Effects of Prescribed Burning on Large Wood Loading in Coastal Plain Streams on the Francis Marion National Forest, South Carolina, 2013

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Introduction

Prescribed or controlled burning is the method of choice for many land managers who wish to influence the species composition, structure, and function of forested ecosystems. Prescribed burning is used to reduce fuels (remove branches, leaves, dead trees), improve habitat for wildlife, control undesirable vegetation and disease, and enhance fire dependent species. These benefits notwithstanding, prescribed burning may reduce the amount of desirable dead wood, hereinafter called large wood, that also provide benefits to forest ecosystems, particularly in streams, wetlands, and riparian areas. 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. 2002, Gurnell et al. 2005, Lawrence et al. 2013).

A number of processes can result in the 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 (Bragg 2000, Golladay et al. 2007, Gregory et al. 2003, Hairston-Strang and Adams 1998, Lienkaemper and Swanson 1987, May and Gresswell 2003, Webb and Erskine 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, Marcus et al. 2011, Neary et al. 2005).

Because of its importance in the structure and function of stream systems, natural resource managers often go to great lengths to restore natural processes that maximize large wood recruitment and retention, as well as to jump start large wood loading where it is lacking. Despite the large body of knowledge on the effects of fire on many of the important attributes (Neary et al. 2008) and functions of forest ecology, relatively little is known about the effects of repeated prescribed burns or wildfire on large wood (LW) loading in streams, particularly in the southeastern US. It therefore is important to understand how common forest management practices such as prescribed burning affect large wood recruitment and retention.

Prescribed burning began on the Francis Marion National Forest (FMNF) in 1944 and since 1956 an average of 30,000-40,000 acres have been burned annually (USDA 1996). Prescribed burning is used on the FMNF to maintain wildlife habitat, promote longleaf pine growth, and create a diverse mosaic of forest types. Prescribed burning is also used to limit resource damage and danger to the public as a result of wildfire by reducing fuel loads (USDA 1996). The current FMNF Forest Plan allows low-intensity prescribed burning in streamside areas as long as the trees and shrubs shading the stream are not killed (USDA 1996). Because of the potential for prescribed burning to interact with large wood in and near the stream channel, the FMNF would like to investigate the effects of prescribed burning on large wood

loading. In 2013, we inventoried LW in 22 coastal plain stream reaches within South Carolina's Francis Marion National Forest (FMNF).

The FMNF partnered with the USDA Forest Service, Southern Research Station, Center for Aquatic Technology Transfer (CATT) to complete large wood inventories on several coastal plain streams located within the proclamation boundary of the FMNF. The inventoried streams were located in prescribed burn compartments with a range of prescribed burn frequency. Our primary objectives were to 1) compare the quantity of large wood in streams with high vs. low burn frequency, and 2) assess the effects of prescribed burning on large wood loading and retention.

Methods

Site Selection

We used 55 sites originally sampled in 1993 (Harnesburger and Dean 1994) as a starting point for stream reach selection. Stream channel characteristics and site photos collected during previous CATT surveys (Coffman et al. 2003, Krause et al. 2010), in combination with burn frequency maps provided the basis for site selection. The selected streams were located in prescribed burn Forest compartments that were either burned frequently, infrequently, or not at all in the period from 2006 to 2012 (Figure 1). Using photographs, stream size information, and field notes, we narrowed the site list to flowing streams with a defined channel. We excluded sites that were predominately swamp because a defined stream channel is necessary for consistency among large wood inventories across multiple streams.

Using the prescribed fire burn-history on the FMNF from 2006 to 2013, we categorized the sites according to their prescribed burn frequency. Sites were categorized as having either a low or high burn frequency. The Forest compartment surrounding the stream channel was burned 0-2 times at low burn frequency sites, and 3-4 times at high burn frequency sites (Figure 1, Table 1; see Appendix A for additional years).

This site selection process gave us 25 sites to visit in the field, of which we sampled 22. Three of the 25 sites where excluded upon the field visit due to the presence of swamp. Of the 22 sampled sites, 10 were low burn frequency and 12 were high burn frequency.

For detailed site maps, see Appendix B.

Sample Design

We deployed 3 crews of 2 people each from March 17-21, 2013 (5 field days). At the inventory start and end location for each site we recorded GPS coordinates, photos, wetted width, and bankfull width. We attempted to inventory 1 km of stream at each site, though this was not always possible due to

encountering swamp, private land, a change in Forest compartment burn frequency, or a lack of water (Table 2).

The inventory of large wood (defined as dead and down, >10 cm diameter, >1 m length, and any part within bankfull channel) included recording the following for each piece of large wood: distance, length, diameter, percent in bankfull, percent submerged, percent charred, channel position, and for charred wood a photo and coordinates (Appendix C). When encountered, we recorded the distance and coordinates for swamps, riparian burn areas, tributaries, and crossing structures (Appendix C). Large wood volume (m^3) and load (m^3/ha) were later calculated, where $volume = \pi \times radius^2 \times length$ and $oad = {volume}/{area}$. Other observations were recorded such as the presence of freshwater mussels, turtles, and beaver activity (Appendix D).

Results

The reach inventory lengths were similar between low and high burn frequency streams; we inventoried an average of 914 m (range 754 -1,023 m) for low burn frequency streams and an average of 970 m for high burn frequency streams (range 521-1,395 m) (Table 2). The large wood counts from these inventories were similar; an average of 89 pieces of large wood per kilometer (range 45-152 and median 84 large wood/Km) for low burn frequency streams and 102 pieces of large wood per kilometer (range 45-233 and median 95 large wood/Km) for high burn frequency streams (Table 3, Figure 4). The volume of wood per hectare (m^3/ha), i.e. wood load, was also similar. Low frequency streams had an average of 101.1 m^3/ha (range 15.5-182.0 m^3/ha) and high frequency streams had an average of 124.6 m^3/ha (range 40.6-295.9 m^3/ha) (Table 4). The volume (m^3) of individual pieces of large wood was similar between low and high burn frequency streams (Figure 5). Approximately half the large wood (52% and 47%) had a volume between 0.01 m^3 and 0.10 m^3 (Figure 5). Volumes in this range equate to size classes 1 and 3 (Table 3). The position of large wood relative to the channel was nearly evenly distributed among three positions (angled, parallel, and perpendicular), as well as between low and high burn frequencies (Figure 6). For high burn frequency streams, the percentage of large wood with visible charring varied among the three positions (Figure 7). The percentage of large wood with charring was least for large wood lying parallel to the channel (23%) and the greatest for large wood lying perpendicular to the channel (41%) (Figure 7).

High burn frequency streams had a much higher amount of charred wood (avg. 32%) than low burn frequency streams (avg. 2%) (Figure 2). Assessing the quantity of large wood with visible charring at each individual inventoried stream again shows much higher quantities for the majority of high burn frequency streams (Figure 3). Specifically, low burn frequency streams had quantities of large wood with visible charring from fire ranging from 0-18% and high burn frequency streams had 6-69% (Figure 3). Of

these sites, only one, an unnamed tributary to Bell Creek (site #29) had a percentage of large wood with charring large enough (18%) to overlap the values found for the high burn frequency streams (Figure 3).

Discussion

The effects of prescribed burning on large wood loading are not well studied; however Neary et al. (2008) states that an appropriately controlled prescribed fire will not affect the accumulation of large wood on the watershed or in the stream channel. They recommend a riparian buffer of at least 30 feet when fire intensity may cause damage to woody vegetation, and no riparian buffer for low intensity burns that will not kill stream shading shrubs and trees. Similarly, the FMNF's management plan allows low-intensity fires (flame length <2 ft) that do not kill stream shading trees and shrubs, to enter the riparian buffer (defined as extending 30 ft plus 1.5 times the percent slope from the water's edge) (USDA 1996).

We found little difference in quantity or volume of large wood between streams with low and high prescribed burn frequencies, but also observed impacts of prescribed fire on living trees and large wood in the riparian area and wetted channel. We observed trees that fell into the stream channel as a result of fire; the base of the tree and nearby stump was burned through. In most cases it appeared that fire had taken hold within a cavity in the base of the tree and the burning subsequently caused the tree to fall (Appendix E). Within the wetted channel we observed charred large wood and cypress knees as well as the complete removal of non-woody riparian vegetation to the water's edge from burning (Appendix E). In addition, we observed an increased amount of charred large wood in high burn frequency streams. These are clear indicators that the prescribed burning on the FMNF does sometimes burn at a high enough intensity to affect large wood in the stream channel and to encroach on and kill riparian vegetation.

The charring of large wood highlights the potentially conflicting management goals of reducing fuel loads and increasing large wood recruitment. One of FMNF's stated reasons for conducting prescribed burns is to manage fuel loads (USDA 1996), but a source of large wood in lowland streams like those on the FMNF is wood laying in the floodplain. This wood can be recruited to the stream channel during floods (Golladay et al. 2007, Wohl et al. 2011) therefore the reduction of floodplain fuel loads by prescribed burning may be reducing the amount of large wood available for recruitment during flooding.

The size (volume) of individual pieces of large wood was similar at low versus high prescribed burn frequencies sites. This similarity suggests that prescribed fire on the FMNF is not resulting in increased inputs of higher volume pieces of large wood. Vaz et al. (2011) found that wildfires do contribute high volume pieces of large wood, but wildfires differ from prescribed burns in many ways. Wildfires consume wood debris, reduce the complexity of large wood (e.g. branches are burned away), and contribute large wood to streams (Jones and Daniels 2008, Marcus et al. 2011, Neary et al. 2008,

Pettit and Naiman 2007, Vaz et al. 2011). Furthermore, they can increase bank erosion and instability, which cause large wood inputs (Marcus et al. 2011, Pettit and Naiman 2007). The toppling of trees killed in a forest fire occurs over the span of decades (Benda and Sias 2003, Marcus et al. 2011). At the stream sites we visited, we did not observe effects of high intensity wildfire. We also did not encounter conditions noted by Hansbarger and Dean (1994) following Hurricane Hugo. They surveyed over 50 sites within 5 years of Hurricane Hugo and found many streams to be impassable due to the amount of large wood added to streams by the hurricane. Phillips and Park (2009) found blowdowns from hurricanes are sufficient to completely block stream channels and Golladay et al. (2007) found flooding from tropical storms to be a significant source of large wood recruitment. It has been over two decades since Hurricane Hugo and the wood load we observed is now comparable to other coastal plain streams. We found an average wood load of 113.9 m^3/ha (n=22) on the FMNF (Table 4), slightly more than what is present in Congaree National Park, SC streams (85 m^3/ha, n=8 ; Wohl et al. 2011), and slightly less than what is present in GA Coastal Plain streams (158 m^3/ha, n=2; Wallace and Benke 1984).

The amount of large wood in streams fluctuates over time and is controlled by a number of short and long term processes (Gregory et al. 2003). A single large wood survey is limited to describing current conditions rather than the state of long term processes controlling large wood recruitment and retention. Preserving those processes is the key to managing for large wood in the long term. Land management practices, including prescribed burning, can impact the amount and size of trees available as well as the frequency and timing of large wood recruitment. Decisions made by today's land managers can have impacts on large wood recruitment and retention for decades to come, yet little is understood about the role of prescribed burning in large wood dynamics. Clearly a better understanding of the effects of prescribed burning on large wood is needed to inform management decisions. In particular, a better understanding of its effects on recruitment (damage to living trees, consumption of fallen trees in the floodplain and riparian areas) and retention (decay rates and transport of charred wood) would be beneficial.

We recommend modifications to our large wood survey protocols to better address some of the issues outlined above and to allow better comparison of results to existing studies. In particular, we recommend a change in the classification of large wood position within the stream channel to include position categories bridge, ramp, pinned, buried, or unattached (Cadol et al. 2009, Wohl et al. 2011). Additionally, we suggest inclusion of a decay-metric (Cadol et al. 2009, Jones and Daniels 2008, Wohl et al. 2011).

In summary, we found little difference in quantity or volume of large wood between streams with low and high prescribed burn frequencies, and loading was similar to other coastal plain streams, suggesting an appropriately controlled prescribed fire program. However, we also observed instances of

prescribed fire causing damage to trees in the riparian area and charred large wood within the floodplain, riparian area, bankfull channel, and wetted channel. While the ultimate loading of large wood may be similar, the processes in low versus high frequency burn sites could be quite different. For example, increased decay rate of charred wood or consumption of large wood by fire may be compensated for by increased input of damaged trees in high frequency prescribed fire areas. The large wood loading may be the same, but the effects on riparian dependent species and the long-term large wood dynamics is almost certainly different. Additional surveys and research are needed to better understand the effects of prescribed burning on the long term recruitment and retention of large wood in coastal plain streams.

Data Availability

The 2013 large wood loading data reside in a MS Access database, which is managed by the CATT, and a copy has been provided to Jeanne Riley, FMSNF Fish Biologist. We will work with the FMSNF to develop custom queries and reports for the MS Access database, as needed.

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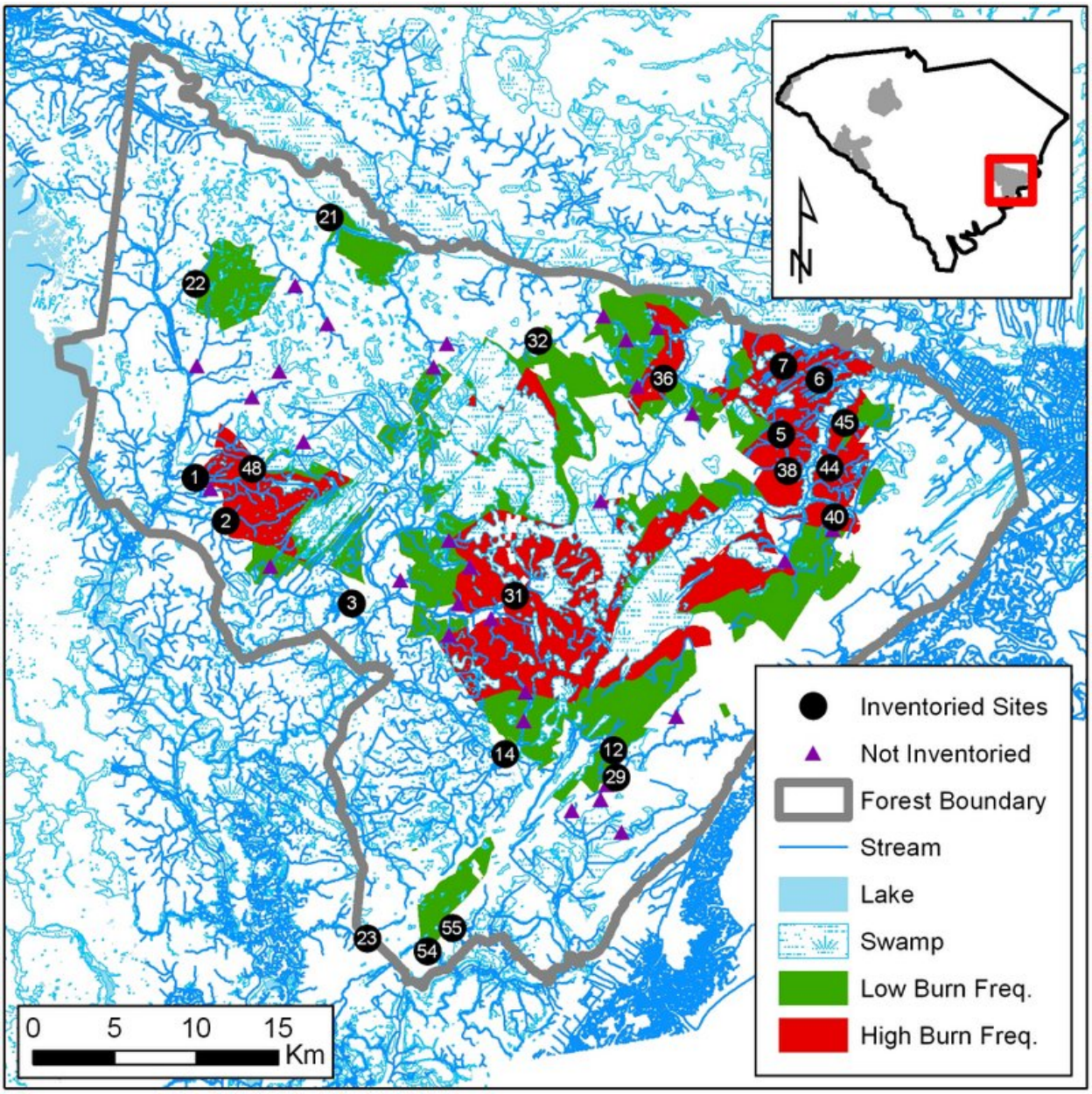


Figure 1. Locations of sites inventoried for large wood on the Francis Marion National Forest; March 2013.

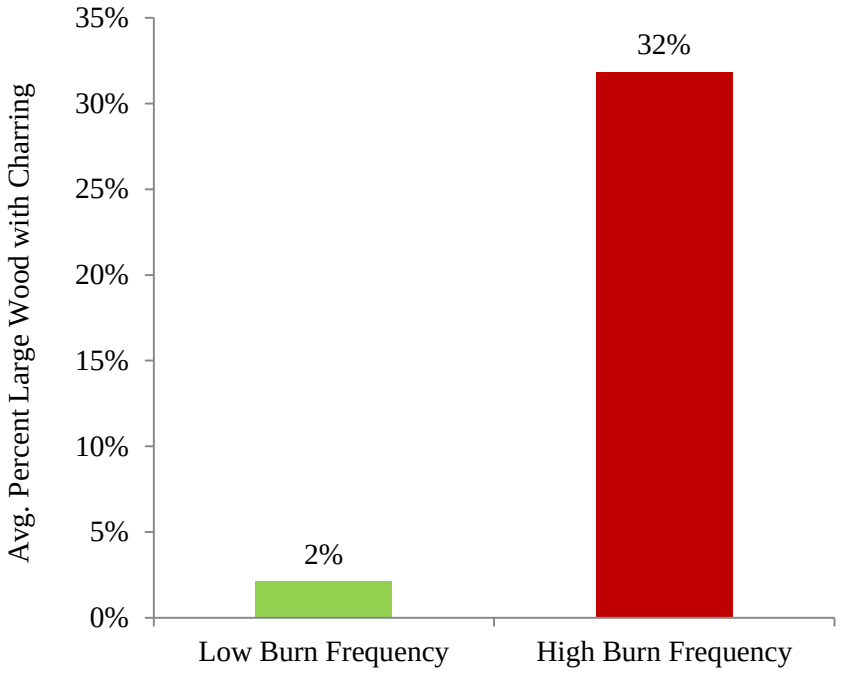


Figure 2. Streams located within Forest compartments burned 0-2 times from 2006-2013 (i.e. low burn frequency) had low (2%) quantities of large wood with visible charring from fire. Whereas streams located within Forest compartments burned 3-4 times from 2006-2013 (i.e. high burn frequency) had higher (32%) quantities of large wood with visible charring from fire.

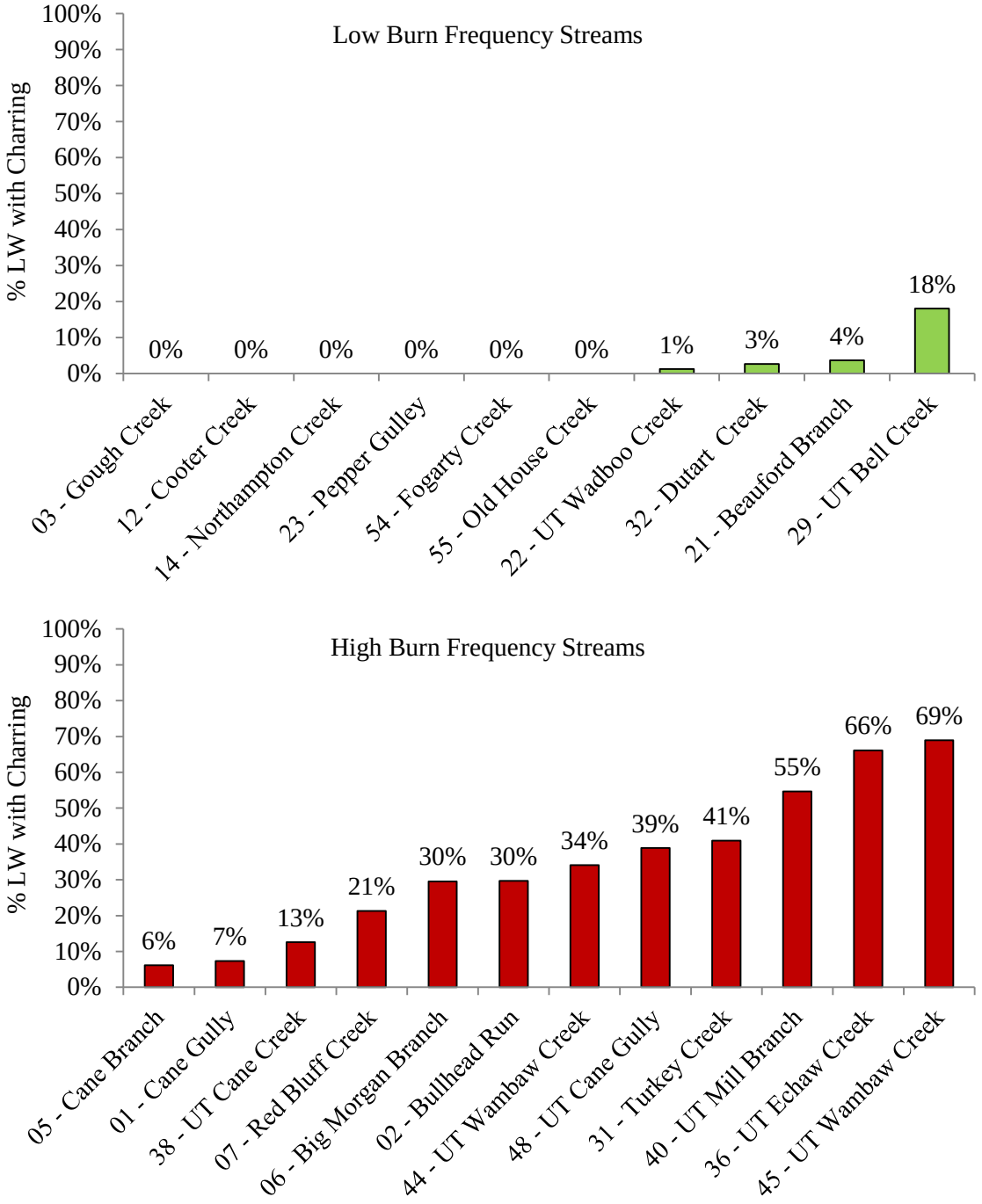


Figure 3. Streams located within Forest compartments burned 0-2 times from 2006-2013 (i.e. low burn frequency) had quantities of large wood (LW) with visible charring from fire ranging from 0-18%. Streams located within Forest compartments burned 3-4 times from 2006-2013 (i.e. high burn frequency) had quantities of large wood with visible charring from fire ranging from 6-69%.

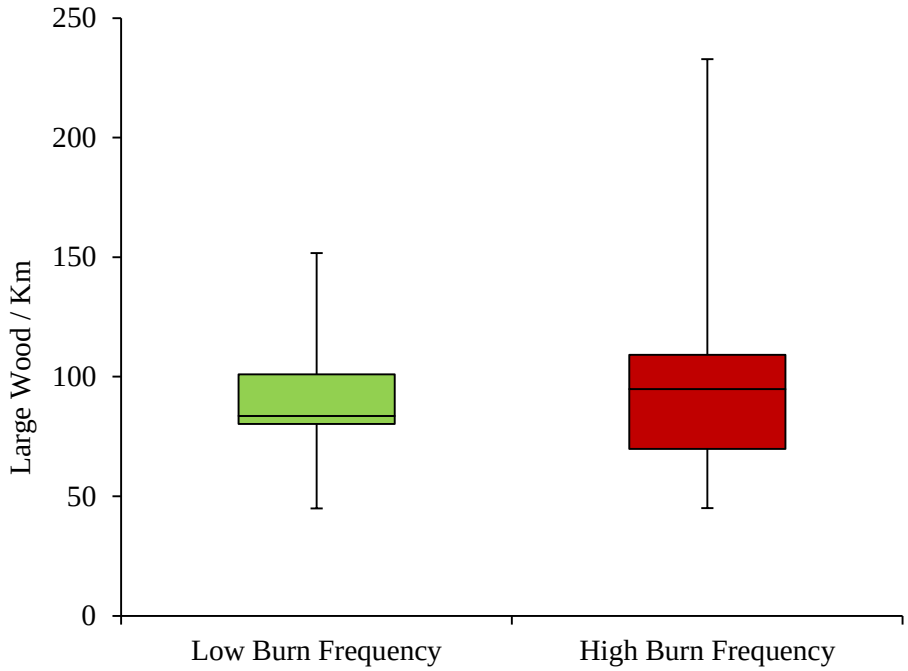


Figure 4. The median quantity of large wood within bankfull per stream kilometer (LW/Km) was similar for low (84 LW/Km) and high (95 LW/Km) prescribed burn frequency streams.

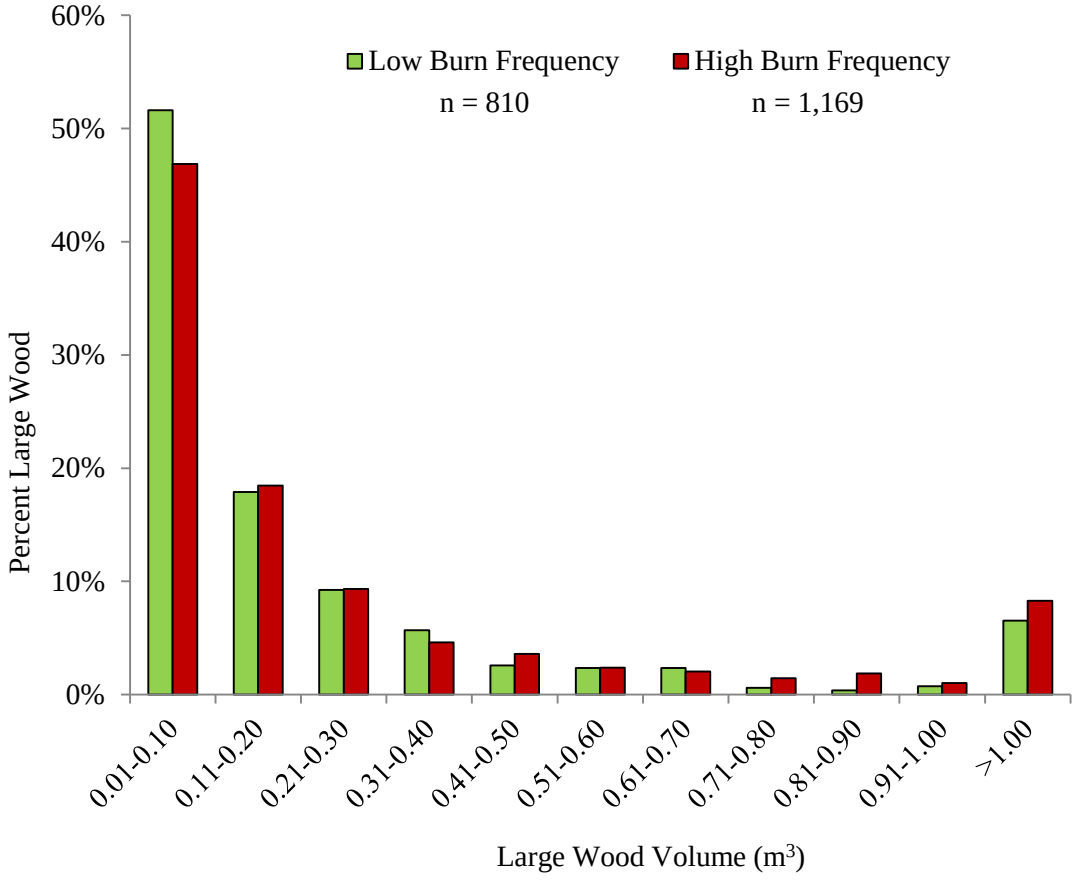


Figure 5. Large wood volume (m^3) was similar between low and high burn frequency streams. Approximately half the large wood (52% and 47%) had a volume between 0.01 and 0.10 m^3.

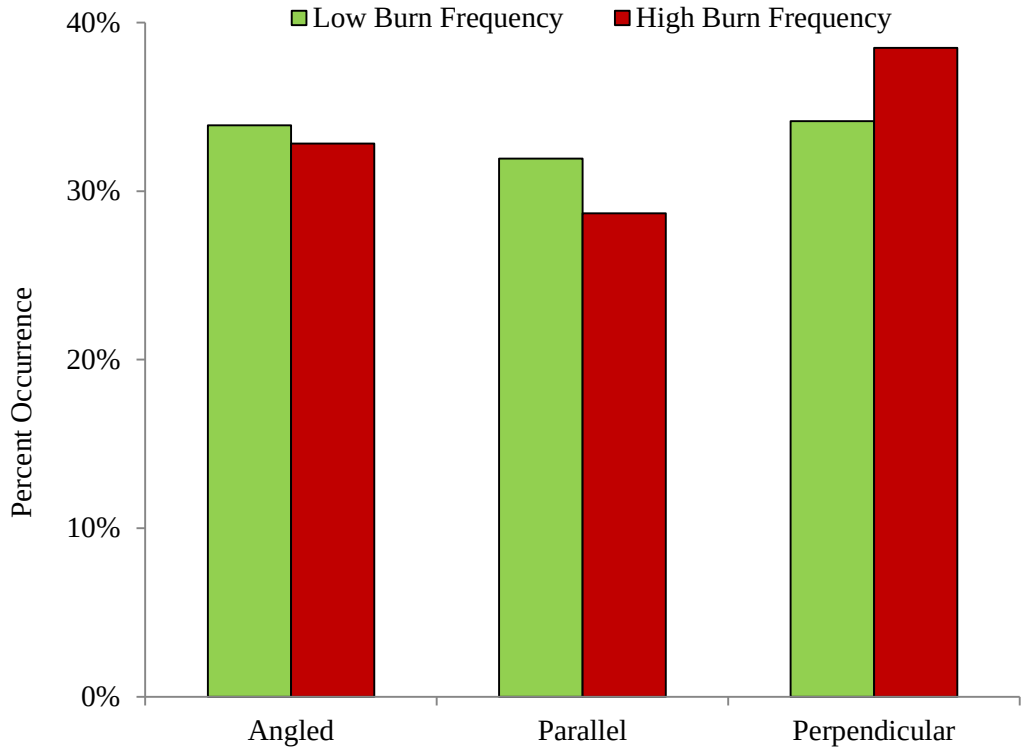


Figure 6. The occurrence of large wood was relatively evenly distributed among three positions (angled, parallel, and perpendicular to stream flow), as well as between low and high burn frequency streams.

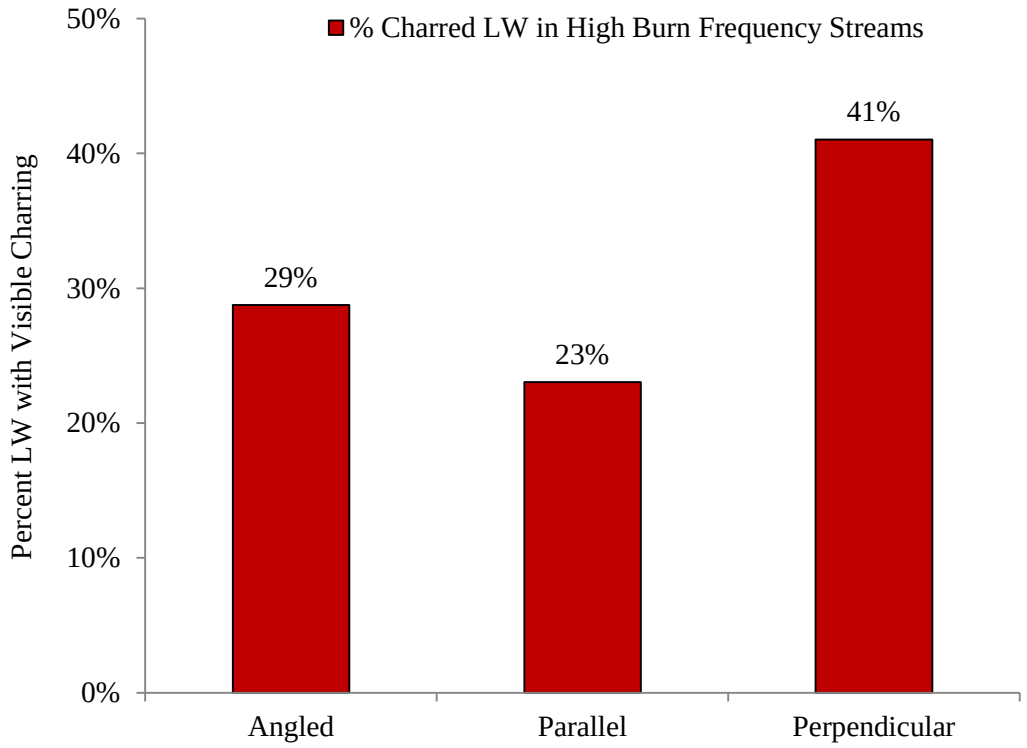


Figure 7. The percentage of large wood (LW) in high burn frequency streams with any amount of visible charring varied with large wood position (angled, parallel, and perpendicular) relative to the stream channel.

Table 1. Inventoried streams and their burn history. Dates with strikethrough occurred after our inventories.

	Site #	Stream	Date Inventoried	USFS Burn Compt. #	Burn Count	Date Burned by Year							
						2006	2007	2008	2009	2010	2011	2012	2013
Low Burn Frequency	3	Gough Creek	3/20/13	none	0								
	12	Cooter Creek	3/18/13	197/198	1			2/21					
	14	Northampton Creek	3/18/13	none	0								
	21	Beauford Branch	3/18/13	8/9/10	1			5/28					
	22	UT Wadboo Creek	3/18/13	19/20	0/1						5/13		
	23	Pepper Gully	3/18/13	none	0								
	29	UT Bell Creek	3/19/13	204	2	3/27			6/3				
	32	Dutart Creek	3/20/13	141	0/1						2/15		
	54	Fogarty Creek	3/18/13	115/116	2			4/14		3/31			
	55	Old House Creek	3/19/13	115/116	0/2			4/14		3/31			
High Burn Frequency	1	Cane Gully	3/19/13	57	4		4/24		2/23		4/13		3/15
	2	Bullhead Run	3/19/13	75/76/78	3		4/25		2/20		2/18		~~3/27~~
	5	Cane Branch	3/17/13	149	4	2/2		3/13		2/17		2/29	
	6	Big Morgan Branch	3/17/13	133	4	3/13		3/21		2/11			3/8
	7	Red Bluff Creek	3/20/13	126	3/4	1/27		3/18		2/18		2/21	
				134		10/31			3/8		2/24		~~3/29~~
	31	Turkey Creek	3/19/13	94	3/4	2/1			1/23			3/16	
				182		5/10		5/15		3/16		3/16	
				178			3/22		3/25		3/18		
	36	UT Echaw Creek	3/21/13	138	4	5/26		3/14		3/26		4/27	
	38	UT Cane Creek	3/20/13	159	3/4	3/6		3/12		3/5		3/28	
				149		2/2		3/13		2/17		2/29	
				148		3/6		3/12		3/6			
	40	UT Mill Branch	3/20/13	157/158	4	3/1		3/11		3/9		3/30	
	44	UT Wambaw Creek	3/17/13	150	4		3/12		3/10	11/10			1/29
				151		3/11		3/17		4/11			2/10
	45	UT Wambaw Creek	3/21/13	131	4		2/28		3/10	11/9			1/28
	48	UT Cane Gully	3/21/13	57	4		4/24		2/23		4/13		3/15

Table 2. Distance inventoried for each sample site, as well as the wetted stream width and bankfull channel width at the inventory start and end.

	Site #	Stream	Distance Inventoried (m)	Width (m) at Inventory Start		Width (m) at Inventory End		Reason Inventory Ended
				Wetted	Bankfull	Wetted	Bankfull	
Low Burn Frequency	3	Gough Creek	1,000	2.9	3.8	2.7	4.1	1 km inventoried
	12	Cooter Creek	890	2.6	4.6	swamp	swamp	swamp
	14	Northampton Creek	930	4.8	5.6	2.3	2.5	culvert, road crossing
	21	Beauford Branch	952	1.7	2.2	2.5	2.7	Forest boundary, ford
	22	UT Wadboo Creek	1,000	2.9	6.5	4.6	8.3	1 km inventoried
	23	Pepper Gulley	972	2.5	3.5	3.2	3.6	overgrown channel
	29	UT Bell Creek	754	3.0	4.5	1.3	2.9	private land
	32	Dutart Creek	812	3.6	5.3	swamp	swamp	swamp
	54	Fogarty Creek	1,023	2.1	2.8	1.9	2.1	1 km inventoried
	55	Old House Creek	803	2.0	5.2	1.6	2.0	confluence of 2 tributaries
		Average	*914*	*2.8*	*4.4*	*2.5*	*3.5*	
High Burn Frequency	1	Cane Gully	700	5.4	7.0	8.3	9.5	NA
	2	Bullhead Run	833	3.6	5.2	5.6	6.8	swamp
	5	Cane Branch	970	8.5	9.0	4.6	11.5	swamp upstream of culvert
	6	Big Morgan Branch	1,395	1.3	2.3	swamp	swamp	1 km inventoried
	7	Red Bluff Creek	698	2.8	3.2	1.5	2.5	small channel, overgrown
	31	Turkey Creek	1,120	8.5	11.5	8.0	11.0	1 km inventoried
	36	UT Echaw Creek	1,292	3.4	4.5	NA	NA	1 km inventoried
	38	UT Cane Creek	1,090	3.0	4.1	1.9	3.3	1 km inventoried
	40	UT Mill Branch	1,035	2.9	3.8	2.3	2.7	1 km inventoried
	44	UT Wambaw Creek	1,182	1.3	2.6	1.1	4.2	1 km inventoried
	45	UT Wambaw Creek	521	1.1	2.6	2.5	3.0	different burn frequency
	48	UT Cane Gully	800	1.9	2.9	2.2	3.3	swamp, different burn freq.
		Average	*970*	*3.6*	*4.9*	*3.8*	*5.8*	

Table 3. Total large wood (LW) counts and LW/Km counts for each stream inventoried, as well as counts per large wood size classes used in other CATT reports; where Size 1 = < 5 m long, 10 cm - 55 cm diameter; Size 2 = < 5 m long, > 55 cm diameter; Size 3 = > 5 m long, 10 cm - 55 cm diameter; Size 4 = > 5 m long, > 55 cm diameter.

	Site #	Stream	Burn Count	Distance Inventoried (m)	LW Count	LW per Km	LW Counts by Size Class				LW per Km by Size Class			
							Size 1	Size 2	Size 3	Size 4	Size 1	Size 2	Size 3	Size 4
Low Burn Frequency	3	Gough Creek	0	1,000	103	103	60	0	41	2	60	0	41	2
	12	Cooter Creek	1	890	135	152	110	0	22	3	124	0	25	3
	14	Northampton Creek	0	930	45	48	33	0	11	1	35	0	12	1
	21	Beauford Branch	1	952	82	86	53	0	28	1	56	0	29	1
	22	UT Wadboo Creek	0/1	1,000	80	80	57	0	23	0	57	0	23	0
	23	Pepper Gulley	0	972	116	119	103	1	12	0	106	1	12	0
	29	Ut Bell Creek	2	754	61	81	35	0	25	1	46	0	33	1
	32	Dutart Creek	0/1	812	77	95	46	0	31	0	57	0	38	0
	54	Fogarty Creek	2	1,023	46	45	43	0	3	0	42	0	3	0
	55	Old House Creek	0/2	803	65	81	52	0	13	0	65	0	16	0
				Average	*81*	*89*	*59*	*0*	*21*	*1*	*65*	*0*	*23*	*1*
High Burn Frequency	1	Cane Gully	4	700	163	233	95	2	59	7	136	3	84	10
	2	Bullhead Run	3	833	91	109	58	0	32	1	70	0	38	1
	5	Cane Branch	4	970	97	100	63	0	32	2	65	0	33	2
	6	Big Morgan Branch	4	1,395	71	51	47	0	24	0	34	0	17	0
	7	Red Bluff Creek	3/4	698	61	87	45	0	15	1	64	0	21	1
	31	Turkey Creek	3/4	1,120	193	172	107	0	86	0	96	0	77	0
	36	UT Echaw Creek	4	1,292	124	96	91	0	33	0	70	0	26	0
	38	UT Cane Creek	3/4	1,090	119	109	82	0	34	3	75	0	31	3
	40	UT Mill Branch	4	1,035	97	94	75	0	21	1	72	0	20	1
	44	UT Wambaw Creek	4	1,182	88	74	52	0	36	0	44	0	30	0
	45	UT Wambaw Creek	4	521	29	56	16	1	12	0	31	2	23	0
	48	UT Cane Gully	4	800	36	45	20	0	16	0	25	0	20	0
				Average	*97*	*102*	*63*	*0*	*33*	*1*	*65*	*0*	*35*	*2*

Table 4. Inventory area and large wood (LW) size, volume, and load for each stream inventoried.

	Site #	Stream	Distance Inventoried (m)	Avg. Wetted Width (m)	Inventory Area (ha)	Avg. LW Length (m)	Avg. LW Diameter (cm)	Avg. LW Volume (m^3)	Total LW Volume (m^3)	Wood Load (m^3/ha)
Low Burn Frequency	3	Gough Creek	1,000	2.8	0.28	5.6	21.1	0.28	29.0	103.5
	12	Cooter Creek	890	2.6	0.23	4.0	20.9	0.25	34.3	148.4
	14	Northampton Creek	930	3.6	0.33	5.8	22.7	0.54	24.4	74.1
	21	Beauford Branch	952	2.1	0.20	5.5	25.3	0.40	32.8	163.9
	22	UT Wadboo Creek	1,000	3.8	0.38	5.3	22.5	0.33	26.1	69.5
	23	Pepper Gulley	972	2.9	0.28	3.2	22.4	0.20	23.1	83.3
	29	Ut Bell Creek	754	2.2	0.16	6.8	24.2	0.48	29.5	182.0
	32	Dutart Creek	812	3.6	0.29	5.6	22.5	0.32	24.7	84.5
	54	Fogarty Creek	1,023	2.0	0.20	2.7	17.3	0.07	3.2	15.5
	55	Old House Creek	803	1.8	0.14	3.7	22.8	0.19	12.4	86.1
			Average	*2.7*	*0.25*	*4.8*	*22.2*	*0.31*	*24.0*	*101.1*
High Burn Frequency	1	Cane Gully	700	6.9	0.48	7.5	25.0	0.87	141.9	295.9
	2	Bullhead Run	833	4.6	0.38	5.4	20.8	0.25	22.4	58.6
	5	Cane Branch	970	6.6	0.64	6.0	22.4	0.39	38.0	59.8
	6	Big Morgan Branch	1,395	1.3	0.18	4.7	23.5	0.27	19.3	106.2
	7	Red Bluff Creek	698	2.2	0.15	4.7	22.5	0.31	18.7	124.6
	31	Turkey Creek	1,120	8.3	0.92	6.2	22.2	0.31	59.8	64.8
	36	UT Echaw Creek	1,292	3.4	0.44	4.0	18.4	0.14	17.8	40.6
	38	UT Cane Creek	1,090	2.5	0.27	5.6	22.9	0.50	59.1	221.4
	40	UT Mill Branch	1,035	2.6	0.27	4.2	26.2	0.37	35.9	133.4
	44	UT Wambaw Creek	1,182	1.2	0.14	5.8	23.3	0.37	32.5	229.0
	45	UT Wambaw Creek	521	1.8	0.09	5.6	22.3	0.25	7.3	78.1
	48	UT Cane Gully	800	2.1	0.16	6.2	20.6	0.38	13.5	82.5
			Average	*3.6*	*0.34*	*5.5*	*22.5*	*0.37*	*38.9*	*124.6*
			Overall Average	*3.2*	*0.30*	*5.2*	*22.4*	*0.34*	*32.1*	*113.9*

Appendix A – Extended Burn History

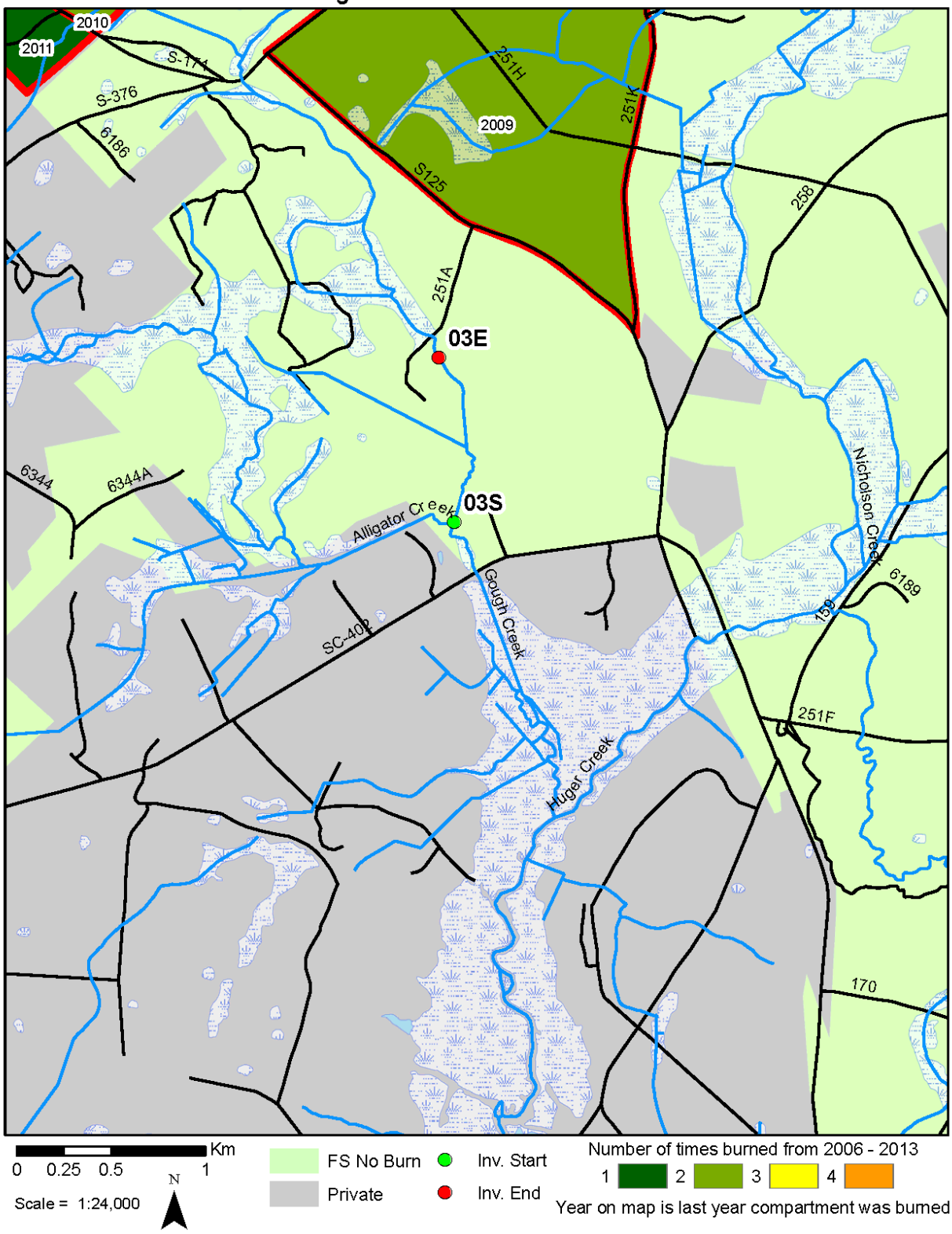
Table C1. Inventoried streams and their burn history from 1991 to 2001. A checkmark indicates that the Forest compartment(s) surrounding the stream was burned partially or completely either to the channel or to the riparian zone. Based on unverified GIS data provided by the FMNF.

			Year Burned										
	Site #	Stream	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Low Burn Frequency	3	Gough Creek											
	12	Cooter Creek			✓		✓			✓			
	14	Northampton Creek											
	21	Beauford Branch						✓					
	22	UT Wadboo Creek	✓	✓	✓								
	23	Pepper Gully	✓	✓									
	29	UT Bell Creek			✓					✓			
	32	Dutart Creek			✓								
	54	Fogarty Creek											
	55	Old House Creek											
High Burn Frequency	1	Cane Gully		✓						✓		✓	
	2	Bullhead Run	✓	✓						✓		✓	
	5	Cane Branch	✓				✓	✓	✓		✓		✓
	6	Big Morgan Branch	✓				✓		✓		✓		✓
	7	Red Bluff Creek		✓	✓	✓		✓	✓	✓	✓	✓	
	31	Turkey Creek	✓		✓	✓		✓	✓	✓	✓	✓	✓
	36	UT Echaw Creek	✓	✓		✓		✓	✓	✓	✓		✓
	38	UT Cane Creek	✓	✓		✓	✓	✓	✓		✓		✓
	40	UT Mill Branch		✓	✓						✓		
	44	UT Wambaw Creek	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
	45	UT Wambaw Creek	✓		✓	✓	✓	✓	✓	✓			✓
	48	UT Cane Gully		✓						✓		✓	

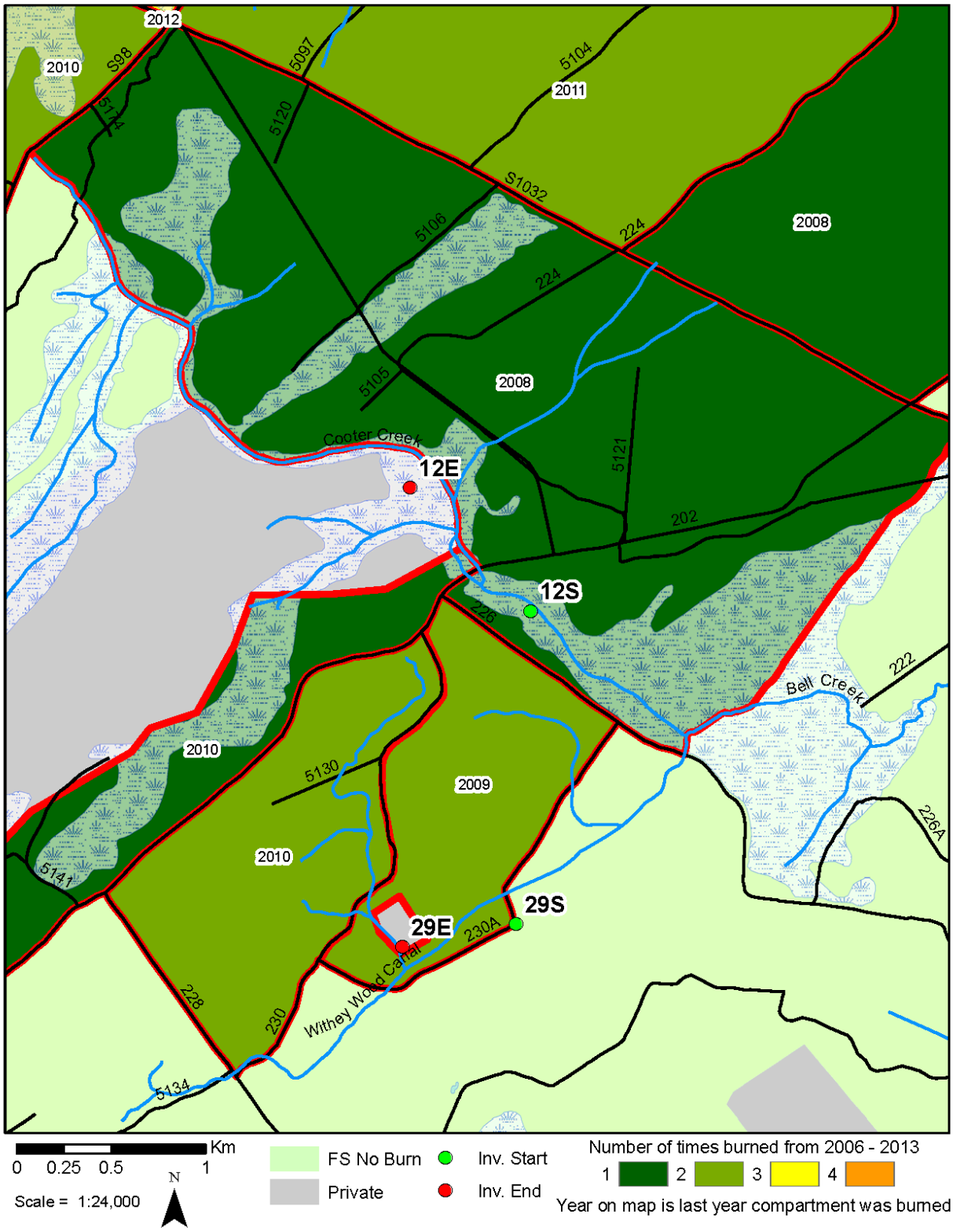
Appendix B – Large Wood Inventory Site Maps

	Site #	Stream
Low Burn Frequency	3	Gough Creek
	12	Cooter Creek
	14	Northampton Creek
	21	Beauford Branch
	22	UT Wadboo Creek
	23	Pepper Gully
	29	UT Bell Creek
	32	Dutart Creek
	54	Fogarty Creek
	55	Old House Creek
High Burn Frequency	1	Cane Gully
	2	Bullhead Run
	5	Cane Branch
	6	Big Morgan Branch
	7	Red Bluff Creek
	31	Turkey Creek
	36	UT Echaw Creek
	38	UT Cane Creek
	40	UT Mill Branch
	44	UT Wambaw Creek
	45	UT Wambaw Creek
	48	UT Cane Gully

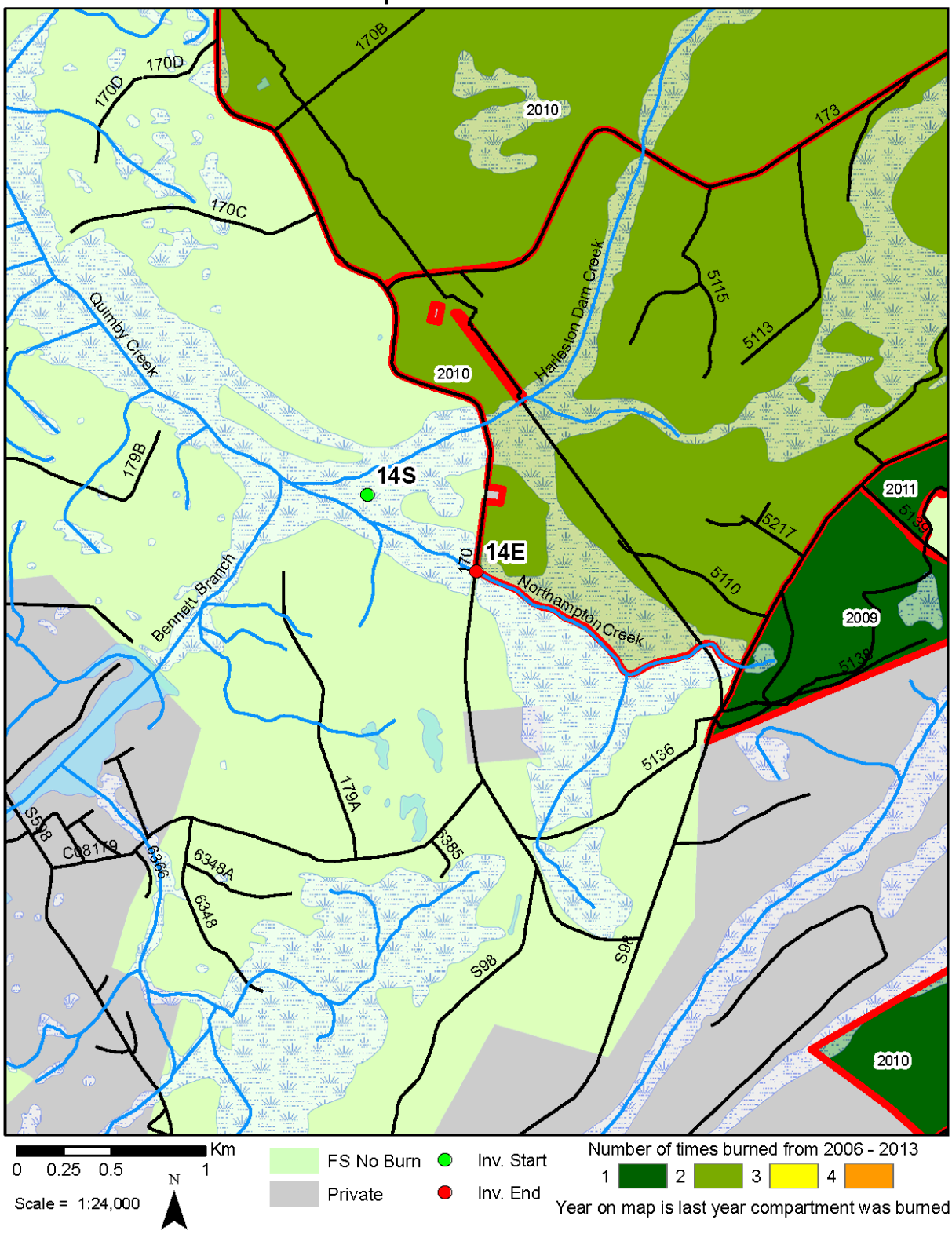
Site Number: 03 Stream: Gough Cr



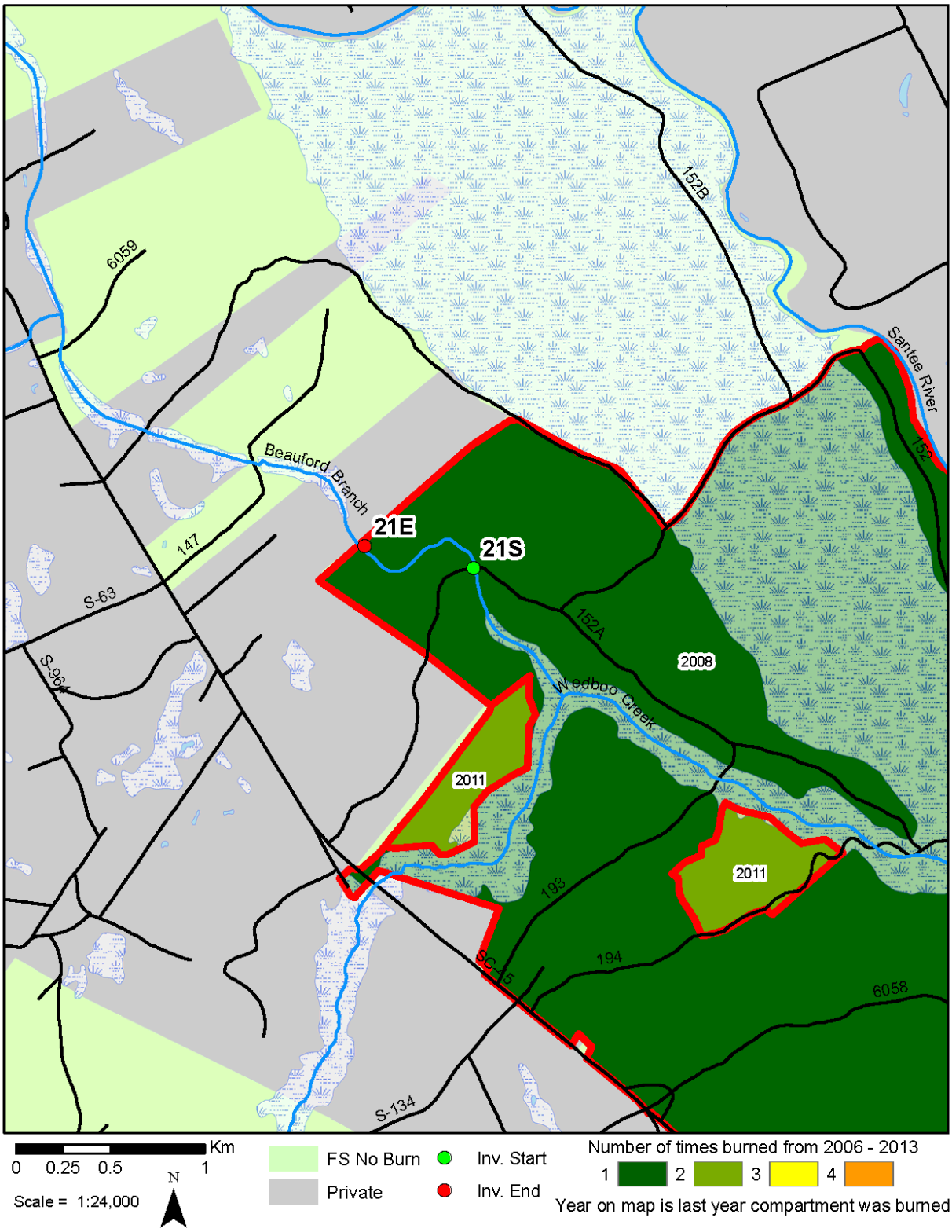
Site Number: 12 Stream: Cooter Cr



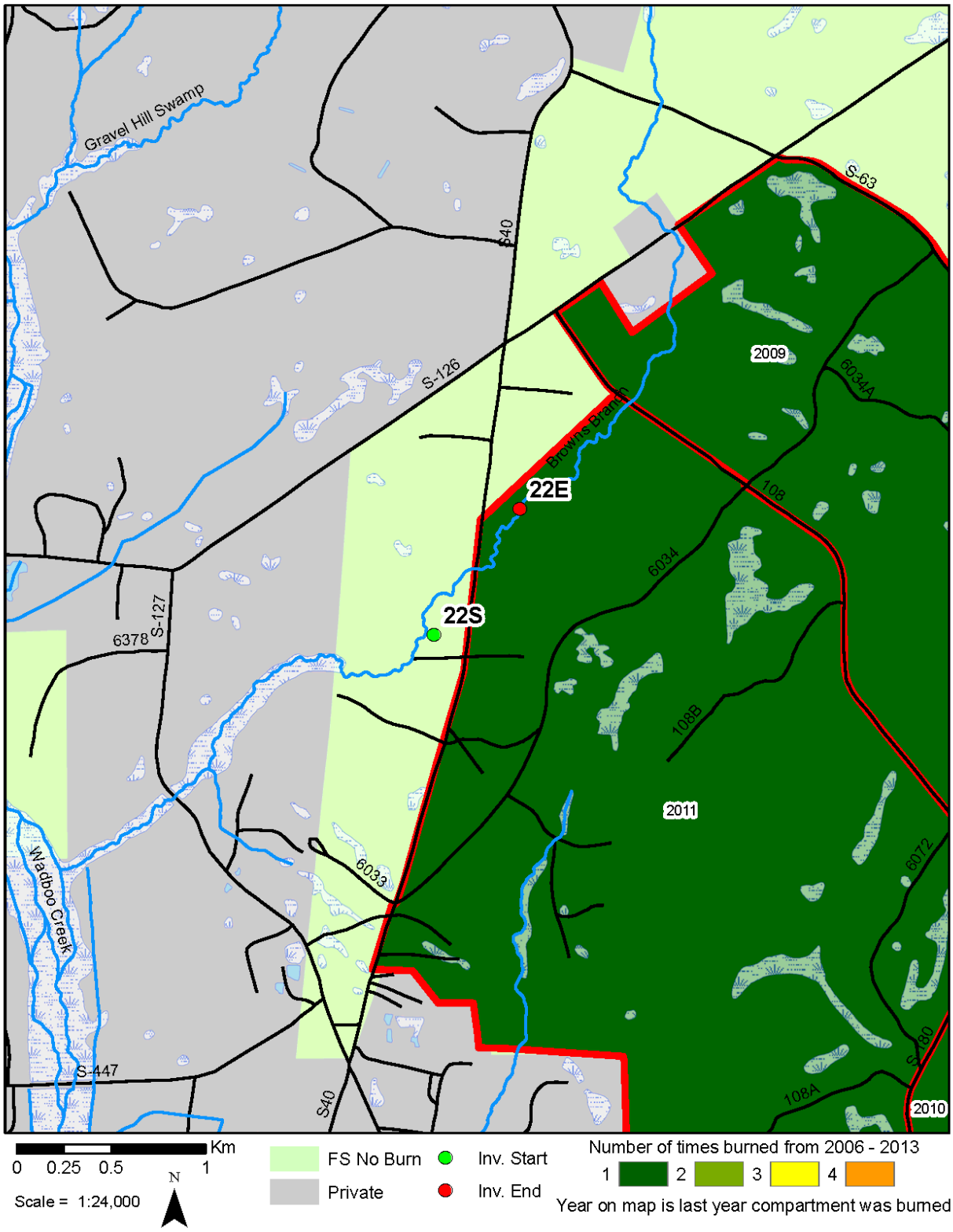
Site Number: 14 Stream: Northampton Cr



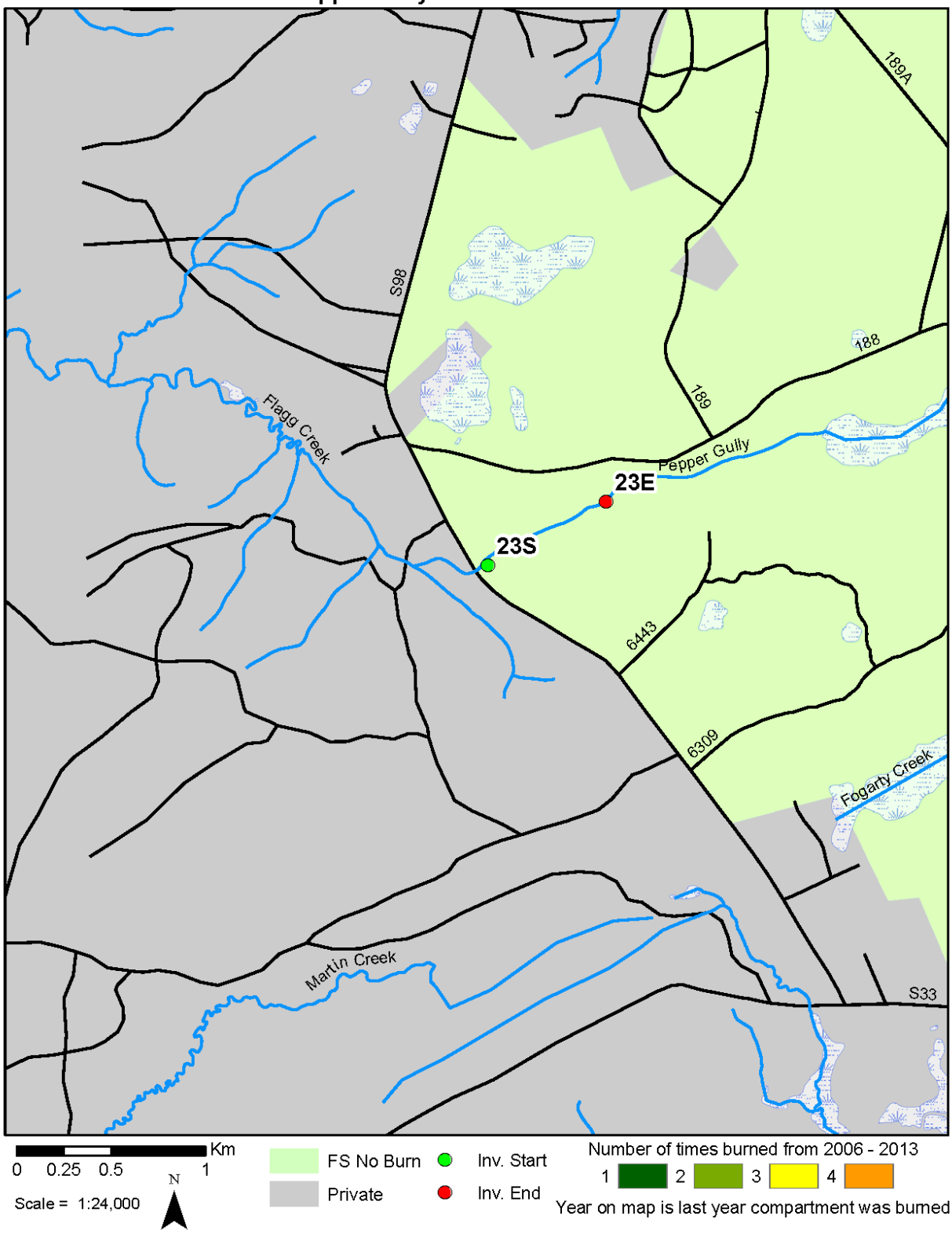
Site Number: 21 Stream: Beauford Br



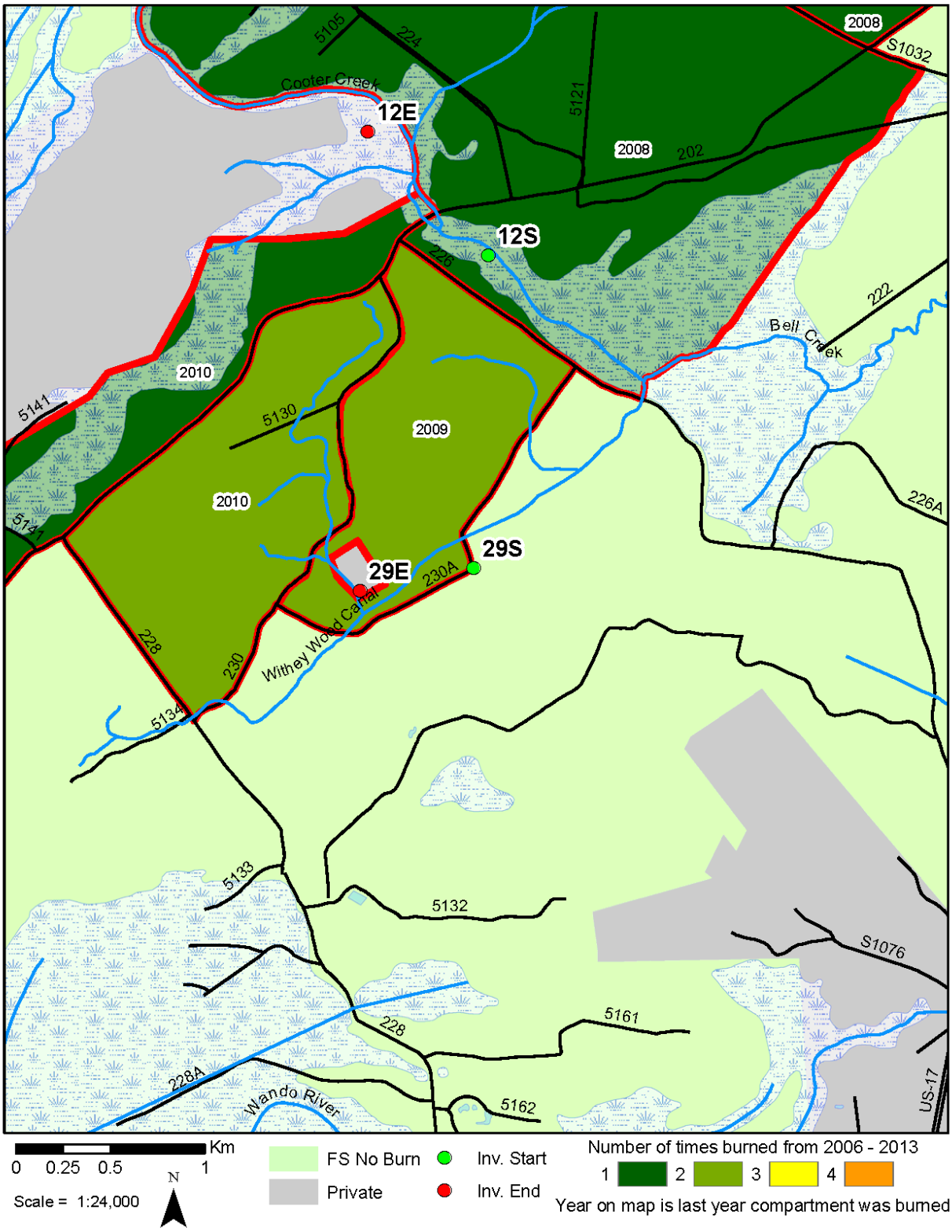
Site Number: 22 Stream: UT Wadboo Cr



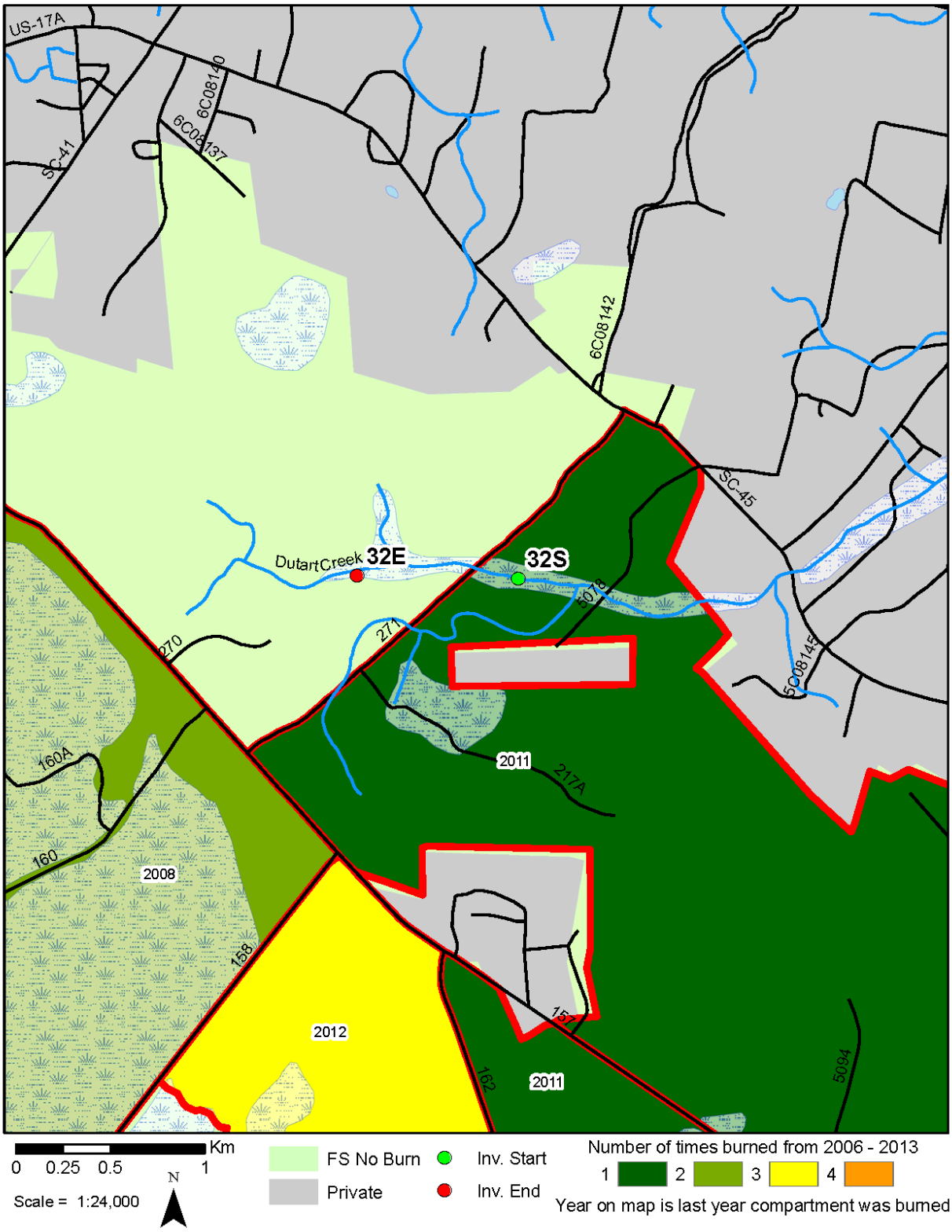
Site Number: 23 Stream: Pepper Gully



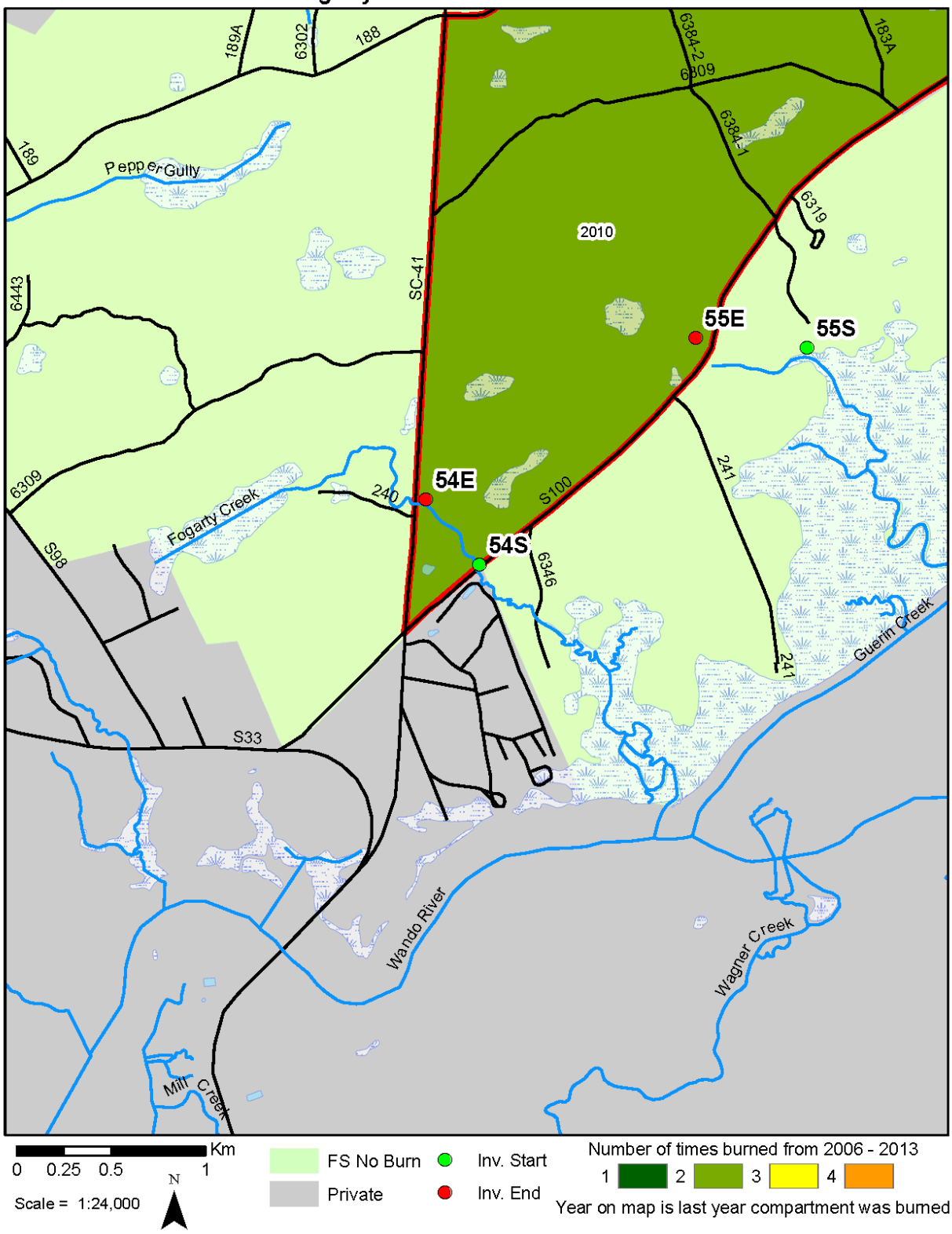
Site Number: 29 Stream: UT Bell Cr



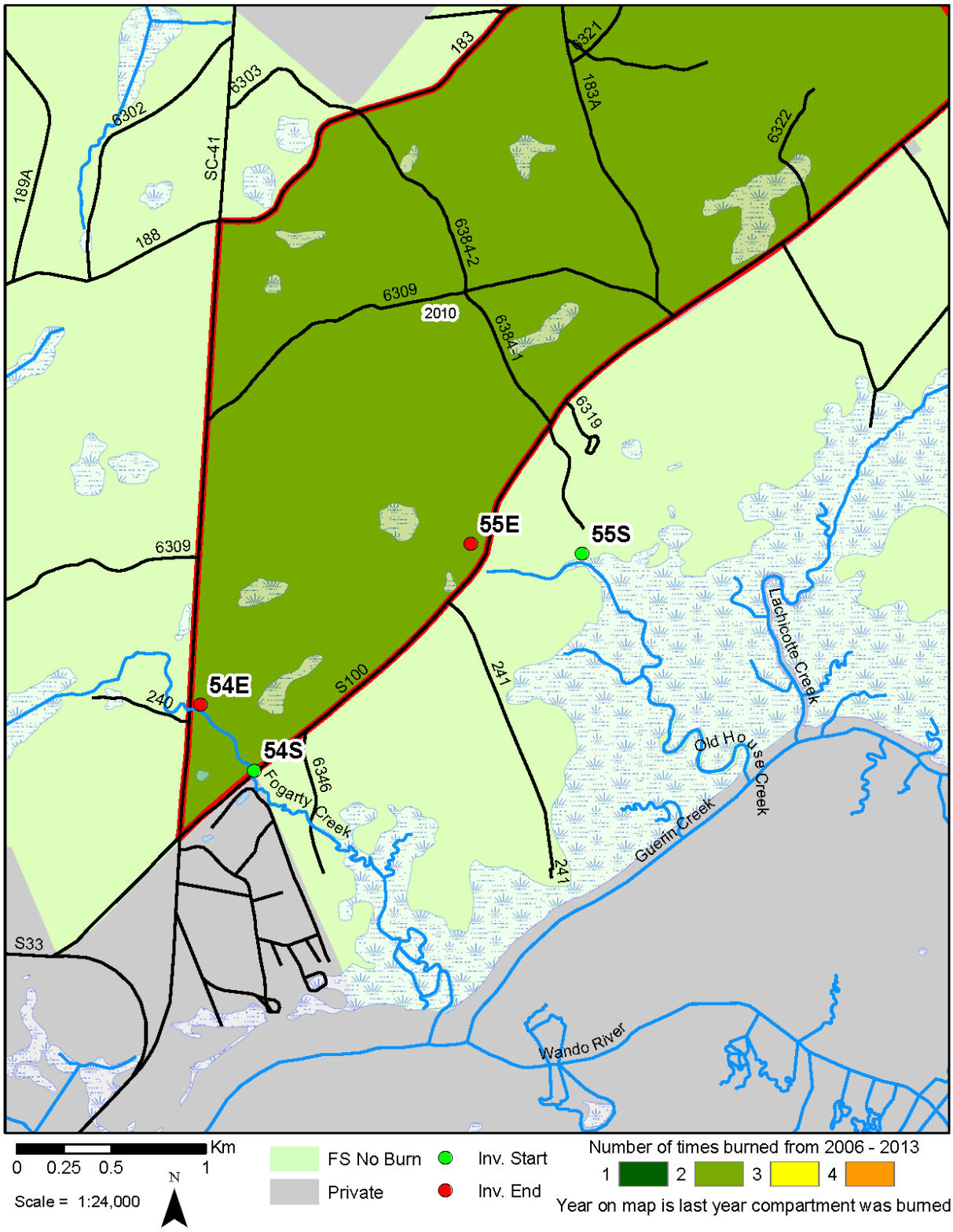
Site Number: 32 Stream: Dutart Cr



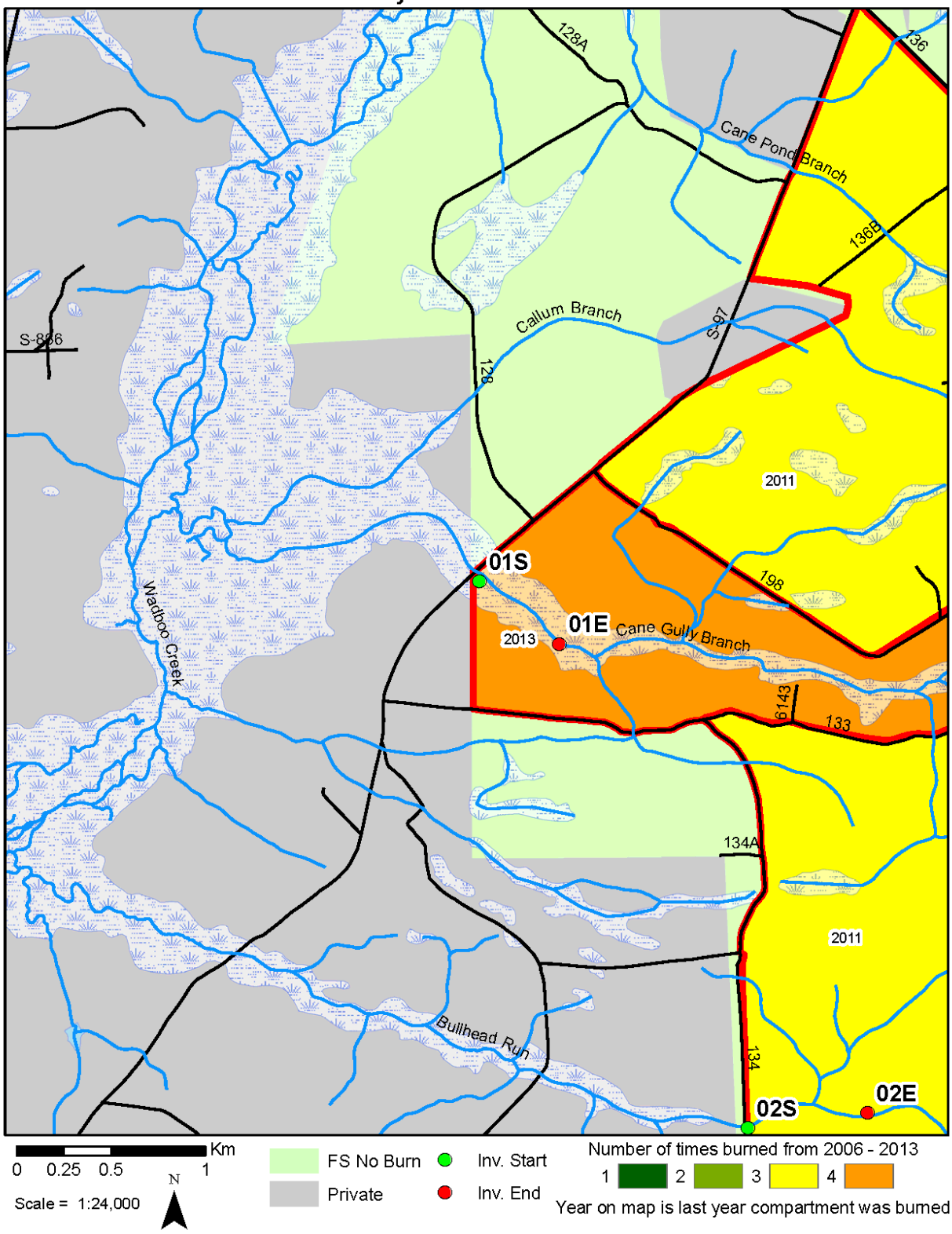
Site Number: 54 Stream: Fogarty Cr



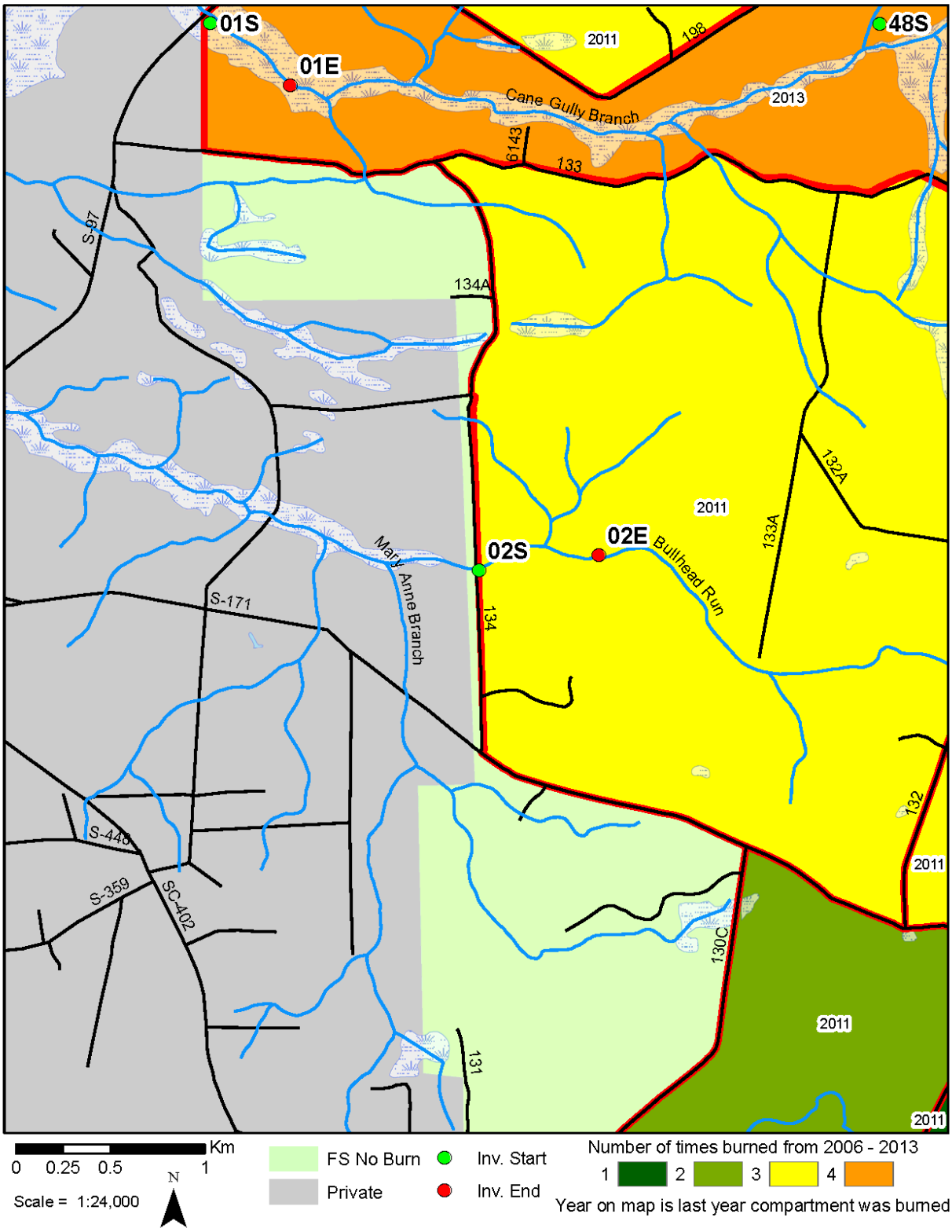
Site Number: 55 Stream: Old House Cr



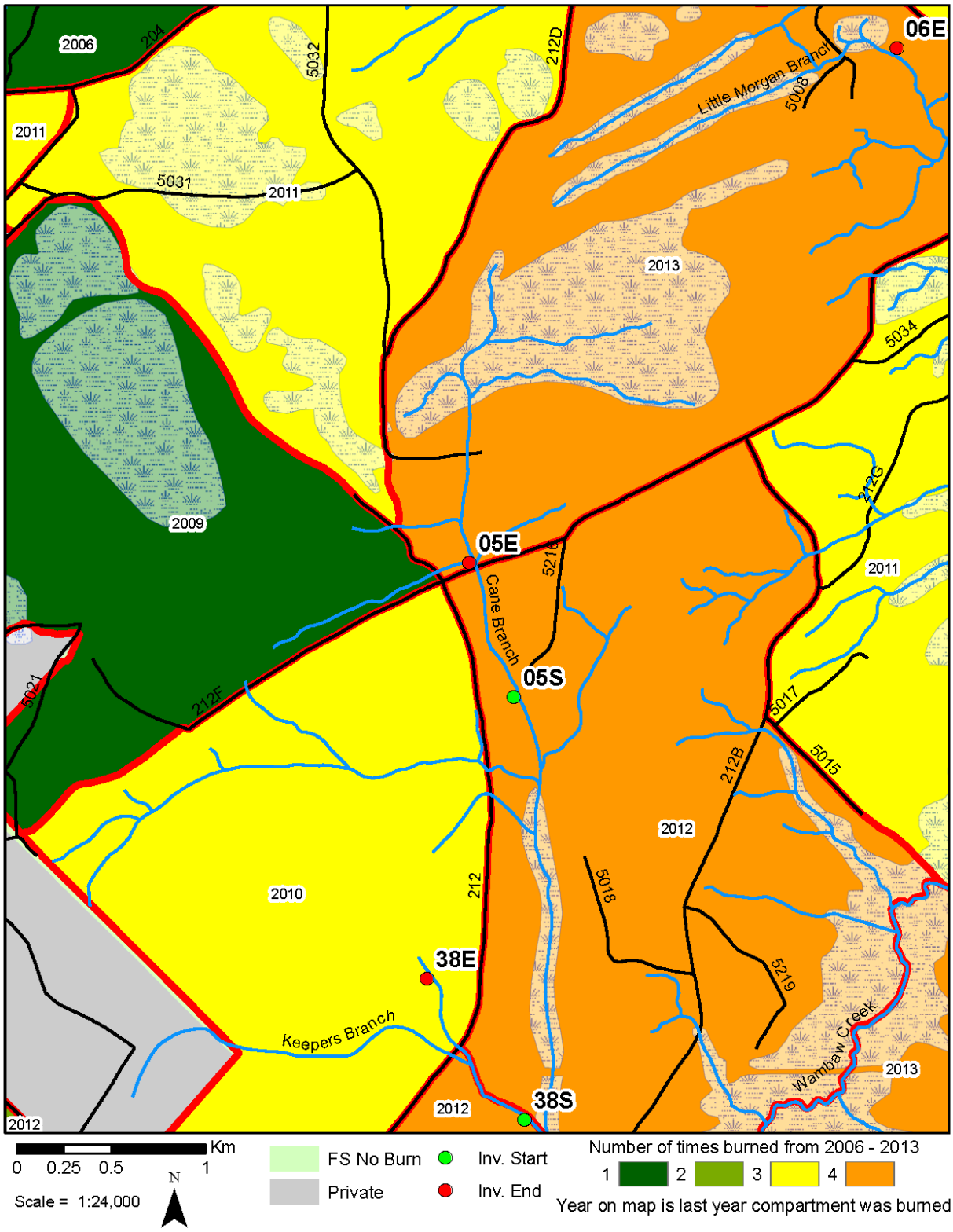
Site Number: 01 Stream: Cane Gully



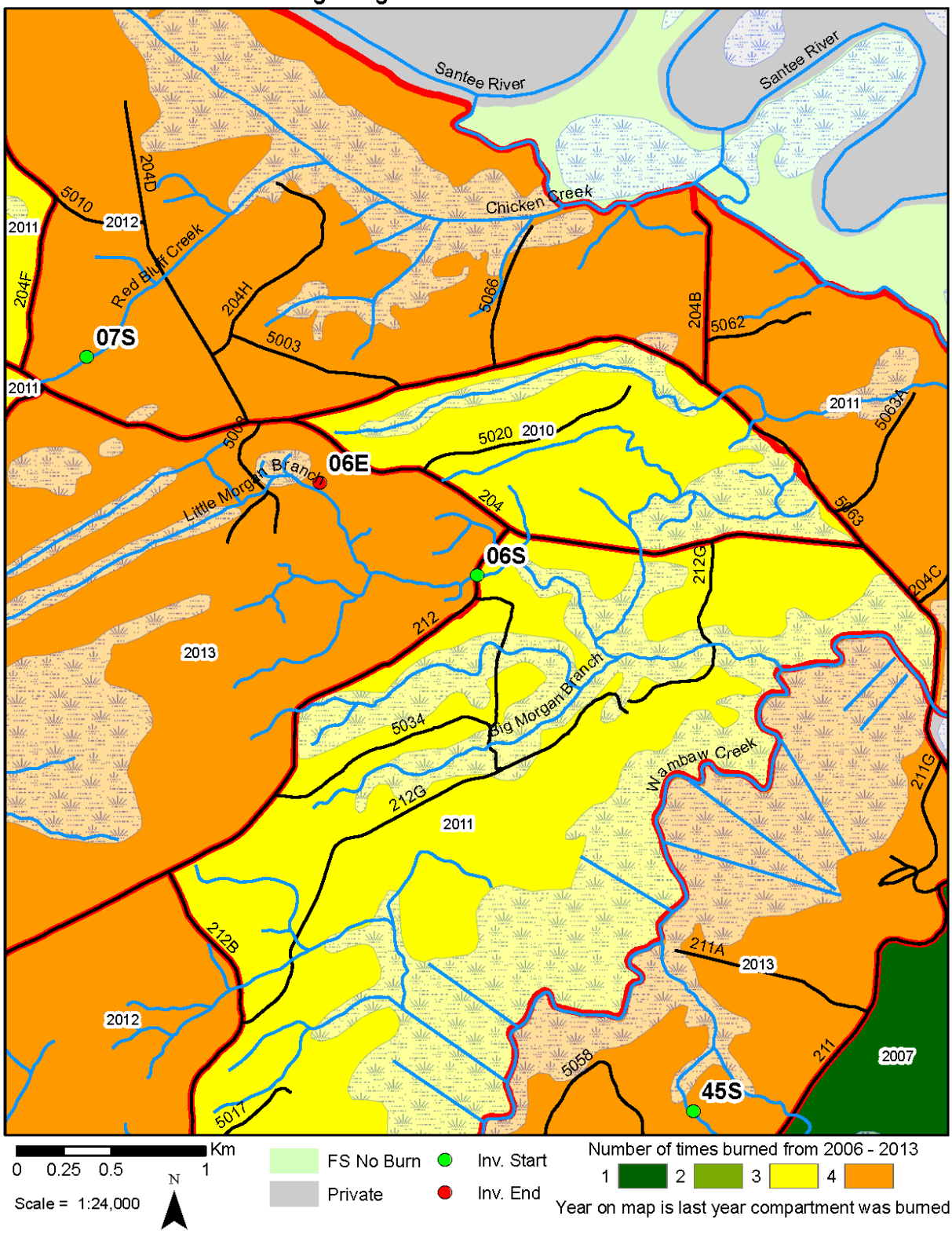
Site Number: 02 Stream: Bullhead Run



Site Number: 05 Stream: Cane Br



Site Number: 06 Stream: Big Morgan Br



0 0.25 0.5 1 Km

Scale = 1:24,000

N

FS No Burn

Private

Inv. Start

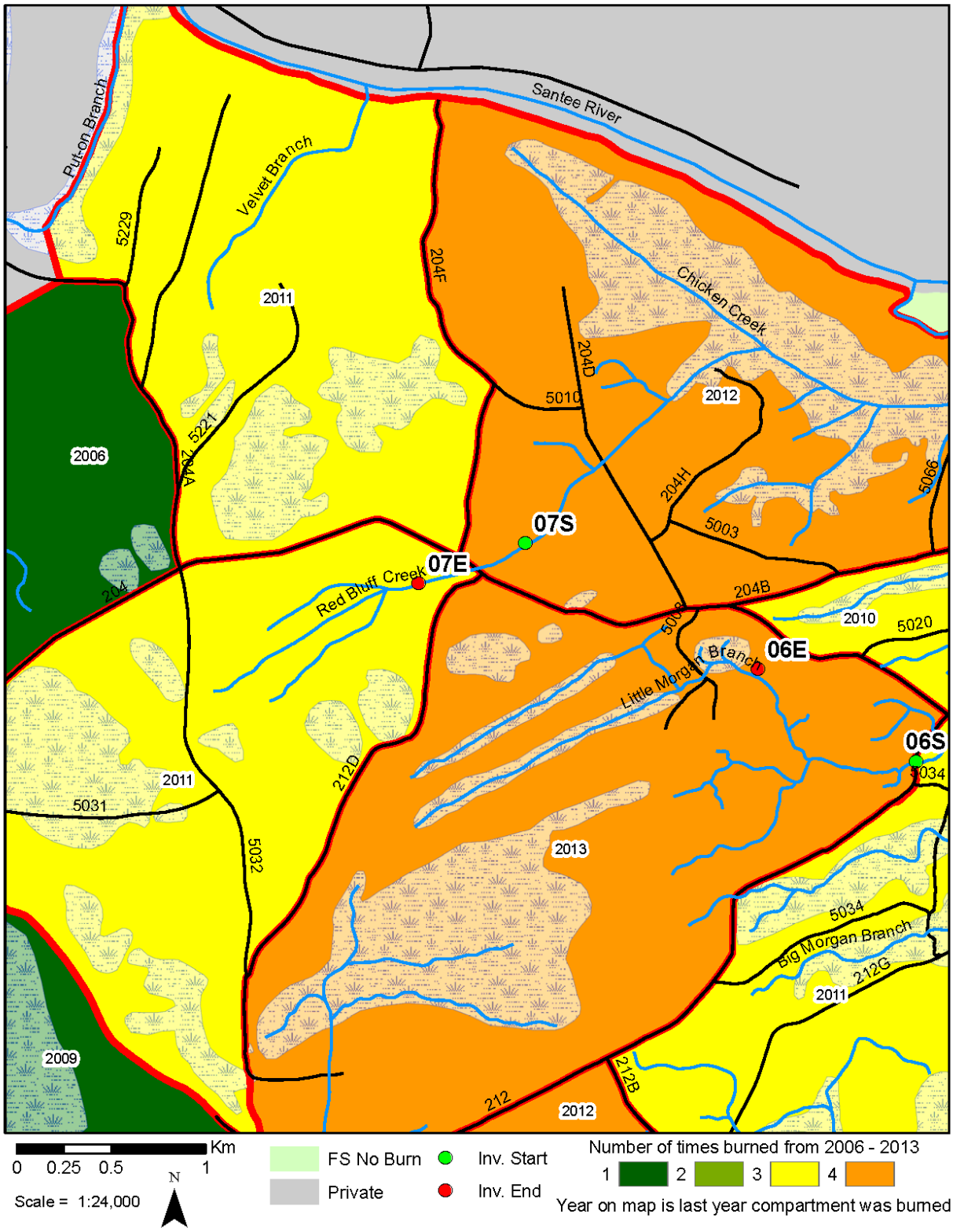
Inv. End

Number of times burned from 2006 - 2013

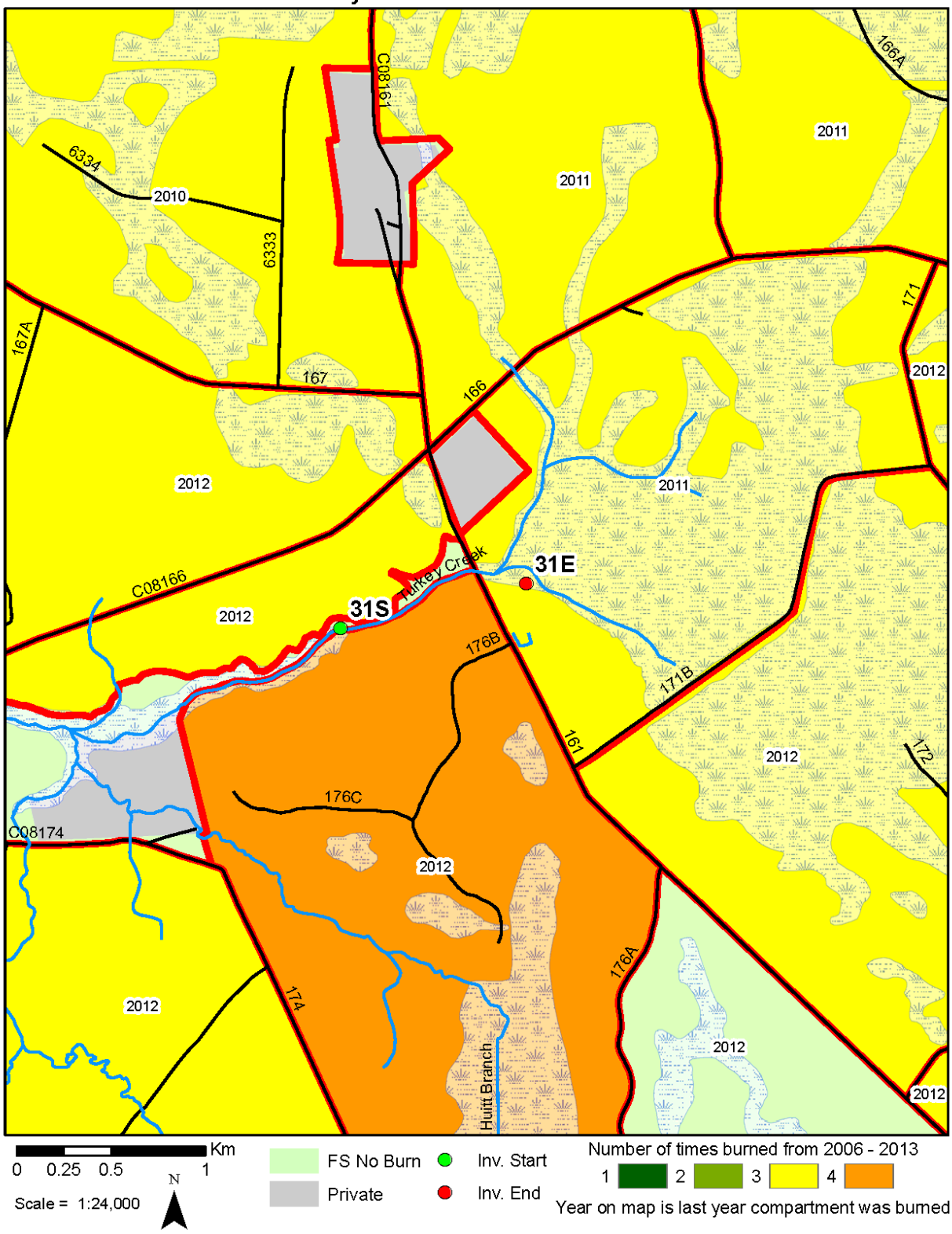
1 2 3 4

Year on map is last year compartment was burned

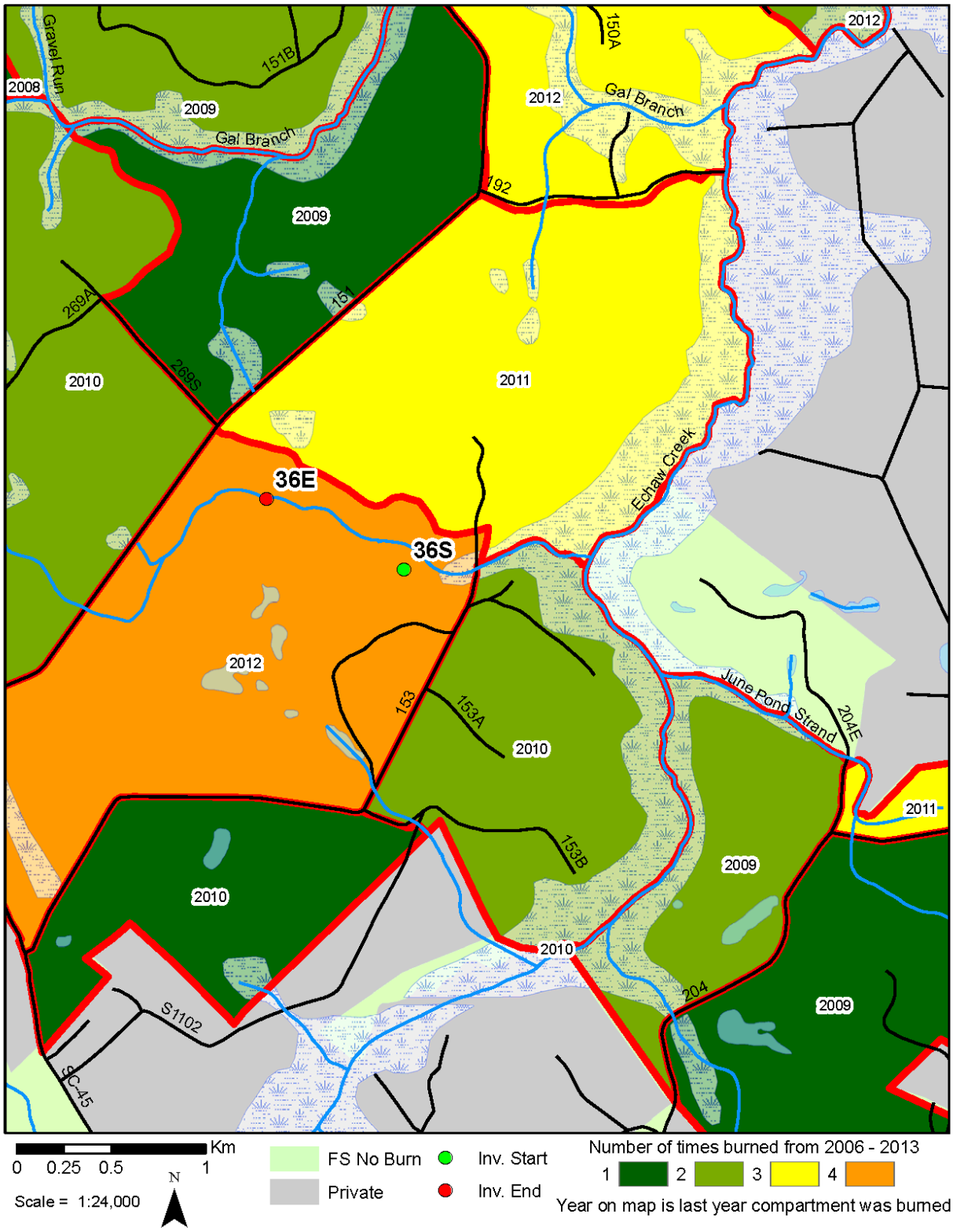
Site Number: 07 Stream: Red Bluff Cr



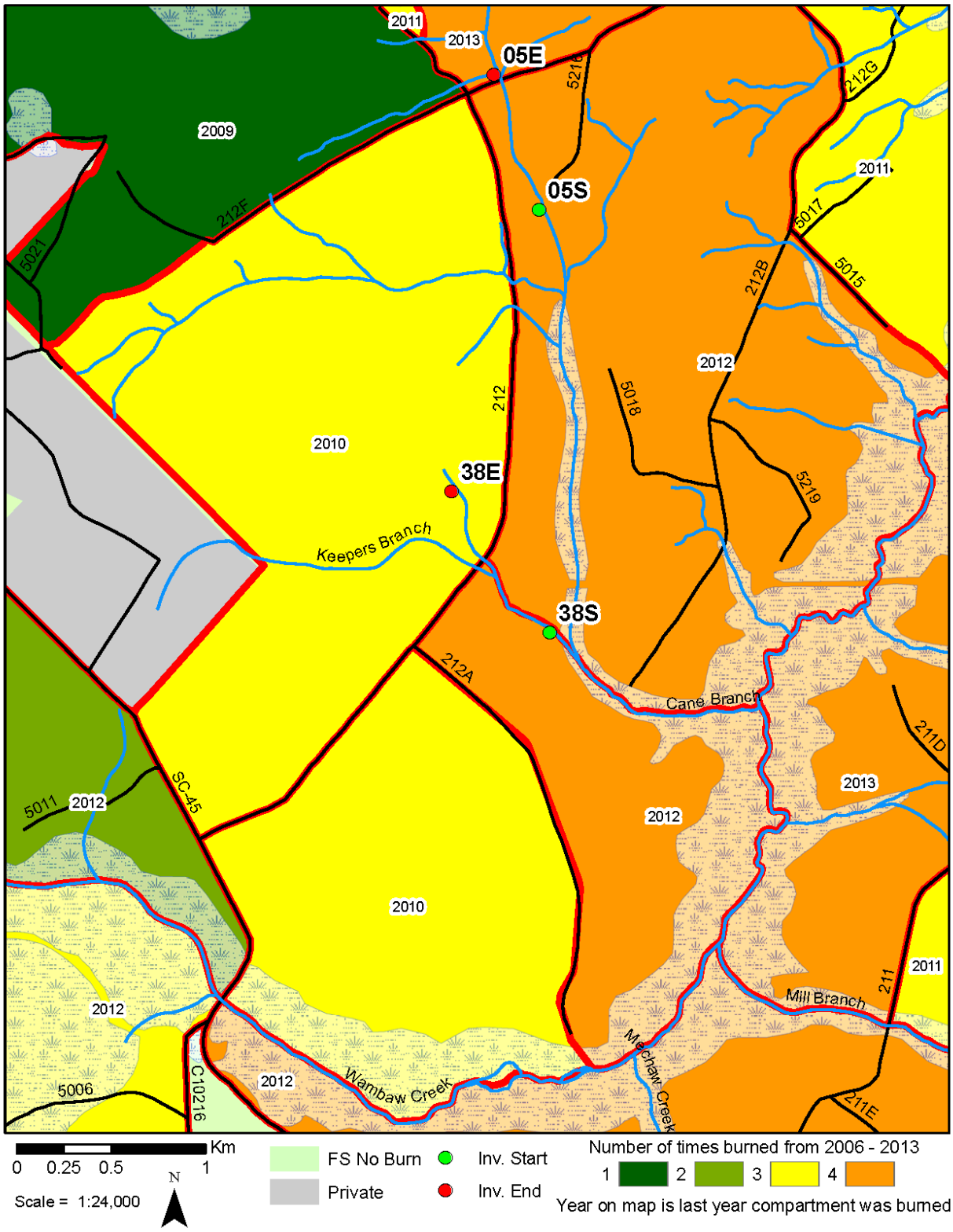
Site Number: 31 Stream: Turkey Cr



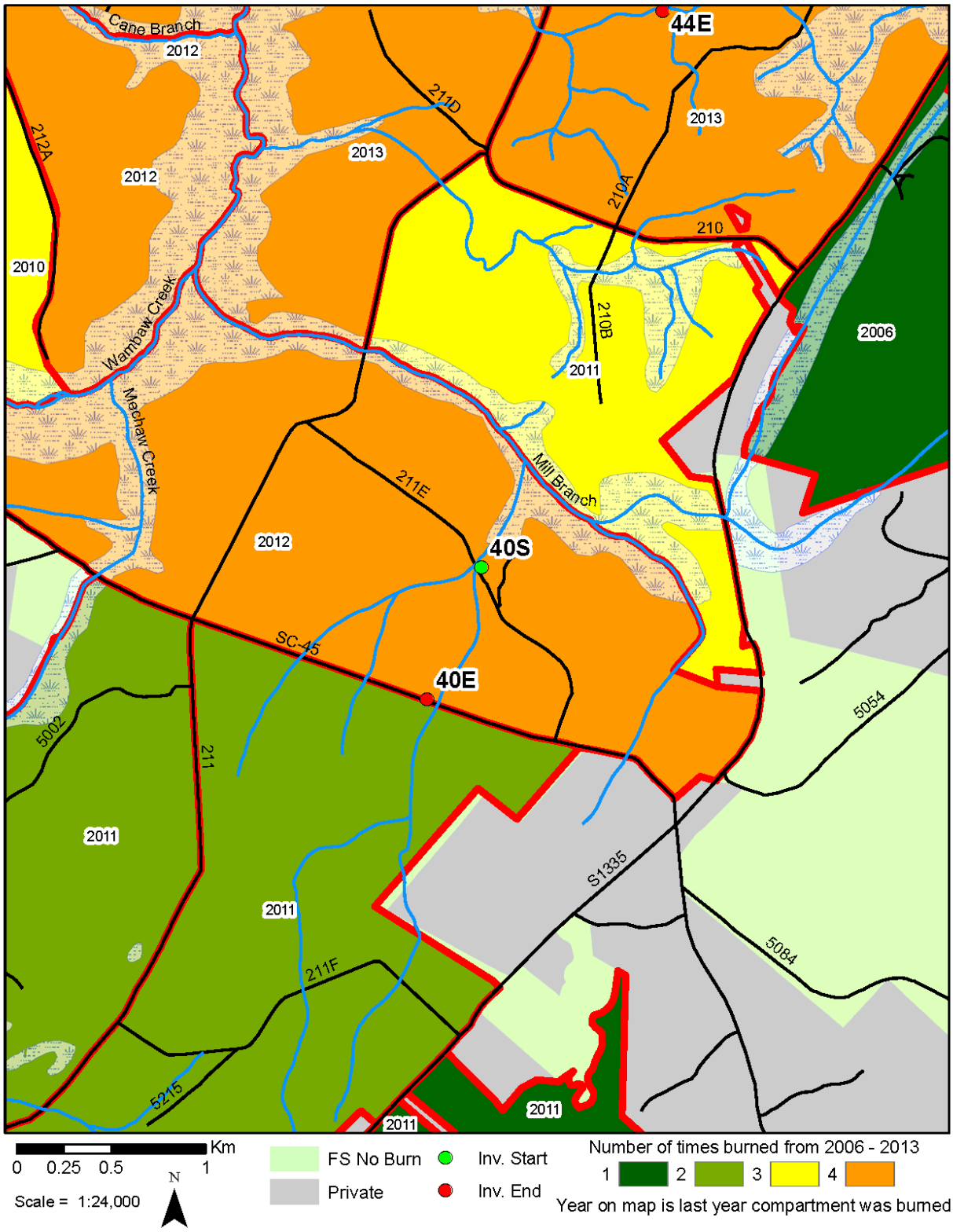
Site Number: 36 Stream: UT Echaw Cr



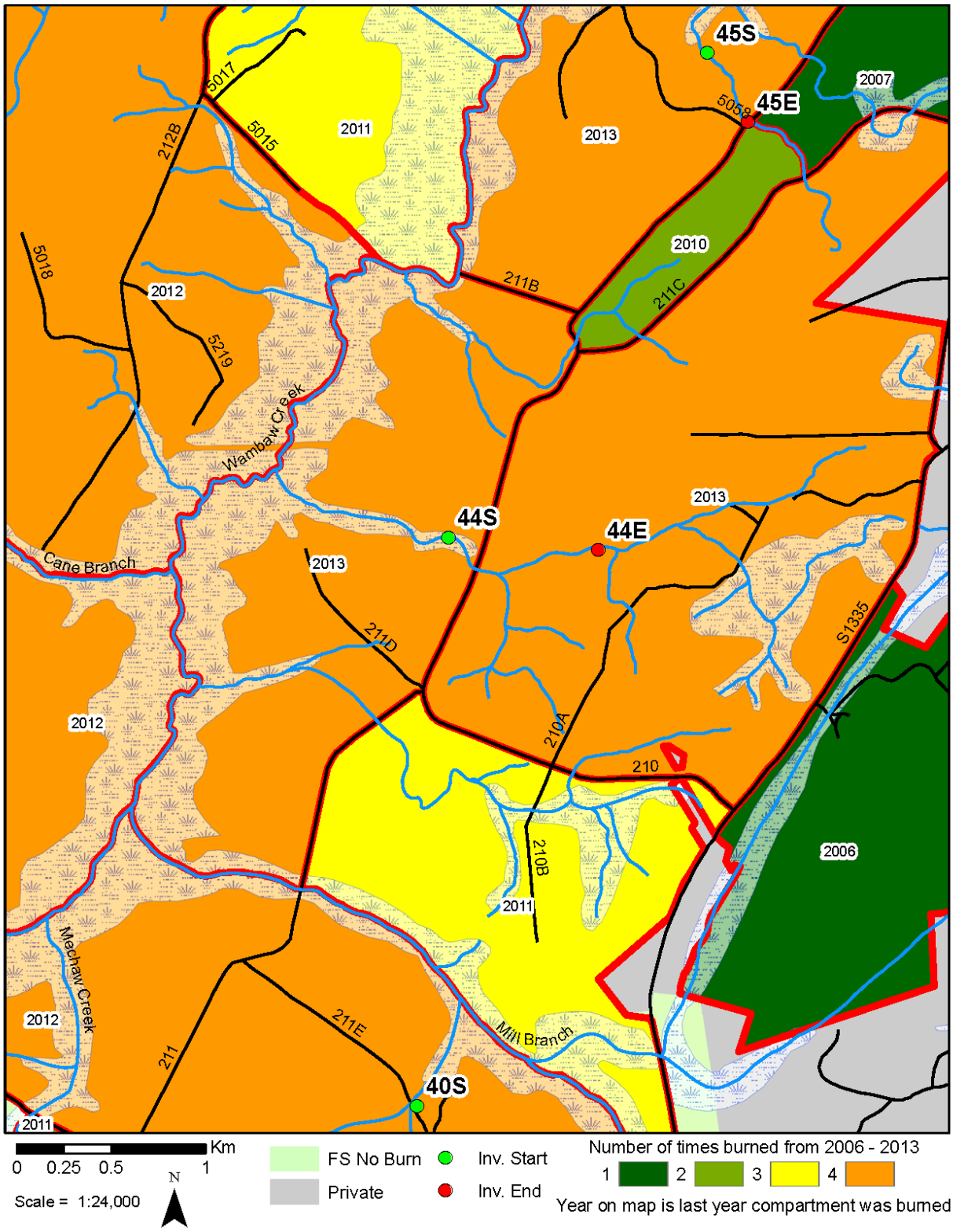
Site Number: 38 Stream: UT Cane Cr



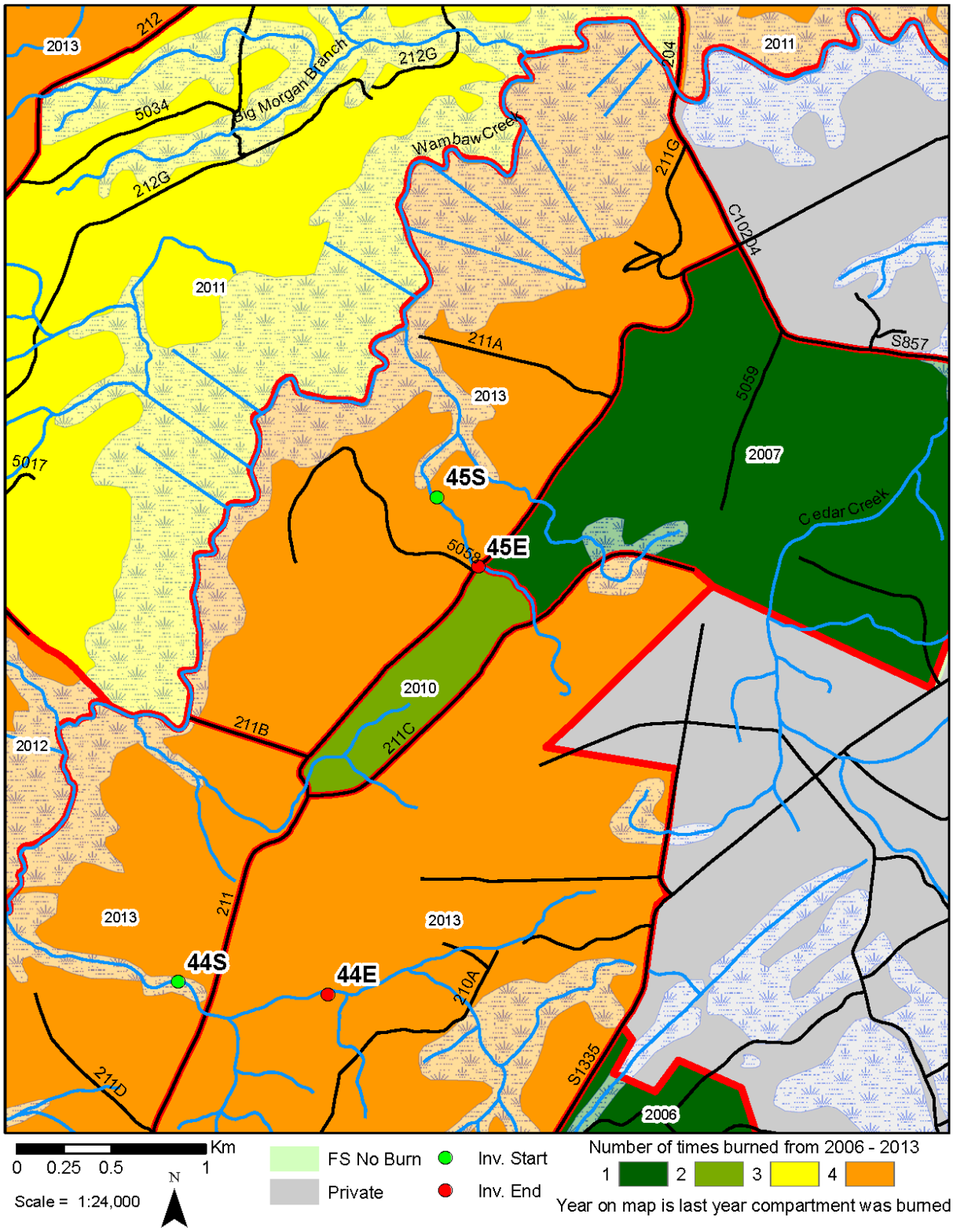
Site Number: 40 Stream: UT Mill Br



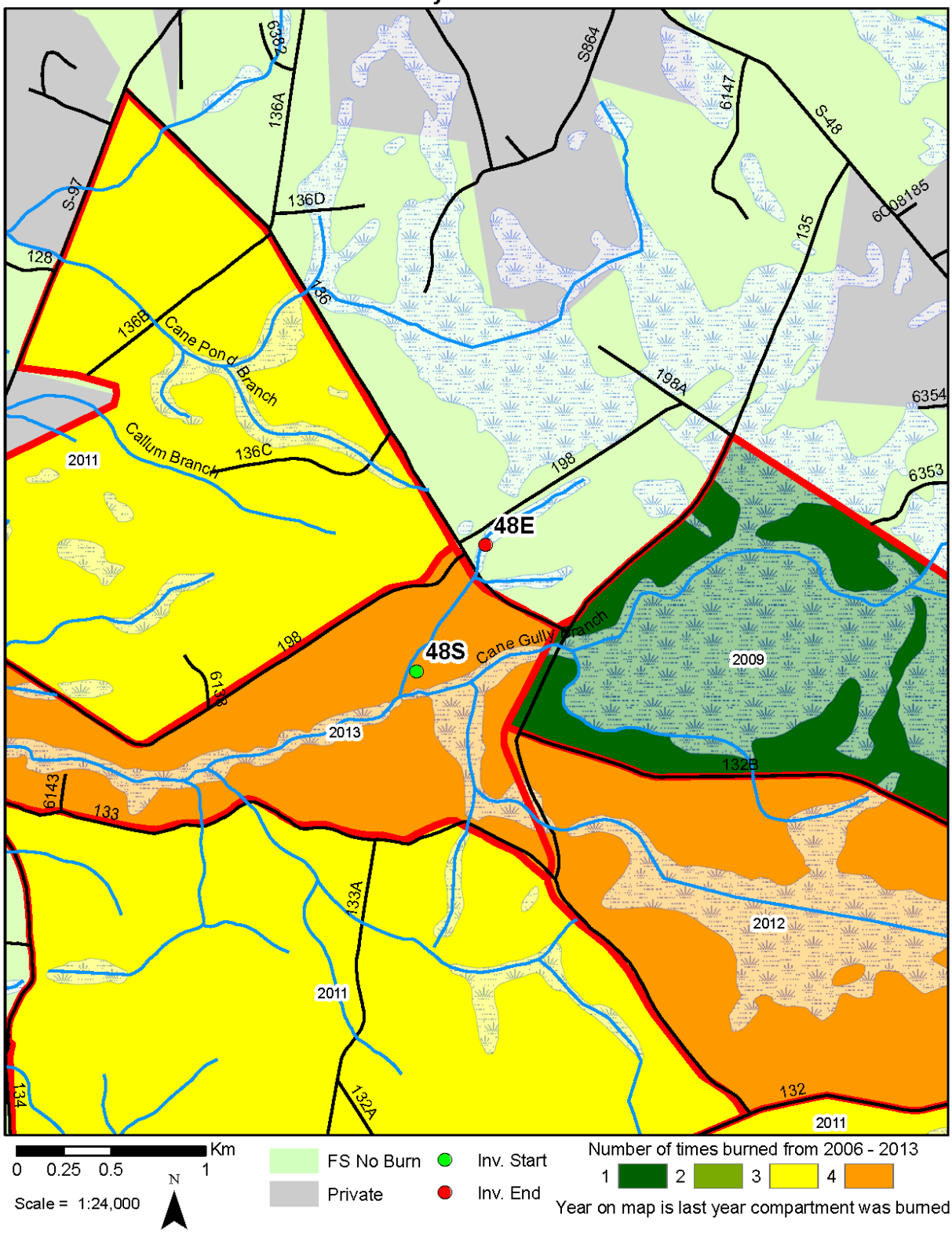
Site Number: 44 Stream: UT Wambaw Cr



Site Number: 45 Stream: UT Wambaw Cr



Site Number: 48 Stream: UT Cane Gully



Appendix C – Large Wood Inventory Field Methods

A. Navigate to Site

1. Perform "Check-Out" when leaving hotel/duty-station using Spot GPS device to send an "ok" message
2. Drive to stream site; typically a road/stream crossing access-point
3. Navigate using maps and GPS
4. Before parking, have spotter get out and make sure the side of the road or pull-off is firm ground (we've had trucks get stuck here with only 2 wheels off the road)

B. Header Data Entry (at start of inventory)

Complete the following header information on PDA data-form (or backup paper datasheet):

1. Site-ID#
2. Stream Name
3. Date
4. Crew
5. Start Waypoint
    - create waypoint on GPS unit and record waypoint name on PDA data-form
    - Waypoint name format is, for example **S01** where **S** is Start and **01** is Site #1
6. Start Photo ID#
    - take photo looking upstream from the inventory start location; record last 3 digits of camera's photo ID#
7. Start Wetted Width
    - measure to nearest 1/10 meter
8. Start Bankfull Width
    - measure to nearest 1/10 meter
9. Start Location Notes
    - record descriptive notes for start location

C. Inventory

Tie hip-chain string downstream of start location and zero counter at start, then walk upstream and record the following units on PDA data-form (or backup paper datasheet):

<u>Large Wood</u>: dead and down, >10cm diameter and >1m length, any part within bankfull

1. Distance
    - measured with hipchain, rounded to nearest 1 meter
2. Length
    - measured with tape measure to nearest 1/10 meter
3. Diameter
    - measured with caliper to nearest 1 centimeter at breast-height
4. % in Bankfull
    - % of log length within the bankfull channel; visually estimate to nearest 10%
5. % Submerged
    - % of log length underwater; visually estimate to nearest 10%
6. % Charred
    - % of log length with burn charring; visually estimate to nearest 10%
7. Channel Position: Angled, Parallel, or Perpendicular

- position of log relative to channel

8. Photo ID# (optional)
    - required for all charred logs
    - record last 3 digits of camera's photo ID#
9. Coordinates (optional)
    - required for all charred logs; record for others if they are noteworthy
    - GPS waypoint name format should be site # and consecutive lettering such as 31large wood[hipchain]
10. Comment (optional)
    - record notes as necessary

<u>Swamps</u>: widened reaches on the main channel with no defined stream banks and diffuse flow

1. Distance
    - measured with hipchain, rounded to nearest 1 meter
    - record the downstream start and upstream end distances as separate features
2. Photo ID# (optional)
    - record last 3 digits of camera's photo ID#
3. Waypoint
    - collect at downstream start and upstream end
    - name format should be site # and consecutive lettering such as 33S[hipchain]
4. Comment (optional)
    - record notes as necessary

<u>Riparian Burn</u>: evidence of burning (charred trees, burned grass, etc.) within 5 m of the stream

1. Distance
    - measured with hipchain, rounded to nearest 1 meter
    - record the downstream start and upstream end distances as separate features
2. Photo ID# (optional)
    - record last 3 digits of camera's photo ID#
3. Waypoint
    - collect at downstream start and upstream end
    - name format should be site # and consecutive lettering such as 24R[hipchain]
4. Comment
    - record side of stream with burn; as looking upstream; right, left, or both sides

<u>Tributaries</u>: wetted or dry channels joining the mainstem (not side-channels)

1. Distance
    - measured with hipchain, rounded to nearest 1 meter
2. Photo ID# (optional)
    - record last 3 digits of camera's photo ID# for any pictures
3. Waypoint (optional)
    - record for large tributaries
    - name format should be site # and consecutive lettering such as 22T[hipchain]
4. Comment

- record side of stream with tributary; as looking upstream; right or left

<u>Bridge, Culvert, Ford, or Dam</u>: crossing structures for roads or trails

1. Distance
   - measured with hipchain, rounded to nearest 1 meter
2. Photo ID#
   - take picture of downstream end of culvert at a minimum
   - record last 3 digits of camera's photo ID#
3. Waypoint
   - name format should be site # and consecutive lettering such as 45X[hipchain]
4. Comment
   - record road or trail name, perch (drop from pipe to water surface), if natural substrate present throughout pipe, width, height, and length of pipe, material (metal, concrete, etc.), number of pipes, any maintenance concerns

<u>Other</u>: any other noteworthy stream features not included above

1. Distance
   - measured with hipchain, rounded to nearest 1 meter
2. Photo ID# (optional)
   - record last 3 digits of camera's photo ID#
3. Waypoint (optional)
   - collect if you feel it will be helpful
   - name format should be site # and consecutive lettering such as 53O[hipchain]
4. Comment
   - record type of feature and any pertinent information about it

Special situations when using the PDA:

- *when entering data into the PDA, if you make an error and click the next button you will not be able to back-up and make corrections; if this happens then reenter the data correctly and use the comment field to note that the previous record needs to be deleted*
- *if the hipchain counter malfunctions and needs to be reset be sure to note in the comment field "HIPCHAIN RESET"*

D. Header Data Entry (at end of inventory)

At end of inventory, return to PDA header and complete the following information on PDA data-form (or backup paper datasheet):

1. End Waypoint
   - create waypoint on GPS unit and record waypoint on PDA data-form
   - waypoint format is, for example **E01** where **E** is End and **01** is Site #1
2. End Photo ID#
   - take photo looking downstream from the inventory start location; record last 3 digits of camera's photo ID#
3. End Wetted Width
   - measure to nearest 1/10 meter
4. End Bankfull Width
   - measure to nearest 1/10 meter

5. End Location Notes
    - record descriptive notes for end location

E. Navigate to Hotel/Duty-Station

1. Perform "Check-In" once arrived at hotel/duty-station using Spot GPS device to send an "ok" message
2. Data download and battery charging
    - give crew leader your PDA, GPS unit, camera, spare batteries, paper datasheets
3. Inform crew leader of any equipment and vehicle issues

Field Equipment Checklist

- ☐ caliper
- ☐ camera
- ☐ first aid kit
- ☐ flagging
- ☐ GPS & spare batteries
- ☐ hardhat
- ☐ hipchain
- ☐ maps
- ☐ measuring tape
- ☐ paper datasheets
- ☐ PDA in field-case
- ☐ pencils
- ☐ sharpies
- ☐ SPOT Unit & spare batteries
- ☐ topofill
- ☐ waders
- ☐ wading boots
- ☐ wading rod
- ☐ water filter

Other Equipment Checklist

- ☐ AA battery charger
- ☐ camera battery charger
- ☐ laptop computer
- ☐ power inverter
- ☐ PDA chargers
- ☐ power strip
- ☐ vehicle GPS

Paper Datasheet

Site#	Crew	Start	End	Notes Page____ of ____
Stream		Waypoint	Waypoint	
		Photo ID#	Photo ID#	
Date		Wetted (m)	Wetted (m)	
		Bankfull (m)	Bankfull (m)	*Channel Position: angled /, parallel II, perpendicular -*

Unit Type	Distance (m)	Length (m)	Diameter (cm)	% in Bankfull	% Submerged	% Charred	Channel Position	Photo ID#	Waypoint	Comment

Appendix D – Notable Observations and Photos

Table D1. Notable observations made at select sites and their location.

Site #	Stream	Observation Notes	Coordinates (UTM NAD83)	Photo ID#
12	Cooter Creek	freshwater mussels	17 S 623797 3656030 & 17 S 623591 3656293	054, 062
21	Beauford Branch	freshwater mussels	17 S 612004 3690344	022-023
22	UT Wadboo Creek	2 spotted turtles (*Clemmys gutta*)	17 S 603602 3688228	052-063
23	Pepper Gully	abandoned tarp/tent campsite	17 S 607718 3647082	095
44	UT Wambaw Creek	1 mud turtle (*Kinosternon subrubrum)*	17 S 640171 3670481	020-022
48	UT Cane Gully	1 mud turtle (*Kinosternon subrubrum)*	17 S 605143 3676543	300-311
54	Fogarty Creek	signs of beaver activity	17 S 610785 3645737	110-111

Site 12, Cooter Creek – freshwater mussels

Site 21, Beauford Branch – freshwater mussels

Site 22, UT Wadboo Creek – spotted turtles (*Clemmys gutta*)

Site 23, Pepper Gully – abandoned camp

Site 44, UT Wambaw Creek – mud turtle (*Kinosternon subrubrum*)

Site 48, UT Cane Gulley – mud turtle (*Kinosternon subrubrum*)

Site 54. Fogarty Creek – signs of beaver activity

Appendix E – Photo Examples of Prescribed Burn Effects

Site 6, Big Morgan Branch – riparian area burned by prescribed fire

Site 31, Turkey Creek – charred log in riparian (upper left) and fallen tree from fire

Site 44, UT Wambaw Creek – fallen trees from fire

Site 48, UT Cane Gulley– riparian area burned by prescribed fire