# Post-fire Inventory of Instream Large Wood in an Old Growth Watershed, Little Santeetlah River, Nantahala National Forest, NC

**Report prepared by:**
**Craig Roghair, Colin Krause, and C. Andrew Dolloff**
**September 2017**

**USDA Forest Service**
**Southern Research Station**
**Center for Aquatic Technology Transfer**
**1710 Research Center Dr.**
**Blacksburg, VA 24060**
**540-230-8126**
**http://www.srs.fs.usda.gov/catt/**

Introduction ..... 2
Methods ..... 2
Sample site description ..... 2
River kilometer (rkm) points ..... 3
LW inventory ..... 3
Riparian fire intensity ..... 3
Fire suppression activity ..... 4
Results ..... 4
LW inventory ..... 4
Riparian fire intensity ..... 4
Fire suppression activity ..... 4
Discussion ..... 5
Literature Cited ..... 6
Figures ..... 8
Tables ..... 14

## List of Figures

Figure 1. Area burned by Maple Springs Fires in fall, 2016 ..... 8
Figure 2. Inventory reach with river kilometer markers on Little Santeetlah Creek ..... 9
Figure 3. Number of pieces of LW per km in Little Santeetlah Creek as observed in 1988 and 2017 ..... 10
Figure 4. Counts of LW from 0.25 km reaches in Little Santeetlah Creek in 1998 and 2017 ..... 11
Figure 5. Riparian fire intensity ..... 12
Figure 6. Fire suppression activity observed near rkm 0.50 ..... 13

## List of Tables

Table 1. Categories used for LW inventories in 1988 and 2017 ..... 14
Table 2. Fire intensity categories used during the 2017 post-fire inventory ..... 14
Table 3. Large wood in each of 5 size categories in Little Santeetlah Creek, 1988 ..... 15
Table 4. Large wood in each of 5 size categories in Little Santeetlah Creek, 2017 ..... 16

## Introduction

Large wood influences a wide variety of features and functions in stream channels including channel morphology, bank and bed erosion, and habitat complexity for microbes, macroinvertebrates, and fish as well as a host of amphibians, reptiles, birds, and mammals (Gregory et al. 2003; Gurnell et al. 2005; Gurnell et al. 2002; Lawrence et al. 2013). A number of processes, including wildfire, can impact recruitment of large wood to stream channels. Some natural processes such as hurricanes, floods, windthrow, and hillslope failures are sporadic and result in rapid accumulation of considerable amounts of large wood (Dolloff et al. 1994; Gregory et al. 2003; Hairston-Strang and Adams 1998; Lienkaemper and Swanson 1987; May and Gresswell 2003). Others, such as insects, disease, and wildfire result in slower accumulation over longer periods of time (Benda and Sias 2003; Evans et al. 2012; Gregory et al. 2003; Marcus et al. 2011; Neary et al. 2005). Despite the large and growing body of knowledge on the effects of wildfire on terrestrial systems, relatively little is known of its impacts on aquatic systems (Flitcroft et al. 2016; Gresswell 1999; Neary et al. 2005) and studies documenting fire effects on large wood (LW) recruitment and retention are relatively few, particularly for the eastern U.S. (Krause et al. 2014).

The Maple Springs wildfire on the Nantahala National Forest, NC was one of over 2 dozen wildfires that burned in the mountains of western North Carolina and eastern Tennessee in the fall of 2016. The Maple Springs fire burned over 3,100 hectares (7,700 acres), with a western flank along the Little Santeetlah Creek (Figure 1). In 2017, the Nantahala National Forest partnered with the USDA Forest Service, Southern Research Station (SRS), Center for Aquatic Technology Transfer (CATT) to complete a post-fire inventory of LW loading, riparian fire intensity, and fire suppression activity on Little Santeetlah Creek. The SRS had previously collected LW data in Little Santeetlah Creek as part of a basin-wide assessment completed in 1988 (Flebbe and Dolloff 1995), allowing us to also examine for changes in LW loading over time.

## Methods

### Sample site description

Little Santeetlah Creek flows east through the Joyce Kilmer-Slickrock Wilderness Area from an elevation of approximately 1,340 m to its confluence at 620 m elevation with Santeetlah Creek over a distance of 6.8 km (Figure 1). Its watershed is entirely old growth containing a mix of forest types, including oak-chestnut, cove hardwoods, oak-pine, northern hardwoods, and grassy and heath balds (Zink et al. 2012). The riparian forest along Santeetlah Creek is over 350 years old and has historically provided a high volume of instream large wood (Hedman et al. 1996). Entirely under Wilderness

management by the Forest Service, the watershed has little development except for several hiking trails and a paved road to a parking and picnic area approximately 1 km upstream of the Santeetlah Creek confluence. Little Santeetlah Creek is designated trout water by North Carolina Department of Environmental Quality and supports a cold water fish community containing Rainbow Trout (*Oncorhynchus mykiss*) at lower elevations and Brook Trout (*Salvelinus fontinalis*) at higher elevations (Flebbe and Dolloff 1995; Roghair et al. 2017).

### River kilometer (rkm) points

We inventoried Little Santeetlah Creek from its confluence with Santeetlah Creek to 6.0 km upstream in 1988, and 6.25 km upstream in 2017. In 1988, the inventory team used a hipchain measuring device to record distance from the confluence with Santeetlah Creek. In 2017, we used the National Hydrography Dataset high resolution (1:24,000) streams layer and ArcMap Construct Points tool to create river kilometer (rkm) points at 0.25 km intervals for Little Santeetlah Creek (Figure 2), and used the rkm points to reference our location in the stream with a Garmin Oregon GPS. Landmarks recorded in the 1988 dataset indicated that our 2017 rkm points were consistent with the 1988 hipchain measurements.

### LW inventory

In 1988, a 3-person team completed a streamwide inventory of fish and habitat in Little Santeetlah Creek, which included counts of LW (Flebbe and Dolloff 1995). The team entered Little Santeetlah Creek at rkm 0.0 and waded upstream to rkm 6.0, counting and recording the number of pieces of LW in each habitat unit (e.g. pool, riffle). We used the 1988 dataset to sum the total pieces of LW in each of 5 size categories (Table 1) within 0.25 km reaches from rkm 0.0 to rkm 6.0.

In 2017, a 2-person team entered Little Santeetlah Creek at rkm 0.0 and waded upstream while counting and tallying LW in each of 5 categories (Table 1). At rkm 0.25 the team summed the total pieces in each category and recorded the totals in an electronic data form. The team proceeded upstream counting and recording LW for each 0.25 km reach until they reached rkm 6.25.

### Riparian fire intensity

At each rkm point (i.e. every 0.25 km) the inventory team assessed the intensity of fire within 30 m of the stream. Standing at the rkm point the team looked upstream, right, left, and downstream as far as the line of sight would allow and assigned riparian fire intensity to one of four categories (Table 2). The team also recorded four photographs at each rkm point to document the upstream, right, left, and downstream views. Right and left were as facing in an upstream direction.

### Fire suppression activity

As the inventory team waded upstream they noted evidence of fire suppression activities such as fire-retardant use, fire-ignition activity (e.g. ping pong balls), pieces of LW that had been cut from or removed from the stream, and fire line clearing within 30 m of the stream channel. The team recorded a GPS waypoint, a photo and a comment on the datasheet for each observation.

## Results

### LW inventory

In 1988, we counted a total of 579 pieces of LW in 6.0 km, for an average of 97 pieces per km (Table 3, Figure 3). In 2017, we counted a total of 2,159 pieces of LW in 6.25 km of stream, for an average of 345 pieces per km (Table 4, Figure 3). Pieces of LW in the smaller diameter size classes (<55 cm diameter) were most abundant in both years (Tables 3 and 4, Figure 4), though we did encounter over 225 pieces in the largest size class (> 55 cm diameter, > 5 m long) in 2017. The amount of LW we found in 2017 was 3.7 times greater than the amount counted in 1988. The amount of LW in individual size categories increased by 3- to 6-times over the 1988 tallies, with the largest increase in LW3 (10 – 55 cm diameter, >5 m long).

### Riparian fire intensity

Fire damage in the riparian was almost exclusively limited to the right (northeast) side of the stream. The only fire damage noted on the left side of the stream was in the area of rkm 2.75. Fire damage for the right side of the stream was not evident at 8 of the 25 rkm points, was low at another 8 points, and was moderate at 9 points. We did not find high fire intensity at any rkm markers (Table 4, Figure 5).

### Fire suppression activity

We noted fire suppression activity within 3 reaches between rkm 0.0 and rkm 1.0, but did not encounter any fire suppression activity further upstream. Fire suppression activity was limited to cutting of downed trees in and near the stream channel where the trail or road came close to the stream (Table 4, Figure 6).

## Discussion

The influence of wildfire on ecological processes in streams is not well understood, particularly in the eastern U.S. Post-wildfire studies from the western U.S. show that LW can increase or decrease in the short- and long-term, with impacts largely regulated by fire intensity, severity, and size (Gresswell 1999). Wildfire results in increases in LW when fire-killed trees topple into the stream channels, or when wood is delivered to channels by mass wasting events such as landslide or debris flows following wildfires (Burton 2005; Flitcroft et al. 2016; Neary et al. 2005). Wildfire causes decreases in LW when spanning pieces are removed from the channel during fire line preparation, when wood is burned as wildfire passes through stream corridors, or when wood accumulations are removed post-fire from areas near infrastructure such as bridges, roads, or buildings (Neary et al. 2005).

The fall 2016 wildfire and related fire suppression activities had little measureable effect on LW loading in Little Santeetlah Creek. The fire intensity, severity, and size were not sufficient to cause LW within or across the channel to burn. Fire line clearing in or near the stream channel was extremely limited and restricted to a small portion of the total stream length, and other fire suppression activities such as the removal of spanning pieces of wood or use of retardant were not observed, though our inventory was several months post-fire. Live trees within the riparian area did not suffer extensive fire damage so the prospect of fire-related changes in LW recruitment in the future is limited as well. Regardless, the first step in understanding the impacts of fire on LW in streams is an immediate post-fire inventory. We encourage similar post-fire inventories to further develop our understanding of fire effects on eastern streams.

Perhaps the most surprising result was the increase in LW from the 1988 to the 2017 inventory. Over the 29-year interval between inventories the total amount of LW nearly quadrupled, with large increases in every size category. Although the watershed is old growth and is managed as Wilderness, it is still impacted by disturbances such as disease, insects, and changes in climate that can change large wood loading and affect fire intervals and intensity. For example, the exotic insect Hemlock Wooly Adelgid invaded the watershed sometime in the early 2000's (USFS 2006) and hemlock is now contributing LW at an increased rate as dead trees shed branches, break off, or topple into the stream (Brandon Fair, CATT pers. obs.). Hemlock has historically been an important contributor to the large wood load in many southern Appalachian streams (Hedman et al. 1996), but its contribution will come to an end as the remaining hemlocks decline in abundance over the next several years. We recommend monitoring LW in Little Santeetlah Creek at regular intervals given that changes occurring in its old growth riparian forest likely will alter LW dynamics for decades to come.

## Literature Cited


Benda, L. E., and J. C. Sias. 2003. A quantitative framework for evaluating the mass balance of in-stream organic debris. Forest Ecology and Management 172(1):1-16.

Burton, T. A. 2005. Fish and stream habitat risks from uncharacteristic wildfire: Observations from 17 years of fire-related disturbances on the Boise National Forest, Idaho. Forest Ecology and Management 211(1-2):140-149.

Dolloff, C. A., P. A. Flebbe, and M. D. Owen. 1994. Fish Habitat and Fish Populations in a Southern Appalachian Watershed before and after Hurricane Hugo.

Evans, D. M., C. A. Dolloff, W. M. Aust, and A. M. Villamagna. 2012. Effects of Eastern Hemlock Decline on Large Wood Loads in Streams of the Appalachian Mountains. Journal of the American Water Resources Association 48(2):266-276.

Flebbe, P. A., and C. A. Dolloff. 1995. Trout Use of Woody Debris and Habitat in Appalachian Wilderness Streams of North Carolina.

Flitcroft, R. L., and coauthors. 2016. Wildfire may increase habitat quality for spring Chinook salmon in the Wenatchee River subbasin, WA, USA. Forest Ecology and Management 359:126-140.

Gregory, S. V., K. L. Boyer, and A. M. Gurnell. 2003. The ecology and management of wood in world rivers. American Fisheries Society, Bethesda, MD.

Gresswell, R. E. 1999. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American Fisheries Society 128(2):193-221.

Gurnell, A., K. Tockner, P. Edwards, and G. Petts. 2005. Effects of deposited wood on biocomplexity of river corridors. Frontiers in Ecology and the Environment 3(7):377-382.

Gurnell, A. M., H. Piegay, F. J. Swanson, and S. V. Gregory. 2002. Large wood and fluvial processes. Freshwater Biology 47(4):601-619.

Hairston-Strang, A. B., and P. W. Adams. 1998. Potential large woody debris sources in riparian buffers after harvesting in Oregon, USA. Forest Ecology and Management 112(1-2):67-77.

Hedman, C. W., D. H. VanLear, and W. T. Swank. 1996. In-stream large woody debris loading and riparian forest seral stage associations in the southern Appalachian Mountains. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 26(7):1218-1227.

Krause, C., C. Roghair, and C. A. Dolloff. 2014. Effects of Prescribed Burning on Large Wood Loading in Coastal Plain Streams on the Francis Marion National Forest, South Carolina, 2013. Unpublished File Report. USDA Forest Service, Southern Research Station, Blacksburg, VA. Available: https://www.srs.fs.usda.gov/catt/pdf/sc/2014_sc_catt_report.pdf (Oct 2017).

Lawrence, J. E., V. H. Resh, and M. R. Cover. 2013. Large-wood loading from natural and engineered processes at the watershed scale. River Research and Applications 29(8):1030-1041.

Lienkaemper, G. W., and F. J. Swanson. 1987. Dynamics of large woody debris in streams in old-growth douglas-fir forests. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 17(2):150-156.

Marcus, W. A., J. Rasmussen, and M. A. Fonstad. 2011. Response of the Fluvial Wood System to Fire and Floods in Northern Yellowstone. Annals of the Association of American Geographers 101(1):21-44.

May, C. L., and R. E. Gresswell. 2003. Large wood recruitment and redistribution in headwater streams in the southern Oregon Coast Range, USA. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 33(8):1352-1362.

Neary, D. G., K. C. Ryan, and L. F. DeBano. 2005. Wildland fire in ecosystems: effects of fire on soils and water. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 250 pages.

Roghair, C., C. Krause, T. Franklin, J. Farmer, and C. Dolloff. 2017. Inventory and Monitoring of Brook Trout in the Santeetlah Creek Watershed, Nantahala National Forest, 2016 - 2017. Unpublished File Report. USDA Forest Service, Southern Research Station, Blacksburg, VA. Available: https://www.srs.fs.usda.gov/catt/pdf/nc/2017_nc_bkt_edna_catt_report.pdf (Oct 2017).

USFS (U.S. Forest Service). 2006. Spread of HWA from 1951 to 2006. Unpublished map animation. USDA Forest Service, Northeastern Area, Newtown Square, PA. Available: http://na.fs.fed.us/fhp/hwa/maps/distribution.shtm (Oct 2017).

Zink, J. M., G. D. Jennings, and G. A. Price. 2012. Morphology Characteristics of Southern Appalachian Wilderness Streams. Journal of the American Water Resources Association 48(4):762-773.

## Figures

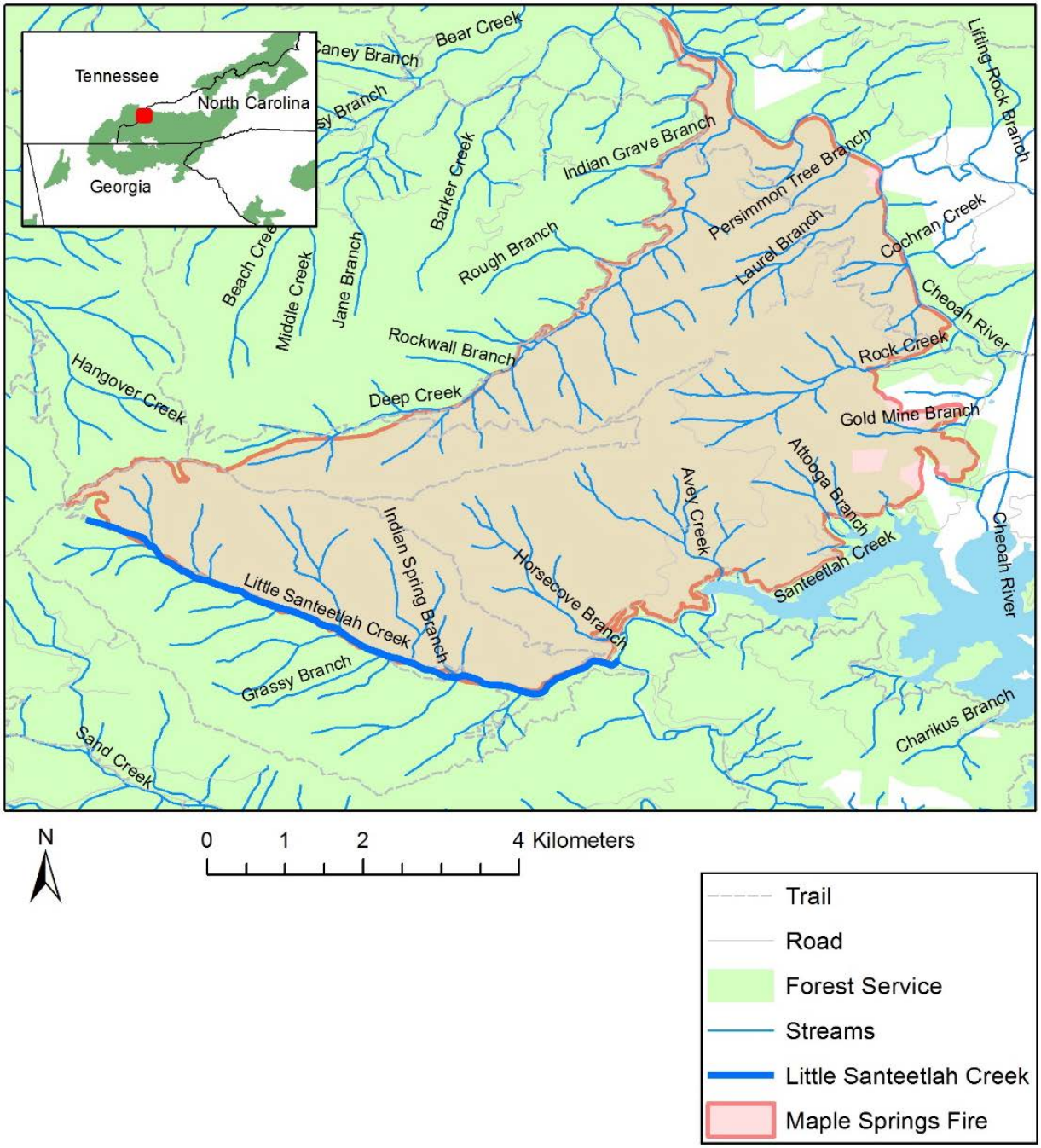


Figure 1. Area burned by Maple Springs Fires in fall, 2016. Little Santeetlah Creek is shown in bold blue.

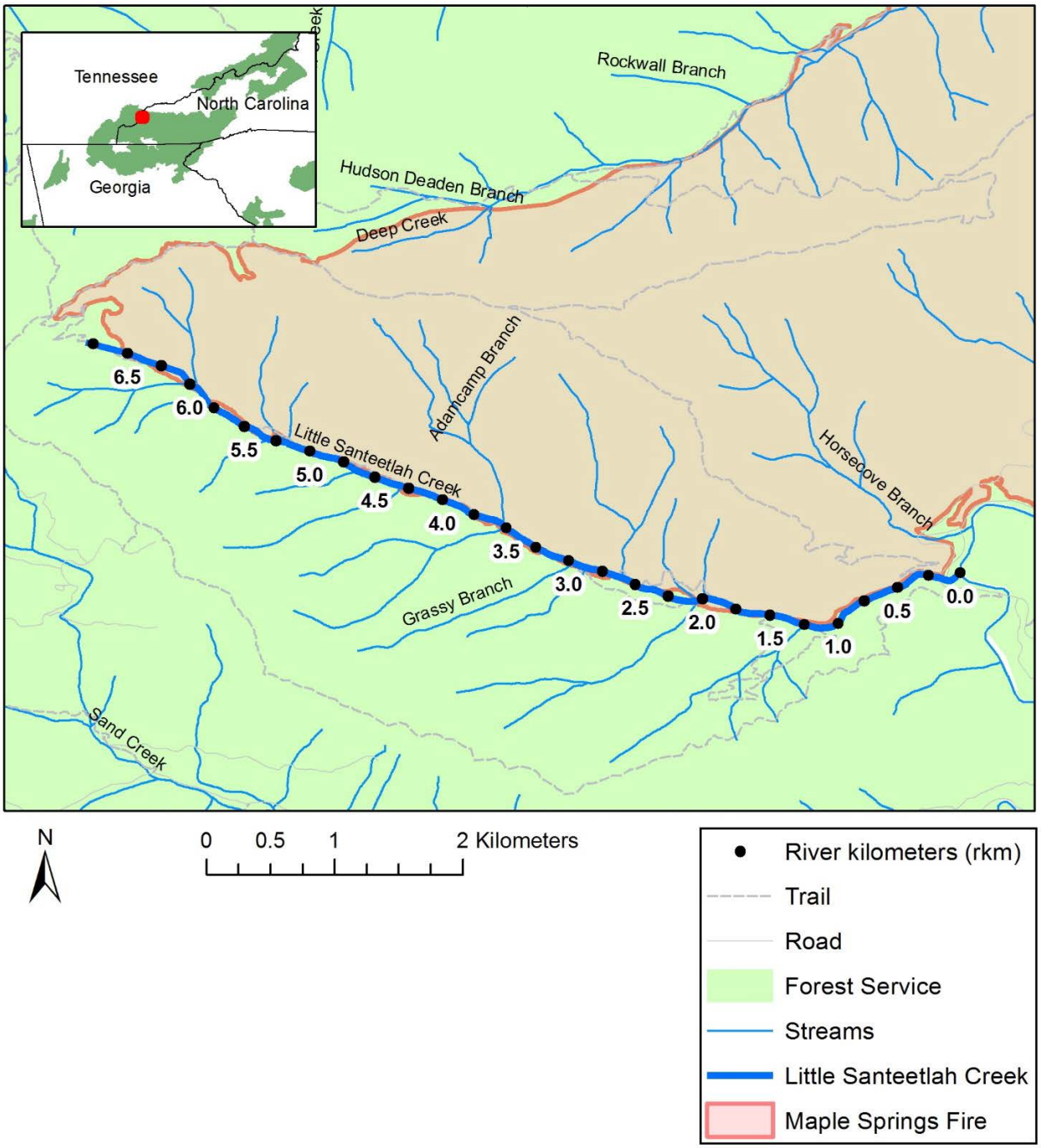


Figure 2. Inventory reach with river kilometer markers on Little Santeetlah Creek. The 1988 stream inventory ended at rkm 6.0 and the 2017 inventory at rkm 6.25.

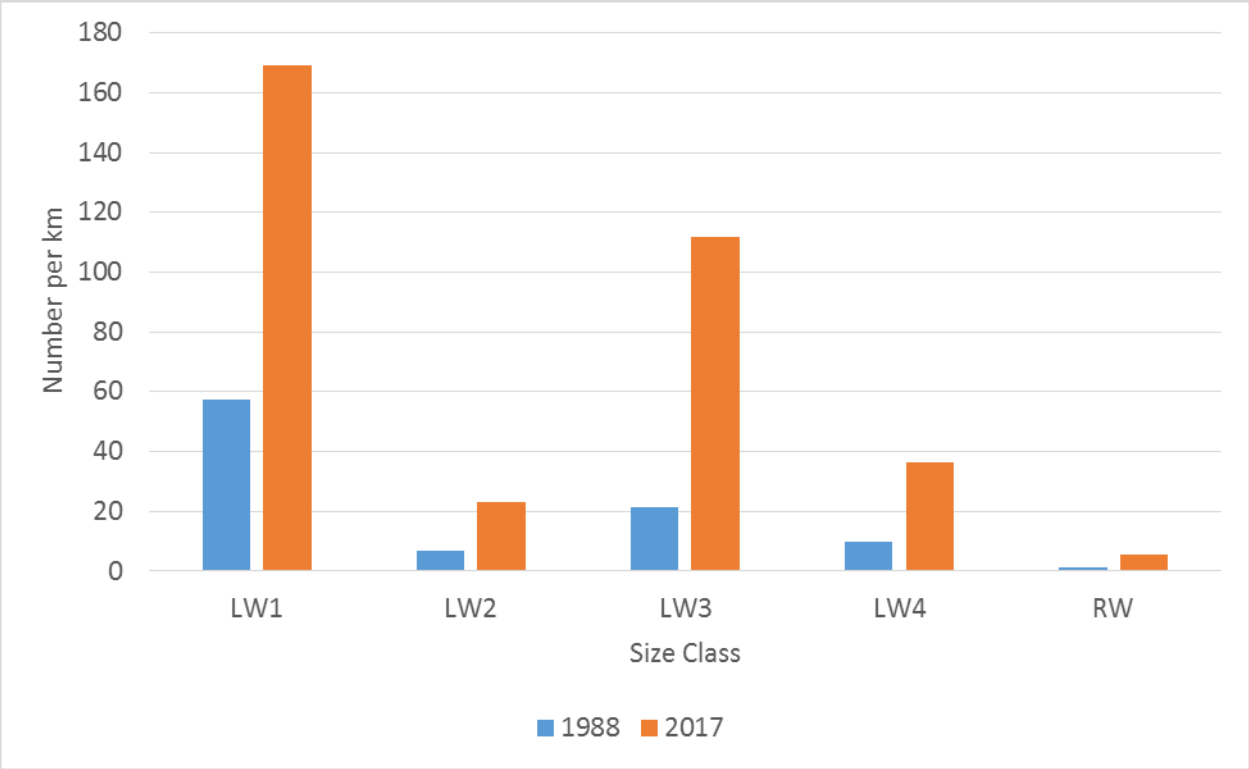


Figure 3. Number of pieces of LW per km in Little Santeetlah Creek as observed in 1988 and 2017.

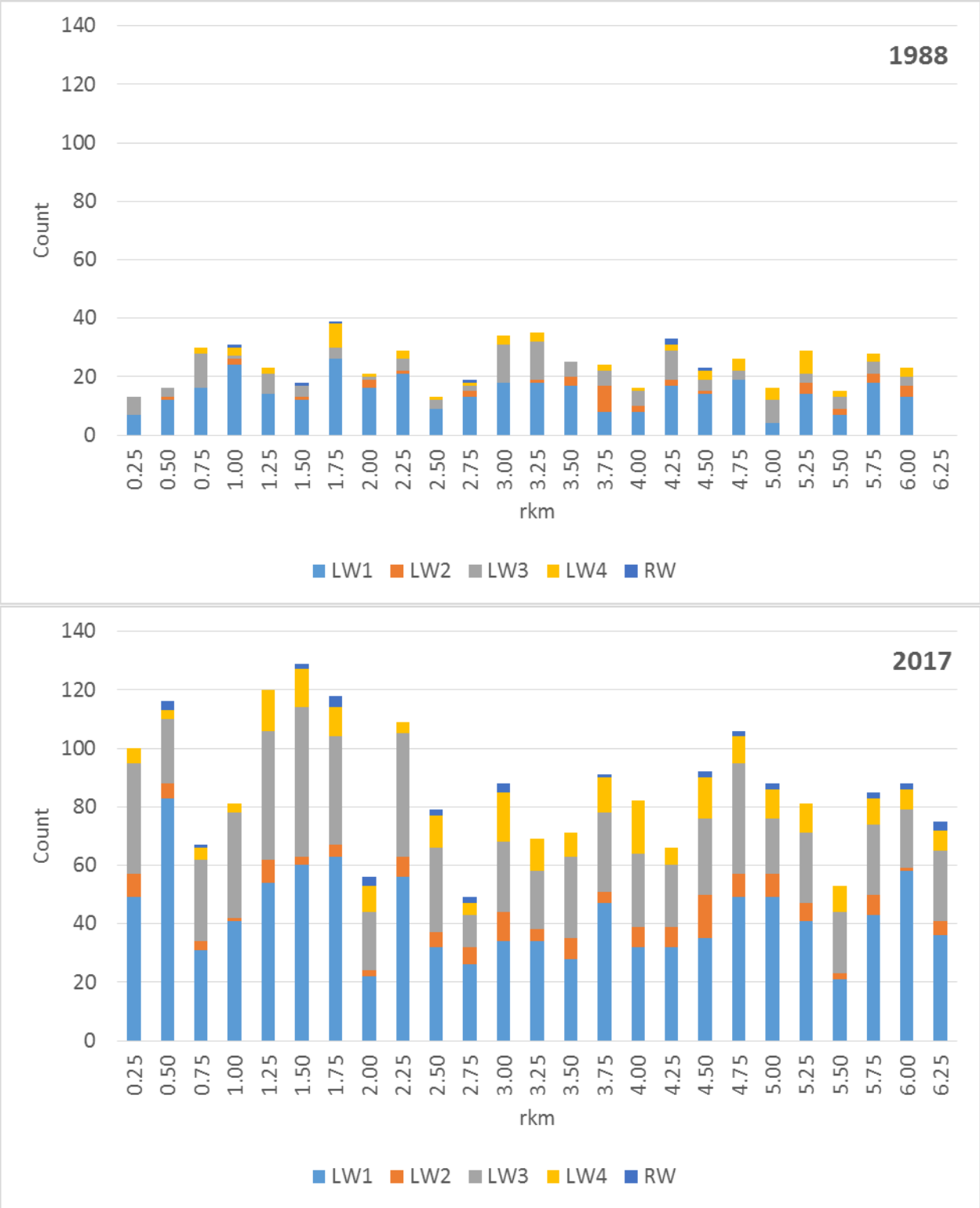


Figure 4. Counts of LW from 0.25 km reaches in Little Santeetlah Creek in 1998 and 2017. The 1988 inventory ended at rkm 6.00.

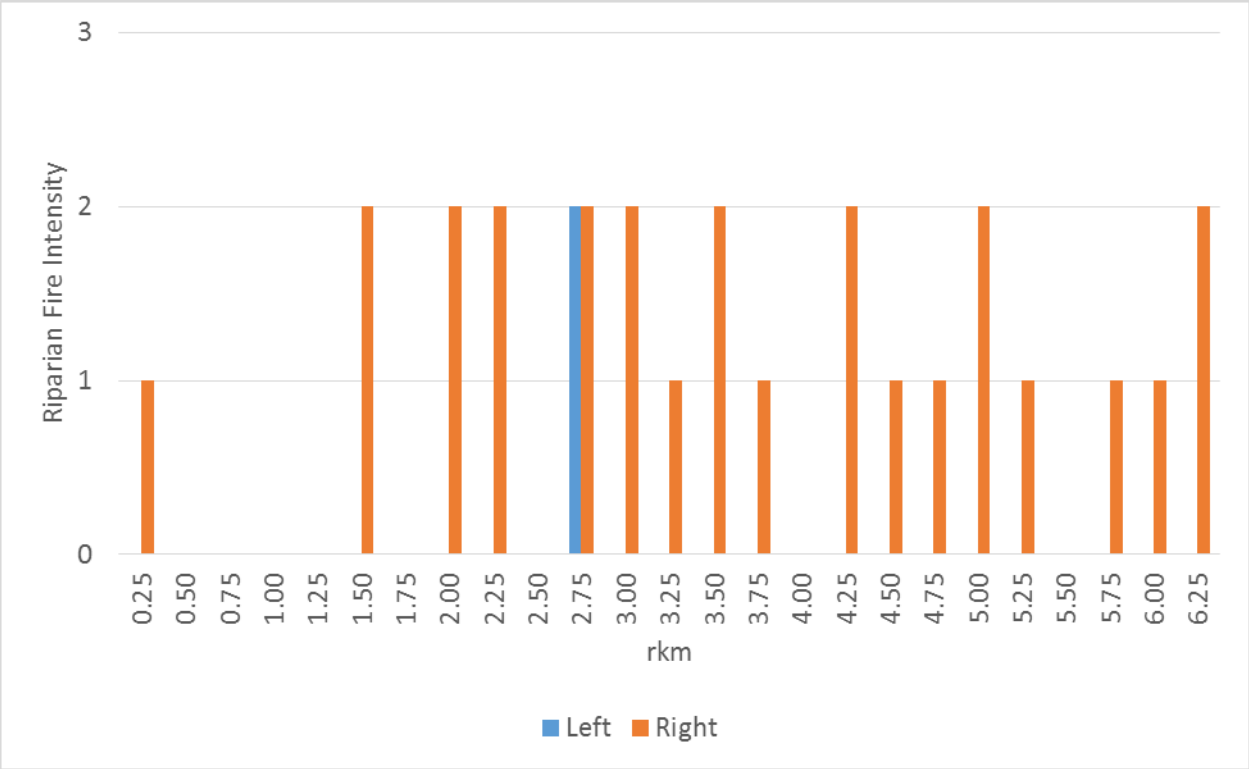


Figure 5. Riparian fire intensity recorded during a post-fire inventory of Little Santeetlah Creek in spring 2017. Wildfire impacted the watershed in fall 2016. Left is the southwest side of the stream, Right is the northeast side of the stream. On y-axis 0 = no evidence of fire, 1 = low, 2 = medium, 3 = high intensity fire evidence. See Table 2 for description of fire intensity indicators.

Figure 6. Several felled trees between the road and stream near rkm 0.5 were noted as fire suppression activity during a post-fire inventory of Little Santeetlah Creek in spring 2017. Wildfire impacted the watershed in fall 2016. Cut trees were observed in a few areas along the road between rkm 0.00 and 1.00, but was not observed in any reaches upstream of rkm 1.00.

## Tables

Table 1. Categories used for LW inventories in 1988 and 2017. Length categories were identical in both years, but diameters categories were slightly different. Since diameter classes are visually estimated we don't believe the differences resulted in any significant changes in classifications.

| Category | Length (m) 1988 & 2017 | Diameter (cm) 1988 | Diameter (cm) 2017 | Description |
|---|---|---|---|---|
| 1 | 1-5 | 11-50 | 10-55 | short, skinny |
| 2 | 1-5 | >50 | >55 | short, fat |
| 3 | >5 | 11-50 | 10-55 | long, skinny |
| 4 | >5 | >50 | >55 | long, fat |
| RW | rootwad | rootwad | rootwad | roots on dead and down tree |

Table 2. Fire intensity categories used during the 2017 post-fire inventory. Fire intensity was estimated for both sides of the stream separately.

| Category | Description | |
|---|---|---|
| 1 | No evidence | no evidence of fire within 30 m of stream |
| 2 | Low | charring of leaf litter, light charring of rhododendron trunks or lower leaves, light charring on tree trunks within 30 m of stream |
| 3 | Medium | fire damage into canopy of rhododendron within 30 m of stream |
| 4 | High | trees large enough to recruit to LW are standing dead or burned out from fire damage within 30 m of stream |

Table 3. Large wood (LW) in each of 5 size categories in Little Santeetlah Creek as recorded during a stream habitat inventory in 1988.

| rkm | LW1 | LW2 | LW3 | LW4 | RW |
|---|---|---|---|---|---|
| 0.25 | 7 | 0 | 6 | 0 | 0 |
| 0.50 | 12 | 1 | 3 | 0 | 0 |
| 0.75 | 16 | 0 | 12 | 2 | 0 |
| 1.00 | 24 | 2 | 1 | 3 | 1 |
| 1.25 | 14 | 0 | 7 | 2 | 0 |
| 1.50 | 12 | 1 | 4 | 0 | 1 |
| 1.75 | 26 | 0 | 4 | 8 | 1 |
| 2.00 | 16 | 3 | 1 | 1 | 0 |
| 2.25 | 21 | 1 | 4 | 3 | 0 |
| 2.50 | 9 | 0 | 3 | 1 | 0 |
| 2.75 | 13 | 2 | 2 | 1 | 1 |
| 3.00 | 18 | 0 | 13 | 3 | 0 |
| 3.25 | 18 | 1 | 13 | 3 | 0 |
| 3.50 | 17 | 3 | 5 | 0 | 0 |
| 3.75 | 8 | 9 | 5 | 2 | 0 |
| 4.00 | 8 | 2 | 5 | 1 | 0 |
| 4.25 | 17 | 2 | 10 | 2 | 2 |
| 4.50 | 14 | 1 | 4 | 3 | 1 |
| 4.75 | 19 | 0 | 3 | 4 | 0 |
| 5.00 | 4 | 0 | 8 | 4 | 0 |
| 5.25 | 14 | 4 | 3 | 8 | 0 |
| 5.50 | 7 | 2 | 4 | 2 | 0 |
| 5.75 | 18 | 3 | 4 | 3 | 0 |
| 6.00 | 13 | 4 | 3 | 3 | 0 |
| 6.25 | NA | NA | NA | NA | NA |
| sum | 345 | 41 | 127 | 59 | 7 |
| per km | 58 | 7 | 21 | 10 | 1 |

Table 4. Large wood (LW) in each of 5 size categories, fire intensity (L = southwest of stream, R = northeast), fire suppression activities and other information collected at each river kilometer marker in Little Santeetlah Creek in spring 2017 following the fall 2016 wildfires.

| rkm | LW1 | LW2 | LW3 | LW4 | RW | Intensity (L) | Intensity (R) | Suppression Activity | Photos | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.25 | 49 | 8 | 38 | 5 | 0 | 0 | 1 | Present | 503-506 | Suppression photos 500-502 |
| 0.50 | 83 | 5 | 22 | 3 | 3 | 0 | 0 | Present | 512-516 | Suppression photos 507-511 |
| 0.75 | 31 | 3 | 28 | 4 | 1 | 0 | 0 | Absent | 517-521 | |
| 1.00 | 41 | 1 | 36 | 3 | 0 | 0 | 0 | Present | 522-525 | Suppression photos 520-521 |
| 1.25 | 54 | 8 | 44 | 14 | 0 | 0 | 0 | Absent | 527-530 | |
| 1.50 | 60 | 3 | 51 | 13 | 2 | 0 | 2 | Absent | 531-534 | A couple trees charred all the way up |
| 1.75 | 63 | 4 | 37 | 10 | 4 | 0 | 0 | Absent | 535-538 | |
| 2.00 | 22 | 2 | 20 | 9 | 3 | 0 | 2 | Absent | 539-541 and 543 | |
| 2.25 | 56 | 7 | 42 | 4 | 0 | 0 | 2 | Absent | 544-547 | |
| 2.50 | 32 | 5 | 29 | 11 | 2 | 0 | 0 | Absent | 548-551 | |
| 2.75 | 26 | 6 | 11 | 4 | 2 | 2 | 2 | Absent | 553-556 | |
| 3.00 | 34 | 10 | 24 | 17 | 3 | 0 | 2 | Absent | 557-560 | Some evidence of burning on left side of stream |
| 3.25 | 34 | 4 | 20 | 11 | 0 | 0 | 1 | Absent | 561-564 | |
| 3.50 | 28 | 7 | 28 | 8 | 0 | 0 | 2 | Absent | 565-568 | |
| 3.75 | 47 | 4 | 27 | 12 | 1 | 0 | 1 | Absent | 569-572 | |
| 4.00 | 32 | 7 | 25 | 18 | 0 | 0 | 0 | Absent | 573-576 | |
| 4.25 | 32 | 7 | 21 | 6 | 0 | 0 | 2 | Absent | 578-581 | |
| 4.50 | 35 | 15 | 26 | 14 | 2 | 0 | 1 | Absent | 582-585 | |
| 4.75 | 49 | 8 | 38 | 9 | 2 | 0 | 1 | Absent | 586-589 | |
| 5.00 | 49 | 8 | 19 | 10 | 2 | 0 | 2 | Absent | 590-593 | |
| 5.25 | 41 | 6 | 24 | 10 | 0 | 0 | 1 | Absent | 594-597 | |
| 5.50 | 21 | 2 | 21 | 9 | 0 | 0 | 0 | Absent | 598-601 | |
| 5.75 | 43 | 7 | 24 | 9 | 2 | 0 | 1 | Absent | 602-605 | |
| 6.00 | 58 | 1 | 20 | 7 | 2 | 0 | 1 | Absent | 606-609 | |
| 6.25 | 36 | 5 | 24 | 7 | 3 | 0 | 2 | Absent | 610-613 | |
| sum | 1056 | 143 | 699 | 227 | 34 | | | | | |
| per km | 169 | 23 | 112 | 36 | 5 | | | | | |