19. Soil and Water: Productivity and Quality

Goals: Maintain soil productivity and minimize soil erosion from land-disturbing activities. Minimize sediment transported to streams from land-disturbing activities. Maintain and restore the biological, physical, and chemical integrity of Tongass National Forest waters.

Objectives: Attain Alaska Region (R-10) Soil Quality Standards. Attain State of Alaska Water Quality Standards.

Background: Implementation of Soil and Water standards and guidelines is necessary to maintain soil productivity and water quality. The Soil and Water standards and guidelines are implemented as Best Management Practices (BMPs) described in FSH 2509.22. Region 10 Soil Quality standards are documented in FSM 2554. Soil conservation practices are used to ensure that ground-disturbing activities will meet the R-10 Soil Quality standards. Typical soil conservation practices include log suspension requirements in timber harvest units and the use of full-bench and end-haul road construction techniques on landslide-prone terrain. Implementation monitoring evaluates whether or not soil conservation practices were required and implemented. Effectiveness monitoring determines whether or not the soil conservation practice used kept the ground-disturbing activity within the R-10 Soil Quality standard.

The State of Alaska water quality standards set standards for chemical, physical, and biologic parameters of waters on national forest system lands. The Forest Service in Region 10 uses best management practices and site-specific prescriptions to meet State of Alaska water quality standards when implementing ground-disturbing activities on national forest system lands.

Soil and Water Question: *Are the soil conservation practices implemented and effective in meeting Alaska Regional Soil Quality Standards and maintaining soil productivity?*

Soil quality monitoring in FY2014 focused on 1) monitoring soil conditions following the use of ground-based yarding equipment on slopes over 30 percent gradient, 2) monitoring soil compaction on the North Kuiu Stream Restoration Project equipment access trails, and 3) monitoring the amount of soil disturbance caused by off-highway vehicle (OHV) use for meat (game) retrieval on the Yakutat forelands. Monitoring reports were written for each of these three projects. Those reports are Landwehr 2014, Landwehr and Foss 2014, and Catterson 2014.

Ground-based equipment operation on slopes over 30 percent gradient

Between 1990 and 2010, most of the ground-based equipment used on the forest was operated on a slash mat on slopes less than 30 percent gradient. Under these conditions soil disturbance and detrimental soil conditions are minimized. Monitoring through the 1990s (Landwehr and Nowacki 1999) showed that, if shovel yarding followed the Soil and Water Conservation Handbook Guidelines, Region 10 Soil Quality Standards could be met and soil disturbance was typically less than 5 percent in a harvest unit. Between the year 2000 and the present day, shovel yarding that followed the guidelines resulted in an average of 3 percent soil disturbance (unpublished data).

In recent years, there has been a desire by many loggers to employ shovel yarding on steeper slopes to reduce logging costs. Shovel yarding costs are approximately half the cost of logging with a short span cable system, and approximately one third of the cost of helicopter logging (USDA Forest Service 2012). Rutting, soil displacement, and soil erosion have been noted on some shovel trails where shovel yarding has been used on steep slopes. There is a need to understand the effects to the soil resource from the use of ground-based equipment on soils on steeper slopes.

Soil and Water Photo 1. Shovel yarder on a steep slope in the Diesel Timber Sale Area.

Monitoring Results

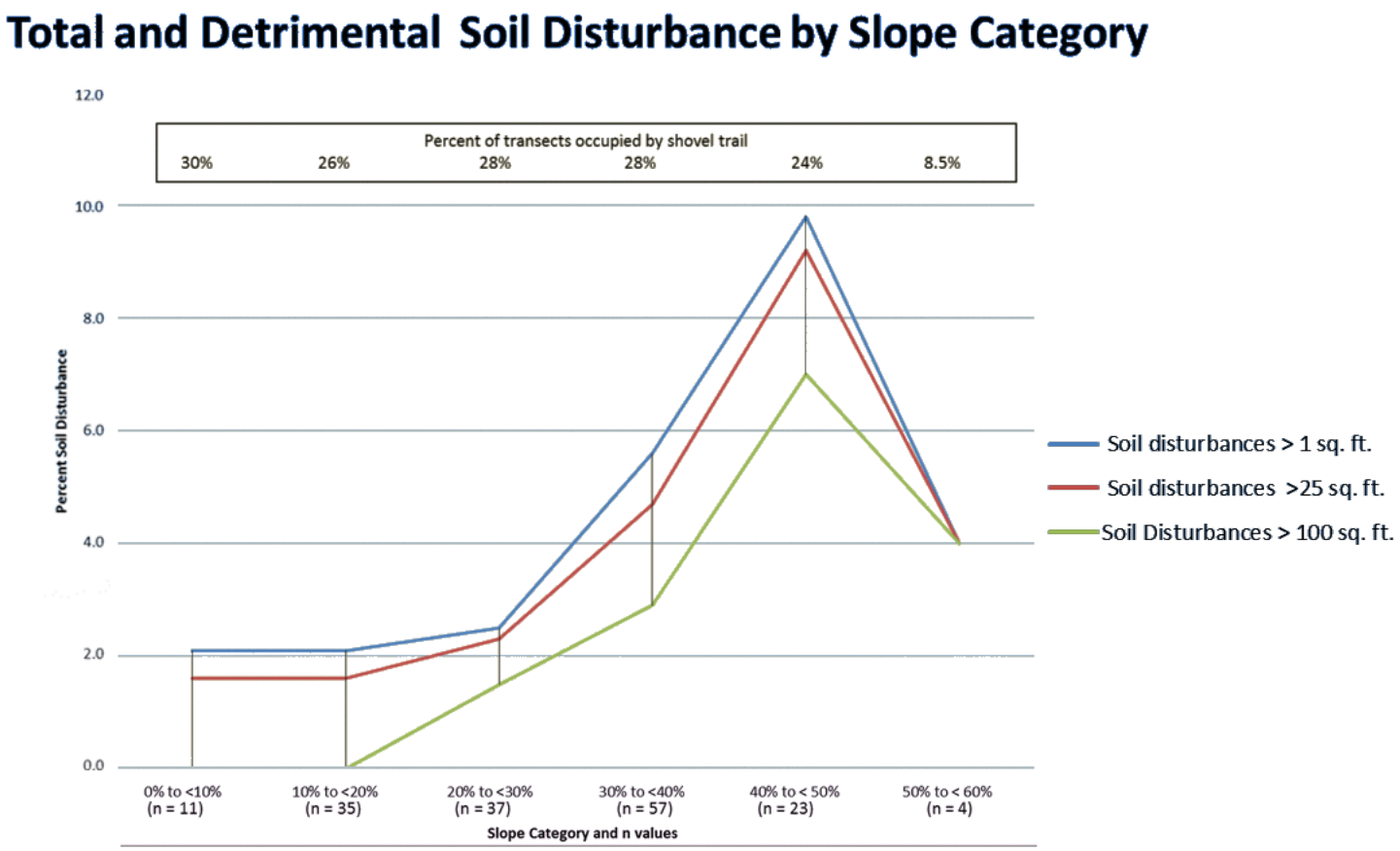
One hundred sixty-seven soil disturbance transects were completed in 10 shovel yard harvest units. Seventy-two transects were on slopes over 30 percent gradient. Based on previous work, soil disturbances were determined to be detrimental to soil productivity based on three different minimum size criteria. The minimum soil disturbance size classes used for analysis are: 1) greater than 1 square foot (Landwehr 1993), 2) greater than 25 square feet (Landwehr 2008), and 3) greater than 100 square feet (Landwehr et al. 2012). Please see the full report (Landwehr 2014) for further discussion regarding the use of the different minimum size criteria for analysis, and the methods used for analysis.

The mean values indicate that all 10 harvest units met the Region 10 soil quality standards for soil productivity based on any of the three minimum size criteria (Table 1). The averages for soil disturbances from shovel yarding in this group of steep slope units is higher (about 6 percent) than average soil disturbance previously documented for shovel yarding on gentler slopes (about 3 percent).

Soil and Water Table 1. Harvest unit mean soil disturbance for portions of 10 steep-slope-shovel-harvest units. All disturbance values include temporary roads, if present.

Sale	Unit	Number of transects	Soil disturbance >1 sq. ft. with temp road	Soil disturbance >25 sq. ft. with temp road	Soil disturbance >100 sq. ft. with temp road
Backline	Backline 4++	52	7.6	7.2	6.7
Backline	Backline 11	10	12.7	10.1	9.6
Tonka	Tonka 207*	14	11.6	10.3	3.4
Diesel	573-10	2	1	0	0
Diesel	573-83*++	9	4.2	3.8	3
Diesel	577-17	14	0.8	0.6	0
Diesel	577-18	21	1.6	1	0.3
Diesel	577-21++	25	2.2	1.6	1
Diesel	577-37	10	5.6	5.4	1
Setter Lake	598-310*	10	13.9	12.8	10.5
		AVE	6.1	5.3	3.6

*Entire harvest unit was sampled.
++ Temporary roads are included in the disturbance values for these harvest units



Soil and Water Figure 1. Soil disturbance by slope class and percent of each slope class occupied by shovel trails.

When the transect data from this monitoring are sorted by 10 percent slope-classes, the data clearly shows an increase in the amount of soil disturbance with increasing slope (Figure 1). In the 50 to 60 percent slope class, data is very limited (n = 4) but all soil disturbances we documented in this slope class were greater than 100 square feet in size. Figure 1 shows only 4 percent detrimental soil conditions in this slope class versus more than 8 percent in the 40 to 50 percent slope class. This is because only 8.5 percent of the transects crossed shovel trails in this slope class versus 24 percent in the 40 to 49 percent slope class. The text box in Figure 1 shows the percent of the slope class area occupied by shovel trails.

If shovel yarding is restricted to slopes less than 30 percent gradient, soil disturbance and detrimental soil conditions can be kept very low, typically less than 3 to 4 percent of a harvest area (Figure 1).

The soil disturbance data was also evaluated using harvest unit mean soil disturbance as a data point (versus using each transect as a data point), the preferred method based on Landwehr and Nowacki (1999). Table 2 displays the mean soil disturbance based on 6 harvest unit areas with slopes less than 30 percent gradient and 6 harvest unit areas with slopes over 30 percent gradient.

Operator skill level, slope length, and soils play a role in the amount of soil disturbance from shovel yard operations, especially on steeper slopes. All operators caused 2 to 8 times as much soil disturbance on slopes over 30 percent when compared to operations on slopes less than 30 percent gradient.

Soil and Water Table 2. Soil disturbance by slope class using harvest unit means as data points.

Slope class	Number of harvest units	Soil disturbances > 1 square foot (percent of unit)	Soil disturbances > 25 square feet (percent of unit)	Soil disturbances > 100 square feet (percent of unit)
0 to 29%	6	2.3	2.0	1.2
30 to 55%	6	8.4	7.4	4.8

Validation of Landwehr's 1993 and 2009 definitions of detrimental soil conditions began in 2007 and continues today. After re-monitoring soil disturbance in 7 harvest units after 15 years of recovery, Landwehr (2008) stated that soil disturbances less than 25 square feet in size are difficult to find after 15 years and are likely not detrimental to soil productivity. Based on these results, the transect data collected for this report documented the size of each soil disturbance and reported detrimental soil conditions based on the 25 square foot minimum size criteria.

Further retrospective monitoring by Landwehr et al. (2012) found that after 50 years of recovery, it is doubtful that soil disturbances less than 100 square feet in size are affecting soil productivity on most productive soils. Based on these findings, the soil disturbance data presented in this report was also analyzed based on a 100 square foot minimum size criteria (Table 2).

Soil and Water Photo 2. Pictures of a cut slope on a shovel trail in Backline Unit 11 (left). Re-contoured cut and fill shovel trail on the steep slope in the Setter Lake harvest unit (right).

Shovel trails typically occupy 25 to 30 percent of the area shovel yarded. If one-third of the trails result in detrimental soil conditions like we have seen on slopes over 40 percent gradient (Figure 1), then the harvest area will likely experience detrimental soil conditions occupying at least 10 percent of the harvest area. If the harvest unit also has temporary roads, the total amount of detrimental soil conditions will be greater.

Action Plan

If a decision is made for economic and logistical reasons to allow ground-based equipment on slopes over about 35 percent gradient, the trails should be agreed upon by the shovel operator and sale administrator and/or in consultation with a soil scientist. If allowed, a plan should be made for rehabilitating detrimental soil conditions on trails approved on slopes over approximately 35 percent gradient.

This monitoring identified differences in detrimental soil conditions as a result of shovel yarding on different slope classes. The differences appear to be significant at 90 percent confidence; however, the variability is wide in several slope classes and our values for precision were not met in several slope classes. Soil disturbance monitoring should continue to add more transect data to the database to reduce the standard error of the mean in most slope classes.

It seems prudent at this time that the forest could adopt minimum size criteria of 25 square feet with a very low risk of missing any detrimental soil conditions. On slopes less than 30 percent gradient and on highly productive soils, disturbances up to 100 square feet are likely not detrimental. Thus until further retrospective monitoring is accomplished and soil specific detrimental soil conditions are identified, this report recommends using the 25 square foot minimum size criteria for detrimental soil conditions with the exception of detrimental erosion and detrimental displacement, which are already identified as a minimum of 100 square feet.

Additional work should be done to identify soil conditions that are reducing growth of desired vegetation in older young-growth stands. This work will help define minimum size criteria for detrimental soil conditions on soils with different inherent productivities. As the forest transitions to young-growth management, it will be important to understand soil conditions that limit or reduce soil productivity and conditions that promote recovery of soil productivity. Recovery of soils damaged by ground-based equipment is being monitored with photo points at several sites on Prince of Wales Island (see the 2013 Annual Tongass National Forest Monitoring and Evaluation Report).

North Kuiu Stream Restoration access trails compaction study

Stream restoration on the Tongass National Forest often requires placement of large woody debris in the stream channel, along stream banks, and on the floodplain. The process involves identifying a source of large woody debris, harvesting the trees, transporting them to the stream and placing them in strategic locations to simulate natural stream structural components. Transporting the logs or logs with root-wads attached is often accomplished with heavy-lift helicopters. When heavy-lift helicopters are not available or are too expensive, the large woody debris is moved to the stream by ground-based equipment.

The North Kuiu Island stream restoration project required about 1,200 pieces of wood. Most of this wood was moved to the stream with ground-based equipment. To move the wood to the stream, six access trails approximately 10 meters wide were cut through 46 year old young-growth. The wide trails were needed for the machines to skid or swing the wood to the stream, similar to a shovel yarding scenario. Unlike shovel yarding, where 1 or 2 passes are made over a shovel trail, the number of passes required to move wood to the stream for the Kuiu project was typically more than 50 with some trails receiving more than 100 passes (Whitacre 2014).

Ground-based equipment operating on wet soil conditions can result in soil compaction. Soil compaction can lead to a decline in the productivity of a site. Fine-textured soils are more susceptible to soil compaction than coarse-textured soils. The access trails created for the North Kuiu Stream Restoration Project crossed alluvial soils belonging to the Tonowek and Tuxekan Soil Series. These alluvial soils are typically well-drained and coarse-loamy in texture (silt loam or fine sandy loam surface textures), often free of gravels in the upper part, moist year round, and can be considered somewhat susceptible to soil compaction when wet. The Tonowek soils are younger soils (Entisols) and typically occur in a floodplain location. The Tuxekan soils are older more developed soils (Spodosols) and typically occur on a terrace or stable spot on a floodplain.

Monitoring Results

We monitored soil bulk density on about 1,000 meters of equipment trails used to deliver wood to the west fork and mainstem Saginaw creeks. The trails average about 10 meters in width and were created by felling 46 year old young-growth trees and laying down a nearly continuous mat of cull logs and slash. Under repeated passes with equipment the cull logs and slash were forced into the soil to a depth of 20 to 30 centimeters, altering the structure of the O, E, and upper B horizons. The puncheon trail was fluffed after stream restoration was complete. Fluffing broke up the dense slash mat and likely loosened the upper layers of soil that the slash had penetrated. Fluffing did not move all of the slash and some slash is still evident in the upper mineral soil horizons.

Soil and Water Photo 3. Access trail at sample point FP1 (left). Access trail at sample point FP3 (right).

Soil bulk density samples indicate that overall the soils under the access trails are not compacted (Table 3). Bulk density values from three of the individual sites on floodplain soils did indicate a 34 percent increase in bulk density under the access trails at a depth of 7.62 to 15.24 centimeters. At the depth of 15.24 to 22.86 centimeters, only two of these sites showed a 47 percent increase in bulk density. The floodplain soils were typically wetter than the terrace soils and a water table was encountered at two of the floodplain sites we sampled. It is likely that soils under a small portion of the shovel trails are detrimentally compacted according to the Region 10 soil quality standards.

Similar to other bulk density sampling on the Tongass National Forest none of the samples we analyzed in this study had bulk density values that exceed published root restriction initiation values or root restriction values for these alluvial soils. There are several reasons for the lack of detrimental soil compaction in most Tongass forest soils. First is the inherent low natural bulk density values of Tongass soils due to relatively low clay content (less than 20 percent clay), the presence of thick duff layers and high organic matter content in the upper layers, and the relatively high rates of soil turbation[1] due to windthrow and rooting of trees and other vegetation.

The north Kuiu stream restoration access trails represent equipment trails with many passes of equipment on silt loam and fine sandy loam soils. The trails may be similar to what we can expect to see on a long primary skid trail used to yard timber from a large young-growth stand on similar soils. As the forest transitions to young-growth management, there is a need to understand the potential effects to soils from skid trails of this type. This monitoring contributes to that understanding.

[1] Soil mixing and turning due to disturbance

Soil and Water Table 3. Fine earth bulk density values for each depth class on and off access trails. Data shown for all 10 sites (40 samples), floodplain sites (16 samples) and terrace sites (24 samples) sorted by depth class.

Location access trail or undisturbed	Depth class (centimeters)	Mean fine earth bulk density (grams/cc)	Standard error	Standard error expressed as percent of mean	90 percent confidence interval	Significantly different
All sites	n=10					
Undisturbed	7.6 to 15.2	0.66	0.04	6%	0.06	
Access trail	7.6 to 15.2	0.71	0.06	8%	0.09	No
Undisturbed	15.2 to 22.9	0.69	0.04	6%	0.07	
Access trail	15.2 to 22.9	0.69	0.07	10%	0.11	No
Floodplain soils	n=4					
Undisturbed	7.6 to 15.2	0.60	0.06	9%	0.09	
Access trail	7.6 to 15.2	0.81	0.08	10%	0.13	No
Undisturbed	15.2 to 22.9	0.67	0.06	8%	0.09	
Skid trail	15.2 to 22.9	0.82	0.13	16%	0.21	No
Terrace soils	n=6					
Undisturbed	7.6 to 15.2	0.69	0.05	8%	0.09	
Skid trail	7.6 to 15.2	0.63	0.08	12%	0.13	No
Undisturbed	15.2 to 22.9	0.70	0.05	8%	0.10	
Skid trail	15.2 to 22.9	0.60	0.05	9%	0.09	No

The use of cull logs and slash to blanket the soil under equipment routes appears to be very effective at preventing detrimental soil compaction. This monitoring, combined with other bulk density monitoring on the forest (Alexander 1990, Foss and Landwehr 2006, Landwehr and Silkworth 2011, Landwehr et al. 2012) support the statement that most Tongass soils are not susceptible to soil compaction from equipment under normal (where a puncheon mat is used) forestry practices.

Action Plan

Re-vegetation of the access trails should be monitored after 5 years to determine if the high slash load is negatively affecting re-vegetation by the desired vegetation (in this case, conifers). After 10 years of growth, the conifers could be monitored to determine if the slash load is affecting growth of the desired vegetation. If tree growth is measured on the access trails, it could be compared to growth on similar soils at the root-wad and log harvested site on the Security Bay Road.

Yakutat forelands meat retrieval OHV trails

The Access and Travel Management Plan for the Yakutat District restricts OHV use to designated trails with one exception. OHV use is allowed off trail for meat retrieval “if they can do so without causing resource damage.” Damage is described as “exposing soil or causing soil displacement on stream banks, cutting living vegetation to create a path, or the creation of ruts 3 inches deep and 20 feet long” (USFS 2008). This monitoring project used a GPS to map OHV trails and create photo points to document soil disturbance and recovery (Catterson 2014).

Monitoring Results

We do not have enough information yet to make management recommendations regarding game retrieval. It is clear that vegetation and soil disturbance can occur from the limited ATV use associated with game

retrieval, but it also seems likely that better-drained areas where sweet gale and willow are dominant can support game retrieval. More resilient plant communities were located adjacent to all the resource damage we observed. User education may be a way to reduce resource damage. Due to the government shut down, we were unable to monitor other sites along the road where game retrieval had occurred. Our sample may be biased in that only the worst trails were easy to find.

Action Plan

1. Continue to monitor game retrieval sites on the forelands including both new trails and those already inventoried.
2. Use the information we collect to make recommendations to users, perhaps in the form of a pamphlet, about how to avoid resource damage.
3. Use the new Yakutat vegetation map to identify areas vulnerable to resource damage and consider additional restrictions in those areas.
4. Consider restoration projects in areas where resource damage has occurred as a result of off designated trail OHV use.

Citations

Catterson, N. 2014. Unpublished. 2013 game retrieval monitoring. USDA Forest Service, Alaska Region, Tongass National Forest Yakutat Ranger District.

Landwehr, D.J. 1993. Unpublished. Soil disturbance monitoring on the 89-94 KPC long-term sale area. Revised methodologies and emphasis areas. USDA Forest Service, Alaska Region, Ketchikan Area.

Landwehr, D.J. and G. Nowacki. 1999. Unpublished. Statistical review of soil disturbance transect data collected on the Ketchikan area, Tongass National Forest. USDA Forest Service, Alaska Region, Tongass National Forest.

Landwehr, D.J. 2008. Unpublished. Soil quality monitoring on the Tongass National Forest. The Tongass' interpretation of the Region 10 soil quality standards. USDA Forest Service, Alaska Region, Tongass National Forest.

Landwehr, D.J. 2009. Unpublished. Soil quality monitoring on the Tongass National Forest. Protocols updated from 1993. USDA Forest Service, Alaska Region, Tongass National Forest.

Landwehr, D.J., D.R. Silkworth and J.V. Foss. 2012. Unpublished. Soil quality monitoring on the Tongass National Forest. The Tongass' Interpretation of the Region 10 soil quality standards. Part 2. Summarizing 4 years of data collection. USDA Forest Service, Alaska Region, Tongass National Forest.

Landwehr, D.J. and J.V. Foss. 2014. Unpublished. Soil quality on the Tongass National Forest. Results of compaction studies conducted on the Kuiu Stream Restoration access trails. USDA Forest Service, Alaska Region, Tongass National Forest.

Whitacre, H. 2014. Unpublished. North Kuiu Stream Restoration Project updates. USDA Forest Service, Tongass National Forest, Petersburg Ranger District.

USDA Forest Service. 2012. Big Thorne draft environmental impact statement. Management Bulletin. R10-MB-736. Thorne Bay, AK: USDA Forest Service, Tongass National Forest, Thorne Bay Ranger District, p. 3-25.