

Soil Monitoring Report

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Gallatin National Forest

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## Introduction

This report documents soil quality monitoring on a timber sale on the Gallatin National Forest in south-central Montana. The Moose-Swan-Tamphrey-Portal (MSTP) timber sale was initiated in 2001 and completed in 2005. It was monitored for soil quality in August of 2005.

Standards for this sale included following the Gallatin National Forest Soil Protection guidelines in effect at the time. The environmental assessments (Gallatin National Forest. 1999a, 1999b) specified the following:

- Designated skid trails will be required for each tractor harvest unit to minimize the area subject to soil disturbance.
- Skid trail spacing will average 75 feet.
- Equipment having a static ground pressure of 11 psi or more will not be permitted off these designated trails at any time.

The present study followed a 2005 BMP (Best Management Practices) review of the entire timber sale (Gallatin National Forest, 2005), which focused on the degree of implementation of those BMP's specified in the Environmental Assessment (Gallatin National Forest. 1999a, 1999b)). This review provided a context and background data for a formal soil monitoring project. All measured units were tractor-harvested in the summer. According to the sale administrator, no equipment was allowed off trail, with the exception of an excavator having a static ground pressure of less than 11 psi.

### *Guidelines for the Protection of Soil Quality*

Forest Plan Standards and Direction

Soil and site productivity issues relate to the Forest Plan as follows: Soil and Water Quality Maintenance: All practices will be designed or modified as necessary to maintain land productivity (p.II-24, Gallatin National Forest, 1986)

Timber Production: Provide a sustained yield of timber products and improve the productivity of timber growing lands (p.II-1, *ibid*). Site preparation and debris disposal methods will be prescribed which maintain an adequate nutrient pool for long-term site productivity through the retention of topsoil and soil organisms.

Soil Quality Guidelines following from the Plan Direction

Regional Guidelines and standards for protection of long term soil productivity are applied. These are dated 11/12/1999 and are titled: FSM 2500 - Watershed and Air Management R-1 Supplement 2500-99-1, Chapter 2550 - Soil Management. They specify no more than 15 percent detrimental disturbance for ground-disturbing activities. Definitions used in this monitoring study follow these requirements.

Local guidelines were established to implement the Regional guides. The present Gallatin guidelines are in the Appendix. These are similar to those in effect in 1999 when the MSTP environmental assessment was completed, with one exception. In 1999, off-skid trail use was allowed with low-ground pressure vehicles. This was eliminated in 2002 as described below.

### ***Previous Studies on the Gallatin Forest***

Formal statistical monitoring was begun in 1990 (Shovic, H. F. and G. Widner, 1991). Conclusions were: 1) soil disturbance was high on tractor sales in the Gallatin National Forest, 2) Regional guidelines were exceeded in both detrimental and severe disturbance categories, with a probable decrease in soil quality, and 3) long term soil productivity may have been affected, as well as long term site productivity. Average detrimental disturbance was 33.3 percent.

The second year of the monitoring study verified these results using a standard method of validating field methods (Shovic, H. F. and K. Birkeland. 1992). Variability was reduced to levels used in research studies. Site preparation was identified as causing a part of the total disturbance. Evaluation in another harvest area confirmed earlier estimates of high disturbance in recent timber sales. Average detrimental disturbance was 56 percent.

Because past harvest practices probably reduced long term site productivity, changes in harvest methods were implemented in 1992. These practices were used as “Best Management Practices” for protection of soil productivity during ground-disturbing activities. They included the using a minimum skid trail spacing of 75 feet, and restricted off-trail use to low-ground pressure vehicles, as well as discouraging un-necessary site preparation with ground-disturbing machinery.

In 1999 monitoring was expanded to review the effects of dispersed skidding practices using “low” ground pressure vehicles. The effects of earlier dispersed skidding practices in the past contributed to the need for these guidelines and their development on the Gallatin National Forest (Shovic, H. F. and K. Birkeland, 1992; Shovic, H. F. and G. Widner, 1991), but with equipment improvements, dispersed skidding was again attempted on the Pole Gulch Timber Sale. However, data on that sale showed that when dispersed skidding was allowed with tracked “low impact” harvester equipment, excessive soil damage probably still occurred (Shovic, H., 1999).

Dispersed skidding practices using equipment with low ground pressure have been successful on National Forests having deep layers of organic material and slash (broken branches.) This layer is from 6 to 20 inches deep and originates from existing organic layers plus slash from the harvest operation. It protects the soil surface from displacement and prevents compaction, and is a standard BMP on many Region-One Forests (Kuennen, L, et. al., May 2000.)

There is no deep litter layer on Gallatin Forest sites (Davis, C. E. and H. F. Shovic. 1996.) Harvest activities leave much less slash because trees are smaller and they are more widely spaced than on more productive sites. (Kuennen, L, et. al., May 2000.) Since we cannot match the soil protection layers used on Idaho forests and their documented protective capabilities, I ceased to recommend any form of dispersed skidding on the Gallatin National Forest, until enough research is done to show that dispersed skidding with new kinds of equipment is not detrimental to soil quality. Therefore, the Gallatin guidelines were changed in 2002 to allow dispersed skidding only where there is a litter and slash layer of at least 8 inches in depth, or frozen or snow covered ground. The present guidelines for protection of soil productivity are in the Appendix.

## **Methods**

Cutting units were selected from the MSTP sale area map to represent the widest geographic range of tractor harvest units. The sampling system was adapted from Howes, et. al., 1983) and earlier monitoring research done on the Gallatin National Forest ((Shovic, H. F. and K. Birkeland, 1992; Shovic, H. F. and G. Widner, 1991). Earlier methods differentiated statistically between kinds of detrimental disturbance at a cost of high sampling frequency (over 700 samples per unit). To reduce cost, this was modified for this study to differentiate only between detrimental and non-detrimental disturbance. Sample size was therefore reduced to about 90, allowing more unit sampling in a shorter time frame.

A randomized starting point, systematic sampling scheme was used. A random azimuth was calculated. Transect locations were determined by calculating a total transect length that would give at least 90 samples with a 15 foot sample spacing. This was broken into at least two trial transects. They were placed on the map on the previously-selected azimuth, equally spaced across the unit. The spacing was selected to be greater than an

average skid trail width. This method minimized auto-correlation with skid trails and maximized potential variation across the sample transects.

Categories of disturbance follow Regional Guidelines (USDA Forest Service, 1999). The following photos were taken on the MSTP site. Note the litter and slash layer is very thin.



UN – Undisturbed – No visible disturbance of the soil surface is apparent.



DE – Deposited – This soil has been accumulated away from its original location, either by equipment or erosion. This is not considered detrimentally disturbed as the topsoil is actually deeper than in a natural state.



CO – Compaction Observed – This soil is observed to be compacted, but is otherwise undisturbed with the organic layer intact.



Normal  
ground  
surface

Post-  
disturbance  
ground  
surface

DI – Displaced – This soil has been removed to another location by equipment.



ER – Eroded – This soil has been detached and removed from the site by wind, water, ice, or gravity.



BD – Burned – This soil has been charred by fire.



PU – Puddled – This soil has been smeared and compacted by equipment. It is also usually displaced or deposited. Infiltration capacity is reduced.

A ruler and tape were used to measure vertical changes in the soil. Measurements were taken to the nearest inch. Sample location was determined by pacing on the appropriate azimuth. Where soils were covered by slash greater than two feet in depth, a 15 foot displacement to the right of the pile was taken in order to get a sample. This was repeated until a sample could be taken. Then the sample technician returned to the original transect.

Detrimental disturbance (as opposed to total disturbance) occurs according to the following criteria.

UN – undisturbed soils are not considered detrimentally disturbed.
DE – deposited soils are not considered detrimentally disturbed.
CO – Compacted soils are considered detrimentally disturbed only if the vertical displacement exceeds one inch. This threshold was developed by estimating a six inch affected layer, and a 15 percent allowable decrease in soil volume over this depth.
DI – displaced soils are considered detrimentally disturbed if the lesser of three inches or 50 percent of the topsoil layer is removed. With an average topsoil depth of nine inches, removal of three or more inches of topsoil constitutes detrimental disturbance.
ER – eroded soils are considered detrimentally disturbed if the lesser of three inches or 50 percent of the topsoil layer has been removed.
BD – burned soils are considered to be detrimentally disturbed if charring occurs at depths greater or equal to two inches.
PU – all puddled soils are considered detrimentally damaged.

Sample point data were input to an ACCESS table. Fields are: Project, Date, DisturbanceCode, Depth, Notes, Transect, ID, Point, and Unit. A filtering query was run against the tabular data to determine “detrimental disturbance”. It’s logic follows from the definition of detrimental disturbance given above.

```
UPDATE SoilMonitoringData SET SoilMonitoringData.Detrimental =  
IIf([DisturbanceCode]="UN","No",IIf([DisturbanceCode]="DE","No",IIf([DisturbanceCode  
]="CO",IIf([Depth]>1,"Yes","No"),IIf([DisturbanceCode]="DI",IIf([Depth]>=3,"Yes","No"  
),IIf([DisturbanceCode]="ER",IIf([Depth]>=3,"Yes","No"),IIf([DisturbanceCode]="BD",IIf  
([Depth]>=2,"Yes","No"),IIf([DisturbanceCode]="PU","Yes","Unknown")))))));
```

The statistical reality check uses the Wald method (<http://www.graphpad.com/articles/CIofProportion.htm>). When an experiment has two possible outcomes, the results are expressed as a proportion. Out of N experiments (or subjects), we observed one outcome (termed "success") in S experiments (or subjects) and the alternative outcome in N-S experiments. Success occurred in S/N of the experiments (or subjects), and we will call that proportion p. Since data are subject to random error, the true proportion of success in the overall population is almost certainly not p. A 95% confidence interval quantifies this uncertainty. We can be 95% sure the overall proportion of success is within the confidence interval (ibid).

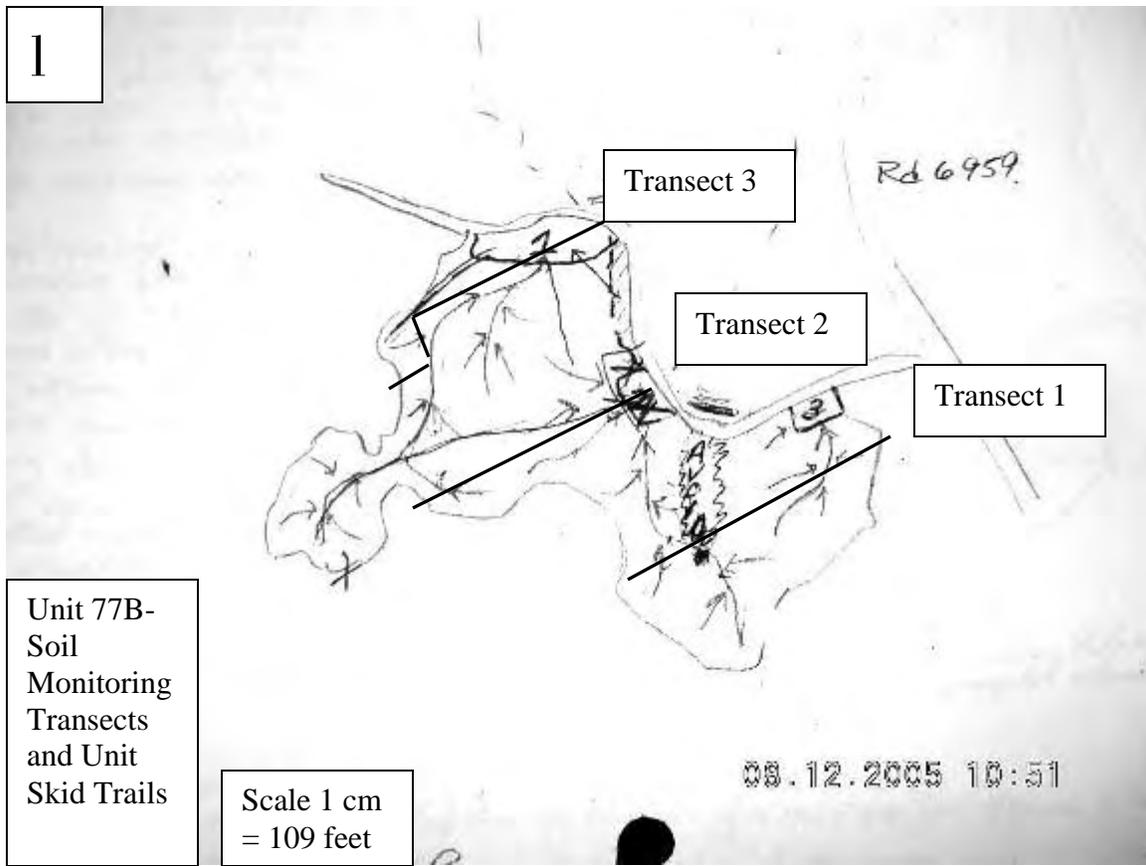
Skid trail spacing and area in landings was calculated from the Timber Sale Administrator Timber Sale Report map, after field verification. Skid trail distance was measured with a distance wheel. Skid trail width was estimated from the Timber Sale Report (12 feet) and field review. Skid trail spacing was determined by measuring spacing between skid trails where they intersected the randomized transects.

Area in landings was measured with a ruler. Landing area is generally marked by "X" on the map, and occasionally numbered (as in 77B). All area in designated skid trails and in landings is considered detrimentally disturbed.

## Results

### *Unit 77B*

This unit was tractor-harvested in 2003. Soils are medium textured, and have formed in glacial till derived from volcanic rocks and landslide debris. Slopes range from 0 to 30 percent with a few pitches steeper than 35 percent. Elevation is 6549 feet MSL. Location is 45 deg. 20 min 24 sec; W111 deg. 8 min. 12 sec. Location by GPS is 45 deg. 16 min 12 sec; W111 deg. 8 min. 4 sec. The figure shown below depicts the unit, scale, landings, skid trails, and transects. This was modified from the Timber Sale Report.



Azimuth for this set of transects was 262 degrees. total ground disturbance was 46/97 or 47 percent, with a Confidence Interval of 38 to 57 percent.

Detrimental Disturbance was 32/97 or 33.0 percent. Confidence interval (Wald method) at 95 percent is 24 to 43 percent. Therefore it is strongly statistically significant that detrimental disturbance is greater than 15 percent.

Skid trail spacing was evaluated using the Timber Sale Area map (see above). After reviewing this map in the field, the existing sample transects were used to calculate average spacing using the skid trails that were crossed by the transects. Average spacing is 119 feet, which is within the guideline of 75 feet minimum.

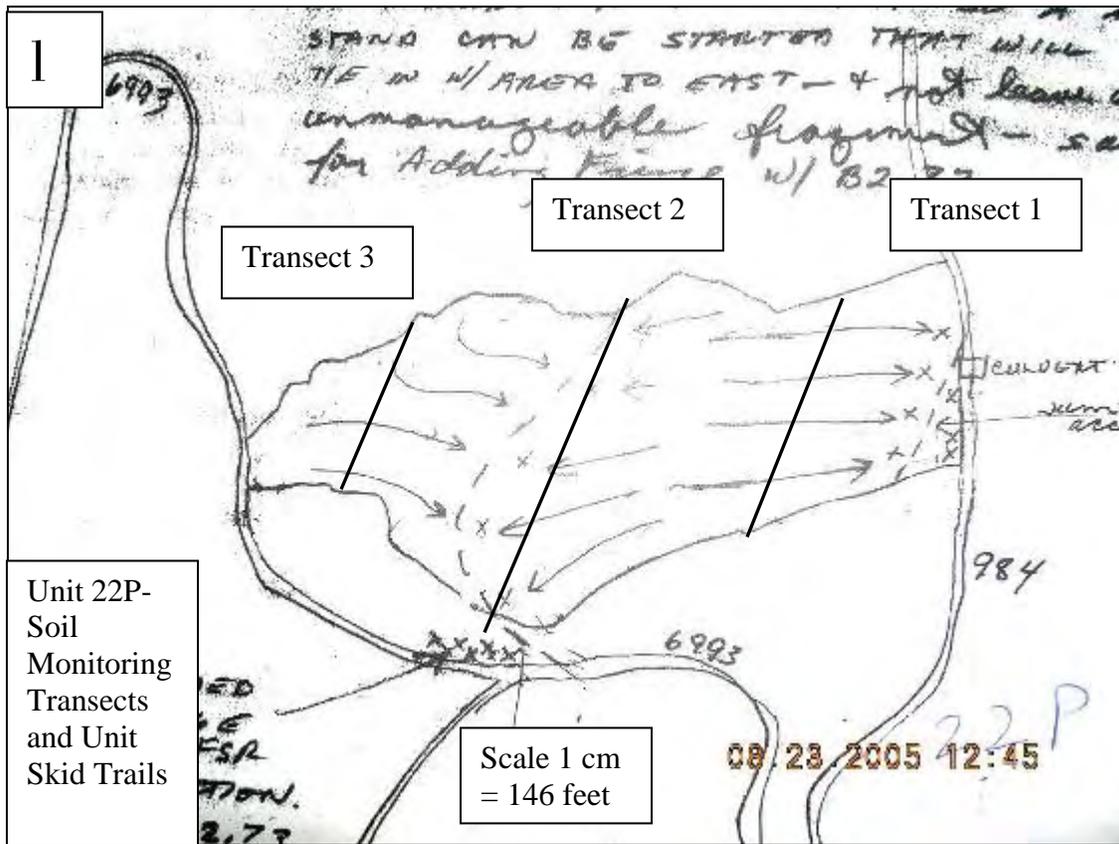
Total skid trail length is 3,210 ft. Estimating 12 feet for a skid trail width gives an area of 38,520 sq. ft. or 9.8 percent of the nine acre (392,040 sq. ft.) cutting unit. Landing area was estimated by ruler. Total landing area is 31,009 sq. ft. This is 7.9 % of the nine acre unit.

Summing disturbance on landings and skid trails gives 17.7 percent. This is close to Regional guidelines. But because total disturbance equaled 33 percent, I conclude off-trail use with ground-disturbing equipment is responsible for increasing disturbance

enough to significantly detrimentally disturb soils in this unit, and by inference, reduce soil productivity.

### Unit 22P

This unit was tractor-harvested in 2001. Soils are moderately-coarse textured with many sub-surface and surface rock fragments, and have formed in glacial till derived from Precambrian crystalline rocks and volcanic rocks. Slopes range from 0 to 20 percent. Elevation is 7775 feet MSL. Location by GPS is 45 deg. 16 min 12 sec; W111 deg. 8 min. 4 sec. The figure shown below depicts the unit, scale, landings, skid trails, and transects. This was modified from the Timber Sale Report.



Azimuth for this set of transects was 30 degrees. Total ground disturbance was 69/149 or 46 percent, with a Confidence Interval of 39 to 54 percent.

Detrimental Disturbance was 35/149 or 23 percent. Confidence interval (Wald method) at 95 percent is 17 to 31 percent. Therefore it is strongly statistically significant that detrimental disturbance is greater than 15 percent.

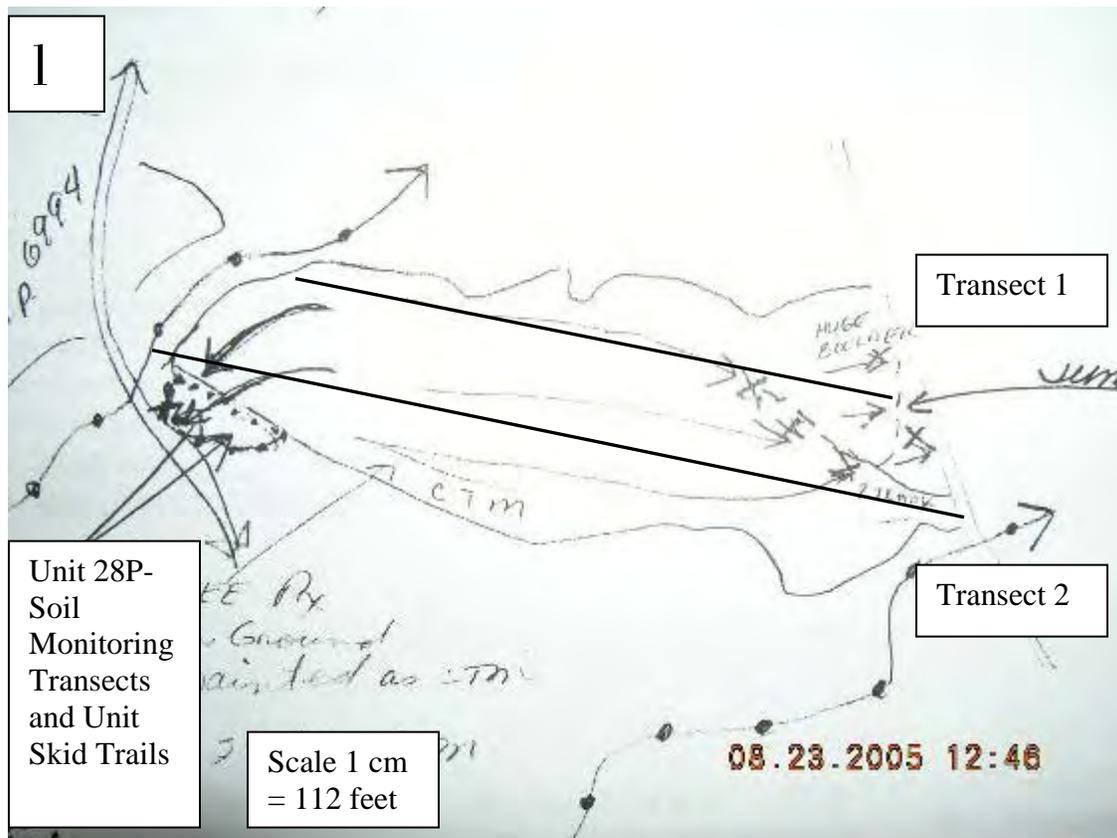
Skid trail spacing was evaluated using the Timber Sale Area map (see above). After reviewing this map in the field, the existing sample transects were used to calculate average spacing using the skid trails that were crossed by the transects. Average spacing is 118 feet, which is within the guideline of 75 feet minimum spacing.

Total skid trail length is 3,650 ft. Estimating 12 feet for a skid trail width gives an area of 43,800 sq. ft. or 7.7 percent of the 13 acre (566,280 sq. ft.) cutting unit. Landing area was estimated by ruler. Total landing area is 36,237 sq. ft. This is 6.4 % of the 13 acre unit.

Summing landings and skid trails gives 14.1 percent. This is within guidelines. Because total disturbance equaled 31 percent, I conclude off-trail use with ground-disturbing equipment is responsible for increasing disturbance enough to significantly detrimentally disturb soils in this unit, and by inference, reduce soil productivity.

### ***Unit 28P***

This unit was tractor-harvested in 2001. Soils are moderately-coarse textured with many sub-surface and surface rock fragments, and have formed in glacial till derived from Precambrian crystalline rocks and volcanic rocks. Slopes range from 0 to 35 percent. Elevation is 7,950 feet MSL. Location by GPS is 45 deg. 15 min 45 sec; W111 deg. 8 min. 2 sec. The figure shown below depicts the unit, scale, landings, skid trails, and transects. This was modified from the Timber Sale Report.



Azimuth for this set of transects was 294 degrees. Total ground disturbance was 66/140 or 47 percent, with a Confidence Interval of 39 to 55 percent.

Detrimental Disturbance = 32/140 or 23 percent. Confidence interval (Wald method) at 95 percent is 17 to 30 percent. Therefore it is strongly statistically significant that detrimental disturbance is greater than 15 percent.

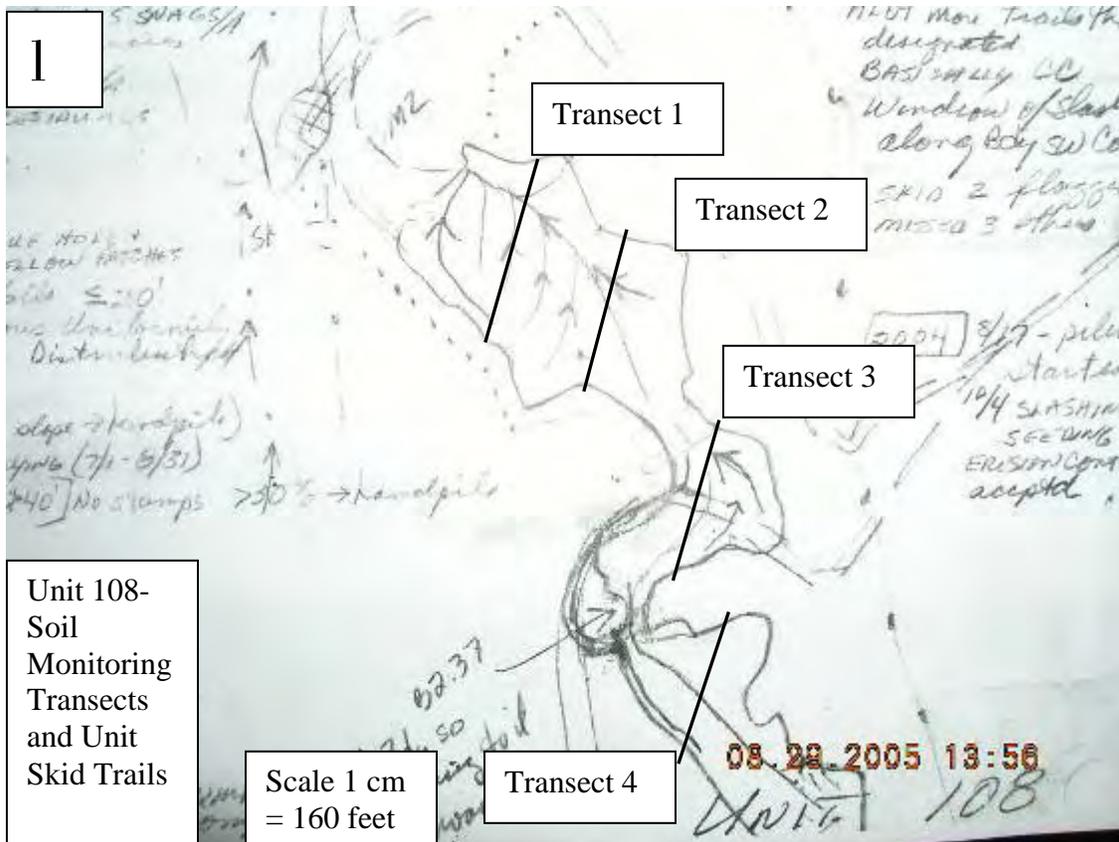
Skid trail spacing was evaluated using the Timber Sale Area map (see above). After reviewing this map in the field, the existing sample transects were used to calculate average spacing using the skid trails that were crossed by the transects. Some skid trails did not show on the sale area map. Average spacing is 118 feet, which is within the guideline of 75 feet minimum spacing.

Total skid trail length is 2,688 ft. Estimating twelve feet for a skid trail width gives an area of 32,256 sq. ft. or 6.2 percent of the 12 acre (522,720 sq. ft.) cutting unit. Landing area was estimated by ruler. Total landing area is 31,360 sq. ft. This is 6.0 % of the 12 acre unit.

Summing landings and skid trails gives 12.2 percent. This is within guidelines. Because total disturbance equaled 23 percent, I conclude off-trail use with ground-disturbing equipment is responsible for increasing disturbance enough to significantly detrimentally disturb soils in this unit, and by inference, reduce soil productivity.

### ***Unit 108***

This unit was tractor-harvested in 2003. Soils are moderately-fine textured with many sub-surface and surface rock fragments, and have formed in glacial till derived from volcanic rocks. Slopes range from 0 to 25 percent. Elevation is 7,665 feet MSL. Location by GPS is 45 deg. 19 min 9 sec; W111 deg. 8 min. 16 sec. The figure shown below depicts the unit, scale, skid trails, and transects. This was modified from the Timber Sale Report.



Azimuth for this set of transects was 16 degrees. Total ground disturbance was 57/121 or 47 percent, with a Confidence Interval of 39 to 56 percent.

Detrimental Disturbance = 37/121 or 31 percent. Confidence interval (Wald method) at 95 percent is 23 to 39 percent. Therefore it is strongly statistically significant that detrimental disturbance is greater than 15 percent.

Skid trail spacing was evaluated using the Timber Sale Area map (see above). After reviewing this map in the field, the existing sample transects were used to calculate average spacing using the skid trails that were crossed by the transects. Average spacing is 66 feet, which is outside the guideline of 75 feet minimum spacing.

The acreage estimate on the Timber Sale Report appears to be inaccurate. My own calculations for area give 12 acres vs. the reported six acres, which also appears to fit the Timber Sale Area map. Therefore I used the 12 acre estimate. For this unit, the landing area was outside the unit boundaries. Therefore, it's area was added to the total unit area to make it compatible with other units' calculations. This makes a total of 523,774 sq. ft. (from the Timber Sale Report) plus 75,690 sq. ft. (from the calculation below) to equal 599,464 sq. ft. (13.7 acres) for Unit 108.

Total skid trail length is 4,460 ft. Estimating twelve feet for a skid trail width gives an area of 53,520 sq. ft. or nine percent of the cutting unit. Landing area was estimated by ruler. Total landing area is 75,690 sq. ft. This is 13 % of the 13.7 acre unit.

Summing landings and skid trails gives 22 percent. This is outside our guidelines. It is probably due to skid trail spacing. Because total disturbance equaled 31 percent, I conclude off-trail use with ground-disturbing equipment contributed to, but did not cause this high detrimental disturbance.

## Discussion

The tables below provide a summary of results.

Unit	Unit Area (acres)	Total Disturbance (%)	Detrimental Disturbance (%)	Confidence Interval for Detrimental Disturbance (%)	Sample Size	
77B	9	47	33	24 - 43	97	
22P	13	46	23	17 - 31	149	
28P	12	47	23	17 - 30	140	
108	14	47	31	23 - 39	121	
Average	12	47	27.5			

Unit	Skid Trail Spacing (feet)	Skid Trail Area (% Detrimental Disturbance)	Landing Area (% Detrimental Disturbance)	Total Skid and Landing (% Detrimental Disturbance)	Non-Skid and Landing (% Detrimental Disturbance)
77B	119	9.8	7.9	17.7	15.3
22P	118	7.7	6.4	14.1	8.9
28P	118	6.2	6.0	12.2	10.8
108	66	9	13	22	9
Average	105	8.2	8.3	16.5	11.0

Note that the average contribution of skid trail and landing use to detrimental disturbance is 16.5 percent. This is a significant improvement over 1990 and 1991 results (averaging 33 percent and 56 percent, respectively). It is likely off trail use is responsible for the continued high total detrimental disturbance (averaging 27.5 percent).

The BMP review (Gallatin National Forest, 2005) concluded that environmental assessment guidelines were generally followed. This monitoring study validates this, with the exception of unit 108 where skid trail spacing was too low. This is probably the reason for the extremely-high detrimental disturbance in this unit.

Under the environmental conditions on the Gallatin Forest, using a “low ground pressure” vehicle off-trail still produced excessive detrimental disturbance. In this study removing the effects of off-trail use would reduce the detrimental disturbance from 27.5 percent to 16.5 percent. Based on these site-specific results, other data from the Gallatin National Forest, and literature, it is probable that there is not enough down-woody material to provide a protective slash mat for the vegetation types common on the Gallatin Forest, even with low-ground-pressure machinery.

Changes were made in Gallatin guidelines in 2002, restricting ANY off-trail ground disturbing activities, unless the ground is snow-covered, frozen, or covered with a protective layer of slash. See the Appendix for the current guidelines. Theoretically, this should eliminate the off-trail contribution to detrimental disturbance.

#### Conclusions

Guidelines in the Environmental Assessment are generally followed in timber sale implementation..

Total detrimental soil disturbance is still very high on Gallatin Forest timber sales, and well outside of Regional Guidelines. This is probably due to the continued use of dispersed skidding and off-trail machinery in an environment that is not conducive to its success.

There has been a long-term improvement in skid and landing design and application. Though the successful application of the Gallatin guidelines for skid trails and landings results in significant ground disturbance, it is still an improvement, if the effects of off-trail use are removed.

Timber sales planned and implemented after 2002 should have significantly less detrimental soil disturbance, because of changes in guidelines made in 2002 further restricting off-trail use.

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## Appendix – Gallatin National Forest Soil Protection Guidelines

Practice 15.26 Implement the Gallatin National Forest Soil Protection Guidelines for all ground-based activities.

**OBJECTIVE:** To protect soil productivity in tractor harvest operations on the Gallatin National Forest

**EFFECTIVENESS:** High

**Effectiveness:** Monitoring of timber sales indicate that these protection measures have minimized soil disturbance and will maintain soil productivity. (Keunnen, L., et.al., May 2000; Shovic, H., 1999). The guidelines for protection of soil productivity on the Gallatin National Forest apply where harvest practices include tractors or other ground disturbing equipment on National Forest lands. The guidelines were developed using Regional and research input and were modified for local conditions. Their purpose is to protect soil productivity for the next generation of forest vegetation. They reflect a "best estimate" of soil disturbance/soil productivity effects, based on scientific research and field experience. They may require modification for site-specific conditions and special logging practices.

### IMPLEMENTATION

Regional Guidelines and standards for protection of long term soil productivity are applied. These are dated 11/12/1999 and are titled: FSM 2500 - Watershed and Air Management R-1 Supplement 2500-99-1, Chapter 2550 - Soil Management. These guidelines allow about 75 percent less disturbance than previous guidelines. This is due to an increase in understanding of the scientific effects of soil disturbance on soil productivity. Little detrimental disturbance occurs under helicopter or skyline harvest areas. Road construction effectively removes soils from productivity. Road obliteration does not restore soil to a productive state unless the road bed is re-contoured and topsoil re-spread to a natural surface contour. For calculations involving area removed from production for roads, road width plus highly disturbed area averages 40 feet in width.

Require a systematic skid trail pattern during logging.

Use ground-based harvest systems only on slopes having sustained grades less than 30 percent.

Maintain an average of at least 75 feet between skid trails, and allow no ground-based equipment off these trails at any time, with the exception of designated landings and roads.

Scarify all skid trails with a 3-4 tooth scarifier to a depth of 6 inches and with tooth spacing about 12 inches. This will reduce compaction on designated skid trails.

The above do not apply if operating on soils with at least 12 inches of snow cover, or over soils frozen to at least 4 inches in depth. Winter logging has a negligible effect on soil or vegetation cover. Do not use mechanical ground-based systems on slopes over 30 percent, since machine impacts can be significant even with snowcover or if frozen.

Allow no mechanical site preparation equipment off established skid roads unless the soil is frozen or snow-covered as discussed above.

Site preparation for fuels will consist of broadcast burn; hand lop and scatter; trample over dry soil (see below), with at least 12 inches of slash between the machine and soil surface; or other similar measures that minimize soil disturbance. Operators will be encouraged to trample only where there is sufficient slash to protect the soil surface. Burning will be strongly considered before the latter two options are specified.

No mechanical site preparation will be specified other than for the fuels and cone preparation purposes as specified above. This will help assure productivity guidelines are met, as scarification for natural regeneration site preparation results in excessive detrimental soil disturbance.