Cache la Poudre Phase 1 Watershed Assessment

Prioritization of watershed-based hazards to water supplies

Report Prepared for:

USDA Forest Service

Rocky Mountain Region

Bark Beetle Incident

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INTRODUCTION

This Phase 1 Watershed Assessment is designed to be the first phase of a process to identify and prioritize sixth-level watersheds based upon their hazards of generating flooding, debris flows and increased sediment yields following wildfires that could have impacts on water supplies. It is intended to expand upon current wildfire hazard reduction efforts by including water supply watersheds as a community value. The watershed assessment follows the ranking procedure for each of the four integral components as prescribed by the Front Range Watershed Protection Data Refinement Work Group (2009).

This Phase 1 Watershed Assessment is one of 15 that are being completed for the Bark Beetle Incident team in the Rocky Mountain Region (Region 2) of the USDA Forest Service (Figure 1). The Bark Beetle Incident team covers the following three National Forests:

1. White River National Forest
2. Medicine Bow-Routt National Forests
3. Arapaho-Roosevelt National Forests

Phase 2 of the Watershed Assessment process would be to gather the key water supply stakeholders to communicate the suggested process, show them the results of Phase 1, listen to any suggested changes, make appropriate changes and build collaborative support for the assessment process. The stakeholder process is critical to local support for the results of the assessment, and the effectiveness of implementing recommendations that would come out of the assessment process.

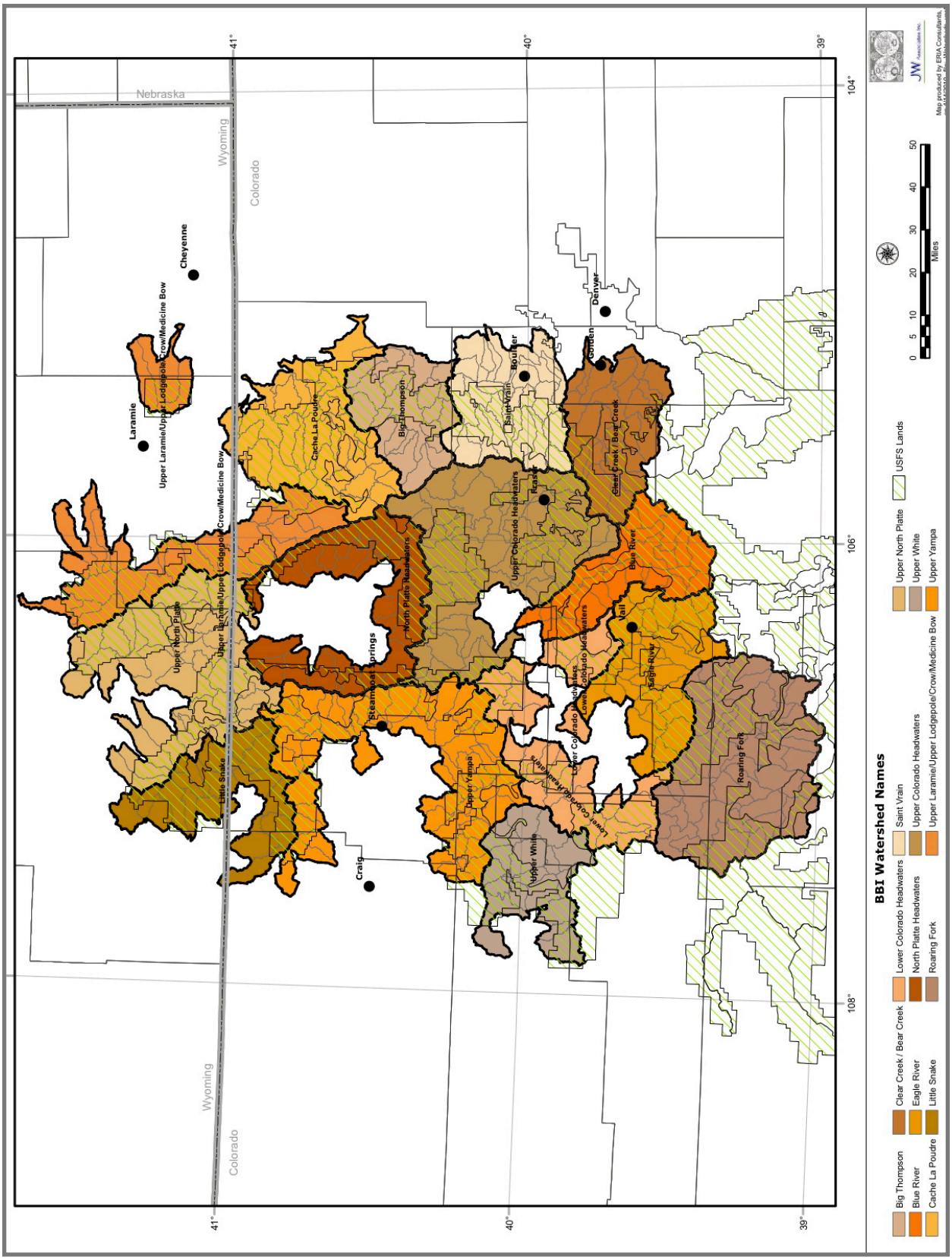

Figure 1. Bark Beetle Incident Phase 1 Watersheds

WATERSHED DESCRIPTION

The Cache la Poudre watershed is a Front Range watershed that typically begins at the continental divide and ends at the start of the western edge of the plains. It is a tributary to the South Platte River. This watershed assessment is designed to assess hazards from wildfire to water supply. Therefore, the subwatersheds that are entirely on the plains to the east were eliminated from this watershed assessment. The plains watersheds would have skewed the results of the assessment because they are relatively flat, have higher road densities and very different fire regimes.

The Cache la Poudre watershed is one fourth-level[1] (eight-digit) watershed (HUC 10190007) that is 1,219,038 acres in size and contains 53 sixth-level watersheds. For this watershed assessment, 20 sixth-level watersheds were eliminated based upon their wildfire hazard, ruggedness, and an examination of how well they fit into this assessment. The Cache la Poudre watershed used in this analysis is 648,045 acres, contains eight fifth-level watersheds and 33 sixth-level watersheds, which are the analysis units for this watershed assessment (Front Range Watershed Protection Data Refinement Work Group 2009). The Cache la Poudre watershed and its fifth-level and sixth-level watersheds are shown on Figure 2 and listed in Table 1.

[I] The watersheds that were used are part of the existing national network of delineated watersheds. Hydrologic Unit Codes (HUCs) are nested watersheds and are designated numerically by levels (Federal Geographic Data Committee 2004). Sixth-level HUCs or watersheds, use the 11th and 12th digits in the HUC code. Fifth-level HUCs use the ninth and 10th digits in the HUC code.

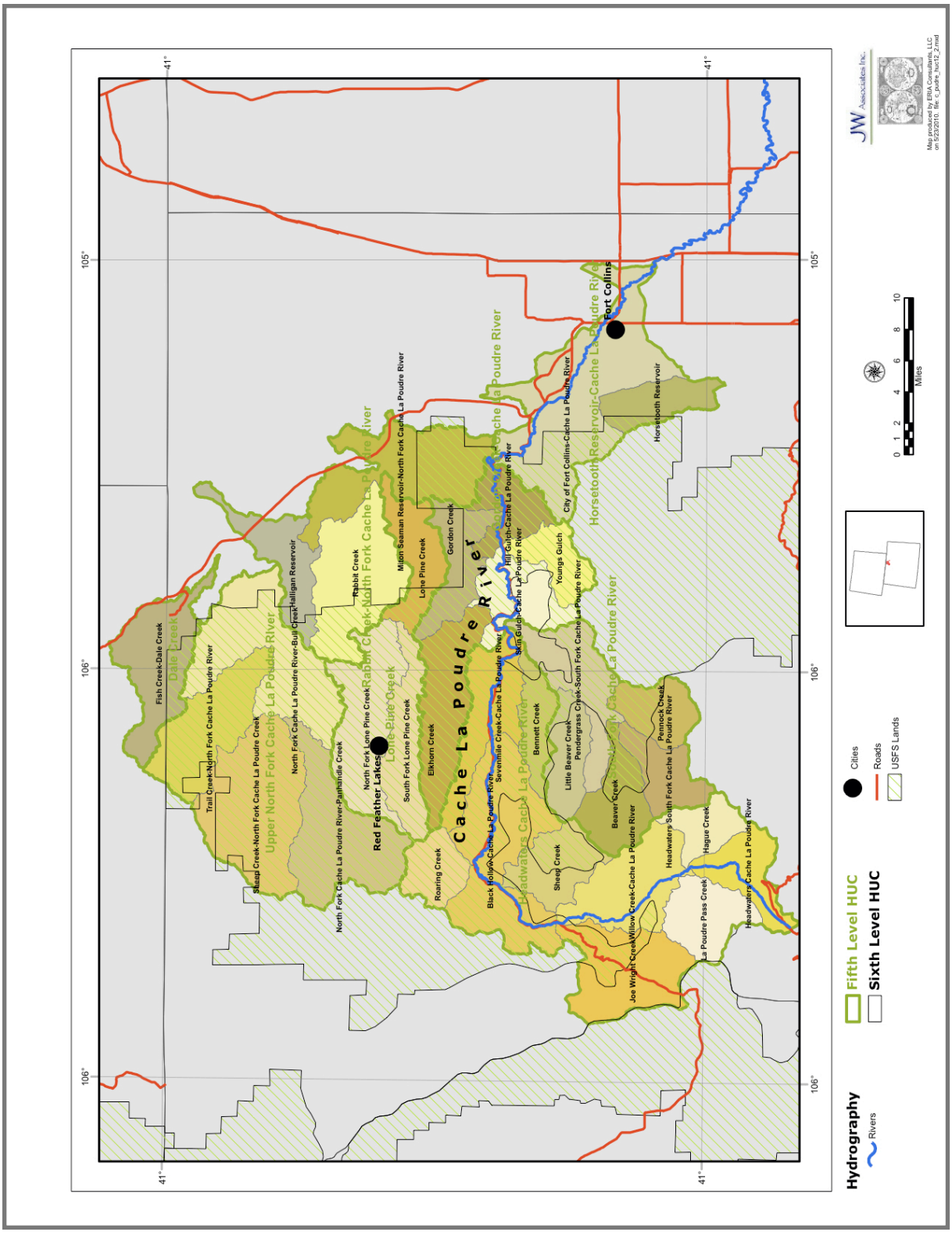

Figure 2. Cache la Poudre Watershed Analysis Area[2]

[2] The fifth-level watersheds are shown in Figure 2.

Table 1. Fifth-level and Sixth-level Watersheds in Cache la Poudre Watershed[3]

Fifth-level Watershed	Sixth-level Watershed	Watershed Area (acres)	Hydrologic Unit Code (HUC)	Map #
South Fork Cache La Poudre River HUC 1019000701	Beaver Creek	14,135	101900070101	305
	Headwaters South Fork Cache La Poudre River	11,094	101900070102	306
	Pennock Creek	11,068	101900070103	307
	Little Beaver Creek	11,562	101900070104	308
	Pendergrass Creek-South Fork Cache La Poudre River	18,639	101900070105	309
Headwaters Cache La Poudre River HUC 1019000702	Hague Creek	8,685	101900070201	310
	Headwaters Cache La Poudre River	12,709	101900070202	311
	La Poudre Pass Creek	14,066	101900070203	312
	Joe Wright Creek	24,468	101900070204	313
	Willow Creek-Cache La Poudre River	21,936	101900070205	314
	Sheep Creek	13,966	101900070206	315
	Roaring Creek	9,938	101900070207	316
	Black Hollow-Cache La Poudre River	37,738	101900070208	317
	Bennett Creek	9,210	101900070209	318
	Sevenmile Creek-Cache La Poudre River	18,640	101900070210	295
Gordon Creek-Cache La Poudre River HUC 1019000703	Elkhorn Creek	22,259	101900070301	296
	Youngs Gulch	9,823	101900070302	297
	Skin Gulch-Cache La Poudre River	14,920	101900070303	298
	Gordon Creek	13,908	101900070304	299
	Hill Gulch-Cache La Poudre River	11,161	101900070305	300
Upper North Fork Cache La Poudre RIver HUC 1019000704	North Fork Cache La Poudre River-Panhandle Creek	29,786	101900070401	301
	Sheep Creek-North Fork Cache La Poudre Creek	35,586	101900070402	302
	North Fork Cache La Poudre River-Bull Creek	34,294	101900070403	303
	Trail Creek-North Fork Cache La Poudre River	23,034	101900070404	304
Dale Creek 1019000705	Fish Creek-Dale Creek	23,097	101900070503	327
Lone Pine Creek HUC 1019000706	South Fork Lone Pine Creek	16,305	101900070601	319
	North Fork Lone Pine Creek	25,269	101900070602	320
	Lone Pine Creek	14,153	101900070603	321
Rabbit Creek-North Fork Cache La Poudre River HUC 1019000707	Halligan Reservoir	15,127	101900070701	322
	Rabbit Creek	28,860	101900070702	323
	Miton Seaman Res.-North Fork Cache La Poudre River	30,516	101900070704	324
Horsetooth Reservoir HUC 1019000708	Horsetooth Reservoir	10,974	101900070802	325
	City of Fort Collins-Cache La Poudre River	51,119	101900070805	326
	Total Area	**648,045**		

[3] Map numbers are used in Figures 3, 6 and 9

WATERSHED ASSESSMENT

The potential of a watershed to deliver sediments following wildfire depends on forest and soil conditions, the physical configuration of the watersheds, and the sequence and magnitude of rain falling on the burned area. High-severity fires can cause changes in watershed conditions that are capable of dramatically altering runoff and erosion processes in watersheds. Water and sediment yields may increase as more of the forest floor is affected by fire.

This Phase 1 - Cache la Poudre Watershed Assessment provides the analysis for the first three components specified in the Front Range Watershed Protection Data Refinement Work Group (2009) procedure. It provides the analysis for: wildfire hazard, flooding or debris flow hazard, and soil erodibility. This Phase 1 assessment then combines those three components into a composite hazard ranking. This report discusses the technical approach for each component and the process used to assemble the watershed ranking.

The categories used in the prioritization are numbered one though five, with one being the lowest ranking and five being the highest. The numeric ranges for each category are as follows;

Category 1 - 0.5 to 1.49
Category 2 - 1.5 to 2.49
Category 3 - 2.5 to 3.49
Category 4 - 3.5 to 4.49
Category 5 - 4.5 to 5.49

The categories are used in this analysis for the purpose of comparing watersheds to each other within the Cache la Poudre watershed. Comparisons with other watershed assessments are not valid because this approach prioritizes watersheds by comparing them to the other sixth-level watersheds only in this watershed assessment area.

Component 1 - Wildfire Hazard

The forest conditions that are of concern for the assessments are the wildfire hazard based on existing forest conditions. The wildfire hazard (Flame Length) was determined using the Fire Behavior Assessment Tool (FBAT) (http://www.fire.org) which is an interface between ArcMap and FlamMap. The input spatial data were collected from LANDFIRE project (http://www.landfire.gov/).

After a mountain pine beetle outbreak there are substantial increases in the amount of fine dead fuels in the canopy. The majority of these fuels remain in the canopy for 2-3 years post outbreak (Knight 1987, Schmid and Amman 1992). Therefore, certain input spatial data sets were updated based on Mountain Pine Beetle (MPB) mortality conditions using USDA Forest Service, Rocky Mountain Region Aerial Detection Survey (ADS) Data from the years 2002-2007 (http://www.fs.fed.us/r2/resources/fhm/aerialsurvey/). The assumptions used in the FBAT model are presented in Appendix A.

The flame length results were divided into five categories of wildfire hazard ranging from lowest (Category 0) to highest (Category 4). The flame length categories that were used are;

Flame Length Category 0 - 0 meters

Flame Length Category 1 - 1 to 10 meters

Flame Length Category 2 - 11 to 25 meters

Flame Length Category 3 - 26 to 40 meters

Flame Length Category 4 - >40 meters

Figure 3 shows the results of the wildfire hazard modeling. The results were categorized by sixth-level watershed into five categories that are used throughout the analysis (see Table B-1 in Appendix B) using the following formula.

Wildfire Hazard Ranking = (Percentage in Category 3 + Percentage in Category 4 * 2)

The categorized wildfire hazard by sixth-level watershed was mapped (Figure 4). The map shows that the highest hazards are in the following sixth-level watersheds: Willow Creek-Cache La Poudre River, Headwaters Cache La Poudre River, Little Beaver Creek, Pendergrass Creek-South Fork Cache La Poudre River, Pennock Creek, Sheep Creek, and La Poudre Pass Creek. Eight watersheds were ranked as Category 4, which is the next highest category (see Table B-1 in Appendix B).

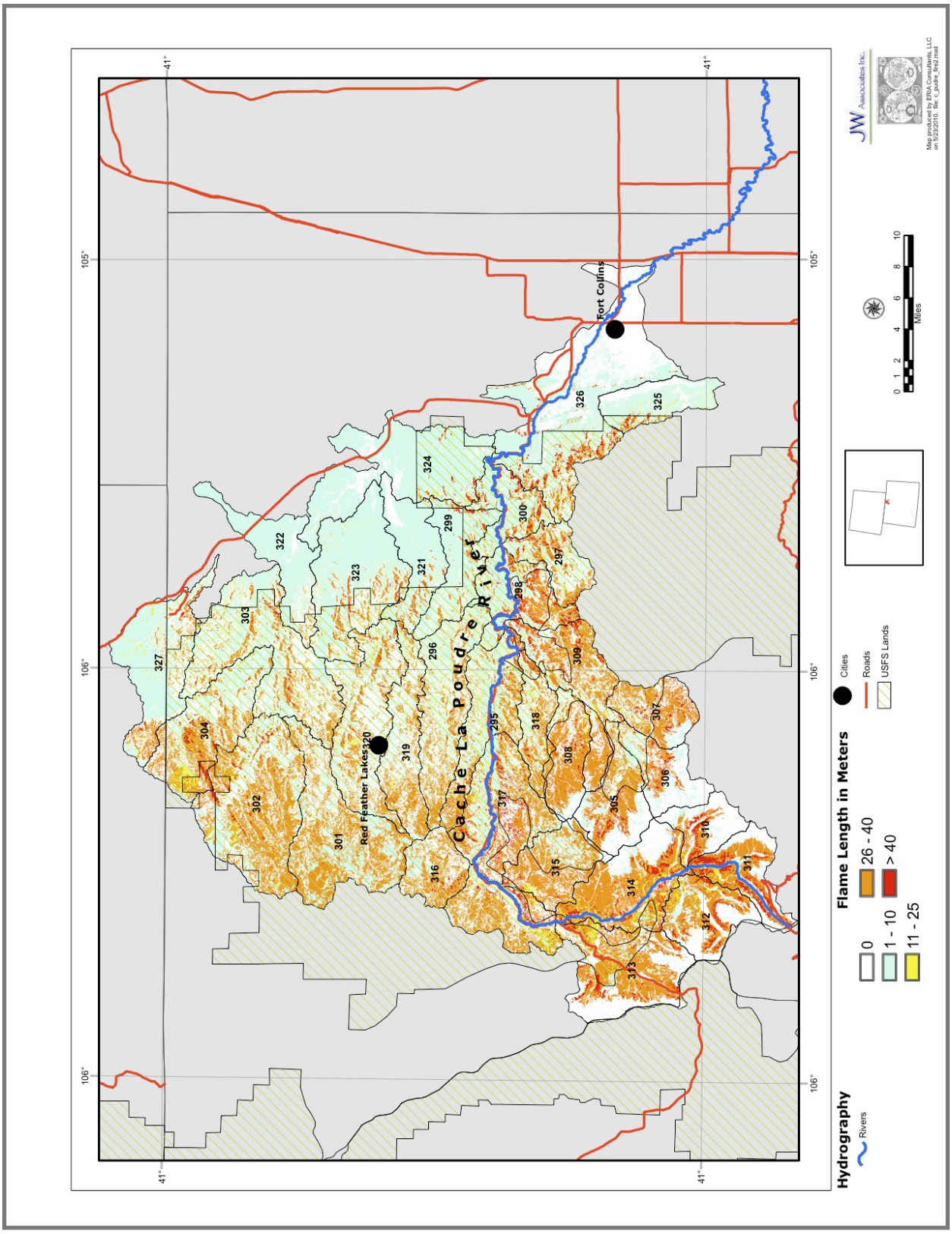

Figure 3. Cache la Poudre Watershed Wildfire Hazard Modeling Results

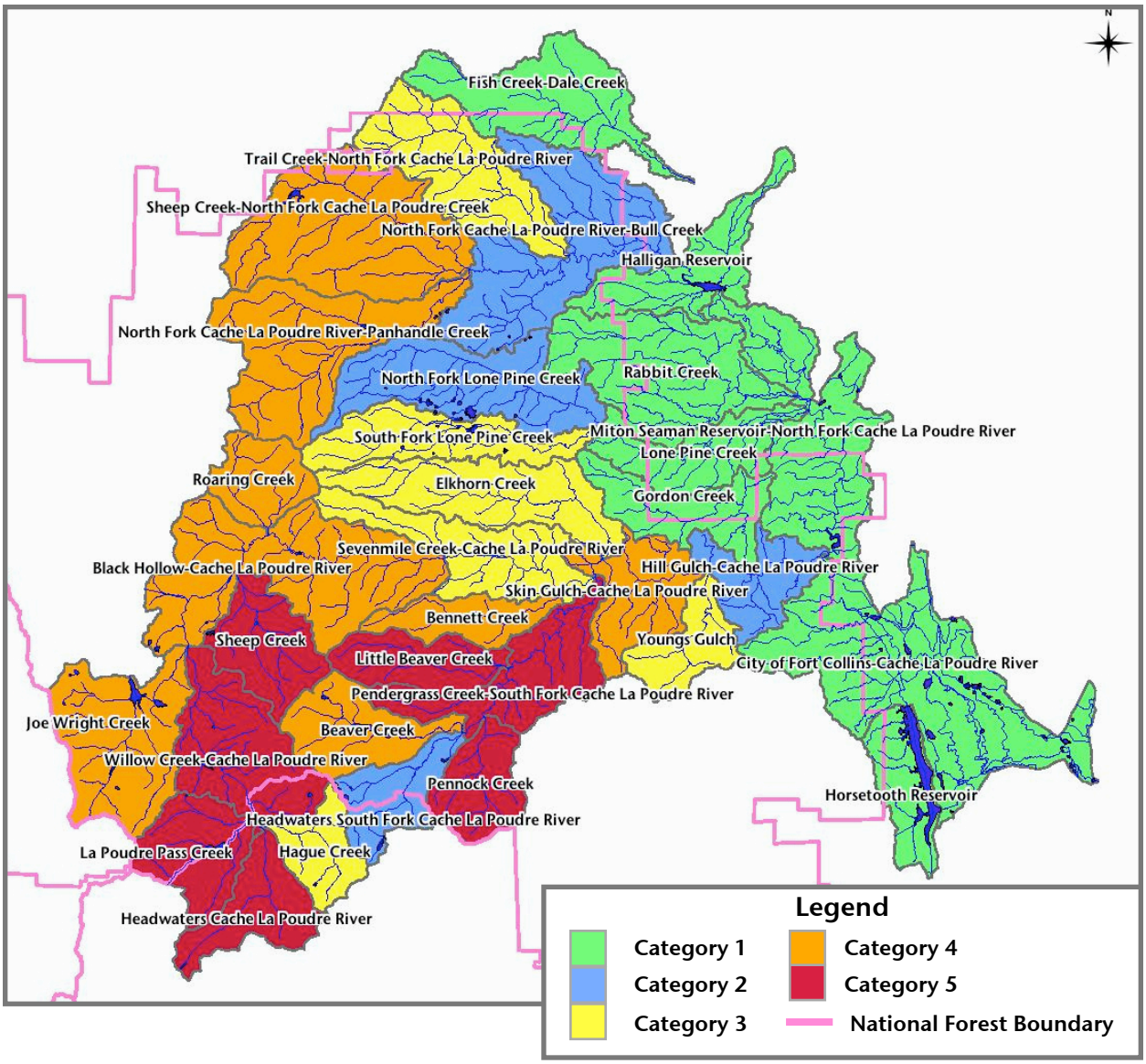

Figure 4. Cache la Poudre Watershed Wildfire Hazard Ranking

Component 2 - Flooding or Debris Flow Hazard

A combination of ruggedness and road density (miles of road per square mile of watershed area) was used to assess the flooding or debris flow hazard portion of the analysis. The two components, ruggedness and road density, are described below.

Ruggedness

Watershed steepness or ruggedness is an indicator of the relative sensitivity to debris flows following wildfires (Cannon and Reneau 2000). The more rugged the watershed, the higher its sensitivity to generating debris flows following wildfire (Melton 1957). The Melton ruggedness factor is basically a slope index.

Melton (1957) defines ruggedness, R, as;

$$R = H_b A_b^{-0.5}$$

Where A_b is basin area (square feet) and H_b is basin height (feet) measured from the point of highest elevation along the watershed divide to the outlet.

The ruggedness result in some watersheds was adjusted because they do not accurately reflect the slope in those watersheds. Those situations are most common in composite watersheds because they are disconnected from their headwaters. These watersheds can have a high hazard for debris flows because they contain a main stem of a creek or river with several steep first order streams as tributaries. In those situations, the ruggedness calculation was adjusted up by reducing the watershed area. These adjustments were completed on the following watersheds; Sevenmile Creek-Cache La Poudre River, Pendergrass Creek-South Fork Cache La Poudre River, Skin Gulch-Cache La Poudre River, Hill Gulch-Cache La Poudre River, and Elkhorn Creek.

Figure 5 displays the categorized ruggedness for the Cache la Poudre Watershed. The tabular results are presented on Table B-2 in Appendix B. The map (Figure 5) shows that the most rugged sixth-level watersheds are Headwaters South Fork Cache La Poudre River, Sevenmile Creek-Cache La Poudre River, Pendergrass Creek-South Fork Cache La Poudre River, Hague Creek, Skin Gulch-Cache La Poudre River, and Bennett Creek.

Headwaters South Fork Cache La Poudre River was skewing the categorization because of its high ruggedness value. The ruggedness value for this watershed was manually given a score slightly higher than the next lowest score (Table B-2 in Appendix B).

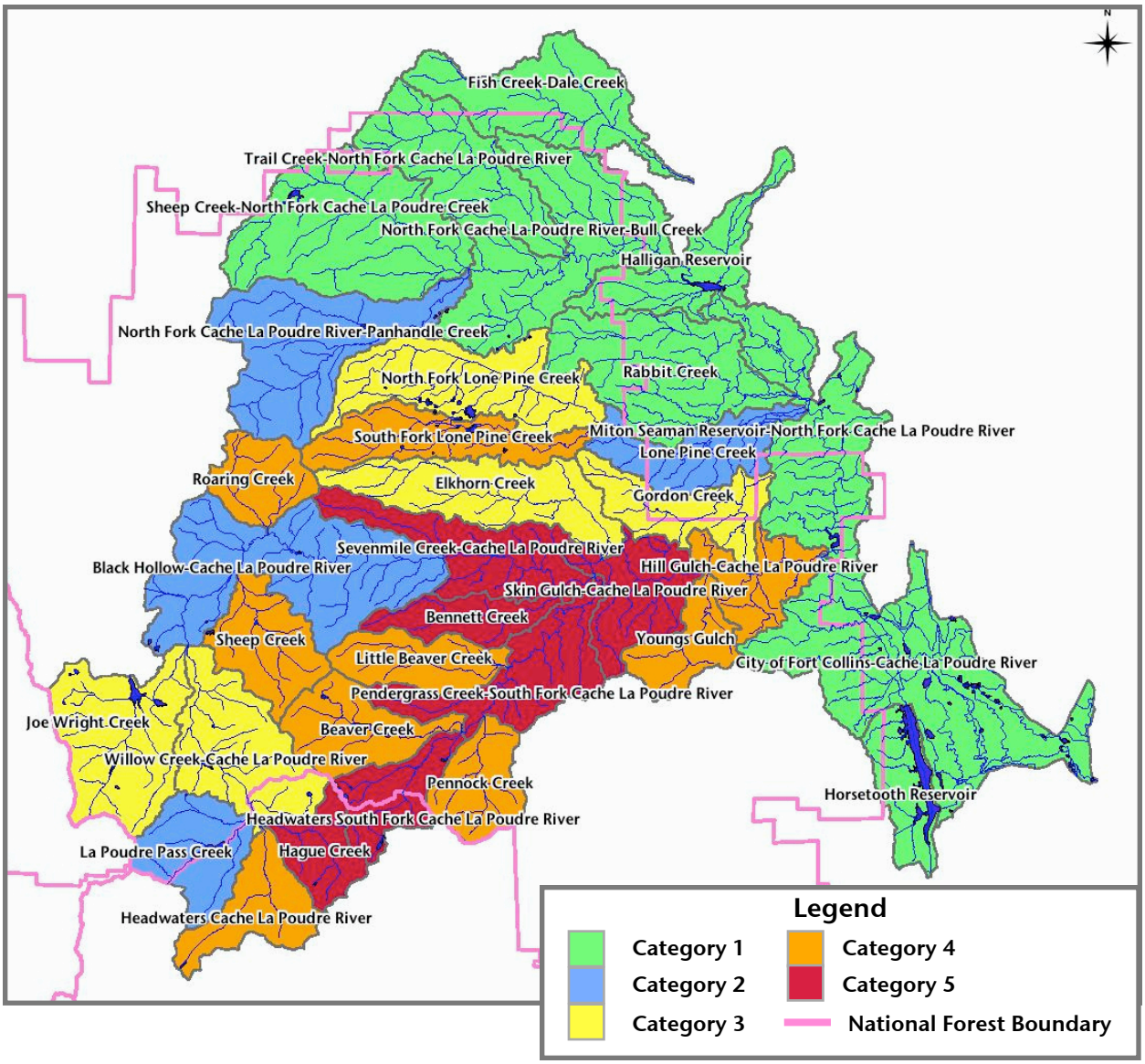

Figure 5. Cache la Poudre Watershed Ruggedness Ranking

Road Density

Roads can convert subsurface runoff to surface runoff and then route the surface runoff to stream channels, increasing peak flows (Megan and Kidd 1972, Ice 1985, and Swanson et al. 1987). Therefore, watersheds with higher road densities have a higher sensitivity to increases in peak flows following wildfires. Road density in miles of road per square mile of watershed area was used as an indicator of flooding hazard. The U.S. Forest Service roads data was used on National Forest System (NFS) lands because it is the most accurate roads data for those roads in the forest. On all other lands the U.S. Census Bureau's Tiger database was used because it is a consistent roads data layer (Figure 6).

Road densities were adjusted in some watersheds for two separate reasons. One reason for adjusting the road density was the situation where a watershed had a much higher road density than the next highest value, so that watershed was skewing the categorization. In that situation, the watershed was manually given a road density slightly higher than the next highest score.

The other situation where road density was adjusted is where some of the roads within a watershed were within towns, developed areas, or outside the forested areas of the watershed. The roads that are of interest in this analysis are those roads that would increase the risk of flooding or debris flows following wildfires in forested areas. The watersheds were all examined by looking at the roads data overlain on digital images and vegetation mapping. If it was found that there were significant lengths of road outside forested areas, the road density in those watersheds was adjusted down based on ocular estimates.

Road density in the North Fork Cache La Poudre River-Panhandle Creek, Gordon Creek, Horsetooth Reservoir, and City of Fort Collins-Cache La Poudre River watersheds were all adjusted down. The adjustments are displayed on Table B-3 in Appendix B.

Figure 7 displays the categorized road density for the Cache la Poudre Watershed and tabular results are presented in Appendix B (Table B-3). Figure 7 shows that the highest rankings are in North Fork Cache La Poudre River-Panhandle Creek, Gordon Creek, North Fork Lone Pine Creek, and Horsetooth Reservoir.

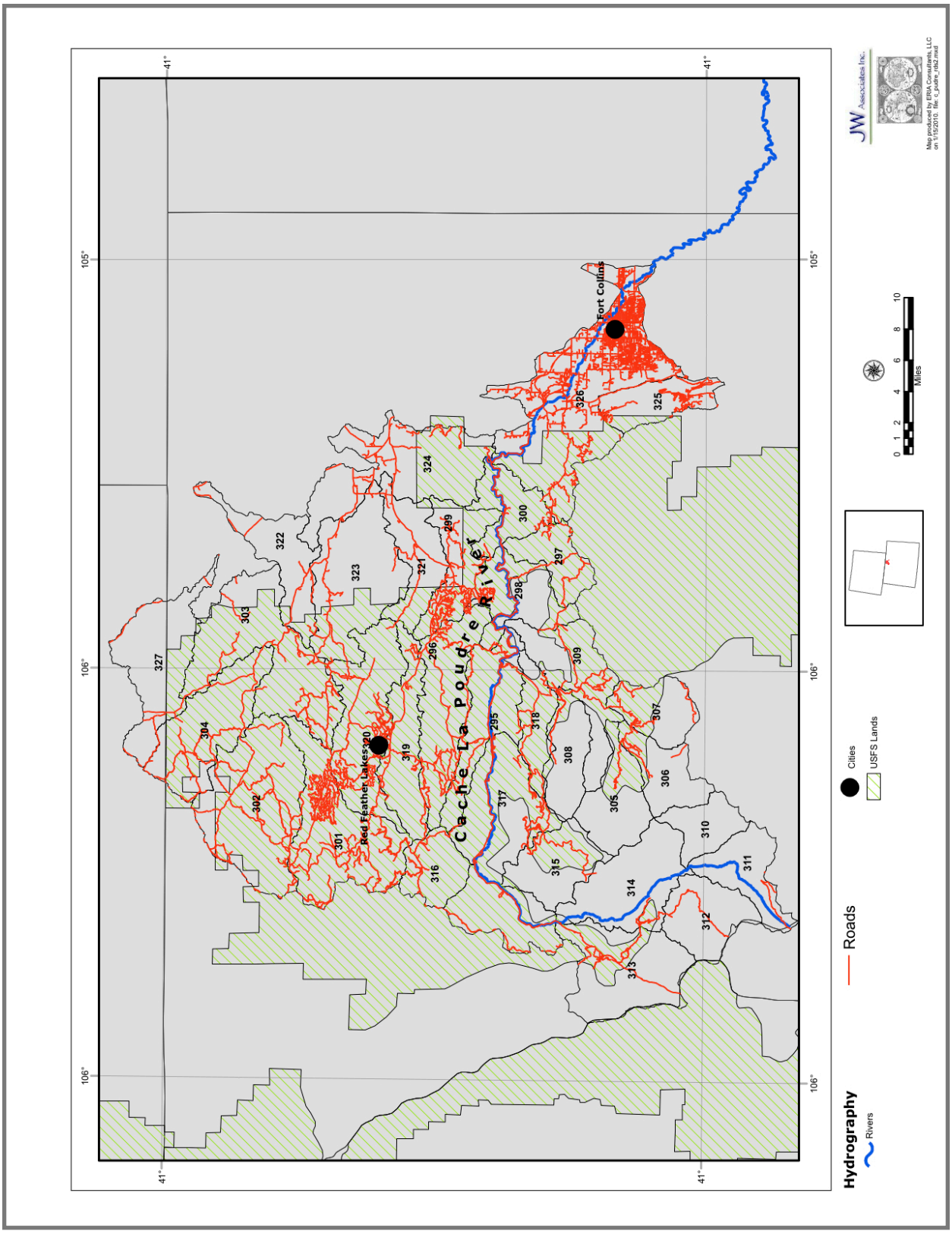

Figure 6. Cache la Poudre Watershed Roads Map

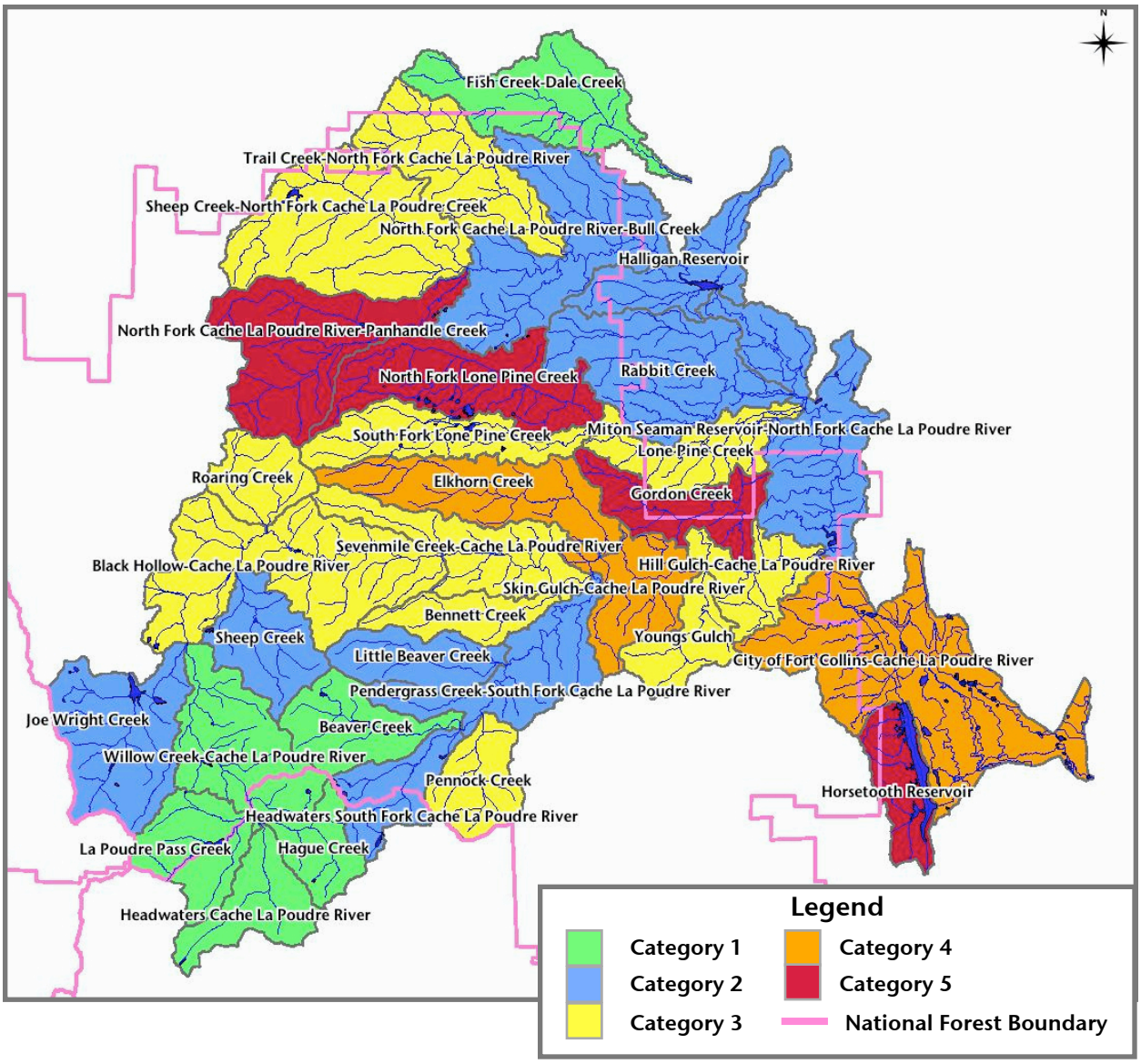

Figure 7. Cache la Poudre Watershed Road Density Ranking

Flooding or Debris Flow Hazard Ranking

The Flooding or Debris Flow Hazard is the combination of ruggedness and road density. The procedure from the Front Range Watershed Work Group (2009) assigned ruggedness a higher value than road density in this ranking. While ruggedness is the most important factor, an increase in road density will magnify the effects of ruggedness on the flooding/debris flow hazard. Accordingly, the analysis for flooding or debris flow hazard for the Cache la Poudre Watershed used the following formula. The results of this calculation were then re-categorized into five hazard rankings.

Flooding or Debris Flow Hazard Ranking = (Road Density Ranking + Ruggedness Ranking * 2)

Figure 8 shows that areas of the watershed with high road densities and high ruggedness rank high in this combined factor. The best way to look at this map is to look at a single watershed on the ruggedness and road density maps, noting the rankings on each. Then look at this map and see how they result in the final ranking for this component. The tabular results are presented in Table B-4 in Appendix B.

The highest ranked sixth-level watersheds are Sevenmile Creek-Cache La Poudre River, Skin Gulch-Cache La Poudre River, Headwaters South Fork Cache La Poudre River, Bennett Creek, Gordon Creek, Pendergrass Creek-South Fork Cache La Poudre River, and Pennock Creek.

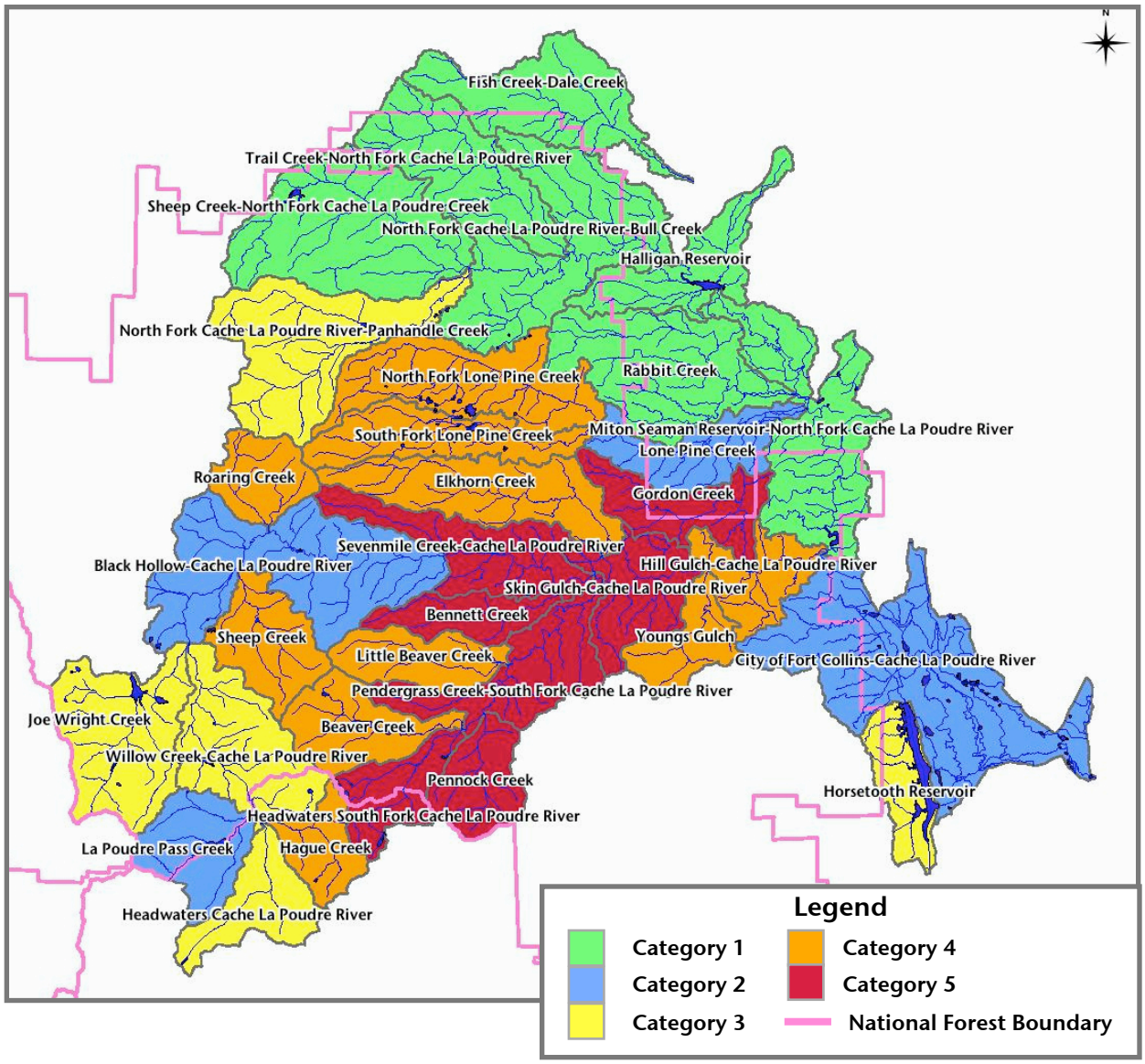

Figure 8. Cache la Poudre Watershed Flooding/Debris Flow Hazard Ranking

Component 3 - Soil Erodibility

High-severity fires can cause changes in watershed components that can dramatically change runoff and erosion processes in watersheds. Water and sediment yields may increase as more of the forest floor is consumed (Wells et al. 1979, Robichaud and Waldrop 1994, Soto et al. 1994, Neary et al. 2005, and Moody et al. 2008) and soil properties are altered by soil heating (Hungerford et al. 1991).

Two soils data sets were evaluated for use in this analysis. They were the U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS) STATSGO and SSURGO soils data. STATSGO data are relatively coarse soils data, created at a scale of 1:250,000 and are available for the entire watershed assessment area. SSURGO soils data do not cover all the watershed assessment area, though efforts by the NRCS are currently under way to produce an updated soils data layer.

The data used in this analysis is the U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS) SSURGO soils data combined with the U.S. Forest Service soils data. SSURGO data does not cover all the watershed but is available at a preferable scale (generally ranges from 1:12,000 to 1:63,360) than STATSGO data. The U.S. Forest Service soils data is comparable with the SSURGO data in scale and quality. Areas without SSURGO data were filled in with U.S. Forest Service soils data (Figure 9).

The soil erodibility analysis used a combination of two standard erodibility indicators: the inherent susceptibility of soil to erosion (K factor) and land slope derived from Unites States Geological Survey (USGS) 30-meter digital elevation models. The K factor data from the SSURGO spatial database was combined with a slope grid using NRCS (USDA NRCS 1997) slope-soil relationships (Table 2) to create a classification grid divided into slight, moderate, severe and very severe erosion hazard ratings.

Table 2. NRCS Criteria for Determining Potential Soil Erodibility

Percent Slope	K Factor <0.1	K Factor 0.1 to 0.19	K Factor 0.2 to 0.32	K Factor >0.32
0-14	Slight	Slight	Slight	Moderate
15-34	Slight	Slight	Moderate	Severe
35-50	Slight	Moderate	Severe	Very Severe
>50	Moderate	Severe	Very Severe	Very Severe

The potential soil erodibility hazard rankings are shown on Figure 10 and the tabular results are presented in Table B-5 in Appendix B. The map shows areas of high soil erodibility in the assessment area. The highest ranked sixth-level watersheds based on soil erodibility are Hague Creek, Black Hollow-Cache La Poudre River, and Headwaters South Fork Cache La Poudre River. The soil erodibility values for North Fork Lone Pine Creek and South Fork Lone Pine Creek were adjusted up due to the presence of granitic soils. Hague Creek and Black Hollow-Cache La Poudre River were skewing the categorization because of their high soil erodibility values and were manually given a score slightly higher than the next highest score (Table B-5 in Appendix B).

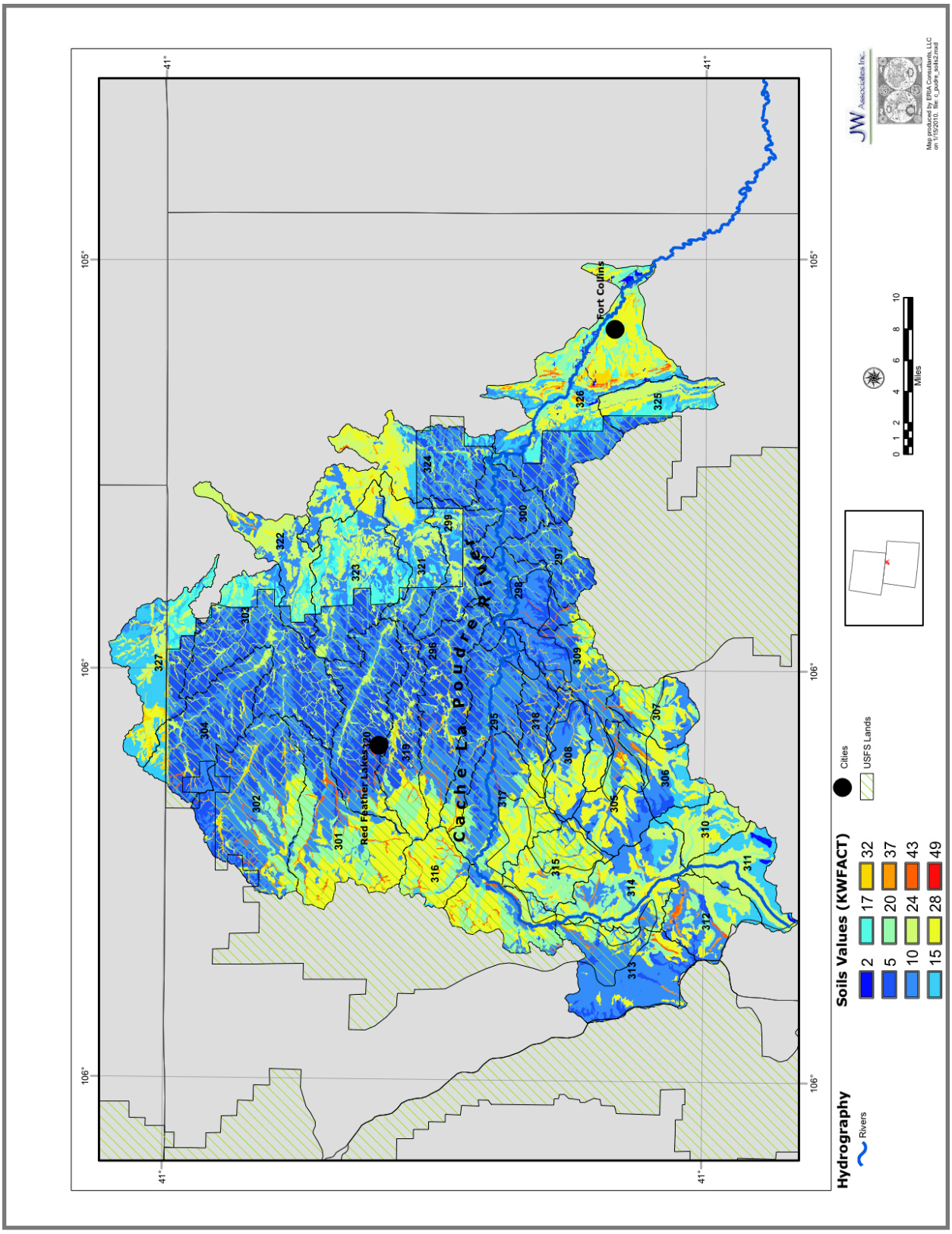

Figure 9. Cache la Poudre Watershed Soils K-Factor Map

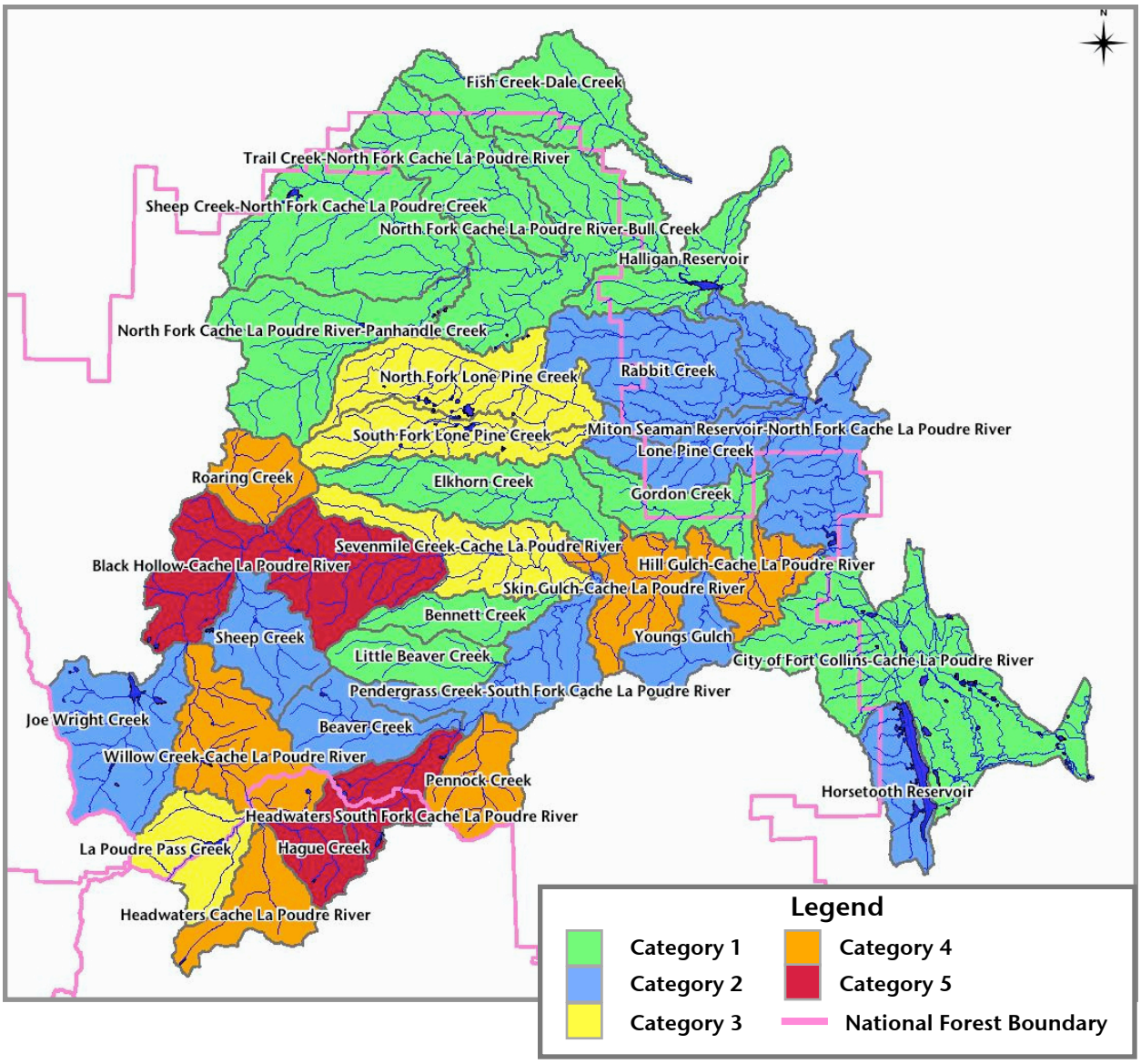

Figure 10. Cache la Poudre Watershed Potential Soil Erodibility Hazard Ranking

Composite Hazard Ranking

The Composite Hazard Ranking combines the first three components (Wildfire Hazard, Flooding/Debris Flow Hazard and Soil Erodibility) by numerically combining their rankings for each sixth-level watershed and then re-categorizing the results. The Composite Hazard Ranking map is useful in comparing relative watershed hazards based solely on environmental factors. Figure 11 shows the Composite Hazard Ranking for the Cache la Poudre Watershed. The tabular results that display the rankings for Wildfire Hazard, Flooding/Debris Flow Hazard and Soil Erodibility, as well as the composite rankings are presented in Table B-6 in Appendix B. The highest ranked sixth-level watersheds are Pennock Creek, Skin Gulch-Cache La Poudre River, Willow Creek-Cache La Poudre River, Headwaters Cache La Poudre River, Headwaters South Fork Cache La Poudre River, Hague Creek, Pendergrass Creek-South Fork Cache La Poudre River, Roaring Creek, and Black Hollow-Cache La Poudre River. Additionally, there are 10 watersheds in Category 4.

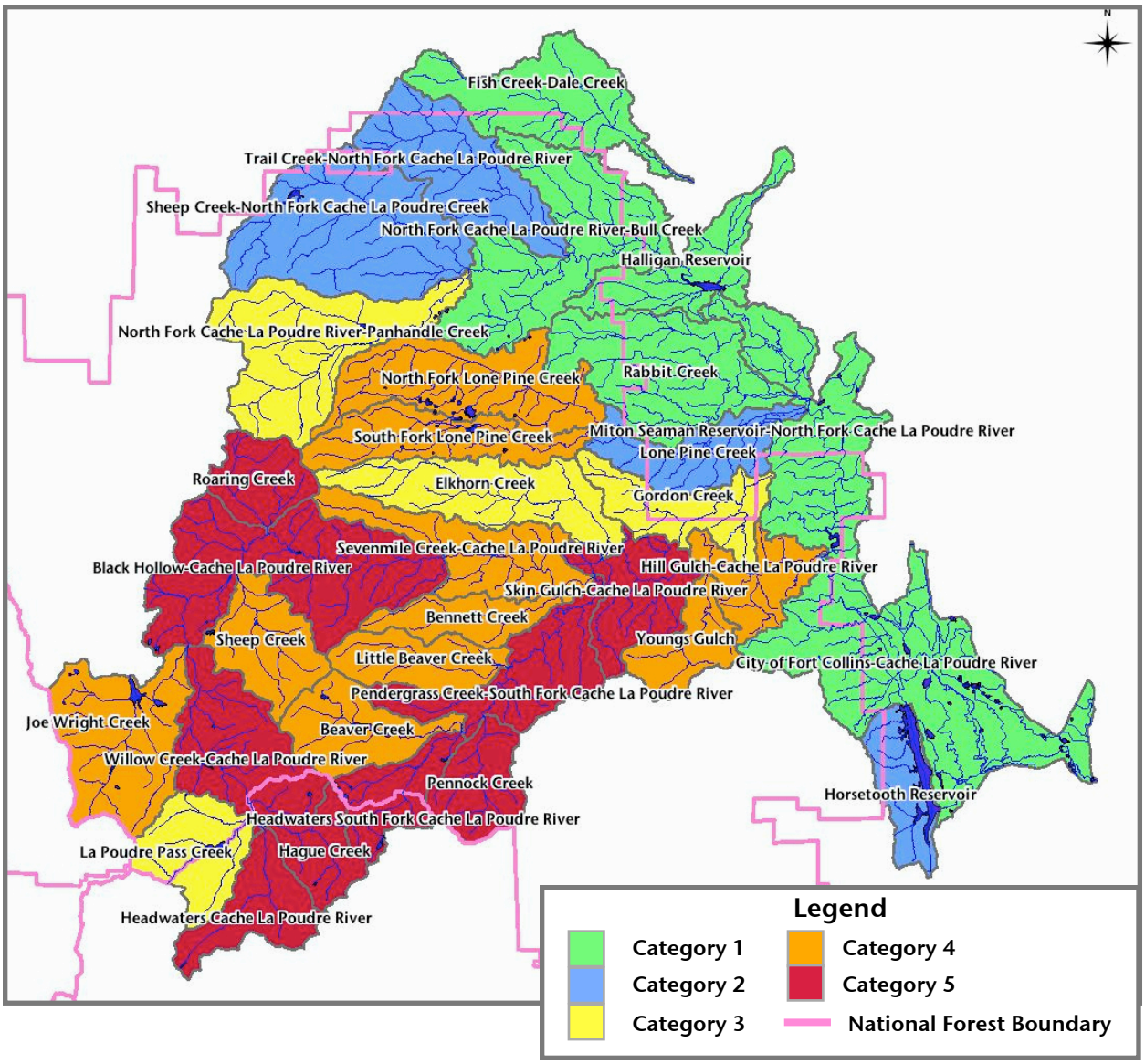

Figure 11. Cache la Poudre Watershed Composite Hazard Ranking

Component 4 - Water Supply Ranking

Surface water intakes, diversions, conveyance structures, storage reservoirs and streams are all susceptible to the effects of wildfires. The suggested approach from the procedure prescribed by the Front Range Watershed Protection Data Refinement Work Group (2009) is to first rank watersheds based upon the presence of water nodes.

Surface drinking water supply collection points from the Source Water Assessment and Protection (SWAP) Program (see http://www.cdphe.state.co.us/wq/sw/swaphom.html for basic information on the SWAP Program) were used to identify which sixth-level watersheds contain critical components of the public water supply infrastructure in Colorado. For this assessment, water nodes were defined as coordinate points corresponding to surface water intakes, upstream diversion points and classified drinking water reservoirs.

Water supply locations may not be identified in the state's database for some drinking water supply reservoirs that do not have associated direct surface water intakes. Also, some water supply reservoirs may not be identified in the SWAP database. The Water Supply map was modified to include these features by including all named reservoirs.

Figure 12 shows the sixth-level watersheds that have water supply locations in blue and those without water supply locations in green.

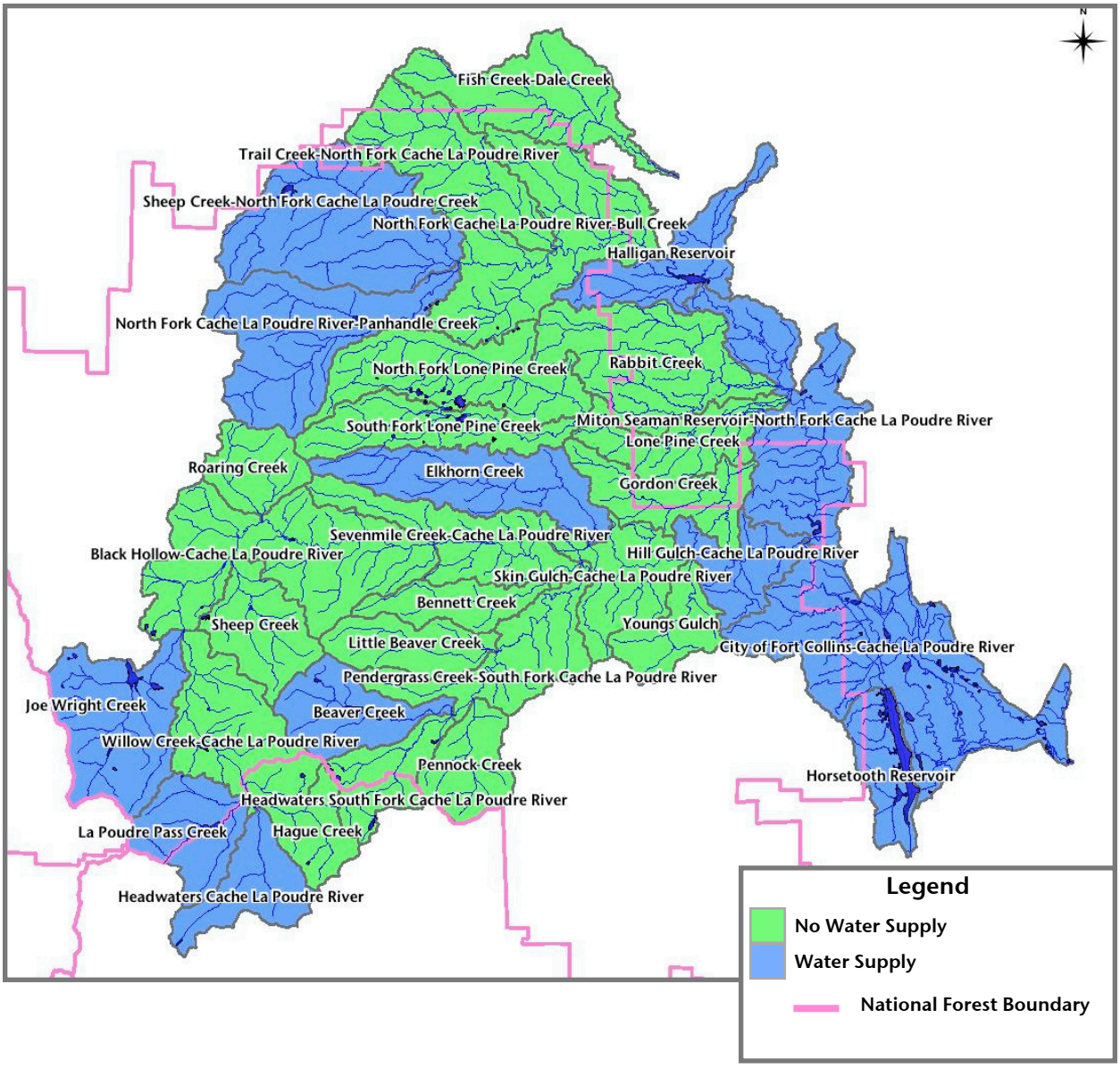

Figure 12. Cache la Poudre Watershed Water Supply Map

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APPENDIX A

CACHE LA POUDRE WILDFIRE HAZARD MODELING METHODOLOGY

The forest conditions that are of concern for the assessments are the wildfire hazard based on existing forest conditions. The wildfire hazard (Flame Length) was determined using the Fire Behavior Assessment Tool (FBAT) (http://www.fire.org) which is an interface between ArcMap and FlamMap. The input spatial data were collected from LANDFIRE project (http://www.landfire.gov/).

After a mountain pine beetle outbreak there are substantial increases in the amount of fine dead fuels in the canopy. The majority of these fuels remain in the canopy for 2-3 years post outbreak (Knight 1987, Schmid and Amman 1992). Therefore, certain input spatial data sets were updated reflecting Mountain Pine Beetle (MPB) mortality conditions using USDA Forest Service, Rocky Mountain Region Aerial Detection Survey (ADS) Data from the years 2002 - 2007 (http://www.fs.fed.us/r2/resources/fhm/aerialsurvey/). The following modeling settings and spatial data modification were used:

Modeling Setting

1. Scott and Burgan (2005) Fire Behavior Model (Fuel Moisture is shown in Table A-1)
2. Uphill wind direction
3. Scott & Reinhardt (2001) crown fire calculation
4. Foliar Moisture at 100%

Spatial Data Modifications

1. Canopy Cover was assigned a value of 10% when coincident with MPB mortality from ADS for years 2002-2007.
2. Canopy Base Height (CBH) was reduced by 25% for MPB mortality derived from ADS for the years 2002-2006.
3. CBH was reassigned a value of 0 for MPB mortality from ADS for the year 2007.
4. Canopy Bulk Density (CBD) was reduced by 50% for MPB mortality derived from ADS for the years 2002-2006

Table A-1. Fuel Moisture (percent) used in FBAT Model Runs

Scott and Burgan (2005) fuel model	1-Hour Fuel	10-Hour Fuel	100-Hour Fuel	Live Herbaceous	Live Woody
1	4	5	8	200	95
2	4	5	8	150	95
3	4	5	8	85	95
4	4	5	8	85	95
5	4	5	8	85	150
6	4	5	8	85	95
7	4	5	8	85	95
8	4	5	8	85	95
9	4	5	8	85	95
10	4	5	8	85	95
11	4	5	8	85	95
12	4	5	8	85	95
13	4	5	8	85	95
14	3	4	8	85	95
15	3	4	8	85	95
16	3	4	8	85	95
17	3	4	8	85	95
18	3	4	8	85	95
19	3	4	8	85	95
20	3	4	8	85	95
21	3	4	8	85	95
22	3	4	8	85	95
23	3	4	8	85	95
24	3	4	8	85	95
25	3	4	8	85	95
26	3	4	8	85	95
27	3	4	8	85	95
28	3	4	8	85	95
29	3	4	8	85	95
30	3	4	8	85	95
31	3	4	8	85	95
32	3	4	8	85	95
33	3	4	8	85	95
34	3	4	8	85	95
35	3	4	8	85	95
36	3	4	8	85	95
37	3	4	8	85	95
38	3	4	8	85	95
39	3	4	8	85	95
40	3	4	8	85	95
41	3	4	8	85	95
42	3	4	8	85	95
43	3	4	8	85	95
44	3	4	8	85	95
45	3	4	8	85	95
46	3	4	8	85	95
47	3	4	8	85	95
48	3	4	8	85	95
49	3	4	8	85	95
50	3	4	8	85	95

Weather Data

The weather data used comes from the Colorado Wildfire Risk Assessment Statewide (CRA) dataset prepared by Sandborn under contract to the Colorado State Forest Service. For the Colorado Fire Risk Assessment nine weather influence zones (WIZ) were developed for analysis purposes. A WIZ is an area where for analysis purposes the weather on any given day is uniform. Within each WIZ, daily weather data was gathered for the years 1980-2006. Where not available, the weather data was gathered from the earliest year through 2006. Several weather stations were analyzed within each WIZ. From this analysis, one representative weather station was selected for each WIZ. From this data set, percentile weather was developed for each WIZ using the Fire Family Plus software package.

For this watershed assessment the percentile weather for WIZ CO 02 (Dowd 1986-2006) was used for all watersheds on the west side of the continental divide and WIZ CO 03 (Coral Creek 1980-2006) was used for all watersheds on the east side of the continental divide. The 20-foot wind speeds for the "High" case was used in the modeling runs (Table A-2).

In addition the wind direction was assumed to be uphill (parallel with slope) in all instances. This setting encourages crown fire initiation and establishes a common baseline for the evaluation of areas within the landscape based upon the fuels hazard represented by vegetation conditions.

Table A-2. Wind Speed (Miles per Hour) used in FBAT Model Runs

Watershed Name	Wind Speed (mph)	Probable Momentary Gust Speed (mph)
North Platte	15	29
Upper North Platte	15	29
Crow/Medicine Bow/Upper Laramie/Upper Lodgepole	12	25
Clear/Bear Creek	12	25
Big Thompson	12	25
Cache la Poudre	12	25
Blue River	15	29
Eagle River	15	29
Upper Yampa	15	29
Little Snake	15	29
Upper White	15	29
Lower Colorado	15	29
Upper Colorado	15	29
Saint Vrain	12	25
Roaring Fork	15	29

Categorization of Results

The FBAT model results were divided into five categories of flame length. These values range from lowest (Category 0) to highest (Category 4) based upon flame length. The flame length categories that were used are:

Flame Length Category 0 - 0 meters

Flame Length Category 1 - 1 to 10 meters

Flame Length Category 2 - 11 to 25 meters

Flame Length Category 3 - 26 to 40 meters

Flame Length Category 4 - >40 meters

APPENDIX B

DETAILED CACHE LA POUDRE WATERSHED ASSESSMENT RESULTS

Table B-1. Cache la Poudre Watershed Wildfire Hazard Ranking

Sixth-level Watershed Name	Watershed Area (acres)	Wildfire Hazard Calculation	Wildfire Hazard Rank
Willow Creek-Cache La Poudre River	21,936	63.3%	*5.5*
Headwaters Cache La Poudre River	12,709	62.6%	*5.4*
Little Beaver Creek	11,562	60.7%	*5.3*
Pendergrass Creek-South Fork Cache La Poudre River	18,639	59.2%	*5.2*
Pennock Creek	11,068	59.2%	*5.2*
Sheep Creek	13,966	56.6%	*5.0*
La Poudre Pass Creek	14,066	53.1%	*4.7*
Joe Wright Creek	24,468	50.9%	*4.5*
Roaring Creek	9,938	50.7%	*4.5*
Black Hollow-Cache La Poudre River	37,738	50.5%	*4.5*
Sheep Creek-North Fork Cache La Poudre Creek	35,586	49.2%	*4.3*
Beaver Creek	14,135	46.2%	*4.1*
Bennett Creek	9,210	45.8%	*4.1*
North Fork Cache La Poudre River-Panhandle Creek	29,786	45.6%	*4.1*
Skin Gulch-Cache La Poudre River	14,920	40.0%	*3.6*
Trail Creek-North Fork Cache La Poudre River	23,034	38.5%	*3.5*
Youngs Gulch	9,823	38.4%	*3.5*
Sevenmile Creek-Cache La Poudre River	18,640	33.9%	*3.1*
South Fork Lone Pine Creek	16,305	33.6%	*3.1*
Hague Creek	8,685	32.4%	*3.0*
Elkhorn Creek	22,259	26.9%	*2.5*
Headwaters South Fork Cache La Poudre River	11,094	25.4%	*2.4*
Hill Gulch-Cache La Poudre River	11,161	25.3%	*2.4*
North Fork Lone Pine Creek	25,269	24.6%	*2.3*
North Fork Cache La Poudre River-Bull Creek	34,294	18.1%	*1.8*
Gordon Creek	13,908	11.7%	*1.3*
Fish Creek-Dale Creek	23,097	11.4%	*1.3*
Rabbit Creek	28,860	10.9%	*1.2*
City of Fort Collins-Cache La Poudre River	51,119	10.1%	*1.2*
Lone Pine Creek	14,153	8.0%	*1.0*
Horsetooth Reservoir	10,974	6.9%	*0.9*
Miton Seaman Res.-North Fork Cache La Poudre River	30,516	2.4%	*0.5*
Halligan Reservoir	15,127	2.1%	*0.5*

Table B-2. Cache la Poudre Watershed Ruggedness Ranking[1, 2, 3]

Sixth-level Watershed Name	Maximum Elevation	Minimum Elevation	Difference Elevation	Ruggedness	Ruggedness Rank
Headwaters South Fork Cache La Poudre River	13,212	8,308	4,904	0.2000	*5.5*
Sevenmile Creek-Cache La Poudre River	10,883	6,524	4,359	0.1874	*5.1*
Pendergrass Creek-South Fork Cache La Poudre River	11,208	6,537	4,671	0.1833	*4.9*
Hague Creek	13,304	9,742	3,562	0.1831	*4.9*
Skin Gulch-Cache La Poudre River	9,558	5,819	3,739	0.1796	*4.8*
Bennett Creek	10,296	6,701	3,595	0.1795	*4.8*
Pennock Creek	11,801	8,144	3,657	0.1666	*4.3*
Beaver Creek	12,471	8,394	4,077	0.1643	*4.2*
Little Beaver Creek	11,490	7,934	3,556	0.1584	*4.0*
South Fork Lone Pine Creek	10,985	6,786	4,198	0.1575	*4.0*
Hill Gulch-Cache La Poudre River	7,800	5,369	2,430	0.1559	*3.9*
Roaring Creek	10,998	7,856	3,142	0.1510	*3.8*
Headwaters Cache La Poudre River	13,268	9,735	3,533	0.1501	*3.7*
Sheep Creek	11,454	7,787	3,667	0.1487	*3.7*
Youngs Gulch	8,856	5,789	3,067	0.1483	*3.7*
Willow Creek-Cache La Poudre River	12,687	8,374	4,313	0.1395	*3.4*
Gordon Creek	8,115	5,707	2,408	0.1383	*3.3*
Elkhorn Creek	10,840	6,540	4,300	0.1381	*3.3*
Joe Wright Creek	12,851	8,377	4,474	0.1370	*3.3*
North Fork Lone Pine Creek	10,653	6,816	3,838	0.1157	*2.5*
La Poudre Pass Creek	12,290	9,676	2,614	0.1056	*2.2*
Black Hollow-Cache La Poudre River	11,221	7,134	4,087	0.1008	*2.0*
North Fork Cache La Poudre River-Panhandle Creek	10,840	7,537	3,303	0.0917	*1.7*
Lone Pine Creek	8,006	5,792	2,214	0.0892	*1.6*
Horsetooth Reservoir	7,167	5,284	1,883	0.0861	*1.5*
Trail Creek-North Fork Cache La Poudre River	9,161	7,006	2,155	0.0680	*0.8*
Rabbit Creek	8,088	5,806	2,283	0.0644	*0.7*
Miton Seaman Res.-North Fork Cache La Poudre River	7,682	5,353	2,329	0.0639	*0.7*
City of Fort Collins-Cache La Poudre River	7,770	4,861	2,909	0.0617	*0.6*
Fish Creek-Dale Creek	8,767	6,832	1,935	0.0610	*0.6*
North Fork Cache La Poudre River-Bull Creek	8,695	6,406	2,289	0.0592	*0.5*
Halligan Reservoir	7,852	6,350	1,502	0.0585	*0.5*
Sheep Creek-North Fork Cache La Poudre Creek	9,870	7,567	2,303	0.0585	*0.5*

[1] Ruggedness is based on Melton (1957)

[2] These watersheds were manually adjusted because they do not accurately reflect the ruggedness in those watersheds. The original values were; Sevenmile Creek-Cache La Poudre River (0.1530), Pendergrass Creek-South Fork Cache La Poudre River (0.1639), Skin Gulch-Cache La Poudre River (0.1467), Hill Gulch-Cache La Poudre River (0.1102), and Elkhorn Creek (0.0978).

[3] Headwaters South Fork Cache La Poudre River (original value 0.2231) was skewing the categorization because of its high ruggedness value and was manually given a score slightly higher than the next highest score.

Table B-3. Cache la Poudre Watershed Road Density Ranking[4]

Sixth-level Watershed Name	Roads (miles)	Roads Adjusted (miles)	Watershed Area (sq. mi.)	Road density (miles per sq. mi.)	Road Density Rank
North Fork Cache La Poudre River-Panhandle Creek	127.3	101.8	46.54	2.19	*5.5*
Gordon Creek	59.4	47.5	21.73	2.19	*5.5*
North Fork Lone Pine Creek	82.9	82.9	39.48	2.10	*5.3*
Horsetooth Reservoir	42.4	31.8	17.15	1.85	*4.7*
Elkhorn Creek	53.1	53.1	34.78	1.53	*4.0*
Skin Gulch-Cache La Poudre River	32.5	32.5	23.31	1.39	*3.7*
City of Fort Collins-Cache La Poudre River	421.0	105.3	79.87	1.32	*3.5*
Sevenmile Creek-Cache La Poudre River	36.5	36.5	29.13	1.25	*3.4*
Bennett Creek	17.7	17.7	14.39	1.23	*3.3*
Sheep Creek-North Fork Cache La Poudre Creek	68.0	68.0	55.60	1.22	*3.3*
South Fork Lone Pine Creek	29.2	29.2	25.48	1.15	*3.1*
Pennock Creek	18.8	18.8	17.29	1.09	*3.0*
Trail Creek-North Fork Cache La Poudre River	36.0	36.0	35.99	1.00	*2.8*
Roaring Creek	15.4	15.4	15.53	0.99	*2.8*
Youngs Gulch	14.4	14.4	15.35	0.94	*2.6*
Hill Gulch-Cache La Poudre River	16.2	16.2	17.44	0.93	*2.6*
Black Hollow-Cache La Poudre River	53.5	53.5	58.97	0.91	*2.6*
Lone Pine Creek	19.4	19.4	22.11	0.88	*2.5*
North Fork Cache La Poudre River-Bull Creek	44.8	44.8	53.58	0.84	*2.4*
Miton Seaman Res.-North Fork Cache La Poudre River	38.6	38.6	47.68	0.81	*2.4*
Pendergrass Creek-South Fork Cache La Poudre River	21.9	21.9	29.12	0.75	*2.2*
Headwaters South Fork Cache La Poudre River	11.7	11.7	17.33	0.68	*2.0*
Halligan Reservoir	14.5	14.5	23.64	0.61	*1.9*
Little Beaver Creek	10.9	10.9	18.07	0.60	*1.9*
Joe Wright Creek	22.8	22.8	38.23	0.60	*1.9*
Sheep Creek	12.2	12.2	21.82	0.56	*1.8*
Rabbit Creek	24.9	24.9	45.09	0.55	*1.8*
Fish Creek-Dale Creek	13.1	13.1	36.09	0.36	*1.3*
La Poudre Pass Creek	7.9	7.9	21.98	0.36	*1.3*
Headwaters Cache La Poudre River	5.5	5.5	19.86	0.28	*1.1*
Beaver Creek	5.8	5.8	22.09	0.26	*1.1*
Willow Creek-Cache La Poudre River	7.3	7.3	34.28	0.21	*1.0*
Hague Creek	0.0	0.0	13.57	0.00	*0.5*
Totals	1,385	1,022	1,012.6	1.01	

[4] The road density was adjusted based upon the procedure discussed in the report (p. 12). The original road density values were; North Fork Cache La Poudre River-Panhandle Creek (2.74), Gordon Creek (2.73), Horsetooth Reservoir (2.47), and City of Fort Collins-Cache La Poudre River (5.27).

Table B-4. Cache la Poudre Watershed Flooding/Debris Flow Hazard Ranking

Sixth-level Watershed Name	Ruggedness Ranking	Road Density Ranking	Combined Numeric Rank	Combined Ranking
Sevenmile Creek-Cache La Poudre River	5.1	3.4	13.47	5.5
Skin Gulch-Cache La Poudre River	4.8	3.7	13.25	5.4
Headwaters South Fork Cache La Poudre River	5.5	2.0	13.05	5.3
Bennett Creek	4.8	3.3	12.86	5.2
Gordon Creek	3.3	5.5	12.14	4.9
Pendergrass Creek-South Fork Cache La Poudre River	4.9	2.2	12.03	4.8
Pennock Creek	4.3	3.0	11.62	4.7
South Fork Lone Pine Creek	4.0	3.1	11.12	4.4
Elkhorn Creek	3.3	4.0	10.62	4.2
Hill Gulch-Cache La Poudre River	3.9	2.6	10.50	4.1
North Fork Lone Pine Creek	2.5	5.3	10.34	4.1
Hague Creek	4.9	0.5	10.31	4.1
Roaring Creek	3.8	2.8	10.30	4.1
Youngs Gulch	3.7	2.6	9.99	3.9
Little Beaver Creek	4.0	1.9	9.94	3.9
Beaver Creek	4.2	1.1	9.57	3.7
Sheep Creek	3.7	1.8	9.15	3.5
North Fork Cache La Poudre River-Panhandle Creek	1.7	5.5	8.85	3.4
Headwaters Cache La Poudre River	3.7	1.1	8.61	3.3
Joe Wright Creek	3.3	1.9	8.42	3.2
Willow Creek-Cache La Poudre River	3.4	1.0	7.71	2.9
Horsetooth Reservoir	1.5	4.7	7.69	2.9
Black Hollow-Cache La Poudre River	2.0	2.6	6.56	2.3
Lone Pine Creek	1.6	2.5	5.67	1.9
La Poudre Pass Creek	2.2	1.3	5.65	1.9
City of Fort Collins-Cache La Poudre River	0.6	3.5	4.74	1.5
Trail Creek-North Fork Cache La Poudre River	0.8	2.8	4.46	1.4
Sheep Creek-North Fork Cache La Poudre Creek	0.5	3.3	4.29	1.3
Miton Seaman Res.-North Fork Cache La Poudre River	0.7	2.4	3.73	1.1
North Fork Cache La Poudre River-Bull Creek	0.5	2.4	3.46	0.9
Rabbit Creek	0.7	1.8	3.18	0.8
Halligan Reservoir	0.5	1.9	2.91	0.7
Fish Creek-Dale Creek	0.6	1.3	2.51	0.5

Table B-5. Cache la Poudre Watershed Soil Erodibility Ranking[5, 6, 7]

Sixth-level Watershed Name	Severe (%)	Very Severe (%)	Soil Erodibility Value	Soil Erodibility Rank
Hague Creek	19.0%	13.3%	0.370	*5.5*
Black Hollow-Cache La Poudre River	22.2%	10.2%	0.360	*5.4*
Headwaters South Fork Cache La Poudre River	17.2%	7.8%	0.328	*4.9*
Willow Creek-Cache La Poudre River	12.8%	8.4%	0.297	*4.4*
Hill Gulch-Cache La Poudre River	25.1%	2.2%	0.295	*4.4*
Pennock Creek	19.4%	5.0%	0.294	*4.4*
Skin Gulch-Cache La Poudre River	23.5%	2.3%	0.281	*4.2*
Headwaters Cache La Poudre River	19.9%	3.7%	0.272	*4.1*
Roaring Creek	15.0%	4.8%	0.246	*3.7*
North Fork Lone Pine Creek	6.0%	1.7%	0.230	*3.4*
Sevenmile Creek-Cache La Poudre River	16.6%	2.2%	0.210	*3.1*
La Poudre Pass Creek	13.2%	2.1%	0.173	*2.6*
South Fork Lone Pine Creek	2.9%	0.4%	0.173	*2.6*
Pendergrass Creek-South Fork Cache La Poudre River	13.5%	1.4%	0.164	*2.5*
Youngs Gulch	14.4%	1.0%	0.163	*2.5*
Joe Wright Creek	11.6%	2.3%	0.163	*2.5*
Lone Pine Creek	11.2%	2.2%	0.156	*2.4*
Beaver Creek	10.5%	2.2%	0.148	*2.2*
Horsetooth Reservoir	10.7%	1.3%	0.134	*2.0*
Rabbit Creek	8.6%	1.8%	0.122	*1.9*
Sheep Creek	6.6%	2.7%	0.120	*1.8*
Miton Seaman Res.-North Fork Cache La Poudre River	8.4%	1.6%	0.117	*1.8*
North Fork Cache La Poudre River-Bull Creek	7.0%	1.2%	0.095	*1.5*
Little Beaver Creek	7.7%	0.7%	0.090	*1.4*
Bennett Creek	7.2%	0.6%	0.084	*1.3*
Gordon Creek	6.4%	0.8%	0.081	*1.3*
North Fork Cache La Poudre River-Panhandle Creek	6.5%	0.7%	0.079	*1.2*
Halligan Reservoir	5.2%	0.7%	0.067	*1.1*
City of Fort Collins-Cache La Poudre River	5.3%	0.6%	0.065	*1.0*
Sheep Creek-North Fork Cache La Poudre Creek	4.5%	0.5%	0.054	*0.9*
Elkhorn Creek	3.7%	0.7%	0.050	*0.8*
Trail Creek-North Fork Cache La Poudre River	2.8%	0.3%	0.034	*0.6*
Fish Creek-Dale Creek	1.9%	0.5%	0.029	*0.5*

[5] Soil Erodibility Value is percentage of Severe plus 2 times the percentage of Very Severe.

[6] The soil erodibility values for North Fork Lone Pine Creek and South Fork Lone Pine Creek were adjusted up (original values of 0.094 and 0.037, respectively) due to the presence of granitic soils.

[7] Hague Creek and Black Hollow-Cache La Poudre River watersheds were skewing the categorization because of their high soil erodibility values (originally 0.456 and 0.425 respectively) and were manually given a score slightly higher than the next highest score.

Table B-6. Cache la Poudre Watershed Composite Hazard Ranking

Sixth-level Watershed Name	Wildfire Hazard Rank	Flooding/ Debris Flow Rank	Soil Erodibility Rank	Composite Hazard Rank
Pennock Creek	5.2	4.7	4.4	5.5
Skin Gulch-Cache La Poudre River	3.6	5.4	4.2	5.1
Willow Creek-Cache La Poudre River	5.5	2.9	4.4	4.9
Headwaters Cache La Poudre River	5.4	3.3	4.1	4.9
Headwaters South Fork Cache La Poudre River	2.4	5.3	4.9	4.8
Hague Creek	3.0	4.1	5.5	4.8
Pendergrass Creek-South Fork Cache La Poudre River	5.2	4.8	2.5	4.8
Roaring Creek	4.5	4.1	3.7	4.7
Black Hollow-Cache La Poudre River	4.5	2.3	5.4	4.6
Sevenmile Creek-Cache La Poudre River	3.1	5.5	3.1	4.5
Hill Gulch-Cache La Poudre River	2.4	4.1	4.4	4.1
Bennett Creek	4.1	5.2	1.3	4.0
Little Beaver Creek	5.3	3.9	1.4	4.0
Sheep Creek	5.0	3.5	1.8	3.9
Joe Wright Creek	4.5	3.2	2.5	3.8
South Fork Lone Pine Creek	3.1	4.4	2.6	3.8
Beaver Creek	4.1	3.7	2.2	3.8
North Fork Lone Pine Creek	2.3	4.1	3.4	3.7
Youngs Gulch	3.5	3.9	2.5	3.7
La Poudre Pass Creek	4.7	1.9	2.6	3.4
North Fork Cache La Poudre River-Panhandle Creek	4.1	3.4	1.2	3.2
Elkhorn Creek	2.5	4.2	0.8	2.7
Gordon Creek	1.3	4.9	1.3	2.7
Sheep Creek-North Fork Cache La Poudre Creek	4.3	1.3	0.9	2.3
Horsetooth Reservoir	0.9	2.9	2.0	2.0
Trail Creek-North Fork Cache La Poudre River	3.5	1.4	0.6	1.8
Lone Pine Creek	1.0	1.9	2.4	1.8
North Fork Cache La Poudre River-Bull Creek	1.8	0.9	1.5	1.3
Rabbit Creek	1.2	0.8	1.9	1.2
City of Fort Collins-Cache La Poudre River	1.2	1.5	1.0	1.1
Miton Seaman Res.-North Fork Cache La Poudre River	0.5	1.1	1.8	1.0
Fish Creek-Dale Creek	1.3	0.5	0.5	0.5
Halligan Reservoir	0.5	0.7	1.1	0.5