer and Perkins 2001; Turton et al. undated; SC FC 1994; TN DOF 2003; TX FS 2000; VA DOF 2002). Factors that are used separately or in combination to establish appropriate SMZ widths include stream type, stream width, and adjacent upland factors (slope and soil).

Minimum widths of SMZs in the southeastern states are in the range of 30 to 200 ft (9 to 61 m) on each side of the stream (Table 2.1). In some states, minimum SMZ widths are greater for perennial streams than for intermittent streams. In other states, minimum widths are the same for perennial and intermittent streams. Virginia specifies a minimum SMZ width of 50 ft (15 m) for all perennial streams and recommends that a 50 ft minimum is also appropriate for intermittent streams where site conditions indicate that SMZs are required.

Florida, Georgia, Kentucky, North Carolina, South Carolina, Texas and Virginia have special SMZ guidelines for trout streams and for waterbodies connected to municipal water supplies. Minimum widths of SMZs are wider for these waters than for other streams.

Stream width is an important factor in SMZ guidelines for perennial streams in Florida and Louisiana. Minimum SMZ width increases with stream width.

Minimum SMZ width guidelines in several states depend on the slope of the land adjacent to the stream channel. As slope increases, so does the width of the SMZ. In some states, slope affects minimum SMZ width for both perennial and intermittent streams. In other states, slope affects SMZ width for perennial streams only. In North Carolina, Texas and Virginia, slope affects SMZ width for special streams only (i.e., trout streams and waters connected to municipal water supplies). In Kentucky, slope affects SMZ width for warm water streams only.

State BMPs generally include qualitative guidance to increase the width of SMZs on a site-specific basis. For example:

- Alabama recommends that "…in no cases should a SMZ be less than 35 ft (11 m) from a definable stream bank" and that "[SMZ] width should be extended to account for erodibility of soil, steepness of slopes and activities to be performed outside of the SMZ."

- Louisiana BMPs indicate that "determination of SMZ width should be site-specific…" and that forest managers should consider "soil type, slope gradient, vegetation cover, flow volume, and stream classification" when designing SMZs for perennial streams.
- North Carolina, Oklahoma, and Texas BMPs recommend SMZs of at least 50 ft (15 m) on each side of perennial and intermittent streams and that forest managers increase SMZ widths as needed on the basis of site-specific factors such as slope, soil type, and vegetation cover type.

In South Carolina and Florida, SMZs have primary zones and secondary zones. Both states restrict harvesting in primary zones but allow clearcutting of secondary zones. Activities that are prohibited or restricted in both primary zones and secondary zones include soil disturbance, site preparation, fertilization, and construction of roads and logging decks.

In South Carolina, primary zone width remains 40 ft (12 m) regardless of slope for perennial and intermittent warm-water streams, but the secondary zone width increases with increasing slope. For perennial streams in Florida, primary zone width is a function of stream width, while secondary zone width is a function of soil sensitivity class (SSC). SSC is based on soils and slope, and provides a general indication as to the potential for soil erosion and stream sedimentation.

Table 2.1 Minimum SMZ Width Guidelines in Southeastern State BMPs

	Perennial Streams		Intermittent Streams	
	Width	Width (trout/MW[a])	Width	Width (trout/MW)
State	---------- ft (m) ----------		---------- ft (m) ----------	
Alabama	35 (10.7)		35 (10.7)	
Arkansas				
Slope (<7%)	35 (10.7)		35 (10.7)	
Slope (7-20%)	50 (15.2)		50 (15.2)	
Slope (>20%)	80 (24.4)		80 (24.4)	
Florida				
Stream width <20ft (6.1m)	35 (10.7)	200 (61)	Stringer + 35 (10.7)	200 (61)
Stream width 20–40ft (6.1-12.2m)	75 (22.9)	200 (61)	Stringer + 35 (10.7)	200 (61)
Stream width >40 ft (12.2m)	200 (61.0)	200 (61)	Stringer + 35 (10.7)	200 (61)
Georgia				
Slope (<20%)	40 (12.2)	100 (30.5)	20 (6.1)	
Slope (21-40%)	70 (21.3)	100 (30.5)	35 (10.7)	
Slope (>40%)	100 (30.5)	100 (30.5)	50 (15.2)	
Kentucky				
Warm water streams (<15% slope)	25 (7.6)		25/5/5	
Warm water streams (>15% slope)	55 (16.8)		25/5/5	
Cold water streams (trout)		60 (18.3)	25/5/5	
Louisiana				
Stream width <20 ft (6.1m)	50 (15.2)		35 (10.7)	
Stream width >20ft (6.1m)	100 (30.5)		35 (10.7)	
Mississippi				
Slope (0-5%)	30 (9)		30 (9)	
Slope (6-20%)	40 (12)		30 (9)	
Slope (21-40%)	50 (15)		30 (9)	
Slope (>40%)	60 (18)		30 (9)	
North Carolina				
Slope (<5%)	50 (15)		50 (15)	
Slope (6-10%)	50 (15)	66 (20)	50 (15)	
Slope (11-20%)	50 (15)	75 (23)	50 (15)	
Slope (21-45%)	50 (15)	100 (31)	50 (15)	
Slope (>46%)	50 (15)	125 (38)	50 (15)	

(Continued on next page. See note at end of table.)

Table 2.1 Continued

State	Perennial Streams		Intermittent Streams	
	Width	Width (trout/MW[1])	Width	Width (trout/MW)
	---------- ft (m) ----------		---------- ft (m) ----------	
Oklahoma	50 (15)		50 (15)	
South Carolina				
Slope (<5%)	1° SMZ: 40 (12) 2° SMZ: na	1° SMZ: 40 (12) 2° SMZ: na	1° SMZ: 40 (12) 2° SMZ: na	1° SMZ: 40 (12) 2° SMZ: na
Slope (5-20%)	1° SMZ: 40 (12) 2° SMZ: 40 (12)	1° SMZ: 80 (24) 2° SMZ: 80 (24)	1° SMZ: 40 (12) 2° SMZ: 40 (12)	1° SMZ: 80 (24) 2° SMZ: 80 (24)
Slope (21-40%)	1° SMZ: 40 (12) 2° SMZ: 80 (24)	1° SMZ: 80 (24) 2° SMZ: 80 (24)	1° SMZ: 40 (12) 2° SMZ: 80 (24)	1° SMZ: 80 (24) 2° SMZ: 80 (24)
Slope (>40%)	1° SMZ: 40 (12) 2° SMZ: 120 (37)	1° SMZ: 80 (24) 2° SMZ: 120 (37)	1° SMZ: 40 (12) 2° SMZ: 120 (37)	1° SMZ: 80 (24) 2° SMZ: 120 (37)
Tennessee				
Slope (0%)	25 (8)		25 (8)	
Slope (10%)	45 (14)		45 (14)	
Slope (20%)	65 (20)		65 (20)	
Slope (30%)	85 (26)		85 (26)	
Slope (40%)	105 (32)		105 (32)	
Slope (50%)	125 (38)		125 (38)	
Slope (60%)	145 (44)		145 (44)	
Texas				
Slope (0-10%)	50 (15)	100 (30)	50 (15)	100 (30)
Slope (11-20%)	50 (15)	150 (46)	50 (15)	150 (46)
Slope (21-45%)	50 (15)	150 (46)	50 (15)	150 (46)
Slope (+45%)	50 (15)	200 (61)	50 (15)	200 (61)
Virginia				
Slope (0-10%)	50 (15)	60 (18)		
Slope (11-20%)	50 (15)	70 (21)		
Slope (21-45%)	50 (15)	100 (31)		
Slope (>45%)	50 (15)	120 (37)		

[1] Recommended SMZ widths for trout streams and waterbodies that are connected with municipal water supplies.

In Florida, primary zone guidelines apply to perennial waterbodies only. Secondary zone guidelines apply to perennial and intermittent waterbodies (streams and lakes) including any stream with "a defined channel." The secondary zone guidelines require leaving a "stringer" of trees on or near the banks of intermittent waterbodies. The stringer provides visual evidence as to the location of intermittent waterbodies and ensures that heavy equipment operation in and around these waterbodies is minimal and thus reduces the threat of sedimentation and bank damage.

BMPs in the Southeast generally allow selective harvesting of SMZs and recommend retaining 25 to 50 ft^2 (2.3 to 4.7 m^2) of basal area per acre or 25-75% crown cover in SMZs for perennial and intermittent streams. As previously mentioned, both Florida and South Carolina allow clearcutting in secondary SMZs but not in primary SMZs. In Alabama, permanent residual tree cover is not required for intermittent and ephemeral streams as long as other vegetation and organic debris are left to

protect the forest floor during regeneration. Site preparation activities in SMZs are generally discouraged or prohibited.

BMP manuals for all states recommend use of harvesting systems and techniques that limit disturbance to soils, the forest floor, and residual vegetation in SMZs. For example, Kentucky's BMPs recommend maintaining a zone of undisturbed ground between disturbed ground and intermittent streams. This approach is known as the "25/5/5 rule." The zone of undisturbed ground should be "25 ft (8 m) of distance on flat ground, which increases 5 ft (2 m) for every 5% increase in slope" (Stringer and Perkins 2001).

Forestry BMPs in many southeastern states include general guidelines to limit disturbance to surface soils and vegetation in the vicinity of ephemeral waterbodies. For example:

- Alabama, Arkansas and South Carolina recommend limiting disturbance to understory vegetation and forest floors in the vicinity of ephemeral areas (e.g., by restricting use of equipment near ephemeral areas during harvesting and site preparation).
- Georgia recommends applying BMPs for intermittent streams to ephemeral areas where "…ephemeral areas transition into well-defined intermittent or perennial streams."
- Mississippi recommends that managers avoid soil rutting, limit the number of crossings, and avoid blocking the flow of water in 'drains' (i.e., ephemeral catchments).
- North Carolina recommends use of directional felling techniques when harvesting near ephemeral areas so that skidders can pick up logs without disturbing soils near ephemeral channels.
- Tennessee recommends that care be taken when operating near ephemeral streams to prevent sediment movement to larger, downstream waterbodies.
- Virginia recommends establishment of SMZs for all ephemeral streams that "exhibit evidence of scouring of the stream channel."

Some states in the Southeast have special guidelines for certain classes of waterbodies. Arkansas recommends "less intensive silvicultural practices" near waterbodies that have been listed as impaired by the Arkansas Pollution Control and Ecology Commission or designated as outstanding resource waters (AR FC 2002). Virginia has forestry BMP recommendations for waterbodies that supply drinking water to municipalities (VA DOF 2002). Florida, Georgia, Kentucky and Louisiana have guidelines for buffer zones around lakes, sinkholes, and certain high-value waterbodies (Table 2.2).

Table 2.2 Recommended Minimum Buffer Widths for Lakes, Sinkholes, and Special Waters Used by Some Southeastern States

State	Perennial	Intermittent
	---------- ft (m) ----------	
Florida[1]		
Lakes	35 (11)	35 (11)
Sinkholes	35 (11)	35 (11)
OFW, ONRW, Class I	200 (61)	200 (61)
Georgia		
Sinkholes	Utilize BMPs for Perennial Streams	
River Corridor Act	100 (30)	
Kentucky [2]		
Sinkholes		
Slope (5%)	30 (9)	
Slope (10%)	35 (11)	
Slope (20%)	45 (14)	
Slope (30%)	55 (17)	
Slope (>40%)	65 (20)	
Louisiana[3]		
Natural & Scenic Rivers	100 (30)	

[1]Perennial lakes and sinkholes are those larger than 2 ac (0.8 ha) in size and maintain almost permanent surface waters. OFW = Outstanding Florida Waters, ONRW = Outstanding National Resources Waters, Class I = waters designated for use as drinking water supplies.
[2]Minimum distances from the silviculturally disturbed area and the point of lowest elevation or open swallet of a sinkhole.
[3]Louisiana recommends only selective harvest near designated Natural and Scenic Rivers.

2.2.2 *Stream Crossing BMPs*

Stream crossings can be important sources of sediment entering streams (Taylor et al. 1999). Therefore, each southeastern state BMP manual suggests planning road systems and harvest operations to minimize the number of crossings. Where crossings are necessary, they should be able to accommodate logging traffic in an effective and environmentally sensitive manner. Proper construction and maintenance of crossings will reduce soil erosion and sedimentation with the added benefits of increasing harvest operation efficiency and lowering equipment maintenance costs.

It is important to note that construction of some stream crossings requires a permit from a state agency or the U.S. Army Corps of Engineers. Many BMP manuals recommend that managers consult with appropriate state and federal agencies to ensure that any planned activities are in compliance with applicable regulations.

State BMPs for all types of stream crossings emphasize the importance of controlling water and sediment movement from approach sections, i.e., sections of roads and skid trails that are connected and adjacent to crossing structures. Recommended practices include applying gravel on surfaces of approach sections and installing structures that divert runoff water into vegetated areas before it reaches the crossing.

BMPs in southeastern states address four types of stream crossings: fords, low water crossings, culverts, and bridges (Table 2.3). A ford is the most basic stream crossing type, consisting only of approach sections and a hard stream bottom. Fords have a natural appearance and require little maintenance. BMPs generally recommend the use of a ford only where the streambed is stable, stream banks are low, and the stream is shallow. Several states recommend that fords only be used for haul roads and not for skid trails.

Table 2.3 Types of Stream Crossings Addressed in BMPs in Southeastern States

	Stream Crossing Types[1]			
	Fords	Low Water Crossings	Culverts	Bridges
Alabama	+		+	+
Arkansas	+		+	+
Florida	+	+	+	
Georgia	+		+	+
Kentucky	+	+	+	+
Louisiana	+		+	+
Mississippi	+		+	+
North Carolina	+		+	+
Oklahoma	+	+	+	+
South Carolina	+		+	+
Tennessee	+		+	+
Texas	+	+	+	+
Virginia	+		+	+

[1] It is important to note that some states group fords and low water crossings into a single category.

The bottom of a ford must have a high load-bearing strength. Stream bottoms consisting of fine-textured materials (i.e., clays, silts, muck) may have insufficient load-bearing strength unless hardened with gravel or other materials. Hardening materials must not substantially alter stream hydraulics and should be removed from the stream when harvesting operations are concluded.

A low water crossing is similar to a ford but generally includes a hard bottom structure consisting of gravel or concrete. Some states differentiate low water crossings from fords, while others use these terms interchangeably.

Fords and low water crossings should be designed to pass low flows and withstand damage to bottom structures and approach sections during high flows. An advantage of fords and low water crossings relative to culverts and bridges is that they often require less fill and soil disturbance during construction.

In situations where fords are not feasible, culverts are often used in streams with small watersheds (Taylor et al. 1999). Culverts can be either temporary or permanent structures and are most commonly made from plastic or corrugated metal pipe.

Culverts must be of sufficient size to allow passage of water during high flows following storm events. According to geomorphic theory, the larger the cross section area of the active stream channel, the greater the channel-forming discharge, and the larger diameter culvert pipe that is required (Rosgen 1996).

Methods used to determine the minimum culvert pipe diameter vary among the states but are generally based on one of five approaches: drainage area, drainage area within a physiographic region, soil types and drainage area, stream cross section area, or stream size.

- Arkansas, Kentucky, Mississippi and Oklahoma use drainage area to determine culvert pipe diameters regardless of physiographic region within the state (AR FC 2002; Stringer and Perkins 2001; MS FC 2000; Turton et al. undated). BMPs in these states do not differentiate between permanent or temporary culverts. See Table 2.4.
- Alabama, Georgia, and South Carolina adjust their recommended culvert diameters based on physiographic region. Georgia and South Carolina provide additional BMP recommendations for culvert diameter requirements based on whether or not the structure is permanent or temporary (SC FC 1994; GA FC 1999). See Table 2.5.
- Tennessee and Virginia adjust their culvert recommendations based on broadly defined regions (VA DOF 2002; TN DOF 2003). See Table 2.6.
- Louisiana and Texas base minimum culvert diameter requirements entirely, or in part, on the National Resource Conservation Service (NRCS) TR-55 method which incorporates soil type, drainage area, and percent slope (LA DAF undated; TX FS 2000). See Table 2.7.
- Florida's BMP manual (FL DOF 2008) provides managers with two options for determining culvert size. One method is based on stream size and site conditions. The other is based on watershed size and involves estimation of the minimum cross section area of culvert pipe needed to pass flows associated with 2.5 inches of rainfall per hour. The second Florida method is similar to the culvert sizing method recommended in North Carolina's BMP Manual (NC DFR 2006). See Table 2.8.

Table 2.4 Minimum Culvert Sizes in Arkansas, Kentucky, Mississippi Based on Drainage Area

	Area Drained -- ac (ha) --	Pipe Diameter -- in (cm) --
Arkansas		
	5 (2)	18 (46)
	10 (4)	24 (61)
	20 (8)	27 (69)
	30 (12)	30 (76)
	40 (16)	36 (91)
	50 (20)	36 (91)
	75 (30)	42 (107)
	100 (41)	48 (122)
	150 (61)	54 (137)
Kentucky		
	2 (1)	12 (31)
	4 (2)	15 (38)
	7 (3)	18 (46)
	12 (5)	21 (53)
	16 (7)	24 (61)
	27 (11)	30 (76)
	47 (19)	36 (91)
	64 (26)	42 (107)
	90 (36)	48 (122)
	120 (49)	54 (137)
	160 (65)	60 (152)
	205 (83)	66 (168)
	250 (101)	72 (183)
	350 (142)	78 (198)
Mississippi		
	<50 (20)	18 (46)
	100 (41)	24 (61)
	200 (81)	36 (91)
	500 (202)	60 (152)
Oklahoma	2 (1)	12 (31)
	4 (2)	15 (38)
	7 (3)	18 (46)
	12 (5)	21 (53)
	16 (7)	24 (61)
	27 (11)	30 (76)
	47 (19)	36 (91)
	64 (26)	42 (107)
	90 (36)	48 (122)
	120 (49)	54 (137)
	160 (65)	60 (152)
	205 (83)	66 (168)
	250 (101)	72 (183)
	350 (142)	78 (198)

Table 2.5 Minimum Culvert Sizes in Alabama, Georgia, and South Carolina for Four Physiographic Regions Based on Drainage Area

	Drainage Area - ac (ha) -	Physiographic Region: Coastal Plain (Lower)	Coastal Plain (Upper)	Piedmont	Mountains
		Minimum Pipe Diameter in (cm)			
Alabama					
	10 (4)	12 (31)	12 (31)	12 (31)	18 (46)
	50 (20)	30 (76)	18 (46)	30 (76)	36 (91)
	100 (41)	48 (122)	30 (76)	42 (107)	48 (122)
	200 (81)	60 (152)	42 (107)	54 (137)	48x2 (122x2)
Georgia					
Permanent	10 (4)	24 (61)	15 (38)	30 (76)	24 (61)
	50 (20)	36 (91)	18 (46)	48 (122)	48 (122)
	100 (41)	48 (122)	24 (61)	54 (137)	60 (152)
	200 (81)	60 (152)	36 (91)	72 (183)	72 (183)
	300 (121)	48x2 (122x2)	54 (137)	84 (213)	78 (198)
Temporary	10 (4.0)	15 (38)	15 (38)	18 (46)	15 (38)
	50 (20)	18 (46)	15 (38)	30 (76)	24 (61)
	100 (41)	24 (61)	18 (46)	36 (91)	30 (76)
	200 (81)	30 (76)	24 (61)	42 (107)	36 (91)
	300 (121)	48 (122)	30 (76)	48 (122)	42 (107)
South Carolina					
Permanent	10 (4)	24 (61)	12 (31)	30 (76)	24 (61)
	50 (20)	36 (91)	18 (46)	48 (123)	48 (123)
	100 (41)	48 (122)	24 (61)	54 (137)	60 (152)
	200 (81)	60 (152)	36 (91)	72 (183)	72 (183)
Temporary	10 (4)	12 (31)	12 (31)	18 (46)	12 (31)
	50 (20)	18 (46)	12 (31)	30 (76)	24 (61)
	100 (41)	24 (61)	18 (46)	36 (91)	30 (76)
	200 (81)	30 (76)	24 (61)	42 (107)	36 (91)

Table 2.6 Minimum Culvert Sizes in Tennessee and Virginia for Three Broadly Defined Physiographic Regions Based on Drainage Area

State	Pipe Diameter -- in (cm) --	Physiographic Area: Flat Country / Coastal	Rolling Country / Piedmont	Mountains
		area drained ac (ha)		
Tennessee				
	15 (38)	11 (5)	6 (2)	1 (0.4)
	18 (46)	18 (7)	9 (4)	2 (0.8)
	21 (53)	28 (11)	14 (6)	3 (1)
	24 (61)	39 (16)	20 (8)	5 (2)
	30 (76)	71 (29)	36 (15)	8 (3)
	36 (91)	115 (47)	59 (24)	14 (6)
	42 (107)	175 (71)	89 (36)	20 (8)
	48 (122)	250 (101)	125 (51)	29 (12)
	54 (137)	345 (140)	175 (71)	40 (16)
	60 (152)	455 (184)	230 (93)	55 (22)
	66 (168)	585 (237)	295 (119)	70 (28)
	72 (183)	735 (298)	375 (152)	85 (34)
Virginia				
Permanent	15 (38)	<8 (3)	<7 (3)	<4 (2)
	18 (46)	8-12 (3-5)	7-10 (3-4)	4-7 (2-3)
	24 (61)	12-25 (5-10)	10-20 (4-8)	7-12 (3-5)
	30 (76)	25-35 (10-14)	20-30 (8-12)	12-15 (5-6)
	36 (36)	35-70 (14-28)	30-50 (12-20)	15-25 (6-10)
	42 (107)	70-100 (28-41)	50-75 (20-30)	25-35 (10-14)
	48 (122)	100-150 (41-61)	75-110 (30-45)	35-55 (14-22)
	54 (137)	150-240 (61-97)	110-170 (45-69)	55-75 (22-30)
	60 (152)	240-360 (97-146)	170-240 (69-97)	75-100 (30-41)
	66 (168)	360-550 (146-223)	240-350 (97-142)	100-135 (41-55)
	72 (183)	-	-	135-200 (55-81)
Temporary	15 (38)	<65 (26)	<35 (14)	<15 (6)
	18 (46)	65-90 (26-36)	35-65 (14-26)	15-25 (6-10)
	24 (61)	90-200 (36-81)	65-110 (26-45)	25-40 (10-16)
	30 (76)	200-400 (81-162)	110-210 (45-85)	40-60 (16-24)
	36 (91)	400-700 (162-283)	210-420 (85-170)	60-135 (24-55)
	42 (107)	-	-	135-230 (55-93)

Table 2.7 Minimum Culvert Sizes in Louisiana and Texas Based on Soil Type, Drainage Area and Slope

State	Soil Type	Area Drained -- ac (ha) --	Slope <5% Minimum Pipe Diameter in (cm)	Slope 5 – 15% Minimum Pipe Diameter in (cm)	Slope >15% Minimum Pipe Diameter in (cm)
Louisiana					
	Light (sands)	<50 (20)	18 (46)	18 (46)	18 (46)
		75 (30)	18 (46)	21 (53)	21 (53)
		100 (41)	21 (53)	21 (53)	24 (61)
		150 (61)	21 (53)	24 (61)	24 (61)
		200 (81)	24 (61)	30 (76)	30 (76)
		250 (101)	27 (69)	30 (76)	30 (76)
		300 (121)	30 (76)	36 (91)	36 (91)
		350 (142)	30 (76)	36 (91)	42 (107)
		400 (162)	36 (91)	36 (91)	42 (107)
	Medium (loams)	5 (2)	18 (46)	18 (46)	21 (53)
		10 (4)	21 (53)	24 (61)	27 (69)
		20 (8)	24 (61)	27 (69)	36 (91)
		30 (12)	27 (69)	30 (76)	36 (91)
		40 (16)	27 (69)	36 (91)	42 (107)
		50 (20)	30 (76)	36 (91)	48 (122)
		75 (30)	36 (91)	42 (107)	-
		100 (41)	36 (91)	48 (122)	-
		150 (61)	42 (107)	-	-
		200 (81)	48 (122)	-	-
	Heavy (clays)	5 (2)	21 (53)	21 (53)	24 (61)
		10 (4)	27 (69)	27 (69)	36 (91)
		20 (8)	36 (91)	36 (91)	42 (107)
		30 (12)	36 (91)	42 (107)	48 (122)
		40 (16)	42 (107)	48 (122)	-
		50 (20)	48 (122)	48 (122)	-
Texas					
	Light (sands)	<50 (20)	18 (46)	18 (46)	18 (46)
		75 (30)	18 (46)	21 (53)	21 (53)
		100 (41)	21 (53)	21 (53)	24 (61)
		150 (61)	21 (53)	24 (61)	24 (61)
		200 (81)	24 (61)	30 (76)	30 (76)
		250 (101)	27 (69)	30 (76)	30 (76)
		300 (121)	30 (76)	36 (91)	36 (91)
		350 (142)	30 (76)	36 (91)	42 (107)
		400 (162)	36 (91)	36 (91)	42 (107)
	Medium	5 (2)	18 (46)	18 (46)	21 (53)
		10 (4)	21 (53)	24 (61)	27 (69)
		20 (8)	24 (61)	27 (69)	36 (91)
		30 (12)	27 (69)	30 (76)	36 (91)

(Continued on next page.)

Table 2.7 Continued

State	Soil Type	Area Drained -- ac (ha) --	Slope <5% Minimum Pipe Diameter in (cm)	Slope 5 – 15% Minimum Pipe Diameter in (cm)	Slope >15% Minimum Pipe Diameter in (cm)
Texas		40 (16)	27 (69)	36 (91)	42 (107)
		50 (20)	30 (76)	36 (91)	48 (122)
		75 (30)	36 (91)	42 (107)	-
		100 (41)	36 (91)	48 (122)	-
		150 (61)	42 (107)	-	-
		200 (81)	48 (122)	-	-
	Heavy	5 (2)	21 (53)	21 (53)	24 (61)
	(clays)	10 (4)	27 (69)	27 (69)	36 (91)
		20 (8)	36 (91)	36 (91)	42 (107)
		30 (12)	36 (91)	42 (107)	48 (123)
		40 (16)	42 (107)	48 (123)	-
		50 (20)	48 (123)	48 (123)	-

Table 2.8 Minimum Culvert Pipe Diameters in Florida and North Carolina Based on Estimates of Cross Section Area of Culvert Needed to Pass Flows Associated with 2.5 Inches of Rainfall Per Hour

Minimum Cross Section Area -- ft^2 (m^2) --	Pipe Diameter -- in (cm) --
0.55 (0.05)	10 (25)
0.79 (0.07)	12 (31)
1.25 (0.12)	15 (38)
1.80 (0.17)	18 (46)
3.10 (0.29)	24 (61)
4.90 (0.46)	30 (76)
7.10 (0.66)	36 (91)
9.60 (0.89)	42 (107)
12.60 (1.17)	48 (122)
15.90 (1.48)	54 (137)
19.60 (1.82)	60 (152)
23.80 (2.21)	66 (168)
28.30 (2.63)	72 (183)
33.20 (3.08)	78 (198)
38.50 (3.58)	84 (213)
44.20 (4.11)	90 (229)

In addition to culvert sizing guidelines, state BMPs suggest installation and maintenance techniques for stabilizing the culvert in the stream channel and minimizing effects on stream flow. States typically recommend use of rock or some other material to minimize stream bank erosion as well as placing a culvert on the streambed and not burying the pipe in the stream channel. All states recommend frequent inspection of culverts to identify maintenance needs. If culverts are undersized or become clogged, stream flow through the culvert will be impeded and scouring of the streambed and streambank around the culvert will increase.

Properly constructed bridges, whether permanent or temporary, have the least potential to restrict stream flow. However, construction and maintenance of permanent bridges can be expensive and labor-intensive. If not installed properly, bridge abutments or piers can cause changes in the stream channel and erosion of the stream bank. Regulations affecting bridge construction vary among states. Federal regulations may apply.

In general, use of bridges is recommended to cross streams draining >300 ac (121 ha) because bridges are often more effective stream crossings during high flows or following storm events (Brinker and Taylor 1997). State BMPs for permanent and temporary bridges include locating the bridge at narrow stream points with firm soils; protecting bridge approaches by using road water control structures or water diversion techniques; protecting the stream channel and bank from erosion during installation and removal; and providing abutments, head walls, and wing walls as necessary to stabilize the structure.

2.2.3 *BMPs for Forest Roads and Skid Trails*

Forest roads and skid trails are essential parts of any forest management operation and may also provide access for recreational activities on forestland. Properly planned, constructed, and maintained forest roads and trails allow for efficient and safe forest management and result in minimal water quality impacts. Poorly located and inadequately constructed roads and trails that do not receive necessary maintenance can deliver substantial amounts of sediment to streams. This is especially true for approaches to stream crossings.

BMPs in all southeastern states emphasize the importance of pre-construction planning and design of road and trail systems. Road system designers are advised to examine soils and topographic maps and aerial photographs, and conduct site inspections so that problem areas (e.g., steep, erosive slopes, streams, etc.) can be avoided or planned for.

State BMP manuals recommend that managers initiate road construction during dry periods and limit the number of stream crossings. It is typically recommended that roads and trails be located outside of SMZs on gentle to moderate slopes. Another common recommendation is to limit the width of access roads to only that width necessary to safely handle traffic and equipment. If roads or trials must be constructed through an SMZ, states generally recommend additional BMP measures to prevent erosion and water quality degradation. For example, stream crossings should be made at locations with gently sloping terrain and at right angles to stream flow wherever possible. It is often recommended that surfaces of approaches to stream crossings be stabilized with gravel or grasses to limit erosion and sediment movement into streams.

Road drainage and maintenance can have important effects on soil erosion and sediment delivery to streams (Table 2.9). All states suggest that roads should follow the contour of the land and have grades less than 10% where possible. In steeper terrain, BMPs recommend that roads be out-sloped so that road surfaces will drain water off quickly and reduce erosion. Insloped roads are typically recommended when constructing roads with gradients greater than 15%, approaching sharp turns, when constructing roads on side slopes, and/or when clayey soils are present. Cross drain culverts should be installed where necessary to ensure proper drainage from inside ditches along insloped

roads. Culverts of this type move water under road surfaces and away from the road prism. Cross drains should be designed to disperse water into vegetated areas where it can percolate into the soil.

Recommended techniques for diverting water away from roads and skid trails in the Southeast include water bars, turnouts, and broad-based dips (Table 2.9). For these water diversion methods to be effective, the slope of the road must be considered during their installation. State BMPs generally recommend that spacing between diversion structures be reduced as the road grade increases (Table 2.10).

Water bars create pronounced humps in road surfaces and are generally used to permanently control runoff on roads and trails that will not be subject to repeated vehicle traffic. State BMP manuals recommend that water bars be installed at 30 to 45° angles to the road surface.

On crown and ditched access roads, water turnouts are recommended to reduce the volume and velocity of water flow within the road drainage ditch. All states recommend that water turnouts be installed at 30 to 45° angles to the road surface and that turnouts should never divert water directly into waterbodies.

State forestry BMP manuals consistently recommend the use of broad-base dips to divert water from permanent roads (Table 2.9). The southeastern states generally recommend that the use of this structure be limited to roads with grades <10%. Broad-based dips are often less expensive to construct than cross-drain culverts. In addition, they remain effective at removing water from the road surface without interfering with repeated use by trucks and skidder traffic, but they can slow traffic speed.

Table 2.9 BMPs for Controlling Runoff from Permanent and Temporary Forest Roads in Southeastern States

	Follow Contour	Out-Sloped Roads	Insloped Roads	Cross Drain Culverts	Open-Top Culverts	Water Bars	Broad-Based Dips	Water Turnouts
Alabama	+	+	+	+		+	+	+
Arkansas	+	+	+	+		+	+	+
Florida	+	+	+	+		+	+	+
Georgia	+	+	+	+		+	+	+
Kentucky	+	+	+	+	+	+	+	+
Louisiana	+	+	+			+	+	+
Mississippi	+	+				+	+	+
North Carolina	+	+	+	+		+	+	+
Oklahoma	+	+	+	+	+	+	+	+
South Carolina	+	+		+		+	+	+
Tennessee	+	+	+	+		+	+	+
Texas	+	+	+	+		+	+	+
Virginia	+	+	+	+	+	+	+	+

Table 2.10 Recommended Spacing between Water Diversion Structures on Forest Roads and Skid Trails in Southeastern States

	Water Bars			Broad-Based Dips			Turnouts		
	Slope	Spacing		Slope	Spacing		Slope	Spacing	
State	(%)	(ft)	(m)	(%)	(ft)	(m)	(%)	(ft)	(m)
Alabama									
	3	200	61.0	3	235	71.6	3	235	71.6
	5	135	41.2	5	180	54.9	5	180	54.9
	10	80	24.4	10	140	42.7	10	140	42.7
	15	60	18.3	15	125	38.1	15	125	38.1
	20	45	13.7						
	30	35	10.7						
	40	30	9.1						
Arkansas									
	2	250	76.2	2	300	91.4	2 – 5	200	61.0
	5	135	41.2	4	200	61.0	5 – 10	100	30.5
	10	80	24.4	6	165	50.3	>10	75	22.9
	15	60	18.3	8	150	45.7			
	20	45	13.7	10	140	42.7			
	30	35	10.7						
Florida[1]									
	SSC1	250	76.2	SSC1	None	None	SSC1	200	61.0
	SSC2	135	41.2	SSC2	180	54.9	SSC2	120	36.6
	SSC3	80	24.4	SSC3	140	42.7	SSC3	100	30.5
	SSC4	60	18.3	SSC4	125	38.1	SSC4	75	22.9
	SSC5	45	13.7	SSC5	120	36.6	SSC5	50	15.2
	SSC6	30	9.1	SSC6	110	33.5	SSC6	40	12.2

(Continued on next page. See notes at end of table.)

Table 2.10 Continued

State	Water Bars			Broad-Based Dips			Turnouts		
	Slope	Spacing		Slope	Spacing		Slope	Spacing	
	(%)	(ft)	(m)	(%)	(ft)	(m)	(%)	(ft)	(m)
Georgia									
	2	245	74.7	3	235	71.6	3	235	71.6
	5	125	38.1	4	200	61.0	4	200	61.0
	10	80	24.4	5	180	54.9	5	180	54.9
	15	60	18.3	6	165	50.3	6	165	50.3
	20	50	15.2	7	155	47.2	7	155	47.2
	25	40	12.2	8	150	45.7	8	150	45.7
				9	145	44.2	9	145	44.2
				10	140	42.7	10	140	42.7
				12	135	41.2	12	135	41.2
Kentucky									
	1	400	122	2 – 5	500-300	152-91	2 – 5	500-300	152-91
	2	245	74.7	6 – 10	300-200	91-61	6 – 10	300-200	91-61
	5	125	38.1	11 – 15	200-100	31-61	11 – 15	200-100	31-61
	10	78	23.8	16 – 18	100	30.5	16 – 18	100	30.5
	15	58	17.7						
	20	47	14.3						
	25	40	12.2						
	30	35	10.7						
	35	32	9.8						
	40	29	8.8						

(Continued on next page. See notes at end of table.)

Table 2.10 Continued

State	Water Bars			Broad-Based Dips			Turnouts		
	Slope	Spacing		Slope	Spacing		Slope	Spacing	
	(%)	(ft)	(m)	(%)	(ft)	(m)	(%)	(ft)	(m)
Louisiana	2	250	76.2	2	300	91.4	2	250	76.2
	3	220	67.1	3	233	71.0	3	220	67.1
	4	190	57.9	4	200	61.0	4	190	57.9
	5	160	48.8	5	180	54.9	5	160	48.8
	6	144	43.9	6	166	50.6	6	144	43.9
	7	128	39.0	7	157	47.9	7	128	39.0
	8	112	34.1	8	150	45.7	8	112	34.1
	9	96	29.3				9	96	29.3
	10	80	24.4				10	80	24.4
	11	60	18.3				11	60	18.3
Mississippi[2]									
	2	250	76.2				2 – 5	200	61.0
	5	135	41.2				6 – 9	100	30.5
	10	80	24.4				>10	75	22.9
	15	60	18.3						
	20	45	13.7						
	25	40	12.2						
	30	35	10.7						
	40	30	9.1						
North Carolina[3]									
	5	135	41.2	4	200		61.0		
	10	80	24.4	5	180		54.9		
	15	60	18.3	6	165		50.3		
	20	45	13.7	7	155		47.2		
	30	35	10.7	8	150		45.7		
				9	145		44.2		
				10	140		42.7		
				12	135		41.2		

(Continued on next page. See notes at end of table.)

Table 2.10 Continued

State	Water Bars			Broad-Based Dips			Turnouts		
	Slope	Spacing		Slope	Spacing		Slope	Spacing	
	(%)	(ft)	(m)	(%)	(ft)	(m)	(%)	(ft)	(m)
Oklahoma									
	2	250	76.2	2 – 4	300-200	91-61	2 – 5	500-300	152-91
	5	135	41.2	5 – 7	180-160	55-49	6 – 10	300-200	91-61
	10	80	24.4	8 – 10	150-140	46-43	11 – 15	200-100	31-61
	15	60	18.3				16 – 18	100	30.5
	20	45	13.7						
	25	40	12.2						
	30	35	10.7						
	40	30	9.1						
South Carolina									
	2	245	74.7	2	300	91.4	2	245	74.7
	5	125	38.1	5	180	54.9	5	125	38.1
	10	80	24.4	10	140	42.7	10	80	24.4
	15	60	18.3	15	125	38.1	15	60	18.3
	20	50	15.2	20	120	36.6	20	50	15.2
	25	40	12.2	25	115	35.1	25	40	12.2
Tennessee[4]									
	2	250	76.2	2	300	91.4			
	5	135	41.2	3	233	71.0			
	10	80	24.4	4	200	61.0			
	15	60	18.3	5	180	54.9			
	20	45	13.7	6	167	50.9			
	25	40	12.2	7	157	47.9			
	30	35	10.7	8	150	45.7			
	40	30	9.1	9	144	43.9			
				10	140	42.7			
				11	136	41.5			
				12	133	40.5			

(Continued on next page. See notes at end of table.)

Table 2.10 Continued

State	Water Bars			Broad-Based Dips			Turnouts		
	Slope	Spacing		Slope	Spacing		Slope	Spacing	
	(%)	(ft)	(m)	(%)	(ft)	(m)	(%)	(ft)	(m)
Texas									
	2	250	76.2	2	300	91.4	2 – 5	200	61.0
	5	135	41.2	4	200	61.0	5 – 10	100	30.5
	10	80	24.4	6	165	50.3	>10	75	22.9
	15	60	18.3	8	150	45.7			
	20	45	13.7	10	140	42.7			
	30	35	10.7	12	130	39.6			
Virginia[5]									
	2	250	76.2	2	300	91.4			
	5	135	41.2	3	235	71.6			
	10	80	24.4	4	200	61.0			
	15	60	18.3	5	180	54.9			
	20	45	13.7	6	165	50.3			
	30	35	10.7	7	155	47.2			
				8	150	45.7			
				9	145	44.2			
				10	140	42.7			
				12	135	41.2			

[1]Florida BMPs designate prescriptions based on Site Sensitivity Classes (SSCs) that are based on soil properties and slope. SSCs are used to indicate the general potential for erosion and sedimentation.
[2]Mississippi BMPs use the term "shallow water bars" when referring to structures similar to broad-based dips. Mississippi BMPs use the term "deep water bars" when referring to structures called "water bars" in other states.
[3]North Carolina BMPs do not specify recommended distances for water turnout placement. Instead turnouts should be installed, "…as needed but frequent enough to provide good drainage and maximum roadbed drying…"
[4]Tennessee BMPs do not specify recommended distances for water turnout placement. The manual does recommend that these water control devices should "… route water into undisturbed areas allowing filtration before entering water bodies."
[5]Virginia BMPs recommend that diversion ditches be installed so as to avoid "…carrying water long distances in roadside ditches."

2.2.4 *BMPs for Fertilizers and Pesticides*

Forest fertilization is an important silvicultural practice that increases tree survival and growth. When conducted properly, forest fertilization poses little threat to stream water quality (NCASI 2001a).

Most of the southeastern states address forest fertilization in their forestry BMP manuals (Table 2.11). An important theme is the need for handling and application procedures that prevent spills and direct application of fertilizer materials into waterbodies. Several states suggest that managers should account for site and weather conditions (e.g., soil type, slope, air temperature, precipitation, wind speed and direction) to minimize potential for fertilizer movement to streams via drift or runoff. Application of fertilizers to SMZs is generally not recommended. SMZs adjacent to application sites should be contiguous to reduce potential for fertilizer nutrients to reach streams via drift or in runoff (Gilliam 1994).

Florida has established fertilizer application limits for elemental nitrogen and phosphorus (FL DOF 2008) (Table 2.11). No more than 1,000 lbs/ac of nitrogen and 250 lbs/ac of phosphorus may be applied during a 20-year period. During any three-year period of a stand rotation, fertilization with nitrogen and phosphorus may not exceed 250 and 80 lbs/ac, respectively. No more than 80 lbs/ac of nitrogen may be applied during the initial two years of stand establishment. Several other states provide qualitative guidance that fertilizer prescriptions should be designed to achieve silvicultural objectives without negatively impacting water quality.

Use of herbicides and other pesticides in the United States is regulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and state pesticide laws. State forestry BMPs typically note that pesticides must be used in accordance with legal requirements and that forest managers should seek guidance from experts (Table 2.12).

BMPs in most southeastern states emphasize the importance of reading the label on herbicides and other pesticide products. The label defines legal restrictions on application rates and other aspects of use.

All southeastern state BMPs allow lawful herbicide applications within all SMZs provided that special measures are taken to prevent chemical drift to streams (Michael and Neary 1993; Michael 2000, 2004). For example, herbicides can be applied in SMZs using low-risk methods such as stem injection (herbicide is injected directly into each target tree) and spot application (placement of herbicide directly onto the soil surface near the base of each target tree). Broadcast applications in SMZs are generally not recommended.

Table 2.11 Topics Addressed in BMPs for Forest Fertilization in Southeastern States

	Application Recommendations	Application not Recommended in SMZs	Consider Weather Conditions Prior to Application	Recommend Tests to Determine Application Rates	Limitations on Application Rates
Alabama	+			+	
Arkansas	+	+	+		
Florida	+	+		+	+
Georgia	+	+	+		
Kentucky	+	+	+	+	
Louisiana	+	+	+		
Mississippi					
North Carolina	+	+		+	
Oklahoma					
South Carolina	+			+	
Tennessee	+	+	+		
Texas					
Virginia	+	+		+	

Table 2.12 Topics Addressed in BMPs for Forest Pesticide Application in Southeastern States

	Use Rates Recommended by Manufacturer	Direct/Spot Applications Permissible in SMZs	Broadcast Applications Permissible in SMZs	Consider Weather Conditions Prior to Application	Application Restricted Near Waterbodies	Disposal and Cleanup Guidance
Alabama	+	+			+	+
Arkansas	+	+		+	+	+
Florida	+	+		+	+	+
Georgia	+	+		+	+	+
Kentucky	+				+	+
Louisiana	+	+		+	+	+
Mississippi	+	+		+	+	+
North Carolina	+	+		+	+	+
Oklahoma[1]						
South Carolina	+	+		+	+	+
Tennessee	+	+		+	+	+
Texas	+	+		+	+	+
Virginia	+	+		+	+	+

[1]Oklahoma recommends that individuals contact personnel with the Department of Agriculture, Food, and Forestry, as well as the Oklahoma State University Department of Forestry or the Oklahoma Forestry Association for information on using forest chemicals.

2.2.5 *BMPs for Harvesting and Reforestation*

Timber felling *per se* typically has minimal, if any, discernible impacts on water quality. Sediment movement associated with transporting (skidding) of logs within a harvest operation can be problematic, however. When impacts occur, they typically result from forest managers not properly implementing BMPs for landings and skid trails (Table 2.13).

Landings are areas where logs are brought for temporary storage, processing, and loading onto trucks. Landings are also known as log decks or sets.

Locations of landings should be established during pre-harvest planning of the road and trail system. All states recommend limiting both the size and number of landings, which in turn limits the number of skid trails and access roads necessary to move logs to and from the landings. Another common BMP is to locate landings on high ground (i.e., well drained areas) so that logs can be skidded uphill. Skidding to a landing on high ground from several directions creates a pattern of skid trails that disperses runoff from the landing.

All states recommend that under no circumstances should a landing be established within or in close proximity to an SMZ because landings are areas of concentrated activity and soil disturbance. All states recommend measures to control water and sediment movement from landings during and after harvest. Control options include stabilizing areas of bare soil by seeding with grasses or covering with logging slash.

BMPs for skid trails are numerous and variable but are generally focused on two main concerns: limiting soil disturbance and careful crossing of streams. BMPs that address soil disturbance are designed to reduce impacts of skid trails on soil productivity and water quality.

During any ground-based harvesting operation, some soil disturbance and rutting are unavoidable. BMPs generally recommend use of equipment with low ground pressure (i.e., tractors with wide tires or tracks) on soils with high susceptibility to compaction, rutting or erosion. Some states recommend cable logging on very steep slopes to avoid soil disturbance and safety concerns associated with ground-based operations on steep slopes. Florida recommends use of mat logging techniques to minimize soil disturbance on very wet areas. The harvest crew lays down a mat of logs and uses the mat as a trail to access the interior of harvest area. Logs in the mat are picked up and hauled out as the harvest crew backs out of the wet area (FL DOF 2008).

All states recommend that managers limit the number and total length of skid trails. As previously mentioned, states generally recommend that logs be skidded uphill, although many states also recommend that logs not be skidded directly up the slope. Skidding at an angle to the slope reduces erosion potential by promoting drainage of water off the skid trail. All states recommend that water diversion techniques be implemented and maintained on skid trails where necessary to control erosion both during and after harvesting.

Some of the most important BMPs for skid trails involve stream crossings. In some cases, crossing a stream with a temporary skid trail may be preferable to a permanent road crossing. State BMPs emphasize limiting disturbance to stream banks by restricting the number of crossings and ensuring that any crossing is installed at a right angle to the stream channel. Some states recommend that, when possible, managers use temporary bridges or portable mats (e.g., wood or steel dragline mats) in place of culverts since the former may have smaller impacts on streams and water quality. State BMPs prohibit transporting logs along a stream channel even if the stream bed is dry.

Table 2.13 Topics Addressed in BMPs for Harvesting, Reforestation and Waste Disposal in Southeastern States

	Placement of Landings and Skid Trails	Limit Skid Trails and Temporary Stream Crossings	Advise Use of Water Diversion Techniques	Procedures for Retiring Landings and Trails	General Site Preparation Recommendations	Waste Disposal Guidance
Alabama	+	+	+	+	+	+
Arkansas	+	+	+	+	+	+
Florida	+	+	+	+	+	+
Georgia	+	+	+	+	+	+
Kentucky	+	+	+	+	+	+
Louisiana	+	+	+	+	+	+
Mississippi	+	+	+	+	+	+
North Carolina	+	+	+	+	+	+
Oklahoma	+	+	+	+	+	+
South Carolina	+	+	+	+	+	+
Tennessee	+	+	+	+	+	+
Texas	+	+	+	+	+	+
Virginia	+	+	+	+	+	+

Mechanical site preparation techniques include shearing, raking, subsoiling, chopping, windrowing, piling, and bedding. These techniques are prescribed on a site-specific basis to achieve various objectives related to reforestation including improvement of soil physical properties; control of unwanted vegetation; and redistribution of woody debris to facilitate prescribed burning, wildfire control, tillage and tree planting.

To minimize erosion and possible sediment transport to waterbodies from site preparation, states have developed BMPs that take into account topography, soils, residual ground cove and other factors that affect potential for soil erosion and sediment transport to streams. Site preparation and reforestation BMPs generally recommend that mechanical equipment be excluded from all SMZs (stream crossings are a notable exception for treatment and restoration of soil conditions) and that mechanical site preparation be limited or even excluded from areas where slopes exceed 25 to 30%. Many states prohibit pushing or piling of logging debris (i.e., slash) into waterbodies (e.g., AL FC 1999; FL DOF 2008). Georgia recommends that managers avoid or restrict site preparation in ephemeral areas where there is potential to reactivate gullies in former agricultural fields (GA FC 1999).

In recent years, chemical site preparation techniques have become increasingly common in forest management in the Southeast and other regions. Research has shown that using chemical site preparation methods can often reduce costs and improve environmental performance while achieving reforestation objectives (Beasley, Granillo, and Zillmer 1986). States recognize that reducing soil disturbance and erosion potential is a key advantage of chemical site preparation over disking and other mechanical methods.

2.2.6 *BMPs for Waste Disposal*

Proper collection and disposal of pesticide and fertilizer containers, used liquids (e.g., oils and cleaners), and other wastes (e.g., old batteries and tires) is necessary to prevent soil and water contamination. All states have general recommendations regarding waste generation and site cleanup (Table 2.13). Generally, these BMPs prohibit on-site disposal of wastes or cleaning of equipment in SMZs and waterbodies. States also recommend that care be taken when performing routine “in the woods” maintenance of heavy equipment and remind managers that used oil and other wastes should be stored and transported off-site and disposed of in accordance with legal requirements.

2.3 State BMP Monitoring Protocols and Implementation Rates

In 2002, the Southern Group of State Foresters (SGSF) published *Silviculture Best Management Practices Implementation Monitoring – A Framework for State Forestry Agencies*. This report describes a framework for evaluating rates of BMP implementation and improving consistency among states in this effort (SGSF 2002). The framework includes guidance determining appropriate sample sizes for monitoring BMP implementation and developing objective measures of BMP implementation.

The SGSF framework requires monitoring in seven BMP categories: harvesting, site preparation, forest roads, stream crossings, streamside management zones, firebreaks, and chemical application. The framework also requires that BMPs be evaluated at three levels: individual BMP practices, BMP categories, and overall BMP implementation (expressed as a percentage). Finally, states are required to assess significant risks to water quality when BMPs are not implemented or not implemented correctly.

In 2008, the SGSF Water Resource Committee published *Implementation of Forestry Best Management Practices: A Southern Regional Report*. This document summarizes 25 statewide BMP implementation surveys conducted in conformance with the SGSF monitoring framework in 11 southeastern states between 1997 and 2007. Alabama and Louisiana are not represented in the report

because their BMP survey methods were not consistent with the regional monitoring framework (but will be in the future). Survey results are summarized in Table 2.14. The remainder of this section summarizes implementation surveys conducted in individual states.

Table 2.14 Summary of 25 Statewide BMP Implementation Surveys Conducted between 1997 and 2007 in Conformance with SGSF Framework (SGSF 2008)

BMP Category	Range of Implementation Rates in All Surveys	Average Implementation Rate in Recent Surveys
Harvesting	52% to 100%	89%
Site Preparation	70% to 99%	90%
Forest Roads	43% to 98%	86%
Stream Crossings	58% to 100%	85%
SMZs	76% to 99%	88%
Fire Breaks	30% to 100%	77%
Forest Chemicals	82% to 100%,	97%
Overall Implementation	56% to 99%	87%

2.3.1 *Alabama*

The Alabama Forestry Commission (AFC) initiated annual BMP compliance surveys in 1994. Originally, surveys were conducted statewide. Recent surveys have covered selected portions of the state each year. Site selection criteria are 1) "well defined as forestry practices;" 2) one-year old or less; 3) in any stage of completion (i.e., ongoing, stopped, or completed); and 4) free from sampling bias. Harvest size, ownership, and access are not considered when selecting a site for monitoring.

AFC monitors implementation of BMPs in seven categories: SMZs, stream crossings, forest roads, timber harvesting, reforestation, stand management, and forested wetland management. Departures from BMPs are rated as to their seriousness. Each harvest site as a whole is rated as to whether BMPs were adequately implemented at the end of the site evaluation.

BMPs were assessed in southwest Alabama from April to July 2005 and in north Alabama in November 2005 (Cartwright 2006; Lowery 2006; Lowery pers. comm.). In southwest Alabama, potential sample sites were identified by aerial reconnaissance. Numbers of potential sites by county were as follows: Baldwin (231), Clarke (296), Conecuh (290), Escambia (242), and Monroe (80). These five counties were chosen for BMP compliance monitoring because of severe hurricane damage and the resulting increased harvesting activities associated with salvage operations. All sites were mapped with GPS coordinates. Ten sites per county (50 sites total) were selected at random, and ground inspection of the sites was completed during the summer/fall of 2005. Three of the 50 sites monitored had violations such as trash remaining on the logging site and incidences of minor fuel spills. Violations at these sites were assessed as minor but nevertheless caused the sites to be rated noncompliant. Thus, the overall site-level compliance rate was 94%.

In north Alabama, aerial surveys identified 635 total logging sites in 2005. From this pool, 112 sites were randomly selected for BMP evaluation. Numbers of evaluations sites per county depended on harvest volume. When this section was prepared, AFC had evaluated BMP compliance at 64 sites in the Northwest and Northeast Regions. Three potential violations were identified at those sites. Overall compliance at the site level was 98%.

Alabama has agreed to change its monitoring program to conform to the SGSF BMP monitoring framework for their next reporting period (SGSF 2008).

2.3.2 *Arkansas*

The Arkansas Forestry Commission (AR FC) conducted statewide BMP monitoring surveys in 1998, 1999, and 2001. Survey methods were modified after state BMP guidelines were revised in 2002.

The following discussion is based on a BMP survey conducted in 2005 (AR FC 2005). In this survey, 249 sites were randomly selected from a pool of 500 candidate sites harvested around the state between September 2002 and March 2004. Sample size was based on a 5% precision target and statistical analyses of data from previous surveys. Monitoring sites were distributed geographically on the basis of 2001 timber severance tax records. Field crews assessed implementation of BMPs in four categories (SMZs, roads, harvesting, and regeneration) by answering 67 yes/no questions.

BMP implementation rates in the 2005 survey were as follows: roads (84%), harvesting (96%), regeneration (84%), and SMZs (84%). The overall BMP implementation rate across all categories was 88%.

Specific areas of concern related to roads were 1) seeding and mulching in a timely manner to reduce erosion (30% implementation rate); 2) erodible areas, where natural vegetation is not sufficient to stabilize the soil, revegetated or stabilized (62%); 3) temporary crossing structures removed and stream banks stabilized and restored after use (62%); 4) rolling dips present where needed (56%); and 5) water bars present as specified on inactive roads (60%). Permanent road stream crossings generally scored well in the survey. However, temporary stream crossings (e.g., fords) were often cited as problematic.

Areas of concern related to harvesting were lack of water bars on closed skid trails (45%), failure to remove temporary fill material from streams (64%), and lack of rolling dips for skid trails on steep grades (29%). In the SMZ category, excessive harvest of timber within SMZs caused the most concern. In this sub-category, 23% of sites examined had <50 ft sq of basal area remaining within the designated SMZ area. An additional concern was failure to install SMZs around lakes and ponds. In the regeneration category, concerns were related to apparent errors in stream identification leading to disturbance of ephemeral streams by mechanical site preparation equipment.

Survey results were reported for each of four landownership categories: industrial, federal, state, and private non-industrial forest landowners. Rates of BMP implementation were 80% for private non-industrial forest landowners, 93% for industrial forests, and >95% for state and federal forestlands. An improvement in implementation rates for roads and harvesting BMPs was noted on industry land when 2005 results were compared to those reported in 2001. The 2005 AR FC report notes, “A good road system and a strong industry certification program have resulted in a high score for these two categories. Companies with forest land certification programs that require BMP training for loggers have a higher degree of BMP implementation.”

2.3.3 *Florida*

Since 1981, the Florida Division of Forestry (DOF) has monitored forestry operations for BMP implementation by conducting biennial surveys. Through 2005, the DOF had evaluated over 4,400 individual forestry operations and recorded statewide implementation ranging from 84% in 1985 to 99% in 2005 (FL DOF 2006). Averaged over years, the FL DOF reports a cumulative statewide average of 93% for overall forestry BMP implementation.

In the 2005 survey, each county was assigned a sampling goal (i.e., number of survey sites) proportionate to that county’s average annual timber removal (Bechtold, Brown, and Sheffield 1995).

The statewide goal was to evaluate 210 sites distributed among 57 counties. Site selection criteria were 1) bona-fide silviculture operations, not land use conversion; 2) silviculture treatments not older than two years; and 3) activities within 300 feet of a waterbody or within a wetland. These criteria provided the FL DOF with a list of sites where "…the greatest potential for forestry-related nonpoint source (NPS) pollution exists, and where any such impacts are still discernible and measurable at the time of the survey." DOF BMP foresters randomly selected sites by flying along selected township and range lines at altitudes of 800-1200 feet. The goal of aerial observation was to minimize sample bias and to maximize the diversity of ownerships and physiographic areas within the BMP implementation survey sample. For areas where overflights were not possible, candidate sites were selected by ground inspection, assigned a number, and then drawn randomly.

Following site selection, a field questionnaire was completed on the ground for each site. The questionnaire consisted of 139 specific yes/no questions directly related to Florida's BMPs. DOF BMP foresters evaluated and scored implementation at three levels on each site: individual practice(s); categories of practices; and overall. For individual practices, implementation was recorded as yes, no, or not applicable. For categories of practices, as well as the overall score, implementation was expressed as a percent of all applicable BMPs.

Each incidence of noncompliance at the practice level was further evaluated to determine if a significant risk to water quality existed. The FL DOF defines significant risk as "a situation or set of conditions where noncompliance with BMPs has resulted, or may result, in the measurable and significant degradation of physical, chemical, or biological integrity of water quality, to the extent that it presents an imminent and substantial danger to the designated beneficial use." When a significant risk has been identified, the BMP forester advises the landowner on how to implement corrective measures. Afterward, a follow-up site evaluation is made to reassess compliance. Landowner non-compliance with recommendations made by the BMP Forester will result in a referral to the appropriate regulatory agency for enforcement action.

In 2005, the FL DOF BMP implementation survey examined 4,477 practices on 190 sites in 39 counties. DOF evaluated BMPs in categories such as streamside management zones (SMZs); wetland forestry operations; roads; stream crossings; timber harvesting, site preparation and planting; fireline construction; and waste disposal. Site distribution among ownership categories was as follows: non-industrial private (24%); industrial (62%); public (13%).

Across all ownership classes, complete implementation of all applicable BMPs was observed at 87% of sites visited. Assessments of individual forestry practices indicate an overall BMP compliance rate of 99%, with site-level averages ranging from 85% to 100%.

The average implementation rate for BMPs in the SMZs category was 99%. Implementation rates for sub-categories were 98% for primary zone, 99% for secondary zone, and 100% for stringers.

Implementation rates for three other BMP categories were 94% for wetland forestry operations, 98% for roads, and 100% for stream crossings. The most commonly cited cause of non-compliance for roads was failure to stabilize critical road segments and install drainage structures (FL DOF 2006).

An implementation rate of 99% was reported for the broad BMP category of timber harvesting, site preparation, and planting. Violations included waterbodies containing excessive logging slash; utilizing inappropriate drainage structures; not stabilizing critical segments as needed; and improper use of drum chopping during site preparation. Implementation rates for BMPs in the fireline and waste disposal categories were 95% and 99%, respectively.

It is noteworthy that FL DOF conducted a BMP effectiveness study in 1996 in conjunction with a BMP implementation survey. This study evaluated the effectiveness of BMPs in preventing impacts

to water quality during forestry operations that included harvesting, mechanical site preparation, and forest chemical application. Florida's Stream Condition Index was the principal measure of water quality. Results showed that when BMPs were properly installed, they were effective in protecting water quality, aquatic habitat, and overall stream ecosystem health (Vowell 2001; Vowell and Fryenborg 2004).

2.3.4 *Georgia*

The Georgia Environmental Protection Division has designated the Georgia Forestry Commission (GA FC) as the agency responsible for the development, implementation, and monitoring of forestry BMPs. The goal of the GA FC is to minimize or prevent NPS pollution contributions from forestry operations. The GA FC conducted BMP implementation and compliance surveys in 1991, 1992, 1998, 2002, 2004 and 2007. Results from the 2007 survey (GA FC 2008) are summarized below.

Objectives of the 2007 survey were to determine rates of BMP implementation; acres in BMP compliance; effectiveness of BMPs for any needed modifications; actual miles of streams that may have forestry water quality impairments; and ownerships and regions to target for future training. Sites were selected using a stratified random sampling procedure that distributed sites across physiographic regions and ownership classes. Sites were eligible for selection if they had been treated silviculturally within the previous two years (preferably within previous six months).

Trained foresters evaluated forestry practices at each of 370 sites by answering 136 specific yes/no questions on a BMP Compliance Survey Form. BMP evaluations occurred at three levels: 1) individual BMP; 2) category of BMP practices; and 3) overall site BMP implementation. For individual BMPs, implementation was recorded as yes, no, or not applicable. For categories of BMP practices and overall site BMP implementation, scores were expressed as a percent of all applicable BMPs. Thirteen categories of BMP practices were evaluated: SMZs, stream crossings, main haul roads, timber harvesting, mechanical site preparation, chemical site preparation outside, firebreak construction, controlled burning, artificial regeneration, forest fertilization, equipment servicing, and special management areas (SMAs). Across all sites, a total of 9,605 individual practices were evaluated.

Inspectors evaluated BMP performance not only in terms of implementation but also in terms of water quality risk and extent of BMP compliance. A water quality risk is "a situation or set of conditions that has resulted, or may result, in erosion or other pollutants entering a water body, an increase in stream temperature, or the physical degradation or obstruction of water bodies observed at each BMP question." BMP compliance is calculated by "dividing the units of measure specific to a forest practice (e.g., number of acres harvested, number of stream crossings, number of road miles) that were in compliance with BMPs by the total number of units measured for that particular practice" (GA FC 2005). Compliance is used when assessing trends in survey results over time.

Statewide rates of BMP implementation and compliance, respectively, by category of practice were as follows: SMZs (89% and 94%); stream crossings (84% and 44%); main haul roads (91% and 92%); timber harvesting (97% and 99.8%); mechanical site preparation (94% and 99.9%); chemical site preparation (97.9% and 100%); firebreak construction (68% and 79%); controlled burning (96% and 99.9%); artificial regeneration (100% and 100%); equipment servicing (99% and 99%); special management areas (92% implementation); and stream miles (92% compliance). No forest fertilization practices were evaluated in the 2007 survey.

By ownership category, statewide BMP implementation rates were as follows: forest industry (96%), corporate (95%); public (88%); and non-industrial private (91%). Most sites (282 of 370) were on non-industrial private forestlands.

For all BMP categories and ownership classes combined, rates of BMP implementation and compliance in 2007 were 92% and 99.7%, respectively. GA FC interpreted its 2007 survey results as indicating that "… as a whole, forest operators appear to be doing a very good job of implementation of forestry BMPs." However, GA FC emphasized opportunities for improvement in the stream crossing category, observing that that "…56% of crossings had some BMP deficiencies, which in many cases were minor deficiencies." Measured rates of BMP implementation for stream crossings were slightly higher in 2007 compared to 2004 (84.4% vs. 79.8%). It was noted that of 268 total crossings on 2007 survey sites, 105 (39%) were associated with skidder fords or debris type crossings. "These automatically count as non-compliant since the BMPs do not recommend their use. Just eliminating these type crossings offers the greatest potential to increase compliance" (GA FC 2008).

2.3.5 *Kentucky*

Kentucky began a regulatory BMP program for timber harvesting in 2000 (Larry Lowe, KY DOF Timber Harvesting Compliance Section Supervisor, 2008 pers. comm.). Kentucky requires that loggers implement all appropriate BMPs to protect water quality and that a Master Logger (any individual who has completed the training program given by the KY DOF) be present during all logging operations.

The KY DOF staff conducts inspections to evaluate BMP compliance rates. The KY DOF has a four-step enforcement process and is empowered to issue fines and designate non-cooperators as "bad actors." Where noncompliance with BMPs is observed, a written warning is issued, describing which requirement is not in compliance. Upon receiving a written warning, an operator has an opportunity to meet with the district forester and the inspector to discuss how to remedy the infraction. This technical assistance meeting is referred to as an informal conference. A logger failing to effectively address an infraction (i.e., written warning) can receive a notice of violation. In some instances, noncompliance can result in a special order being issued that allows the KY DOF to shut down a portion of the operation until compliance is achieved. Where violations pose significant threats to water quality, an emergency order can be issued which will shut down the entire operation. The KY DOF can initiate administrative hearings, levy fines, or bring court actions for all violations deemed to have impacts or potential impacts on water quality.

The KY DOF conducted its second round of BMP compliance surveys in 2007. To identify a potential pool of sample sites, the KY DOF conducted aerial surveys and randomly selected 122 sites for monitoring. Inspectors evaluated BMPs in the following categories: access roads, skid trails, and landings; vegetative establishment of disturbed soils; SMZs; sinkholes; logging debris; fertilizers; and timber harvesting in wetland areas. Within these categories, 35 sub-categories of BMPs were evaluated by answering yes/no questions. Full compliance for a specific BMP is reached when all applicable practices are properly implemented. Those practices deemed to be noncompliant were further evaluated to determine whether 'a significant risk' to water quality existed (Larry Lowe, KY DOF, pers. comm.).

Inspectors assessed 2011 forestry practices and determined that 1367 (68%) had been implemented in full compliance with BMPs. Implementation scores for individual BMP categories were as follows: access roads, skid trails and landings (67%): vegetative establishment of disturbed soils (41%); SMZs (68%); sinkholes (97%); logging debris (86%); and, timber harvesting in wetlands (43%). None of the sites had been fertilized. Inspectors recorded 310 significant risks to water quality. Most of these significant risks were associated with two areas: roads, skid trails and landings (194 out of 310); and SMZs (80 out of 310).

KY DOF conducted its first round of BMP compliance monitoring in 2005. Overall compliance was 56% (KY DOF 2006, unpublished data). Comparison of the two rounds of BMP monitoring indicates

a 12% increase in compliance. As noted by SGSF (2008), there is tendency for states with young monitoring programs like Kentucky to increase levels of BMP implementation through time.

2.3.6 *Louisiana*

To evaluate rates of BMP implementation in Louisiana, the Louisiana Department of Agriculture and Forestry (LDAF) Office of Forestry has been conducting inspections on silvicultural sites since 1991. Xu and Rutherford (2005) summarized data collected at 145 sites between October 2003 and March 2004. Sites covered a range of forest management strategies, ownership groups, vegetation types, and site types. Five broad categories of BMPs were evaluated: SMZs, permanent access roads, timber harvesting, site preparation and reforestation, and fireline construction. In addition, specific recommendations within categories were evaluated. For example, the SMZ category included seven specific recommendations, while fireline construction included two specific recommendations.

BMPs that met or exceeded specific recommendations were assessed as "implemented." Rates of implementation were characterized using two metrics: 1) implementation percentage relative to all sites assessed, and 2) implementation percentage relative to sites where particular BMPs were applicable. The latter results are most meaningful (Xu and Rutherford 2005) and are summarized below.

Implementation rates for specific recommendations in Louisiana's SMZ category were in the range of 80% to 98%. Stream crossings were identified as an area for improvement. In contrast, there were very few violations of guidelines for locating roads and landings outside of SMZs.

Implementation rates for eight recommendations related to access roads ranged from 62 to 95%. A recommendation for seeding and/or mulching to increase road stability had the lowest implementation rate in this category.

Implementation rates for nine recommendations in the timber harvesting category ranged from 70% to 97%. Areas for improvement were skid trails, temporary roads, and stabilization of landings by seeding and/or installing water bars. Implementation rates for tree felling and debris in watercourses were intermediate at 85%. Implementation rates were relatively high for recommendations to keep service equipment away from streams and waterbodies (97%); avoid skidding or forwarding in watercourses (91%); minimize skidding across streams (93%); cross streams at right angles (92%); and minimize skid trails on steep slopes (91%).

Recommendations related to site preparation and reforestation BMPs had implementation rates of 83% and 90%, respectively. Low implementation rates were reported for fireline construction with 79% properly located on the contour and 66% having water bars or proper diversions installed on erodible steep slopes.

In addition to evaluating individual practices, inspectors assessed the overall level of BMP implementation at each site as adequate or not adequate. Of the 145 sites, 139 (96%) were assessed as adequate. All inadequate sites were on non-industrial private forestlands. Technical assistance from a consulting forester, industrial forester, or LDAF forester was found to have positive effects on BMP implementation rates (Xu and Rutherford 2005).

Louisiana has agreed to change its monitoring program to conform to the SGSF BMP monitoring framework for their next reporting period (SGSF 2008).

2.3.7 *Mississippi*

In June 2006, the Mississippi Forestry Commission (MFC) completed a BMP survey on forestland in the Mississippi Department of Environmental Quality Basin Group 1 (Harris 2006). Basin Group 1

covers approximately 10,000 mi^2 and includes the Big Black, Tombigbee, and Tennessee River Basins.

The MFC used aerial reconnaissance to identify potential survey sites. Criteria used to identify potential sites were 1) harvesting must have occurred within the past 24 months; 2) sites must be at least 10 acres in size; 3) site selection does not consider ownership; and 4) surface water does not have to be present on the site.

From the pool of potential sites, 203 sites were randomly selected for evaluation. The MFC Water Quality Team answered 73 survey questions at each site to assess implementation of 55 specific BMPs in seven categories: SMZs, stream crossings, forest roads, site preparation, landings, wetlands, and fireline construction. Results were used to estimate implementation rates at three levels: individual practices, categories of practices, and an overall site rating (Harris 2006).

The Water Quality Team also recorded significant risks to water quality, when "during a normal rainfall, sediment is likely to be delivered to a permanent water body." Evidence of water quality impairment was not required for a determination of significant risk.

The MFC Water Quality Team examined a total of 7,277 practices across the Basin Group I region. A total of 6,453 (90%) were implemented in compliance with applicable BMPs (Harris 2006). Implementation rates exceeded 93% for BMPs in the site preparation, landings, wetlands, and fireline construction categories. An implementation rate of 77% was reported for BMPs related to skid trails and temporary roads. For stream crossings and permanent roads, the average implementation rate was 88%.

It was determined that 133 of 7,277 practices had created significant risks to water quality. Most of the significant risks were related to permanent roads (37), SMZs (36), skid trails and temporary roads (32), and stream crossings (20). No significant risks to water quality were found associated with wetlands or fireline construction categories. One significant risk was found in the site preparation category and seven significant risks were reported for landings.

Harris (2006) noted that most risks to water quality in the permanent roads category were associated with the individual practice of "road meets grade specifications." For the SMZ category, risks to water quality were focused in four areas: blocking a stream's natural flow of water; SMZ established according to BMP specifications; harvesting/thinning within SMZ according to BMP specifications; and stream course clear of logging debris. Ten of the 32 significant risks to water quality in the skid trail and temporary roads category were due to these areas not being properly stabilized. Finally, for stream crossings, risks resulted from crossings not being properly installed.

2.3.8 *North Carolina*

The North Carolina Division of Forest Resources (DFR) established forestry BMPs to ensure that forestry operations are in compliance with the state's nine Forest Practice Guidelines (FPGs) related to water quality. Mandatory FPGs were established to keep forestry operations exempt from provisions of the 1973 North Carolina Sediment Pollution Control Act. The state's BMPs are the more specific on-the-ground methods that, when applied correctly, would achieve the state's FPGs.

DFR completed forestry BMP surveys in 1995, 1996, 2000, and 2005. The following discussion is focused on survey results published in 2005 (NC DFR 2005).

Objectives of the 2005 statewide survey were to 1) measure at least 200 active harvest sites annually for a three-year period; 2) determine the level of forestry BMP implementation; 3) document DFR prevention of NPS pollution from forest harvesting; and 4) assess implemented BMPs for strengths and limitations with respect to water quality protection. The survey was conducted in all three of

North Carolina's physiographic regions and included sites in all 100 counties. The survey was limited to active logging sites with harvests greater than five acres. DFR defined active harvest sites to be "the ongoing operation of tree felling or transport/loading of equipment at the time the survey was conducted." This also included pre-harvest activities such as forest road, access road, and skid trail construction, as well as post-harvest site closing procedures.

An important criterion used in the site selection process was presence of waterbodies. Sites eligible for selection had intermittent or perennial streams (or other waterbodies) within the harvest area or within 50 feet of the harvest area boundaries.

Inspectors evaluated BMPs in categories related to the state's FPGs for water quality: SMZs, stream temperature, debris entering streams, waste entering streams, permanent forest roads, skid trails, stream crossings, access road entrances, and project site rehabilitation (NC DFR 2005). Implementation in each category was measured as the percentage of applicable practices that had been conducted in accordance with BMPs.

BMP implementation rates in the Coastal Plain and Piedmont (85 and 87%, respectively) exceeded those in the Mountains (69%). Statewide implementation rates were >85% for BMPs related to SMZs, stream temperature management, debris entering streams, waste entering streams, and access roads. Statewide implementation rates for stream crossings, skid trails, and site rehabilitation BMPs were 65%, 72%, and 41%, respectively.

Inspectors determined that 8% of practices that had been implemented in accordance with BMPs had created some risk to water quality. When BMPs were not implemented, 42% of assessed practices created some risk to water quality. Risks to water quality were more common in the mountains than in other regions.

Across all regions and BMP categories, the average BMP implementation rate in the 2005 survey was 82%. This result is consistent with information from routine inspections of 3281 active harvest sites that were conducted during the same time as the BMP survey. The routine inspections found that 82% of harvest sites were in compliance with FPGs for water quality.

2.3.9 *Oklahoma*

The Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) – Forestry Services Division is responsible for monitoring rates of BMP implementation within the state. Forestry BMP recommendations were first adopted in 1976 and the ODAFF completed its first implementation survey in 1978. Additional surveys were conducted in 2003-2004 and in 2006.

Objectives of the 2006 statewide survey were to 1) measure the degree of implementation of forestry BMPs; 2) evaluate the general effectiveness of BMPs as applied operationally; 3) identify areas in the state where more intensive education and training are warranted; and 4) provide feedback to loggers, landowners, timber buyers, and mill operators to improve silvicultural operations.

ODAFF identified a pool of potential sites by sending out written requests for information on recently completed harvest sites to the forest products industry, agency personnel, private forestry consultants, large landowners, the U.S. Forest Service, and tribal forest owners (Hunkapillar and Atkinson 2004). The ODAFF set a target of sampling 100 sites throughout the state with emphasis on eastern counties where forestry is prevalent (Darryl Hunkapillar, Oklahoma Forestry Services Division, pers. comm.). Evaluation sites were randomly selected from the pool of potential sites with constraints on site distribution among counties and ownership categories (industrial, public, and non-industrial private). Site distribution among counties was based on U.S. Forest Service data on timber harvest and timberland ownership (Hunkapillar and Atkinson 2004).

Inspectors used a BMP monitoring checklist to guide site evaluations. Survey questions were worded so that an answer of "no" would indicate a departure from a BMP. Prior to inspection, permission from the landowner was obtained and only sites where access was granted were sampled. At each site, inspectors assessed practices for compliance with applicable BMPs in the following categories: permanent roads, secondary roads and skid trails, stream crossings, SMZs, site preparation, landings, and wetlands. In addition, inspectors assessed whether practices had created 'significant risks' to water quality as recommended by the SGSF.

Inspectors assessed 2052 practices and recorded 172 departures from BMPs (92% implementation rate). Five significant risks to water quality were recorded.

BMP implementation rates for forest ownership categories were as follows: public (98%), industrial (93%) and non-industrial private (87%). Implementation rates for BMP categories were as follows: permanent roads (90%), secondary roads and skid trails (77% with 1 significant water quality risk), stream crossings (91% with 2 significant water quality risks), SMZs (97%), site preparation (90% with 2 significant water quality risks), landings (98%), and wetlands (100%).

In the permanent roads category, implementation rates were relatively low for road drainage (77%) and stabilization (79%). Problem areas related to secondary roads and skid trails were: roads and trails having slopes less than 15% (78%) and water control devices present and working (52%).

In the stream crossings category, BMPs for permanent crossings were implemented correctly in all 11 instances where they were applicable. The implementation rate for minimizing the number of temporary crossings was also 100%. Opportunities for improvement were identified for two BMPs related to temporary crossings: using the correct stream crossing structure (82%); and restoring and stabilizing crossings (65%).

Areas for improvement in other BMP categories included full compliance with SMZ width guidelines (89%) and avoiding SMZs during site preparation (82%). In addition, erosion control practices for firelines were not in compliance with BMPs at four of the eight sites where they were applicable. Wetland BMPs were implemented properly on the one site where they were applicable.

2.3.10 *South Carolina*

The South Carolina Forestry Commission has conducted several surveys to evaluate implementation of forestry BMPs. Surveys conducted in 1990, 1991, 1994 and 1997 measured compliance with BMPs related to timber harvesting. Surveys conducted in 1996 and 1999 were focused on BMPs related to site preparation.

A survey conducted from 2001 to 2003 evaluated implementation of BMPs for both harvesting and site preparation (Jones 2005). The survey process included the following elements: 1) 200 sites were located and an initial site visit was made to determine compliance with timber harvesting BMPs; 2) one year after the harvest, each site was revisited, and sites that received site preparation treatments were evaluated for BMP compliance; and 3) two years after harvest, an additional site visit was conducted, and sites that received site preparation treatments in the intervening year were evaluated for compliance with site preparation BMPs.

The first step in site selection was an aerial survey conducted in January 2001 to identify a pool of potential sites of at least 10 acres where trees had been harvested within the previous six months. Presence of streams and/or wetlands was not required. From the pool, 200 sites were randomly selected for BMP evaluation with constraints on site distribution among counties, physiographic regions, soil types and forest ownership classes. Site distribution among counties was based on timber harvest data obtained from the U.S. Forest Service.

During 2002, an additional 100 sites that had been recently site-prepared were located and evaluated for compliance with site preparation BMPs. These additional sites were selected because it was not possible to evaluate site preparation BMPs at many of the original 200 harvest sites for various reasons (e.g., because site preparation was not part of the reforestation plan at many sites).

Trained foresters evaluated compliance with BMPs in several categories and recorded any observed impacts on water quality. Timber harvest categories were road systems, road stream crossings, SMZs, log decks, and harvesting systems. Site preparation categories were mechanical site preparation, chemical site preparation, and prescribed burning. Compliance in each category was rated pass/fail on the basis of answers to several yes/no questions. An overall compliance rating for each site (excellent, adequate, or inadequate) was determined after all BMP categories had been assessed.

Site-level compliance with timber harvesting BMPs in South Carolina was 94% (Jones 2005). For the 200 sites inspected, the distribution of compliance ratings was excellent (10), adequate (178), and inadequate (12). Reported impacts to water quality at sites with inadequate compliance included sedimentation, algae blooms, and excessive logging debris in stream channels. BMP compliance for stream crossings was adequate or better at 78% of the sites. Compliance with SMZ guidelines was adequate or better at 87% of the sites.

Compliance with site preparation BMPs was 96% (Jones 2005). For the 198 sites inspected, the distribution of compliance ratings was excellent (15), adequate (166), and inadequate (7). Deficiencies in BMP implementation for mechanical site preparation included inadequate protection of gullies, excessive soil in windrows, and chemical applications within the primary SMZ.

2.3.11 *Tennessee*

Surveys of BMP implementation in Tennessee were conducted in 1993, 1996, and 2003. This section focuses on the 2003 survey, which was conducted by the University of Tennessee, Department of Forestry, Wildlife & Fisheries, and the Tennessee Dept. of Agriculture, Division of Forestry. Information about this survey was provided by Professor Wayne Clatterbuck at the University of Tennessee (pers. comm.).

Analyses during survey planning indicated that a sample of at least 98 harvest sites should be evaluated to provide reliable statewide information on BMP implementation rates. Subsequently, 215 sites were randomly selected from a pool of potential sites so there would be adequate representation within each of Tennessee's Forest Inventory and Analysis regions (East, Plateau, Central, West-Central and West). Sample sizes in each region were based on timber harvest data (Schweitzer 2000).

Site selection criteria included harvested sites of at least five acres; land remaining in forest (i.e., no change in land use); landowner agreement to site visits; all harvest activities completed prior to visit; and harvest occurred after January 2001. Inspectors evaluated BMPs in five categories: haul roads, skid trails, log landings, SMZs, and stream crossings. At many sites, one or more of the BMP categories was not applicable.

At each site, implementation of applicable BMP categories was rated using a 1 to 5 scale, with a score of 1 representing a threat to water quality. Across all sites, average implementation rating was highest for BMPs related to log landings (3.88) and lowest for BMPs related to stream crossings (3.15). Scores were generally lower in western parts of the state and in the Plateau region than in other regions.

BMPs for stream crossings were applicable at only 69 of 215 sites. This could be due to several factors including compliance by timber sale planners and loggers with the recommended practice of minimizing the number of crossings to the extent feasible. However, threats to water quality were more common for stream crossings than for any other BMP category.

2.3.12 Texas

The Texas Forest Service (TFS) has conducted six surveys of BMP implementation since 1992. This section focuses on a survey conducted from 2003 to 2005 (Simpson, Donellan, and Harrington 2005) in accordance with SGSF monitoring guidelines.

TFS evaluated BMP implementation on 156 sites distributed throughout East Texas and across several forest ownership classes. These sites were randomly selected from a pool of candidate sites identified using both aerial surveys and site knowledge from TFS personnel. Trained TFS foresters evaluated BMPs in several categories: permanent roads, skid trails and temporary roads, stream crossings, SMZs, site preparation, landings, and wetlands.

Data were collected in accordance with a Quality Assurance Project Plan approved by the Texas State Soil and Water Conservation Board and EPA. Inspectors used an evaluation form to guide site evaluations. Survey questions were worded so that an answer of "no" would indicate a departure from a BMP. Inspectors also assessed whether practices had created a significant risk, i.e., "a situation or set of conditions that have resulted in or will result in the measurable and significant degradation of water quality that could have been remedied or otherwise mitigated" (Simpson, Donellan, and Harrington 2005).

BMP implementation rate across all 156 sites was 92%, with a total of 21 significant risks to water quality (Simpson, Donellan, and Harrington). Implementation rates by ownership class were as follows: public (98% with no significant risks); industry (96% with three significant risks); corporate (96% with one significant risk); non-industrial private (89% with 17 significant risks).

BMPs for permanent roads were applicable on 120 of 156 sites. The overall implementation rate for these BMPs was 93% with two significant risks. Implementation rates for specific BMPs with the permanent roads category ranged from a low of 81% for roads reshaped and properly stabilized to a high of 99% for the following BMPs: avoiding sensitive areas; meeting grade specifications; and ditches not connected to streams. The implementation rate for BMPs related to temporary roads was 90% with four significant risks.

Streams were present on 120 of the 156 sites. The implementation rate for BMPs related to SMZs for all stream categories was 91% with seven significant risks. For perennial streams only, BMP implementation was 98% for SMZs.

Stream crossing BMPs had lower implementation rates than BMPs in other categories. Implementation rates were 81% for permanent roads and only 31% for temporary roads.

Areas for improvement related to SMZs and stream crossings include stabilization of crossing structures; post-harvest restoration of stream channels at temporary crossing locations; ensuring correct SMZ width for perennial and intermittent streams; and removing debris from streams following thinning.

2.3.13 *Virginia*

The Virginia Department of Forestry (VA DOF) conducts quarterly field audits of BMP implementation and effectiveness. Audit objectives include:

- Quantify levels of effort in attempting to use BMPs and whether BMPs utilized meet technical specifications. Audit question: "Has an effort been made to use best management practices regardless of VA DOF technical specifications (yes or no)?"

- Identify current levels of BMP implementation as compared to the technical BMP standards. Audit question: "Were all necessary best management practices applied to technical specifications expressed in the BMP manual (yes or no)?"
- Identify levels of potential sedimentation. Audit question: "Does the potential exist for sediment from surface runoff to develop due to not meeting VA DOF technical standards (yes or no)?"
- Identify levels of active sedimentation. Audit question: "Does sedimentation from surface runoff exist now due to not meeting VA DOF technical specifications (yes or no)?"

Virginia state law requires landowners or managers to notify the VA DOF at least three days prior to conducting a timber harvest; therefore, a pool of potential survey sites is readily available. For each survey, the VA DOF randomly selects and audits at least 30 timber harvests from their database. Inspectors assess BMPs in nine categories: stream crossings, water control structures, seeded areas, SMZs, skid trails/road grade, rutting, gravel/mats, oil spill/trash, and other.

When this section was prepared, the most recent BMP audit data available was for 2006 (VA DOF 2007). Effort, expressed as a percentage of the total needed, ranged from 2% to 119%. Lowest effort scores were for BMPs related to soil rutting (2%) and seeding (11%). Effort to implement BMPs for water control structures was 59%. Higher levels of effort were recorded for stream crossings (119%), road/trail grade (94%), SMZs (86%), gravel/mats (100%), and oil spills and trash (84%). Stream crossing effort exceeded 100% because VA DOF personnel determined total efforts observed (178) exceeded the number needed (149) (VA DOF 2007).

Rates of BMP implementation in full compliance with BMP technical specifications were as follows: soil rutting (1%), water control structures (35%), stream crossings (68%), SMZs (83%), oil spill/trash (90%), and road/trail grade and gravel mats (91% each). Percentages of sites with potential or active sedimentation were 9% and 6%, respectively (VA DOF 2007). Virginia has revised its monitoring program to conform to the SGSF BMP monitoring framework for their upcoming quarterly field audits (William Lakel, VA DOF, pers. comm.).

2.4 Summary

All of the southeastern states have developed forestry BMP programs as cornerstones of their efforts to control NPS pollution associated with forest management activities. Important elements of these programs include BMP manuals, surveys to assess implementation rates, educational effort to promote understanding and use of BMPs, and regulatory authority to control the activities of "bad actors" when they refuse to use BMPs and cause impacts to water resources.

State forestry agencies and other stakeholders in southeastern states are familiar with scientific research that has demonstrated the effectiveness of BMPs such as establishing SMZs and controlling water and sediment movement from roads. As a result, there is a high degree of consistency in the main topics addressed in state BMP guidelines across the region. State BMP guidelines vary, however, with respect to many details such as minimum SMZ widths for perennial and intermittent streams, procedures for determining minimum culvert size, and relationships between road grade and recommended distance between water control structures.

Every state in the region has conducted at least one survey to assess rates of BMP implementation. Variability in methods among surveys limits the comparability of results. Consistency in methods is increasing because all states in the region are in various stages of implementing recommendations contained in *Silviculture Best Management Practices Implementation Monitoring – A Framework for State Forestry Agencies* (SGSF 2002).

Collectively, southeastern state reports on BMP implementation surveys support several general but important observations.

- State forestry agencies and other stakeholders are committed to ensuring high rates of BMP implementation in the southeastern states.
- States use results of their BMP implementation surveys to identify opportunities for improvement and set priorities in their BMP outreach and education programs.
- Several states have reported differences in BMP implementation rates among forest ownership classes, with generally higher rates on public and industrial lands than on non-industrial private lands.
- Several states have identified opportunities to improve implementation of BMPs related to skid trails and temporary stream crossings.
- Implementing BMPs reduces water quality risks substantially but does not eliminate them.
- Failure to implement BMPs often does not cause a significant risk or impact to water quality.
- Several states that have conducted multiple monitoring surveys have reported increasing rates of overall BMP implementation through time.

3.0 WESTERN STATES

3.1 Introduction

Prior to the 1972 Clean Water Act, only one state in the West (Oregon) had a law addressing nonpoint source pollution resulting from forest management (Ice et al. 2004). After adoption of the Clean Water Act, all states in the West began to develop NPS pollution control programs that include forestry components.

Today, BMPs in a majority of western states are embedded in regulatory programs that include state-specific requirements for compliance with forest practices rules (FPRs) related to water quality and other objectives. As a result, summarizing and comparing forestry BMP programs is somewhat more difficult in the West than in some other regions.

This section provides information about requirements or recommendations for water resource protection in forest management operations in the following states: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. In addition, this section provides information about approaches used by these states to assess BMP compliance, implementation, and effectiveness. Individual state summaries are not meant to be comprehensive, as the guidelines for many of the states are quite extensive and requirements can vary substantially among regions and forest types within a state.

3.2 Forest Practices Rules and Best Management Practices

3.2.1 *Alaska*

Alaska's Forest Resources and Practices Act (FRPA; Alaska Statute 41.17) was adopted in 1978. The FRPA governs how timber harvesting, reforestation, and timber access should occur on both private and public forestlands. Major revisions to the FRPA were adopted in 1990 to address riparian management on private land, enhance notification procedures, reorganize the Alaska Board of Forestry, and establish enforcement procedures for violations. Additional changes to the act occurred in 1999, 2003, and 2004 (AK DNR-DOF 2004).

The FRPA is designed to protect fish habitat and water quality and to ensure prompt and successful reforestation while providing for a healthy timber industry. More specifically, the FRPA has five major provisions: 1) requiring landowners to notify the state before beginning commercial timber operations; 2) setting standards for forest management along waterbodies; 3) allowing harvests (with agency approval) of individual trees within buffers when it can be done without harming fish habitat or water quality; 4) setting standards to prevent erosion into waterbodies; and 5) requiring reforestation on all forest ownerships except where land will be converted to another land use.

All harvest operations that contain or border surface waters or riparian areas must comply with the FRPA, regardless of their size. Under the FRPA, management guidelines have been developed for three regions, and the standards for harvesting, reforestation, and riparian areas vary among them. Region I covers coastal forests from southeastern Alaska through Prince William Sound, the eastern Kenai Peninsula, the Kodiak Archipelago, and parts of the Alaska Peninsula. Region II is the boreal forest south of the Alaska Range. Forest management operations must comply with Alaska's FRPA if they are larger than 10 ac (4 ha) in Region I or larger than 40 ac (16 ha) in Region II. Region III is the boreal forest of interior Alaska. In this region, guidelines in the FRPA apply to all operations larger than 40 ac (16 ha) for forest landowners that own more than 160 ac (65 ha) in total.

Prior to conducting forest management operations, a landowner or forest manager must file a detailed operations plan with the state forester. It must be filed at the local forestry division area office with jurisdiction, and must be submitted on a form provided by the Division of Forestry that covers topic areas expressed in the FRPA regulations. After an operating plan is submitted, the state forester's office reviews the proposal, provides comments and recommendations, solicits input from other agencies, requests changes to the plan, and either accepts or rejects the harvesting request. The FRPA also provides information about conducting inspections (AAC 95.254) and implementing corrective actions (if necessary) to protect water quality (AAC 95.255). Regulations relevant to water quality in the FRPA regulations are covered in Article 2 (riparian standards), Article 3 (road construction), and Article 4 (timber harvesting).

3.2.1.1 *Stream Classification and Riparian Management Zones*

Establishing riparian standards for waterbodies in Alaska begins with classifying the surface water features on site. Waterbody classification guidelines in Alaska are somewhat complex because they depend on land ownership type and region. A detailed explanation of stream classification guidelines, adapted from FRPA guidelines, is shown in Table 3.1, and a summary of the regulations and statutes for riparian areas associated with waterbodies and acceptable management activities is shown in Table 3.2. Management activities in riparian areas must also account for slope stability standards where, again, differences in the slope stability matrix vary by region and landownership (Table 3.3). Operations within a riparian area involving roads, stream crossings, and fill materials must be identified in the operating plan.

Table 3.1 Alaska's Stream Classification Matrix by Land Ownership Group for Regions I-III [adapted from the Alaska DNR-DOF Forest Resources and Practices Regulations (AK DNR-DOF 2004)]

Stream Type	Private Land	State Land	Other Public Land
All Regions	Use 11 AAC 95.265 (b) through (f) for specific procedures on classification.		
Region I	See also 11 AAC 95.265(g) and its Table A for clarifications on determining when a stream is anadromous.	Classification of surface waters must indicate whether or not the surface waters are anadromous or contain high value resident fish under AS 41.17.950. [AS 41.17.950(1), (10) and 11 AAC 95.265(a)(4)] In the absence of a site-specific determination by the deputy commissioner, the state forester shall presume for planning purposes that a stream is anadromous waters that are without department documentation of a physical blockage and has a stream gradient of ≤8%. [AS 41.17.118(c)]	Classification of surface waters must indicate whether or not the surface waters are anadromous or contain high value resident fish under AS 41.17.950. [AS 41.17.950(1), (10) and 11 AAC 95.265(a)(4)]
Type I-A Waterbody	Anadromous waterbody: 1. stream/river of any size having an average gradient of ≤8%, with banks held in place by vegetation, channels not excised, and a substrate composed of rubble, gravel, sand, or silt; 2. consists of wetlands and lakes; and, 3. is an estuarine with salt-tolerant vegetation. [11AAC 95.265(a)(1) and AS 41.17.950(27)]		
Type I-B Waterbody	An anadromous waterbody that does not meet the definition of a Type I-A waterbody. [11AAC 95.265(a)(1) and AS 41.17.950(28)]		
Type I-C Waterbody	A waterbody that is not anadromous, that is a tributary of a Type I-A or Type I-B waterbody, and has a gradient of 12% or less. [11AAC 95.265(a)(1) and AS 41.17.950(29)]		
Type I-D Waterbody	A waterbody that is not anadromous, that is a tributary of a Type I-A or Type I-B waterbody, and has a gradient greater than 12% or less. [11AAC 95.265(a)(1) and AS 41.17.950(30)]		
Other Waterbodies	Any surface waters that do not meet the criteria set out in AS 41.17.950(27-30) and do not have a riparian area, but are subject to surface water quality protection BMPs in accordance with this chapter. [11 AAC 95.265(a)(1)]		

(Continued on next page.)

Table 3.1 Continued

Stream Type	Private Land	State Land	Other Public Land
Region II	Classification of surface waters must indicate whether surface waters are anadromous or contain high value resident fish under AS 41.17.950 [11 AAC 95.265(a)(2)]	Classification of surface waters must indicate whether or not the surface waters are anadromous or contain high value resident fish under AS 41.17.950. [AS 41.17.950(1), (10) and 11 AAC 95.265(a)(4)] In the absence of a site-specific determination by the deputy commissioner, the state forester shall presume for planning purposes that a stream is anadromous waters that are without department documentation of a physical blockage and has a stream gradient of ≤8%. [AS 41.17.118(c)]	Classification of surface waters must indicate whether or not the surface waters are anadromous or contain high value resident fish under AS 41.17.950. [AS 41.17.950(1), (10) and 11 AAC 95.265(a)(4)]
Region III		In the absence of a site-specific determination by the deputy commissioner, the state forester shall presume for planning purposes that a stream is anadromous waters that are without department documentation of a physical blockage and has a stream gradient of ≤8%. [AS 41.17.118(c)]	
Type III-A Waterbody	(1) non-glacial high value resident fish waterbody greater than 3ft in width at the ordinary high water mark; (2) non-glacial anadromous waterbody; or (3) backwater slough; [11 AAC 95.265(a)(3) – private, 95.265(a)(5) – other public land, and AS 41.17.950(31) – definition]		
Type III-B Waterbody	A glacial high value resident fish waterbody or a glacial anadromous waterbody; does not include a glacial backwater slough; [11 AAC 95.265(a)(3) – private, 95.265(a)(5) – other public land, and AS 41.17.950(33) – definition]		
Type III-C Waterbody	A non-glacial high value resident fish waterbody that is less than or equal to 3ft in width at the ordinary high water mark and that does not contain anadromous fish [11 AAC 95.265(a)(3) – private, 95.265(a)(5) – other public land, and AS 41.17.950(33) – definition]		

Table 3.2 Summary of Alaska's Regulations and Statutes for Riparian Zones Based on Region (I-III) and Land Ownership Group [adapted from the Alaska DNR-DOF Forest Resources and Practices Regulations (AK DNR-DOF 2004)]

Stream Type	Private Land	State Land	Other Public Land
Region I	Private forestland adjacent to the following waterbodies and located in Region I is subject to riparian standards established in this section [AS 41.17.116(a)]	1. Harvest of timber may not be within 100 ft (30 m) immediately adjacent to an anadromous or high value resident fish waterbody; 2. Between 100 and 300 ft (30 and 91 m) from the waterbody, harvest of timber may occur but must be consistent with the maintenance of important fish habitat as determined by the state forester with due deference to the deputy commissioner. [AS 41.17.118(a)(2)]	Harvest of timber may not be undertaken within 100 ft (30 m) of an anadromous or high value resident fish waterbody; [AS 41.17.119(1)]
Type I-A Waterbody	1. Operations within 100 ft (30 m) of the waterbody or to the break of the slope (whichever is smaller) shall be conducted in accord with the slope stability standards; and, 2. Harvest of timber may not be undertaken within 66 ft (20 m) of the waterbody [AS 41.17.116(a)(1)]		
Type I-B Waterbody	1. Operations within 100 ft (30 m) of the waterbody or to the break of the slope (whichever is smaller) shall be conducted in accord with the slope stability standards; and, 2. Harvest of timber may not be undertaken within 66 ft (20 m) of the waterbody or to the break of the slope (whichever is smaller) [AS 41.17.116(a)(2)]		
Type I-C Waterbody	1. Operations within 100 ft (30 m) of the waterbody or to the break of the slope (whichever is smaller) shall be conducted in accord with the slope stability standards; and, 2. Where prudent, the operator shall retain low value timber within 25 ft (8 m) of the water body or to the limit of the area described in (1) of this section (whichever area is greater) where the width of the waterbody is a. greater than 13 ft (4 m) at the ordinary high water mark; or b. greater than 8 ft (2.4 m) at the ordinary high water mark if the channel is incised [AS 41.17.116(a)(3)]		
Type I-D Waterbody	1. Operations within 50 ft (15 m) of the waterbody or to the break of the slope (whichever is smaller) shall be conducted in accord with the slope stability standards; and, 2. The operator shall, where prudent, retain low value timber within 25 ft (8 m) of the waterbody or to the limit of the area described in (1) of this section (whichever is greater) where the width of the waterbody is a. >13 ft (4 m) at the OHWM; or b. >8 ft (2.4 m) at the OHWM if the channel is incised [AS 41.17.116(a)(4)		

(Continued on next page.)

Table 3.2 Continued

Stream Type	Private Land	State Land	Other Public Land
Region II	A timber harvest within 100 ft (30 m) from the shore or bank of an anadromous or high value resident fish waterbody must be located and designed primarily to protect fish habitat and surface water quality from significant adverse effects [11 AAC 95.260(b)]	Same as Region I (previous page)	Same as Region I (previous page)
Region III	Private forestland adjacent to the following waterbodies and located in Region III is subject to riparian standards established in this section [AS 41.17.116(b)]		
Type III-A Waterbody	Harvest of timber may not occur within 66 ft (20 m) of a waterbody [AS 41.17.116(b)(1)]	Harvest of timber may not be undertaken within 100 ft (30 m) of a waterbody, except that between 66 and 100 ft (20 and 30 m) from a waterbody, harvest of timber may be undertaken where consistent with the maintenance of important fish and wildlife habitat as determined by the state forester with the concurrence of the deputy commissioner [AS 41.17.118(a)(1) and AS 41.17.119(2)]	
Type III-B Waterbody	Harvest of timber may not occur within 33 ft (10 m) of a waterbody; between 33 and 66 ft (10 and 20 m) from a waterbody up to 50% of the standing white spruce trees having at least a 9 in (23 cm) diameter at breast height may be harvested without requiring a variation [AS 41.17.116(b)(2)]	Harvest of timber may not be undertaken within 50 ft of a waterbody, between 50 and 100 ft (15 and 30 m) from the waterbody, up to 50% of the standing white spruce trees having at least a 9 in (23 cm) diameter at breast height may be harvested [AS 41.17.118(a)(1) and AS 41.17.119(2)]	
Type III-C Waterbody	Harvest of timber within 100 ft (30 m) of the waterbody must be located and designed primarily to protect fish habitat and surface water quality as determined by the state forester with due difference to the deputy commissioner [AS 41.17.116(b)(3)]	Harvest of timber within 100 ft (30 m) of a waterbody must be consistent with the maintenance of important fish and wildlife habitat as determined by the state forester with due deference to the deputy commissioner [AS 41.17.118(a)(1) and AS 41.17.119(2)]	

Table 3.3 Alaska's Slope Stability Standards for Regions I-III and State and Other Public Lands [adapted from the Alaska DNR-DOF Forest Resources and Practices Regulations (AK DNR-DOF 2004)]

Stream Type	Private Land	State and Other Public Lands
Region I Type I-A Type I-B Type I-C	The area within 100 ft (30 m) of an OHWM of a Type I-A, I-B, I-C waterbody or to the break of the slope to that of the waterbody (whichever occurs first) [11 AAC 95.280(a)(1)]	Within 100 ft (30 m) of an OHWM of an anadromous or high value resident fish waterbody, or a waterbody with a gradient of 12% or less that is a tributary to an anadromous or high value resident fish waterbody, and within 50 ft (15 m) of all other tributaries to anadromous and high value resident fish waterbodies [11 AAC 95.280(b)(1)
Type I-D	The area within 50 ft (15 m) of an OHWM of a Type I-D waterbody or to the break of the slope, whichever occurs first [11 AAC 95.280(a)(2)]	
Region II	None	Within 100 ft (30 m) of an OHWM of an anadromous or high value resident fish waterbody [11 AAC 95.280(b)(2)]
Region III	None	

Table 3.4 Alaska's Spacing Recommendations for Drainage Structures Used on Forest Roads [adapted from the Alaska DNR-DOF Forest Resources and Practices Regulations (AK DNR-DOF 2004)]

Grade %	Region I ft (m)	Region II and III ft (m)
0-2	Meet other standards of this section	
2-7	1,000 (305)	1,500 (457)
8-15	800 (244)	1,000 (305)
>15	600 (183)	800 (244)

3.2.1.2 *Roads and Stream Crossings*

Article 3 of the FRPA provides standards for forest roads, including their location, construction, drainage, water crossings, maintenance, and closure. The guidelines for road location are general in nature, but suggest that operators minimize the number of roads and stream crossings, use existing roads when feasible, fit roads to existing topography, ensure roads cross streams at right angles, and avoid areas where fine textured soils are present. Road construction guidelines state that operators should avoid locating roads on slopes greater than 67%, on unstable slopes, or in slide-prone areas. When this is not possible, the operator must adhere to the guidelines specified in AAC 95.290(b). Other guidelines include minimizing sedimentation by using appropriate erosion control measures, avoiding placement of woody debris (intentionally or unintentionally) into streams, properly disposing of overburden and wastes, and keeping mechanized equipment out of surface waters.

Road drainage standards require operators to "…minimize erosion of a road bed, cut bank, and fill slope through use of cross drains, ditches, relief culverts, bridges, water bars, diversion ditches, or other structures demonstrated to be effective" (AAC 95.295). Spacing requirements for these structures are shown in Table 3.4. Other requirements include out-sloping or ditching roads on the uphill side; using settling basins, cross drains, or vegetated areas to minimize sediment reaching waterbodies, and following specific provisions for relief culverts (AAC 95.295(h) and 95.305).

Alaska's regulations provide guidelines for temporary and permanent bridges (AAC 95.300), as well as culverts and fords (AAC 95.305). Temporary and permanent bridges must be constructed to pass or withstand 25 and 50 year floods, respectively, without damage and must allow for fish passage in accordance with AS 41.14.840 and AAC 95.305(c). Guidelines are available for using ice bridges in Region III (AAC 95.305(e)). The minimum diameter allowed for culverts is 12 inches, and temporary and permanent culverts must withstand 25- and 50-year floods, respectively. Numerous guidelines specific to anadromous fish waters and non-fish-bearing streams are found in AAC 95.305(a) 3-9. Fords may be used during periods of low water; however, if a ford crosses anadromous fish waters, written approval is required from the deputy commissioner. Ford construction must also comply with guidelines outlined in AS 41.14.840.

Maintenance requirements for forest roads are based on whether the road is active (six requirements) or inactive (three requirements) (AAC 95.315 b and c, respectively). Furthermore, the Department of Forestry has the discretion to require landowners to fix water quality problems resulting from roads and can implement monetary penalties for poorly maintained roads. When closing roads (AAC 95.320), operators must utilize water control structures and ensure they work properly and must block roads to prevent unwarranted access. Permanently closed roads must also have all water crossings removed, except when "such removal would cause adverse impacts to water quality or fish habitat."

3.2.1.3 *Timber Harvesting*

Timber harvesting guidelines are outlined in FRPA Article 4 and address landings, felling trees, stream bank integrity, and tracked and wheeled harvest systems. Landings must be constructed in a manner that minimizes sedimentation of surface and standing waters by limiting the size of landings and utilizing appropriate water diversion techniques (AAC 95.345 a and b). Ground-based harvesting systems have several requirements regarding skid trails and soil compaction (AAC 95.365). In short, these guidelines focus on limiting the number of trails, minimizing damage to residual trees, and using appropriate water diversion techniques. In order to protect streams and their banks from disturbance, operators are required to minimize disturbance to residual trees and understory vegetation adjacent to surface waters (AAC 95.350). Felling guidelines recommend directional felling of merchantable timber and actions required for removal of timber and woody debris entering streams. Limbs and other debris must be removed from fish-bearing streams within 48 hrs, and

operators must remove boles as soon as feasible. Debris must be removed from non-fish-bearing streams and surface waters at the earliest feasible time.

3.2.2 *Arizona*

While there are 19 million acres of forestland in the state, most acres support pinyon-juniper and pure juniper stands with low growing stocks and harvest levels (O'Brien 2002). Of the roughly 4 million acres of productive forest in the state, more than half is in federal ownership. As a result, the state relies heavily on U.S. Forest Service BMP standards and guidelines and tribal forest management programs to ensure that silvicultural operations protect water quality from NPS pollution. Arizona has not prepared its own statewide guidelines or regulations for controlling forestry NPS pollution.

NPS pollution resulting from forest management activities in Arizona is generally low and is not viewed as a priority within the state. In fact, silviculture is not even listed as a probable source of stress to Arizona streams in the state's 2004 305(b) report, even though sediment-related pollution (~200 stream mi or 322 km) ranks second among NPS problems behind heavy metals (AZ DEQ 2004). The major sources of NPS pollution identified by the Arizona Department of Environmental Quality result from agriculture (i.e., grazing and crop production), mining, and hydrologic modification.

3.2.3 *California*

California's Forest Practice Act (FPA), known as the Z'Berg-Nejedly Forest Practice Act, was adopted in 1973. Under this Act, Timber Harvesting Plans, Nonindustrial Timber Management Plans, and other types of plans for timber operations on all non-federal forestlands must be approved by the California Department of Forestry and Fire Protection (or CAL FIRE) prior to start of harvesting. Submitted plans are evaluated for compliance with the FPA and Forest Practices Rules (FPRs) adopted by the California State Board of Forestry and Fire Protection, as well as other state legislation, including: the California Environmental Quality Act, the Protection of Forest, Range and Forage Lands – Prohibited Activities, the Wild and Scenic Rivers Act, and the Professional Foresters Law. Along with other state agencies (collectively known as the Review Team), including the California Department of Fish and Game, California Geological Survey, and Regional Water Quality Control Boards, CAL FIRE conducts pre-harvest inspections of proposed harvest areas to determine if the submitted plans are in compliance with the FPA, FPRs, and other laws and regulations. This usually results in Review Team requests for additional plan-specific mitigation measures following the completion of the pre-harvest inspection. CAL FIRE also conducts field inspections during active timber operations, when logging is completed, and during an erosion control maintenance period one to three years after harvesting is finished.

The FPRs are frequently revised by the State Board of Forestry and Fire Protection, with the most recent version of the rules published for 2007 (CAL FIRE 2007). The guiding philosophy for the adoption of the FPRs is to achieve "maximum sustained production of high quality timber products…while giving consideration to values relating to recreation, watershed, wildlife, range and forage, fisheries, regional economic vitality, employment, and aesthetic enjoyment" (PRC § 4513(b)). The FPRs, therefore, set the minimum standards for forest practices to ensure maximum sustained timber production. The 2007 FPRs are subdivided into seven subchapters, with Subchapters 4, 5, and 6 (Forest District Rules) being the regulations related to forest management. These include 14 articles that cover topics such as silvicultural methods, harvest practices and erosion control, site preparation, watercourse and lake protection, hazard reduction, fire protection, wildlife protection practices, and logging roads and landings. The requirements set forth in the subchapters and articles apply to the state as a whole, which is divided into three broad forest districts: Coast, Northern, and Southern. Individual county requirements and regulations are also included for six counties.

Frustration with California's FPRs is often expressed as a result of their organization and comprehensive nature. The 2007 FPRs are 212 pages long. Furthermore, some rules are not applicable or vary among the three forest districts, and many counties have added supplementary rules to forestry practices within their jurisdictions (Dicus and Delfino 2003). Additionally, there is frustration because the rules or requirements of other regulatory agencies often conflict or overlap the FPRs. Since July 2000, more restrictive interim threatened or impaired watershed rules (i.e., T or I Rules) have been required for watersheds with anadromous fish species that have been listed as threatened, endangered, or candidate under the state or federal Endangered Species Acts. These rules cover a significant percentage of commercial timberlands, particularly in the North Coast region. In order to minimize confusion and standardize BMP regulation comparisons among the states, California's individual county rules are not covered by this document.

The remainder of this section will focus on four articles in California's FPRs that are based on BMPs for controlling NPS pollution associated with forest management activities: harvesting practices and erosion control (Article 4); site preparation (Article 5); watercourse and lake protection (Article 6); and logging roads and landings (Article 12).

3.2.3.1 *Harvesting and Erosion Control*

California's guidelines for harvesting and erosion control (Article 4) are intended to limit damage to residual trees during harvest, prevent declines in water quality, and maintain site productivity by minimizing soil loss. These rules fall into several categories: felling practices, mechanized equipment operation, cable yarding, equipment servicing and waste disposal, water breaks, and temporary water crossings (i.e., tractor crossings). Guidelines for felling trees are broadly defined, with the exception of specific limits on stump heights in the Southern District. Generally, these guidelines focus on minimizing breakage or damage to merchantable timber and residual trees as well as guidance for harvesting in sensitive areas such as riparian zones.

Rules for mechanized equipment focus on construction and use of temporary roads (i.e., skid roads or trails) to limit water quality impacts as a result of transporting timber to and from loading decks. The major requirements are to minimize the number of tractor roads, make roads only as wide as necessary, use existing roads where feasible, and use waterbreaks or other structures appropriately. Additional restrictions apply in three circumstances: 1) where slopes exceed 65%; 2) where slopes exceed 50% and erosion hazards are high/extreme; and 3) where slopes exceed 50% and lead without sufficient flattening to dissipate water flow and trap sediment before it reaches a watercourse or lake.

Section 914.6 [934.6, 954.6] of the FPRs covers nine standards for installation, use, and maintenance of waterbreaks on tractor roads (i.e., skid trails), access roads, and landings. Regulations require waterbreaks to be constructed as follows: "…cut diagonally a minimum of 15.2 cm (6 in) into the firm roadbed…and shall have a continuous firm embankment of at least 15.2 cm (6 in) in height immediately adjacent to the lower edge of the waterbreak cut." There are other major requirements for waterbreaks. All water bars must 1) be established prior to the winter period (November 15-April 1) and must also be installed prior to sunset on all constructed tractor roads and skid trails October 15-November 15 and April 1-May 1 if the National Weather Service forecast predicts a >30% chance of rain in the succeeding 24 hours; 2) follow standards for spacing based on hazard rating (Table 3.5); 3) be installed at all natural watercourses; 4) direct-discharge water into some form of vegetative cover, duff, slash, etc.; and 5) be maintained for at least one year, and possibly up to three years, after filing of a work completion report.

Table 3.5 California Requirements for the Maximum Distance Allowed between Waterbreaks [adapted from the 2007 California Forest Practices Rules (CAL FIRE 2007)]

Hazard Rating	Road or Trail Gradient							
	<10%		11 – 25%		26 – 50%		>50%	
	ft	m	ft	m	ft	m	ft	m
Extreme	100	30	75	23	50	15	50	15
High	150	46	100	30	75	23	50	15
Moderate	200	61	150	46	100	30	75	23
Low	300	91	200	61	150	46	100	30

California regulations restrict tractor road construction and use within watercourse and lake protection zones. In addition, they require that land managers limit the number of stream crossings needed; where possible, land managers are encouraged to utilize existing crossings. Additional rules for tractor/skidder watercourse crossings within all state forest districts are based on the presence of fish. The FPRs require that stream crossings that support fish "…shall allow for unrestricted passage of all life stages of fish that may be present, and for unrestricted passage of water." Detailed information about the type, method of installation, maintenance, and removal (if necessary) are required when filing a plan. When culverts are needed, the plan must also include information on the length and minimal diameter of the culvert to be installed.

3.2.3.2 *Watercourse and Lake Protection*

Requirements for watercourse and lake protection are intended to ensure that "the beneficial functions of riparian zones are protected from potentially significant adverse site-specific and cumulative impacts associated with timber operations" (Sections 916, 936, 956). The major provisions in this section are associated with the establishment of watercourse and lake protection zones (WLPZs). Requirements for WLPZs in California are based on a watercourse classification system. Class I includes "watercourses or springs serving as domestic water supplies, onsite and/or within 1000 ft (305 m) downstream of the operations area, and/or those watercourses where fish are always or seasonally present, including habitat to sustain fish migration and spawning." Class II watercourses are those where fish are always or seasonally present onsite and/or within 1000 ft (305 m) downstream, and/or those that contain aquatic habitat for non-fish aquatic species. Class III watercourses have no aquatic life present and show evidence of being capable of transporting sediment downstream to larger watercourses (Class I or Class II) under normal high water flow conditions after completion of timber operations. Man-made watercourses that supply downstream domestic, agricultural, hydroelectric, or other beneficial uses are categorized as Class IV.

Restrictions on forest management activities in WLPZs are intended to prevent deposition of soil and organic debris into waterbodies and to limit the construction of roads near watercourses. Trees harvested in WPLZs must be felled away from waterbodies, and in situations where there is less than 50% canopy coverage in WLPZs of Class I and II waters, only sanitation salvage harvesting is allowed.

WLPZ widths for Class I watercourses (both T or I Rules and standard rules) are shown in Table 3.6. For the standard rules, WLPZ width varies by slope gradient, with Class I WLPZs varying from 75 to 150 ft (23 to 46 m) with expansion based on site specific investigations. The T or I Rules specify that

Class I WLPZs are to be 150 ft (46 m) wide, with overstory canopy retention of 85% for the first 75 ft (23 m) and 65% for the second 75 ft (23 m).

Where management activities are allowed in WPLZs, specific criteria for large woody debris recruitment must be followed. Under standard rules, at least two large living conifers per acre (at least 16 in (41 cm) diameter at breast height (dbh) and 50 ft (15 m) tall) must be retained within 50 ft (15 m) of all Class I and II watercourses. Where T or I Rules are in effect for Class I watercourses, managers must retain the 10 largest conifers within 50 ft (15 m) of the watercourse that are most conducive to wood recruitment in each 330 ft (101 m) segment of the WPLZ.

Protective measures and WPLZ widths for Class III and IV waterbodies are determined on a site-specific basis (Section 916.4(c)). Where management activities occur adjacent to Class III watercourses, the plan must include an equipment limitation zone of at least 25 ft (8 m) where the sideslope is less than 30% and at least 50 ft (15 m) where steepness exceeds 30%. However, an equipment limitation zone is not required where slopes are less than 30% if erosion potential is low.

Designing protective measures for WLPZs begins with a registered professional forester (RPF) conducting a site visit to map and designate (i.e., mark with flagging) all watercourses that contain or conduct Class I, II, III, or IV waters. As part of the field examination, the RPF will also map the location of spawning and rearing habitat for anadromous salmonids, as well as the condition of the habitat (e.g., water temperature; presence of large wood debris and its effects on stream flow and stream bed conditions; stability of channels, banks, and side slopes; and structure and diversity of riparian plant communities).

Maps of habitat locations and conditions are used to define WPLZ protective measures. Letter designations (A through I) (Table 3.6) corresponding to standard sets of protective measures are assigned to watercourse segments identified during the field inspection. Detailed descriptions of the nine standard protective measures for watercourses are found in Section 916.5(e) of the FPRs. Protective measures must be clearly defined in timber harvesting plans.

3.2.3.3 *Site Preparation*

Site preparation FPRs are designed to "prevent substantial adverse effects to soil resources and to fish and wildlife habitat, and prevent the degradation of the quality and beneficial uses of water." Article 5 contains four sections; however, those covering use of heavy equipment and treatment of vegetative matter are most pertinent to water quality. In general, regulations for heavy equipment use require that managers refrain from mechanized activities during saturated soil conditions or wet weather, that water crossings adhere to state guidelines, and that all sites utilize water diversion practices (i.e., energy dissipators). Site preparation burning is permissible but must comply with regulations specified in 14 CCR §§ 917 [937, 957] through §§ 917.7 [937.7, 957.7]. Broadcast burning is also permissible but may not fully consume larger organic debris that provides soil stability on slopes and watercourse banks.

Table 3.6 Procedures for Determining the Width and Additional Protective Measures[1] Required for California's Watercourse and Lake Protection Zones [adapted from the 2007 California Forest Practices Rules (CAL FIRE 2007)]

	Class I		Class II		Class III[2]		Class IV[2]	
Slope Class	Width - ft (m) -	Protective Measure	Width - ft (m) -	Protective Measure	Width - ft (m) -	Protective Measure	Width - ft (m) -	Protective Measure
<30	75 (23)	BDG	50 (15)	BEI	See CFH		See CFI	
30-50	100 (30)	BDG	75 (23)	BEI	See CFH		See CFI	
>50	150 (46)[3]	ADG	100 (30)[4]	BEI	See CFH		See CFI	

[1]See Section 916.5(e) of the CA FPR for detailed explanation of the protective measures required
[2]See Section 916.4(c), 936.4(c), 956.4(c)
[3]Subtract 50 ft (15 m) width when cable yarding
[4]Subtract 25 ft (8 m) width when cable yarding

3.2.3.4 *Logging Roads and Landings*

California's FPRs for logging roads and landings cover nine sections that include planning, construction, water crossings, maintenance, and retirement or abandonment. General requirements that should be considered by land managers when planning the placement of roads and landings include using existing roads whenever possible; employing layouts that minimize total road mileage; planning new roads that minimize disturbance to the natural features of a site; avoiding constructing roads or landings near the bottoms of steep and narrow canyons, through marshes and wet meadows, on unstable areas, near watercourses, or near existing nesting sites of threatened or endangered bird species; limiting the number of watercourse crossings; establishing roads in areas of stable soils to minimize effects on watercourses; and utilizing logging systems that will reduce excavation or placement of fill material on unstable areas.

When planning a harvest, all logging roads must be located and classified as temporary, seasonal, or permanent on the plan map. Locations of road failures on existing roads that will be reconstructed must also be noted. Logging roads and landings are to be planned and located to avoid WLPZs and unstable areas, but exceptions may be proposed in the plan by the RPF. Unless justified in the plan and accepted by CAL FIRE, general planning requirements for roads include these provisions: 1) all roads should be a single-lane width that is compatible with the largest type of equipment used and have turnouts at reasonable intervals; 2) roads will achieve balance between cut volume and fill volume as much as possible; and 3) insloped and ditched roads will have an adequate number of structures to promote effective drainage.

Logging roads must be constructed or reconstructed in accordance with the 22 FPR requirements found in Sections 923.2, 943.2, and 963.2 or as proposed by the RPF and explained and justified in the plan. Regulations regarding relationships between road length and slope are covered by three standards (Section 923.2(b, c, and f)). Regulations regarding road fill materials and through fill across watercourses are found in seven standards (Section 923.2(d, e, f, g, j, m, and u)), while requirements for drainage and watercourse crossings are covered in eight standards (Section 923.2(h, n, o, p, q, r, s, and t)). Finally, road construction is prohibited in WPLZs, except for watercourse crossings, and exceptions must be clearly specified in the plan (Section 923.2(u)).

As with tractor roads, the FPRs require that locations of all road-stream crossings (both permanent and temporary) be identified on the plan map. If the crossing structure is a culvert, the plan must also identify the minimum size intended for use. Permanent crossings that are new or upgraded must accommodate 100-year flow events (as well as accompanying sediment and debris loads); must not impeded upstream and downstream passage of fish or listed aquatic species during any life stage; and must accommodate the natural movement of bedload to form a continuous bed through the length of the culvert.

Road maintenance and abandonment regulations are designed to minimize runoff, erosion, and landslides. The required maintenance period for erosion control structures on roads and landings is at least one year, and may be extended up to three years. In T or I Rule watersheds, a maintenance period of three years is required [14 CCR § 1050]. Prior to the winter period, watercourse crossings not sufficient to handle 50-year flood events must be removed and temporary roads must be closed to vehicle traffic. Roads being properly abandoned (i.e., decommissioned) must meet standards specified in five requirements found in Section 923.8. These provisions include blocking roads to prevent recreational traffic, stabilizing the road surface by grading or shaping roads to adequately drain water and prevent erosion, and removing watercourse crossings.

3.2.4 *Colorado*

Colorado has more than 20 million acres of forest but only about 3 million acres of non-federal productive forest suitable for timber production. Forest inventory data show substantial timber volumes in the state; however, growth and harvest rates are very low (USDA-FS 2004).

In 1998, in partnership with the Colorado Timber Industry Association, the Colorado State Forest Service developed BMPs to protect water quality. The BMPs are known as Forest Stewardship Guidelines (FSGs) and are implemented using a non-regulatory approach that emphasizes landowner education and logger training. The FSGs are based in part on Montana's forest management guidelines (CO FS 1998).

Colorado's FSGs are in six broad categories: forest roads, streamside management, wildfire, timber harvesting, hazardous substances, and stream crossings. Each category contains several subcategories with recommendations.

3.2.4.1 *Forest Roads*

Recommended BMPs for forest roads begin with effective pre-harvest planning, design, and location. When existing roads cannot be used or are not suitable, the FSG calls for planning the location of new roads before harvesting operations begin in order to reduce "unnecessary road construction and limit the extent of roads." Other BMPs include locating roads on natural benches and along contours; avoiding steep grades for prolonged periods; establishing roads on stable geology; and avoiding slide-prone areas. Colorado's BMPs also recommend that roads avoid wet areas, minimize the number of stream crossings, and plan the placement of crossings to minimize potential for water quality impacts. Finally, the FSG recommends that roads incorporate water diversion structures to control drainage and limit erosion.

Road construction BMPs focus on methods to control erosion and stabilize slopes created during the construction process. One primary mechanism for controlling erosion is to balance cut and fill materials, or use full bench construction where stable fill construction is not possible. The FSG recommends constructing cut and fill slopes at stable angles, with a 3:1 slope the maximum recommended on stable slopes and soils. Erodible areas should be stabilized by seeding, mulching, or any other method to minimize sediment movement off the road surface. The FSG also provides numerous recommendations for controlling sediment movement from borrow pits and overburdened disposal areas.

Recommendations for road drainage center on BMPs for both outsloped and insloped roads and road drainage structures. The two predominant recommendations are 1) to vary road grades to reduce flow in roadside ditches, in culverts, on fill slopes, and on road surfaces; and 2) to design roads for minimal disruption of drainage patterns. Guidelines for installation of road drainage structures are general in nature but recommend that energy dissipators (rock piles, logs, etc.) be used to slow sediment movement and that drainage water be routed through areas where sediment can settle out before reaching a waterbody. Practices recommended for road closure include limiting access (e.g., gating, placing an earthen berm at road access points, etc.) and utilizing appropriate drainage control structures on roads (e.g., crowning, out-sloping, in-sloping, and water bars).

3.2.4.2 *Streamside Management Zones*

The Colorado State Forest Service recommends streamside management zone (SMZ) widths of at least 50 ft (15 m) for perennial and intermittent streams. However, the manual advises that SMZ widths should be extended to include all riparian areas along a stream and where steep slopes and erodible soils are present. Management is allowed within SMZs with two recommendations: 1) leave hardwoods and unmerchantable conifers and shrubs in the SMZ; and 2) leave merchantable trees if

basal area is not sufficient to stabilize the stream bank or to provide large woody debris to the stream channel. The Colorado State Forest Service recommends use of directional felling in SMZs and leaving sufficient ground cover to trap sediment.

3.2.4.3 *Timber Harvest and Silvicultural Chemicals*

Timber harvesting BMPs for Colorado provide recommendations for use of skid trails and placement of landings. The number of landings should be minimized in order to reduce the number of skid trails needed, and water diversion techniques should be used to control erosion. Specific recommendations on how to construct water bars and their recommended spacing are provided (Table 3.7). Managers are also advised to avoid skidding logs up steep grades (>40%). Reforestation BMPs are brief, but recommend removal of all trash from the site and general precautions if prescribed burning is going to be used. For herbicide and pesticide applications, BMPs recommend that an adequate buffer zone be utilized to ensure protection of surface waters. The manual recommends a buffer at least 150 ft (46 m) wide. Other recommendations include applying chemicals using the manufacturer's recommended rate and during favorable weather conditions (i.e., calm winds and dry days).

3.2.4.4 *Stream Crossings*

When planning a stream crossing, Colorado BMPs recommend that managers account for soils, stream size, stream bank and bottom characteristics, road approach conditions, cost of construction, and the amount of use a stream crossing will experience. Bridges, culverts, and fords are applicable stream crossing structures; however, the FSG discourages use of the latter because they can repeatedly disturb the stream bed. Recommendations for crossings are general in nature but advocate enabling fish passage during all types of flow, crossing streams at right angles (when practical), using culverts with 18 in (46 cm) minimum diameters for permanent streams, and constructing as few stream crossings as necessary.

Table 3.7 Colorado's Recommended Linear Distance (ft/m) for Spacing of Water Bars on Roads and Skid Trails [adapted from Colorado's Forest Stewardship Guidelines (CO FS 1998]

Road or Trail Slope (%)	Unstable Soils (High Erosion Hazard) ----- ft (m) -----	Stable Soils (Low Erosion Hazard) ----- ft (m) -----
2	135 (41)	170 (52)
5	100 (30)	140 (43)
10	80 (24)	115 (35)
15	60 (18)	90 (27)
20	45 (14)	60 (18)
+25	30 (9)	40 (12)

3.2.5 *Idaho*

The Idaho Forest Practices Act (IFPA) was adopted in 1974 to "…assure the continuous growing and harvesting of forest trees and to maintain forest soil, air, water, vegetation, wildlife, and aquatic habitat" (ID DOL 2000). The IFPA requires forest practices rules for both state and private lands, while federal forestland management must meet or exceed the requirements of state rules. The IFPA

created an advisory board consisting of forest landowners, operators, citizens, and environmental and fisheries experts to recommend forestry guidelines to the State Land Board.

The IFPA requires that forest managers obtain a Certificate of Slash Compliance, or "brush number," and submit a Forest Practice Notice if operations fall into one of five categories: 1) timber harvesting and related road construction; 2) road construction and reconstruction away from the harvesting area but associated with harvesting; 3) reforestation; 4) application of chemicals for forest management purposes; or 5) management of slash resulting from harvest, management, or improvement of forest tree species, and use of prescribed fire. Activities exempt from Forest Practice Notice requirements include routine road maintenance, recreational uses, non-commercial cuttings, and any preparatory work such as tree marking, surveying and road flagging.

No forest management plan is required at the time of filing a Certificate of Slash Compliance or Forest Practice Notice. Forest management activities may begin upon Idaho Division of State Lands (IDL) acceptance of the notification. Notification is valid for the management period; however, expired notifications must be renewed before the practice can continue. Filing for an extension and other changes in a notification must be done within 30 days by the person who filed the original notification.

The IDL has Forest Practice Advisors at offices across the state. These individuals provide information and technical assistance to forestland owners and managers who have questions regarding forestry BMPs. When forest management operations violate the IFPA and corrective measures are not made in a reasonable time period, the IDL has authority to take enforcement actions against responsible parties.

Idaho's BMPs are in five categories: streamside management, stream crossings, roads, timber harvest, and hazardous substances (ID DOL 2000). Within these categories, there are several minimum standards that landowners and land managers are required to meet or exceed under the IFPA.

3.2.5.1 *Stream Classification*

Waterbody classification has important roles in Idaho's BMPs. Class I streams and lakes support all or part of a fish species' habitat requirements (i.e., spawning, rearing, or migration) or are used as domestic water supplies. Class II waterbodies generally refer to headwater streams or minor drainages. Class I and Class II streams are roughly equivalent to perennial and intermittent streams, respectively.

3.2.5.2 *Stream Protection Zones*

Stream protection zones (SPZs) are at least 75 ft (23 m) wide on each side of a Class I stream, measured from the ordinary high water mark (OHWM) or definable bank. The minimum SPZ on Class II streams is 30 ft (9 m) from the OHWM. When Class II streams do not drain into Class I streams, the minimum SPZ is 5 ft (2 m). Idaho recommends that the widths of SPZs for both stream types be adjusted to include wetland and riparian areas and to provide additional protection near steep slopes or highly erosive areas.

Limited management is allowed within Idaho's SPZs. Recommendations include leaving at least 75% of existing shade adjacent to streams, limiting disturbance to residual standing trees, and maintaining sufficient ground cover to trap sediment efficiently. To achieve these objectives, managers should keep mechanized harvesters and forwarders out of SPZs, use directional felling away from streams, and use cable or tree length yarding techniques to limit soil disturbance and reduce slash in SPZs. Additional topics addressed in SPZ guidelines include conifer harvesting, regeneration, and influences on SPZ hydrology.

Tree retention guidelines for Class 1 streams apply to standing conifers, hardwoods, and snags within 50 ft (15 m) of the OHWM (Table 3.8). These guidelines vary depending on stream width but generally define minimum numbers of standing trees in each of four diameter classes per 1,000 ft (305 m) of stream length. A snag can be counted as a standing tree as long as snag height is more than 1.5 times the distance from the snag to the OHWM. However, no more than 50% of the residual standing trees in any diameter class can be snags.

Tree retention guidelines for Class II streams are intended to provide soil stabilization and water filtering. These guidelines require retention of at least 140 standing trees (diameter ≥3 inches) per 1,000 ft of stream length within 30 ft (9 m) of the OHWM (Table 3.8). This requirement applies only to Class II streams that flow into Class I streams; i.e., there is no requirement to retain standing trees along Class II streams that do not flow into Class I waterbodies.

Table 3.8 Minimum Standing Tree Requirements for Idaho's Class I and Class II Streams. [adapted from the Idaho Forest Practices Act (ID DOL 2000)]

	Class I			
Tree Diameter	Stream Width >20 ft (>6 m)	Stream Width 10 to 20 ft (3 to 6 m)	Stream Width <10 ft (<3 m)	Class II
3 to 7.9 in (8 to 20 cm)	200	200	200	140
8 to 11.9 in (20 to 30 cm)	42	42	42	-
12 to 19.9 in (30 to 51 cm)	21	21	-	-
+20 in (+51 cm)	4	-	-	-

Land managers may submit a request to IDL for a site-specific riparian management prescription for use instead of standard retention guidelines. IDL and the manager then may jointly develop an SPZ management plan that considers stream characteristics and the need for woody debris recruitment, stream shading, and wildlife habitat features.

3.2.5.3 *Roads*

Idaho's BMPs for forest roads address planning, design, and location; construction; drainage; maintenance; and retirement. It is recommended that managers plan roads to the minimum standards necessary to meet their intended uses and minimize construction of new road networks. Existing roads should be used when possible. New roads should have the minimum width necessary consistent with safety and operational objectives. Roads should be located outside of SPZs and the number of stream crossings should be minimized.

Idaho has many BMPs for road construction. Examples include limiting the amount of soil excavated; using excavated soil for fill; and using mulch or seeding to stabilize highly erosive areas.

Road drainage BMPs are intended to maintain road stability and control sediment delivery to streams. Idaho's BMPs emphasize designing roads to 1) minimize disruption of natural drainage patterns and 2) enable effective management of concentrated flows. Road drainage features (e.g., cross-drains, culverts, water bars, and dips) should direct concentrated flows into sediment traps (e.g., catch basins), vegetated areas, slash piles, or other areas that promote sediment settling structures. The spacing between drainage features should be small enough to ensure that peak discharge flows "will not exceed the capacity of the individual drainage facility." Insloped roads should "plan ditch gradients steep enough, generally greater than 2%, but less than 8% to prevent sediment deposition and ditch erosion," and drain dips should be constructed "deep enough into the sub-grade so that traffic will not obliterate them."

Idaho's BMPs also emphasize the importance of maintaining road surfaces and drainage structures and of avoiding use of roads in wet or saturated conditions. Closed roads should be crowned, outsloped, insloped, or cross-ditched, closed to vehicular traffic, and mulched or seeded if necessary.

3.2.5.4 *Stream Crossings*

The Stream Channel Protection Act of 1971 (Title 42, Chapter 38 Idaho Code) requires a permit from the Idaho Department of Water Resources (IDWR) for "any alterations within the beds and banks of continuously flowing natural streams in Idaho." Constructing permanent and temporary stream crossing structures including fords, culverts, bridges, rip-rapping, or other bank stabilization techniques requires a permit. When filing a joint application for use with the IDWR (and, if necessary, IDL and U.S. Army Corps of Engineers) an applicant must include a description of the structure, information on its location, and why the structure is needed. The application evaluation process may also require a field visit by IDWR personnel.

Design considerations for culverts get the most attention in Idaho's BMP manual. The state requires culverts that can handle 50-year peak flows, have at least an 18 in (46 cm) diameter (except in the upper Snake River Basin, where a 15 in (38 cm) minimum is allowed), and allow fish passage on all Class I streams. Guidelines for culvert sizes are based on watershed area and are differentiated among the northern (Table 3.9) and southern (Table 3.10) regions of the state. In cases where culverts in excess of 6 ft (2 m) in diameter are necessary, they must be designed by a professionally trained hydrologist. Other required culvert BMPs include placing culverts slightly below normal stream grade to avoid culvert outfall barriers and limiting disturbances upstream from the culvert to prevent blockage.

Table 3.9 Culvert Sizing Table Requirements Used in Northern Idaho and the Salmon River Drainage [adapted from the Idaho Forest Practices Act (ID DOL 2000)]

Watershed Area ac (ha)	Required Culvert Diameter in (cm)	Capacity $ft^3\ sec^{-1}$ ($m^3\ sec^{-1}$)
<32 (<13)	18 (46)	6 (0.2)
33 – 74 (13 – 30)	24 (61)	12 (0.4)
75 – 141 (30 – 57)	30 (76)	20 (0.6)
142 – 240 (57 – 97)	36 (91)	32 (0.9)
241 – 366 (97 – 148)	42 (107)	46 (1.3)
367 – 546 (148 – 221)	48 (122)	65 (1.8)
547 – 787 (221 – 319)	54 (137)	89 (2.5)
788 – 1027 (319 – 416)	60 (152)	112 (3.2)
1028 – 1354 (416 – 548)	66 (168)	142 (4.0)
1355 – 1736 (548 – 703)	72 (183)	176 (5.0)
1737 – 2731 (703 – 1105)	84 (213)	260 (7.4)
2732 – 4111 (1105 – 1664)	96 (244)	370 (10.5)
4112 – 5830 (1664 – 2359)	108 (274)	500 (14.2)
5831 – 8256 (2359 – 3341)	120 (305)	675 (19.1)

Table 3.10 Culvert Sizing Requirements Used in Southern Idaho [adapted from the Idaho Forest Practices Act (ID DOL 2000)]

Watershed Area Ac (ha)	Required Culvert Diameter in (cm)	Capacity $ft^3\ sec^{-1}$ ($m^3\ sec^{-1}$)
<72 (<29)	18 (46)	6 (0.2)
73 – 150 (29 – 61)	24 (61)	12 (0.4)
151 – 270 (61 – 109)	30 (76)	20 (0.6)
271 – 460 (109 – 186)	36 (91)	32 (0.9)
461 – 720 (186 – 291)	42 (107)	46 (1.3)
721 – 1025 (291 – 415)	48 (122)	65 (1.8)
1026 – 1450 (415 – 587)	54 (137)	89 (2.5)
1451 – 1870 (587 – 757)	60 (152)	112 (3.2)
1871 – 2415 (757 – 977)	66 (168)	142 (4.0)
2416 – 3355 (977 – 1358)	72 (183)	176 (5.0)
3356 – 5335 (1358 – 2159)	84 (213)	260 (7.4)
5336 – 7410 (2159 – 2999)	96 (244)	370 (10.5)
7411 – 9565 (2999 – 3871)	108 (274)	500 (14.2)
9566 – 11780 (3871 – 4767)	120 (305)	675 (19.1)

3.2.5.5 *Silvicultural Chemicals*

Use of silvicultural pesticides and fertilizers is permissible in Idaho as long as managers comply with federal and state regulations (Idaho Pesticide Law, Tide 22, Chapter 34, Idaho Code) governing the storage, handling, application (including licensing of applicators), and disposal of hazardous substances. BMPs for chemicals include these provisions: 1) chemical applications in SPZs should be made by hand (e.g., using a backpack sprayer) and only to specific targets; 2) a 25 ft (8 ft) buffer from surface waters is required when chemicals are applied using ground-based power equipment; and 3) a buffer of at least 100 ft (30 m) is required for aerial applications.

Idaho's BMPs recommend use of integrated pest management approaches to weed and pest control, including manual, biological, mechanical, and chemical means. When chemical applications are warranted, they should be made during appropriate weather conditions (calm winds and dry air) and at the optimum time to control the target pests.

3.2.6 *Montana*

In July 1989, the Montana Forestry Technical Committee published an initial set of statewide forestry BMPs. The recommendations were updated in 1997 and published in Montana's Nonpoint Source Management Plan (MT DEQ 2001). A recent update of forestry BMPs occurred in January 2006. BMP categories include forest roads, timber harvesting and site preparation, stream crossings, winter logging, and hazardous substances (Rogers 2007).

For the most part, Montana's BMPs encourage adherence to general principles and guidelines for controlling NPS pollution. Guidelines related to SMZs are more prescriptive and are intended to ensure that managers implement land management practices that comply with Montana's 1991 Streamside Management Zone Act (SMZA) (MCA 77-5-301 through 307).

3.2.6.1 *Stream Classification*

Montana classifies streams into three categories. Class I stream segments support fish, normally have surface flow during six months of the year, or contribute surface water flows to other waterbodies. Class II segments are streams that are not classified as either Class I or Class III, and do not support fish. These stream segments have surface flows for six months or more and do not contribute flow to waterbodies, or have surface flow less than six months and contribute flow to waterbodies. Class III stream segments do not support fish and rarely contribute to surface flows to downstream waters.

3.2.6.2 *Streamside Management Zones*

SMZA regulates commercial harvesting in or near streamside areas. It requires SMZs along all streams, with buffer width dependant on sideslope steepness and presence of adjacent wetlands. The Act defines an SMZ as "a stream, lake, or other body of water and an adjacent area of varying width where management practices that might affect wildlife habitat or water quality, fish, or other aquatic resources need to be modified. The SMZ encompasses a strip at least 50 ft (15 m) wide on each side of a stream, lake, or other body of water, measured from the ordinary high water mark (OHWM), and extends beyond the OHWM to include wetlands and areas that provide additional protection in zones with steep slopes or erosive soils."

SMZ boundaries are determined by measuring along the slope of the SMZ perpendicular to the waterbody from the OHWM to a point 50 ft distant. SMZs must be expanded beyond 50 ft as necessary to include wetlands that are adjacent to waterbodies. When slopes adjacent to Class 1 or Class 2 streams are >35%, widths are adjusted as follows: 1) where a bench is present between 50 and 100 ft (15 and 30 m) the SMZ shall extend to the edge of the bench closest to the stream segment; 2) where a road occurs between 50 and 100 ft (15 and 30 m) the SMZ shall extend to the toe of the road

fill; and 3) where no road or bench is present the SMZ shall be at least 100 ft (30 m) in width. For Class III stream segments the width will be at least 50 ft (15 m) for SMZs with slopes >35%.

The SMZA prohibits certain activities within the SMZ that can be summarized as the "seven don'ts":

- Don't build roads in the SMZ except to cross a stream.
- Don't sidecast road fill in streams during road maintenance operations.
- Don't broadcast burn in the SMZ.
- Don't handle or use hazardous chemicals in the SMZ in a manner that pollutes streams.
- Don't operate mechanical equipment within at least 50 ft (15 m) of any stream, lake, or other body of water.
- Don't clearcut within the SMZ.
- Don't deposit slash in streams.

The Montana Department of Natural Resources and Conservation (DNRC) must approve any exceptions to these prohibited practices. It must also be notified prior to the start of any forest practice, and any requests to conduct an alternative practice must be submitted to the appropriate DNRC field office. Alternative practices require an environmental review, and all requests are reviewed and commented on within ten days of submission.

Use of equipment in SMZs is prohibited except on established roads and under certain exceptions. When SMZ widths extend more than 50 ft (15 m) from the OHWM to encompass adjacent wetlands, harvesting with mechanized equipment is permissible so long as this equipment remains 50 ft (15 m) from the stream, and harvesting is done during winter conditions with adequate snow or frozen ground and operation of equipment does not cause ground disturbance. On Class III streams, mechanized equipment can cross the SMZ (and the waterbody it surrounds) at locations spaced approximately 200 ft (61 m) apart in order to limit road construction and skid trails. Additionally, when logs are cable-yarded across Class I and II waterbodies, the logs must be fully suspended unless otherwise allowed under the Natural Streambed and Land Preservation Act of 1975 (MCA 75-7-101).

The SMZA prohibits clearcutting of SMZs and any type of selective harvest within the first 50 ft (15 m) beyond the OHWM. For Class I waterbodies, treatments must retain 50% of trees ≥8 in (≥20 cm) dbh or ten trees ≥8 in (≥20 cm) dbh, whichever is greater, in each 100 ft (30 m) of the SMZ. For Class II waterbodies, 50% of trees ≥8 in (≥20 cm) dbh or five trees ≥8 in (≥20 cm) dbh, whichever is greater, must be retained in each 100 ft (30 m) of the SMZ. Shrubs and sub-merchantable trees must be protected as much as possible for the full width of the SMZ for Class I, II, and III waterbodies. Trees retained in the SMZ must be representative of the size and species of the pre-harvest stand.

Road construction in SMZs is prohibited except to cross waterbodies. The construction of roads across waterbodies is not regulated by the SMZA but is regulated by the Natural Streambed and Land Preservation Act when it affects a perennial stream. Within the SMZ, fill deposition is only allowed for the purpose of crossing a waterbody. Specific requirements are also provided in the SMZA for road construction in the eastern zone of Montana, which has unique geomorphic channel conditions and highly erodible soils.

Under the Natural Streambed and Land Preservation Act, also known as the 310 Law, any activity that results in the physical alteration or modification of a perennial stream (including the streambed and stream banks) must be approved in advance by the local conservation district. Permanent and temporary crossing structures and bank stabilization measures are subject to 310 permits. Landowners

or managers must submit a permit application to the local conservation district that includes the location of the crossing, a description of its type, and how it will be installed. A field visit is often part of the review process.

Other provisions in the SMZA cover hazardous/toxic materials, side-casting of soils, and slash deposition. The Act prohibits handling, storage, application, or disposal of hazardous or toxic materials within SMZs "in ways that might impact water quality." Applications of herbicides and pesticides are permitted in SMZs but must be done so that these chemicals do not enter a waterbody. Applications of herbicides must not severely impact vegetation in the SMZ "to an extent which impairs the capacity of the SMZ to provide shade or act as an effective sediment filter." Additionally, side-casting road material into SMZs during road and stream crossing construction and depositing slash into streams is prohibited.

3.2.7 *Nevada*

Nevada has less than 10 million acres of forestland, of which less than 100,000 acres is non-federal productive forest suitable for timber production. Growing stock volumes and timber harvest volumes in Nevada are by far the lowest among the western states (Ice et al. 2004).

Despite low levels of timber production, silvicultural activities in Nevada are strictly regulated by the Nevada Forest Practice Act (NFPA) of 1955 (Nevada Revised Statute, Chapter 528) and the state's Diffuse Source Law. Prior to any logging operation, landowners or managers must secure a permit from the State Forester Fire Warden. Permit applications are made at Division of Forestry field offices and must be supported by a detailed logging plan. Information contained in the logging plan should include, but is not limited to 1) topographical maps showing exterior boundaries of the areas to be logged and existing and proposed roads, structures, and landings;(2) volume of timber to be removed; 3) time required for harvest; 4) percentage of merchantable volume to be harvested and composition of residual stands (if any); 5) a revegetation plan (if applicable); 6) slash disposal and cleanup plans; 7) road construction and erosion control measures; 8) fire prevention plans and procedures; and 9) tools and equipment suitable and available for fire fighting, as well as the number of men available for fire fighting.

In addition to the timber harvesting plan, Nevada requires a performance bond to ensure satisfactory compliance with NFPA. The amount of the performance bond is set by the State Forester Fire Warden and is based on the contract price or value of the timber to be cut. Commercial timber harvesting is minimal in the state and is almost always near Lake Tahoe. As a result, it is subject to increased public scrutiny (Ice et al. 2004). Timber harvests in that area are also subject to regulation by the Tahoe Regional Planning Agency and must adhere to the agency's rules. There have been no defaults on the performance bonds in recent years.

Topics addressed in NFPA regulations include cutting practices away from waterbodies (NRS 528.050), activities prohibited near waterbodies (NRS 528.053), and control of erosion from management activities (NRS 528.055). Activities prohibited near waterbodies include felling of trees, skidding, construction of roads or landings, and operation of vehicles within 200 ft (61 m) of a waterbody. This distance is measured from the high water mark of any waterbody unless a variance is first obtained from a committee composed of the State Forester Fire Warden, the Director of the Department of Wildlife, and the State Engineer.

To control erosion, water breaks or culverts are required for all roads, skid trails, and firebreaks no later than November 15 of each year. Water breaks and culverts must be located to discharge into areas with minimal fill and sufficient water filtering capacity to remove sediment. Distances between these structures should be small enough to prevent significant soil erosion by surface flows. Guidelines for water break or culvert intervals are as follows: 100 to 200 ft (30 to 61 m) on slopes

≤10%; 75 to 150 ft (23 to 46 m) on slopes 11 to 25%; 50 to 100 ft (15 to 30 m) on slopes 26 to 49%; and 30 to 75 ft (9 to 23 m) on slopes ≥50%. Exceptions may be appropriate where road drainage and erosion are controlled effectively by other methods such as outsloped road surfaces and placement of slash to retard water movement (NRS 528.0552, 528.0553, and 528.0554). Seeding of roads, trails, and landings is required at the completion of harvesting operations.

3.2.8 *New Mexico*

New Mexico's Forest Conservation Act (FCA) (NMSA 68-2-1 to 68-2-25) was adopted in 1978 and revised in 2002. Statutory authority for enforcement is given to the Energy, Minerals, and Natural Resources Department, Forestry Division (DOF).

FCA requires permits for commercial timber harvests (harvests that cover 25 ac, 10 ha or more). Harvest permits are not required for pre-commercial thinning and operations smaller than 25 ac (10 ha). A Forest Harvest Practice Plan must be developed to provide descriptions of harvest and erosion management measures that include skid trails, landings and roads, streamside management areas, slash treatment, fire, and areas where excessive slopes are present. Adherence to the New Mexico forest practice rules is required regardless of the size of the operation (NM EMNRD-DOF 2002).

DOF may issue a notice of deficient condition for violations of the FCA or harvest permit conditions where violations cause harm to the forest or forest resources, and will require the responsible party to cease the violation and take corrective action to repair the deficient condition. Criminal penalties for violating the FCA or a filed harvest permit are also possible. Violations are misdemeanors punishable by fines up to $1000(US), imprisonment up to one year, or both for each violation.

3.2.8.1 *Streamside Management Areas*

Requirements for streamside management areas (SMAs) are discussed in NM 19.20.4.9.G. SMAs include areas within 50 ft (15 m) of the OHWM of all perennial and intermittent waterbodies. Adjustments to SMA widths are recommended to account for slope or other features (Table 3.11). When a pre-existing road is within 50 ft (15 m) of the OHWM, the SMA must end at the road's edge closest to the waterbody. Disturbance in SMAs should be minimized by limiting skidder traffic and road construction. No new roads can be constructed within an SMA unless permission is granted by DOF. Harvests within SMAs must use directional felling and leave enough hardwood, unmerchantable conifers, and shrubs to provide sufficient shading to avoid adverse temperature changes in lakes or watercourses.

3.2.8.2 *Timber Harvest*

Harvest practice standards are intended to "minimize channelized flow erosion," which includes rill and gully erosion (NM 19.20.4.9(D)). Erosion control measures must be in place following a harvest as soon as possible and no later than 30 days post-harvest. Seeding is required within 180 days following harvest for areas of exposed mineral soils. Guidelines in this section also cover the minimum spacing requirements for water bars and other erosion control structures found on roads, skid trails, and landings (Table 3.12).

Table 3.11 Streamside Management Area Widths for New Mexico's Watercourses [adapted from New Mexico Forest Practices Guidelines (NM EMNRD-DOF 2002)]

Slope above Stream (%)	SMA Width ft (m)
0	50 (15)
10	70 (21)
20	90 (27)
30	110 (34)
40	130 (40)
50	160 (49)
60	180 (55)
70	200 (61)

Table 3.12 New Mexico Minimum Recommended Water Bar Spacing Requirements [adapted from New Mexico Forest Practices Guidelines (NM EMNRD-DOF 2002)]

Road Grade (%)	Spacing Interval ft (m)
0 – 4.9	150 (46)
5.0 – 9.9	130 (40)
10.0 – 14.9	75 (53)
15.0 – 24.9	50 (15)
25.0 – 40.0	25 (8)

3.2.8.3 *Skid Trails and Landings*

Requirements for skid trails and landings (NM 19.20.4.9.D) focus on limiting erosion and disturbance of watercourses. Skid trails are not to be located on excessive slopes and must be established in a manner that limits disturbances to a stream channel and bank. Skidding is prohibited within any watercourse and across perennial waterbodies. Exceptions to the latter must be approved by DOF. Skidder crossings of perennial watercourses must be at right angles to the main channels and drainage may not enter streams as a result of crossings. Landings should be planned in advance of harvest and must have adequate drainage that eliminates discharge from a watercourse.

3.2.8.4 *Forest Roads*

The FCA has eight specific guidelines for forest roads (NM 19.20.4.9.F). Erosion control measures require that roads be outsloped or ditched on the uphill side and have appropriate drainage features such as cross drains, drivable dips, water bars or other structures demonstrated to be effective at limiting erosion. Requirements for spacing of cross drains are shown in Table 3.13.

Roads are required to be as narrow as possible and may not exceed 24 ft (7 m) in width. The guidelines for locating, designing, and constructing roads are general in nature but advise that they not be located on slopes >60% and that road grades be kept to a minimum (usually <10%). Culverts must handle, at a minimum, 25-year flood events. Culvert size is determined using the "Hasty Method," which calculates the cross-sectional area of the culvert needed (Table 3.14). Erosion control measures must be in place and stream crossing structures should be removed when roads are closed.

Table 3.13 Recommended Spacing for Water Bars and Grade Dips on Roads in New Mexico[1]
[adapted from New Mexico Forest Practices Guidelines (NM EMNRD-DOF 2002)]

Location of road	North & East Aspects									South & West Aspects								
	Top 1/3 of Slope			*Middle 1/3 of Slope*			*Bottom 1/3 of Slope*			*Top 1/3 of Slope*			*Middle 1/3 of Slope*			*Bottom 1/3 of Slope*		
Parent Material[2]	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F
Slope (%)	ft (m)									ft (m)								
80	145 (44)	121 (37)	95 (29)	127 (39)	103 (31)	77 (24)	109 (33)	85 (26)	59 (18)	129 (39)	105 (32)	79 (24)	111 (34)	87 (27)	61 (19)	93 (28)	69 (21)	43 (13)
70	140 (43)	116 (35)	90 (27)	122 (37)	98 (30)	72 (22)	104 (32)	80 (24)	54 (17)	124 (38)	100 (30)	74 (23)	106 (32)	82 (25)	56 (17)	88 (27)	64 (20)	38 (16)
60	135 (41)	111 (34)	85 (26)	117 (36)	93 (28)	67 (20)	99 (30)	75 (23)	49 (15)	119 (36)	95 (29)	69 (21)	105 (32)	77 (24)	51 (16)	83 (25)	59 (18)	33 (10)
50	130 (40)	106 (32)	80 (24)	112 (34)	88 (27)	62 (19)	94 (29)	70 (21)	44 (13)	114 (35)	90 (27)	64 (20)	96 (29)	72 (22)	46 (14)	78 (24)	54 (17)	28 (9)
40	125 (38)	101 (31)	75 (23)	107 (33)	83 (25)	57 (17)	89 (27)	65 (20)	39 (19)	109 (33)	85 (26)	59 (18)	91 (28)	67 (20)	41 (13)	73 (22)	49 (15)	23 (7)
30	120 (37)	96 (29)	70 (21)	102 (31)	78 (24)	52 (16)	84 (26)	60 (18)	34 (10)	104 (32)	80 (24)	54 (17)	86 (26)	62 (19)	36 (11)	68 (21)	44 (13)	18 (6)
20	115 (35)	95 (29)	65 (20)	97 (30)	73 (22)	47 (14)	79 (24)	55 (17)	29 (9)	99 (30)	75 (23)	49 (15)	81 (25)	57 (17)	31 (10)	63 (19)	39 (12)	13 (4)
10	110 (34)	86 (26)	60 (18)	92 (28)	68 (21)	42 (13)	74 (23)	50 (15)	24 (7)	94 (29)	70 (21)	44 (13)	76 (23)	52 (16)	26 (8)	58 (18)	34 (10)	8 (2)

[1] Spacing recommendations in table are based on a road grade of 4%. Adjustments for other road grades are as follows: for a road grade of 2%, add 15 ft (5 m); for a road grade of 6%, subtract 8 ft (2.4 m); for a road grade of 8%, subtract 15 ft (5 m); and, for a road grade of 10%, subtract 24 ft (7 m).
[2] Parent materials are classified according to texture of surface soils. C=coarse, M=medium, F=fine

Table 3.14 Cross-Sectional Area and Diameter of Round Culverts Required for Streams in New Mexico [adapted from New Mexico Forest Practices Guidelines (NM EMNRD-DOF 2002)]

Cross-Sectional Area ft^2 (m^2)	Culvert Diameter in (cm)
1.25 (0.12)	15 (38)
1.80 (0.17)	18 (46)
3.10 (0.29)	24 (61)
4.90 (0.46)	30 (76)
7.10 (0.66)	36 (91)
9.60 (0.89)	42 (107)
12.60 (1.17)	48 (122)
15.90 (1.48)	54 (137)
19.60 (1.82)	60 (152)
23.80 (2.21)	66 (168)
33.20 (3.08)	78 (198)
38.50 (3.58)	84 (213)
44.20 (4.11)	90 (229)

3.2.9 *Oregon*

Forestry operations on non-federal lands in Oregon are regulated under the state Forest Practices Act (FPA) and Forest Practice Administrative Rules (FPRs). The FPA was first adopted in 1971. Recent revisions to the FPA and FPRs went into effect January 1, 2006 (Oregon Administrative Rules 629, Division 600 – 680).

The Oregon Board of Forestry has sole authority to develop and enforce statewide FPRs (OR DOF 2006). Under the direction of the Board, the Oregon Department of Forestry (ODF) conducts several regulatory and non-regulatory programs, including a Forest Practices Monitoring Program (FPMP) that provides information about the adequacy of the FPA and FPRs and how to improve them.

The FPRs include broad, statewide requirements as well as rules that must be implemented on a site-specific basis. The former include requirements related to notification. ODF must be notified at least 15 days prior to beginning forestry operations such as harvesting, thinning, site preparation, road construction, and chemical applications. Notifications include basic information about the type of operation, its location, and the parties involved. ODF reviews notifications to determine whether a site inspection or technical assistance visit is necessary to avoid potential water quality problems.

Other topics addressed in broad, statewide rules include slash disposal, forest chemicals, and harvest size. Site-specific rules cover reforestation, forest roads, timber harvesting, streamside areas, sensitive wildlife habitat, and scenic highways. BMPs for these site-specific activities are discussed in more detail below.

3.2.9.1 *Stream Classification*

Water protection rules for riparian management areas (RMAs) are found in Division 635. Required BMPs for RMAs are based on stream and wetland types. Oregon classifies streams into one of three beneficial use categories. Streams that have fish are classified as Type F. Streams that do not have fish but are used as domestic water supplies are Type D. All other streams are Type N.

Type N streams are further classified as perennial (Np) or seasonal (Ns). These two stream types are generally referred to as headwater streams (Danehy and Ice 2007).

In addition to beneficial use categories, Oregon has three size categories of streams based on average annual flow. Small streams have average annual flows of 2 ft^3/sec (0.06 m^3/sec) or less; medium streams have average annual flows between 2 and 10 ft^3/sec (0.06 and 0.28 m^3/sec); and large streams have average annual flows of 10 ft^3/sec (0.28 m^3/sec) or greater.

3.2.9.2 *Riparian Management Areas (RMAs)*

Widths of RMAs for streams are based on stream type and stream size (Table 3.15). Minimum widths are determined as "a slope distance from the high water level (HWL) of main channels" and, in general, range from 20 to 100 ft (6 to 30 m). RMA widths must be expanded beyond the minimum to entirely include any stream-associated wetland or side channels plus an additional 25 ft (8 m). This additional provision is not required for small Type N streams.

Table 3.15 Riparian Management Area Widths for Type F, D, or N Streams in Oregon [adapted from Oregon Forest Practices Act (OR DOF 2006)]

	Type F	Type D	Type N
	---------- ft (m) ----------		
Large	100 (30)	70 (21)	70 (21)
Medium	70 (21)	50 (15)	50 (15)
Small	50 (15)	20 (6)	See OAR 629-640-0200

Management activities in RMAs must comply with requirements that depend on stream type, geographic region, tree stocking and species composition in RMAs, and the type of harvest operation being conducted outside the RMA (Tables 3.16 and 3.17). Type 1 harvests require reforestation and do not require wildlife leave trees outside the RMA. A reforestation requirement is triggered when a harvest "leaves a combined stocking level of free-to-grow seedlings, saplings, poles and larger trees that is less than the stocking level established by rule of the board which represents adequate utilization of the productivity of the site." Type 2 harvests require wildlife leave trees outside of the RMA but do not require reforestation because of adequate post-harvest combined stocking of free-to-grow seedlings, saplings, poles and larger trees. Minimum leave tree requirements for Type 2 harvests depend on site class. For site Classes I, II, and III (annual growth ≥120 ft^3/ac, 8.4 m^3/ac), the leave tree requirement per acre is at least 50 trees with dbh of 11 in (28 cm) or an equivalent basal area in larger trees. For site Classes IV and V, the requirement per acre is at least 30 trees with 11 in (28 cm) dbh or an equivalent basal area in larger trees per acre. For site Class VI, the requirement per acre is at least 15 trees with dbh 11 in (28 cm) or an equivalent basal area in larger trees. A Type 3 harvest is a management scheme that requires reforestation and wildlife leave trees (OAR 629-640-0000).

For Type F streams, managers must retain all understory vegetation within 10 ft of the high water line (HWL), all trees within 20 ft (6 m) of the HWL, and all trees leaning over the channel. All downed wood and snags must be retained within the RMA. Requirements also exist for conifer leave trees in RMAs: at least 40 live conifer trees per 1000 ft (305 m) along large streams and 30 live conifers for every 1000 ft (305 m) along medium streams. All leave trees must be ≥ 11 in (28 cm) for large Type F streams, and ≥ 8 in (20 cm) dbh for medium Type F streams. Additional requirements for leave trees and/or snags are noted in OAR 629-640-0100(6) for both large and medium Type F streams, and

additional geographic region-specific requirements are found in OAR 629-640-0100(7) and OAR 629-640-0100(8) (Tables 3.16 and 3.17). In addition, OAR 629-640-0110 provides information on live tree retention credits for improving Type F streams. In general, for each conifer log placed into large or medium Type F streams, the basal area credit is twice the basal area of the log placed.

As with Type F streams, guidelines for Type D and large and medium Type N streams include retention of all understory vegetation within 10ft (3m) of the HWL and all trees within 20ft (6m) of the HWL. All trees leaning over the channel as well as downed woody debris and snags must be retained in these stream RMAs. Managers must retain at least 30 conifers per 1000 ft (305 m) along large Type D and Type N streams and 10 live conifers per 1000 ft (305 m) along medium Type D and Type N streams. Prescription requirements for leave trees vary by region and harvest type. Requirements by region for Type D and large and medium Type N streams are shown in Tables 3.18 and 3.19.

ODF determines where a small Type N stream is perennial (Np) or seasonal (Ns) on the basis of an expectation about whether or not the stream will have surface flows after July 15. Managers are encouraged to retain understory vegetation and non-merchantable conifers (i.e., conifer trees <6 in, 15 cm dbh) within 10 ft (3 m) of the HWL of small Np streams and must keep equipment out of small Np and Ns channels. Tree retention in the RMZs of these streams may be required to protect unstable areas, tributary junctions, and areas prone to debris torrents.

3.2.9.3 *Significant Wetlands and Lakes*

Water protection rules for significant wetlands and lakes are explained in Divisions 645 and 650, respectively. RMAs 100 ft wide are required for significant wetlands other than estuaries, bogs, seeps and springs. Managers must follow requirements for a resource site evaluation outlined in OAR 629-665-0020. When forest management operations may affect a significant wetland, a written management plan must be submitted to ODF for review. The plan must include information on reforestation prescriptions; retention of live trees, snags and understory vegetation; and measures to protect soil and hydrologic functions.

RMAs for lakes are measured from the HWL. Required RMA widths are 100 ft (30 m) for large lakes (>8 ac / 3.2 ha) and 50 ft (15 m) for other lakes that have fish use or that are ≥0.5 ac (0.2 ha) in size. No RMA is required for lakes that do not have fish and are <0.5 ac (<0.2 ha) in size.

Guidelines for RMAs around wetlands and lakes require retention of approximately 50% of the original live trees, by species, in each of the following dbh classes: 6 to 10 in (15 to 25 cm), 11 to 20 in (28 to 51 cm), 21 to 30 in (53 to 76 cm), and >30 in (>76 cm) for significant wetlands and lakes. Managers also must retain trees bordering significant wetlands and minimize disturbance to understory vegetation during harvest operations.

Table 3.16 Requirements for Tree Retention in RMAs along Type F Streams in Oregon: Type 2 or Type 3 Harvest Units [adapted from Oregon Forest Practices Act (OR DOF 2006)]

	Basal Area per 1000 ft (305 m) of Stream, Each Side					
	Large Type F RMA = 100 ft (30 m)		Medium Type F RMA = 70 ft (21 m)		Small Type F RMA = 50 ft (15 m)	
Geographic Region	Standard Target	Active Mgmt Target[1]	Standard Target	Active Mgmt Target	Standard Target	Active Mgmt Target
	ft^2 (m^2)					
Coast Range & S. Coast	230 (21)	170 (16)	120 (11)	90 (8)	40 (3.7)	20 (1.9)
Interior & W. Cascade	270 (25)	200 (19)	140 (13)	110 (10)	40 (3.7)	20 (1.9)
Siskiyou	220 (20)	170 (16)	110 (10)	90 (8)	40 (3.7)	20 (1.9)
E. Cascade & Blue Mtn.	170 (16)	130 (12)	90 (8)	70 (6.5)	50 (4.6)[1]	50 (1.6)[2]

[1]Active Management Target applies in certain situations where RMA management promotes improvement in habitat conditions for fish (e.g., where harvesting in hardwood-dominated RMAs promotes conifer development).

Table 3.17 Requirements for Tree Retention in RMAs along Type F Streams in Oregon: Type 1 Harvest Units [adapted from Oregon Forest Practices Act (OR DOF 2006)]

	Basal Area per 1000 ft (305 m) of Stream, Each Side					
	Large RMA = 100 ft (30 m)		Medium RMA = 70 ft (21 m)		Small RMA = 50 ft (15 m)	
Geographic Region	Standard Target	Active Mgmt Target	Standard Target	Active Mgmt Target	Standard Target	Active Mgmt Target
	ft^2 (m^2)					
Coast Range & S. Coast	300 (28)	270 (25)	160 (15)	140 (13)	50 (4.6)	30 (2.8)
Interior & W. Cascade	350 (33)	310 (29)	180 (17)	160 (15)	50 (4.6)	30 (2.8)
Siskiyou	290 (27)	260 (24)	140 (13)	120 (11)	50 (4.6)	30 (2.8)
E. Cascade & Blue Mtn.	220 (20)	200 (19)	120 (11)	100 (9)	50 (4.6)[1]	50 (4.6)[2]

[1]Maximum live conifer tree basal area that must be left is 40 ft^2 (3.7 m^2). The remaining basal area may come from snags, dying or recently dead trees, or hardwood trees if available within the RMA.
[2]Live conifer basal area may be reduced to 30 ft^2 (2.8 m^2) for the active management target. The remaining part of the basal area requirement must come from snags, dying or recently dead trees, or hardwood trees if available within the RMA.

Table 3.18 Requirements for Tree Retention in RMAs along Type D Streams as well as Large and Medium Type N Streams in Oregon: Type 2 and Type 3 Harvest Units
[adapted from Oregon Forest Practices Act (OR DOF 2006)]

	Basal Area (ft^2) per 1000 ft (305 m) of Stream, Each Side		
	Large Type D & N RMA = 70 ft (21 m)	Medium Type D & N RMA = 50 ft (15 m)	Small Type D RMA = 20 ft (6 m)
	Standard Target	Standard Target[1]	Standard Target
Geographic Region	---------- ft^2 (m^2) ----------		
Coast Range & S. Coast	90 (8)	50 (4.6)	0
Interior & W. Cascade	110 (10)	50 (4.6)	0
Siskiyou	90 (8)	50 (4.6)	0
E. Cascade & Blue Mtn.	70 (6.5)	50 (4.6)	0

[1]Hardwoods may count up to 30 ft^2 (2.8 m^2) per 1000 ft (305 m) of meeting the standard target.

Table 3.19 Requirements for Tree Retention in RMAs along Type D Streams as Well as Large and Medium Type N Streams in Oregon: Type 1 Harvest Units
[adapted from Oregon Forest Practices Act (OR DOF 2006)]

	Basal Area per 1000 ft (305 m) of Stream, Each Side		
	Large Type D & N RMA = 70 ft (21 m)	Medium Type D & N RMA = 50 ft (15 m)	Small Type D RMA = 20 ft (6 m)
	Standard Target	Standard Target[1]	Standard Target
Geographic Region	---------- ft^2 (m^2) ----------		
Coast Range & S. Coast	140 (13)	60 (5.6)	0
Interior & W. Cascade	160 (15)	60 (5.6)	0
Siskiyou	120 (11)	60 (5.6)	0
E. Cascade & Blue Mtn.	100 (9)	60 (5.6)	0

[1]Hardwoods may count up to 30 ft^2 (2.8 m^2) per 1000 ft (305 m) of meeting the standard target.

3.2.9.4 *Treatment of Slash*

Rules regarding treatment of slash establish requirements for mechanical site preparation and prescribed burning (Division 615). The purpose of these rules is to minimize risks to water quality that may occur while recognizing that management of slash is necessary to prepare sites for future planting.

When using mechanical site preparation, managers shall avoid RMAs and "provide adequate distance between disturbed soils and water of the state to filter sediment." Mechanical site preparation is prohibited where erosion is visible (e.g., gullies), where soil exposure or compaction may occur, and on slopes > 35%. Exceptions to the slope restriction may apply during dry periods.

Uses of prescribed fire must comply with Oregon's Smoke Management Plan and follow guidelines for protecting waterbodies. When using prescribed fire, managers are required to describe in a written plan how impacts to waterbodies will be minimized. Plans are required when burning within 100 ft (30 m) of Type F and Type D streams, within 100 ft (30 m) of large lakes, or within 300 ft (91 m) of significant wetlands.

3.2.9.5 *Pesticides and Fertilizers*

Oregon's FPRs include several requirements related to pesticides. Chemicals may only be applied under weather conditions that are favorable with respect to water quality protection. Managers must keep daily records of pesticide applications, and notification of pesticide use is required under some circumstances. Aerial applications shall not occur within 60 ft (18 m) of significant wetlands, Type F and Type D streams, large lakes, other lakes with fish use, or areas of standing open water larger than 0.25 ac (0.1 ha) in size. Aerial applications must be parallel to the waterbody when made within 100 ft (30 m). When applying chemicals on the ground, managers must provide a 10 ft (3 m) buffer for each of the aforementioned areas.

Managers are not permitted to apply fertilizers within 100 ft (30 m) of streams used as water supplies. Fertilizers must not be applied directly to large areas of standing water or to aquatic areas of Type F and D streams, large and medium Type N streams, large lakes, and lakes with fish use.

3.2.9.6 *Landslides*

Forest management operations in areas with high landslide hazard must comply with water quality and public safety regulations including a requirement to submit a written plan and comply with special restrictions on road construction and ground-based harvesting (Division 623). Plans must identify potential landslide areas, exposure categories, impact ratings, and safety risks from forest management (623-0100 through 623-0500). In addition, managers must implement stream protection measures to "… reduce or eliminate woody debris loading, and to retain large standing trees in locations where they might slow debris torrent movement along debris torrent-prone streams…" (OAR 629-623-0600). Where a substantial or intermediate risk to public safety exists, managers are required to 1) fell trees in a way that minimizes slash accumulations in torrent-prone stream channels; 2) remove slash piles from stream channels; and 3) protect large standing leave trees along likely depositional reaches. Leave trees must be larger than 20 in (51 cm) dbh, within 50 ft (15 m) of the active channel, and left for a distance of at least 300 ft (91 m) or the depositional length of the channel, whichever is less.

3.2.9.7 *Road Construction, Maintenance, and Stream Crossings*

Forest practice rules on road construction, stream crossings, and road maintenance are found in Division 625. The primary requirement is notification and submission of written plans for roads. To ensure that roads are properly located, designed, and constructed, management plans must be

submitted to the State Forester before beginning any activity outlined in 625-0100(2) through (4). Recommended road measures include limiting their use on steep or erosive areas where water quality impacts may result, minimizing the number and length of roads by using existing roads when feasible, and limiting the number of stream crossings. When constructing new roads, managers must design roads only as wide as necessary and minimize the use of cut and fill materials to reduce landslide risks.

Requirements for road drainage seek to limit alteration of stream channels and delivery of sediment to waterbodies. Drainage structures should be located based on the following priority: 1) drainage shall not be concentrated into headwalls, slide areas, landslide hazard locations, or erodible fill-slopes; 2) waters shall not be diverted from stream channels into roadside ditches; 3) dips, water bars, or cross-drain culverts will be installed above and away from stream crossing structures; 4) drainage structures must be used when roads cross springs, seeps, or other wet areas; and 5) the drainage system will use grade reversals, insloping or outsloping, ditches, culverts, or water bars as necessary to limit the development of gully erosion on the road surface. When retiring a road, managers are required to block access and take reasonable actions to ensure that runoff and erosion will not enter waterbodies. Reasonable actions may include removal of stream crossing fills, pullback of fill on steep slopes, frequent cross ditching, and seeding or mulching.

For stream crossing structures, including culverts, bridges, and fords, managers must minimize excavation of side slopes near the channel, minimize the volume of fill materials used for a crossing, and use stabilization methods (e.g., seeding, mulching, gravel) that prevent erosion of the fill material and the stream channel. For fills over 15 ft (5 m) deep, however, the chance of erosion and blow-out is high; therefore, mangers must submit a written plan that describes the amount of fill needed and the design of the drainage structure to be used. At a minimum, all stream crossings must pass 50-year peak flows. For culverts, additional requirements include that the culvert must not pond water at the inlet and must allow migration of adult and juvenile fish, both upstream and downstream, during conditions “when fish movement in that stream normally occurs.” Routine inspection and maintenance of crossings is required to ensure adequate passage of water and fishes. Other fish passage requirements for stream crossing structures may fall under the authority of other state agencies not associated with the Oregon Board of Forestry (ORS 498.268 and 509.605).

3.2.9.8 *Harvesting*

The purpose of the FPRs for harvesting (Division 630) is to establish requirements for forest management that will maintain site productivity, minimize soil and debris entering waterbodies, and protect wildlife and fish habitat. To limit water quality impacts, managers should avoid skidding and yarding logs on wet, easily compacted, or unstable soils. Skid trails should be kept to a minimum and located on stable soils, while yarding operations should be limited to uphill whenever practical. Downhill yarding operations should have mechanisms in place that limit soil erosion and transport.

On steep slopes (>60%) and on slopes >40% with highly erosive soils, managers are subject to the provisions outlined in Sections (4) through (9) in 630-0150. Some key requirements related to water quality in these steeply sloping areas include locating skid trails at least 100 ft (30 m) from waterbodies, avoiding establishment of skid trails straight up and down slopes, and using cross-drain structures.

Landings should have effective drainage structures installed both during and after logging. Additional requirements for landings include keeping them outside RMAs, limiting their size, and locating them on stable soils.

Drainage requirements for roads and skid trails include using drainage dips, grade reversals, or other structures to channel water away from waterbodies and through vegetated areas. Retired skid trails should have water bars installed.

Several requirements for ground-based harvesting equipment near waterbodies are outlined in OAR 630-0800. The purpose of these regulations is to limit disturbances to stream beds and banks when utilizing temporary skidder stream crossings. Mechanized equipment is prohibited in any stream channel except where an appropriate temporary stream crossing structure is used. Managers should also limit the number of stream crossings.

When crossing streams that hold surface waters during harvest, mangers shall use structures that withstand erosion and minimize sedimentation, choose locations for crossings that minimize cuts and fills, use temporary structures that do not impact fish movement on Type F streams, and remove all temporary crossings following completion of management operations. A written plan submitted to the State Forester is required (OAR 630-0800(c)) when fills over 8 ft (2 m) deep are needed for temporary crossings.

Managers must minimize the number of skid trails in RMAs and, except at stream crossings, must not locate trails within 35 ft (11 m) of Type F or Type D streams. On temporary stream crossing approaches, the use of effective sediment barriers (e.g., water bars, diversion dips) is required to limit erosion after completing the harvest or prior to the rainy season.

3.2.10 *Utah*

Utah's Non-Point Source Management Plan was amended in 1998 to include Forest Water Quality Guidelines (Forest Water Quality Guidelines) to protect surface water quality. The guidelines are similar to BMPs used in Colorado and Montana.

The Utah state legislature passed the Utah Forest Practice Act (UFPA) in 2001. The UFPA established procedures for registration of forest operators and procedures for notifying state officials of plans to conduct forest management activities. Operators are required to complete and submit a registration form provided by the Department of Natural Resources, Division of Forestry, Fire, and State Lands. The operator is assigned a registration number and informed of the date the registration expires. Registration is valid for a period of two years. Notifications must be sent to Division headquarters or one of six area offices at least 30 days prior to commencement of forest operations. BMPs are referred to as Forest Water Quality Guidelines (UT DNR-DFFSL 2002).

3.2.10.1*Stream Classification*

Forestry BMPs depend on waterbody classification (Class I or Class II). Class I waterbodies meet one of more of the following criteria: used for any part of a fish's lifecycle; used as domestic water supply; or perennial streams that contribute significant flow to downstream fisheries. Streams that do not meet these criteria are defined as Class II streams. Indicators of Class II streams include presence of a defined channel and banks; presence of an Ordinary High Water Mark (OHWM); and continuous or intermittently flowing water.

3.2.10.2*Streamside Management Zones*

SMZ widths for Class I and II streams are based on the OHWM on each side of the stream and are adjusted for slope. Minimum recommended SMZ widths for Class I streams are 75 ft (23 m) for slopes <35% and 100 ft (30 m) for slopes >35%. Recommended Class II SMZ widths are 35 ft (11 m) and 50 ft (15 m) for slopes <35% and >35%, respectively. In addition, a 15 ft (5 m) undisturbed strip that begins at the OHWM is recognized within the SMZ. Management is allowed within the SMZ except in the undisturbed strip, and should leave an adequate number of trees (in all age/size classes)

and understory vegetation to provide shade and a source of large woody debris. Minimum shading recommendations for Class I streams is 50 ft^2 (4.7 m^2) of basal area or 50% canopy cover. Class II streams require 25 ft^2 (2.3 m^2) of basal area or 25% canopy cover for shading.

3.2.10.3 *Forest Roads, Skid Trails, and Stream Crossings*

FWQGs recommend planning road locations prior to harvest in order to limit their number as well as the number of stream crossings needed. Road construction recommendations are for cut and fills, shaping road surfaces, and water diversion structures. On slopes greater than 60%, excavated (cut) material should not be side cast to create a fill slope. Fill should only be used when slopes are 50% or less and should be compacted. Slopes should also be seeded as soon as possible to limit erosion.

Recommended designs for crowned, insloped, and outsloped roads are provided in the FWQG. Surface drainage structures may include broad-based dips, turnouts (diversion ditches), water bars, and cross-drain culverts. FWQGs recommend that broad-based dips be used on roads with grades of <10% and that they be spaced a minimum of 150 ft (46 m) apart. Turnouts should be graded on a 2-3% slope to allow constant drainage of water and sediment into forest vegetation. Cross-drain culverts should be used on insloped roads and be sized to handle a 25-year, 24 hr storm event on temporary road crossings and a 50-year, 24 hr storm event for permanent road crossings. Water bars should be 2 ft (0.6 m) deep by 3 to 4 ft (0.9 to 1.2 m) wide at an angle of 30-45 degrees across the road. Spacing recommendations for each of these water diversion techniques are in Table 3.20.

The primary recommendation for skid trails in Utah's FWQG is that they occupy no more than 15% of a harvest area. Skidding directly up and down slopes is not recommended, and where possible trails should be kept on grades <15%. On steep grades (>15%), water diversion structures such as water bars should be used. FWQGs for landings include avoiding placement in or near SMZs, minimizing number and size, and diverting any runoff away from waterbodies.

Culverts should be sized to handle a 25-year, 24 hr storm event on temporary stream crossings and 50 yr, 24 hr storm event for permanent stream crossings. The minimum culvert diameter recommended is 15 in (38 cm). Culvert size is based on stream cross-sectional area. The streambed in a ford should have a firm rock bottom, water depths should be <3 ft (<0.9 m), and road approaches should be stabilized with non-erodible material.

Table 3.20 Distance between Water Diversion Structures Recommended for Roads in Utah [adapted from Utah's Forest Water Quality Guidelines (UT DNR-DFFSL 2002)]

Road Grade %	Spacing ft (m)
2	250 (76)
5	135 (41)
10	80 (24)
15	60 (18)
20	45 (14)
25	40 (12)
30	35 (11)
40	30 (9)

3.2.10.4 *Chemical Applications*

The FWQGs note that managers must follow label instructions for chemical applications and recommends applying chemicals only when wind speeds are <5 mph (<8 kph). Special care is recommended to avoid applications near or directly into waterbodies.

When chemicals are applied aerially, a 75 ft (23 m) buffer (in addition to the SMZ requirements) is recommended. Mechanical applications should provide an additional 25 ft (8 m) buffer. For hand applications, chemicals should be applied only to specific targets and overspray should not occur near waterbodies.

3.2.11 *Washington*

The Forest Practices Board adopts forest practices rules (FPRs) for Washington State. The FPRs give directions on how to implement the Forest Practices Act (Chapter 76.09 RCW) and Stewardship of Non-Industrial Forests and Woodlands (Chapter 76.13 RCW). The FPRs establish minimum standards for forest management practices such as harvesting, road construction, fertilization, and forest chemical applications. In addition, water quality protection rules must be approved by the Department of Ecology prior to Board adoption.

The Timber, Fish, and Wildlife Agreement, finalized in 1987, established regulations and procedures for cooperatively managing the state's private and state timberlands. Parties to the agreement included private landowners, Native American tribes, state agencies, and environmental groups. With regard to water quality, this rule expanded protection for riparian areas and increased regulations on use of forest chemicals. In 2001, the original Timber, Fish, and Wildlife stakeholder group was expanded to include federal agencies and the FPRs were overhauled to address federal requirements for protection of freshwater habitats under the Endangered Species Act and for water quality under the Clean Water Act (Ice et al. 2004).

Washington FPRs were established in 1975 and have been revised considerably, with significant changes related to water quality protection occurring in 1987, 1992, and 2001 (Holter 2001; Ice et al. 2004). Revisions in 2005 and 2006 addressed several topics including FPR practices and procedures; policy and organization; watershed analysis; timber harvesting; reforestation; application and notification requirements; and road construction and maintenance.

The Forest Practices Board Manual (FPBM) serves as an advisory technical supplement to the forest practices rules, Title 222 WAC (WA DNR 2007). This report summarizes requirements laid out in the FPR and FPBM for timber harvesting (including riparian and wetland management zones), forest roads (including stream crossings), and forest chemicals.

3.2.11.1 *Classification Schemes for Waterbodies and Forests*

FPR requirements laid out in the FPBM depend on Washington's classification schemes for waterbodies, forests, and management activities. There are five types of waterbodies (WAC 222-16-031). Type 1 waters are all waters of the state within their "ordinary high water marks" inventoried as "shorelines of the state." In general, these are large, fish-bearing waterbodies (i.e., rivers). Type 2 waters are segments of natural waters not classified as Type 1 with high fish or human use. Type 3 waters are segments of waterbodies that have moderate to slight fish or human use. Type 4 waters are perennial non-fish-bearing streams. Finally, Type 5 waters are non-fish-bearing intermittent waterbodies.

In the future, Washington will use a permanent water typing system that will classify waterbodies as Type S, Type F, and Type N, with Type N waters further classified as Np or Ns waters (WAC 222-16-030). Type Np waters are perennial non-fish habitat streams. Type Ns waters are seasonal, non-fish habitat streams where flow is not present for at least some portion of a year under normal rainfall conditions. Even though this classification system is still being developed, the text herein refers to the permanent water typing system. Conversions comparing the two systems are shown in Table 3.21.

Table 3.21 Washington State Conversion Table for Permanent and Interim Water Types

Interim Water Typing	Permanent Water Typing
Type 1 Water	Type S
Type 2 & 3 Water	Type F
Type 4 Water	Type Np
Type 5 Water	Type Ns

Forests are classified by site quality and region. Site classes I through IV have been established for eastern and western Washington using the state soil survey.

All forest operations must follow requirements of the FPRs, but the scrutiny and length of review for a proposed operation depends on the management activity class (WAC 22-16-050). Class I practices are management schemes that have been determined to have no direct potential for impacting public resources such as water quality. Class II forest practices have been determined to have a less than ordinary potential to damage public resources. Class III forest practices are those not contained in Class I, II, or IV. Class IV includes two subcategories. Class IV–Special covers several types of practices that have potential to cause substantial impacts and must be conducted in accordance with requirements of the State Environmental Policy Act. Class IV–General covers practices conducted on certain types of land including sites that are not being reforested due to conversion to non-forest use.

3.2.11.2 *Western Washington Riparian Management Zones*

Washington's FPRs include very detailed and specific requirements for riparian management zones (RMZs). There are substantial differences in RMZ requirements between western Washington and eastern Washington.

In eastern Washington, RMZs for Type S and F Waters have three zones: 1) the core zone nearest the waterbody; 2) the inner zone in the middle of the RMZ; and 3) the outer zone. In general, all timber harvest is prohibited in core zones except during construction of stream crossings and associated road segments. Trees cut during construction may be removed from the site; however, trees damaged or cut by yarding activities must be left on site.

Management activities in inner zones of RMAs must meet or exceed stream shade requirements and RMA stand requirements necessary to achieve the goal in WAC 222-30-010(2): "to protect aquatic resources and related habitat to achieve restoration of riparian function; and maintenance of these resources once restored." Stand requirements refer to conditions considered necessary to achieve desired future conditions and include numbers of trees per acre, basal area per acre, and proportion of conifers in the combined inner zone (core zone plus inner zone).

Required RMZ dimensions vary depending on site class, bankfull width of the waterbody, and management harvest option to be utilized in the inner zone.

- Managers must use a no-harvest option when minimum RMZ stand requirements are not present in the combined inner zone. RMZ width requirements for this option are shown in Table 3.22
- Management Option 1 involves thinning from below, i.e., harvesting smaller diameter trees with the objective of accelerating the growth of larger residual trees and thus reducing the time required to achieve desired future conditions related to large wood inputs to streams, fish habitat, and water quality. RMZ width requirements for Option 1 are the same as for no management (Table 3.22). Thinning cannot decrease the proportion of conifer species in the stand and the number of residual conifers in the inner zone must be ≥57 per acre. Shade retention guidelines must be met for any harvest within 75 ft (23 m) of the outer edge of the stream's bankfull width or the outer edge of a channel migration zone (CMZ), whichever is greater. A CMZ is the area in which an active stream channel is prone to move.
- Management Option 2 involves retaining trees closest to the stream. This option may be used only in 1) RMZs for site classes I through III on streams that are ≤10 ft (≤3 m) wide, and 2) RMZs in site classes I and II for streams >10 ft (>3 m) wide. RMZ width requirements for Option 2 are shown in Table 3.23. Additional requirements in Option 2 include the following.
    - For streams ≤10 ft (≤3 m) wide, harvesting is not permitted within 30 ft (9 m) of the core zone.
    - For streams >10 ft (>3 m) wide, harvesting is not permitted within 50 ft (15 m) of the core zone.
    - A minimum of 20 conifers ≥ 12 in (30 cm) dbh per acre must be retained in the inner zone, and trees must be harvested starting at the outermost portion of the inner zone and progressively inward toward the waterbody.

Timber harvests in RMZs of Type S and Type F streams must leave ≥20 trees per acre in the outer zone. Retained trees may be dispersed or clumped.

- In a dispersal strategy, retained trees must be conifers ≥ 12 in (30 cm) dbh scattered throughout the outer zone.
- There are two clumping strategies.
    - Trees ≥ 8 in (20 cm) dbh can be clumped around sensitive features (seeps, springs, forested wetlands, etc.). Trees can be hardwoods or conifers.
    - If sensitive features are not present, clumps must be distributed throughout the outer zone and retention trees must be conifers ≥12 in (30 cm) dbh.

Table 3.22 Minimum RMZ Widths for Western Washington: No Management and Option 1 [adapted from the Washington Forest Practices Board Manual (WA DNR 2007)]

Site Class	RMZ Width ft (m)	Core Zone Width[1] ft (m)	Inner Zone Width[2] ft (m) Stream Width ≤10 ft (≤3 m)	Inner Zone Width[2] ft (m) Stream Width >10 ft (>3 m)	Outer Zone Width[3] ft (m) Stream Width ≤10 ft (≤3 m)	Outer Zone Width[3] ft (m) Stream Width >10 ft (>3 m)
I	200 (61)	50 (15)	83 (25)	100 (30)	67 (20)	50 (15)
II	170 (52)	50 (15)	63 (19)	78 (24)	57 (17)	42 (13)
III	140 (43)	50 (15)	43 (13)	55 (17)	47 (14)	35 (11)
IV	110 (34)	50 (15)	23 (7)	33 (10)	37 (11)	27 (8)
V	90 (27)	50 (15)	10 (3)	18 (6)	30 (9)	22 (7)

[1]Core zone width is measured form the outer edge of bankfull width or outer edge of CMZ of water.
[2]Inner zone width is measured from the outer edge of the core zone.
[3]Outer zone width is measured from the outer edge of the inner zone.

Table 3.23 Minimum RMZ Widths for Western Washington: Option 2 [adapted from the Washington Forest Practices Board Manual (WA DNR 2007)]

Site Class	RMZ Width	Core Zone Width[1]	Inner Zone Width[2] Stream Width ≤10 ft (≤3 m) MFD[4]	Inner Zone Width[2] Stream Width ≤10 ft (≤3 m) MFD[4]	Inner Zone Width[2] Stream Width >10 ft (>3 m) MFD[4]	Inner Zone Width[2] Stream Width >10 ft (>3 m) MFD[4]	Outer Zone Width[3] Stream Width ≤10 ft (≤3 m)	Outer Zone Width[3] Stream Width >10 ft (>3 m)
	---------- ft (m) ----------						----- ft (m) -----	
I	200 (61)	50 (15)	84 (26)	30 (9)	84 (26)	50 (15)	66 (20)	66 (20)
II	170 (52)	50 (15)	64 (20)	30 (9)	70 (21)	50 (15)	56 (17)	50 (15)
III	140 (43)	50 (15)	44 (13)	30 (9)	**	**	46 (14)	**

[1]Core zone width is measured form the outer edge of bankfull width or outer edge of CMZ of water.
[2]Inner zone width is measured from the outer edge of the core zone.
[3]Outer zone width is measured from the outer edge of the inner zone.
[4]MFD = Minimum floor distance.
**Option 2 for site class III streams >10 ft (3 m) is not permitted because of the minimum floor constraint (100 ft, 30 m)

RMZ requirements for Type N streams in western Washington begin with an equipment limitation zone that is at least 30 ft (9 m) wide measured from bankfull width of all perennial and seasonal streams. Additional requirements to establish no-harvest buffers apply to Np streams. The width of a required no-harvest buffer on an Np stream is always 50 ft, but the length of the buffer depends on 1) the total length of the Np stream, and 2) distance of a harvest unit containing an Np stream segment from the confluence of the Np stream with a Type S or Type F stream. Many additional requirements are outlined in WAC 222-30-021(2ii-vi).

3.2.11.3 *Eastern Washington Riparian Management Zones*

In eastern Washington, riparian zone management is intended to provide stand conditions that vary over time and mimic disturbance regimes common on the eastside of the state. Eastside RMZs are measured from the outer edge of a stream's bankfull width or CMZ (whichever is greater) and extend to the limits described in Tables 3.24 and 3.25.

Type S and F streams have three zones: core, inner, and outer zones. The RMZ core zone extends 30 ft (9 m) for all timber habitat types and is measured from the edge of the bankfull stream width or the edge of the channel migration zone, whichever is wider. No timber harvest is allowed except operations related to forest road construction and stream crossings. Trees cut for these activities may be removed from the site; however, trees damaged or cut by yarding activities must be left on site.

The width of the inner zone from the edge of the core zone depends on stream size: 70 ft on streams with bankfull width >15 ft (>5 m); and 45 ft (14 m) on streams with bankfull widths < 15 ft (5 m) (Tables 3.24 and 3.25). Management requirements for inner zones vary among habitat types, which include Ponderosa pine, mixed conifer stands, and high elevation forests (WAC 222-30-022(1)(i through iii).

Outer zone widths range from 0 to 55 ft (0 to 17 m) for Type S and F streams depending on site classification and stream width (Tables 3.24 and 3.25). Management requirements for the outer zone vary among habitat types. Tree retention requirements in low elevation types are expressed in terms of numbers of dominant/co-dominant trees per acre: 15 for Ponderosa pine, 10 for mixed conifers. For high elevation habitat types, requirements for western Washington RMZs apply (WAC 222-30-021(1)(c)). Adjustments to the leave tree requirements can be made if a large woody debris placement plan is approved.

RMZ requirements for Type Np and Ns streams include an equipment limitation zone at least 30 ft (9 m) from the outer edge of the bankfull width. For Type Np waters, tree retention requirements in a 50 ft RMZ depend on cutting method used in the adjacent harvest.

- For partial harvests, retention requirements in outer zones depend on habitat type and are the same as in inner zones. Other retention requirements depend basal area requirements include accounting for stream-adjacent parallel roads, leaving the 10 largest trees per acre, and leaving up to 40 trees per acre ≥10 in (≥25 cm) dbh. Protection of sideslope seeps is also required, with a 50 ft (15 m) partial cut buffer measured from the outer perimeter of the perennially saturated soil zone.

- For clearcut harvests, a no harvest buffer must be delineated along 50% of the length of Np streams. This buffer must meet the basal area requirements for each of the timber habitat types specified in WAC 222-30-022(1)(b)(i through iii). The clearcut portion of an Np stream boundary must not exceed 30% of the total length of the Np stream; not exceed 300 continuous feet (91 m) in length; not be located within 500 ft (152 m) of a Type S or Type F water; and not occur within 50 ft (15 m) of a sensitive area as defined in WAC 222-16-010.

Table 3.24 RMZ Width Requirements in Eastern Washington: Streams with Bankfull Widths ≤15 ft (≤5 m) [adapted from the Washington Forest Practices Rules (Chapter 222-30 WAC)]

Site Class	Total RMZ Width	Core Zone Width	Inner Zone Width	Outer Zone Width
	ft (m)			
I	130 (40)	30 (9)	45 (14)	55 (17)
II	110 (34)	30 (9)	45 (14)	35 (11)
III	90 (27)	30 (9)	45 (14)	15 (5)
IV	75 (23)	30 (9)	45 (14)	0
V	75 (23)	30 (9)	45 (14)	0

Table 3.25 RMZ Width Requirements in Eastern Washington: Streams with Bankfull Widths >15 ft (>5 m) [adapted from the Washington Forest Practices Rules (Chapter 222-30 WAC)]

Site Class	Total RMZ Width	Core Zone Width	Inner Zone Width	Outer Zone Width
	ft (m)			
I	130 (40)	30 (9)	70 (21)	30 (9)
II	110 (34)	30 (9)	70 (21)	10 (3)
III	100 (30)	30 (9)	70 (21)	0
IV	100 (30)	30 (9)	70 (21)	0
V	100 (30)	30 (9)	70 (21)	0

3.2.11.4 *Wetland Management Zones*

Washington's wetland typing system is used to identify areas that require a wetland management zone (WAC 222-16-035). Wetlands are broadly classified as forested or non-forested. Non-forested wetlands are classified as Type A wetlands if they are greater than 0.5 ac (0.2 ha) in size and associated with at least 0.5 ac (0.2 ha) of standing or open water. Type B wetlands refer to all other non-forested wetlands greater than 0.25 ac (0.1 ha). For a wetland to be considered forested, it must have (or would have if the trees were mature) a crown closure of 30% or more.

Wetland management zones (WMZs) apply to all Type A and B wetlands. Requirements depend on the size of the wetland and its type (Table 3.26). A total of 75 leave trees per acre must be retained within a WMZ with the following provisions: in western Washington, diameters must be greater than 6 in (15 cm); in eastern Washington, diameters must be greater than 4 in (10 cm). When feasible, wildlife reserve trees should be retained. Partial or patch-cutting is permissible as long as openings do not exceed 100 ft (30 m), and openings must be spaced not be closer than 200 ft (61 m). Ground-based mechanized equipment shall not be used without permission and harvests must follow guidelines set out in WAC 222-30-010(7)(f).

Table 3.26 Wetland Management Zones Required in Washington
[adapted from the Washington Forest Practices Rules (Chapter 222-30 WAC)]

Wetland Type	Non-forested Wetland Area		Maximum WMZ Width	Average WMZ Width	Minimum WMZ Width
	ac	ha	ft (m)	---------- ft (m) ----------	
A (including bogs[1])	>5	2	200 (61)	100 (30)	50 (15)
A (including bogs)	0.5 to 5	0.2 to 2	100 (30)	50 (15)	25 (8)
A (bogs only)	0.25 to 5	0.1 to 2	100 (30)	50 (15)	25 (8)
B	>5	2	100 (30)	50 (15)	25 (8)
B	0.5 to 5	0.2 to 2			25 (8)
B	0.25 to 5	0.1 to 2	NR	NR	

[1]For bogs, both forested and non-forested acres are included
[2]NR = not required.

3.2.11.5 *Forest Roads, Landings and Water Crossings*

Requirements for forest roads are found in WAC Chapter 222-24 Road Construction and Maintenance. The chapter covers requirements not only for roads, but for landing location and construction and water crossing structures. The requirements are a guide so that roads do not interfere with fish passage at all life stages, result in mass wasting, or cause runoff and sediment transport into typed waters. Furthermore, roads should divert runoff away from typed waters and into areas with adequate access to the forest floor and crossings should provide passage of woody debris downstream and protect stream integrity.

There are 22 requirements for the location and design of roads (WAC 222-24-020). Among these are BMPs for stream-adjacent parallel roads, construction on side slopes, road width, and water diversion practices. Except for crossings, newly constructed stream-adjacent parallel roads (within 200 ft, 61 m of typed waters) must not be located within natural drainages, CMZs, sensitive sites, equipment limitation zones, or RMZs when impacts to fish and wildlife habitat may occur. Forest management proposals that include plans to construct new stream-adjacent parallel roads must have onsite reviews to evaluate compliance with the Endangered Species Act. In addition, roads within 200 ft (61 m) of typed waters should have adequate sediment control BMPs that include seeding, armoring ditches, catch basins, temporary sediment traps, and rocking road surfaces near crossings. Roads constructed on side slopes (>60%) must utilize full bench construction techniques when a potential for water quality impairment exists. Road widths should average <32 ft (<10 m) for two lane roads and <20 ft (<6 m) for single lane roads. Recommendations for water diversion practices on forest roads include in-sloping, out-sloping, and crowning. The use of sub-grade roads is not recommended, as this practice does not adequately drain water off the road.

Drainage structures referred to in the FPBM cover BMPs for relief culverts, dips, water bars, drainage diversions, ditch-outs (i.e., turnouts), ditches, and energy dissipators. Each of these methods has specific, detailed requirements for installation. General priorities include 1) installing structures as close as possible to streams; 2) installing drainage structures in natural drainage areas; 3) preventing water diversions from one basin to another; and 4) placing structures at low points on the road profile. Additional drainage structures may be needed where ditch water delivers sediment to typed waters, scouring is visible in a ditch, and ditch flow rates exceed the capacity of cross-drain or relief culverts.

When abandoning roads, the BMP goals are to re-establish natural drainage and to leave the road prism in a condition that will not negatively impact water quality. The road prism is the area of ground containing the road surface, cut slope, and fill slope. Installation of self-maintaining drainage structures is recommended. This includes removing relief culverts, earthen berms or dips, and loosening soils on roads to promote re-vegetation. Water bars should be installed to intercept ditch flows and to direct outflows into stable, vegetated areas. When removing water crossing structures, managers must meet Forest Practice Application/Notification (FPA/N) and Hydrologic Project Approval (HPA) (if necessary) requirements, re-establish the natural streambed as close as possible to original conditions, and stabilize stream banks.

Landings can be sources of sediment to typed waters due to runoff and mass failures (i.e., landslides). WAC 222-24-035(1) requires that forest managers "locate landings to prevent potential or actual damage to public resources." In other words, avoid excessive excavation and filling when establishing landings. Landings shall not be located within natural drainage channels, CMZs, RMZ core and inner zones, Type Np RMZs, sensitive sites, equipment limitation zones, and Type A or B wetlands or their WMZs. In erosive terrain, the number of landings should be minimized. Drainage practices for landings include sloping surfaces (2 to 5%); installing water diversion techniques to move water away from typed waters; constructing landings during dry weather; and installing self-maintaining drainage structures.

The FPRs for water crossings are covered in WAC 222-24-040. It is important to note that installation or replacement of any water crossing structure often requires an FPA/N form and may also require an HPA from the Washington Department of Fish and Wildlife (WDFW). General BMPs recommended for all water crossings, including fords, culverts, and bridges, include limiting the number of crossings; staying away from areas requiring steep road approaches as well as braided stream channels; and avoiding placement near sediment deposition areas and downstream of areas that consist of erodible slopes and unstable soil features. When utilizing a culvert, it is recommended that mangers 1) have a headwater depth to culvert diameter ratio of 0.9 or less when using native soils as fill material; 2) match culvert width to the natural channel to reduce ponding; 3) match the culvert to the slope and elevation of the stream channel; and 4) align the culvert with the stream channel. Additionally, it is recommended that managers account for debris torrents and high flow events when properly sizing a water crossing structure.

Specific requirements and BMPs for water crossing structures are based on waterbody type. For both Type S and Type F waters, installation of crossing structures is regulated either by the Department of Natural Resources (DNR) through the FPA/N, WDFW through the HPA, or both entities. Managers apply for both stream crossing permits when filing an FPA/N. In fish-bearing waters, crossing structures must allow for fish passage during all life stages for both resident and anadromous fish. Managers are also encouraged to verify the water type with DNR before beginning construction of any water crossing structure, especially when planning water crossing structures for Type Np and Ns waters. General requirements for crossings in these waters are that they be large enough to accommodate 100-year flood events and handle the passage of debris associated with these high flow events.

When managers plan to use culverts as stream crossing structures, one of three sizing procedures must be used: the sizing table method; the bankfull width method; or the hydraulic design method. The sizing table method uses bankfull width and average bankfull depth to determine the diameter required for a culvert (Table 3.27). It is important to note that this table provides a guide to sizing but managers may need to increase diameters to handle debris movement downstream. The bankfull width method uses width at the stream crossing to determine the diameter of the culvert required. The hydraulic design method uses estimated stream flows. Recommended culvert diameters by this method are based on local 100-year flood flow calculations and a nomograph that calculates

diameters for Type N waters (FPBM Part 6.3, Water Crossing Structures for Type N Waters). Table 3.28 provides a comparison of the three methods, including their complexity, data and analysis requirements, and where to use each.

While culverts and bridges are acceptable stream crossing structures for most waterbodies, ford crossings are only acceptable during periods of low or no stream flow. As a result, these structures can be used in Type Np and Ns waters (WAC 222-24-040). Fords should be used when traffic is minimal, in waterbodies that require little maintenance (i.e., rocky stream bottoms, gradual stream approaches), and when culverts or bridges cannot be used due to high debris loading in the stream.

3.2.11.6 *Pesticides and Fertilizers*

Vegetated buffers are required to keep chemicals out of surface waters and wetlands. State law requires detailed records from the landowner on when chemicals were applied, what chemicals were applied, and where chemicals were applied (WAC 16-228-190). Pesticides are not to be applied to core and inner zone vegetation, channel migration zones of all Type S or Type F waters, Type Np RMZs, sensitive site buffers, or Type A and B WMZs. In addition, managers must maintain an offset from the outer edge of the inner zone to ensure protection of water resources when applying pesticides aerially near Type S and F waters and Type A and B wetlands (Tables 3.29 and 3.30). Aerial applications near Type N waters with surface water and Type B wetlands must follow the guidelines summarized in Table 3.31. Other applicable requirements for aerial pesticide applications include applying chemicals parallel to buffer strips, using spray equipment with immediate shutoff valves, shutting off spray equipment during turns over open water, posting signage at least five days prior to application, and leaving that signage in place for at least 15 days after application. Specific BMPs that include nozzles, boom length, operating pressure, and air speed for aerial applications can be seen in FPBM Section 12.

Ground applications of pesticides are prohibited within the core and inner zones and the CMZ of Type S and F waters. A no-spray buffer strip of 25 ft (8 m) is required for Type A and B wetlands and on all sides of all other surface waters. Dry stream segments do not require a buffer if there is no water present at the time of application. Hand applications of pesticide must only reach specific target species and are not allowed in the core zone and CMZ of Type S and F waters. Exceptions to the limits of both ground and hand applications of pesticides in RMZs are noted for noxious weed control.

Fertilizer use within RMZs and WMZs is permissible by hand application only. Additional BMPs for fertilizers recommend that ground and hand applications prevent nutrients from entering Type A and B wetlands and all typed waters. Exceptions are noted, however, for Type Np and Ns waters that have no surface water present. Regulations for aerial applications are numerous and include a 25 ft (8 m) buffer from the edge of the CMZ on all Type S and F waters. Applications should be parallel to all waterbodies, with flight paths adjusted to prevent direct application to buffers or WMZs, and units to be fertilized must be clearly identified for the operator applying the fertilizer.

Table 3.27 Washington's Culvert Sizing Requirements for Water Crossings Using the Sizing Table Method
[adapted from the Forest Practices Board Manual (WA DNR 2007)]

Bankfull Width ft (m)	Average Bankfull Depth in (cm)											
	3 (8)	6 (15)	9 (23)	12 (30)	15 (38)	18 (46)	21 (53)	24 (61)	27 (69)	30 (76)	33 (84)	36 (91)
1 (0.3)	15 (38)	18 (46)	24 (61)	30 (76)	--	--	--	--	--	--	--	
2 (0.6)	24 (61)	30 (76)	30 (76)	36 (91)	42 (107)	42 (107)	48 (122)	48 (122)	--	--	--	
3 (0.9)	30 (76)	36 (91)	42 (107)	48 (122)	48 (122)	48 (122)	54 (137)	54 (137)	54 (137)	60 (152)	60 (152)	60 (152)
4 (1.2)	30 (76)	42 (107)	48 (122)	54 (137)	54 (137)	54 (137)	60 (152)	60 (152)	66 (168)	66 (168)	72 (183)	72 (183)
5 (1.5)	36 (91)	48 (122)	54 (137)	54 (137)	60 (152)	60 (152)	66 (168)	66 (168)	72 (183)	72 (183)	78 (198)	78 (198)
6 (1.8)	36 (91)	48 (122)	54 (137)	60 (152)	66 (168)	66 (168)	72 (183)	72 (183)	78 (198)	78 (198)	84 (213)	84 (213)
7 (2.1)	42 (107)	54 (137)	60 (152)	66 (168)	72 (183)	72 (183)	78 (198)	78 (198)	84 (213)	84 (213)	90 (229)	90 (229)
8 (2.4)	42 (107)	60 (152)	66 (168)	72 (183)	78 (198)	78 (198)	84 (213)	84 (213)	84 (213)	90 (229)	90 (229)	90 (229)
9 (2.7)	48 (122)	60 (152)	66 (168)	78 (198)	78 (198)	84 (213)	84 (213)	90 (229)	90 (229)	90 (229)	96 (244)	96 (244)
10 (3.0)	54 (137)	66 (168)	72 (183)	78 (198)	84 (213)	84 (213)	90 (229)	90 (229)	96 (244)	96 (244)	96 (244)	
11 (3.4)	60 (152)	66 (168)	72 (183)	84 (213)	84 (213)	90 (229)	90 (229)	96 (244)	96 (244)			
12 (3.7)	66 (168)	72 (183)	78 (198)	84 (213)	90 (229)	90 (229)	96 (244)	96 (244)				
13 (4.0)	66 (168)	78 (198)	78 (198)	90 (229)	90 (229)	96 (244)						
14 (4.3)	72 (183)	78 (198)	84 (213)	90 (229)	96 (244)	96 (244)						
15 (4.6)	78 (198)	84 (213)	90 (229)	96 (244)	96 (244)							
16 (4.9)	78 (198)	84 (213)	90 (229)	96 (244)								
17 (5.2)	84 (213)	90 (229)	96 (244)									
18 (5.5)	84 (213)	90 (229)	96 (244)									
19 (5.8)	90 (229)	96 (244)										
20 (6.1)	96 (244)	96 (244)										

Table 3.28 Comparison of Methods Used to Size Culverts for Type N Waters in Washington [adapted from the Forest Practices Board Manual (WA DNR 2007)]

	Culvert Diameter Sizing Method		
	Sizing Table	Bankfull Width	Hydraulic Design
Summary	Enter bankfull width & average bankfull depth into culvert sizing table[1]	Choose culvert diameter equal to or greater than bankfull width	Calculate 100 yr flow, determine culvert size using nomograph.
Complexity	Medium-to-Low	Low	High
Data requirements	Measured bankfull width and depth	Measured bankfull width	100 yr flow
Analysis requirements	See Table 29 in WA DNR 2007	None	Peak flow calculation followed by use of nomograph
Does method provide for debris passage	Somewhat	Yes	No[2]
Where to use	Anywhere bankfull width and depth are easily determined Where basin area and/or hydrology are uncertain	When simplicity is needed Where bankfull width is clear, but depth uncertain Where abundant debris movement is present at the site	Where hydraulic expertise is available Where site specific design and/or non-round culverts are desired Where bankfull width and depth is difficult to determine

[1]See Table 3.27.
[2]This method requires "local knowledge" to accurately predict additional culvert sizing requirements to handle passage of woody debris.

Table 3.29 Washington's Requirements for Buffers on Type S and Type F Waters When Applying Pesticides Aerially [adapted from the Forest Practices Board Manual (WA DNR 2007)]

		Wind Factor[1]			
		Favorable		Calm or Unfavorable	
Nozzle	Application Height	Buffer	Offset from Inner Zone	Buffer ft (m)	Offset from Inner Zone
Regular[2]	Low (# 16 ft, 5 m)	Width of inner zone	As needed for safety	100 ft (30 m), or the inner zone, whichever is greater	50 ft (15 m)
	Medium (17 to 50 ft, 5 to 15 m)	Width of inner zone	As needed for safety	250 ft (76 m)	NA
	High (51 to 65 ft, 16 to 20 m)	Width of inner zone	As needed for safety	325 ft (99 m)	NA
Raindrop[3]	Low (# 16 ft, 5 m)	Width of inner zone	As needed for safety	Width of inner zone	20 ft (6 m)
	Medium (17 to 50 ft, 5 to 15 m)	Width of inner zone	As needed for safety	Width of inner zone	20 ft (6 m)
	High (51 to 65 ft, 16 to 20 m)	Width of inner zone	As needed for safety	125 ft (38 m), or inner zone, whichever is greater	20 ft (6 m)

[1]Detailed examples for determining wind factors are shown in FBM Section 12.
[2]Coarse spray droplets are approximately 9% of spray-droplet volume (≤150 μ).
[3]Ultra-coarse spray droplets are approximately 1% of spray droplet volume (≤150 μ).

Table 3.30 Washington's Requirements for Buffers on Type A and Type B Wetlands When Applying Pesticides Aerially [adapted from the Forest Practices Board Manual (WA DNR 2007)]

		Wind Factor[1]			
		Favorable		Calm or Unfavorable	
Nozzle	Application Height	Buffer	Offset from WMZ	Buffer ft (m)	Offset from WMZ
Regular[2]	Low (# 16 ft, 5 m)	Width of WMZ	As needed for safety	150 ft (46 m)	NA
	Medium (17 to 50 ft, 5 to 15 m)	Width of WMZ	As needed for safety	250 ft (76 m)	NA
	High (51 to 65 ft, 16 to 20 m)	Width of WMZ	As needed for safety	325 ft (99 m)	NA
Raindrop[3]	Low (# 16 ft, 5 m)	Width of WMZ	As needed for safety	Width of WMZ	20 ft (6 m)
	Medium (17 to 50 ft, 5 to 15 m)	Width of WMZ	As needed for safety	Width of WMZ	20 ft (6 m)
	High (51 to 65 ft, 16 to 20 m)	Width of WMZ	As needed for safety	125 ft (38 m), or the WMZ, whichever is greater	20 ft (6 m)

[1]Detailed examples for determining wind factors are shown in FBM Section 12.
[2]Coarse spray droplets are approximately 9% of spray-droplet volume (≤150 μ).
[3]Ultra-coarse spray droplets are approximately 1% of spray droplet volume (≤150 μ).

Table 3.31 Buffers Required During Aerial Applications of Pesticides for Type Np or Ns Waters with Surface Water Present and Type B Wetlands Less Than 5 ac (2 ha) [adapted from the Forest Practices Board Manual (WA DNR 2007)]

	Wind Factor[1]	
	Favorable	Unfavorable
Nozzle	Buffer width, ft (m)	
Regular[2]	50 (15)	100 (30)
Raindrop[3]	50 (15)	70 (21)

[1]Detailed examples for determining wind factors are shown in FBM Section 12.
[2]Coarse spray droplets are approximately 9% of spray-droplet volume (≤150 μ).
[3]Ultra-coarse spray droplets are approximately 1% of spray droplet volume (≤150 μ).

3.2.12 *Wyoming*

Wyoming's forestry BMPs are part of the 2004 *Wyoming Nonpoint Source Management Plan* (NPSMP) prepared by the Department of Environmental Quality (WY DEQ 2004). These BMPs are based on guidelines initially presented in *Silviculture Best Management Practices of Wyoming* (1997) developed by the Wyoming State Forestry Division. Wyoming's BMPs are also based on federal NPS control guidelines, e.g., *Soil and Water Conservation Practices Handbook* (Forest Service Handbook 2509.22); *Watershed Conservation Practices Handbook* (Forest Service Handbook 2509.25); and USDA Natural Resource Conservation Service District Practice Standards.

Forestry BMPs in the NPSMP are divided into five sections: 1) planning; 2) harvesting, thinning, slash treatment, and revegetation; 3) roads; 4) pesticides, herbicides, fertilizers, and chemicals; and 5) fire management. The planning section contains practices that should be implemented during the planning of a timber sale. The other four sections apply to on-site procedures.

Each section is further divided into individual numbered practices. For example, Practice #3 addresses riparian area designation and provides specific guidance for minimizing effects of road building and harvesting in riparian areas. Buffer recommendations are based on slope and do not differ among stream types. For riparian areas with slopes <35%, buffer widths of 50 ft (15 m) or equal to the height of mature trees (whichever is greater) are recommended. On slopes >35%, buffer widths of 100 ft (30 m) are recommended and "need to be given special technical consideration and should be coordinated with the appropriate technical agencies." When chemicals are applied, a buffer of 150 ft (46 m) is recommended.

Overall, recommended BMPs are less detailed and prescriptive in Wyoming than in many other western states. This may be due to the fact that roughly 79% of the forestland in Wyoming is managed by federal or state agencies and a large percentage of the state's marketable timber is on public lands (WY DEQ 2004). Furthermore, harvest levels in Wyoming are low relative to those in some other states (Ice et al. 2004).

3.3 State BMP Monitoring Protocols and Rates of Implementation/Compliance

3.3.1 *Alaska*

Section 95.825 of the Forest Resources Practices Act (FRPA) establishes water quality monitoring requirements for private and public forestlands in Alaska. The Alaska Department of Forestry (DOF), with input from the Department of Environmental Conservation (DEC), instructs the forest landowner, timber owner, operator, or forest manager to, "…conduct routine or comprehensive water quality monitoring for the purpose of assessing the impacts of operations on water quality and protected water uses, and for the purpose of demonstrating the effectiveness of best management practices in meeting water quality standards." Routine monitoring includes, at a minimum, visual inspection of streams to assess turbidity levels and can also include temperature measurements during harvesting operations. If routine monitoring is deemed necessary by DOF during harvesting operations, the guidelines are as follows: 1) make water quality observations at one or more locations at regular intervals; 2) use simple, qualitative assessment techniques; and 3) report data findings and any measures implemented to correct water quality problems to DOF and DEC.

Guidelines for monitoring BMP implementation are found in the 2005 DOF report *Implementing Best Management Practices for Timber Harvest Operations*. The scope of the monitoring covers all harvests subject to the FRPA, which includes public and private forestlands. Therefore, the number of site evaluations is dependent on the number of harvests and varies by year and region. The major BMP monitoring categories include riparian areas, timber harvesting, road construction, drainage, bridges, culverts, and road maintenance. Several subcategories for each BMP are also provided. Culverts, for example, are evaluated for the following BMPs: 1) culvert is not perched; 2) culvert terminates on non-erodible material; 3) clear of mobile slash; 4) catch basins and headwalls; and 5) culverts are of proper length.

Implementation scores are based on answers to four questions.

1. Is the BMP applicable to the harvest activity?
2. Did the operator implement the BMP correctly?
3. How frequently did the operator implement the BMP?
4. How well was the BMP implemented?

Scoring is based on a five-point scale as follows: 1 indicates that few or no attempts were made to implement a BMP when it was necessary or the BMP was applied ineffectively; 2 indicates that an operator occasionally made efforts to implement a BMP when needed or on occasion the BMP was effective; 3 means that an attempt was made to implement the BMP when necessary and the BMP was somewhat effective; 4 indicates that a BMP was frequently implemented when required on a harvest site and was usually effective; 5 indicates that the BMP was consistently implemented when necessary and that the BMP was effective.

Scoring is based on the BMP characteristic "that has the lowest performance by the operator." For example, a site evaluation indicated that a forest manager frequently implemented a BMP (a possible score of 4) when it was necessary; however, the manner in which the BMP was applied was only somewhat effective in protecting water quality (a possible score of 3). In this case, the BMP score would be 3. In addition to on-site scoring, evaluators are advised to provide comments on the scoring sheets to assist the reviewer and to note whether or not the BMP was effective.

Results of BMP monitoring conducted in 2005 have been summarized (AK DNR-DOF 2005). Implementation surveys were conducted in two areas: coastal (essentially Region I) and northern (Regions II and III).

A total of 93 score sheets were completed in the coastal BMPs surveys. Overall BMP compliance was 94% (4.7 out of 5). In the northern area, 74 score sheets were completed and overall compliance was 4.2 (84%).

DOF identified a need for improvement in implementation of BMPs related to roads and stream crossings across the two areas. Specific concerns included roads were not retired properly, with "structures still remaining in place making these roads passable to vehicle traffic." Culvert failures due to landslides were also noted, as were instances of blocked and washed out culverts. Impacts to water quality and fish habitat were noted in some instances. However, DOF indicated that the "affected roads have healed over well and no significant degradation to fish habitat or chronic degradation of water quality is ongoing" (AK DNR-DOF 2005). DOF also noted that some log stringer bridges were beginning to fail and could create future potential water quality problems.

DOF noted that the number of BMP compliance monitoring sheets filed in 2005 was double that of the previous year. DOF continued efforts to ensure consistent interpretation of BMPs across sites and has begun providing on-site assistance to individual field foresters during field inspections. Priority areas for 2006 were to increase field visits and compliance monitoring in Region III, the Interior Region (AK DNR-DOF 2005).

3.3.2 *California*

California has made substantial investments in monitoring compliance with its Forest Practice Rules (FPRs). Monitoring efforts since 1993 are summarized below.

From 1993 through 1995, the California Department of Forestry and Fire Protection (CAL FIRE) and the California State Board of Forestry and Fire Protection (CSBOF) completed a Hillslope Monitoring Program (HMP) pilot project to develop methods for evaluating both implementation and effectiveness of state forest practice rules to protect water quality (Tuttle 1995).

The HMP was originally adapted from USDA Forest Service hillslope monitoring protocols (USDA-FS 1992). The program conducted statewide evaluations of California's FPRs from 1996 through 2002 using an annual random sample of 50 completed Timber Harvest Plans (THPs) and Nonindustrial Timber Management Plans (NTMPs) that had over-wintered from one to four years. Detailed information was collected for randomly selected forest roads, skid trails, Watercourse and Lake Protection Zones (WLPZs), landings and watercourse crossings. Information on mass wasting features (e.g., landslides) was also recorded when encountered. Site evaluations were done by highly qualified independent contractors who acted as third party auditors. Findings from an initial 150 plans were summarized in 1999 (CSBOF 1999). Results from 300 plans were reported in 2002 (Cafferata and Munn 2002).

HMP evaluations showed that implementation rates of the FPRs related to water quality averaged 94.5%. Individual practices required by the forest practice rules were found to be effective in preventing hillslope erosion when properly implemented. Implementation of applicable rules at erosion sites was almost always less than that required by the FPRs. Roads and water crossings were found to produce the greatest adverse impacts to water quality (CSBOF 1999; Cafferata and Munn 2002). These conclusions were similar to those reached in an earlier audit of 100 THPs (CSWRCB 1987).

Approximately 20% of the watercourse crossings evaluated had major departures from rule requirements. The majority of the evaluated crossings were existing structures that were in place prior to the development of the THP. Crossings installed as part of the THP had a significantly lower rate of problem points per crossing when compared to existing crossings. Common crossing problems included culvert plugging, stream diversion potential, fill slope erosion, scour at the outlet, and ineffective road surface cutoff waterbreaks.

Assessments of road drainage structures (e.g., waterbreaks, rolling dips, cross drain culverts, etc.) found that 5.5% of structures were inadequately designed, constructed or maintained and that approximately 15% of inventoried road erosion features (i.e., rills, gullies, mass failures, cutbank/ fillslope sloughing) delivered sediment to stream channels. These erosion features were usually caused by a drainage feature deficiency attributable to practices out of compliance with FPRs. Most of the identified road problems were related to inadequate size, number, and location of drainage structures; inadequate waterbreak spacing; and lack of cover at waterbreak discharge points.

WLPZs were found to retain high levels of post-harvest canopy and surface cover, and to prevent harvesting related erosion. Mean total canopy exceeded FPR requirements in all three Forest Practice Districts and was approximately 80% in the Coast Forest Practice District for both Class I and II watercourses. The frequency of erosion events related to current operations in WLPZs was very low for Class I, II, and III watercourses. Landings and skid trails were not found to be producing substantial impacts to water quality.

From 2001 through 2004, CAL FIRE and the CSBOF completed additional monitoring of FPR implementation and effectiveness with the initial phase of the Modified Completion Report monitoring program (MCR). The goal of the MCR is twofold: 1) to assess water quality related FPR implementation rates; and 2) to examine the effectiveness of properly implemented FPRs in protecting water quality by retaining canopy and groundcover in WPLZs, preventing erosion, preventing sediment transport, and/or preventing sediment transport to stream channels.

The random sample size of the MCR for 2001 through 2004 was approximately 12.5% of the THPs undergoing completion report field inspections. Field inspections were conducted by CAL FIRE's Forest Practice Inspectors, but trained professionals from other state agencies were also allowed to participate. For each THP evaluated, four sites were randomly selected and evaluated, including one road segment, one WLPZ segment, and two watercourse crossings. Evaluations were performed once after logging was completed, and for some plans, a second time after one to two over-wintering periods at the road and stream crossing sites. The data reported in the MCR complement the more detailed and costly data provided by the earlier HMP.

For the first phase of the MCR (2001 to 2004), 281 THPs were assessed throughout the state. Numbers of sites by region were as follows: 146 sites in the Coastal Region (R-1); 76 sites in the Inland Region – North (R-2); and 59 sites in the Inland Region – South (R-4). Of the plans sampled, 187 contained WLPZs and therefore were evaluated for percent total canopy coverage and erosion features. Canopy coverage was assessed by randomly locating 200 ft (61 m) WPLZ segments for Class I and II watercourses and evaluating the canopy cover using a sighting tube and a 50-point grid pattern.

Canopy cover assessments for Class 1 and Class 2 WLPZs produced similar results in the MCR and HMP. In Class 1 WLPZs, for example, the MCR / HMP scores by region were as follows: R-1 (84%/ 83%), R-2 (69% / 61%); R-4 (71% / 67%) (Brandow, Cafferata, and Munn 2006).

Erosion features were observed in 19 WLPZs, or 10.2% of those monitored. Only three erosion features were clearly related to current timber harvesting operations. Two were attributed to sediment transport from a landing. The third was attributed to a gully with insufficient ground cover (i.e., groundcover of <70%). The remaining WLPZ erosion features were not related to current forestry operations and included impacts from old roads and skid trails, a county road, and numerous other non-forestry disturbances.

MCR monitoring for roads occurred at 244 randomly selected 1,000 ft (305 m) road segments (i.e., 46 road miles). Of the 1,991 road features rated for implementation, only 83 departures from the FPR requirements were observed. This equates to a 95.8% implementation rate. The MCR report also indicated that these departures from the FPRs tended to be clustered, with 33 departures found within five road segments.

The distribution of assessed road segments among implementation rating classes in the 2001 to 2004 MCR was as follows: exceeds rule (6%); acceptable (76%); marginally acceptable (14%); and departures from FPRs (~4%). Lack of compliance was often related to road drainage.

Evidence of sediment delivery to stream channels was found for nine road-related features (i.e., < 1% of features rated for effectiveness). Five of the nine instances of sediment delivery were attributed to non-compliance with FPRs. Two of the five attributed to non-compliance involved sediment movement onto “erodible materials or failure to discharge into cover” and three were found to have “an inadequate number of drainage structures or inadequate spacing.” Among features with some evidence of erosion (e.g., rills, gullies, mass failures), approximately 8% delivered sediment to stream channels

The MCR evaluated implementation of 357 watercourse crossings: 221 culverts (149 existing and 72 new), 89 fords, 41 removed or abandoned crossing features, and 6 bridges. Detailed information on watercourse crossing implementation rates for roads (14 CCR 923) and skid trails (14 CCR 914) are found in Table 3.32. Overall, 17% of the water crossings examined had departures from the FPRs, 19% were marginally acceptable, and 64% met or exceeded the FPRs.

Watercourse crossing effectiveness was examined on 289 crossings, and 53 (18.3%) were found to have active or potential effects on water quality. These effects were attributed to culvert diversion potential (19 instances), culvert plugging (10 instances), culvert gradient (5 instances), culvert sizing (4 instances), culvert alignment (3 instances), and corrosion (3 instances). These MCR finding were consistent with results from the HMP project (Cafferata and Munn 2002).

Overall, CAL FIRE and the CSBOF characterized compliance rates with California’s FPRs as high in the recent MCR report (Brandow, Cafferata, and Munn 2006). This document also indicated that the FPRs are highly effective in preventing erosion and sediment transport to waterbodies during and after forest management operations. Recommendations in the MCR included 1) continued emphasis on education, licensing, inspection, and enforcement; and 2) because departures from the FPRs were rare, “the best inspection strategy is to have the inspector focus on THPs and locations where their experience and previous plan review indicate that problems are most likely to occur. After a quick prioritization, inspectors should visually observe as much ground as possible to maximize detection of departures from FPRs, which are important but uncommon occurrences.”

A second phase of the MCR monitoring program with the more descriptive title Forest Practice Rule Implementation and Effectiveness Monitoring (FORPRIEM) was implemented in 2007 using a randomly selected 10% sample of completed THPs. Slight modifications for monitoring protocols have been made to address concerns raised by reviewers of final report produced for the first phase of the program.

In addition to FORPRIEM, California initiated a new Interagency Mitigation Monitoring Program (IMMP) pilot project in 2006. IMMP field monitoring teams are composed of one representative from each of the state Review Team agencies: CAL FIRE, California Department of Fish and Game, California Geological Survey, and Regional Water Quality Control Boards. Two teams have been formed, one team for the North Coast area and one for the northern interior part of the state. The team approach is being used to provide a balance of interests for all the Review Team agencies and greater public confidence in the monitoring results. Data collection is focused on high risk (non-random) watercourse crossings and road segments that drain to the crossings, since past monitoring work has shown that these are particularly high risk sites for sediment delivery to stream channels.

Table 3.32 California Forest Practices Rules Rates of BMP Implementation for Waterbody Crossings (Brandow, Cafferata, and Munn 2006)

Rule Number	Rule Description	Total Observations without a NA	Departure from FPR (%)
923.4(n) 943.4(n) 963.4(n)	Crossing/approaches maintained to prevent diversion	246	6.9
923.2(i) 923.2(i) 923.2(i)	Where needed, trash racks installed to minimize blockage	65	6.2
923.4(m) 943.4(m) 963.4(m)	Inlet/outlet structures, etc. repaired, replaced, installed	130	5.4
923.3(f) 943.3(f) 963.3(f)	Crossings and fills built or maintained to prevent diversion	301	5.0
923.4(l) 943.4(l) 963.4(l)	Drainage structures or trash rack maintained/repaired as needed	127	4.7
923.3(d)(1) 943.3(d)(1) 963.3(d)(1)	Removed crossings – fills excavated to adequately reform channel	91	7.4
923.8 943.8 963.8	Abandoned crossings maintenance free drainage	35	5.7
923.8 943.8 963.8	Abandoned crossings – minimizes concentration of runoff	35	5.7

(Continued on next page.)

Table 3.32 Continued

Rule Number	Rule Description	Total Observations without a NA	Departure from FPR (%)
923.8(b) 943.8(b) 963.8(b)	Abandoned crossings – appropriate stabilization of cut and fills	35	5.7
923.8(c) 943.8(c) 963.8(c)	Abandoned crossings – grading of road surface for dispersal of flow	36	5.6

The first phase of the IMMP pilot project (2006) revealed that monitoring protocols required modification and revised protocols were tested in the second phase (2007). The first phase also showed that improper installation of high risk crossings and drainage structures near crossings is often the major cause of water quality problems. A preliminary conclusion from the pilot work in Phase 1 is that improved implementation of practices can be accomplished with additional timber operator education and more frequent multi-agency crossing inspections, both during logging operations and immediately following completion of harvesting.

3.3.3 *Idaho*

In 2001, Idaho published the results of the state's fifth statewide Forest Practices Water Quality (FPWQ) audit (Hoelscher et al. 2001). That survey was conducted during the summer months of 2000. The purpose of the audit was to assess the implementation and effectiveness of Idaho's forest practices described in the 1998 Forest Practices Act (FPA).

The 2000 FPWQ Audit team included representatives from the Idaho Department of Lands (IDL), the Idaho Department of Fish and Game, the Intermountain Forest Association, the Idaho Forest Owners Association, the USDA Forest Service, and the Idaho Department of Environmental Quality. The audit team's objectives were 1) to assess the extent to which the FPRs were implemented and whether the FPRs functioned as intended when applied correctly; 2) to determine the FPRs' effectiveness in protecting stream habitat through maintenance of woody debris recruitment, shade, fish passage, and by preventing sediment delivery to waterbodies from roads; and 3) to make recommendations for revisions to the FPRs.

Site selection was accomplished by the IDL by evaluating timber sale notification forms and receipts. A pools of candidate sites for monitoring was generated using the following criteria: 1) timber sale area must occur in an unstable geologic type as defined in IDL's 2000 Forest Practices Cumulative Watershed Effects (CWE) Process for Idaho; 2) timber sale boundaries must border or include a Class I stream; 3) timber harvests must have occurred between 1996 and 1999; and 4) ten sales must be selected from each of the administrative units of land ownership, including public (state and federal lands), industrial private, and non-industrial private forestlands.

From the pool of candidate sites, 20 were randomly selected from each of four land ownership groups and classified as audit semi-finalists. These 80 sales were then plotted on a map. The 40 sales closest together geographically were selected as the primary sales to be audited, thereby allowing the most convenient travel logistics.

To evaluate rates of compliance with Idaho's FPRs, the FPWQ audit team was split into two groups. One group evaluated road segments and skid trails, road construction, and maintenance (i.e., compliance with Rule 040). The other group evaluated a Class I stream segment to assess compliance with Rule 030 (timber harvest).

Quantitative assessment procedures were used to evaluate compliance with rules for streamside shading (Rule 030.07.ii), leave trees within the Streamside Protection Zone (SPZ) (Rule 030.07.iv), site-specific riparian prescriptions (Rule 030.07.e.vii), and fish passage (Rule 040.02.g). Rates of FPR implementation for individual timber sales were calculated by dividing number of implemented rules by number of applicable rules. Overall compliance/non-compliance determinations for each sale were based on the collective professional judgment of the audit team. Disagreements were settled in a voting process in which the majority ruled.

FPRs require 75% shading of the stream channel. Of the 40 timber sales evaluated, 95% met this requirement. Estimated shade levels were 73% and 71% at the two sites that did not meet the requirement. Data on pre-harvest stream shading were not available, so it was not clear whether insufficient shading was due to harvesting.

Five sales (12.5%) were not in compliance with Rule 030 requirements for the minimum number of leave trees to be retained on each side of a stream. At these sites, loggers harvested trees in the SPZ even though the number of leave trees did not meet the standard before harvest.

Thirty Class I stream crossings were evaluated within the 40 timber sales. Stream crossings were divided into two categories: new or existing structures. New refers to crossings that were constructed during the most recent timber sale. Existing refers to structures that were installed before the audited timber sale occurred.

The overall compliance rate for crossings was 57%. Eighteen stream crossing structures were culverts, of which only five (27.7%) were found to be in compliance with FPRs. The remaining crossing structures (bridges, fords, and temporary crossings) were all in compliance.

Of the 13 culverts not in compliance, two were new and 11 were existing. Both of the new non-compliant culverts were on non-industrial private lands. To improve culvert compliance rates with fish passage requirements, the audit team recommended that the FPRs specify water velocity or drop requirements that would ensure adequate fish passage.

3.3.4 *Montana*

The Montana Department of Natural Resources and Conservation (DNRC) has convened a forestry BMP technical working group to provide recommendations to DNRC since 1986. Members of the working group represent a range of forestry interests. Some members of the working group have served on BMP field audit teams.

In 2006, DNRC's Forestry Division audited BMPs for implementation and effectiveness at 44 sites across the state (Rogers 2007). The number of audit sites was determined by logistical considerations that included 1) maximum number of days (10) that volunteer members of audit teams could commit to the process; and 2) the number of audits a team could reasonably conduct in one day (generally two audits per day).

The first step in the site selection process was to prepare a list of recent harvest sites. Information about recent harvest sites was solicited from state, federal and industrial forest owners. Harvest sites on non-industrial private forests (NIPF) were identified through consultations with DNRC foresters and analysis of data in DNRC's hazard reduction agreements database.

Harvest sites were screened using the following criteria: 1) harvesting must have occurred between 2003 and 2005; 2) some portion of a harvest tract must be located within 200 ft (61 m) of a stream; 3) harvest unit size ≥ five acres; and 4) timber removals ≥ 5 MBF per acre for west side harvests and ≥ 3 MBF per acre for eastside harvests.

Sites meeting these minimum criteria were placed in a pool of candidate sites. Audit sites were selected from the pool using several criteria. An overriding objective was to have a minimum of five audit sites in each of three regions (northwest, west, and east/central) and four ownership groups (state, federal, industrial, and NIPF). An additional objective was to maximize the number of BMPs evaluated by giving priority to sites with the following sets of characteristics.

- (Priority 1) riparian harvest, new road construction or reconstruction, stream crossing culvert installation, and slash disposal complete
- (Priority 2) stream within 200 ft (61 m) of a harvest unit, new road construction or reconstruction, stream crossing culvert installation, slash disposal complete
- (Priority 3) stream within 200 ft (61 m) of a harvest unit, new road construction or reconstruction, stream crossing culvert installation, slash disposal incomplete
- (Priority 4) stream within 200 ft (61 m) of a harvest unit, new road construction or reconstruction, stream crossing without new culvert installation, slash disposal complete
- (Priority 5) stream within 200 ft (61 m) of a harvest unit, new road construction or reconstruction, stream crossing without new culvert installation, slash disposal incomplete
- (Priority 6) stream within 200 ft (61 m) of a harvest unit and slash disposal complete
- (Priority 7) stream within 200 ft (61 m) of a harvest unit and slash disposal incomplete

Audits were conducted by three teams (one for each region). Each seven-member team had a fisheries biologist, a forester, a hydrologist, a conservation group representative, a road engineer, a soil scientist, and either a logging professional or a representative of NIPF landowners.

Audit teams evaluated a maximum of 50 BMP practices and 12 SMZ practices at each audit site. The auditors used a five-point scale to rate BMP implementation (Ehinger and Potts 1990): 5 = operation exceeds BMP requirements; 4 = operation meets BMP requirements; 3 = minor departure from the BMP intent; 2 = major departure from BMP intent; and 1 = gross neglect.

Auditors used a similar system to evaluate BMP effectiveness: 5 = improved protection of soil and water resources over pre-project condition; 4 = adequate protection of soil and water resources; 3 = minor and temporary impacts on soil and water resources; 2 = major and temporary or minor and prolonged impacts on soil and water resources; and 1 = major and prolonged impacts on soil and water resources. Adequate protection indicates that small amounts of material eroded on the site but did not reach draws, channels, or the annual floodplain. Minor impact indicates that some material eroded and was delivered to draws but not to streams. Major impact indicates that material eroded and was transported to streams or annual floodplains. Temporary impacts are those lasting a year or less or no more than one runoff season. Prolonged impact" last more than one year.

The overall BMP implementation rate in 2006 was 96%. Implementation rates were ≥ 93% in all ownership classes. Departures from BMPs were distributed among severity classes as follows: 58 minor; 2 major; 0 gross neglect.

More than half (55%) of the audit sites had no departures from BMPs. Practices exceeded BMPs requirements at seven sites.

The overall BMP effectiveness rating of assessed practices across all regions and ownership groups was 97%. Of 1,603 practices evaluated, 46 had effectiveness scores less than 4 (adequate protection). These 46 inadequate practices were distributed among audited sites as follows: 18 sites had one or more practices with a score of 3 (minor temporary impacts); 7 sites had one or more practices with a score of 2 (major temporary or minor prolonged impacts); and 2 sites had one or more practices with a score of 1 (major and prolonged impacts).

Eight of the BMPs evaluated by audit teams were considered high risk, i.e., most important for protecting water quality. These BMPs included providing adequate road surface drainage for all roads; passing road drainage through adequate filtration zones before it enters a stream; stabilizing erodible soils; maintaining erosion control features; designing and locating skid trails to avoid concentrating runoff; providing adequate drainage for temporary roads, skid trails, and fire lines; limiting water quality impacts of prescribed fire; and preventing erosion of culvert and bridge fills.

Implementation and effectiveness ratings for high risk BMPs were 89% and 92%, respectively, across all regions and ownership groups. Most departures from high risk BMPs were minor.

SMZ rules were applicable at all 44 audit sites. Implementation and effectiveness ratings for these rules were 98% and 99%, respectively. Ten departures from SMZ rules were noted at six sites. Six of these departures had no impacts, two had minor impacts, and two had major impacts. The departures included equipment operating in the SMZ (four instances); SMZ width not maintained (three instances), and SMZ not maintained and properly marked (three instances).

3.3.5 *Oregon*

The Oregon Department of Forestry (ODF) completed a major BMP Compliance Monitoring Project in 2002. Objectives were to assess landowner compliance and identify opportunities (i.e., education, technology transfer) to increase compliance rates (OR DOF 2002a).

A pool of candidate sites was identified using two criteria: harvest units must be associated with a waterbody (i.e., stream or wetland); and harvest notification must have occurred in 1998. Monitoring sites were selected from this pool using a procedure designed to achieve several objectives.

- Distribute monitoring sites among districts on the basis of number of harvest notifications in each district. Include at least 10 sites per district.
- Capture many sites with fish-bearing streams.
- Distribute sites among landowner classes on the basis of total area of operations with streams in each landowner class.

BMPs were evaluated at 189 sample units (harvest sites). Actual distributions of units among districts and landowner classes varied somewhat from targets for various reasons. For example, the distribution of units among ownership classes (actual/target) was as follows: industrial (77%/70%); non-industrial 15%/20%); and other (8%/10%). Fifty-six percent of the units had Type F streams and 44% had only Type D or N streams or significant wetlands.

A theoretical maximum of 150 FPRs could be evaluated at each sample unit. FRPs are in 10 categories: planning (division 605); slash (division 615); chemical and other petroleum products (division 620); road construction and maintenance (division 625); harvesting (division 630); vegetation retention along streams (division 640); significant wetlands (division 645); lakes (division 650); other wetlands and seeps (division 655); and operations near waters of the state (division 660).

Data were collected on two forms: compliance rating data and numeric data. Compliance rating forms were completed by a retired forest practice forester. All the rules that applied to each unit were rated as compliant/non-compliant. Noncompliance, when identified, was further described as administrative, potential resource impact, or resource impact. Administrative noncompliance refers to an activity that did not comply with notification and/or written plan requirements described in the rules. Potential resource impacts were recorded for on-the-ground practices that were out of compliance with BMPs but had not caused identifiable impacts to riparian or channel conditions. Resource impacts were recorded when on-the-ground practices had resulted in significant losses of riparian vegetation, channel alteration, or delivery of sediment, slash, or other waste to waters of the state.

Numerical data were collected by two-person field survey teams. Numeric data are a combination of quantitative (Q) and categorical (C) assessments. For example, in the case of RMAs, the team established transects spaced 200 ft (61 m) apart for the entire length of the RMA. Along each transect, the team documented area of ground and vegetation disturbance (Q); source of disturbance (C); accumulations of slash in the channel (C); width of no-cut buffers (Q); sediment delivery (Q); sediment source (C); and effects of ground and vegetative disturbance on stream and riparian resources (Q & C). In addition, if the riparian area was managed to meet a basal area target, the team conducted a 100% cruise of conifers and other trees and snags that count towards the basal area target (Q).

On average, 71 BMPs were evaluated at each sample unit (13,506 total BMPs). Levels of compliance (Question 1) for sample units ranged from 79% to 100%. Average compliance was 96% overall. Of 502 non-compliant practices observed, 185 were administrative in nature, 147 were potential water resource issues, and 170 had caused observable effects on riparian areas and/or streams (OR DOF 2002a). Many sample units (76%) had a least one non-compliant practice, of which 40% had at least one non-compliant practice that resulted in actual or potential impacts to riparian areas or streams.

Compliance rates varied substantially among FPRs. Compliance rates ≥ 98% were measured for 72 FPRs in areas such as RMA reforestation timing; chemical applications; new road location; new road prism design; cable yarding near waterbodies; landings; and vegetation retention for Type F, D and N streams.

Oregon DOF identified ten areas with significant compliance issues, defined as compliance < 96% and/or ≥ five non-compliant practices reported (OR DOF 2002a). These areas were slash piling near waterbodies (90% compliance); removal of petroleum-related waste (82%); stream crossing fill stability (84%); road surface drainage and maintenance (86% and 94%, respectively); felling trees into small Type N streams (83%); skid trails near waters of the state (92%); removal of temporary crossings (48%); protection of other wetlands (70%); prior approval requirements (90%); and written plan requirements (77%).

Of the 13,506 activities assessed in this survey, 170 (1.2%) were found to be non-compliant with Oregon's FPRs and resulted in resource impacts. These instances of non-compliance were in four groups: significant slash accumulations below a high water line (53 instances); damage or excessive removal of RMA vegetation (30); alteration of stream bed or banks with sediment delivery (11); and sediment delivered below the high water line (76).

The 76 instances of sediment delivery were further separated into two sub-categories: road-related and harvesting-related. There were 36 cases deemed to be forest road related and 40 cases classified as harvesting related (OR DOF 2002a). The major non-compliance areas included road drainage (11 cases), road maintenance (10), eroding stream crossing fills (10), stream crossing design (10), removal of temporary stream crossings (11), and ineffectively drained skid trails near streams (9). Sediment delivery resulting from these activities was generally small. Sixty-two instances had estimated sediment delivery volumes of <10 yd^3 (<7.7 m^3), 28 had <1 yd^3 (<0.8 m^3) of sediment movement, and two cases had sediment delivery estimated to be in excess of 100 yds^3 (77 m^3).

The survey design was not appropriate for assessing whether stream crossings were in compliance with requirements related to fish passage and peak flow. Therefore, an additional study was conducted at a random sample of 98 stream crossings (OR DOF 2002b). Potential sample locations were identified by searching Oregon's Forest Activities Computerized Tracking System for forest management activities that included road construction. Samples locations were selected using three criteria: new road construction or re-construction; construction during 1998; and operations within 100 ft (30 m) of a waterbody. At each crossing, 13 compliance metrics were assessed including culvert gradient, outlet migration, inlet/outlet countersinking, and road fill depth and armoring. Findings were reported in ODF Technical Report 14, *Compliance with Fish Passage and Peak Flow Requirements at Stream Crossings* (OR DOF 2002b).

- 74% of culvert crossings were installed in accordance with the FPRs. Common reasons for lack of compliance with culvert FPRs included installation of culverts at too steep a gradient; selection of an alternative that was inappropriate for the channel gradient; and excessive outlet drops.
- 95% (93 out of 98) of the crossings were in compliance with requirements to have sufficient capacity for calculated 50-year peak flows.
- Four crossings (all fords) were not evaluated for fish passage. Of the remaining 94 crossings, 67 (71%) were considered likely to pass both juvenile and adult fish during all design flows.

3.3.6 *Utah*

Utah monitors implementation of its Forest Water Quality Guidelines (FWQG) to achieve three objectives: 1) to determine whether FWQGs are being applied; 2) to assess the effectiveness of the FWQGs at reducing NPS pollution; and 3) to provide information to improve and revise the FWQGs (UT DNR-DFFSL 2006).

A recent study of FWQG implementation was conducted in six administrative units: Bear River, Wasatch Front, Northeast, Central, Southeast, and Southwest. A pool of potential survey sites was obtained by examining Notifications of Intent to harvest timber that were submitted to the state Division of Forestry, Fire, and State Lands (DOF) between 2002 and 2005. A total of 99 Notifications of Intent had been submitted. Of these, DOF selected 40 sites for evaluation with a goal of having audit sites well distributed across the state on both private and state forestlands. Federal forestlands were not included in the assessment.

Audit teams evaluated a potential maximum of 76 FWQG practices at each site. Audit teams first determined whether each FWQG was applicable to the site. Implementation of applicable FWQCs was scored as follows: operation exceeds FWQGs (5 points); operation meets FWQGs (4 points); minor departure from FWQGs (3 points); major departure from FWQGs (2 points); or gross neglect of FWQGs (1 point). Minor departures were defined as "departures of small impact potential distributed over a localized area, or over a larger area where the potential for impact(s) is low." Major departures were defined as "departures of large impact potential or to the FWQG not being applied."

Gross neglect referred to clearly evident large and direct impacts and disregard for FWQG application.

A total of 1,515 practices were evaluated. Implementation rates (percent of practices with scores of 4 or 5) for 13 categories of FWQCs ranged from 64% to 94% (Table 3.55). Most departures from BMPs were minor. Categories with the highest implementation rates were chemical management (90%), SMZs (92%) and prescribed fire (94%). Categories with the lowest implementation rates were road construction (64%), skid trails (77%) and site preparation (78%). The overall implementation rate was 81% on both private and state lands.

FWQGs associated with forest roads include 17 specific guidelines in three categories. Implementation rates by category were planning (79%), construction (64%), and maintenance (81%). For specific road-related guidelines, relatively high implementation rates were measured for avoiding road construction in unstable areas (97%), utilizing appropriate stream crossing structures (92%), and limiting construction during wet periods and on frozen ground (88%). Guidelines with relatively low implementation rates included road surface drainage (49%), use of water diversion techniques (53%), proper use of berms to divert water (61%), and avoiding road use during wet periods (63%). In categories other than roads, FWQCs with relatively low implementation rates included use of water diversion devices on skid trails (63%), restoring or retiring landings after harvest (71%), and avoiding excessive slash accumulations (59%).

Table 3.33 Implementation Rates of Utah's FWQGs to Protect Water Quality (UT DNR-DFFSL 2006)

		FWQG Application – Percent of Practices Rated (%)			
Activity	# of Practices Rated	Meet or Exceed (Scores = 4 & 5)	Minor Departure (Score = 3)	Major Departure (Score = 2)	Gross Neglect (Score = 1)
SMZ	71	92	6	1	1
Road Planning	168	79	17	4	0
Road Construction	152	64	24	12	0
Road Maintenance	130	81	17	1	1
Stream Crossings	70	86	14	0	0
Skid Trails	226	77	17	6	0
Landings	164	89	9	2	0
Timber Harvesting	270	83	11	6	1
Site Preparation	128	78	18	4	0
Chemical Management	30	90	7	3	0
Prescribed Fire	68	94	6	0	0
Forest Wetlands	38	89	11	0	0

Audit teams assessed FWQG effectiveness to "determine the relative degree of providing expected or desired protection to forest, soil and water resources." Effectiveness was scored on a six point scale: improved protection of forest, soil, and water resources (6 points); adequate protection (5 points); minor and temporary impacts (4 points); minor and prolonged impacts (3 points); major and temporary impacts (2 points); and major and prolonged impacts (1 point). Minor impacts were instances where erosion and delivery of sediment to waterbodies were not clearly evident. Major impacts resulted in erosion and sediment delivery to waterbodies. Temporary impacts were those lasting less than one year, while prolonged impacts where those lasting more than 1 year.

Of 1,515 assessed practices, 79% were rated adequate protection or better and 19% were rated minor/ temporary impacts. Major impacts (both temporary and prolonged) were reported for less than 2% of assessed practices.

3.3.7 *Washington*

To evaluate levels of compliance with Washington's Forest Practices Rules (FPRs), the Department of Natural Resources (DNR), Department of Ecology, and Department of Fish and Wildlife audited 97 forest practice applications (FPAs) in 2006 (Lingley and Tausch 2007). Site evaluations were conducted using protocols described in DNR's Forest Practice Compliance Monitoring Program (FPCMP).

A sample pool was obtained from the Forest Practice Application Review database. The initial pool included approximately 5,400 Class II, Class III, and Class IV-S operations with approval dates from August 2004 through July 2005. A random sample of 600 operations was sub-sampled to create a sub-pool of 254 operations having roads and harvesting activities. From that sub-pool, 97 operations with completed activities were selected for audit. Selected operations included 32 on non-industrial private lands and 64 on industrial forest lands.

Site audits focused only on forest management activities related to roads and riparian rules because such activities have greatest potential to "adversely impact the environment and public safety." Data were collected using seven road rule forms, nine riparian rule forms, and two post-survey forms. These 18 forms contained a total of 234 possible questions, with each question taken directly from sections in the Forest Practices Act related to road construction and maintenance (WAC 222-24) or riparian management activities (WAC 222-30).

Categories of compliance for assess activities were exceeds rule, compliant, or non-compliant. Exceeds rule indicated that a landowner conducted forest management activities in excess of minimum requirements. Compliant and non-compliant indicated that a landowner did or did not meet the relevant protection objective identified in the FPA and FPRs.

In cases of non-compliance, violations were characterized as trivial (minor impacts of short duration over a small area); apparent (impacts to resources, but generally of moderate effect); or major (damage to public resources is evident or potential for damage to public resources is high). A no call rating was recorded when the field team didn't feel comfortable with making a determination of the non-compliance level.

Overall, 224 of 278 (81%) assessed activities were in compliance with FPRs, including 30 activities with an 'exceeds rule' rating (Lingley and Tausch 2007). Compliance rates for riparian and road-related activities were 74% and 86%, respectively. No violations were characterized as major.

There are substantial differences in riparian rules between western Washington and eastern Washington. Compliance rates for riparian rules by region, activity class, and landowner group are shown in Table 3.34.

In western Washington, overall rates of compliance with riparian rules for non-industrial and industrial lands were 70% and 71%, respectively. Low rates of compliance with tree retention rules were reported for Option 1 activities (thinning from below) (12%) and Option 2 activities (leaving trees closest to water) (63%).

In eastern Washington, overall rates of compliance with riparian rules for non-industrial and industrial lands were 69% and 87%, respectively. Instances of non-compliance had various causes such as harvesting within the inner zone, improper wetland typing, and excess slash in the channel.

A total of 31 instances of non-compliance with riparian rules were reported across the state. One of these instances was characterized as major. Ten instances were rated trivial, 20 were rated apparent, and two were in the no call category.

Instances of non-compliance with riparian rules included 14 activities in which insufficient numbers of trees were retained in core, inner, or outer zones of riparian management areas. Percent of required leave trees after harvest was ≥ 90% for eight of these non-compliant activities; 75% to 85% for two activities; 54% to 64% for three activities; and 35-39% for one activity.

Assessments of compliance with forest road rules (WAC 222-24) were focused only on activities that occurred near waterbodies. The overall compliance rate for road-related activities was 86% (Table 3.35). Rates of compliance were similar for non-industrial and industrial lands (88% and 85%, respectively). Instances of non-compliance had various causes including improper placement of runoff control structures; road ditches connected to streams; undersized culverts; failure to use sediment traps near crossings; elevated culvert inlet; failure of a culvert's fill; and landing located too close to stream.

Table 3.34 Status of Compliance Across All Landowner Groups with the Forest Practices Rules for Riparian Management Areas in Western and Eastern Washington [adapted from Lingley and Tausch (2007)]

	Western Washington Riparian Management Areas					
Status of Compliance	No Inner Zone Harvest	DFC Option 1[1]	DFC Option 2[1]	Type N Water	Wetlands	Totals
No. of Exceeds	5	0	4	12	2	23
No. of Compliant	16	1	6	24	1	48
No. of Non-compliant	8	6	6	6	1	27
Total	29	7	16	42	4	98
Exceeds (%)	17%	0%	25%	29%	50%	24%
Compliant (%)	55%	14%	38%	57%	25%	49%
Compliant+Exceeds (%)	72%	14%	63%	86%	75%	73%
Non-compliant (%)	28%	86%	38%	14%	25%	28%

	Eastern Washington Riparian Management Areas					
Status of Compliance	Ponderosa Pine	Mixed Conifer	High Elevation	Type N Water	Wetlands	Totals
No. of Exceeds	0	0	0	1	0	1
No. of Compliant	4	3	0	12	2	21
No. of Non-compliant	0	1	0	4	1	6
Total	4	4	0	17	3	28
Exceeds (%)	0%	0%	na	6%	0%	4%
Compliant (%)	100%	75%	na	71%	67%	75%
Compliant+Exceeds (%)	100%	75%	na	77%	67%	79%
Non-compliant (%)	0%	25%	na	24%	33%	21%

[1]The DNR-FPCMP discovered one application with intersecting desired future condition (DFC) Option 1 and DFC Option 2 riparian management areas and was unable to determine the status of compliance for this FPA. As a result, the number of sample sites was reduced by one for these categories.

Table 3.35 Status of Compliance Across all Landowner Groups with the Forest Practices Rules for Roads in Western and Eastern Washington [adapted from Lingley and Tausch (2007)]

Status of Compliance	Road Compliance in Washington							
	Roads				Type N Waters			
	Construction	Maintenance	Abandonment	Landings	Permanent Crossings	Temporary Crossings	Fords	Total
Exceeds	2	0	3	1	0	0	0	6
Compliant	35	17	12	46	14	1	0	125
Non-compliant	10	5	0	1	4	0	1	21
Total	47	22	15	48	18	1	1	152
Exceeds	4%	0%	20%	2%	0%	0%	0%	4%
Compliant	75%	77%	80%	96%	78%	100%	0%	82%
Compliant + Exceeds	79%	77%	100%	98%	76%	100%	0%	86%
Non-compliant	21%	23%	0%	2%	22%	0%	100%	14%

The total number of non-compliant activities related to roads was 21. Instances of non-compliance were distributed among severity rating classes as follows: trivial (5), apparent (10), major (0), no call (6).

To improve compliance rates, Lingley and Tausch (2007) recommended efforts to clarify some FPR requirements, noting that compliance rates were low for FPRs that are "…vague and lack implementation guidance." These authors also recommend increased training and education on topics such as identifying bankfull width, stream typing, Type N riparian management zones, Type S and Type F riparian management, and road maintenance responsibilities.

3.3.8 *Wyoming*

Cooperative efforts to measure and improve BMP implementation in Wyoming have been organized through Wyoming Timber Industry Association (WTIA), Wyoming Department of Environmental Quality, and Wyoming State Forestry Division.

Six harvest sites were evaluated in 2004 (WTIA 2005).There were two sites in each of three ownership groups (private, state, and federal). Site selection criteria were 1) harvesting must have been completed in the last two years; 2) harvesting must have produced a minimum of 1,000 board ft ac^{-1}; and 3) the harvest area must have some type of water resource present.

At each audit site, 42 BMP practices were evaluated and rated for implementation and effectiveness. Site inspections were conducted over the course of one week, with the audit team spending approximately a half day at each site. The teams did not inspect the entire harvest area or each mile of road, but instead focused on critical portions where BMP implementation was most important.

Each member of the audit team prepared an independent evaluation. When evaluations had been completed at a site, audit team members gathered to integrate their results and develop consensus ratings of implementation and effectiveness for each practice. Implementation ratings were 1) gross neglect of the BMP; 2) major departure from the BMP; 3) minor departure from the BMP; 4) meets the standard requirements of the BMP; 5) exceeds requirements of the BMP. Effectiveness was rated as adequate or inadequate, with impacts to water and soil resources defined as minor or major and the length of the impact as either temporary or prolonged.

A total of 194 practices were rated across the six sites. Of these, 187 (96%) met or exceeded BMP requirements. The audit team found no instances of gross neglect or major departures from BMPs, but reported that 6% of assessed practices were inadequate with respect to effectiveness. All practices with inadequate effectiveness were characterized as having minor and temporary impacts on soil or water resources.

3.4 Summary

All states in the West have forest practices rules or recommended BMPs for silvicultural operations to reduce NPS pollution (Table 3.36). Seven states have regulatory forest practices acts (Alaska, California, Idaho, New Mexico, Nevada, Oregon, and Washington). Montana has a regulatory streamside management act. Arizona, Colorado, Wyoming base their forestry NPS controls programs on voluntary BMPs. Utah relies on voluntary BMPs but also has a forest practices act that requires registration of forest operators and notification of intent to conduct forest practices.

Timber production and harvest levels vary greatly among Western states. States with the highest levels of timber production generally have complex programs for controlling forestry NPS pollution and have invested substantial resources in monitoring compliance with forest practice rules. In contrast, states with much lower levels of timber production (e.g., Arizona, Colorado, New Mexico,

and Nevada) have much simpler NPS control programs and have elected to devote scarce resources to priorities other than BMP implementation surveys (Ice 2004).

Colorado has been active in education outreach, largely through the Central Rockies Sustainable Forestry Education Program, which includes a 30-hour course on forest BMPs. Instead of conducting field surveys of BMP implementation, Colorado has collected anecdotal feedback on BMP implementation rates through these workshops (Ice et al. 2004). The Colorado State Forest Service and the Colorado Timber Industry Association hope to initiate a statewide audit of BMP implementation at some time in the future.

Arizona and Nevada have not conducted any formal forestry BMP implementation surveys. Nevada, however, requires forest managers to obtain a performance bond and there have been no defaults on the bonds in recent years (Ice et al. 2004).

Rates of BMP implementation in New Mexico have been conservatively estimated to be 75% (Ice and Stuart 2001). This was determined by evaluating the mandatory inspection reports filed for each timber harvest plan. The authors caution, however, that this approach probably underestimates current levels of BMP implementation within the state.

Recent survey data indicate statewide rates of implementation or compliance as follows: Alaska (89%); California (94%); Idaho (96%); Montana (96%); Oregon (96%); Utah (81%); Washington (80%); and Wyoming (97%). These data are valuable for gauging progress in forestry NPS control programs within individual states and for identifying areas where improvement is needed. Cross-state comparisons are of limited value because performance measures and data collection protocols vary greatly across the region.

Table 3.36 Checklist of Western State Silviculture NPS Control Programs for Water Quality Maintenance During Silvicultural Activities

State	Forestry BMPs Recommended	Forest Practice Act/Rules	Implementation Survey(s)	Effectiveness Study/Survey
Alaska	+	+	+	+
Arizona[1]	+			
California	+	+	+	+
Colorado	+			
Idaho	+	+	+	+
Montana	+	+	+	+
Nevada	+	+		+
New Mexico	+	+		
Oregon	+	+	+	+
Utah	+	+	+	+
Washington	+	+	+	+
Wyoming	+		+	+

[1]Arizona does not have any state specific forestry BMPs recommended by the state. However, for forest management activities it is recommended that Federal or Tribal guidelines be implemented.

State expenditures for forestry NPS control programs vary substantially among western states (Ellefson et al. 2006) (Table 3.37) and are likely a small fraction of total economic costs of NPS control programs to forest owners (NCASI 1994). State expenditures are associated with activities such as rule-making, permit approval, onsite inspections, and enforcement programs. In 2003, states in the West region had 337 full-time equivalent regulatory staff, of which 35% were used by forest resource management agencies and 26% by air and water pollution control agencies (Ellefson, Kilgore, and Granskog 2006).

Table 3.37 State Expenditures in 2003 of State Regulatory Forest Practices Programs Focused on Non-Federal Forestlands (adapted from Ellefson, Kilgore, and Granskog 2006)

State and Law	State Expenditures (x $1000US)
Alaska Forest Resources and Protection Act	718
California Z'Berg-Nejedly Forest Practices Act	13,748
Idaho Forest Practices Act	1,457
Montana Notification and Streamside Management Act	614
Nevada Forest Practice Act	704.5
New Mexico Forest Conservation Act	500
Oregon Forest Practices Act	7,800
Utah Forest Practices Act	220
Washington Forest Practices Act	9,656

Waterbody classification schemes play important roles in riparian management guidelines and other aspects of forestry NPS control programs in the West (Table 3.38). Many states in the region categorize waterbodies based on the presence or absence of fish and whether or not the waterbody is a source of drinking water. Classification schemes range from relatively simple in Colorado (perennial or intermittent streams) and Idaho (Class I or Class II) to much more complex in Alaska and Washington.

Requirements for tree retention in streamside management zones also range from relatively simple to very complex across the region. Washington's riparian rules appear to be the most complex of all. Schuett-Hames and Conrad (2002) estimated that there are 50 unique combinations of riparian management prescriptions under Washington's FPRs. Extreme complexity appears to be causing compliance issues (Lingley and Tausch 2007).

Table 3.38 Checklist of the Major Criteria Used by States in the West When Establishing Widths of Riparian Management Areas

State	Stream Types[2]	Stream Classification: Fish-Bearing	Non-Fish-Bearing	Perennial Intermittent Ephemeral	Regional Forest Types	Criteria for Establishing Width[1]: HWM	OHWM	CMZ	BFW	Channel or Bank	Other Requirements or Recommendations: Leave Tree	Shade	Woody Debris
Alaska	9	+	+		+		+			+	+		
Arizona													
California	4	+	+							+	+	+	+
Colorado	2			+						+	+		+
Idaho	2	+	+				+			+	+	+	
Montana	3	+	+				+				+		
Nevada[3]				+		+							
New Mexico	2			+			+				+		
Oregon	3	+	+		+	+					+	+	+
Utah	2	+	+				+				+	+	+
Washington	4	+	+		+			+	+		+	+	+
Wyoming[4]	3			+									

[1]Criteria for determining width of riparian buffers in this region are generally based on determining the extent of the: high water mark (HWM), ordinary high water mark (OHWM), channel migration zone (CMZ), bankfull width (BFW), or the channel or bank of a watercourse. [2]This includes all state surface waterbody classifications and regional sub-classifications (if applicable). [3]A stream is defined in Nevada as, "a natural watercourse designated by a solid line or dash and three dot symbol shown in blue on the most recently published United States Geological Survey 7.5 minute series topographic map." [4]Wyoming defines a stream or stream course as a natural channel with defined bed and banks. These waterbodies may be perennial, intermittent, or ephemeral with regard to water flows.

BMPs for roads are important parts of forestry NPS control programs throughout North America and especially in regions with steep terrain where erosion potential is greatest. Implementation/ compliance surveys have identified opportunities for improvement in several states. For example, compliance for road related activities in Washington averaged 86% overall, but was less than 80% for some specific practices (Table 3.35). Road-related drainage design and maintenance in Oregon scored 86.5% and 94.2%, respectively. Oregon considers any activity that has a compliance score <96% and five or more non-compliant practices as an area of lower compliance. Utah scored the lowest in terms of road construction compliance at 64%. Fortunately, water quality impacts associated with instances of non-compliance with road-related guidelines were generally assessed as minor and short duration in these states.

In California and Montana, recent surveys found rates of compliance with forest road requirements of 95.8% and 89%, respectively. In California's most recent MCR, evidence of sediment transport to watercourses was found only 83 times out of 1,991 features evaluated. These data come from analyses of 244 randomly selected 1000 ft (305 m) road segments (approximately 46 miles). California also rated road effectiveness (1,147 total features evaluated) and reported that 3.1% of these features showed signs of erosion and sediment transport and only 0.8% resulted in sediment transport to streams. In other words, road FPR effectiveness was 96.1%. For Montana, the 89% implementation rate reported in 2006 covered what the state classifies as high risk BMPs. These practices include draining road surfaces, passing road drainage through adequate filtration zones, stabilizing erodible soils, maintaining erosion control features, adequately draining temporary roads, and preventing erosion of culvert and bridge fills.

Several western states have reported lower compliance rates for stream crossings than for forest roads and riparian tree retention. Culverts in particular are most often cited as sources of concern with respect to effects on hydrology, water quality and fish passage. Problems associated with culverts can be broken down into two areas: installation and maintenance. Table 3.39 outlines some of the major requirements or recommendations made by states in the West regarding culvert installation. Recommendations regarding maintenance often highlight the need for inspection and removal of debris after high rainfall events. While watercourse crossing structures need more attention, states in the West note that impacts from these structures are often minor.

Table 3.39 Minimum Culvert Requirements or Recommendations Used by the Western States During Their Installation

State	Minimum Culvert Diameter in (cm)	Other Culvert Requirements or Recommendations
Alaska	12 (30.5) temporary 12 (30.5) permanent	• Withstand 25 yr and 50 yr floods for temporary and permanent streams, respectively. • Entrance and exit must match lateral stream course
Arizona		
California	Diameter must be specified in the THP	• Accommodate 100 yr floods and associated debris/sediment loads. • Allow natural movement of bedload • Allow unlimited anadromous fish passage
Colorado	18 (45.7) permanent	• Place culvert below normal grade.
Idaho	18 (45.7) permanent 15 (38) in specified watersheds	• Permanent culverts must accommodate 50 yr flows
Montana	15 (38) permanent	• At a minimum, accommodate a 25 yr flood frequency. • Place culvert slightly below normal stream grade. • Allow adequate passage of fish when present
New Mexico	15 (38)	• At a minimum, accommodate a 25 yr flood frequency. • Install in a manner that prevents blockage and erosion near outlet. • Align culvert exactly with the stream, on existing grade, and at a depth of the streambed
Oregon	Not specified	• At a minimum, accommodate a 50 yr peak flow. • Not restrict fish passage when movement would normally occur
Utah	15 (38)	• Temporary, accommodate a 25 yr, 24 hr storm event • Permanent, accommodate a 50 yr, 24 hr storm event • Place culvert slightly below the stream grade.
Washington	Permanent Type S and F Waters • HPA needed from WDNR Permanent Type Ns • 15 (38) Eastern and 18 (46) Western Permanent Type Np Waters - 24 (61) Temporary Type Np and Ns Waters • Must pass highest peak flow event expected during length of intended use	• For permanent Type Ns and Np waters, culverts must withstand 100 yr flood events • Specify in harvest plan which culvert sizing method was used (i.e., sizing table method, bankfull width method, or hydraulic design method)

4.0 MIDWESTERN STATE S

4.1 Introduction

Forestry best management practices (BMPs) have been adopted to control forestry nonpoint sources in the states of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, North Dakota, South Dakota, and Wisconsin. This section provides information about major elements of BMP programs in these Midwest states including BMPs for streamside management zones, stream crossings, forest roads, fertilizer and pesticide applications, harvesting and reforestation, and waste disposal. This section also provides information about approaches used by Midwest states to assess BMP implementation.

The initial impetus for BMP development in the region was the Federal Water Pollution Control Amendments of 1972 (i.e., Clean Water Act). More recently, forest certification programs have been a major driving force behind the revision of BMP standards and monitoring programs by the forest products industry and numerous public landholding entities in the Midwest region. For example, in February 2009 Michigan released an updated version of its BMP manual in context of seeking certification for state forestlands (Howard Lindberg, Senior Resource Forester, Plum Creek Timber Company; pers. comm.). As a result, the forestry community is making substantial efforts to validate BMP effectiveness and monitor implementation.

4.2 Midwestern State Forestry BMP Recommendations

4.2.1 *Streamside Management Zones*

All states in the region recommend the use of streamside management zones (SMZs) to protect water quality. Minimum recommended widths for SMZs range from 35 to 200 ft (11 to 61 m) (Table 4.1).

Minnesota requires that SMZ width be established from a stream's bankfull elevation (MN FRC 2005). Bankfull elevation is defined by the state as "the height of the streambank at which the stream cannot hold anymore water without it beginning to spill out onto the floodplain."

North Dakota, Wisconsin, and Illinois use the ordinary high water mark (OHWM) as the inner SMZ boundary when establishing SMZ widths (ND FS 1999; Holaday 2003; IL DNR 2000). Wisconsin defines the OHWM as "the point on the bank or shore up to which the presence and action of the water is so continuous as to leave a distinct mark either by erosion, destruction of terrestrial vegetation, or other easily recognizable characteristics" (Holaday 2003).

Indiana, Missouri, and Michigan use the streambank as a starting point when determining SMZ width (IN DNR 2007; MO DOC 2006; MI DNR & DEQ 1994). South Dakota recommends using either the OHWM or a definable stream bank as a starting point to establish SMZ width (SD DENR 2003).

As in other regions, stream classification has important roles in SMZ guidelines in the Midwest. Typically, streams are classified as perennial, intermittent or ephemeral (see section 2.2.1). The BMP manuals for Illinois and Wisconsin provide definitions for lakes and streams as well as criteria for identifying perennial and intermittent stream types.

Every state in the region has recommendations regarding the minimum width of SMZs (Table 4.1).

Table 4.1 Recommended Minimum SMZ Widths in Midwestern States

State & Waterbody Type	Stream Types: Perennial	Intermittent	Ephemeral
	ft (m) or ac (ha)		
Illinois	50 (15)	25 (8)	
Indiana			
Perennial watercourse widths			
>40 ft (>12 m)	200 (61)		
20 to 40 ft (6 to 12 m)	75 (23)		
<20 ft (<6 m)	50 (15)		
Intermittent watercourses		25 (8)	
Reservoirs & their tributaries	75 (23)		
Other lakes & ponds	35 (11)		
Iowa			
Stream width			
<20 ft (<6 m)	50 (15)	50 (15)	
20 to 40 ft (6 to 12 m)	75 (23)	75 (23)	
>40 ft (>12 m)	150 (46)	150 (46)	
Michigan	100 (30)	100 (30)	
Minnesota			
Trout Streams & Lakes			
Even-age mgmt	150 (46)	150 (46)	
Uneven-age mgmt	200 (61)	200 (61)	
Non-trout Streams & Lakes			
Even-age mgmt			
Stream width			
>10 ft (>3 m)	100 (30)	100 (30)	
<10 ft (<3 m)	50 (15)	50 (15)	
Lake area			
>10 ac (>4 ha)	100 (30)		
<10 ac (<4 ha)	50 (15)		
Uneven-age mgmt			
Stream width			
>10 ft (>3 m)	200 (61)	200 (61)	
3 to10 ft (1 to 3 m)	100 (30)	100 (30)	
<3 ft (<1 m)	50 (15)	50 (15)	
Lake area			
all sizes	200 (61)		
Missouri			
Primary Zone	25 (8)	25 (8)	
Secondary Zone	variable	variable	

Table 4.1 Continued

State & Waterbody Type	Stream Types		
	Perennial	Intermittent	Ephemeral
	---------- ft (m) or ac (ha) ----------		
North Dakota	60 (18)	60 (18)	
South Dakota	50 (15)		
Wisconsin	100 (30)	35 (11)	35 (11)

- Minimum SMZ width is the same for perennial and intermittent streams in Michigan (100 ft / 30 m) and in North Dakota (60 ft/18 m). South Dakota recommends a minimum width of 50 ft (15 m) for perennial streams.
- A single factor (stream width or stream type) is used to determine minimum SMZ width in Illinois, Iowa, and Wisconsin.
- Indiana uses stream width to establish minimum SMZ widths for perennial streams, and has fixed minimum SMZ widths for other types of waterbodies.
- In Minnesota, minimum SMZ width depends on stream type (trout vs. non-trout, perennial vs. intermittent), stream width or lake size, and type of forest management system used outside the SMZ (e.g., even-aged or uneven-aged).

Several states have recommendations to increase SMZ width beyond the minimum on a site-specific basis. For example:

- Illinois recommends consideration of slope and soil erosion potential when setting SMZ widths. The general guideline for perennial streams is that width should increase by 40 ft (12 m) for every 10% increase in slope. For intermittent streams, width should increase 20 ft (6 m) for every 10% increase in slope.
- Iowa recommends increasing SMZ widths in areas with steep slopes and / or highly erodible soils.
- Michigan has guidelines for adjusting SMZs for streams and lakes for slope. When slopes adjacent to the SMZ are in the range of 10-20%, the minimum width of the SMZ should be 115 ft (35 m). For every 10% increase in slope beyond 20%, the SMZ width should increase by 20 ft (6 m).

The primary SMZ in Missouri remains 25 ft (8 m) regardless of slope for perennial and intermittent streams. The secondary SMZ starts at the outer edge of primary SMZ and extends for a distance that increases with slope. The recommended width of the secondary SMZ in feet is twice the percent slope of adjacent land.

SMZ guidelines in Wisconsin vary among the following classes of waters: lakes and navigable perennial streams, navigable intermittent streams, and non-navigable streams. A waterbody is navigable "…if it has a bed and banks, and it is possible to float a canoe or other small craft in the waterway on a regular reoccurring basis, even if only during spring runoff (Holaday 2003)." Perennial and intermittent waterbodies that appear on USGS topographical maps (7.5 minute/

1:24,000 scale) are considered navigable. Other lakes and streams may be determined to be navigable by a Wisconsin DNR water management specialist. Ephemeral waters are non-navigable. When ephemeral areas are observed in the field, the state recommends a minimum SMZ width of 35 ft (11 m) and operating heavy equipment, "within 15 ft (5 m) of the OHWM only when the ground is frozen or dry."

Indiana defines ephemeral streams as watercourses that "generally occur in the upper reaches of a watershed and flow after heavy rains, snow melt, or when soils are saturated" (IN DNR 2007). While Indiana does not specifically recommend a SMZ for these streams, it does provide recommendations to enhance water quality protection during forest management. Recommendations include minimize soil disturbance; limit the number of crossings with equipment; remove any channel blockages; stabilize erosive areas; avoid broadcast applications of chemicals and fertilizers when water is present; and, avoid diverting runoff from roads and skid trails into ephemeral areas.

North Dakota and South Dakota recommend that forest management activities near ephemeral streams limit disturbance to the soil surface (ND FS 1999; SD DENR 2003). Typically, this means limiting mechanical equipment operation in the vicinity of the definable stream bank or channel (if applicable) or OHWM. All state BMP manuals recommend that managers make efforts to keep the forest floor, surface organic materials, or understory vegetation intact around stream channels regardless of stream types.

4.2.2 *SMZ Management*

All states in the Midwest allow harvesting in their SMZs (Table 4.2). The complexity of SMZ management prescriptions varies substantially among states. In general, all states base their prescriptions on retaining a certain level of residual basal area, vegetative cover, or minimizing soil disturbances within a SMZ during harvest.

Table 4.2 Checklist of Parameters Used by States When Establishing Forest Management Recommendations within SMZs

State	SMZ Management Allowed	Basis for SMZ Management Systems			
		Basal Area	Shading / Cover	Leave Tree	Other[1]
Illinois	+				+
Indiana	+		+		
Iowa	+				+
Michigan	+		+		
Minnesota	+	+		+	
Missouri	+	+			
North Dakota	+		+		
South Dakota	+		+		
Wisconsin	+	+		+	

[1]Both Illinois and Iowa recommend forest management in SMZs be done in a way that maintains adequate vegetative cover to protect the site and that managers minimize harvesting and equipment use within SMZs, respectively.

The BMP manuals for the states of Iowa and Illinois do not provide quantitative recommendations for basal area retention in SMZs. Instead, Iowa recommends that managers "minimize harvesting in and around" and "limit wheeled equipment within" the SMZ (IA DNRF 2007). Illinois recommends that any forest management in SMZs be done in a way that "purposefully regenerates the forest while maintaining adequate vegetative cover to protect the site (IL DNR 2000)." Furthermore, both states recommend that management in SMZs minimize soil exposure and compaction to protect ground vegetation and the litter layer.

Missouri, Wisconsin, and Minnesota all have recommended BMPs for basal area retention in managed SMZs. In general, the basal area recommendations for managed SMZs within these states range from 25 to 80 ft^2/ac (7.3 to 23.4 m^2/ha).

Missouri recommends that 60 ft^2/ac (17 m^2/ha) of basal area be retained within both the primary and secondary SMZs. In the primary SMZ, harvested logs should be cabled out. In the secondary SMZ, use of mechanized ground-based equipment to remove logs is permissible (MO DOC 2006).

BMPs for managing SMZs in Wisconsin recommend retaining 60 ft^2/ac (17 m^2/ha) of basal area; however, the state also recommends that the leave trees should have at least 5 in dbh (Holaday 2003). Selective harvesting should be used to promote long-lived tree species identified in the state's BMP manual such as maples, ash, elms, oaks, hemlock, white pine, red pine, and white cedar. The recommended minimum interval between harvests is 10 years. Managers are advised to avoid using mechanized equipment within 50 ft (15 m) of the OHWM on perennial streams or 15 ft (5 m) of the OHWM on intermittent streams unless the ground is frozen.

In Minnesota, no minimum tree diameter has been established for SMZ leave trees. The state differentiates leave tree requirements based on the presence (or absence) of trout and the type of management system utilized (MN FRC 2005). For trout-bearing waterbodies and their tributaries, the state recommends a minimum residual basal area for even-aged and uneven-aged management of 60 and 80 ft^2/ac (17 and 23.4 m^2/ha), respectively. Where even-age management is practiced near trout-bearing streams, Minnesota recommends additional leave trees in harvested areas outside of SMZs. In other words, additional leave trees should be left adjacent to the SMZ "in clumps, varying in size with a minimum size of 0.25 ac (0.1 ha)." Furthermore, the SMZ area should not be used when calculating the recommended minimum of 5% leave trees in an even-age harvest unit. With uneven-age management, recommendations for additional leave tree do not apply.

For non-trout-bearing waterbodies in Minnesota, it is recommended that SMZs in even-aged management systems have a residual basal area that ranges between 25 to 80 ft^2/ac (7.3 to 23.4 m^2/ha) depending on forest type. Recommendations for additional leave trees outside of SMZs are the same as for trout-bearing streams. In uneven-age forest management systems, state BMPs recommend that residual basal area in SMZs be at least 80 ft^2/ac (23.4 m^2/ha) and do not require additional tree retention outside of SMZs.

Indiana, Michigan, North Dakota, and South Dakota use stream shading or residual canopy cover as the basis for their SMZ tree retention guidelines. These states also recommend minimizing disturbances to shrubs and ground cover. In Indiana, the state's BMP manual recommends that managers retain at least 50% canopy cover on perennial watercourses (IN DNR 2007). Michigan recommends that when managing SMZs, "harvesting/cutting specifications should be modified to retain a sufficient number of trees to maintain shading of the stream and to leave a stable, undisturbed forest floor" (MI DNR & DEQ 1994). North Dakota advises managers to use selective harvesting outside of the 15 ft (5 m) exclusion zone (area directly adjacent to the streambank), maintain ground cover, and to limit the use of heavy equipment in the SMZ (ND FS 1999). South Dakota recommends that managers retain shrubs, deciduous trees, and some merchantable conifers adjacent to the stream;

limit the size of SMZ openings to <600 ft (<183 m) of stream length to prevent increasing stream temperatures; and maintain groundcover in the SMZ to trap sediment (SD DENR 2003).

4.2.3 *Stream Crossing BMPs*

Midwest state forestry BMP manuals suggest that the best way to maintain water quality during forest management is to avoid crossing a stream. Since this is not always a viable option, these manuals emphasize the importance of installing stream crossing structures in an effective and environmentally sensitive manner. Properly constructed and maintained stream crossings reduce erosion and sedimentation with the added benefits of increasing harvesting efficiency. All states recommend crossings be designed, installed, and maintained to minimize disturbance of the streambank and stream channel. Minimizing disturbances to streams will reduce impacts to water quality and aquatic biota.

Midwest states generally recognize three types of stream crossings for use in forest management: fords, culverts, and bridges. Many states in this region require a permit or notification when designing and installing these water crossing structures on perennial and intermittent streams (Table 4.3).

- North Dakota recommends that managers or landowners contact and coordinate with their local Water Resource District when planning the construction of permanent and temporary crossings.
- Wisconsin requires a permit "…to construct a ford or install a culvert or bridge across a navigable perennial or intermittent stream (Chapter 30, Wisconsin Statutes). Additionally, a flooding easement from upstream property owners must be obtained in Wisconsin for stream crossings that are not designed to pass 100-year floods. Iowa has a similar requirement for a culvert flood easement."
- The Michigan Natural Resources and Environmental Protection Act requires a permit for any "…occupation, construction, filling, or grade change within the 100 yr floodplain of a river, stream, drain, or lake." The Act considers bridges and culverts to be "an occupation of the floodplain." Michigan also requires a permit for any activity that disturbs "...land below the OHWM." Road, pedestrian, and utility crossings of streams are examples of activities requiring state permits.
- Illinois and Minnesota require permits in some circumstances. Illinois requires a permit for "construction in a floodway of any stream [intermittent or perennial] if the drainage area exceeds 1 mi^2 (2.59 km^2) in an urban area or 10 mi^2 in a rural area." Minnesota does not require a permit to "construct a bridge or culvert, or to fill or excavate the bed of a public watercourse having a total drainage area, at its mouth, of 5 mi^2 or 3,200 ac (13 km^2 or 1295 ha) or less." Certain provisions, however, must be also be met, including 1) providing at least 7 days notice to county zoning officials and local Soil and Water Conservation Department; 2) the structure will not divert water to a different watershed; 3) the project will not dam the watercourse; and 4) the watercourse is not officially designated as a trout water or trout stream tributary.

Table 4.3 Checklist of State Recommended BMPs for Stream Crossings

	Permit or Notification Required	Fords	Culverts	Bridges	Winter or Temporary Crossings
Illinois	+	+	+	+	+
Indiana		+	+	+	+
Iowa	+	+	+	+	+
Michigan	+				
Minnesota	+	+	+	+	+
Missouri		+	+	+	
North Dakota	+	+	+	+	
South Dakota		+	+	+	
Wisconsin	+	+	+	+	+

All states in the region recommend some general BMPs for using a ford or drive-through (Table 4.3). These BMPs include locating fords in areas where the stream bank is low and the stream bottom is stable and rocky. Most states recommend use of fords only when flows are low or nonexistent. Illinois, Iowa, and Wisconsin recommend use of fords only when crossing dry streambeds or where fording would cause minimal water quality impacts. Minnesota has nine criteria that must be met in order for installing a ford not to require a permit (MN FRC 2005). Among these criteria are: normal summer flows must not exceed a 2 ft (0.6 m) depth; the original streambank is no higher than 4 ft (1.2 m); normal flows are not reduced by the structure; and the stream is not designated a trout stream or a tributary of a trout stream.

Many states in this region have recommendations for using temporary, skidder stream crossings (i.e., pole fords and frozen fords). The primary recommendation for skidding logs across streams is to use permanent crossings. When using these structures is not feasible, pole fords (frozen fords are acceptable during winter logging) are generally accepted for crossing small streams. States recommend that these stream crossing structures be used temporarily and removed immediately after use. Only Indiana has BMPs that recommend limiting the use of pole fords to intermittent or ephemeral streams (IN DNR 2007). Other states with recommended BMPs for using pole or frozen fords include Illinois, Wisconsin, and North Dakota (Table 4.3).

In situations where fords are not allowed or are not a practical stream crossing structure, culverts are recommended to cross streams with small watersheds. All state BMPs recognize the importance of installing culverts of sufficient size to allow passage of aquatic life and high water flows.

The processes or metrics used to determine the appropriate culvert diameter vary among the states and are based on one of six approaches: drainage area, soil types and drainage area, stream cross section area (i.e., Hasty Method), stream width, stream size and site condition method, or a minimal diameter/peak flow approach.

Iowa and Wisconsin recommend using culverts with at least 12 in (30 cm) diameters (IA DNRF 2007; Holaday 2003). North Dakota, South Dakota and Missouri recommend a minimum culvert diameter of 15 in (38 cm) (ND FS 1999; SD DENR 2003; MO DOC 2006), while Michigan recommends a minimum diameter of 18 in (46 cm) (MI DNR & DEQ 1994).

Missouri recommends sizing culverts for stream crossings and cross drains based on drainage area (i.e., recommended culvert size increases with drainage area) (Table 4.4). Indiana BMPs use this approach also but with adjustment of recommended culvert diameters to account for both slope and

soil type (Table 4.5). Michigan and South Dakota recommend calculating culvert size using end area or cross sectional area. In Michigan, the Hasty Method requires information on the depth of the stream and the widths of the stream channel at the high water mark and at the stream bottom. The formula [height x (Width OHWM + Width bottom)] is correlated with the appropriate (or minimum) culvert size (Table 4.6). In a slightly different approach, South Dakota recommends measuring the width of the stream channel at the high water mark and the stream channel depth. Multiplying the width by the depth determines the channel area. To compensate for peak flows, South Dakota recommends that managers always round up to the next largest diameter pipe. For example, a 15 in (38 cm) diameter culvert is recommend for streams with areas equal to 1 ft^2 (0.093 m^2) while an 18 in (46 cm) culvert is recommended for streams with areas equal to 1.5 ft^2 (0.14 m^2). If the area is calculated to be 1.2 ft^2 (0.11 m^2), it is recommended that managers use at least an 18 in (46 cm) diameter pipe.

Iowa, North Dakota and Wisconsin require that culverts be sized to pass 100-year flood or peak flow events. Iowa and Wisconsin also have laws governing impacts to property owners upstream. For these two states, the landowner or contractor is responsible for obtaining a flood easement from any affected property owners upstream of culvert crossings that are not designed to pass 100-year flood events. Both Iowa and Wisconsin, therefore, recommend that landowners and managers contact the USDA Natural Resource Conservation Service or private engineering or forestry consultants to properly size culverts.

Illinois determines appropriate culvert sizes utilizing the stream size/site condition method (IL DNR 2000). The procedures for determining culvert diameter are as follows: 1) determine both the channel width and depth; 2) determine whether upstream slope is flat (0-0.5% slope), moderate hilly (2-10% slope), or extremely hilly (>10% slope); and 3) read the culvert size from the appropriate table (Table 4.7).

Minnesota recommends a minimum culvert diameter of 15 in (38 cm) with site-specific adjustment of the minimum by selecting, "…a diameter equal to the narrowest width (top of the bank to top of the bank) of the stream. Determine this width in a straight section of the stream near the intended stream crossing" (MN FRC 2005). When multiple culverts may be needed, "one should be buried (1/6 of diameter) and others should be about 1 ft (0.3 m) higher in order to maintain adequate water depth within one culvert for fish migration during low stream flow." Minnesota also recommends that landowners and managers consult with local offices of Soil and Water Conservation Districts or the Natural Resources Conservation Service for information on sizing culverts properly.

While bridges may have the least impacts on stream hydrology and water quality, their construction and maintenance can be expensive. Furthermore, bridge installation is often site-specific depending on site characteristics (e.g., stream width, channel depth, and approach characteristics). Therefore, state BMP manuals in the Midwest provide limited guidance for installing permanent and temporary bridges. Commonly recommended BMPs for bridge installation include locating the bridge at narrow stream points, protecting bridge approaches by using water control structures, and protecting the streambank and channel from erosion. Many states require notification of bridge construction or a permit from a state agency. Generally, when a permit is required the landowner or manager must provide a detailed plan to an agency outlining how a bridge will be constructed and what methods are in place to limit its impacts to stream hydrology and aquatic life.

Table 4.4 Recommended Diameters of Culverts Based on Drainage Area for Missouri [adapted from the Missouri Watershed Protection Guidelines (MO DOC 2006)]

Drainage Area ac (ha)	Culvert Diameter in (cm)
10 (4)	18 (46)
50 (20)	42 (107)
100 (41)	48 (122)
200 (81)	72 (183)

Table 4.5 Minimum Culvert Sizing Requirements Based on Soil Type, Area Drained above the Culvert, and Slope for Indiana [adapted from the Indiana Forestry Best Management Practices Field Guide (IN DNR 2007)]

		Slope		
		<5%	5 – 15%	>15%
	Area Drained	Minimum Pipe Diameter		
Soil Type	-- ac (ha) --	---------- in (cm) ----------		
Light (sands)	5 (2)	18 (46)	18 (46)	18 (46)
	10 (4)	18 (46)	18 (46)	18 (46)
	20 (8)	18 (46)	18 (46)	18 (46)
	30 (12)	18 (46)	18 (46)	18 (46)
	40 (16)	18 (46)	18 (46)	18 (46)
	50 (20)	18 (46)	18 (46)	18 (46)
	75 (30)	18 (46)	21 (53)	21 (53)
	100 (41)	21 (53)	21 (53)	24 (61)
	150 (61)	21 (53)	24 (61)	24 (61)
	200 (81)	24 (61)	30 (76)	30 (76)
	250 ()	27 (69)	30 (76)	30 (76)
	300 ()	30 (76)	36 (91)	36 (91)
	350 ()	30 (76)	36 (91)	42 (107)
	400 ()	36 (91)	36 (91)	42 (107)
Medium (loams)	5 (2)	18 (46)	18 (46)	21 (53)
	10 (4)	21 (53)	24 (61)	27 (69)
	20 (8)	24 (61)	27 (69)	36 (91)
	30 (12)	27 (69)	30 (76)	36 (91)
	40 (16)	27 (69)	36 (91)	42 (107)
	50 (20)	30 (76)	36 (91)	48 (122)
	75 (30)	36 (91)	42 (107)	-
	100 (41)	36 (91)	48 (122)	-
	150 (61)	42 (107)	-	-
	200 (81)	48 (122)	-	-

Table 4.5 Continued

Soil Type	Area Drained -- ac (ha) --	Slope <5% Minimum Pipe Diameter in (cm)	Slope 5 – 15% Minimum Pipe Diameter in (cm)	Slope >15% Minimum Pipe Diameter in (cm)
Heavy (clays)	5 (2)	21 (53)	21 (53)	24 (61)
	10 (4)	27 (69)	27 (69)	36 (91)
	20 (8)	36 (91)	36 (91)	42 (107)
	30 (12)	36 (91)	42 (107)	48 (122)
	40 (16)	42 (107)	48 (122)	-
	50 (20)	48 (122)	48 (122)	-

Table 4.6 Recommended Minimum Culvert Diameters for Streams in Michigan Based on Culvert End Area [adapted from MI DNR and DEQ (1994)]

Culvert End Area ft^2 (m^2)	Diameter in (cm)
1.80 (0.17)	18 (46)
3.10 (0.29)	24 (61)
4.90 (0.46)	30 (76)
7.10 (0.66)	36 (91)
9.60 (0.89)	42 (107)
12.60 (1.17)	48 (122)
15.90 (1.48)	54 (137)
19.60 (1.82)	60 (152)
23.80 (2.21)	66 (168)
28.30 (2.63)	72 (183)
33.20 (3.09)	78 (198)
38.50 (3.58)	84 (213)
44.20 (4.11)	90 (229)

Table 4.7 Recommended Culvert Diameters Based on Upstream Slope for Flat, Moderately Hilly, and Extreme Hilly Conditions in Illinois [adapted from Illinois Forestry BMP Manual (IL DNR 2000)]

Flat Conditions - Upstream slopes (0 to 0.5%)

	Stream Depth ft (m)							
Stream Width ft (m)	0.5 (0.2)	1.0 (0.4)	1.5 (0.5)	2.0 (0.6)	2.5 (0.8)	3.0 (0.9)	3.5 (1.1)	4.0 (1.2)
1 (0.4)	12 (30)	12 (30)						
2 (0.6)	12 (30)	12 (30)	18 (46)	24 (61)				
3 (0.9)	12 (30)	15 (38)	18 (46)	24 (61)	30 (76)	36 (91)		
4 (4.3)	12 (30)	18 (46)	21 (53)	27 (69)	33 (84)	36 (91)	42 (107)	
5 (1.5)	12 (30)	18 (46)	21 (53)	30 (76)	36 (91)	42 (107)	48 (122)	54 (137)
6 (1.8)	12 (30)	21 (53)	24 (61)	33 (84)	42 (107)	42 (107)	54 (137)	60 (152)
7 (2.1)	15 (38)	21 (53)	24 (61)	36 (91)	42 (107)	48 (122)	60 (152)	60 (152)
8 (2.4)	15 (38)	24 (61)	30 (76)	36 (91)	42 (107)	54 (137)	60 (152)	2-48 (122)
9 (2.7)	15 (38)	24 (61)	33 (84)	42 (107)	48 (122)	54 (137)	60 (152)	2-54 (137)
10 (3.1)	18 (46)	27 (69)	36 (91)	42 (107)	48 (122)	60 (152)	2-42 (107)	2-54 (137)

Moderate Hilly Conditions - Upstream slopes (2 to 10%)

	Stream Depth ft (m)							
Stream Width ft (m)	0.5 (0.2)	1.0 (0.4)	1.5 (0.5)	2.0 (0.6)	2.5 (0.8)	3.0 (0.9)	3.5 (1.1)	4.0 (1.2)
1 (0.4)	12 (30)	21 (53)						
2 (0.6)	15 (38)	27 (69)	36 (91)	48 (122)				
3 (0.9)	18 (46)	33 (84)	42 (107)	54 (137)	54 (137)	3-54 (137)		
				2-42 (107)		4-42 (107)		
4 (4.3)	21 (53)	36 (91)	48 (122)	2-48 (122)	3-48 (122)	4-48 (122)	*	
				3-36 (91)	4-42 (107)			
5 (1.5)	27 (69)	42 (107)	54 (137)	2-48 (122)	3-48 (122)	4-54 (137)	*	*
				3-42 (107)	4-42 (107)			
6 (1.8)	30 (76)	42 (107)	60 (152)	2-54 (137)	4-48 (122)	*	*	*
				3-42 (107)				

(Continued on next page.)

Table 4.7 Continued

Moderate Hilly Conditions - Upstream slopes (2 to 10%)

Stream Width ft (m)	Stream Depth ft (m)							
	0.5 (0.2)	1.0 (0.4)	1.5 (0.5)	2.0 (0.6)	2.5 (0.8)	3.0 (0.9)	3.5 (1.1)	4.0 (1.2)
7 (2.1)	30 (76)	48 (122)	60 (152)	3-48 (122) 4-42 (107)	4-54 (137)	*	*	*
8 (2.4)	33 (84)	54 (137)	2-54 (137) 3-48 (122)	3-54 (137) 4-48 (122)	4-54 (137)	*	*	*
9 (2.7)	36 (91)	54 (137)	2-54 (137) 3-48 (122)	3-54 (137) 4-48 (122)	*	*	*	*
10 (3.1)	42 (107)	60 (152)	3-48 (122) 4-42 (107)	4-54 (137)	*	*	*	*

Extreme Hilly Conditions - Upstream slopes (> 10%)

Stream Width ft (m)	Stream Depth ft (m)							
	0.5 (0.2)	1.0 (0.4)	1.5 (0.5)	2.0 (0.6)	2.5 (0.8)	3.0 (0.9)	3.5 (1.1)	4.0 (1.2)
1 (0.4)	15 (38)	30 (76)						
2 (0.6)	21 (53)	42 (107)	54 (137)	2-54 (137) 3-42 (107)				
3 (0.9)	27 (69)	48 (122)	2-48 (122) 3-42 (107)	3-48 (122)	4-54 (137)	*		
4 (4.3)	33 (84)	54 (137)	2-54 (137) 3-42 (107)	3-54 (137) 4-48 (122)	*	*	*	
5 (1.5)	36 (91)	60 (152)	2-60 (152) 3-48 (122)	4-54 (137) 5-48 (122)	*	*	*	*
6 (1.8)	42 (107)	60 (152)	3-54 (137) 4-48 (122)	*	*	*	*	*

(Continued on next page.)

Table 4.7 Continued

Extreme Hilly Conditions - Upstream slopes (> 10%)

Stream Width ft (m)	Stream Depth ft (m)							
	0.5 (0.2)	1.0 (0.4)	1.5 (0.5)	2.0 (0.6)	2.5 (0.8)	3.0 (0.9)	3.5 (1.1)	4.0 (1.2)
7 (2.1)	42 (107)	2-48 (122) 4-36 (91)	3-54 (137) 4-48 (122)	4-60 (152)	*	*	*	*
8 (2.4)	48 (122)	2-54 (137) 3-48 (122)	4-54 (137) 5-54 (137)	*	*	*	*	*
9 (2.7)	54 (137)	2-60 (152) 3-48 (122)	4-60 (152) 5-54 (137)	*	*	*	*	*
10 (3.1)	54 (137)	3-54 (137) 4-48 (122)	*	*	*	*	*	*

4.2.4 *BMPs for Forest Roads*

All state BMP manuals in the Midwest provide guidance regarding permanent (haul) and temporary (skidder) roads (Table 4.8). In general, states recommend that both road types be properly planned so that resource extraction can be done efficiently with minimal impacts. Each state forestry BMP manual provides recommended practices for forest roads that fall into broad categories covering planning and location, construction (summer and winter), drainage, maintenance, and retirement.

Without proper planning, poorly located and improperly constructed roads can result in sediment transport from roads to streams. All state BMP manuals recognize the importance of road planning and design. In fact, this is generally the first topic covered under forest roads within each BMP manual. State BMPs recommend that land managers examine soil and topographic maps and conduct site inspections so that potential problem areas can be avoided. State BMP manuals also recognize the importance of stream crossings and road approaches to crossings. Therefore, all states in this region recommend that landowners and managers pay increased attention to forest road approaches to stream crossings.

All state BMP manuals recommend using existing roads when possible, limiting the number of new roads, limiting road length, and limiting the number of stream crossings. It is also advised that roads be constructed outside of SMZs, be constructed on well drained soils (when possible), follow natural contours, and be placed on gently sloping terrain (Table 4.8).

Generally, states in the region recommend that road grades not exceed 10%. Iowa's BMPs recommend that road grades not exceed 5% while Missouri recommends road grades of 8% or less. The length of road segments on steep grades should be limited to control erosion.

When constructing new roads, all states recommend that road designs minimize cuts and fills. Some states also note the importance of balancing cuts and fills.

For limiting runoff and erosion, states provide recommendations for crowned, insloped, or outsloped roads. Road drainage from outsloped roads should move off of the road surface in a manner that promotes dispersal, filtering by vegetation, and re-infiltration to soil. Insloped roads are typically recommended when constructing roads on steep terrain and on fine textured soils. When using insloped roads, states recommend installing cross drain culverts to ensure proper road drainage. Sizing for cross-drain culverts varies by states; however, the minimum size is generally the same as that recommended for culverts used to cross streams. Cross-drain culvert diameters increase as the road drainage area above the culvert increases.

BMP manuals in the Midwest emphasize the importance of maintaining adequate road drainage to limit erosion and sediment delivery to waterbodies. In addition to cross drains, road drainage techniques discussed in Midwest BMP manuals include water bars, broad-based dips, water turnouts (wing ditches and diversion ditches), and open-top culverts (Table 4.8). Water bars are typically recommended for use on skid trails or when closing out haul roads. The other techniques are commonly used for active haul roads. Several states recommended that use of broad-based dips be limited to grades less than 10%. BMP manuals also note that gravelling, seeding or mulching of exposed soil can be useful in controlling erosion from roads.

Regardless of the water diversion techniques used, their effectiveness is based on their correct installation and appropriate spacing in relation to the slope of the road. In general, state BMPs recommend that spacing between diversion structures be reduced as the road grade increases (Tables 4.9 and 4.10). State BMP manuals consistently recommend that drainage from control structures be directed into areas where water will be dispersed and sediment will be able to settle out.

Table 4.8 Checklist of State Recommended BMPs for Water Drainage and Water Diversion Techniques for Controlling Runoff from Permanent and Temporary Forest Roads

	Follow Contour	Out-sloped Roads	Insloped Roads	Cross Drain Culverts	Open-Top Culverts	Water Bars	Broad-Based Dips	Water Turnouts
Illinois	+	+	+	+	+	+	+	+
Indiana	+	+	+	+	+	+	+	+
Iowa	+	+	+	+	+	+	+	+
Michigan	+	+	+	+	+	+	+	+
Minnesota	+	+	+	+	+	+	+	+
Missouri	+			+		+	+	+
North Dakota	+	+	+	+	+	+	+	+
South Dakota	+	+	+	+	+	+	+	+
Wisconsin	+	+	+	+	+	+	+	+

Table 4.9 Recommended Spacing Distance between Water Bars for Haul Roads and Skid Trails for the Midwestern States

	States								
	IL	IN	IA	MI	MN	MO	ND[1]	SD	WI
Slope (%)	Recommended Spacing Distance ft (m)								
1	400 (122)		400 (122)			400 (122)			400 (122)
2	250 (76)	250 (76)	250 (76)	250 (76)	250 (76)	245 (75)		250 (76)	250 (76)
5	130 (40)	125 (38)	130 (40)	135 (41)	130 (40)	125 (38)		135 (41)	130 (40)
10	80 (24)	80 (24)	80 (24)	80 (24)	80 (24)	78 (24)		80 (24)	80 (24)
15	50 (15)	60 (18)	50 (15)	60 (18)	50 (15)	58 (18)		60 (18)	50 (15)
20	45 (14)	40 (12)		45 (14)		47 (14)		45 (14)	
25	40 (12)	30 (9)	40 (12)		40 (12)	40 (12)			40 (12)
30				35 (11)		35 (11)			
35						32 (10)			
40						29 (9)			

[1]The North Dakota forestry BMP manual does not provide recommended spacing distances for water bars. Instead, the manual recommends spacing for drain-dips.

Table 4.10 Recommended Distances between Broad-Based Dips for Haul Roads in the Midwest

	States								
	IL	IN	IA	MI	MN	MO	ND	SD[1]	WI
Slope (%)	Recommended Spacing Distance ft (m)								
1	500 (152)		500 (152)		500 (152)	500 (152)	500 (152)		500 (152)
2	300 (91)	300 (91)	300 (91)	300 (91)	500 (152)	300 (91)	500 (152)		300 (91)
3				235 (72)	300 (91)		300 (91)		
4				200 (61)	300 (91)		300 (91)		
5	180 (55)	180 (55)	180 (55)	180 (55)	180 (55)	180 (55)	180 (55)		180 (55)
6				165 (50)	180 (55)		180 (55)		
7				155 (47)	180 (55)		180 (55)		
8				150 (46)	150 (46)		150 (46)		
9				145 (44)	150 (46)		150 (46)		
10	150 (46)	140 (43)	150 (46)	140 (43)	150 (46)	140 (43)	150 (46)		150 (46)
12				100 (30)	130 (40)		130 (40)		
15	130 (40)	125 (38)	130 (40)		130 (40)		130 (40)		130 (40)
20	120 (37)	120 (37)			110 (34)		110 (34)		
25	110 (34)	115 (35)	110 (34)						110 (34)

[1]The South Dakota forestry BMP manual does not provide recommended spacing distances for broad-based dips but does provide some insight into their construction and utility for draining water from the road surface.

4.2.5 *BMPs for Fertilizers and Pesticides*

Three Midwest states mention fertilizer use in their BMP manuals. Missouri indicates use of fertilizers for silvicultural purposes is "…virtually non-existent" in the state and, as a result, no recommendations are provided (MO DOC 2006). The Minnesota BMP manual acknowledges the benefits of fertilizer use but indicates that "recommendations for forest fertilization need to be better refined in order to understand situations in which this practice is biologically beneficial and economically effective." Minnesota does, however, provide two broad recommendations for using fertilizers (MN FRC 2005). First, nutrient analysis of the soil and fertilizer should be done before application. The second recommendation is that when applying fertilizers, "water quality guidelines related to pesticide use should be followed when applying fertilizers." In South Dakota application of fertilizers must be done in accord with the state's fertilizer rules (see South Dakota Codified Law 38-19 and Administrative Rule 12:44).

In recent years, the use of herbicides for site preparation has become increasingly common and all states in this region have established BMPs for the proper use of herbicides and other pesticides during forest management (Table 4.11). Use of herbicides lowers potential for sediment transport to streams compared to disking and other tillage treatments by not disturbing the soil surface. Many states in the Midwest recognize these benefits. For example, Michigan's BMP manual states that herbicides have an "…advantage over mechanical means [of site preparation] because there is no soil disturbance and can be used where steep slope prevents use of machinery" (MI DNR & DEQ 1994). Furthermore, the potential for impacts to water quality due to herbicide transport to streams has been demonstrated to be small (NCASI 2007a).

Herbicide use is regulated by the Federal Insecticide, Fungicide and Rodenticide Act which, in general, requires that any pesticide be applied in accordance with requirements on the pesticide's label. Most Midwest BMP manuals provide further guidance to protect non-target species as well as water quality. Some states (e.g., Michigan, Wisconsin and South Dakota) provide limited guidance with regard to herbicide applications in their BMP manuals, but instead refer the reader to other sources of information. In Michigan, for example, BMPs note that the Michigan Pesticide Control Act regulates the use, handling, and application of pesticides in the state. Wisconsin's BMP manual directs the reader to review the manual titled *Pest Management Principles for the Commercial Applicator: Forestry* which provides extensive information on requirements for pesticide use in the state. The South Dakota BMP manual recommends that applicators familiarize themselves with state legal requirements for chemical application (see South Dakota Codified Law 38-20A, 38-21 and Administrative Rule 12:56). BMP manuals in Illinois and Minnesota provide more detailed application recommendations, include references to additional resources, and identify authorities to contact when questions arise.

Iowa, Illinois, Minnesota, North Dakota, South Dakota, and Wisconsin all recommend the use of an integrated pest management strategy to controlling pest species. Integrated pest management uses a combination of manual, mechanized, biological, chemical, and preventative measures to reduce the impacts of unwanted pest and vegetation species. The state manuals, however, provide little guidance on how this management approach should be done. For example several manuals indicate that this approach may "…reduce dependence on the use of chemicals." Wisconsin suggests that those interested in integrated pest management contact the state Department of Natural Resources for more information.

Five states in the region provide guidance for applying chemicals aerially. Illinois, Iowa, and Wisconsin recommend two BMPs for aerial applications. First, managers should use only a licensed applicator. Second, watercourses should be identified prior to application and avoided during application when using chemicals not registered for aquatic use. North Dakota recommends that aerial

applications leave at least a 50 ft (15 m) wide buffer along surface waters and avoid spraying chemicals within the SMZ (ND FS 1999). Minnesota recommends that applications be preformed when wind speeds are less than six mph (MN FRC 2005).

BMPs generally emphasize the importance of reading the label on herbicides and other pesticide products. The label defines legal restrictions on application rates and other aspects of use. In addition, state BMPs generally restrict herbicide use within SMZs to spot applications and similar techniques that minimize potential for chemical movement to surface waters (Table 4.11). Iowa, Illinois, and Wisconsin also recommend that managers avoid applying herbicides in areas where the chemicals can kill stabilizing vegetation on slopes, gullies, and other fragile areas subject to erosion that drain into surface water.

Finally, all states in this region provide some information or guidance for the storage and disposal of forest chemicals following their use. The primary recommendations are to avoid storing or mixing chemicals near waterbodies or within SMZs and to avoid cleaning equipment in or near waterbodies. Disposal BMPs for states in the region center on following the manufacturers' recommended procedures when discarding excess chemicals, removing and disposing of used containers according to local, county or state guidelines, and developing plans to address spills that may occur during cleanup or disposal.

4.2.6 *BMPs for Harvesting and Reforestation*

There is a high degree of consistency among Midwest states with respect to topics addressed in BMPs for harvesting and reforestation (Table 4.12). These topics include landings (i.e., log decks), skid trails, temporary stream crossings, water diversion techniques, and general site preparation guidelines.

Determining the location of landings prior to harvesting is critical to reduce sediment movement from both the landing and from skidder traffic transporting logs to these areas. All states, therefore, recommend planning the location of landings prior to installing the access road and primary skid trail system.

All states recommend that landings be located outside of SMZs. It is also generally recommended that managers use existing landings if they are available. When this is not feasible, states recommend that managers limit both the size and number of landings. Limiting the number of landings limits the number of skid trails and access roads necessary to move logs to and from the landings. States in this region also recommend that landings be located on well drained soils with minimal slopes, on ground "shaped to promote efficient drainage" (i.e., crowned areas), or on frozen ground during winter harvests. The states of Illinois, Iowa, Missouri, North Dakota, and Wisconsin also recommend that residue piles be located away from waterbodies and natural drainages (i.e., ephemeral areas) in order to avoid movement of organic materials into streams. Finally, all states recommend that managers take steps to ensure that sediment runoff following harvesting operations is controlled by seeding bare areas with grasses or covering areas of bare soil with logging slash.

State BMPs for skid trails are numerous and variable but generally are focused on two areas: limiting disturbance to soils and protecting streams during crossing. State BMPs for skid trails recommend that managers minimize impacts both to soil productivity (e.g., rutting, puddling, and compaction) and water quality. All states recommend that harvesting operations limit the number of skid trails and their length.

Table 4.11 Checklist of State Recommended BMPs for Forest Chemical Application Which Includes Herbicides, Fungicides, and Insecticides

	Use Rates Recommended by Manufacturer	Direct/Spot Applications Permissible in SMZs	Aerial Application Guidance	Consider Weather Conditions Prior to Application	Application Restricted Near Waterbodies	Disposal and Cleanup Guidance
Illinois	+	+	+	+	+	+
Indiana	+	+		+	+	+
Iowa	+	+	+	+	+	+
Michigan	+	+		+	+	+
Minnesota	+	+	+	+	+	+
Missouri	+	+			+	
North Dakota	+	+	+	+	+	+
South Dakota	+	+		+	+	+
Wisconsin	+	+	+	+	+	+

Table 4.12 Checklist of State Recommended BMPs for Harvesting, Reforestation, and Waste Disposal

State	Placement of Landings and Skid Trails	Limit Skid Trails and Temporary Stream Crossings	Advise Use of Water Diversion Techniques	Procedures for Retiring Landings and Trails	General Site Preparation Recommendations	Waste Disposal Guidance
Illinois	+	+	+	+	+	+
Indiana	+	+	+	+	+	+
Iowa	+	+	+	+	+	+
Michigan	+	+	+	+	+	+
Minnesota	+	+	+	+	+	+
Missouri	+	+	+	+	+	+
North Dakota	+	+	+	+	+	+
South Dakota	+	+	+	+	+	+
Wisconsin	+	+	+	+	+	+

A method to limit the number of skid trails is to reuse existing trails. Iowa, Illinois, and Wisconsin, all recommend that managers consider using existing trails if they provide good long-term access and will bring about minimal environmental impacts.

BMPs in several states recommend against skidding logs up steep slopes, but concepts of slopes too steep for skidding vary somewhat among states: 10% in Michigan; 15% in Illinois, Iowa and Wisconsin; 20% in Indiana; 30% in North Dakota.

All states recommend that water diversion techniques be used and maintained during and after harvesting. Common recommendations call for water bars and water turnouts to be installed and maintained on retired roads and skid trails.

State BMPs for skidder crossings or other temporary stream crossings focus on limiting disturbances to the stream bank. In general, states recommend minimizing the number of stream crossings and using permanent crossings where feasible.

Illinois, Iowa, and Wisconsin provide guidelines for using pole ford crossings where temporary crossings are necessary. These guidelines include 1) using these structures only in small streams by placing poles or small logs side by side on the streambed; and 2) removing the structure immediately after use. States also recommend keeping skidder traffic out of stream channels except at designated crossings and avoiding log transport along stream channels.

Site preparation BMPs generally recommend that mechanical equipment be excluded from all SMZs. Most states in the region recommend that mechanized activities limit soil movement across the site and into woody debris piles. Minnesota recommends that piling or windrowing should be avoided and that forest managers "…scatter slash across the site." It is also recommended that forest residues be deposited in stable areas outside of SMZs and that mechanized equipment avoids going directly upslope. Illinois recommends that managers consider using herbicides instead of mechanical site preparation, since "the use of herbicides causes less disturbance to the soil." Only one state in the region, South Dakota, has a logging slash law. South Dakota law (South Dakota Codified Laws 12-10-26 and 21-10-27 and South Dakota Administrative Rule 12:12:12) requires that managers properly deal with logging residues after harvest. In short, the law requires that logging slash "…be treated by lopping and scattering the vegetation, by removal from the site or by piling and burning."

4.2.7 *BMPs for Waste Disposal*

Almost all states in the Midwest have general recommendations for waste disposal and site cleanup following harvest (Table 4.12). Generally, these BMPs discourage disposal of waste on site or cleaning of equipment in SMZs and waterbodies. South Dakota and Illinois, for example, recommend that equipment maintenance and refueling take place at least 100 ft (30 m) from a watercourse. Iowa recommends a distance of 150 ft (46 m). States also recommend that care be taken when performing routine maintenance of heavy equipment and remind managers to collect all used wastes. Once collected, these materials should be safely stored away from watercourses and transported off site. It is also important to note that these chemicals should also be disposed of in accordance with municipal and state guidelines.

4.3 State BMP Monitoring Protocols and Implementation/Compliance Rates

This section provides a summary of the methods and results of surveys conducted by Midwest states to evaluate rates of BMP implementation.

4.3.1 *Indiana*

Indiana's forestry BMPs were adopted in 1996 and a BMP field manual was published in 1998. The Department of Natural Resources – Division of Forestry (DNR), in cooperation with the Woodland Steward Institute, developed a statewide program to monitor rates of BMP implementation. BMP monitoring was conducted in 1996, 1997, 1999, and 2000 (Sobecki and McCoy 2004).

The objectives of the state's BMP monitoring program is to 1) assess BMP effectiveness in minimizing soil erosion and stream sedimentation; 2) provide data on rates of BMP implementation; 3) identify areas to focus future program training and educational efforts; 4) identify BMP specifications which may need technical modifications; and 5) identify methods to improve future monitoring efforts. Monitoring is conducted by interdisciplinary teams of four to six people. Teams are assigned to different sites across the state. Each team is lead by a DNR forester to provide technical and logistic support while the remaining survey team members come from a variety of natural resource backgrounds.

Monitoring surveys have covered 222 sites that have ranged in size from 7 to 260 acres. Sites were evaluated within two years of harvesting. The number of sites evaluated varied among the four rounds of sampling: 43 sites in 1996; 49 sites in 1997, 35 sites in 1999, and 26 sites in 2000. Sites were distributed among ownership categories as follows: state (44%); non-industrial private (48%); all others (county, federal, and industrial) (8%).

Site evaluations were guided by the state's BMP field manual and Indiana's Forestry BMP Monitoring Worksheet. At each site, monitoring teams evaluated 58 BMPs in five categories: forest access roads, landings, skid trails, stream crossings, and SMZs. BMPs were rated for implementation and effectiveness in protecting water quality using a five-point scale: 0 = not applicable; 1 = practices meet or exceed BMP recommendations; 2 = minor departures from BMP requirements; 3 = major departures; 4= gross neglect. Minor departures were defined in three ways: BMP practice not clearly needed; BMP practice attempted but applied poorly; or small potential for soil to reach streams. Major departures were defined as a practice clearly needed and not applied; departure from recommended practice; or, potential for soil to reach a stream.

Results from all four years of BMP monitoring were reported by Sobecki and McCoy (2004). The overall BMP implementation score was 88%. The implementation score on non-industrial private forests (85%) was slightly below average. BMP implementation scores for forest access roads and log landings were 93% and 94%, respectively. Two of 15 BMPs dealing with road drainage and stability had relatively low scores: "appropriate road stabilization, drainage and diversions installed" (76%); and "water diversions functioning properly" (86%). Areas for improvement with respect to log landing BMPs were "landings avoid concentrating or collecting runoff" (87%) and "proper water diversions in working order" (84%).

Implementation scores were below average for skid trails (77%), stream crossings (79%), and SMZs (81%).

- For skid trails, four of the 10 BMPs evaluated in this category scored less than 77%. The implementation score for "appropriate drainage and diversions installed" was only 35%. In this category, 48% of the inspection sites had minor departures, 15% had major departures, and 2% of the sites surveyed had instances of gross neglect.

- Only 76 of the 222 sites evaluated had a stream crossing present. Implementation rates for five of the 13 BMPs in this category were 79% or less. Areas with the lowest BMP implementation rates were "streambank approaches properly designed and stabilized" (56%) and "water runoff diverted from road prior to crossing" (45%).
- BMPs for SMZs were not applicable at many sites (e.g., 53 sites had no stream present). Scores were relatively high for "minimal exposed mineral soil" (97%) and "adequate tree stocking in the primary SMZ" (95%). Areas for improvement were "SMZs free of roads and landings (except crossings)" (69%) and "diverting water from trails before entering the RMZ" (71%).

The 2004 Indiana BMP Final Report indicates five key areas where improved BMP implementation is warranted: proper placement and construction of water diversion practices; implementing procedures to divert water from streams and SMZs; removing organic material from stream channels; designing adequate crossing structures; and avoid skidding in stream channels (Sobecki and McCoy 2004). These areas are currently being addressed by logger BMP training programs.

4.3.2 *Minnesota*

The Sustainable Forest Resources Act (SFRA) of 1995 mandated that BMPs provide protection for a broad range of functions and values associated with Minnesota's forestlands. To accomplish this, the Minnesota Forest Resources Council (MFRC) utilized a multi-stakeholder process to develop guidelines to protect soil productivity, wildlife habitat, riparian management zones, and cultural and historic resources. These guidelines were integrated with existing BMPs in Minnesota's comprehensive Timber Harvest and Forest Management (TH/FM) guidelines, published in 1999.

Additionally, the SFRA required that a process be developed to monitor forest management practices. The monitoring objective is to "…evaluate the implementation of the guidelines through field visits to randomly selected recent timber harvest sites on state, county, national forest, tribal, other public agency, forest industry, other corporate, and non-industrial private forests (NIPF)."

In response to SFRA requirements, a monitoring program was initiated in 2000 by Minnesota's Division of Natural Resources (DNR) with oversight by the MFRC. In 2004, DNR published a report summarizing three years of monitoring at sites harvested prior to the publication of the state's integrated TH/FM guidelines (Dahlman and Phillips 2004). The information contained in this report is intended to be used as baseline data for comparison with future BMP implementation assessments.

Site selection procedures varied among years. Site selection in 2000 and 2001 occurred in 41 townships located in the state's forested region. Aerial photography was used in each of these primary sampling units (PSUs) to identify a pool of harvest sites for monitoring. In 2000, the criterion for including a half township in the pool of PSUs was that it contains at least 160 acres of forestland. This criterion, however, failed to provide an adequate number of sample sites for monitoring. Funding was not available to provide aerial photography for a larger number of PSUs, and as a result, the area for forestland required for each PSU was increased from 160 acres to six sections (3,840 acres) of timberland in order to increase the number of harvest sites identified per PSU. This modification was retained in 2001. In 2002, however, concerns over sample bias were expressed. Furthermore, there was interest in combining guideline monitoring with monitoring land use change and harvest in riparian areas. As a result, satellite imagery was used to identify the pool of sample sites for 2002.

Implementation of TH/FM guidelines was monitored in the following forestland ownership categories: state, county, public, forest industry, non-industrial private forest (NIPF), and other (tribal, other public and non-forest industrial). A total of 315 timber harvesting sites were evaluated

over the three years of monitoring and distributed across the MFRC-defined landscape regions. The majority of sites (293) were located in the Northern, Northeast, and North Central regions of Minnesota. The landownership breakdown of monitoring sites was as follows: state (103 sites), county (96), NIPF (68), USFS (30), forest industry (12), and other (6). The categories of BMPs examined in this report include use of filter strips and riparian management zones (RMZs), protection of water quality and wetlands (waterbody crossings and approaches), and protection of forest soil resources (landings, roads, and skid trails).

During the three survey years, a total of 1,262 filter strips were identified for wetlands and open water bodies associated with monitored timber harvest sites. Implementation of BMPs for minimizing disturbance in filter strips was assessed by estimating amount of disturbance to mineral soils (<5% or >5% mineral soil exposure) and distribution of soil disturbance (dispersed or concentrated). Effective applications of BMPs for filter strips (< 5% mineral soil exposure; dispersed) were found for 73% of the site evaluations (Dahlman and Phillips 2004).

Implementation scores for RMZ width and tree retention guidelines were 31% for waterbodies within harvest areas and 64% for waterbodies adjacent to harvest areas. These guidelines were implemented most frequently for streams wider than 3 ft (76%) and for open water wetlands larger than 10 acres (65%). Low implementation scores for RMZs were attributed to evaluations being conducted on sites that were harvested prior to the publication of the current TH/FM guidebook (Dahlman and Phillips 2004).

During three years of monitoring, the DNR assessed 548 road and skid trail crossings as well as 1,033 stream crossing approaches and 80 wetland approaches found. A majority of the crossings and approaches (68%) were reported to be winter-only operations conducted while soils were frozen and with minimal soil disturbance. Data collected in the 2002 survey indicated that a majority of approaches to waterbodies were in good condition, with 6% showing signs of erosion and rutting and only 3.4% having sediment reaching a wetland or waterbody.

Implementation scores were relatively high for BMPs to protect soil resources. The TH/FM guidelines recommend that forest roads and landings occupy no more than 3% of the harvest area. The statewide averages were similar all three years and averaged 3% for all ownerships.

A total of 540 landings were identified across the three years of monitoring. Both landings and maintenance areas were located outside of wetlands and waterbodies 79% of the time and were generally in good condition. For example, in 2002, 83% of all landings were vegetated with minimal rutting and soil erosion evident.

The TH/FM guidelines for forest roads recommend using appropriate water diversion and erosion control practices, especially on road segments with grades exceeding 2%. A total of 311 road segments with a grade ≥ 2% were identified during the three years of monitoring. More than 85% of the segments had a grade < 10%, as is recommended in the TH/FM guidelines. Only 46 road segments had grades > 10%. However, of the 156 road segments with grades between 5 and 10%, only 22 had water diversion and erosion control devices installed. Sampling in 2002 indicated that more than 59% of these road segments had visible erosion occurring and nearly 12% had sediment reaching a wetland or waterbody. The 2004 monitoring report described these results as "… a cause for concern that has been and will continue to be addressed in future training programs." A majority of the monitoring sites (57%) were found to have minimal, randomly distributed, and lightly trafficked skid trails across the harvest sites.

Dahlman and Phillips (2004) indicate that results of BMP surveys are being used by the Minnesota DNR to establish a baseline "against which future implementation monitoring of Minnesota's timber harvest and forest management guidelines can be assessed." The authors suggest that the forestry community in Minnesota complied "reasonably well" with some of the TH/FM guidelines. Implementation scores were highest on public and industrial forestlands and lower on non-industrial forestlands. Priorities for improvement include BMPs for water diversion and approaches to stream crossings.

4.3.3 *Missouri*

The State of Missouri conducts annual BMP implementation surveys of five randomly chosen sites on private forestland. The site visits are conducted by the Missouri Forest Products Association Logger Trainer (Glenda Fry, Missouri Forest Products Association, 2007; pers. comm.). At each site, the logger trainer evaluates 45 BMPs in six areas: road construction and reconstruction, road maintenance, stream crossings, site preparation and slash treatment, trash and foreign substances, and SMZs. Applicable BMPs are scored for implementation and effectiveness using five-point scales (5 indicating high levels of implementation or effectiveness).

Interpretations of survey results are limited by small sample size. Average implementation scores were 3 for road construction/reconstruction and 4 for road maintenance. Areas for improvement related to roads include stabilizing erodible soils and proper implementation and maintenance of water diversion techniques such as water bars and turnouts. For the most part, site preparation BMPs were implemented correctly where applicable. However, excessive rutting was noted at one site. None of the survey sites had a stream or waterbody present, so BMPs for stream crossings and SMZ characteristics were not evaluated.

4.3.4 *South Dakota*

South Dakota's forestry BMPs were initially drafted in 1980 and revised in 1993 and 2003 (Everett 2005). Both sets of BMP revisions were adopted in the South Dakota Nonpoint Source Pollution Management Plan and approved by the Environmental Protection Agency. The Black Hills Forest Resource Association and its members partnered with the South Dakota Department of Environment and Natural Resources and the South Dakota Department of Agriculture - Division of Resource Conservation and Forestry to conduct a series of BMP training sessions and timber sale field audits in 2001.

A recent BMP survey was conducted in 2004. Seven timber sales were audited, evaluating implementation and effectiveness of nearly 100 BMP elements at each site. Audit sites were distributed among state, federal, and private forestlands. Site selection criteria were adapted from procedures used in Montana: 1) harvest operations must have been completed within the last two years; 2) ≥2,000 board-feet per acre harvested from a site; 3) site must contain live water in the form of a stream or creek, or have other significant water resources; 4) one of the sites should be a re-audit of a site from 2001; 5) one of the sites should be a currently active timber sale; and 6) sites should equally represent private, federal, and state landownership (Everett 2005). Implementation was rated on a five-point scale. An implementation score of five indicated that BMP requirements were exceeded, whereas a score of one indicated gross neglect.

Overall, BMP implementation (i.e., across all landownership groups) in the 2004 survey was 92% (Everett 2005). Implementation met or exceeded BMP standards in 371 of 405 instances monitored. Of the documented departures, 32 were considered to be minor in nature. Only two instances of major departures from recommendations were reported and no instances of gross neglect were reported. Areas for improvement include road design, road drainage (especially near stream crossings), and

culvert size and installation. For culverts, "…inadequate or confusing explanations in the BMPs may be the source of much of the confusion in this matter" (Everett 2005).

4.3.5 *Wisconsin*

The Wisconsin Department of Natural Resources – Division of Forestry (WI DOF) has the task of monitoring levels of BMP implementation under the state's Water Quality Program. Monitoring implementation of BMPs was initiated in 1995. Since 1995, nearly 500 timber sales have been monitored for their BMP application and effectiveness. Site selection is done by using a database of timber sales for a particular landowner category (e.g., county, federal, private industrial, private non-industrial, state, or tribal). A potential list of field sites is compiled, randomly ordered, and checked against three eligibility criteria: at least one acre of harvesting was on a wetland; the sale was conducted within 200 ft of a waterbody; or a significant length of wetland was crossed during the harvest.

In 2003, Wisconsin DOF developed a new approach to BMP monitoring in collaboration with a BMP Advisory Committee. Site evaluations involve teams visiting and evaluating timber sales for BMP application and effectiveness in various locations throughout the state. Monitoring teams include people with diverse backgrounds and interests.

The new approach was applied in a survey of county and state forestlands in 2003 (Holland 2004). Monitoring teams visited 31 harvest sites on county forests and 29 harvest sites on state forests. Each site was evaluated using a BMP Monitoring Worksheet that consisted of three sections: evaluating BMP implementation and effectiveness; a supplemental questionnaire; and a professional judgment rating. Implementation was scored using a four-point scale: BMP applied correctly = 1; BMP applied but incorrectly = 2; BMP not applied = 3; insufficient information to rate = 4.

Overall implementation scores on state and county forestlands were 90% and 93%, respectively (Holland 2004). When BMPs were applied correctly, they were judged to be 100% effective at reducing impacts to water quality. When BMPs were not applied correctly or when necessary, impacts to water quality were common. Implementation scores on both county and state forests were relatively high (>90%) for fuels, RMZs, timber harvesting, and wetland categories. Implementation scores for road BMPs were higher on county forests (96%) than on state forests (71%). Implementation scores for skid trails for county and state forests were 69% and 78%, respectively.

In 2006, BMP evaluations were conducted on 28 federal and 33 industrial timber sales. Overall implementation scores for federal and industrial lands were 95% and 94%, respectively (Shy and Wagner 2007). Scores for both ownership categories were high in the following BMP categories: fuels, lubricants, waste and spills (≥98%) and timber harvesting (99%). On federal timber sales, scores for other BMP categories were RMZs (94%), wetlands (93%), roads (93%), and skid trails (97%). Scores on industrial timber sales were RMZs (95%), wetlands (98%), roads (90%), and skid trails (89%). In over 99% of the cases where BMPs were correctly applied when necessary, there were no observed adverse impacts to water quality for both owner groups.

4.4 Summary

There is a remarkable degree of consistency in many aspects of forestry BMPs for water quality protection among the Midwest states. These BMPs were developed in response to nonpoint source (NPS) control provisions of the federal Clean Water Act. Most states in the region have updated their BMP manuals at least once (or are currently engaged in a BMP review).

Forestry BMPs in most of the Midwest states are elements of state NPS control programs. In Minnesota, BMPs have been integrated into Timber Harvest/Forest Management (TH/FM) guidelines that were developed following passage of the state's Sustainable Forest Resources Act (SFRA) in

1995. SFRA established policies and programs to ensure sustainable use and management of the state's forest resources. Priorities include the TH/FM guidelines; landscape-level forest resource planning and coordination; and supporting programs that address monitoring, research, and education.

Many aspects of forestry BMP programs are non-regulatory in the Midwest. For example, Wisconsin's 2003 BMP manual states that "BMPs may be modified for specific site conditions with guidance from a forester or other natural resource professional if modifications provide equal or greater water quality protection." It is important to note, however, that all uses of pesticides and many kinds of stream crossings are regulated under federal and / or state laws.

Stream crossing regulations and methods for sizing culverts vary substantially among the Midwest states. Other aspects of guidelines for forest roads, skid trails and crossings are generally similar across the region.

All states in the region recommend use of SMZs to protect streams. There is considerable variability among states in various aspects of SMZ guidelines such as minimum SMZ widths; procedures for expanding SMZs beyond the minimum to account for slope and other factors on a site-specific basis; and management recommendations for SMZs (Tables 4.1 and 4.2). SMZ guidelines are substantially more detailed and complex in Minnesota than in other Midwest states.

There is considerable variation among states in the region with respect to BMP monitoring objectives and methods. States that have reported results of BMP implementation surveys include Indiana, Minnesota, Missouri, South Dakota, and Wisconsin. North Dakota is currently preparing a report based on activities of its Forest Stewardship Monitoring Team (Tom Berg, North Dakota State University, 2007; pers. comm.). Limited investment in forestry BMP monitoring in some states is likely due to the fact that forestry is a minor contributor to NPS pollution in the Midwest (NCASI 1996; Phillips and Blinn 2004).

Results of BMP monitoring surveys have identified roads and skid trail as areas for improvement. In contrast, BMPs for stream crossings were generally not identified as problem areas by states in this region. Indiana and Minnesota indicate that results of BMP monitoring are being used to set priorities in BMP training and education programs.

5.0 NORTHEASTERN STATES

5.1 Introduction

Forestry best management practices (BMPs) have been adopted by all states in the Northeast as a cornerstone of efforts to control NPS pollution associated with forest management activities. Some states have developed timber harvest regulations while others require permits, notification, or both for certain activities such as stream crossings. As a result, some BMPs in the region are legal requirements while others are recommended.

Among the northeastern states, West Virginia and Maine have made the largest investments in monitoring implementation of forestry BMPs. Other states in the region have decided to allocate scarce resources to other priorities for various reasons. Most states in this region indicate on their 305(b) Assessment Reports to EPA that forestry is a minor contributor to water quality impairment (NCASI 2001b). Several states in the region have regulatory programs that they believe provide adequate assurance that BMPs are being implemented.

This section provides information about forestry BMPs and BMP monitoring in Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Vermont, and West Virginia. Additional information about forestry NPS programs in these states (and in Connecticut, Delaware and Rhode Island) can be found in previous NCASI reports (e.g., NCASI 1996, 2001b).

5.2 Northeastern State Forestry BMP Requirements and Recommendations

5.2.1 *Examples of State Laws Affecting Forest Management*

In Maine, forest management activities that may affect water quality are regulated under several state statutes. These include the Land Use Regulation Commission (12 MRSA, Chapter 206A), the Shoreland Zoning Act (38 MRSA, Chapter 3, Section 435), the Natural Resource Protection Act (38MRSA, Chapter 3, Section 480A), and the Maine Forest Practices Act (12 MRSA, Chapter 805, Section 8867). Maine has also created a Forest Advisory Team to provide technical assistance and support for water quality issues (ME DOC 1995). This team includes representatives from several state agencies and forestry stakeholder groups. The state forestry BMP manual is linked to related laws and regulations, and BMPs have been established as part of existing regulations (NCASI 2001b).

Maryland's Sediment Control Program regulates non-agricultural, land disturbing activities. Legal requirements for forest management are defined in *Maryland Erosion and Sediment Control Standards and Specifications for Forest Harvest Operations* (MD DOE 2005). Forest management operations that disturb more than 5,000 ft^2 or 100 yd^3 (465 m^2 or 77 m^3) of soil must have an approved erosion and sediment control plan. Additional requirements apply to waterway construction (i.e., stream crossings) and to operations that affect non-tidal wetlands and Chesapeake Bay critical areas.

In Massachusetts, the goal of the state's BMPs is to minimize "…overland speed and volume of water carrying sediment and nutrients" (Kittredge and Parker 1999). BMPs are designed to limit NPS impacts to waterbodies and wetlands, drinking water supplies, and aquatic biota. Legal requirements are defined in the Massachusetts Forest Cutting Practices Act (FCPA) (MGL Chapter 132, sections 40–46). FCPA requires landowners/operators to file a Forest Cutting Plan (FCP) at least 10 business days prior to conducting a harvest. The FCP must include a description of the erosion control measures that will be implemented on site. Furthermore, the FCP must map the locations of all roads, primary skid trails, stream and wetland crossings, and the general location of all erosion control measures (e.g., SMZs).

New Hampshire has four laws that regulate forest management activities (NH DRED 2004). These are Timber Tax Law or Notice of Intent to Cut (RSA 79:10), New Hampshire Wetlands Law, Basal Area Law (RSA 227-J:9), and the Slash Law (RSA 227-J:10). The notice of intent to cut is required prior to any harvesting. The state's basal area regulation requires "…that forested buffers be left along town and state roads, streams, and bodies of water, following a timber harvest." The law requires that no more than 50% of the basal area can be removed each year, leaving a well-distributed, healthy stand of trees within 150 ft (46 m) of any standing body of water greater than 10 ac (4 ha), any fourth order or higher stream, or a public highway. Additionally, basal area requirements apply within 50 ft (15 m) of any other stream, river, or brook that is not a fourth order or higher stream which normally flows throughout the year or, any standing body of water less than 10 ac (4 ha) associated with a stream, river, or brook which normally flows throughout the year.

New Jersey regulates management in forested wetlands under the 1987 Freshwater Wetlands Protection Act. Normal harvesting conducted in accordance with a forest management plan approved by the State Forester is exempt from obtaining a wetland permit. Management activities must meet minimum standards for protecting surface water quality; must be conducted in accordance with state BMPs; and must be normal silviculture conducted as part of an ongoing operation (NJ BFM 1995).

In New York, the state's Department of Environmental Conservation (DEC) is charged with establishing and enforcing water quality protection laws. A Protection of Waters Permit is required from DEC for forest management activities that disturb the bed or banks of classified streams. This includes the installation stream crossings and the placement of fill materials for access, construction or installation of roads, bridges and culverts below the mean high water level, including adjacent and contiguous wetlands.

In Ohio, application of silvicultural BMPs is specified in the Ohio Agricultural and Silvicultural Abatement Law (OASAL) enacted in 1991 (Ohio State University 1999). Unacceptable NPS pollution resulting from forest management can result in regulatory actions against the landowner/operator. The OASAL standards provide the landowner/operator with the option of submitting an operation and management plan to the Soil and Water Conservation District prior to initiating harvest operations.

Harvesting of timber in Pennsylvania is considered an earth disturbance activity since it exposes soils, disturbs the forest floor, and has the potential to impact water quality. Because of this, forest management activities are regulated by the Pennsylvania Department of Environmental Protection (DEP) Chapter 102 Rules and Regulations that were adopted under the state's Clean Streams Law. Harvest operations 25 ac (10 ha) or greater require a permit from DEP. Furthermore, DEP Chapter 105 regulations govern the crossing of streams; construction of fords, culverts, and bridges; and other anthropogenic impacts to water resources. Some activities are covered by General Permits (GP) such as GP#7 for minor stream crossings and GP#8 for temporary road crossings (PA DEP 2003).

In Vermont, amendments to the state's water quality protection statutes (10 VSA 1259) passed in 1986 established a requirement that forestry practices be implemented in accordance with Acceptable Management Practices (AMPs). AMPs have been adopted as regulations. When complaints are filed against a forestry operation, the Vermont Division of Forestry is responsible for investigation and preliminary enforcement under a Memorandum of Agreement with the Department of Environmental Conservation (VT DFPR 1987). AMPs are similar to BMPs and, hereafter, will be referred to as such.

The West Virginia Division of Forestry (DOF) has responsibility for monitoring provisions of the Logging Sediment Control Act (LSCA) (WV DOF 2005). The law states that after September 1, 1992, anyone "…conducting a logging operation, buying timber, or buying logs for resale is required to be licensed by the DOF." The LSCA has six main requirements for forest management operations: 1) logger licensing; 2) logger certification; 3) timbering operation notification; 4) logging operation posting; 5) enforcement for activities causing stream sedimentation or the potential for sedimentation; and 6) reclamation activities to be completed within seven days of the date specified on the notification form.

5.2.2 *Streamside Management Zones*

Within the Northeast, most states recommend or require SMZs along perennial and intermittent watercourses. Minimum widths for SMZs in the region range from 25 to 200 ft (8 to 61 m) (Table 5.1).

Table 5.1 Recommended Minimum Widths for Streamside Management Zones for States in the Northeast

State & Waterbody Type	Stream Types: Perennial	Intermittent	Ephemeral
	ft (m)		
Maine	25 (8)	25 (8)	
Maryland	50 (15)	50 (15)	
Massachusetts	50 (15)	50 (15)	
New Hampshire	50 (15)	50 (15)	
New Jersey			
Slightly erodible soils			
0-10% slope	25 (8)	25 (8)	
11-20% slope	40 (12)	40 (12)	
21-45% slope	70 (21)	70 (21)	
Severely erodible soils			
0-10% slope	50 (15)	50 (15)	
11-20% slope	130 (40)	130 (40)	
21-45% slope	200 (61)	200 (61)	
New York	50 (15)	50 (15)	
Ohio			
Rural watersheds	25 (8)		
Municipal watersheds	50 (15)		
Pennsylvania			
Rural watersheds	25 (8)	25 (8)	
Municipal watersheds	50 (15)	50 (15)	
Vermont	50 (15)	50 (15)	
West Virginia	100 (30)	100 (30)	25 (8)

Maine recommends establishing SMZ widths beginning at a water body's normal high water mark (NHWM). The NHWM is the place on the stream bank where the highest water levels typically occur. Features used to discern the NHWM include undercutting of the streambank, changes in vegetation types, root scaring, and water marks on the stems of trees. The remaining states in this region all use the streambank as a starting point when determining a SMZ buffer width.

New York recommends a 50 ft (15 m) SMZ for all perennial and intermittent streams. All other states provide guidance for adjusting SMZ widths based on stream type, stream width, and/or adjacent upland factors (e.g., slope, soil erodibility, etc.).

- Maine recommends increasing SMZ width by 20 ft (6 m) for every 10% increase in slope. Maine also recommends "increasing the width of the filter area and install more BMPs when local conditions call for it." Ephemeral areas flowing into perennial or intermittent water bodies are mentioned as an example of areas where enhanced SMZ BMPs may be appropriate.

- Maryland recommends a minimum SMZ width of 50 ft (15 m) along all waters of the state. This minimum width is adjusted for slope using the following formula: 50 ft (15 m) + (2 ft x %slope). However, SMZs do not need to exceed 150 ft (46 m).
- Massachusetts recommends increasing filter strip widths by 40 ft (12 m) for every 10% increase in slope for the following waterbodies: stream widths >25 ft (>8 m), ponds ≥10 ac (≥4 ha), and designated scenic and outstanding resource waters and their tributaries. Where slopes exceed 30%, the filter strip will extend 100 ft (30 m) back from the bank or, to the point between 50 and 100 ft (15 and 30 m) from the bank, where a break in the topography reduces the slope to less than 30% (Kittredge and Parker 1999).
- New Hampshire and Vermont recommend increasing SMZ width by 20 ft (6 m) for every 10% increase in slope.
- New Jersey requires buffers of at least 150 ft (46 m) for wetlands of exceptional resource value and in areas adjacent to "…trout production waters or their tributaries."
- For every 10% increase in slope, Ohio and Pennsylvania recommend increasing SMZ width by 20 ft (6 m) in rural watersheds and by 40 ft (12 m) in municipal watersheds.
- West Virginia recommends different minimum buffer widths for perennial, intermittent, and ephemeral streams. West Virginia also recommends that adequate SMZs be maintained around all lakes or ponds, perennial flowing natural springs, and all springs and reservoirs serving as a domestic water supply.

5.2.3 *SMZ Management*

All states in the Northeast allow harvesting in their SMZs (Table 5.2). In general, all states base their management prescriptions on retaining a certain level of residual basal area or shading; minimizing soil disturbance; and/or restricting the operation of mechanized equipment within SMZs. The complexity of SMZ management BMPs varies among states.

Pennsylvania recommends that managers "…keep soil disturbance in the filter strip to a minimum." The state also recommends that when an area of soil is exposed in an SMZ, additional measures may be necessary to prevent sediment movement into streams. These measures may include straw bale barriers, mulch, or silt fences (PA DEP 2003). Disturbances within 50 ft (15 m) of a stream may require a water obstruction permit from the county conservation district or DEP Regional Office.

New Hampshire, New Jersey, New York, Ohio, Vermont and West Virginia recommend limiting the operation of mechanized equipment in SMZs. For example, New York suggests that mechanized equipment "…remain at least 50 ft (15 m) away from waterbodies" and recommends minimizing disturbance to soil and vegetation within 10 ft of the stream bank (NY DEC 2000).

When soils are exposed in a SMZ, West Virginia and New Hampshire recommend stabilizing the area with mulch or seed as soon as possible (WV DOF 2005;NH DRED 2004). New Jersey recommends limiting equipment in SMZs, using harvesting systems that minimize soil disturbance, and protecting trees that provide bank stabilization and shading (NJ BFM 1995). Ohio BMPs recommend light harvesting in SMZs that "preserves adequate shading of permanently flowing streams and maintains satisfactory stream water temperature."

Table 5.2 Checklist of Parameters Used by States When Establishing Forest Management Recommendations within SMZs

State	SMZ Management Allowed	Basis for SMZ Management Systems			
		Basal Area	Shading / Cover	Leave Tree	Other[1]
Maine	+		+		
Maryland	+	+		+	
Massachusetts	+	+			
New Hampshire	+				+
New Jersey	+		+		
New York	+		+		
Ohio	+		+		
Pennsylvania	+				+
Vermont	+		+		
West Virginia	+		+		

[1]New Hampshire and Pennsylvania BMP manuals do not provide specific guidelines for managing SMZs. However, these states state that management activities in SMZs should limit disturbance to soils.

Vermont's BMPs for SMZs state that "…light thinning or selection harvesting can occur so that breaks made in the canopy are minimal and continuous cover is maintained." Vermont also recommends that mechanized equipment remain at least 25 ft (8 m) away from a waterbody (VT DFPR 1997).

Massachusetts requires SMZs (i.e., filter strips) along all waterbodies and certified vernal pools. Additionally, the state requires that no more than 50% of the overstory basal area in a SMZ may be cut at any one time and at least five years must elapse before additional harvests in a SMZ may occur (Kittredge and Parker 1999). Exceptions to these requirements are possible and must be clearly outlined in the Forest Cutting Plan.

Maine allows management in SMZs and recommends that an adequate canopy of overstory and understory vegetation be retained (Moesswilde 2004). Additionally, the state's BMP manual recommends that when working near waterbodies landowners/operators should "…find out what town, state, and federal standards apply, and if permits are needed." The Maine BMP manual also recommends that some waterbodies may require wider SMZs to prevent windthrow or provide adequate shade for waterbodies.

5.2.4 *Stream Crossing BMPs*

BMPs in all states in the Northeast provide general guidance for the installation, use, and removal of stream crossing structures such as fords, pole fords, culverts, and bridges. Recommended objectives when constructing stream crossings generally include 1) minimize the number of crossing structures; 2) minimize impacts to the streambed and banks; 3) limit alterations to streamwater flows; 4) maintain fish passage; 5) minimize runoff from stream crossing approaches; and 6) implement stream crossing close out procedures properly.

Many states in the Northeast require permits or notification when crossing a stream. For example, Pennsylvania requires a permit or a waiver of permit for all newly installed stream crossings from a conservation district of the Department of Environmental Protection (DEP) Regional Office (PA DEP 2003). Permanent crossing structures require a detailed, site-specific design plan. Temporary crossings, those that will be used less than one year on non-public roads, can be permitted though a General Permitting process (GP-8). The GP-8 allows stream crossings using a culvert, series of culverts, bridge, or ford.

The Maine Department of Conservation – Forest Service requires by law that stream crossings allow fish passage, "through or underneath" the structure (ME DOC 2005). Use of temporary crossings is limited to "…a few months, require permits, and/or require certain measures or design features." Landowners and managers are encouraged to contact the Maine Department of Inland Fisheries and Wildlife to help identify streams with fish habitat.

New York requires a permit for stream crossings installed on a New York State Department of Environmental Conservation (NYSDEC) classified stream (NY DEC 2000).

New Jersey's Flood Hazard Area Control Act Rules (NJAC 7:13) apply to construction within and/or adjacent to the 100-year floodplain of non-delineated streams or the flood hazard area of delineated streams. Under the Act, construction of permanent structures (e.g., bridges, culverts, and fords) is regulated and requires a Stream Encroachment Permit. In the case of temporary crossings, the New Jersey DEP may issue a letter of no jurisdiction rather than a permit.

Vermont has an Alteration of Streams Law that requires a permit from the Natural Resources Agency where structures may modify the course, flow, or cross-section of a stream (10 V.S.A. 1021, 1025).

All states in the Northeast provide general guidance for stream crossings in their forestry BMPs (Table 5.3). For example, many states discourage the use of fords or recommend their use only when certain conditions exist or as a last resort. West Virginia's BMP manual states that "stream fords are permissible as a last resort, but only when the stream bottom is rock based and can support truck traffic." New Hampshire allows fording of streams but only when it is not feasible to construct a bridge or install a culvert. The streams must have no or low streambanks. New Hampshire prohibits fords on all streams in watersheds tributary to drinking water supplies. New Jersey recommends that managers "limit the use of fords to areas where the streambed has a firm bottom or where the bottom has been armored with stable material…" Ohio recommends that streambanks and streambeds be armored and that approaches be stabilized. Pennsylvania allows for the use of fords; however, this crossing is not acceptable for skid roads/trails or when crossing high quality or exceptional value streams. Maryland has several restrictions when utilizing fords. The state recommends limiting their use and removal October 1-April 30 for all Class III and Class IV Trout waters. For other streams in Maryland, use or removal of a temporary ford is prohibited March 1-June 15 of each year due to fish spawning during this period. In Massachusetts, use of a ford (or culvert) is not permissible when crossing a stream within 1000 ft (305 m) of a public water supply. Instead, all stream crossings in this situation must be bridged crossings.

Most states recommend limiting the use of fords to haul roads, i.e., use of fords by skidders and forwarders is discouraged or prohibited. For example, New Hampshire's BMP manual has in bold text the phrase "Skidding across stone fords is prohibited." Vermont, however, takes an opposite approach regarding fords. "Truck road crossings of all permanent streams shall be over a bridge or culvert. Streams may be forded by skid trails only where streambeds have stable beds and stable, gradual approaches."

Table 5.3 Checklist of State Recommended BMPs for Stream Crossings

		Stream Crossing Structure			
	Permit or Notification Required	Fords	Culverts	Bridges	Winter or Temporary Crossings
Maine	+	+	+	+	+
Maryland	+	+	+	+	+
Massachusetts	+	+	+	+	+
New Hampshire		+	+	+	+
New Jersey	+	+	+	+	+
New York	+	+	+	+	+
Ohio		+	+	+	+
Pennsylvania	+	+	+	+	
Vermont		+	+	+	+
West Virginia		+	+	+	+

Maryland, Maine, and New Hampshire all provide detailed specifications for installing or utilizing fords as a stream crossing structure. Maryland and New Hampshire have the most detailed specifications for utilizing fords. In addition to restrictions on use of fords, major specifications cover areas such as stream characteristics where fords are feasible; armoring approaches (i.e., aggregate size and placement); types of bedding material; and placement of bedding aggregate material.

Maine, Massachusetts, New Hampshire, Ohio, and Vermont provide recommendations for utilizing pole fords and slash/brush crossings. Recommendations for pole fords include construction and use during low or no flows; construction in a manner that allows streamflow passage and does not dam up water; and utilization of practices that protect the streambank and channel. Maine and Vermont also provide recommendations for winter crossings. Use of slash and brush crossings (sometimes referred to as brushing-in) is recommended for protecting a streambed during winter conditions when a stream is frozen. All fill material from both pole and slash/brush fords should be removed immediately after use to prevent the blockage of streamwater.

In situations where fords are not allowed or are not practical, states recommend the use of culverts or bridges. For small watersheds, those less than 500 ac (202 ha), culverts are generally the most feasible stream crossing structure. All states in the Northeast provide recommendations for installing culverts. As with fords, it is important to remember that a permit may be required prior to installing a temporary or permanent culvert type crossing.

The recommended minimum culvert diameters for the region range from 6 inches in Maine to 15 in (38 cm) in New Jersey, Vermont, and West Virginia. While the minimum diameter mentioned in West Virginia's BMP manual is 15 in (38 cm), the state recommends using at least an 18 in (46 cm) diameter pipe for stream crossings. Maryland, New Hampshire, New York, Pennsylvania, and Ohio all recommend a minimum culvert diameter of 12 in (30 cm). Massachusetts recommends a minimum culvert diameter size of 8 in (20 cm).

Most states recommend adjusting minimum diameters based on drainage area (Tables 5.4 and 5.5). As drainage areas increase, recommended culvert diameters increase to handle the larger volumes of water passing through the structure.

Massachusetts recommends sizing culvert diameters based on a 25-year storm interval and two terrain classes. Type I terrain is defined as "forested and rolling" with slopes ranging between 5 and 10%. Type II terrain is defined as "forested and hilly" with slopes ranging from 10 to 30%.

New Hampshire's BMP guidelines recommend the use of a culvert/emergency spillway when a culvert is expected to be installed for prolonged periods (i.e., time periods longer than the duration of the harvest). The emergency spillway should be sized to handle a 10-year flood event and is used to divert high flows around the culvert.

New Jersey recommends that slope and soil type be taken into account when determining culvert diameters (Table 5.5). Pennsylvania's recommendations for culvert diameters are based on the type of pipe, corrugated or smooth.

West Virginia's recommendations for culverts have been modified from Helvey and Kochenderfer (1988). The culvert recommendations are based on diameters needed to carry storm flow from forested drainages ranging in size from 10 to 400 ac (4 to 162 ha) with a recurrence interval of 50 years. Furthermore, areas with clayey soils may require larger diameter culverts when used as permanent crossings.

In Maryland, the minimum culvert diameter is 12 in (30 cm) and diameter is adjusted based on stream cross sectional area. Specifications for culverts in Maryland state that culvert diameter shall be "…the largest pipe diameter that will fit into the existing channel without major excavation of the waterway channel or without major approach fills." When the channel width exceeds three feet, more than one culvert pipe may be used until the cross sectional area of the culvert "…is greater than 60% of the cross sectional area of the existing channel." The state's BMP manual also requires that culverts be sized properly to convey normal stream flows.

Maine's procedure for determining culvert size includes four steps.

1. Determine the degree of flooding the culvert must handle without being washed out. Temporary culvert openings that will be removed before spring runoff should be designed to handle a one- to three-year flood event. Temporary culverts in place during spring runoff and permanent culverts that will receive routine maintenance should be designed to handle at least a 10-year flood event. Permanent culverts that will not be maintained should be designed to handle a 25-year flood event.

2. Determine the culvert opening size needed to convey the expected flood event. This involves measuring stream dimensions (e.g., width at the HWM and average stream depth from the NHWM) and use of look-up tables for 10- and 25-year flooding events that are provided in the Maine BMP manual.

3. Select a culvert diameter that corresponds to the recommended opening size (Table 5.6).

4. Adjust the culvert diameter to minimize impacts to the stream channel and streambank, allow the passage of normal flows, and allow fish passage when water is present.

Table 5.4 Minimum Recommended Culvert Diameters for States in the Northeast as Determined Using Drainage Area above the Culvert

	State										
	MA[1]		NH		NY	OH	PA		VT		WV
Culvert diameter in (cm)	Type I Terrain	Type II Terrain	Soil Type I	Soil Type II			Pipe A	Pipe B	Soil Type I	Soil Type II	
	Drainage area ac (ha)										
8 (20)	1 (0.4)	1 (0.4)									
12 (30)	5 (2)	5 (2)	2 (1)	9 (4)	2 (1)	2 (1)	2 (1)	3 (1)			
15 (38)	10 (4)		4 (2)	16 (7)	4 (2)	4 (2)	4 (2)	5 (2)	16 (7)	4 (1.6)	<8 (3)
18 (46)	15 (6)	10 (4)	7 (3)	25 (10)	7 (3)	7 (3)	7 (3)	8 (3)	25 (10)	7 (2.8)	10 (4)
20 (51)											20 (8)
21 (53)			12 (5)	40 (16)	11 (5)	12 (5)	11 (5)	12 (5)	40 (16)	12 (5)	
24 (61)	20-30 (8-12)	15-25 (6-10)	16 (7)	55 (22)	16 (7)	16 (7)	16 (7)	18 (7)	55 (22)	16 (7)	30 (12)
26 (66)											40 (16)
27 (69)					23 (9)		23 (9)	29 (12)			
28 (71)											50-60 (20-24)
30 (76)	35-50 (14-10)	30-45 (12-18)	27 (11)	84 (34)	34 (14)	27 (11)	34 (14)	42 (17)	84 (34)	27 (11)	70-80 (28-32)
32 (81)											90 (36)
33 (84)					45 (18)		45 (18)	58 (23)			
34 (86)											100 (40)
36 (91)	75 (30)	50-75 (20-30)	47 (19)	130 (53)	62 (25)	47 (19)	62 (25)	80 (32)	130 (53)	47 (19)	125 (51)
38 (97)											150 (61)
40 (102)											175 (71)
42 (107)			64 (26)	190 (77)	110 (45)	64 (26)	110 (45)	140 (57)	190 (77)	64 (26)	200 (81)
46 (117)											250 (101)
48 (122)	100-150 (40-61)	100-150 (40-61)	90 (36)	260 (105)	200 (81)	90 (36)	200 (81)	250 (101)	260 (105)	90 (36)	300 (121)
54 (137)			120 (49)	335 (136)	300 (121)	120 (49)	300 (121)	400 (162)	335 (136)	120 (49)	350 (142)
60 (152)	200-250 (81-259)	200-250 (81-259)	160 (65)	400 (162)		160 (65)			400 (162)	166 (67)	
66 (168)			205 (83)	550 (223)		205 (83)			550 (223)	205 (83)	
72 (183)			250 (101)	640 (259)		250 (101)			650 (263)	250 (101)	
78						350 (142)					

Table 5.5 Recommended Minimum Culvert Pipe Diameters Based on Soil Type and Drainage Area Utilized in New Jersey [adapted from New Jersey's Forestry and Wetlands Best Management Practices Manual (NJ BFM 1995)]

Drainage Area	Light Soils			Medium Soils			Heavy Soils		
Ac (ha)	0-5	5-15	15+	0-5	5-15	15+	0-5	5-15	15+
2 (<1)	15 (38)	15 (38)	15 (38)	15 (38)	15 (38)	15 (38)	15 (38)	18 (46)	18 (46)
4 (<2)	15 (38)	15 (38)	15 (38)	15 (38)	15 (38)	18 (46)	21 (53)	21 (53)	21 (53)
6 (2)	15 (38)	15 (38)	15 (38)	15 (38)	18 (46)	21 (53)	21 (53)	27 (69)	27 (69)
8 (3)	15 (38)	15 (38)	15 (38)	15 (38)	18 (46)	21 (53)	24 (61)	27 (69)	30 (76)
10 (4)	15 (38)	15 (38)	15 (38)	18 (46)	21 (53)	24 (61)	27 (69)	30 (76)	36 (91)
20 (8)	15 (38)	15 (38)	15 (38)	21 (53)	24 (61)	30 (76)	30 (76)	36 (91)	42 (107)
30 (12)	15 (38)	15 (38)	15 (38)	21 (53)	27 (69)	36 (91)	36 (91)	42 (107)	48 (122)
40 (16)	15 (38)	15 (38)	15 (38)	24 (61)	30 (76)	36 (91)	42 (107)	48 (122)	54 (137)
50 (20)	15 (38)	15 (38)	18 (46)	27 (69)	36 (91)	42 (107)	42 (107)	48 (122)	
60 (24)	15 (38)	15 (38)	18 (46)	27 (69)	36 (91)	42 (107)	42 (107)	54 (137)	
70 (28)	15 (38)	18 (46)	18 (46)	27 (69)	36 (91)	42 (107)	48 (122)	54 (137)	
80 (32)	15 (38)	18 (46)	21 (53)	30 (76)	36 (91)	48 (122)	48 (122)		
90 (36)	15 (38)	18 (46)	21 (53)	30 (76)	36 (91)	48 (122)	48 (122)		
100 (40)	15 (38)	18 (46)	21 (53)	30 (76)	42 (107)	48 (122)	48 (122)		
150 (61)	18 (46)	21 (53)	24 (61)	36 (91)	42 (107)	54 (137)	54 (137)		
200 (81)	21 (53)	21 (53)	27 (69)	36 (91)	48 (122)				
250 (101)	21 (53)	24 (61)	27 (69)	42 (107)	48 (122)				
300 (121)	21 (53)	27 (69)	30 (76)	42 (107)	54 (137)				
350 (142)	24 (61)	27 (69)	30 (76)	42 (107)	54 (137)				
400 (162)	24 (61)	27 (69)	36 (91)	48 (122)					

Table 5.6 Relationship between Culvert Diameters and Opening Sizes Recommended in Maine [adapted from Moesswilde (2004]

Opening size ft^2 (m^2)	Culvert Diameter in (cm)
0.20 (0.02)	6 (15)
0.80 (0.07)	12 (30)
1.25 (0.12)	15 (38)
1.75 (0.16)	18 (46)
2.40 (0.22)	21 (53)
3.15 (0.29)	24 (61)
4.90 (0.46)	30 (76)
7.05 (0.66)	36 (91)
9.60 (0.89)	42 (107)
12.55 (1.17)	48 (122)
15.90 (1.48)	54 (137)
19.65 (1.83)	60 (152)
23.75 (2.21)	66 (168)
28.68 (2.67)	72 (183)

States in the Northeast generally recommend placing culverts on the same grade as the streambed and along the stream's centerline; constructing so that the culvert extends at least 1 ft (0.3 m) beyond the fill or roadbed; covering the culvert with aggregate to a depth of at least 1 ft (0.3 m) or half the diameter of the culvert (whichever is greater); stabilizing or armoring the culvert's inlets and outlets; and performing routine maintenance. In contrast to other states, Maine recommends that permanent

culverts be placed slightly below the stream grade to avoid perching which can impede stream flow and fish passage.

In general, states in the Northeast encourage use of bridges, either temporary or permanent, when crossing streams during forest management. In fact, many states in the region recommend using temporary bridges for crossings in place of fords and temporary culverts. All state BMP manuals in the Northeast provide recommendations for installing permanent and temporary bridges. However, the range and specificity of those recommendations varies. Recommendations are generally more detailed and specific in Maine, Maryland and Ohio. Commonly recommended BMPs for bridge installation include locating the bridge at narrow stream points, protecting bridge approaches by using water control structures, and protecting the streambank and channel from erosion. States also provide recommendations for minimizing and stabilizing exposed soils on crossing approaches. Many states require permits based on detailed designs and environmental assessments prior to construction of permanent bridges.

5.2.5 *BMPs for Forest Roads*

All state BMP manuals in the Northeast recognize proper road design and maintenance as critical elements in efforts to protect water quality (Table 5.7). General topics addressed in road BMPs include planning and location, construction, drainage, maintenance, and closing or retirement.

Generally, state BMPs recommend that land managers examine soils, slope, and conduct site inspections to avoid potential problem areas prior to construction. Furthermore, states recognize the potential negative impacts that stream crossings and their road approaches can have on water quality. Therefore, states recommend that landowners and managers pay special attention to design and maintenance of forest road approaches to stream crossings.

All of the state BMP manuals recommend using existing roads when possible and controlling the number of new roads, total road length, and number of stream crossings. Many states recommend that roads be constructed outside of SMZs, and that roads be constructed on well drained soils, follow contours, and have minimal slopes (Table 5.7). Where existing roads are not available or feasible to use, states recommend that new roads be constructed to minimize and balance cuts and fills.

A majority of states in the region recommend that road grades remain less than 10%. These states include New Hampshire, New Jersey, New York, Ohio, Pennsylvania and Vermont. Maine suggests that the ideal road grade is 2-5% and recommends road grades less than 15% in mountainous areas and less than 10% elsewhere. Massachusetts recommends road grades of less than 5%. Maryland and West Virginia recommend road grades of less than 15%.When road grades must exceed 10-15%, states generally recommended that managers limit the length of the road (e.g., steep segments should less than 200 to 300 feet in length) to reduce erosion.

Effective road drainage is the most important factor limiting erosion and sediment delivery to streams. To promote drainage, states recommend proper grading so that roads are crowned, insloped, or outsloped depending on the location of the road. States also recommend 1) using gravel or mulch on road surfaces where necessary to control erosion, and 2) installation of drainage structures such as broad based dips, cross drain culverts, and open-top culverts to control flow off the road surface.

Table 5.7 Checklist of State Recommended BMPs for Water Drainage and Water Diversion Techniques for Controlling Runoff from Permanent and Temporary Forest Roads

	Follow Contour	Out-sloped Roads	Insloped Roads	Cross Drain Culverts	Open-Top Culverts	Water Bars	Broad-Based Dips	Water Turnouts
Maine	+	+	+	+		+	+	+
Maryland	+	+	+	+		+	+	+
Massachusetts	+				+	+	+	+
New Hampshire	+	+	+	+	+	+	+	+
New Jersey	+	+	+	+		+	+	+
New York	+	+	+	+	+	+	+	+
Ohio	+	+	+	+	+	+	+	+
Pennsylvania	+	+	+	+	+	+	+	
Vermont	+			+	+	+	+	+
West Virginia	+	+	+	+	+	+	+	

States including Maine, Maryland, New Hampshire, New Jersey, and West Virginia provide detailed recommendations and specifications for road construction and maintenance. General recommendations for outsloped roads advise that water should move gently off of the road surface in a manner that encourages dispersal, filtering by vegetation, and re-infiltration to soil. For insloped roads, states recommend using cross drain culverts and provide recommendations for their sizing and spacing. Crowned roads are recommended for removing water off the road surface when the terrain is relatively level or the road surface is on a steep side hill.

Road drainage BMPs include guidelines related to water diversion structures such as water bars, broad-based dips, turnouts, cross-drain culverts, open-top culverts, and pole-culverts (Table 5.7). States often recommend installation of water bars on skid trails or when 'closing out' or retiring haul roads. Water bars are not recommended for use on active haul roads.

All state forestry BMP manuals provide recommendations regarding the installation and spacing of water bars (Table 5.7). Water bars should be installed at 10-45° angles to the road surface and should direct drainage water into vegetated areas. Spacing recommendations are based on slope and are similar among the states (Table 5.8).

All states except Pennsylvania and West Virginia provide guidance for utilizing water turnouts (i.e., wing ditches or diversion ditches). Turnouts are used to reduce the volume and slow the velocity of water traveling within a road drainage ditch. As with water bars, turnouts should direct runoff into vegetated areas and not directly into streams.

All state forestry BMP manuals in the Northeast recommend the use of broad-based dips to divert water from permanent, active roads (Table 5.7). Recommended spacing of broad-based dips is similar among the states (Table 5.9). States in the region typically recommend using these structures on roads with grades <10% and designing the structure to direct runoff into vegetated areas. Broad-based dips are often less expensive to construct than cross-drain culverts. West Virginia's BMP manual states that broad-based dips "…may be substituted for other surface water cross drain practices." An added benefit of this structure is that it does not interfere with road use by vehicles. Furthermore, broad-based dips require little to no maintenance compared to open-top culverts which can become plugged with debris and sediment.

5.2.6 *BMPs for Fertilizers and Pesticides*

Massachusetts, New Hampshire, New Jersey, Ohio, and Pennsylvania provide guidance for fertilizer applications conducted as part of seeding operations designed to stabilize landings, log decks, roads and skid trails. Massachusetts also provides brief recommendations regarding use of fertilizers to promote tree growth. Massachusetts recommends applying slow-release fertilizers, using soil and/or foliage analysis to determine fertilizer application rates, and avoiding application of fertilizers within SMZs to reduce potential for nutrient loading of streams.

Use of herbicides and other pesticides is regulated by the Federal Insecticide, Fungicide and Rodenticide Act which, in general, requires that any pesticide be applied in accordance with requirements on the pesticide's label. Most states in the Northeast have their own pesticide laws and regulations that supplement federal requirements.

Table 5.8 Recommended Spacing Distance between Water Bars in the Northeastern States

Slope (%)	States									
	ME	MD	MA	NH	NJ	NY	OH	PA	VT	WV
	Recommended Spacing Distance ft (m)									
1	400 (122)		400 (122)		400 (122)	400 (122)			400 (122)	100 (30)
2	250 (76)	230 (70)	245 (75)	250 (76)	245 (75)	250 (76)	250 (76)	250 (76)	250 (76)	100 (30)
3	250 (76)									100 (30)
5	135 (41)	135 (41)	125 (38)	135 (41)	125 (38)	125 (38)	135 (41)	135 (41)	135 (41)	100 (30)
10	80 (24)	80 (24)	78 (24)	80 (24)	78 (24)	80 (24)	80 (24)	80 (24)	80 (24)	50 (15)
15	60 (18)	60 (18)	58 (18)	60 (18)	60 (18)	60 (18)	60 (18)	60 (18)	60 (18)	50 (15)
20	45 (14)	45 (14)	47 (14)	45 (14)	45 (14)	50 ()	45 (14)	45 (14)	45 (14)	40 (12)
25			40 (12)				40 (12)	40 (12)	40 (12)	40 (12)
30			35 (11)	35 (11)	35 (11)	35 (11)	35 (11)	35 (11)	35 (11)	40 (12)
35			32 (10)							40 (12)
40			29 (9)		30 (9)	30 (9)		30 (9)	30 (9)	40 (12)

Table 5.9 Recommended Distances between Broad-Based Dips in the Northeastern States

Slope (%)	States									
	ME	MD	MA	NH	NJ	NY	OH	PA	VT	WV[1]
	Recommended spacing distance ft (m)									
1	500 (152)		500 (152)		500 (152)	500 (152)	500 (152)		500 (152)	
2	250 (76)	300 (91)	300 (91)	300 (91)	300 (91)	300 (91)	300 (91)	300 (91)	300 (91)	
3	165 (50)	235 (72)					250 (76)	250 (76)		
4		200 (61)		200 (61)				200 (61)		
5		180 (55)	180 (55)		180 (55)	180 (55)	180 (55)	180 (55)	180 (55)	
6	165 (50)	165 (50)		165 (50)			165 (50)	170 (52)		
7		155 (47)						160 (49)		
8		150 (46)		150 (46)				150 (46)		
9		145 (44)						140 (43)		
10	140 (43)	140 (43)	140 (43)	140 (43)	140 (43)	40 (43)	140 (43)		140 (43)	
12		135 (41)		130 (40)	135 (41)					
15	125 (38)						130 (40)		130 (40)	
20	100 (30)						120 (37)		120 (37)	
25							65 (20)			

[1]West Virginia recommends using broad-based dips on skid trials and haul roads having a gradient of 10% or less. Furthermore, "spacing of broad-based dips should be approximately 100 ft (30 m) apart but never exceed 150 ft (46 m) apart."

Three states in the Northeast have recommendations for the proper use of pesticides during forest management in their state BMP manuals (Table 5.10). BMPs in Maine include 1) maintaining required buffers between spray operations and waterbodies; 2) applying chemicals during favorable weather conditions; 3) following label recommendations for application, handling, and storage; 4) mixing, loading, and storage should be done away from waterbodies and outside of SMZs; 5) removing all stored chemicals from the site when they are no longer needed; and 6) having spill kits available for the cleanup of spills. In addition, all pesticide applications in Maine must be conducted in accordance with guidelines specified by the state Board of Pesticide Control. These guidelines require that applicators be licensed and certified by the Board. Landowners and forest managers who wish to apply pesticides themselves should contact the Board before proceeding.

Massachusetts has pesticide BMPs very similar to Maine's. In addition, Massachusetts requires a 100 ft (30 m) buffer along all water bodies for aerial pesticide applications and notes that applicators should avoid direct application to water bodies. For ground and other types of applications, applicators are required to maintain a 25 ft (8 m) buffer along water bodies. Spills should be reported immediately to the Pesticide Control Board and the Service Forester. Commercial pesticide applicators in Massachusetts must be certified by the state Pesticide Control Board. The state's Pesticide Control regulations (333 CMR 12.03) require a 400 ft (122 m) buffer around all public drinking water supplies. Applicators are also required to notify adjacent landowners.

New Jersey has 10 BMPs regarding the application of pesticides during forest management. Many of these are similar to Maine's pesticide BMPs. For aerial applications of pesticides, New Jersey recommends a buffer area of at least 50 ft (15 m) around all waterbodies. Additionally, New Jersey's BMPs for streamside management zones include special guidelines for use of pesticides in these areas.

New York's BMPs acknowledges the benefits and potential impacts of pesticide applications, particularly when applied near waterbodies. Readers are advised to direct questions regarding the application of chemicals to the New York State Department of Environmental Control.

5.2.7 *BMPs for Harvesting and Reforestation*

BMPs for timber harvesting in the Northeast emphasize the importance of pre-harvest planning to minimize potential impacts on water quality associated with skid trails, landings, and mechanical site preparation (Table 5.11). All states recommend that locations of landings (log decks) and associated skid trials be determined prior to installing access roads and primary skid trails. Landings should be located outside of SMZs and/or away from waterbodies. States also recommend utilizing existing landings when feasible, limiting the size and number of landings, and utilizing water diversion techniques when necessary to reduce sediment runoff from landings. When harvest operations are completed, states recommend seeding log decks with grasses or covering the surface with logging slash.

States in the Northeast provide numerous BMPs for skid trails. Generally, state BMPs recommend limiting disturbance to soils (i.e., the number of trails), protecting streams during crossing, limiting the number of temporary stream crossings, locating skid trails cross-slope to minimize erosion, avoid skidding logs directly up slope, and avoid skidding up grades that exceed 10 to 15%. All states recommend installing water diversion techniques, like water bars and water turnouts, on skid trails and retired roads (Table 5.8).

Table 5.10 Checklist of State Recommended BMPs for Silvicultural Pesticide Applications

	Use Rates Recommended by Manufacturer	Direct/Spot Applications Permissible in SMZs	Aerial Application Guidance	Consider Weather Conditions Prior to Application	Application Restricted Near Waterbodies	Disposal and Cleanup Guidance
Maine	+	+		+	+	+
Maryland						
Massachusetts	+	+	+	+	+	+
New Hampshire						
New Jersey	+	+	+	+	+	+
New York						
Ohio						
Pennsylvania						
Vermont						
West Virginia						

Table 5.11 Checklist of State Recommended BMPs for Harvesting, Reforestation, and Waste Disposal

State	Placement of Landings and Skid Trails	Limit Skid Trails and Temporary Stream Crossings	Advise Use of Water Diversion Techniques	Procedures for Retiring Landings and Trails	General Site Preparation Recommendations	Waste Disposal Guidance
Maine	+	+	+	+		+
Maryland	+	+	+	+		
Massachusetts	+	+	+	+		+
New Hampshire	+	+	+	+		
New Jersey	+	+	+	+	+	
New York	+	+	+	+		+
Ohio	+	+	+	+		+
Pennsylvania	+	+	+	+		
Vermont	+	+	+	+		
West Virginia	+	+	+	+		

All states in the region have recommendations or requirements for closing out a harvest site. These generally include installing water diversion structures as needed to control erosion on roads, trails, and log decks; seeding areas of bare soil; and limiting access (i.e., gating access roads) after harvest. Pennsylvania, New Hampshire, and Vermont recommend reshaping and stabilizing all roads and skid trails, removing nonpermanent stream crossing structures, installing appropriate water diversion techniques, as well as seeding and mulching areas where significant erosion and sedimentation may occur (e.g., log decks, stream approaches). Close-out procedures in West Virginia require seeding of roads and skid trails in SMZs when slopes exceed 10 and 15%, respectively. West Virginia also requires seeding and mulching of all landings, areas with disturbed mineral soils in SMZs, and any road that disturbs mineral soil and exceeds 20% slope. In addition to implementing several of the procedures mentioned above, Massachusetts requires that managers notify a Service Forester to schedule a final site inspection.

New Jersey is the only state in the region that provides guidelines for site preparation (Table 5.11). Guidelines related to water quality include maintaining natural drainage; avoiding altering surface and subsurface hydrology of wetlands; avoiding mechanical site preparation where slopes exceed 30% and within SMZs; avoiding connecting planting beds to drainage ditches and waterbodies; and using herbicides instead of mechanical site preparation to control competing vegetation on highly erodible soils.

5.2.4.6 *BMPs for Waste Disposal*

Four states in the Northeast have recommendations or guidance for waste disposal and site cleanup following harvest in their BMP manuals (Table 5.11). Ohio and New York BMPs simply recommend that all trash (e.g., used oil filters, parts, and solvents) be removed from the site. Massachusetts recommends that forest operators 1) perform preventative maintenance to minimize risk of leaks and spills (e.g., check hoses and fittings regularly), and 2) have oil-absorbent mats or other waste cleanup articles on site for spill containment and cleanup. Maine has the most detailed recommendations regarding storage and disposal of wastes. The state's BMPs include using appropriate storage containers; maintaining and repairing all equipment outside of SMZs; having spill kits on site; and collecting all trash from the logging site and disposing of it properly.

5.3 Northeastern State BMP Monitoring Protocols and Implementation/Compliance Rates

In a study conducted for NCASI, Lloyd Irland evaluated silvicultural NPS pollution control programs for twelve northeastern states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia) using published information and interviews with state program managers and researchers (NCASI 2001b). The report highlighted many aspects of state NPS programs including BMP monitoring. A key finding was that many northeastern states consider forestry to be an insignificant source of water quality problems relative to other sources. As a result, many states in the region are reluctant to direct scarce resources to monitoring implementation and effectiveness of forestry BMPs. Maine and West Virginia are notable exceptions. In other states, funds to address forestry NPS issues are usually directed to logger education and training programs.

To encourage greater attention to BMP monitoring, the Northeastern Area Association of State Foresters (NAASF) and the U.S. Forest Service Northern Region for State and Private Forestry (USFS) jointly developed a protocol for measuring BMP implementation and effectiveness (Welsch, Ryder, and Post 2007). Collaborators included the New York City Watershed Agricultural Council Forestry Program and state forestry agencies in Delaware, Indiana, Maine, Maryland, Massachusetts, New Hampshire, New York, Ohio, Pennsylvania, Vermont, Virginia, West Virginia, and Wisconsin. The Protocol has been tested at 700 plots and demonstrated for several stakeholder groups. Agency

personnel in 10 states have had training in use of the Protocol. More recently, the Protocol was formally adopted by the NAASF for use in 20 states.

The remainder of this section summarizes BMP implementation and effectiveness surveys conducted in the Northeast.

5.3.1 *Maine*

Maine has been actively involved in developing and testing the NAASF/USFS BMP Monitoring Protocol in recent years. Previously, three BMP implementation and effectiveness surveys were conducted in the state. Results of the first study were published by Briggs, Cormier, and Kimball (1998). Subsequent surveys were conducted by the Maine Forest Service in 2001 and 2005.

The study by Briggs and colleagues concluded that Maine's BMPs were highly effective when implemented properly. However, implementation of individual BMPs was highly variable across the state (Briggs, Cormier, and Kimball 1998). In response to this finding, the Maine Forest Service (MFS) was tasked by the state legislature to evaluate BMP implementation rates (PL 1997, Chapter 648). The MFS, with assistance from a Forest Advisory Team, developed a BMP monitoring protocol to assess BMP implementation and effectiveness across the state.

BMP effectiveness is assessed by evaluating effects of harvest activities on soil movement and delivery to waterbodies. Selection of monitoring sites is done randomly using Forest Operations Notification (FON) forms within the state's 10 forestry districts. Site evaluations are conducted by MFS personnel. Data collection is focused on recently harvested areas where surface waters are present.

The following discussion of results is based on data collected during the state's second round of monitoring from June 2001 to November 2003 (ME DOC 2005). In this survey, surface water was present on 288 of 452 randomly selected harvest sites in the FON database. Water bodies on these sites were primarily first order and second order streams (32 and 30%, respectively).

Overall, BMPs were used appropriately or with a "good attempt, but needs improvement" on 75% of the sites evaluated (ME DOC 2005). These findings represent a 12% increase over the previous round of MFS monitoring published in 2001. The MFS 2005 publication also reported a minimal attempt to implement BMPs on 16% of the monitoring sites. No attempt to implement BMPs was evident at 8% of the sites. No evidence of major soil transport or deposition within waterbodies was observed on the 150 sites where BMPs were implemented properly. BMPs were rated highly effective in preventing soil transport to waterbodies on 82% of the sample sites. This represented a 22% improvement over the 2001 MFS report.

BMPs for logging filter strips were used appropriately or with a "good attempt, but needs improvement" on 89% of the sites evaluated. Comparable implementation rates for other BMPs were as follows: skid trails (86%), haul roads (78%), haul road filter strips and drainage systems (74%), and temporary stream crossings (54%).

Most survey sites (88%) were on industrial or non-industrial private ownerships. Implementation rates (sum of the appropriate use and good attempt categories) for industrial and non-industrial ownerships were 81% and 70%, respectively. The implementation rate for a relatively small sample of "investor" forestland sites was 65%.

MFS has identified three areas to target for improved rates of BMP implementation: investor forestland ownerships, temporary stream crossings, and haul roads. MFS plans to address these issues by improving training for Certified Logging Professionals and Certified Master Loggers and at workshops for landowners held throughout the state.

In November 2006, the MFS published findings from a statewide BMP survey conducted between April 2005 and December 2005. This survey was used to assess BMP implementation and effectiveness during logging operations using, for the first time, the NAASF/ USFS regional BMP Monitoring Protocol (ME DOC 2006). Levels of BMP compliance measured in this survey are not directly comparable to results of previous surveys due to differences in methods. When BMPs were appropriately applied, 92% of surveyed stream approaches showed no evidence of direct soil transport into waterbodies. Furthermore, 79% of crossing structures did not increase sediment transport. Timber harvests in riparian areas retained an average 80% canopy closure. At sites where BMPs were not applied appropriately, sediment reached a waterbody at 25% of the approaches and 44% of the stream crossings. It is noteworthy that 45% of monitored sites with a waterbody present did not have a stream crossing present. This suggests that pre-harvest planning BMPs are being applied as intended to limit numbers of stream crossings and, as a result, reduce the potential for sediment transport to waterbodies.

5.3.2 *Maryland*

With funding from an EPA Section 319 grant, Maryland evaluated BMP implementation on 99 harvest sites across the state (Koehn and Grizzel 1995). Harvest unit size ranged from 10 to 350 acres and sites were selected based on the presence of surface water to ensure that SMZs and/or stream crossings would be evaluated in the site surveys. Survey sites were selected from a screening of sediment and erosion control plans approved between January 1993 and March 1994. Three to six survey sites were selected in each county (depending on past harvest activity) and represented approximately 12% of the sediment and erosion control plans filed statewide. A site evaluation form was developed that contained 23 questions separated into five categories: haul roads and skid trails; stream crossings; SMZs; landings and log decks; and soil stabilization. Questions about roads and trails addressed access point protection, location and construction, drainage, and rutting. Stream crossing questions focused on the number of crossings, disturbances to streambanks, and drainage. Questions about SMZs focused on retention of buffers, disturbance in the SMZ, and debris in waterbodies. Landing and log deck questions focused on placement, drainage, and litter on site. Stabilization questions addressed erosion control on cut and fill sites, landings, and skid trails.

Across all categories, BMP implementation for the state averaged 82%. At the regional level, the lower Coastal Plain and Eastern Shore had the highest implementation rates (89%), followed by the Piedmont (86%), Mountain Region (78%), and Upper Coastal Plain (75%). At the category level, BMP implementation rates were as follows: haul roads and skid trails (82%), stream crossings (75%), SMZs (83%), landings and log decks (90%), and soil stabilization (68%).

The state also evaluated BMP effectiveness using a paired watershed approach after securing another EPA Section 319 grant (MD DNR website, accessed 6/5/2007). This study evaluated effectiveness in Maryland's Piedmont region by measuring effects of forestry activities conducted in accordance with BMPs. The study was completed in April 2000 and concluded that Maryland BMPs were effective as indicated by no significant changes in stream macroinvertebrates, temperature, or suspended sediment levels.

Maryland has been involved in development and testing the NAASF/USFS BMP Monitoring Protocol. The state has collected field data to assist in the testing and validation of the protocol. Also, the state recently collected data on BMP implementation (Anne Hairston-Strang, Forest Hydrologist, MD DNR-FS, pers. comm.). This survey evaluated 39 harvests conducted across the state between 2003 and 2004. Overall, statewide compliance was 81%. At the category level, BMP compliance rates were as follows: harvest entrance (84%), haul roads (94%), skid trails (77%), harvest landings (97%), stream crossings (68%), SMZs (83%), and harvest aesthetics (72%).

5.3.3 *Massachusetts*

To reduce NPS pollution during forest management, Massachusetts relies on the enforcement of the state's Forest Cutting Practices Act (FCPA, Chapter 132). The state's BMP manual is designed to clarify guidelines in the FCPA and the Wetlands Protection Act (Chapter 131) since implementation of specific BMPs is required under the FCPA. Massachusetts also requires a timber harvest plan (THP) or notice of intent to harvest to be filed at least 10 days prior to harvest. Loggers are required to be licensed.

The state considers its regulatory mechanisms sufficient to ensure high rates of BMP implementation. Compliance with the FCPA is believed to be high because very few violations have been reported in the state's General Environmental Impact Report as required under the state's Environmental Policy Act. The 1996 Statewide Water Quality Assessment mentioned no instances of water pollution resulting from forest management and the state reports approximately 800 harvest operations annually (NCASI 2001b). More recently, Massachusetts has been actively involved in the development and testing of the NAASF/USFS BMP Monitoring Protocol and has collected field data to assist in the testing and validation of the protocol.

5.3.4 *New Hampshire*

New Hampshire has participated in the NAASF/USFS BMP Monitoring Protocol by collecting field data on implementation and effectiveness. However, the state has not conducted a formal field survey on BMP implementation or effectiveness. The state reports that approximately 5000 timber harvests occur annually (NCASI 2001b). Routine inspections by the New Hampshire Forest Service occur at approximately 3000 sites to examine permit compliance with wetland and stream crossing laws. While there is no data base on the occurrence of violations, it is estimated that 100 violations or potential violations are reported to the Wetlands Bureau annually. The most common violations reported involve "…skidding in brooks and failure to complete recommended steps for putting a [forest] operation to bed" (NCASI 2001b).

5.3.5 *New Jersey*

Operational forestry in New Jersey is generally limited in scale and often occurs on small tracts of non-industrial private forestland. The number of commercial logging operations per year is typically less than 250. In a 1994 report on NPS pollution, the New Jersey Department of Environmental Protection characterized forestry has having minimal, localized impacts (NCASI 2001b). The New Jersey Forest Service conducts an onsite review of BMP implementation upon request and will investigate when notified of potential impacts to water quality.

5.3.6 *New York*

The New York Department of Environmental Conservation and the New York City Watershed Agricultural Council Forestry Program have participated in developing the NAASF/ USFS BMP Monitoring Protocol by collecting field data on implementation and effectiveness. In addition to this recent effort, two BMP surveys have been conducted in the state (King 1989; Schuler and Briggs 2000).

King (1989) described an initial survey conducted by the state Department of Environmental Conservation to evaluate implementation of BMPs in New York's Timber Harvest Guidelines (THGs). The survey showed, in general, low compliance rates with the guidelines. However, analysis of the data coupled with field observations indicated generally low impacts of forestry operations without BMPs compared to potential erosion expected with proper BMPs implementation. Overall, the King (1989) survey noted low levels of compliance for stream crossings (40%) and transportation systems or roads (42%).

More recently, a survey of BMP implementation and effectiveness in the Adirondack and Catskill regions of New York was conducted by Schuler and Briggs (2000). For this survey, 53 sites in both regions were surveyed during the summers of 1997 and 1998, respectively. The primary site selection criterion was that harvests must have occurred within 18 months of the survey. Presence of waterbodies within or adjacent to the harvest site was not a requirement for site selection. Survey sites ranged from 5 to 300 acres. The survey sites in the Adirondack region were selected on four private industrial ownerships. Survey sites in the Catskill region were selected on state and non-industrial private ownerships with assistance of staff from the New York Department of Environmental Conservation, New York City Department of Environmental Protection, and the New York City Watershed Forestry Program. These sites were identified from known harvest operations, state tax law (480a) harvest plans, and/or stream crossing permits.

Each site survey evaluated the application of 42 specific BMPs in the following categories: haul roads, landings, skid trails, equipment maintenance/operation, and SMZs. For each site, all haul roads, skid trails, and landings were walked to assess BMP application. SMZs were inspected around perennial streams, wetlands, lakes, and ponds. Implementation of BMPs on each survey site was determined only where a practice was needed. For each instance where a BMP was deemed necessary, one of the following BMP implementation ratings was given: 1) BMP not implemented or implemented improperly; 2) BMP implementation with minor deviations from the recommendations; and 3) BMP correctly implemented.

The study defined BMP effectiveness as "…the ability of the BMP to maintain pre-harvest water quality conditions as indicated by the lack of a visible sediment trail (or a turbid plume) originating from a missing or poorly applied BMP." Movement of sediment was used as an indicator of BMP effectiveness (except for BMPs dealing with litter on landings and woody debris in streams). Sediment transport to waterbodies was considered an impact. For each BMP implementation rating given, one of three effectiveness ratings was given: 1) direct impact on water resources (a sediment trail visible from a poorly implemented or missing BMP);(2) indirect impact (a sediment trail was traced from a poorly implemented or missing BMP to a point on the land but did not reach a waterbody); and 3) adequate protection of water resource (no sediment trail evident).

Across both the Adirondack and Catskill sample regions, average rates of BMP implementation for the five categories were as follows: 78% for haul roads, 87% for landings, 59% for skid trails, 88% for equipment maintenance and operation, and 73% for SMZs. Departures from haul road BMPs often involved road drainage with 67% of Adirondack roads and 50% of Catskill roads assessed as having adequate drainage. Problem areas related to skid trails included skidders working too close to water bodies; failure to stabilize potentially erosive areas; and excessive numbers of temporary stream crossings. Problem areas related to SMZs were inadequate stabilization of approaches to water crossings (33% implementation); excessive soil disturbance in SMZs; and excessive logging debris in water bodies.

Effectiveness was evident when BMPs were applied at all harvest sites. Statistical analyses indicated a relationship between BMP implementation and prevention of sediment transport to waterbodies.

5.3.7 *Pennsylvania*

An estimated 12,000 logging operations are conducted in Pennsylvania each year. Pennsylvania regulates timber harvesting and construction of roads and stream crossings under the state's Erosion and Sedimentation Pollution Control Program which is administered by the state's Department of Environmental Protection (NCASI 2001b).

Pennsylvania's Bureau of Forestry NPS program "is primarily geared toward educating loggers about environmentally sound silviculture, and erosion and sediment pollution control practices. This training consists of structured classroom sessions, distribution of published materials, and on-site assistance provided by 45 Service foresters located throughout the state" (NCASI 2001b).

Pennsylvania's 305(b) Assessment Reports indicate that forestry is not a significant source of NPS pollution in the state. Pennsylvania has not conducted formal surveys to assess BMP implementation but has participated in the development of the NAASF/USFS BMP Monitoring Protocol. Numerous studies of BMP effectiveness have been conducted at the USFS Leading Ridge Experimental Watershed in Central Pennsylvania.

5.3.8 *Vermont*

Vermont has participated in testing the NAASF/USFS BMP Monitoring Protocol by collecting field data on implementation and effectiveness. In addition, two studies have been conducted in the state to evaluate BMP compliance (Brynn and Clausen 1991; VT FRAC 1996).

Brynn and Clausen (1991) evaluated 78 recently completed timber harvests to assess their compliance with the state's required BMPs. The study focused on forest roads and stream crossings. The authors noted evidence of sediment movement to streams at 46% of the survey sites with streams, and woody debris in streams on 65% of the sites. Compliance with BMPs for filter strips (i.e., SMZs) was greater than 90%. Haul roads and skid trails typically failed to meet the state's BMP guidelines. However, only minimal impacts from soil erosion were reported on water quality.

The Vermont Forest Resources Advisory Committee (1996) Assessment Working Group reviewed BMP compliance within 17 timber harvest sites. Compliance with the state's 24 recommended BMPs was evaluated using a point system. The Working Group noted major departures from drainage BMPs on forest roads and skid trails. For example, surveyors indicated that 46 drainage structures were required for the 6,864 ft (2,092 m) of roads evaluated; however, only 19 were implemented. Of the 4.5 miles of skid trails sampled, only 80 drainage structures were installed versus 207 structures recommended by BMPs. The surveyors also found that eight of 17 stream crossings increased deposition of fine sediment downstream of the structures.

5.3.9 *West Virginia*

West Virginia's Logging and Sediment Control Act (LSCA) became effective in 1992 and requires notification of harvesting, state certification in logger training (including BMPs), licensing of loggers, and reclamation of sites upon completion of logging. Notification forms are filed by loggers but are not signed by the landowners. Notification must occur no more than three days prior to and not later than three days after initiating operations. Administration and enforcement of the LSCA rests with area foresters with the Department of Forestry (DOF) (WV DOF 2005). Approximately 3000 notices of intent to harvest are filed annually (NCASI 2001b).

The West Virginia DOF has conducted periodic surveys to quantify BMP implementation (Whipkey and Glover 1987; Whipkey 1991; Egan, Whipkey, and Rowe 1998). A recent implementation survey by Wang and Goff (2008) in conjunction with the DOF evaluated BMPs at 33 harvest sites with stream crossings and/or SMZs. BMP implementation and effectiveness were assessed only where the BMP had been applied or should have been applied. Implementation was assessed using a three-point scale: 0 = BMP not used or applied poorly; 1 = BMP implemented with minor deviations from recommendations; 2 = BMP applied correctly. BMP effectiveness was assessed in terms of visual evidence of sedimentation or surface runoff. The overall rate of BMP implementation (score of 1 or 2) was 85%. Implementation rates for BMP categories were as follows: haul roads (84%), skid trails (86%), landings (81%), and SMZs (80%). Areas for improvement included drainage of roads and skid trails; maintaining adequate spacing between skid trails and water bodies; and location of landings and haul roads away from SMZs.

5.4 Summary

Most states in the Northeast have regulatory elements in their forestry NPS programs. These include notification of intent to harvest, filing of management or erosion/sediment control plans, and slash laws. In addition, many states require notification, management plans, and permits for stream crossings.

All states in the Northeast have developed forestry BMPs and recommend or require their use during forest management. Some states provide very specific technical information while others provide more general guidance on controlling erosion.

There is a high degree of consistency in topics addressed in state BMPs across the region. This is attributable to the influence of watershed research stations in the region. For example, the early research conducted at Hubbard Brook in New Hampshire provided basic understanding of forest management effects on water quality as well as the role of BMPs in protecting water quality. Other major research watersheds in the region include Fernow in West Virginia and Leading Ridge in Pennsylvania. Research at these locations has played key roles in defining critical elements of BMPs and in demonstrating their effectiveness. This research has also guided the development of BMP parameters such as general width prescriptions for SMZs and guidelines for road drainage structures.

All states in the region recommend the use of SMZs to protect streams. As in other regions, there is some variation among states in details of SMZ management guidelines and methods used for determining SMZ widths.

All of the northeastern states recognize the importance of BMPs for roads, skid trails and stream crossings in efforts to control runoff and sediment movement to surface waters. Relatively low implementation rates for these BMPs in some surveys may be due in part to the fact that some roads were constructed prior to BMP development and in part to the difficulty of developing general quantitative prescriptions (e.g., for spacing between road drainage structures) that are generally applicable across broad and diverse regions.

A majority of states in the Northeast have not elected to make major investments in BMP monitoring, with West Virginia and Maine being the most notable exceptions. Methods used in BMP implementation surveys have varied among and within states. Rates of BMP implementation reported in recent surveys were Maine (75%), Maryland (82%), New York (77%), and West Virginia (85%). States that have conducted multiple surveys have indicated increasing rates of BMP implementation. The 2005 survey conducted in Maine, for example, indicated a 12% increase in implementation from the previous survey in 2001 (ME FS 2002).

6.0 CANADIAN PROVINCES

6.1 Introduction

Federal and provincial laws are driving forces in Canada for the development of forest management guidelines to control nonpoint source (NPS) pollution. Provincial authorities have the lead role in developing NPS guidelines that are consistent with national goals and each province's unique laws and traditions. In British Columbia, for example, there are seven Acts relevant to forestry (TFC/WS 2004). Responsibility for implementing these Acts rests with several provincial agencies including the Ministry of Forests and Range and the Ministry of Environment. To assist managers in adhering to legal requirements, British Columbia has developed 12 guidebooks that define standards for forest management and suggest practices that could be implemented to achieve the objectives laid out in the provincial Acts (BC MOF 2007). The *Fish-Stream Crossing Guidebook* (BC MOF 2002a) and the *Forest Road Engineering Guidebook* (BC MOF 2002b) include many provisions related to protection of water resources.

In Saskatchewan, the Ministry of Environment is working to fulfill a legislated mandate to produce four manuals that will provide guidance for a variety of forest management activities in the province. Each of the four manuals (Forest Planning, Forest Operations, Compliance, and Scaling) will contain details on applicable objectives, procedures, standards, and guidelines to be followed for a particular subject area by a licensee. Standards and guidelines specific to each of Saskatchewan's four Forest Management Agreements can be viewed at http://www.environment.gov.sk.ca/Default.aspx?DN =903599a5-ccce-47ac-9355-c17650a1e263.

Other examples of provincial forestry guidelines include the *Alberta Public Lands Operational Handbook* (AB SRD 2004) and *Forest Management Manual for New Brunswick Crown Land* (NB NR 2004). These publications (and similar documents in other provinces) address water resource protection as well as many other topics.

This section provides an overview of provincial forest management guidelines related to NPS pollution control. In addition, this section provides information about approaches used to assess compliance with NPS guidelines.

6.2 Federal Legislation Relevant to Forest Management

The Fisheries Act and the Navigable Waters Protection Act are the federal laws with greatest influence on efforts to control NPS pollution associated with forest management activities. Other relevant federal laws include the Species at Risk Act and the Canadian Environmental Assessment Act.

The Fisheries Act establishes environmental performance standards for activities that have the potential to negatively impact fish populations and their habitat (Government of Canada 1985a). In the context of forest management, affected activities can include timber harvesting adjacent to watercourses, road construction and stream crossings. Implementation authority rests with the federal Department of Fisheries and Oceans.

The Navigable Waters Protection Act regulates activities that can interfere with vessel passage and commerce on navigable waterways (Government of Canada 1985b). Implementation authority rests with Transport Canada. Affected forestry activities include road construction and stream crossings.

6.3 Provincial Legislation and Guidelines Relevant to Forest Management

Provinces have primary responsibility for regulation of forest management activities and their effects on watercourses. Each province has developed Acts or Regulations that provide a foundation and framework for forest management policies and prescriptions (Table 6.1). Publications by Decker (2003), The Forestry Corporation and Watertight Solutions (TFC/WS 2004), and NCASI (2007b) provide detailed descriptions of provincial Acts and Regulations related to forestry, wetlands, and water resources.

Provincial forestry guidelines interpret the Acts and Regulations in terms of practical approaches for compliance. However, enforcement of legal requirements must be based on the Acts and Regulations themselves, not the interpretive guidelines (TFC/WS 2004).

Table 6.1 Summary of Provincial Legislation Relevant to Forest Management and Water Quality [adapted from NCASI 2007b]

Province	Legislation	Description
Alberta		
	Water Act	Focuses on managing and protecting Alberta's water and administrative processes (e.g. compliance and license issues).
	Environmental Protection and Enhancement Act	Supports the protection, enhancement and wise use of the environment. Is the legal basis for environmental assessment process.
	Public Lands Act	The Act deals with ownership titles of beds and shores of all permanent and naturally occurring bodies of water.
	Forests Act	Provides the legislative framework for administering forest lands including allocation of timber, annual allowable cut, dues etc.
British Columbia		
	Water Act	The Act deals with the use and transport of water and alteration of streams and rivers. Wells and ground water are included in this act.
	Water Protection Act	Promotes sustainable use of water resources.
	Environment Management Act	Regulates waste disposal, waste discharge, and spills (solid waste, hazardous waste). Also deals with contaminated sites and the remediation process.
	Environment Assessment Act	Regulates environmental assessment process for development proposals including ways to eliminate, minimize, mitigate or compensate impacts of such projects.
	Forest Act	Establishes the framework for forest management, including technical and practical aspects of harvesting and industrial development.
	Forest Practices Code of British Columbia Act	Legislation and regulations that addresses the sustainable use of forest resources
	Forest and Range Practices Act	Legislation, regulations, standards, and guidelines dealing with forests and range lands.

Table 6.1 Continued

Province	Legislation	Description
Manitoba		
	Water Protection Act	Provides for the protection and stewardship of water resources
	Forest Act	Provides for the administration and regulation of forests on Crown lands.
	Environment Act	Provides for environmental licensing process for forest management including environmental assessment
Newfoundland and Labrador		
	Water Resources Act	Creates provisions for the protection of water and water resource management
	Lands Act	Law respecting Crown land which includes water
	Forest Act	Law respecting the management, harvesting and protection of the forest
New Brunswick		
	Crown Lands and Forests Act	Outlines the authority, administration, management of Crown lands and forestry
	Clean Water Act	Outlines the authority of government and overarching activities as related to the protection of water resources
	Clean Environment Act	Outlines authority and overarching activities related to air, soil and water
Nova Scotia		
	Environment Act	An Act to reform the environmental laws of the province and to encourage and promote the protection, enhancement and prudent use of the environment
	Forest Enhancement Act	An Act to encourage the development and management of forest land in Nova Scotia
	Forests Act	An Act respecting the administration and management of Forests
	Crown Lands Act	An Act respecting the administration and management of Crown lands
	Water Resources Protection Act	An Act to protect the water resources of Nova Scotia

Table 6.1 Continued

Province	Legislation	Description
Ontario		
	Crown Forest Sustainability Act	Defines forest sustainability and provides mechanisms to ensure sustainability
	Environmental Assessment Act	Defines conditions for undertaking an environmental assessment for any major new project that can impact the environment. Includes Crown lands.
	Clean Water Act	Purpose of this Act is to protect existing and future sources of drinking water.
	Lakes and Rivers Improvement Act	To provide for the management, protection, preservation and use of the waters of the lakes and rivers
Quebec		
	Environment Quality Act	Sets out regulatory guidelines for environment including: water, air, hazardous materials, and environmental impact assessment.
	Forest Act	Fosters recognition of the forest as a common heritage and promotes sustainable forest development.
Saskatchewan		
	The Environmental Assessment Act	Regulates developments, which have significant impact on the environment including Industrial Forest Management Activities.
	Environmental Management and Protection Act	Regulation to protect the air, land and water resources and regulating and controlling potentially harmful activities and substances.
	The Forest Resources Management Act	Promotes the sustainable use of forest land.
	Saskatchewan Watershed Authority Act	Provides the mandate to manage, develop and conserve water resources and related land resources in Saskatchewan.
	Watersheds Association Act	Creates authority to Watershed Boards to act within the province's watersheds.

All provinces have established forestry guidelines for NPS pollution control. The complexity and specificity of these guidelines varies substantially among the provinces. Recurring topics include watercourse classification, riparian buffers, roads and stream crossings, forest chemicals, timber harvesting and reforestation, and waste disposal.

6.4 Provincial Watercourse Classifications and Forested Riparian Buffer Guidelines

Provinces use a variety of schemes for classifying watercourses (e.g., streams, lakes, and ponds) (Table 6.2). Understanding applicable schemes is prerequisite to establishing riparian forest buffers, prescribing acceptable management practices, establishing road approaches, and installing and removing watercourse crossing structures.

While watercourse classification systems vary among the provinces, the general approach is to characterize streams and lakes based on their size and on one or more of the following criteria: watershed area, stream order, and stream channel width. Further refinement of stream classifications is often based on the presence or absence of fish.

All provinces require that forested buffers be retained around watercourses. Descriptions and terms used to define forested buffers vary substantially. Buffer width prescriptions depend on a province's watercourse classification (Table 6.2) and are either fixed or variable within a category of watercourses. Variable width systems typically consider topography (e.g., slope) and/or fish presence or absence to determine buffers width. The width of a riparian buffer is typically measured from the high water mark (HWM), which is defined as the boundary point where riparian vegetation transitions into upland vegetation or a break in topography occurs.

Management is generally allowed within riparian buffers in designated management zones or through a governmental approval process (e.g.., approval of forest management plans). In contrast, forest management is not allowed in riparian buffers in Newfoundland and Labrador.

6.4.1 *Alberta*

Alberta watercourses are classified based on flow regime and channel development. Large permanent stream have well-defined floodplains in valleys greater than 400 m wide; unvegetated channels greater than 5 m (16 ft) wide; and continuous flows. Small permanent streams have continuous flows; valleys less than 400 m (1,312 ft) across with floodplain development; and channels between 0.5 to 5 m (1.6 to 16 ft) wide with well defined banks. Intermittent streams have distinct channels up to 0.5 m (1.6 ft) wide with some streambank development but contain water only during wet periods of the year. Ephemeral streams or vegetated draws have little to no channel development with little or no flow except during snowmelt or rainfall (AB EP 1994; AB SRD 2002).

Alberta mandates the use of fixed-width buffers based on a watercourse's classification, with buffer widths ranging from 30 to 100 m (98 to 328 ft). A 100 m (328 ft) buffer is required on all lakes and ponds. For large permanent streams, a 60 m (197 ft) buffer is required. Both small permanent and intermittent streams require 30 m (98 ft) buffers. Variances from these required buffers are possible but only with prior approval.

Table 6.2 Generalized Stream Classifications and Riparian Buffer Requirements for the Canadian Provinces

Providence & Classification	Watercourse Description	Riparian Buffer Requirements
Alberta		
Large Permanent	Channel >5 m (16 ft); flows year round	60 m (197 ft)
Small Permanent	Channel 0.5 to 5 m (1.6 to 16 ft) wide; flows year round	60 m (197 ft)
Intermittent	Stream width <0.5 m (1.6 ft) some bank development	Protect understory
Ephemeral	Rainfall or snowmelt driven	Protect understory
Water Source Areas	Areas with saturated soils/seepages	20 m (66 ft)
Lakes	No waterfowl or sport fishing	100 m on lakes >16 ha 328 ft on lakes >40 ac
Lakes	Recreation, waterfowl, or fish sport fishing	100 m on lakes >4 ha 328 ft on lakes >10 ac
British Columbia		
Streams (S1)	≥100 m ≥328 ft	100 m (0 m RZ / 100 m MZ) 328 ft (0 ft RZ/ 328 ft MZ)
Streams (S1)	>20 m >66 ft	70 m (50 m RZ / 20 m MZ) 230 ft (164 ft RZ / 66 ft MZ)
Streams (S2)	>5 and ≤20 m >16 and ≤66 ft	50 m (30 m RZ / 20 m MZ) 164 ft (98 ft RZ / 66 ft MZ)
Streams (S3)	>1.5 and ≤ 5 m >5 and ≤16 ft	40 m (20 m RZ / 20 m MZ) 131 ft (66 ft RZ / 66 ft MZ)
Streams (S4)	<1.5 m <5 ft	30 m (0 m RZ / 30 m MZ) 98 ft (0 ft RZ / 98 ft MZ)
Streams (S5)	>3 m >10 ft	30 m (0 m RZ / 30 m MZ) 98 ft (0 ft RZ / 98 ft MZ)
Streams (S6)	≤3 m ≤10 ft	20 m (0 m RZ / 20 m MZ) 66 ft (0 ft RZ / 66 ft MZ)
Lakes (L1)	>5 ha >12.4 ac	10 m (10 m RZ / 0 m MZ) 33 ft (33 ft RZ / 0 ft MZ)
Lakes (L2)	1 to 5 ha 2.5 to 12.4 ac	30 m (10 m RZ / 20 m MZ) 98 ft (33 ft RZ / 66 ft MZ)
Lakes (L3)	1 to 5 ha 2.5 to 12.4 ac	30 m (0 m RZ / 30 m MZ) 98 ft (0 ft RZ / 98 ft MZ)
Lakes (L4)	0.5 to 1 ha 1.2 to 2.5 ac	30 m (0 m RZ / 30 m MZ) 98 ft (0 ft RZ / 98 ft MZ)

(Continued on next page)

Table 6.2 Continued

Providence & Classification	Watercourse Description	Riparian Buffer Requirements
Newfoundland & Labrador	Delineated watercourses and watercourses >1m (3.3 ft) wide	20 m (66 ft)
Nova Scotia	Delineated watercourses	20-60 m (66-197 ft)
Prince Edward Island	Slopes ≤9% Slope >9%	20 m (66 ft) 30 m (98 ft)
New Brunswick	Channels <0.5 m (1.6 ft) wide Drainage areas <600 ha (1,483 ac) Drainage areas >600 ha (1,483 ac)	3 m (10 ft) 15 m (49 ft) 30 m (98 ft)
Quebec	All watercourses	20 m (66 ft)
Ontario	Slopes 0-15% Slopes 16-30% Slopes 31-45% Slopes 46-60%	30 m (98 ft) 50 m (164 ft) 70 m (230 ft) 90 m (295 ft)
Manitoba		
Class 1 Streams	Drainage area >50 km^2 (19 mi^2); Continuous flow; Fish present	100 m (328 ft)
Class 2 Streams	Drainage area <50 km^2 (19 mi^2); Continuous or seasonal flow; Fish present	100 m (328 ft)
Productive Lakes	Permanently filled waterbody	100 m (328 ft)
Small Lakes/Ponds	Spring or runoff fed No large fish present	100 m (328 ft)
Saskatchewan		
Class I Streams	1st to 3rd Order Drainage area <50 km^2 (19 mi^2) No fish present	15 m (328 ft)
Class I Streams	1st to 3rd Order; Drainage area <50 km^2 (19 mi^2); Fish present	30 m (328 ft)
Class II Streams/Lakes	≥4th Order; Drainage area >50 km^2 (19 mi^2); Seasonal fish populations	30 m (328 ft)
Class II Streams/lakes	≥4th Order, Drainage area >50 km^2 (19 mi^2); Permanent fish populations	90 m (328 ft)

6.4.2 *British Columbia*

Streams in British Columbia are classified on the basis of channel width and fish presence/absence. Fish-bearing streams are determined by the presence of anadromous salmonids or other sport fishes reported on provincial fish inventories. When a fish inventory is not available, fish presence is assumed where stream gradient is less than 20% and the stream is a tributary to a fish-bearing stream or lake.

There are six main classes of streams in British Columbia (BC MOF 1995a). Fish-bearing watercourses are assigned to classes S1 to S4 on the basis of channel width. The largest streams are in class S1 and divided in subclasses: large rivers > 100 m (328 ft); and smaller rivers > 20 m (66 ft) wide. Stream categories S2, S3, and S4 have width limits in the range of 20 to 1.5 m. Non-fish-bearing streams are in classes S5 (width > 3 m) and S6 (width < 3m). Lakes are classified on the basis of size, e.g., lakes with areas > 5 ha are in class L1 while lakes with areas < 1 ha are in class L4.

Forested buffers in British Columbia are referred to as riparian management areas (RMAs). The width of RMAs is based on the size of the watercourse, presence or absence of fish, and biogeoclimatic zone (BC MOF 1995a). Each RMA buffer width is based on two zones, the reserve zone and the management zone (BC MOF 1995a; McCleary and Mowat 2002). A reserve zone is the inner zone of a RMA where no harvesting is permitted. The management zone is the outer zone of a RMA where selective harvesting is permitted.

The width of a RMA bordering streams ranges from 20 to 100 m (66 to 328 ft) and is dependent upon a stream's classification. All streams have a management zone where selective harvesting is allowed while the RMA bordering larger streams (S1-S3) has a reserve zone and a management zone. Large rivers (S1) require the largest RMA: 100 m (328 ft). Small, non-fish-bearing streams have the smallest RMAs: 30 m (98 ft) for S5 and 20 m (66 ft) for S6.

For lakes, RMA buffers range from 10 m (33 ft) for large lakes (L1) to 30 m (98 ft) for smaller lakes (L2, L3, and L4). A 10 m (32 ft) reserve zone is required on lakes classified as L1 and L2. However, for L1 lakes larger than 1,000 ha, a 10 m management zone (instead of a 10 m reserve zone) is required because very large lakes are considered to have relatively low sensitivity to NPS pollution that may result from forest management (Garman and Moring 1991).

6.4.3 *Manitoba*

In Manitoba, streams with continuous flow are classified as Class I if located in watersheds greater than 50 km^2 and Class II if located in watersheds less than 50 km^2 in area. The presence or absence of fish is also used to establish subclasses of streams. Lakes in Manitoba are classified as either productive (permanently filled with water, important fish habitat) or small lakes/ponds (may be permanently filled, but generally spring or runoff fed) (MB NR 1996). Forested buffer zones in the province of Manitoba are a minimum of 100 m (328 ft) wide from the normal HWM for all watercourse designations (Wedeles and Williams 1995).

6.4.4 *New Brunswick*

New Brunswick classifies streams based on drainage area. Watercourses draining more than 600 ha (1,483 ac) are considered large while small watersheds are those draining less than 600 ha (1,483 ac) (NB DNRE 1996).

Watercourse Buffer Zones (WBZs) is the term used when referring to riparian buffers in New Brunswick. The width of a WBZ is measured from the "area of the streambank with stable vegetation at least 2 m (6.6 ft) in height."

WBZ width is based on the size of the drainage area above the watercourse and slope. Generally, WBZ width is 30 m if drainage area is > 600 m, or 15 m if drainage area is < 600m. For bank slopes less than 24%, a 30 m (98 ft) WBZ is required. A WBZ of 60 m (197 ft) is required when bank slope exceeds 25%.

Additionally, natural watercourses less than 0.5 m in width are required to have a 3 m (9.8 ft) WBZ as long as "there is minimal bank disturbance during the harvesting" (NB DNRE 1996; MacLauchlan 1994). Streams designated as critical habitats (i.e., spawning grounds or rearing habitat) must have a WBZ of at least 60 m (197 ft) and when protecting waterfowl the WBZ must either be 60 m (197 ft) or 100 m (328 ft).

6.4.5 *Newfoundland and Labrador*

Newfoundland and Labrador refer to landscape features surrounding watercourses simply as riparian buffers. A riparian buffer at least 20 m (66 ft) in width is required along all watercourses found on 1:50,000 topographic maps and for waterbodies greater than 1 m (3.3 ft) wide that are not visible on these topographic maps (Goose et al. 1998; Scruton et al. 1997). The buffer width is measured outward from the HWM. Harvesting within a buffer is prohibited. Required buffer widths increase with bank slope. When the bank slope is greater than 30%, the buffer width must be 20 m + 1.5 x slope (%) (Scruton et al. 1997).

6.4.6 *Nova Scotia*

Riparian buffers in Nova Scotia are referred to as Special Management Zones (SMZs). An SMZ at least 20 m (66 ft) in width is required for all watercourses found on a 1:50,000 topographic maps and for streams greater than 50 cm (20 in) wide, all lakes and ponds, marshes with permanent water openings, and all saltwater bodies (NS NR 1997; Scruton et al. 1997).

For streams less than 50 cm wide, harvesting is permissible up to the streambank. However, equipment elimination zones of at least 5 m (16 ft) are required.

SMZ width must be increased when slopes exceed 20%. Managers are required to add 1 m (3.3 ft) to the SMZ width for every 2% increase in slope beyond 20%. The maximum SMZ width in Nova Scotia is 60 m (197 ft) (Duke 1997).

6.4.7 *Ontario*

Waterbodies in Ontario are defined as "…headwater lakes, lakes greater than 10 ha (25 ac) or that possess fisheries potential, and/or permanent and intermittent streams which provide habitat for fish" (ON MNR 1994). Riparian buffers in Ontario are referred to as Areas of Concern (AOCs).

Retaining AOCs along watercourses is based on the presence or absence of fish and fish habitat. If a stream does not support fish, harvesting is permissible up to the streambank. When fish are present in a watercourse, the width of an AOC is adjusted for slope and ranges from 30 to 90 m (98 to 295 ft) in width. Slope ranges are 0-15%, 16-30%, 31-45%, and 46-60% and require AOCs of 30 m (98 ft), 50 m (98 ft), 70 m (230 ft), and 90 m (295 ft), respectively (ON MNR 1994, 1995). In areas where windthrow is prevalent, the width of an AOC may also be increased.

6.4.8 *Prince Edward Island*

Prince Edward Island defines watercourses as "…all streams, estuaries, intermittent streams, and springs that have a definable sediment bed and banks that are connected to larger permanent streams, or have a 72 hour continuous flow between July 1 and October 31" (PE DAF undated). Riparian buffers are referred to as Forested Riparian Zones (FRZs). The width of FRZs depends on the bank slope adjacent to the watercourse. When bank slope is ≤ 9%, a 20 m (66 ft) FRZ is required. A 30 m (98 ft) FRZ is required when the bank slope exceeds 9% (PE DAF undated).

6.4.9 *Quebec*

Quebec has a broad definition of watercourses and requires a 20 m (66 ft) riparian management area (RMA) along all watercourses. RMA width increases to 60 m (197 ft) for fish-bearing watercourses. The width of an RMA is delineated beginning at the point where merchantable size timber is first present.

6.4.10 *Saskatchewan*

Watercourse classification in Saskatchewan is outlined in *Fish Habitat Protection Guidelines* and based on watershed drainage area (Sentar Consultants, Ltd. 1995). In some Forest Management Agreements (FMAs), watercourse classifications are further refined to include stream order (TFC/WS 2004). Class I or small streams are those with a drainage area <50 km^2 or a stream order of 3 or less. Class II streams have a stream order ≥4 (even with basin area less than 50 km^2). In some FMA documents, Class II streams are defined as rivers and streams that do not meet Class I criteria but are evident on 1:15,000 forest vegetation inventory maps and aerial photos (TFC/WS 2004).

In Saskatchewan, riparian buffers are commonly referred to as reservations. The width of a reservation is measured from the normal HWM and ranges from 15 to 90 m (49 to 295 ft). For Class I streams that have no commercial or game species, reservation widths are a minimum of 15 m (49 ft). Class I streams with commercial or game fish species present (at least seasonally) are required to have at least 30 m (98 ft) buffers. For Class II streams or lakes, the minimum reservation buffer is 30 m (98 ft). However, if a Class II stream or lake possesses fish populations suitable for angling or is capable of supporting a fish population introduced by stocking, the minimum buffer width is extended to 90 m (295 ft).

6.5 Managing Riparian Forests

There is substantial variation among provinces with respect to laws affecting management of riparian forests. Nevertheless, most provincial guidelines for riparian forest management allow some forms of harvesting and address similar topics including selective cutting, tree retention and shading, timing of harvest, restrictions on use of heavy equipment, and management of woody debris. Newfoundland and Labrador do not allow harvesting within riparian buffers (Decker 2003).

Most provinces recommend selective harvesting in portions of riparian buffers where harvesting is allowed. Selective harvesting guidelines are often expressed as limits on timber removal or in terms of characteristics of trees remaining after harvest.

In general, limits on timber removal are in the ranges of 30 to 50% of pre-harvest merchantable timber volume, stand basal area, or cover (Decker 2003). For example, Nova Scotia and Quebec limit removals of merchantable timber in SMZs to 40% and 30%, respectively (NS NR 1997; QC MRN 2002).

Timber removals in New Brunswick's WBZs are limited to 30% of the basal area during any 10-year period (NB DNRE 1996). In addition, New Brunswick recently established a Watershed Protected Area Designation Order to provide additional water quality protection (i.e., WBZs greater than 30 m) in 30 municipal watersheds (NB DELG undated). The Order creates three Protected Area classes or zones in these watersheds and permits selective harvesting in the setback zones between 30 to 75 m (98 to 246 ft) in southern New Brunswick and 15 to 75 m (49 to 246 ft) in northern New Brunswick. No more than 30% of the timber can be removed once every 5 years (Decker 2003).

Selective harvesting is permitted within FRZs on Prince Edward Island. Selective harvesting cannot remove more than 1/3 of the live trees from the FRZ in a 10-year period from two stem diameter classes, 10 to 30 cm (4 to 12 in) and >30 cm (4 to 12 in) measured 20 cm (8 in) above the tree base (PE DAF undated). The goal of having two differing size classes for harvest is to produce an uneven-aged stand that is structurally diverse and supports greater species diversity. Trees <10 cm (<4 in) in diameter must remain undisturbed in the FRZ during the harvest event. Harvested trees can be equally distributed throughout the FRZ or concentrated into selectively harvested patches not greater than 0.2 ha (0.5 ac) in size with 0.1 ha (0.25 ac) of uncut forested area between patches. The goal of concentrating harvesting into patches is to increase diversity of the terrestrial organisms in the FRZ by increasing the amount of edge habitat (PE DAF undated; Decker 2003).

Ontario allows harvesting of up to 50% of basal area in AOCs. Harvesting methods may include selective harvesting, patch cutting, or strip cutting (Archibald et al. 1997). Strip cutting, which is unique to the province, allows a strip of timber removal within the AOC so long as the cut is parallel to the watercourse and follows the contour of the land (ON MNR 1994, 1995).

Three provinces in eastern Canada have established shading requirements (Decker 2003). The maximum size of canopy openings allowed in both New Brunswick and Prince Edward Island is 10 m (33 ft). Nova Scotia allows a maximum opening of 15 m (49 ft).

Riparian management guidelines for Manitoba are currently under revision by Manitoba Conservation (formerly Manitoba Natural Resources). The Forest Practices Committee, created in 2000, is made up of representatives from Manitoba Conservation departments, Manitoba Water Stewardship, and the forest products industry. Currently, management of riparian buffers is allowed (MB NR 1996). "As long as the integrity of the sensitive area or natural feature is maintained a buffer may be actively managed. A variety of management prescriptions are available and can be applied. These prescriptions will take into account such factors as vegetation, slope, soil, wildlife and fisheries values, unique features, line of sight, recreational interests, location, and time of year" (MB MNR 1996). Where riparian buffer management is allowed, only selective harvesting systems can be used. Furthermore, mechanized equipment use and slash are not allowed within 15 m (50 ft) of the normal HWM. Harvesting in riparian buffers is also limited to sites that are well drained or to winter when soils are frozen (MB MNR 1996).

Riparian forest buffers in Saskatchewan range from 15 to 90 m (49 to 295 ft) in width and are dependent upon watercourse classification and fish presence. Exposure of soil within a riparian buffer is prohibited; therefore, harvesting times are restricted to well drained, dry sites or when the ground in the buffer is frozen (Decker 2003). New guidelines are currently under development and "some forest companies have identified alternative riparian management options, which reflect the likely direction of the new guidelines, and with Saskatchewan Environment approval have implemented these as operational practices" (TFC/WS 2004). Selective harvesting may therefore occur within Saskatchewan's riparian buffers if management prescriptions for riparian buffers are clearly defined in a Forest Management Agreement (FMA).

One recently submitted and approved FMA by Weyerhaeuser Canada outlines the company's plan for managing riparian buffers within the Prince Albert FMA Area (Weyerhaeuser FMA 2007). The FMA identifies guidelines that will be followed during forest management to achieve approved objectives and legal requirements. The Weyerhaeuser FMA stated that the company would implement the following management prescriptions: 1) a 10 m (33 ft) no harvest zone on large streams and lakes; 2) a 30 m (98 ft) limited harvest on large streams/lakes and small lakes with high slopes; and, 3) a 10 m (33 ft) machine free zone on small lakes with both high or low slopes. As noted in TCF/ WS (2004), "provincial staff identified the Weyerhaeuser Prince Albert riparian management and stream crossings guidelines (part of the Weyerhaeuser FMA Standards and Guidelines) as an example of the current direction for changes in [the provincial] standards."

The approach to riparian buffer management used in Alberta is similar to that used in Manitoba. For large permanent and small permanent watercourses, no disturbance or removal of merchantable timber is allowed within 60 m (197 ft) and 30 m (98 ft) of the HWM, respectively. However, management is permissible when an Annual Operating Plan (AOP) has been approved by Alberta Environment (AB EP 1994).

British Columbia has the most complex riparian guidelines of any Canadian Province (Decker 2003; TFC/WS 2004). The *Riparian Management Guidebook* sets out the prescriptions that are permissible in riparian management areas (RMAs). British Columbia divides a RMA into two zones: the reserve zone and management zone. The width of these two zones is variable and based on watercourse attributes. No harvesting is allowed in a reserve zone while harvesting in the management zone must abide by the basal area retention requirements. Within the management zone of all lakes and wetlands, 25% basal area retention is required. For large streams (S1, S2, or S3), at least 50% basal area retention is required. Retention of 25% of initial basal area is required on S4 and S5 streams. On small, non-fish-bearing streams (S6), 5% retention of timber is required (BC MOF 1995a). Equipment limitations have also been established in RMAs. Harvesting equipment is prohibited in the reserve zone and only limited use is allowed in a management zone. Attempts are also made to retain all non-merchantable conifers, understory deciduous trees, shrubs, and herbaceous vegetation within 10 m (33 ft) of stream reserve zones and 20 m (66 ft) of wetland and lake reserve zones (Decker 2003).

6.6 Forest Roads and Stream Crossings

All provinces have established guidelines and guidebooks that cover the design, installation, maintenance, and removal or retirement of forest roads and watercourse crossings (Tables 6.3 and 6.4). An overarching goal is to protect fish, their habitat, and ensure fish passage.

Provincial guidelines range from non-technical lists of objectives (e.g., reducing sedimentation and ensuring fish passage) to very extensive, detailed technical manuals. Recurring topics in road guidelines include planning (i.e., road layout and design), construction, drainage, maintenance, and retirement. Recurring objectives in watercourse crossing guidelines include correctly identify watercourse type, determine which structure is most appropriate, obtain necessary permits, schedule installation and removal dates, achieve technical specifications, and implement appropriate maintenance practices.

6.6.1 *Forest Roads*

Requirements for installing new roads generally vary based on the road type, extent of the road network, watercourse crossing locations, and other resource values. Provincial planning processes typically identify three types of forest roads: primary, secondary, and tertiary or temporary roads (MB MF 1996; BC MOF 2002b; NB NR 2004; MB NR 1996). Primary roads are considered permanent or main access roads that are accessible year-round or during all weather conditions. Secondary roads

are also all weather roads that are maintained for a period of years (e.g., <5 years) and provide access to and within a harvest area. Tertiary or temporary roads are often used seasonally. Winter roads are one example of this road type since they are designed for short-term use and only when the ground is frozen.

Table 6.3 Checklist of Provincial Information on Forest Roads, Road Drainage, and Water Diversion Techniques for Controlling Runoff and Stream Sedimentation

	Road Construction	Road Maintenance	Road Retirement	Road Drainage	Water Diversion Structures
Alberta	+	+	+	+	+
British Columbia	+	+	+	+	+
Manitoba	+	+	+	+	+
New Brunswick	+	+	+	+	+
Newfoundland & Labrador	+	+	+	+	+
Nova Scotia	+	+	+	+	+
Ontario	+	+	+	+	+
Prince Edward Island	+	+	+	+	+
Quebec	+	+	+	+	+
Saskatchewan	+	+	+	+	+

Table 6.4 Checklist of Provincial Requirements for Constructing Stream Crossing Structures

Province	Permit Required	Stream Crossing Structure[1]		
		Fords	Culverts	Bridges
Alberta	+	+	+	+
British Columbia	+	+	+	+
Manitoba	+	+	+	+
New Brunswick	+	+	+	+
Newfoundland & Labrador	+	+	+	+
Nova Scotia	+	+	+	+
Ontario	+	+	+	+
Prince Edward Island	+	+	+	+
Quebec	+	+	+	+
Saskatchewan	+	+	+	+

[1]It is important to note that provinces have recommendations for permanent and temporary bridges as well as multiple forms of instream culverts.

The permitting phase of the road planning processes varies among provinces and depends on factors that include the type of road being constructed and its location (private lands or Crown land). In British Columbia, the Ministry of Forests (MOF) has developed a detailed manual, the *Forest Road Engineering Guidebook*, as well as a package of road design and layout forms and administrative procedures (BC MOF 2002b). A MOF district manager approves all road construction under various permits. In general, approval for constructing or modifying roads is not required for 1) in-block roads (unless they cross high risk areas); 2) modifying watercourse crossings (unless replacement or new construction is required); and 3) emergency related work (BC MOF 2002b).

In Manitoba, the planning process for forest roads on Crown lands has three elements: Forest Management Plans (FMPs), Annual Operating Plans (AOPs), and Forestry Road Development Plans (MB C 2005). A FMP describes the general strategies used by a company for its harvest operations, which includes proposed roads. Guidelines for forest road FMPs are provided by Manitoba Conservation (MB NR 1996). Standard operating procedures related to forestry road development include detailed guidelines in the following areas: 1) centerline clearing methods; 2) right-of-way clearing methods; 3) debris disposal methods; 4) construction standards; 5) construction methods for water crossings; 6) erosion control measures; 7) visual buffer plans; 8) borrow pit rehabilitation plans; and 9) monitoring and maintenance activities. AOPs describe in much greater detail the types of forestry roads that will be created during harvesting operations during a planning year. Finally, a Forestry Road Development Plan provides additional information in the form of maps, tables, and text describing all existing and proposed roads within distinct geographic areas within a forest management license.

New Brunswick's Crown land licensees have the responsibility for planning, constructing, and maintaining a road network (NB NR 2004). Licensees are required to identify their road network (including planned roads) and outline the maintenance to be performed in their AOPs. Roads must be constructed in accordance with guidelines in the *Forest Management Manual* (NB NR 2004).

Road guidelines in most provinces address road location relative to watercourses. For example:

- British Columbia and New Brunswick require that roads not be constructed within riparian or streamside management zones (BC MOF 2002b; NB NR 2004).
- Manitoba recommends that all roads should be constructed at least 100 m (328 ft) from a permanent watercourse and 30 m (98 ft) from any intermittent watercourse or water source area (MB C 2005). In instances where this is not possible, a buffer zone of undisturbed vegetation can be used so long as its width is equal to the following equation: 10 m + 1.5 x the slope angle.
- Alberta guidelines for separating road construction from watercourses vary according to the watercourse type as follows: 1) large permanent: 60 m (197 ft) from HWM or water source area within the buffer; 2) small permanent: 30 m (98 ft) from HWM or water source area within the buffer; 3) intermittent: 30 m (98 ft) from HWM or water source area within the buffer; 4) ephemeral: construction not permitted within a watercourse or a water source area (AB Transportation 2001). Exceptions to these requirements are possible with approval of a Forest Officer or if alternatives are specified in an approved AOP.

Forest road guidelines emphasize the importance of controlling the extent and location of soil disturbance associated with forest roads, skid trails, landings (i.e., log decks), and timber harvesting. Common recommendations include avoiding unstable areas, following natural ridges and contours, avoiding excessive soil exposure, and reducing rutting. British Columbia recommends that soil disturbance be limited to no more than 10% of a harvest area and, on sensitive sites, must be 5% or less (TFC/WS 2004). Landings in British Columbia should be established at least 30 m (98 ft) from

fish-bearing streams. Alberta recommends controlling the area rutted during harvesting (<5%) and the amount of soil disturbed, compacted, or exposed (AB EP 1994).

Road guidelines also emphasize the importance of proper road drainage in efforts to control erosion and sediment delivery to streams. Effective drainage increases the stability of road prisms by preventing saturation and controls the volume and velocity of surface flows. Ditches, cross-drain culverts, and other water control structures should not discharge runoff and sediments directly into watercourses or onto unstable soils.

Road drainage requirements are most detailed in British Columbia under the Forest Practices Act Road Regulations. The *Forest Road Engineering Guidebook* recommends installing drainage control structures during construction that are sufficient "…to ensure flows are controlled and, where required, water quality is maintained should a peak flow event occur." Managers are also advised to 1) avoid wet or saturated soils; 2) construct stable cut and fill slopes; 3) avoid or limit in-stream work; 4) install sufficient water diversion structures to reduce ditch line erosion; 5) use aprons at the inlet/outlet of culverts; 6) use armoring, silt fences, or sediment traps in ditches to reduce erosion; and 7) re-vegetate exposed or disturbed soils as soon as possible (BC MOF 2002b).

Cross drain culverts are used to remove and disperse water from ditches along insloped roads. Guidelines for sizing of culverts vary among the provinces. For example:

- New Brunswick recommends a minimum culvert diameter of 300 mm (12 in) for artificial channels constructed for surface drainage (NB NR 2004). Determining adequate spacing of cross-drain culverts and other water diversion structures (e.g., take-off ditches) is done using the following equation: spacing = 500 m (1,640 ft) / road grade (%) (NB NR 2004).
- British Columbia recommends a minimum pipe diameter of 400 mm (16 in) for dry sites and 600 mm (24 in) for wet sites. British Columbia does not provide recommendations for spacing these water diversion structures since "with so many factors influencing placement of cross-drain culverts, it is not recommended that spacing tables be used unless the designer has experience and augments the tables with consideration of site-specific conditions (BC MOF 2002b)."

Another commonly cited water control practice is the use of diversion ditches or take-off ditches. These are channels or cutouts that divert high flows from a drainage ditch onto vegetated areas. These features are typically placed on the approaches to stream crossings on roads with steep grades.

Routine inspections of roads and stream crossings to determine maintenance needs are required by all provinces. Generally, requirements for inspections are specified in a FMP or AOP. Some inspection schedules are weather dependent (e.g., following major precipitation events) while others are fixed (e.g., annual).

Access restrictions can make important contributions to preventing road deterioration and controlling erosion, especially during wet weather and in areas subject to high levels of recreational use (TFC/WS 2004). Methods include installation of gates, earthen berms, and fences; and removal of watercourse crossings. Road retirement guidelines may include access restrictions as well as re-vegetation, removal of watercourse crossings, and installation of water control devices.

6.6.2 *Stream Crossings*

Provinces require permits for many kinds of stream crossings on both private and Crown lands (Table 6.4). For example:

- In New Brunswick, "all permanent or temporary watercourse crossing structures on Crown land require approval from the DNR [Department of Natural Resources] through the Operating Plan process." Furthermore, crossings on streams with drainage areas exceeding 600 ha (1483 ac) require a Watercourse and Wetland Alteration permit (NB NR 2004).
- In Manitoba, a Manitoba Environment Act License may be required for activities that may impact the environment. To acquire a license, managers must submit an application and additional documentation such as a project description, description of potential impacts water resources and fish, and mitigation measures to be implemented (FAO/MB NR 1996). All proposals are reviewed by Manitoba Environment and other federal and provincial departments.
- In British Columbia, stream crossing structures are regulated under the Forest Practices Code and guidelines are spelled out in the *Fish-Stream Crossing Guidebook* (BC MOF 2002a). This includes requirements and recommendations as to what type of stream crossing structure to use as well as what permitting/approval process is required.

Guidelines in all provinces emphasize the importance of planning to minimize impacts of stream crossings. Planning topics include the layout of the road approach to the watercourse; the type of crossing structure; and the location of the structure. Recurring guidelines include: minimizing the number of crossings needed; installing structures where the watercourse is straight and at its narrowest; and crossing watercourses at right angles at locations with stable banks and where approaches have minimal grade.

Another common requirement during the planning phase is to identify the location and extent of important fish habitat including areas used for spawning, feeding, rearing, or over-wintering. Manitoba recommends that all stream crossings be located at least 500 m upstream from such areas (FAO/MB NR 1996).

Scheduling the installation and removal of crossing structures is also a major BMP. These operations should be done according to weather conditions (i.e., when the ground is frozen, period of low stream flow, rainfall is minimal, etc.) and fish requirements.

Many provinces provide a detailed list of fish species and their spawning or migration periods and, as a result, recommend or require taking these events into account when planning any work within a watercourse. A detailed list of instream work windows is provided for managers in British Columbia's *Fish-Stream Crossing Guidebook*. The work windows are based on fish species and provincial fisheries zones and defined as "approximations for a particular species over an entire specified area and should be considered time periods of reduced risk only" (BC MOF 2002a). Quebec's guidelines for watercourse crossings also specify dates for activities based on provincial administrative region and fish species (Hotte and Quirion 2003). Manitoba's recommendations are more general with the guidebook providing information on fish spawning periods for some common species found in provincial streams (FAO/MB NR 1996).

Choosing the appropriate stream crossing structure is based on a multitude of physiographic factors including stream type, stream depth, and channel width. Economic considerations and periodicity of use, in accord with environmental requirements, also factor into the selection process. Many provinces provide flow diagrams or decision matrices to determine the best crossing structure to use based on numerous criteria (BC MOF 2002b; NB NR 2004).

Most provincial guidebooks express a preference for temporary or permanent bridges for crossing a watercourse. For example, the Manitoba stream crossing guidebook ranks its preference of stream crossing structures as follows: 1) bridges; 2) open-bottom arch culvert; 3) open-bottom box culvert; 4) horizontal ellipse culvert; 5) closed-bottom arch culvert; 6) closed bottom box culvert; and 7) round culverts (FAO/MB NR 1996).

Reasons cited by provinces for preferring bridges include minimal impacts on fish passage and aquatic habitat, small impacts on stream banks and channels, and the ability to handle high stream flows. General guidelines for bridge construction include proper design and placement of abutments so as to not impact flows, using riprap or wing-walls to armor the pier, limiting both channel and bank erosion, and stabilizing exposed soils on all approaches to the crossing (e.g., gravel, seeding, hay bales, etc.).

Guidelines for culverts vary somewhat among provinces. In British Columbia, open-bottomed culverts are the preferred crossing structure (BC MOF 2002a). Use of this structure type does not need approval from provincial or federal authorities if the structure does not disturb stream banks, channels, and/or fish habitat. Closed-bottom culverts (e.g., corrugated pipes) are generally not recommended for use in the province. However, exceptions are allowed in British Columbia for small, low gradient streams (<6%) with marginal fish habitat or non-fish-bearing streams (TFC/WS 2004). Alberta does not recommend the use of closed-bottom culverts when stream gradient exceeds 3.5% and fish passage is necessary (AB E 2001b). In Manitoba, open-bottom culverts are recommended when fish passage is a factor since these structures maintain the natural stream bottom.

Some provinces discourage use of multiple culverts (FAO/MB NR 1996; AB E 2001b; NB NR 2004). For example, Manitoba does not recommend using multiple culverts because "…they are more likely to become blocked than a single large culvert. However, if more than one culvert is required, establish a minimum of 2 m (6.6 ft) between adjacent culverts to provide adequate downstream resting areas for fish" (FAO/MB NR 1996). When using two culverts, New Brunswick recommends that one culvert be set 15 cm (6 in) below the existing stream channel, while the invert of the other culvert is set at an elevation equal to the streambed (NB NR 2004). Spacing between culverts should be one-half the diameter of the culverts or 1 m (3.3 ft), whichever is greater.

Considerations when using closed-bottom culverts include placement, embedment, and velocity of the water passing through the culvert. In general, culverts should be aligned along the stream gradient in a manner that prevents ponding of water up-stream and excessive drop downstream.

It is often recommended that closed or round culverts be embedded. Recommendations for embedment, however, vary by province. British Columbia recommends that culverts be embedded at least 40% of the culvert diameter or 0.6 m (2 ft), whichever is greater (BC MOF 2002a). British Columbia also requires that a round culvert be sized to pass 100-year peak flows after embedment.

Alberta has two guidelines regarding round culvert embeddedness (AB E 2001b). First, for streams with <0.5% grade, embed the culvert at least 10% of diameter below the streambed elevation if normal water depths are <50 cm (<20 in), or place the culvert at the water body bed elevation if normal water depth is >50 cm (>20 in). Second, for streams with gradients between 0.5 to 3.5%, the diameter of the culvert should be at least 1.25x the channel width and the downstream invert should be embedded at least 20% below the elevation of the streambed. Manitoba recommends placing culvert bottoms a minimum of 30 cm (12 in) or 10% of the culvert diameter, whichever is greater, below the normal streambed (FAO/MB NR 1996).

Since water flow velocity through a culvert is a function of a culvert's length, a common provincial recommendation is to minimize culvert length to aid in fish passage. With regard to maintaining specific velocities, Manitoba recommends that the average cross-sectional velocity should not exceed 0.8 m/sec (2.6 ft/sec) for culverts longer than 25 m (82 ft) and 1.0 m/sec (3.3 ft/sec) for culverts less than 25 m (82 ft) (FAO/MB NR 1996). To reduce culvert velocity, provincial guidebooks include various suggestions such as installing baffles, placing boulders in the culvert, or using a tailwater control device (FAO/MB NR 1996; AB E 2001b; BC MOF 2002a).

While fords are the simplest of the stream crossing structures available for use in forest management, this method of crossings streams is generally discouraged in Canada. For example, in British Columbia, fords are discouraged on fish-bearing streams, and when being considered for use, managers should consult the appropriate fisheries agency (BC MOF 2002a). In New Brunswick fording is not considered "…a routine means of crossing watercourses," and as a result, can only be used when approved in the Operating Plan (NB NR 2004).

New Brunswick, Manitoba and Alberta have guidelines regarding use of fords (FAO/MB NR 1996; AB E 2001b; NB NR 2004). These recommendations include: constructing and using fords during dry periods; choosing sites with low, stable stream banks (e.g., <2 m in height), firm streambeds, and low water depths (e.g., <100 cm); limiting the width of the crossing (e.g., <10 m); and eliminating use during fish spawning and migration periods (FAO/MB NR 1996; AB E 2001b; NB NR 2004).

6.7 Pesticides and Fertilizers

The Pest Control Products Act is the overarching federal legislation that governs registration, labeling, and classification of herbicides and other pesticides in Canada. The registration process allows for the sale of pesticides that meet criteria for effectiveness and safety. Labeling defines proper use and handling procedures for each pesticide product. Classification determines potential uses: restricted, commercial, or domestic. Restricted pesticides uses are subject to interdisciplinary review and permit requirements under provincial legislation. Pesticides registered for use in wooded areas are in several categories (PMRC 1993).

- *Forest Management – Restricted.* Covers aerial or ground-based applications of pesticides to more than 500 ha (1,236 ac) of a wooded area or a site to be planted.
- *Woodland Management – Restricted.* Covers aerial applications of pesticides to no more than 500 ha (1,236 ac) of a wooded area or a site to be planted.
- *Woodland Management – Commercial*. Covers ground-based applications of pesticides to no more than 500 ha (1,236 ac) of a woodland sites or treed areas (of the kind ordinarily expected in municipal parks). Also covers aerial and ground-based applications along rights-of-way in woodlands and forests.

Administration of the Pest Control Products Act and related provincial laws is a joint responsibility of Health Canada's Pest Management Regulatory Agency and provincial authorities. Several provincial governments have developed supplemental guidelines for forestry applications (Table 6.5). Regulations governing pesticide use can differ between private and Crown lands. Requirements may include regulatory agency notification in AOPs, SOPs, or FMPs and obtaining appropriate permits. To help managers comply with federal and provincial regulations, several provinces have published herbicide manuals or guidebooks (BC MOF 2002c; AB SRB 2004; NB NR 2004; WNLMF 1999; NS NR 2007; OM NR 2004; PE EEF 2007).

Table 6.5 Checklist of Topics Addressed in Provincial Guidelines for Forest Pesticide Applications

	Permit or Notification Required	Application Timelines Provided	Aerial Application Guidelines	Ground Application Guidelines	Establish Chemical Buffer or No Treatment Zones	Disposal and Cleanup Guidance
Alberta	+	+	+	+	+	+
British Columbia	+	+	+	+	+	+
Manitoba				+	+	
New Brunswick	+	+	+		+	
Newfoundland & Labrador	+		+	+	+	+
Ontario	+	+	+	+	+	+

While requirements vary considerably among provinces, an overarching goal is to limit the movement of pesticides into watercourses. To accomplish this goal, provinces generally recommend establishing set-backs or buffers along watercourses.

- Manitoba recommends that managers leave at least 8 m (26 ft) buffers along surface waters when chemicals are applied by ground methods (MB MF 2005).
- In Newfoundland, managers are encouraged to create buffers of at least 44 m (144 ft) around all sensitive areas (WNLMF 1999). Buffers zones must be established to protect water quality during chemical applications. Buffer widths for herbicide applications (at least 44 m) are smaller than for insecticide applications (400 m from freshwater).
- Nova Scotia requires a 60 m (197 ft) buffer around potable waters and a 30 m (98 ft) buffer for other watercourses (NS NR 2007).
- Alberta regulates "…the use, application, storage, or washing of equipment within 30 horizontal meters (98 ft) of an 'open body of water'…" and must be in accordance with the Environmental Code of Practice for Pesticides (AB E 2001a).
- On New Brunswick's Crown lands, herbicide setbacks of 65 m (213 ft) are required around all watercourses (NB NR 2004). New Brunswick also requires that "no application [of herbicide] is conducted within 3 km (1.86 mi) upstream from the extraction point of a designated watershed."
- In British Columbia, a 10 m (33 ft) pesticide-free zone, except for biological pesticides, must be maintained around all watercourses located in designated community watersheds. Furthermore, a pesticide free zone must also be maintained within 100 m (328 ft) upslope of community water intake structures (BC MOF 1996).

In addition to maintaining adequate buffer widths during herbicide applications, provinces also provide information on notification requirements, recommendations for the timing of herbicide application, and appropriate application methods. Notification requirements may vary with factors such as proximity to dwellings and public areas, proximity to drinking water supplies, application method, extent of the treatment area, and chemicals being applied. Recommended application dates or application windows may be established to ensure efficacy of pesticide treatments while reducing potential to impact water quality (BC MOF 2002c; NS NR 2007; NB NR 2004).

Fertilizers receive less attention than pesticides in most provincial guidelines. British Columbia, however, has published *Forest Fertilization* and *Silvicultural Prescription Guidebooks* (BCMOF 1995b, BC MOF 2000).

British Columbia requires that broadcast fertilization does not occur within 100 m (328 ft) upslope of a community water intake or within 10 m (33 ft) of a perennial stream that is visible from the air (BCMOF 1995b). A 10 m (33 ft) no fertilizer application zone is also required for designated fisheries lakes and streams (S1 to S4 stream types) as well as streams that flow into designated fisheries streams (S5 and S6 stream types). Buffer strips, 10 m (33 ft) in width, are also required on waterbodies found on private forestlands. Applications of nitrogen fertilizers also may not cause nitrate levels in a watercourse to exceed 10ppm (measured immediately after application downstream) and chlorophyll may not exceed 2µg/L in lakes and 5mg/m^2 in a stream.It is noteworthy that application of fertilizers can be required in British Columbia when "a person who is required to establish a free growing stand on an area under a silviculture prescription must carry out a fertilization treatment on the area before the end of the free growing assessment period, if the district manager is of the opinion that the treatment is necessary to achieve a healthy free growing stand

within the free growing assessment period specified in the prescription" (BC MOF 1995b). The recommended range of applications rates in BC is 200 to 225 kg N/ha for coastal forests and 175 to 200 kg N/ha for interior forests (BC MOF 1995b). Significant increases in applications rates must be approved by the forest district manager. In general, it is not recommended that fertilizers be applied during the spring and summer months (April 1-September 15). Instead, fall fertilization projects are recommended.

6.8 Harvesting

Provinces regulate timber harvesting through several mechanisms including restrictions on harvest rates at the provincial and watershed levels. Restrictions at the provincial level are designed to promote sustainable wood flows over the long term and to achieve other objectives. Restrictions at the watershed scale are intended to minimize impacts of harvesting on water yield and water quality but their effectiveness has generally not been established (TFC/WS 2004).

In addition to harvest limits, provinces have established guidelines for the size of harvest units as well as the silvicultural methods employed.

- New Brunswick limits clearcut blocks to 25 ha (62 ac) or less and requires a 100 m (328 ft) wide buffer strip between blocks (NB DELG undated).
- Ontario recommends that clearcut block sizes be less than 260 ha (643 ac) and that treatment boundaries follow natural contours to limit the potential for erosion (ON MNR 1995).
- In Quebec, the maximum clearcut size varies by region with maximum sizes in the south, central, and northern regions of 50, 100, and 150 ha, respectively (QC MRN 2002). Within a clearcut harvest block, managers must preserve stands with tree heights less than 7 m (23 ft) for a minimum of 30% of the cut block. Another management technique employed in Quebec is pre-commercial thinning of 33% of the forestland prior to harvest.
- In Alberta, a two-phase silvicultural system is used in which the initial harvest is limited to 50% or less of the watershed area and a second harvest is allowed in 20 years, or when tree regeneration reaches a specified height (TFC/WS 2004).

In addition to constraints on the size and location of timber harvest blocks, provincial guidelines recommend limiting the extent of exposed soil in harvested areas. All provinces specify minimum distances that landings, forest roads, and skid trails must be from watercourses to reduce the potential of erosion and sediment transport to streams. Locations of roads, landings and skid trials should be planned prior to harvest to limit soil exposure and compaction. Landings and log decks should be established on high and dry soils and have erosion control techniques in place when necessary. Areas with high potential for landslides should be avoided.

Stabilizing forest roads during harvest operations is another important aspect of guidelines for controlling NPS pollution. Road stabilization techniques include limiting access during wet periods, using water diversion techniques (e.g., water bars, cross-drain culverts, broad-base dips), placing gravel on road surfaces, and seeding. Roads should be designed so that water flowing from road surfaces, ditches or drainage structures is dispersed onto vegetated areas away from watercourses.

Provincial harvest guidelines suggest that potential impacts on soils and water quality can be reduced by 1) harvesting during dry weather conditions or when the ground is frozen, and 2) avoiding wet areas and restricting operations during wet weather conditions when utilizing ground based harvesting systems.

6.9 Waste Disposal

All provinces have recommendations regarding the proper handling and disposal of fuel, chemicals, and wastes. For example, Alberta requires that all waste management be carried out in accordance with the province's EPEA Waste Control Regulation. Generally, waste disposal guidelines cover topics such as minimizing threats to human health, watercourses, ground water, and aquatic biota. Recommend practices include locating storage sites away from waterbodies, conducting routine maintenance and washing of equipment away from waterbodies, limiting the amounts of fuel and solvents on site, having spill containment systems on storage tanks, having emergency spill kits on site, and preparing response plans for spills and other emergencies (MB MF 1996; WNLNF 1999; AB SRD 2004; NB NR 2004).

6.10 Provincial Compliance Monitoring Protocols and Reporting

Field audits of forest management activities on public lands may take many different forms including inspections by regulatory agencies, self inspections, and third party audits (TFC/WS 2004). The latter are generally associated with voluntary forest certification programs. Audits are generally focused on evaluating field performance relative to legal standards and requirements of site-specific plans such as FMPs and AOPs.

This section provides a summary of provincial efforts to evaluate rates of compliance with forestry guidelines for NPS pollution control.

6.10.1 *Alberta*

Alberta Sustainable Resource Development (AB SRD) is responsible for the management of Crown lands within the province under the Forest Act and Public Lands Act. Within AB SRD, the Public Lands and Forests Division monitors compliance of licensees with the two Acts and their associated regulations. Compliance is assessed through scheduled or random site audits and field checks of self-reporting licensees. Compliance audits cover topics ranging from aesthetics to harvesting operations, road related activities, and watercourse crossings (AB EP 1999). Violations are referred to as contraventions. When violations are identified, "the operator will be given the opportunity to voluntarily rectify the contravention" (AB SRD 2007). The Public Lands and Forests Division has authority to levy penalties and must disclose violations to the public. Summary tables of violations are updated weekly and can be found on the AB SRD website. The 2007 list of violations does not specifically reference any water quality related violations (AB SRD 2007). Instead, violations are reported under broad reaching categories such as unauthorized use of public land or unauthorized timber harvest.

6.10.2 *British Columbia*

The Forest Practices Board (FPB) conducts monitoring of government licensees for compliance with the Forest and Range Practices Act (FRPA) and the Wildfire Act. Compliance audits focus on forest planning and on management practices (BC FPB 2007. Audits are conducted annually at sites selected at random using criteria and procedures established in the Compliance Audit Reference Manual (BC FPB 2003).

Outcomes of field audits include compliance, not significant non-compliance, significant non-compliance, and significant breach (BC FPB 2003). A significant breach designation requires the auditor to "…conduct tests to confirm whether or not there has been a breach. If it is determined that a significant breach has occurred, the auditor is required by the FPB Regulation to immediately advise the Board, the party being audited, and the Ministers of Forests and Range" (BC FPB 2003).

Results of field audits are reported to the FPB with a copy to the licensee. A licensee or person that may be adversely impacted by the report is provided with an opportunity to provide comments to the board. Once the representation process has concluded, the report is finalized and released to the licensee, federal and provincial governments, and then to the public.

Following are examples of results from audits conducted in 2006 and 2007.

- FPB conducted an audit of license holders in the Fort St. Johns Code pilot project area (BC FPB/ARC/87). The audit assessed the holders of 19 timber sale licenses in the following areas: operational planning, 350 km (218 mi) of roads, three bridges, 32 well-growing blocks, and 25 harvest cutblocks. The FPB auditors certified that both the British Columbia Timber Sale program and its licensees had complied in all significant respects with all major legislative requirements of the FRPA (BC FPB/ARC/87).

- FPB audited five licensees in the Sunshine Coast Forest District (BC FPB/ARC/88). The audit focused on the following forest management areas: timber harvesting; road construction, maintenance and deactivation; and bridge construction and maintenance. Overall, the forest management activities monitored in this forest district "…complied in all significant respects with the requirements of the Forest Practices Code of British Columbia Act (BC FPB/ARC/88)."

- The FPB audited one license holder with harvest rights in the North Coast Forest District, specifically forest tracts north and south of Prince Rupert (BC FPB/ARC/89). The FPB audit team assessed the planning, activities, and obligations of the licensee in the following areas: operational planning, 30 harvest cutblocks, more than 80 km (50 mi) of forest roads, 14 bridges, 33 cutblocks with silvicultural obligations, and fire preparedness. The FPB auditors concluded that the licensees complied in all significant respects with requirements of the Code, FRPA, Wildfire Act, and related regulations (BC FPB/ARC/89).

- The FPB has conducted several compliance audits of forest agreements and licenses in and around the Nass Valley (BC PFB/ARC/90). An audit completed in early 2007 examined operational planning, harvesting activities, silviculture activities, road construction, maintenance, and decommissioning. It was determined that the Kalum Forest District manager and all but one licensee complied in all significant respects with the applicable silviculture, road maintenance, bridge maintenance and road deactivation requirements of the Code. One licensee was found to be in significant non-compliance with obligations related to harvest, silviculture, bridge inspection, road maintenance or road deactivation (FPB/ACR/90).

6.10.3 *Manitoba*

Manitoba Conservation Natural Resource Officers (NROs) "…monitor all harvest activities to ensure they are in accordance with the approved AOP [Annual Operating Plan] and are in keeping with the requirements of various acts, regulations, policies and operating guidelines" (MB NR 1996).

6.10.4 *New Brunswick*

The Crown Lands and Forest Act requires the Department of Natural Resources and Energy (DNRE) to evaluate the forest management performance of each of its Crown Timber Licenses at five-year intervals. Information collected from these site evaluations is used to assess whether or not to extend a FMA.

Results have been reported for audits conducted by DNRE staff from 1997 to 2002 (NB DNRE 2006). The audits covered all 10 of the licenses in the province. These licenses are managed by six forest products companies. Performance was assessed in two areas: implementation of the 1997 management plan (1997-2002 activities) and preparation of the 2002 management plan.

Evaluations of activities conducted under 1997 management plans addressed the following topics: 1) basic silviculture; 2) remedial treatment of basic silviculture treatments; 3) timber harvesting (including watercourse buffers); 4) fish habitat protection (including watercourse crossings); and 5) wildlife habitat management (NB DNRE 2006). Performance of licenses was found to be satisfactory or better with respect to maintaining appropriate stream buffer zones, restricting machine operations near streams, and proper installation of water crossings.

6.10.5 *Newfoundland and Labrador*

The Department of Natural Resources Forest Services division oversees forest use and management of public lands in two areas: 1) forest resource utilization, protection, conservation and management; and 2) enforcement of provincial acts and regulations. Enforcement actions are documented in an Annual Performance Report. Enforcement actions include Written Warnings, Summary Offence Tickets, and Court Information under the Wildlife Act, Forestry Act, Federal Fisheries Act (inland), All-Terrain Vehicle Regulations, and the Migratory Bird Conservation Act. The total number of enforcement actions was 1406 in 2004-2005 (NL DNR 2005).

6.10.6 *Nova Scotia*

The Nova Scotia Department of Natural Resources reported on the results of a field audit of soil disturbance and permanent watercourse crossing structures in 2004. The project evaluated impacts of harvesting on water quality and the effectiveness of riparian buffer zones on first and second order streams as well as lake catchments (NS DNR 2004). Project participants included Nova Forest Alliance Model Forest, Nova Scotia Department of Natural Resources, Environment Canada, Halifax Regional Water Commission, Bowater Mersey Ltd., Elmsdale Lumber Company, University of New Brunswick, Nova Scotia Department of Environment, and Natural Resources Canada.

Eight watersheds were evaluated: three treatment watersheds and one control in each of two groups referred to as Pockwock and Bowater. Treatment watersheds were 59.7 to 174.4 ha (148 to 431 ac) in size with total road surface, as a percentage of watershed area, in the range of 0.4 to 1.5%. Project activities included an assessment of soil disturbance, inspections of permanent structures (e.g., watercourse crossings, roads and landings), and measurements of water quality.

Estimates of soil disturbance due to machine traffic were in the range of 18.8% to 39.4% on harvested areas. Intact forest floor and light slash was the dominant surface condition observed, covering about 62% of harvested areas. Impacts were considered light as a result of low soil hazard ratings for five of the six watersheds (NS DNR 2004).

The report does not indicate any water quality problems resulting from the installation and use of permanent structures. “From a review of the water chemistry collected throughout the project the construction of the roads had no effect on the water chemistry in the respective streams. Some areas

had temporary bridges in place during the harvesting process. Again, there was no change in the water chemistry of the streams" (PB WPP 2005).

6.10.7 *Ontario*

Forest license holders in Ontario must assess their own compliance with forest management guidelines. Licensees must report all incidents of non-compliance to the Ontario Ministry of Natural Resources (MNR).

The MNR may conduct random compliance assessments as well as planned audits. The MNR may overrule industry reports of compliance and has responsibility for determining mitigation measures when moderate or significant incidences of non-compliance are reported. When incidences of non-compliance are deemed to be minor, license holders may remedy the problem. In some circumstances, licensees may report incidents as "In Compliance with Comments." This category recognizes "…that a minor situation is present, with small variances due to operating conditions and/or operational practices. However, the situation is recognized as generally correctable, with some room for improvement in operational practices" (ON MNR 2005).

Inspection reports prepared by MNR and licensees are submitted to a provincial web-based database system called Forest Operations Information Program. When non-compliance or significant non-compliance is observed, companies must notify the MNR within five working days (non-compliance) or within 24 hours (significant non-compliance) (ON MNR 2007). The MNR must notify the licensee within the same time periods when it observes violations. MNR also must "… make available to the public, via this web site, management unit annual reports of forest operations inspections prepared in accordance with the Forest Management Planning Manual" (ON MNR 2007).

Each compliance assessment must cover four kinds of operations: access, harvest, renewal, and maintenance (ON MNR 2005). Within each of these categories, many activities are assessed. Topics addressed in access assessments include road construction, water crossings, Areas of Concern (AOCs) (i.e., streamside management zones), and fire prevention. Harvest assessments cover activities related to AOCs, cutting, utilization, wood measurement/movement, and fire prevention. Renewal assessments cover post-harvest activities related to forest regeneration such as pesticide application and fire prevention. Maintenance assessments cover stand tending activities as well as pesticides and fire prevention. Each activity must be assessed as in compliance, not in compliance, or in compliance with comments.

MNR provincial survey data for the 2003-2004 fiscal years show that license holders reported 325 instances of non-compliance while MNR reported 412 instances (ON MNR 2007). Of the instances reported by MNR, 336 were classified as minor, 66 as moderate, and 10 as significant. Of the 10 significant instances, three were related to access operations, six were related to harvest operations, and one was related to forest renewal operations (ON MNR 2007).

6.10.8 *Quebec*

In 2001, the Forest Act (section 35.6) granted authority to the Minister of Natural Resources, Wildlife and Parks (MRNFP) to establish forest resource protection and development objectives for each provincial forest management unit. The MRNFP evaluates performance on five year intervals of holders of Forest Management Agreements (FMAs) and Timber Supply and Forest Management Agreements.

To comply with the directives of Quebec's Forest System, managers must adhere to goals defined in the 1996 Forest Act, including preservation of biological diversity, maintenance and improvement of forest ecosystem condition and productivity, conservation of soil and water resources, and maintaining forest ecosystem function as a component of global ecological cycles (QC MRNFP

2003a, 2003b). Objectives related to soil and water resources address three topics: rutting; loss of productive forest areas; and protection of aquatic habitats from severe erosion and sedimentation (QC MRNFP 2003a). Performance indicators are being developed for each objective to, "…measure whether or not agreement and contract holders have achieved that objective at the end of the planning exercise…" The indicators will be submitted for public consultation before the next general forest management plans are submitted in 2010.

The MRNFP's rutting indicator is assessed after regeneration cutting. It does not apply to partial harvests because "…very little rutting has been detected on these sites in the past, and second because the measurement method itself is unsuitable" (QCMRNFP 2003a). Rutting of harvested sites is classified as severe, moderate or, minimal. Rutting is considered severe when it has occurred "…on more than 20% of the total length of felling and hauling trails." Sites with "little or no disturbance" have rutting on <20% of the total length of felling and hauling trails. Sites are considered to have moderate disturbance when rutting is found to be significant on the site but cannot be classified into one of the two previous categories (QC MRNFP 2003a). The goal of the MRNFP is for over 90% of harvest sites in a given year to have little or no disturbance and no harvest sites in the severe disturbance category.

The MRNFP indicator for avoiding loss of productive forests is based on the formula (A–B)/A where A equals the total area logged and B equals the total area converted to forest roads or disturbed along roadsides. MRNFP suggests that given variation in conditions within the province, "…it is not possible to set a single, standard threshold for the province as a whole" (QC MRNFP 2003a). Therefore, in the near term, the MRNFP will define target levels of improvement for individual forest management units.

The MRNFP indicator for avoiding impacts on aquatic habitat is based on evaluation of 87 parameters including culvert sizing, watercourse buffer strips, and diversion of runoff from roadside ditches. Some parameters are given more weight than others when calculating an overall indicator score. Results are also weighted by size of harvest units when calculating indicator scores at scales larger than a single site (QC MRNFP 2003b).

Site-level evaluations of overall compliance are based on twelve indicators including indicators related to soil and water quality protection (QC MRNFP 2003b). Failure to achieve a passing score of 75% can affect future allowable harvest volumes for agreement holders or lead to imposition of a remedial program.

6.10.9 *Saskatchewan*

The Forest Resources Management Act (FRMA) and accompanying regulations establish a framework for the provincial government and forestland managers to plan, monitor, and report aspects of their sustainable forest management practices (SK E undated). FRMA amendments adopted in 2002 define requirements for monitoring of harvest activities, assessing compliance with guidelines, and reporting. Each holder of a Forest Management Agreement must have an independent audit of its forestry operations every five years. Field audits are funded by the company and the results are made public. A Saskatchewan Environment (SE) Officer can routinely conduct inspections on a licensee's forest operations. In some instances, a licensee can conduct self-audits and report findings to the SE Officer. Self-audits are currently being conducted by only a few licensees on a trial basis. Saskatchewan Environment is in the process of developing a Compliance Manual in accordance with FRMA (SK E undated).

Insufficient compliance can lead to written warnings, administrative penalties, stop work orders, and enforcement actions. Written warnings indicate that an operation is "…not in compliance with a plan [FMP or AOP] or condition of harvest, but an officer wants to work with the violator to meet the conditions set out in the plan and ensure proper forest management goals are met" (SK E undated). Warnings come in two forms, "poor" or a Notice of Violation. A Notice of Violation notes the section of the FRMA that was violated and how the incident(s) will be mitigated. Administrative penalties of up to $10,000(CDN) can be assessed when non-compliance occurs. Stop work orders are issued by environmental officers to stop unlawful harvesting or to "…stop activities that have damaged or are likely to damage Crown resource land or forest products on Crown land" (SK E undated). Stop Work Orders also include requirements as to which actions must be taken to repair or prevent additional impacts.

Enforcement activities conducted during the 2002-2003 fiscal year have been summarized (SK E undated). The report does not include details about non-compliant activities (e.g., whether non-compliant practices were related to roads, crossings, etc.). The report covers 789 audits including 57 self inspections. A total of 235 violations were noted in the following areas: FRMA and Regulations (216); The Litter Control Act (14); The Environmental Management and Protection Act (3); The Prairie and Forest Fire Act (1); and Occupational Health and Safety (1). There were also 11 administrative penalties for over harvesting, failure to pay dues or fees, and breach of license. There were also 11 charges filed which resulted in nine convictions. A total of $14,500(CDN) was collected in administrative penalties and fines.

6.11 Summary

All provinces have developed forestry regulations and guidelines that address multiple objectives including protection of water resources. Key topics in forestry guidelines related to NPS pollution control are generally similar across Canada and include streamside management zones, roads and skid trails, stream crossings, forest chemicals, timber harvesting, and waste disposal. At the same time, there are many differences among provinces in important aspects of forestry NPS guidelines such as levels of detail and complexity, specific prescriptions, and compliance assessment protocols.

All provinces require forested buffers along all watercourses and restrict the management of these forest stands in varying degrees. Newfoundland and Labrador do not allow management within their watercourse buffers. Management guidelines in other provinces are generally based on some form of selective harvesting and typically include recommendations regarding tree retention, watercourse shading, coarse woody debris recruitment, timing of harvesting, and restrictions on operation of machinery.

Guidelines generally emphasize the importance of planning and engineering in efforts to control water and sediment movement from roads, skid trails, and landings. Recurring themes include the benefits of effective road drainage; controlling the extent and location of roads, trails and landings; and controlling the timing of road construction and harvesting operations relative to seasonal variation in weather and soil conditions.

Provinces generally require permits for installation of watercourse crossings, but details of requirements vary substantially. Common guidelines include limiting the number of crossings; installing structures where the watercourse is straight and narrow; crossing watercourses at right angles; and minimizing the approach grade to the crossing. Several provinces have guidelines that restrict installation, maintenance and removal of crossing structuring relative to spatial and temporal variation in fish habitat. For example, some guidelines identify seasonal operations windows when work on crossings can be conducted without interfering with fish spawning or migrations.

Use of herbicides and other pesticides is regulated under the federal Pest Control Products Act and various provincial laws. Additional restrictions on pesticide use in forestry guidelines to protect water resources vary somewhat among provinces but generally emphasize the importance of riparian buffers. British Columbia is the only province that provides detailed guidelines regarding use of fertilizers.

All provinces have mechanisms to assess compliance of forestry operations with legal requirements and management guidelines. These mechanisms vary greatly among jurisdictions. In general, compliance assessments cover many aspects of forestry operations and are not designed specifically to measure implementation of guidelines related to protection of water resources. In many cases, compliance monitoring is an integral part of an enforcement program design to identify and correct violations of legal requirements. Monitoring results are often expressed in terms of overall compliance with requirements of management plans for specific areas; or in terms of total numbers of violations in broad categories for an entire province.

In summary, all provinces have adopted forestry BMPs for water quality protection. These guidelines are based on scientific principles and reflect differences among provinces in climate, terrain, and socio-economic factors. Implementation is an integral part of compliance with a much broader set of management guidelines and standards.

7.0 SYNTHESIS

This report documents differences and similarities in forestry BMPs among jurisdictions. The differences are attributable to variability among states and provinces in legal, political, and socioeconomic factors as well as climate, soils, topography, and aquatic biota (Ice et al. 2004; Aust and Blinn 2004; NCASI 2007a, 2007b). Similarities are attributable to the fact that forestry BMPs are based on a substantial body of research that has 1) identified the most important sources of NPS pollution in managed forests and 2) demonstrated the effectiveness of control and mitigation measures that are embodied in BMPs (e.g., Aust and Blinn 2004; Ice et al. 2004; Ice and Stednick 2004; Kochenderfer 1995; Kochenderfer and Aubertin 1975; Kochenderfer and Helvey 1989; Kochenderfer, Wendel, and Smith 1984; Lynch, Corbett, and Mussallem 1985; Shepard et al. 2004; NCASI 2007b; Yoho 1980).

Several overarching themes are apparent in forestry NPS programs in all jurisdictions: 1) minimizing soil compaction and the extent of bare soils; 2) separating exposed soils from surface waters; 3) separating fertilizer and herbicide applications from surface waters; 4) inhibiting hydraulic connections between bare ground and surface waters; 5) providing forested buffers around watercourses; and 6) designing stable roads and watercourse crossings (Olszewski and Jackson 2006).

These common themes are reflected in forestry BMPs for water quality protection across North America. For example, BMPs in all jurisdictions include special management restrictions in buffer zones adjacent to streams. However, there is substantial variation among jurisdictions in streamside buffer widths, criteria for establishing those widths, and management restrictions within buffers. As with overall nonpoint source (NPS) program design, variability in riparian buffer BMPs is attributable to efforts by states and provinces to apply general principles to their own circumstances.

Monitoring BMP implementation or compliance is an aspect of forestry NPS control programs that varies greatly among jurisdictions (Phillips and Blinn 2007). Some differences include how often surveys are conducted; how sample sizes are determined (e.g., number of audit sites); which BMP categories or criteria are evaluated; and how implementation is scored and reported. Among jurisdictions that regulate forestry practices, some have decided to rely on their regulatory mechanisms to ensure BMP implementation (e.g., Massachusetts and Manitoba) while others have

invested substantial resources in separate BMP implementation studies (e.g., California). Among states with non-regulatory BMPs, some have elected to invest in BMP monitoring studies (e.g., Texas) while others have not (e.g., Arizona). Variability in BMP monitoring methods makes it difficult to assess BMP implementation rates at geographic scales larger than single states or provinces (Ice and Schilling 2007). Regional monitoring protocols have been developed in the U.S. Northeast and Southeast in an attempt to encourage greater consistency in BMP monitoring among states in those regions.

Proponents of BMP implementation monitoring note that jurisdictions that have conducted multiple surveys have reported increasing BMP compliance (Stuart 1996). For example, the Florida Division of Forestry conducted its first BMP compliance survey in 1981 and found statewide compliance at almost 93% while, in 2005, overall statewide compliance was found to be 99% (Vowell and Lima 2006). Similar results have been reported for Montana which conducted its first compliance survey in 1990. At that time, application of practices that meet or exceed BMP requirements was found to be 78% (Rogers 2007). In 2006, compliance was 96%.

Monitoring BMP implementation can also be useful in identifying problem areas and driving continuous improvement in NPS control programs. Monitoring results from several jurisdictions indicate higher rates of BMP implementation on public and industrial forestlands than on non-industrial private forests. In Washington, compliance was relatively low for forest practices rules that were "…vague and lack implementation guidance" (Lingley and Tausch 2007). To correct this deficiency the authors recommended clarifying the language of some rules while also increasing training and educational opportunities in specific problem areas.

Some jurisdictions with high rates of BMP implementation attribute this success to outreach and education programs.

- The North Carolina Forestry Association ProLogger program has had a positive effect on BMP implementation. In 2005, BMP implementation on sites managed by certified ProLoggers was 84% while implementation was lower (78%) on sites harvested without a ProLogger trained forester (NC DFR 2005).
- In Arkansas, "high scoring of harvest BMPs can be attributed to the large number of loggers trained by the Arkansas Timber Producers Association as required by the Sustainable Forestry Initiative Program (SFI) which is supported by the industrial forest landowners" (AR FC 2005).
- The Texas Forest Service recently reported that "BMP implementation was higher on sites in which the receiving mill was known to be a SFI participant. This occurrence was documented on 57 sites with an implementation rating of 95.5%, compared to an 89.5% implementation rating on 99 sites in which the timber went to other mills or the receiving mill was unknown" (TX FS 2005).

Some jurisdictions have designed their BMP surveys to measure both implementation and effectiveness. Results suggest that many technical violations of BMPs do not cause impacts to water quality. For example, Montana's BMP Working Group records a "major departure" from BMPs when "material erodes and is delivered to a stream or annual floodplain." From 1996 to 2006, the average number of technical violations of BMPs declined from 3 to 1.5 per site. Over the same time period, the incidence of "major departures" declined from 0.3 to 0.1 per site (Rogers 2007).

Cost and competing priorities are often important barriers to BMP implementation monitoring. In many jurisdictions, forestry is a minor contributor to water quality problems relative to other nonpoint sources such as agriculture and urban runoff. As a result, agencies responsible for controlling NPS pollution are often reluctant to direct scarce resources to monitoring implementation of forestry BMPs.

Going forward, "How good is good enough?" is one of the most important policy and scientific questions facing the forestry and environmental communities regarding BMPs for water quality (Olszewski and Jackson 2006). It is clear that potential for water quality impacts is reduced by forest management practices that minimize soil disturbances, promote regeneration, and disperse surface runoff. Some studies have found that impacts of forestry operations conducted in accordance with BMPs were biologically non-significant, with measures of biological conditions in streams being more responsive to shifting environmental conditions than to effects of timber harvesting (Vowell and Fryenborg 2004; Griswold et al. 2006).

In summary, all jurisdictions in North America with substantial levels of timber harvest have made substantial investments in their forestry NPS control programs. These programs are based on BMPs that have been proven effective through research and practical experience. Many jurisdictions have invested in BMP monitoring programs and report generally high levels of compliance and/or few significant risks to water quality (Archey 2004). Opportunities for improvement have been identified and are being pursued through cooperative efforts of government agencies, forest certification bodies, forestry professionals, and other stakeholders.

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