Compliance Analysis of Forestry Best Management Practices in West Virginia

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ABSTRACT

A total of 29 forestry best management practices (BMPs) were measured on 116 randomly selected sites harvested between November 2003 and March 2004 in West Virginia using four checklists on haul roads, skid trails, landings, and in streamside management zones (SMZs). Landowners were contacted to gain permission for site visits according to the random list. Data collected were analyzed statistically to examine the significant differences of BMP compliance rates among forester involvement, ownership, harvest method, and forest district. Results indicate that BMP compliance was generally better when a forester was involved with the harvest or on industry lands. Forester involvement, ownership, and harvest method did not significantly affect most of BMP compliance rates. BMP compliance on skid trails, at landings, and overall compliance by site differed significantly among six forest districts in West Virginia.

Keywords: *best management practices, compliance, logging, timber harvesting, forest operations*

Introduction

Forestry best management practices (BMPs) were developed to protect water resources while conducting forest management activities. All states that are active in forestry utilize BMP programs, and many state forestry agencies periodically assess the extent of BMP implementation (Prud'homme and Greis 2002, Shepard et al. 2004). The BMP guidelines vary from state to state, but they all focus on erosion control and water quality (Phillips et al. 2000). The principal cause of degradation of water quality associated with harvesting activities is erosion from highly disturbed areas, such as roads and log landings, with eventual sedimentation in streams (Kochenderfer et al. 1997). As early as 1955, it was stated that without careful placement and installation of roads and landings, stream sedimentation will increase beyond normal geologic processes (Tebo 1955, Reinhart et al. 1963, Hewlett 1979). This is one of the major reasons for adequate application, effectiveness, and compliance of forestry BMPs.

In 1972, a committee was established with the West Virginia Chapter of the Society of American Foresters, the West Virginia Sawmill Association, and the Appalachian Hardwood Manufacturers, Inc. (WVDOF 1986). This committee developed forest practice standards, which included some BMP guidelines. West Virginia passed its own Water Pollution Control Act in 1974, and a State 208 Silvicultural Technical Action Committee completed a silvicultural water quality management plan for West Virginia in 1979 (Sherman 1985). The Logging Sediment Control Act (LSCA) was passed by West Virginia Legislature in 1992. The purpose of this act is to decrease erosion and sediment while improving logging practices. The LSCA contains 14 sections to aid loggers in better management plans as well as to set mandates for all logging companies to follow. The West Virginia Division of Forestry (WVDOF) was given the responsibility for regulating all harvesting activities in the state under the LSCA. State foresters retain the authority to issue citations, shutdowns, and orders for reclamation when necessary. The WVDOF provides training on the LSCA and BMP guidelines by offering workshops and the BMP guideline booklet.

Four BMP assessment studies have been conducted in West Virginia since the initiation of the BMP guidelines (Paff 1981, Whipkey and Glover 1987, Whipkey 1991, Egan et al. 1998). Previous BMP compliance studies in West Virginia indicate that BMPs are widely implemented and there has been a general increase in compliance over the years. Wang et al. (2004) reported that West Virginia compliance rates also compare well with other northeastern states. These studies, however, only addressed compliance rates associated with haul roads, skid trails, and landings without further analysis of how factors such as ownership, forester involvement, and others variables affect compliance. Egan (1999) examined foresters and logging contracts and BMP compliance in 1999. He concluded that landowners who hired a professional forester to conduct their timber sales had a higher level of compliance with forestry BMPs (Egan 1999). Ten years have past since the last statewide BMP assessment in West Virginia. From review of this historical information, the objectives developed for this study were to:

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1. statistically examine the BMP compliance rates on haul roads, skid trails, landings, and in streamside management zones (SMZs) and
2. evaluate how significantly forester involvement, ownership, harvest method, or forest district affect BMP compliance rates in West Virginia.

Materials and Methods

Sampling Procedures

Harvested sites where operations commenced from November 2003 to March 2004 in each of six West Virginia forest districts were randomly selected as possible sample sites following a sampling protocol used by a previous assessment in the state (Egan and Rowe 1997, Egan et al. 1998). The sampling process began in Forest District 3 since that district conducts the most logging activities in the state (**Fig. 1**). A random sample size of 30 sites were first chosen from Forest District 3 based on a total of 347 ($x_3 = 347$) potential harvested sites started between November 2003 and March 2004. The number of sites to be sampled in the other districts, represented by n_i, was determined by using the formula:

$$\begin{cases} n_i = \dfrac{x_i}{x_3}(30) \\ i = 1, 2, \ldots, 6 \end{cases} \qquad [\mathbf{1}]$$

where:

x_i = the number of harvested sites in a district during the designated time period.

The sampled sites in each district represented nearly 10 percent of the harvested sites during the sampling period. A total of 116 sites were surveyed throughout the six forest districts of West Virginia from May 2004 to August 2005 (**Table 1**) (Wang et al. in press).

Once the sample size was determined in each district, notification forms required by the WVDOF, including harvest and tract information, were obtained from the district office to determine tract size, forester involvement, harvest method, and ownership. There are three main types of harvest methods listed on WVDOF timber harvesting notification forms: selection or marked timber, diameter limit cut or logger's choice, and clear cut. If more than one type of harvest method was indicated for a larger tract, the harvest method of the larger acreage was used in data analysis.

BMP Measurements

A total of 29 BMPs were measured in the field for haul roads, skid trails, landings, and SMZs by using four checklists (WVDOF 2002). BMPs measured on haul roads include: length, grade, use of culverts, and use of cross drainages. BMPs measured on skid trails included length, grade, water bars present and needed, length smooth, length of berm removed, and length outsloped. BMPs measured on landings consisted of the number of approach roads diverted, location

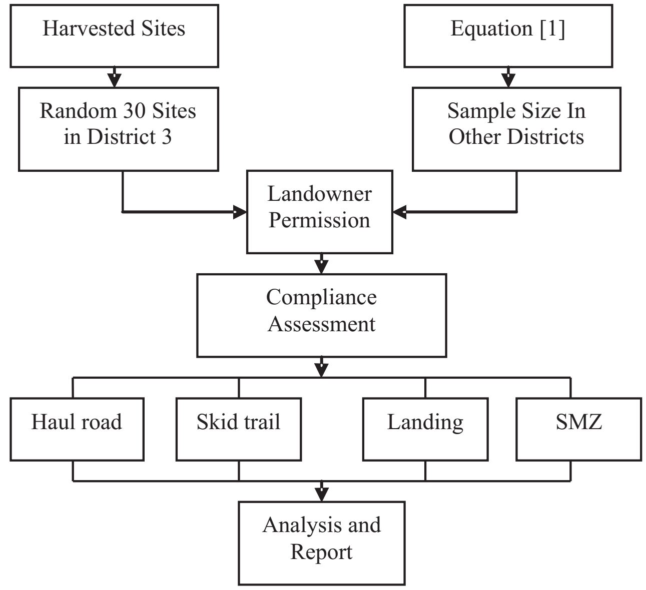

Figure 1. ~ *Flow chart of BMP assessment process.*

Table 1. ~ *Number of samples by forest district.*

West Virginia forest district	Number of samples (n_i)	Harvested sites (x_i)
1	24	270
2	17	194
3	30	347
4	10	97
5	17	189
6	18	195

in or outside of the SMZ, landing smooth, drained, seeded, and mulched. BMPs associated with the SMZ checklist included SMZ width, equipment operations, soil exposure, stabilization of soil, and the use of existing roads, if applicable. The zero width of SMZ was recorded for comparison purposes when activity was found in entire length of the stream.

Slopes of skid trails, haul roads, and SMZs were measured using a clinometer. Slope measurements for haul roads were taken at grade breaks or curves in order to determine BMP compliance on each road/trail segment. Length measurements were taken with a laser rangefinder to accurately determine the lengths of skid trail and haul road segments. The length of segments where gravel was applied and the length of seeding and mulching on the haul road and skid trail segments were also measured. Equipment operations were assumed to have occurred on these sites if disturbance of the site with bare soil exposure was present.

Data Analysis

BMP compliance rates were computed as:

1. Length-based BMPs: For example, the compliance percentage of smooth length on skid trails was derived by dividing the total length of smooth skid trails by the total length of skid trails measured for a tract and multiplying 100. The same process was applied for all length related BMP compliances. Sections are considered smooth in the case of no ruts or ruts that are less than 6 inches deep.
2. Number-based BMPs: The compliance rate for the use of water bars was obtained by dividing the number of water bars present in a road/trail segment by the number recommended for the same segment by the guidelines.
3. Yes/No-based BMPs: Some BMPs measured, either on landings or in SMZs, only employed "Yes" or "No" answers, which were then converted to 1 or 0. The percent compliance for these BMPs was computed by dividing the number of samples answered "Yes" by the total number of samples for that tract or attribute.

Data collected for each attribute or BMP were summarized statistically on haul roads, skid trails, landings, or in SMZs. The BMP compliance percentages were also compared statistically among districts, harvest methods, forester involvement, and ownership using a general linear model (GLM).

$$\begin{aligned} Y_{ijklm} &= \mu + F_i + D_j + H_k + O_l + F_i D_j + \\ &\quad F_i H_k + D_j H_k + F_i O_l + D_j O_l + \varepsilon_{ijklm} \\ i &= 1,2 \\ j &= 1,2,3,4,5,6 \\ k &= 1,2,3 \\ l &= 1,2 \end{aligned} \quad [2]$$

where:

Y_{ijklm} = the m^{th} observation of the measured BMPs and

μ = the grand mean of each response variable.

F_i = the effect of the i^{th} forester involvement factor. This variable shows whether or not either the property owner or the timber owner employed a forester during the harvesting process.

D_j = the effect of the j^{th} forest district in West Virginia, which allowed for BMP compliance comparisons among forest districts,

H_k = the effect of the k^{th} harvest method,

O_l = the effect of the l^{th} ownership factor, which was defined as either private or industrial, and

ε_{ijklm} = an error component that represents uncontrolled variability.

Results

Tract size of investigated sites ranged from 3 to 226 acres in size, with an average size of 58 acres. Foresters were employed on 68 percent of the sites visited. Sixty-six percent of 116 sites were owned by private landowners while 34 percent were owned by industry. Each of the three harvest methods were represented on these sites, including 44 percent selection cuts, 36 percent diameter-limit cuts, and 20 percent clearcuts.

Haul Road Compliance

Seven BMPs were measured for haul road compliance. Based on the measurements on 54 sites with haul roads, the average grade of haul roads was 5 percent ranging from 1 to 17 percent (**Table 2**). On average, one cross drainage structure was installed for each haul road segment measured, while the BMPs suggest that the average number of cross drainage structures actually needed was two. The length of gravel applied on haul road averaged 271 feet, much longer than the suggested 38 feet of gravel per segment needed to comply with the BMP. About 10 percent of the haul roads needed to be seeded and mulched due to a steep grade or being constructed in a SMZ. Two percent of the haul roads were constructed inside of a SMZ. More than 98 percent of the haul roads were seeded and mulched properly.

The mean and significant level of compliance were summarized for each BMP measured on the haul roads between forester involvements, between ownerships, among harvest methods, and among forest districts (**Table 3**). There was a significant difference in seed applied, mulched applied, and haul road out of SMZ between forester involvement and no forester involved. The overall BMP compliance of 86 percent on haul roads with forester involvement was significantly different from the overall BMP compliance of 67 percent on haul roads without forester involvement (F = 5.43; df = 1,53; p = 0.0263). Ownership and harvest method, however, did not significantly affect BMP compliance rates on haul roads. The BMP requiring haul road grade of less than 15 percent was significantly different between districts 1 and 4 and districts 5 and 6 (F = 6.65; df = 5,53; p = 0.0002). Similarly, the compliance in seed applied, mulch applied, and haul road out of

Table 2. ~ *Statistics of BMPs or attributes measured on haul roads.*

BMP	No.	Mean	SD[a]	Min.	Max.
Grade less than 15% (%)	100	4.9	3.3	1	17
Culverts present (no.)	86	0.2	0.4	0	1
Culverts needed (no.)	86	0.2	0.4	0	1
Cross drainages present (no.)	99	1.2	1.7	0	10
Cross drainages needed (no.)	99	2.3	3.7	0	26
Gravel applied (ft.)	100	271	343	0	2,640
Gravel needed (ft.)	99	38	126	0	1,084
Seed applied (ft.)	100	32	82	0	487
Seed needed (ft.)	98	31	81	0	487
Mulch applied (y/n)	100	0.2	0.4	0	1
Mulch needed (y/n)	100	0.1	0.3	0	1
SMZ violation (ft.)	98	7.9	32	0	252

[a] SD = standard deviation

Table 3. ~ *Means and significance levels of percent compliance for BMPs on haul roads.*[a]

	Grade less than 15%	Gravel applied	Culvert used	Cross drainage	Seed applied	Mulch applied	Out of SMZ	Overall compliance
				Forester involvement				
Yes	97A	99A	96A	58A	100A	100A	47A	86A
No	94A	98A	33A	40A	29B	29B	18B	67B
				Ownership				
Private	95A	98A	60A	50A	67B	58A	33A	78A
Industrial	100A	100A	94A	58A	100A	100A	50A	87A
				Harvest method				
Clearcut	100A	100A	100A	40A	100A	100A	--	86A
Diameter limit	94A	96A	50A	67A	67A	50A	29A	79A
Selection	96A	100A	69A	47A	82A	78A	28A	80A
				Forest district				
1	100A	100A	100A	44A	86A	83AB	70A	85A
2	100A	97A	33A	43A	25B	25B	29B	67A
3	100A	100A	95A	51A	100A	100A	--	85A
4	100A	91A	--	75A	100A	--	--	89A
5	67B	100A	--	50A	--	--	--	78A
6	80B	100A	--	67A	75A	67AB	0C	70A

[a] Means with the same letter in a group of a column are not significantly different at $\alpha = 0.05$ (ANOVA).

SMZ was also significantly different among forest districts. But, the overall BMP compliance on haul roads did not differ significantly among six forest districts.

Skid Trail Compliance

At least the first 500 feet of each skid trail leaving the landing were measured for BMP compliance. Measurements were also taken on each trail constructed off of the first 500 feet, which was considered the area more likely to erode and transport sediment to the landing area. Of the total length measured only 2 percent of the skid trails exceeded 20 percent grade with the maximum grade of 24 percent (**Table 4**). There were 1.1 water bars per measured skid trail segment, less than the recommended number of water bars of 1.7 per segment. The amount of skid trails that were considered smooth was 88 percent. Sixty-one percent of the skid trails measured were outsloped. But, only 40 percent of them had the berm removed for proper drainage. The average length of seeded skid trails was 54 feet per measured segment, even though the average length of skid trails recommended by the BMPs to be seeded was only 17 feet per segment. Although mulch was required on 23 percent of the measured trail segments, it was applied on 27 percent of the segments. About 3.5 feet per segment of skid trails were built in the SMZ, which were the trails that either crossed streams or ran parallel to them within the designated SMZs.

Both forester involvement ($F = 4.29$; df = 1,115; $p = 0.0413$) and ownership ($F = 6.44$; df = 1,115; $p = 0.0129$) significantly affected the number of water bars applied (**Table 5**). Forester involvement and ownership, however, did not significantly affect overall BMP compliance on skid trails. Harvest method did not significantly affect most of the BMPs on skid trails. There were significant differences in most of the BMPs on skid trails among forest districts. For example, a significant difference existed in the compliance of water bars applied among districts ($F = 2.47$; df = 5,115; $p = 0.0382$). The compliance of 100 percent in mulch applied in District 6 was significantly different from other districts ($F = 2.56$; df = 5,115; $p = 0.0329$). The overall BMP compliance on skid trails was significantly different among forest districts ($F = 2.80$; df = 5,115; $p = 0.0216$), ranging from 60 percent in District 5 to 80 percent in District 4. Significant differences were also found among the interactions between forester involvement and forest district for the length of skid trail outsloped.

Table 4. ~ *Statistics of BMPs or attributes measured on skid trails.*

BMP	No.	Mean	SD[a]	Min.	Max.
Grade less than 20% (%)	853	8.2	5.2	0	24
Water bars present (no.)	853	1.1	1.3	0	11
Water bars needed (no.)	852	1.7	1.1	0	10
Length smooth (ft.)	853	157	88	0	477
Length of berm removed (ft.)	852	103	103	0	477
Length outsloped (ft.)	853	114	103	0	471
Seed applied (ft.)	853	54	83	0	405
Seed needed (ft.)	853	17	38	0	369
Mulch applied (y/n)	853	0.27	0.44	0	1
Mulch needed (y/n)	853	0.23	0.42	0	1
SMZ violation (ft.)	624	3.5	25	0	303

[a] SD = standard deviation

Table 5. ~ *Means and significance levels of percent compliance for BMPs on skid trails.*[a]

	Grade less than 20%	Water bars applied	Length smooth	Length of berm	Length outsloped	Length seeded	Mulch applied	Length out of SMZ	Overall compliance
					Forester involvement				
Yes	99A	56A	92A	38A	64A	68A	67A	57A	69A
No	99A	44B	92A	44A	73A	63A	59A	43A	67A
					Ownership				
Private	99A	45B	93A	46A	70A	66A	65A	45A	68A
Industrial	99A	65A	90A	29B	61A	68A	65A	63A	68A
					Harvest method				
Clearcut	100A	62A	94A	26B	68A	70A	74A	100A	71A
Diameter limit	99A	48B	87A	37AB	60A	62A	58A	33A	63A
Selection	99A	50AB	94A	49A	73A	68A	67A	62A	71A
					Forest district				
1	100A	48BC	90A	49A	61ABC	65BC	64B	49AB	67ABC
2	98AB	30C	97A	53A	85A	61C	51B	61AB	68ABC
3	100A	63AB	91A	31AB	77AB	42C	54B	86AB	66BC
4	100A	79A	96A	35AB	74AB	92AB	78AB	100A	80A
5	100A	48BC	89A	19B	47C	68BC	53B	47AB	60C
6	97B	46BC	93A	53A	57BC	100A	100A	10B	75AB

[a] Means with the same letter in a group of a column are not significantly different at $\alpha = 0.05$ (ANOVA).

Landing Compliance

Six BMPs were measured on landings (**Table 6**). The distance that a landing was outside of an SMZ was measured for determining the SMZ violation. Eighty-six percent of landings had no SMZ violations. The number of skid trails that had turnouts or diversion ditches used in landing reclamation averaged 1.5 per landing ranging from 1 to 4, while the number of diversion trails needed per landing was between 0 and 4 with an average of 1.2. Results from the examination of landings for proper reclamation indicated higher compliance with landing smoothness (88%), proper drainage (95%), seed applied (80%), and mulch applied (77%).

Means and significance levels of compliance percentages for these six BMPs on landings were compared among forester involvement, ownership, harvest method, and forest district (**Table 7**). Forester involvement significantly affected the number of landings that were constructed outside of SMZs (F = 10.21; df = 1,103; p = 0.0020). This was also true for the number of trails that used structures to divert water from running onto the landings (F = 7.03; df = 1,103; p = 0.0096). Forester involvement did not significantly affect the overall BMP compliance on landings. Similarly, the compliance rate on the number of trails diverted water from landings differed significantly between ownerships. There were no significant differences in most of the BMPs on landings among harvest methods. But, BMP compliance on landings differed significantly among forest districts. For example, a compliance of 100 percent for landings being seeded (F = 3.0; df = 5,103; p = 0.0276) and mulched (F = 2.49; df = 5,103; p = 0.0384) in District 6 was significantly different from other districts. The overall BMP compliance on landings differed significantly among forest districts (F = 2.57; df = 5,103; p = 0.0338) and varied from 76 percent in District 3 to 92 percent in District 6.

Table 6. ~ *Frequencies of BMPs measured on landings.*

BMP	Number Yes	Number No	Percentage Yes	Percentage No
SMZ violation (y/n)	18	113	14	86
Landing smooth (y/n)	115	16	88	12
Landing drained (y/n)	125	6	95	5
Landing seeded (y/n)	105	26	80	20
Landing mulched (y/n)	101	30	77	23
Approach trails diverted (no.)	--	--	--	--

SMZ Compliance

A total of 51 SMZs were assessed during this study including 7 (14 %) ephemeral streams, 17 (33%) intermittent streams, and 27 (53%) perennial streams (**Table 8**). The average SMZ width measured for ephemeral streams was 39 feet with a range of 18 to 50 feet (**Table 8**). The SMZ width for intermittent streams ranged from 0 to 100 feet with an average of 46 feet while the SMZ width averaged 48 feet for perennial streams ranging from 0 to 100 feet. The average length of skid trails inside of SMZ was 37 feet ranging from 0 to 300 feet. The distance of skid trails reclaimed in SMZs was between 0 and 150 feet with an average of 59 feet.

Evidence of equipment use was noted in 98 percent of the SMZs investigated (**Table 9**). Soil exposure was found in 88 percent of the SMZs but 90 percent were stabilized. Fifty-three percent of landings were constructed outside of the

Table 7. ~ *Means and significance levels of percent compliance for BMPs on landings.*[a]

	Outside of SMZ	Trails diverted from water	Landing smooth	Landing drained	Landing seeded	Landing mulched	Overall compliance
			Forester involvement				
Yes	98A	82A	83A	92A	80A	76A	85A
No	81B	60B	87A	95A	77A	74A	81A
			Ownership				
Private	89A	66B	85A	91A	80A	77A	82A
Industrial	94A	90A	84A	95A	73A	68A	84A
			Harvest method				
Clearcut	95A	90A	86A	93A	83A	79A	90A
Diameter limit	86A	66B	84A	94A	78A	78A	81A
Selection	97A	75AB	84A	93A	79A	72A	83A
			Forest district				
1	100A	74AB	75A	83A	83AB	83ABC	83AB
2	84AB	56B	98A	98A	77AB	64BC	80AB
3	95AB	88AB	74A	87A	60B	53C	76B
4	100A	97A	80A	95A	85AB	85ABC	90A
5	100A	65AB	94A	100A	88AB	88AB	89AB
6	78B	67AB	89A	100A	100A	100A	92A

[a] Means with the same letter in a group of a column are not significantly different at $\alpha = 0.05$ (ANOVA).

Table 8. ~ *Statistics of some BMPs measured in SMZs*

BMP	No.	Mean	SD[a]	Min.	Max.
Ephemeral stream SMZ width (ft.)	7	39	81	18	50
Intermittent stream SMZ width (ft.)	17	46	35	0	100
Perennial stream SMZ width (ft.)	27	48	25	0	100
Skid trail inside SMZ (ft.)	51	37	73	0	300
Skid trail reclaimed (ft.)	51	59	49	0	150

[a] SD = standard deviation

Table 9. ~ *Frequencies of some BMPs measured in SMZs.*

	Number		Percentage	
BMP	Yes	No	Yes	No
Minimum equipment use (y/n)	50	1	98	2
Soil exposed (y/n)	45	6	88	12
SMZ stabilized (y/n)	46	5	90	10
Landing outside SMZ (y/n)	27	24	53	47
Landing reclaimed (y/n)	46	5	90	10
Haul road outside SMZ (y/n)	26	20	57	43
Haul road reclaimed (y/n)	20	21	49	51
Riprap installed (y/n)	34	16	68	32

SMZs, and 90 percent of the total landings in the SMZs were reclaimed. Of the 43 percent of haul roads built in SMZs, about half were reclaimed after harvest. Riprap was installed on 68 percent of the sites with SMZs.

Means and significance levels of BMPs measured in SMZs were analyzed with respect to forester involvement, ownership, harvest method, and forest district (**Table 10**). None of these factors significantly affected SMZ width. Forester involvement significantly affected the use of equipment in SMZs ($F = 8.44$; $df = 1,33$; $p = 0.0103$). There was a significant difference in haul roads reclaimed between ownerships, with 61 percent compliance on industry lands and 46 percent compliance on private lands ($F = 4.48$; $df = 1,50$; $p = 0.0424$). Harvest method was the only variable that significantly affected equipment use in SMZs. There were no significant differences among forest districts for five BMP compliance rates in SMZs. The overall compliance rate of BMPs measured in SMZs also showed no significant difference among districts, with overall rates ranging from 47 percent in District 2 to 67 percent in District 5.

Overall BMP Compliance

Individual BMP compliance was summarized to develop the overall BMP compliance by site. The overall BMP compliance was also analyzed by forester involvement, ownership, harvest method, and forest district. The compliance with BMPs was generally higher on sites with forester involvement and on industry lands. Forester involvement resulted in an increase of 6 percent in the overall BMP compliance rate from 70 to 76 percent while the overall BMP compliance rates increased from 73 percent on private lands to 75 percent on industry lands. Neither ownership nor harvest method affected the overall BMP compliance significantly. The overall BMP compliance rate varied from 71 percent in diameter-cut sites, to 75 percent in selection cut sites, and to 77 percent in clearcut sites. The overall BMP compliance by site showed significant differences among forest districts ($F = 2.94$; $df =$

Table 10. ~ *Means and significance levels of percent compliance for BMPs in SMZs.*[a]

	SMZ width	Min. equipment use	Soil disturbed	SMZ stabilized	Haul road reclaimed	Skid trail reclaimed	Landing reclaimed	Riprap installed	Overall compliance
				Forester involvement					
Yes	46A	34B	5A	87A	51A	67A	88A	67A	59A
No	44A	55A	25A	96A	46A	54A	78A	53A	54A
				Ownership					
Private	42A	40A	15A	87A	46B	61A	83A	58A	55A
Industrial	52A	50A	10A	100A	61A	63A	87A	89A	62A
				Harvest method					
Clearcut	25A	25B	0A	100A	67A	100A	100A	67A	61A
Diameter limit	46A	73A	13A	94A	55A	58A	75A	69A	58A
Selection	48A	13B	17A	86A	41A	58A	91A	64A	55A
				Forest district					
1	52A	13C	13A	88A	71A	66A	88A	71A	61A
2	43A	0C	42A	92A	0B	25A	100A	50A	47A
3	65A	0C	0A	87A	33AB	60A	73A	60A	48A
4	50A	50B	0A	50B	50AB	100A	50A	50A	55A
5	35A	100A	20A	100A	--	44A	100A	80A	67A
6	32A	94A	0A	100A	75A	88A	75A	75A	61A

[a] Means with the same letter in a group of a column are not significantly different at $\alpha = 0.05$ (ANOVA).

5,115; $p = 0.0159$) and changed from 70 percent in District 3, to 71 percent in District 2, 72 percent in District 1, 74 percent in District 5, 80 percent in District 4, and 82 percent in District 6. Differences can occur between districts due to topography as well as practices conducted in that area.

Discussion and Conclusions

BMPs were generally better complied with when a forester was involved with the harvest or on industry lands. This suggests that foresters are having a positive effect on timber harvesting and BMP applications in the state, as was determined in Egan's work in 1999 (Egan 1999). When private landowners hired foresters, they developed a better understanding of the harvest and were therefore more satisfied with the operations. On the other hand, forest product companies that are represented by professional foresters usually contract with loggers to harvest the timber. These loggers are generally better informed about BMP compliance, and the harvesting is regularly supervised by professional foresters. Many of these companies also have a long-term investment interest in their property and manage the timber as a sustainable resource that will continue to produce revenue. Frequently, private landowners will harvest timber from their property for short-term financial gain rather than for long-term sustainability (Egan and Rowe 1997). With a long-term interest in forest sustainability and stewardship, and a better understanding of forest harvesting and its associated practices and regulations, significant improvements in BMP compliance could be realized.

Forester involvement did not significantly affect some of the BMP compliance associated with haul roads, skid trails, landings, and SMZs; it only significantly affected the overall BMP compliance on haul roads. This study found that both ownership and harvest method did not significantly affect the overall compliance rates on haul roads, skid trails, at landings, or in SMZs.

There was a significant difference for overall BMP compliance in the state among six forest districts varying from 70 to 82 percent. There was higher BMP compliance on haul roads in District 4 (89%), which may be due to the district having the smallest sample size, the greater percentage of sites sampled on industry lands, and/or more professional forester involvement than in other districts. The BMP compliance on skid trails differed significantly among forest districts and ranged from 60 percent in District 5 to 80 percent in District 4. In District 5, the topography and soil type increased the logging difficulty, but with the proper implementation of BMPs, logging can occur with few sediment control issues. The BMP compliance for landings ranged from 76 percent in District 3 to 92 percent in District 6 and was significantly different among districts. There was no significant difference for the BMP compliance in SMZs among forest districts. It varied from 48 to 67 percent and was generally lower than on haul roads, skid trails, or landings.

A lower BMP compliance rate of 49 percent was measured in SMZs of perennial streams. These areas can be difficult to reclaim due to the amount of water present. The compliance rate for BMPs in SMZs along intermittent streams was 64 percent, while an overall compliance of 61 percent was achieved in SMZs on ephemeral streams. The sample sites for this study were logged during winter and spring months, when the majority of annual precipitation falls and most streams could have water in them. It is much harder for loggers to avoid these smaller ephemeral streams during these seasons as many may not have water running in them during dry periods. Lower compliance with SMZ-related BMPs were found on sites with skid trails constructed inside of SMZs, poorly constructed sites, or sites with no water bars. It is also the case for the sites with landings that were constructed in SMZs but were not reclaimed properly. These factors could lead to an increase in runoff and sedimentation due to the proximity to the stream.

This statewide BMP assessment provides detailed analysis on how forester involvement, ownership, harvest, and forest district affected BMP compliance. Results indicate that more haul roads, skid trails, and landings are being properly reclaimed in West Virginia, improving both erosion control and aesthetics. When the public sees well-reclaimed landings, haul roads, and skid trails, they tend to be more accepting of logging operations. A positive public perception helps support loggers, foresters, and forest product companies' efforts and investments in professional and sustainable forest management practices. The findings from this study could be useful in planning future statewide or regional BMP assessment, locating BMP problem areas, developing BMP education programs, and aiding analysis of interrelationships of BMP compliance and other operational factors.

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