Saint Vrain Phase 1 Watershed Assessment

Prioritization of watershed-based risks to water supplies

Report Prepared for:

USDA Forest Service

Rocky Mountain Region

Bark Beetle Incident

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Saint Vrain - Phase 1 Watershed Assessment

Prioritization of watershed-based hazards to water supplies

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 16 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.

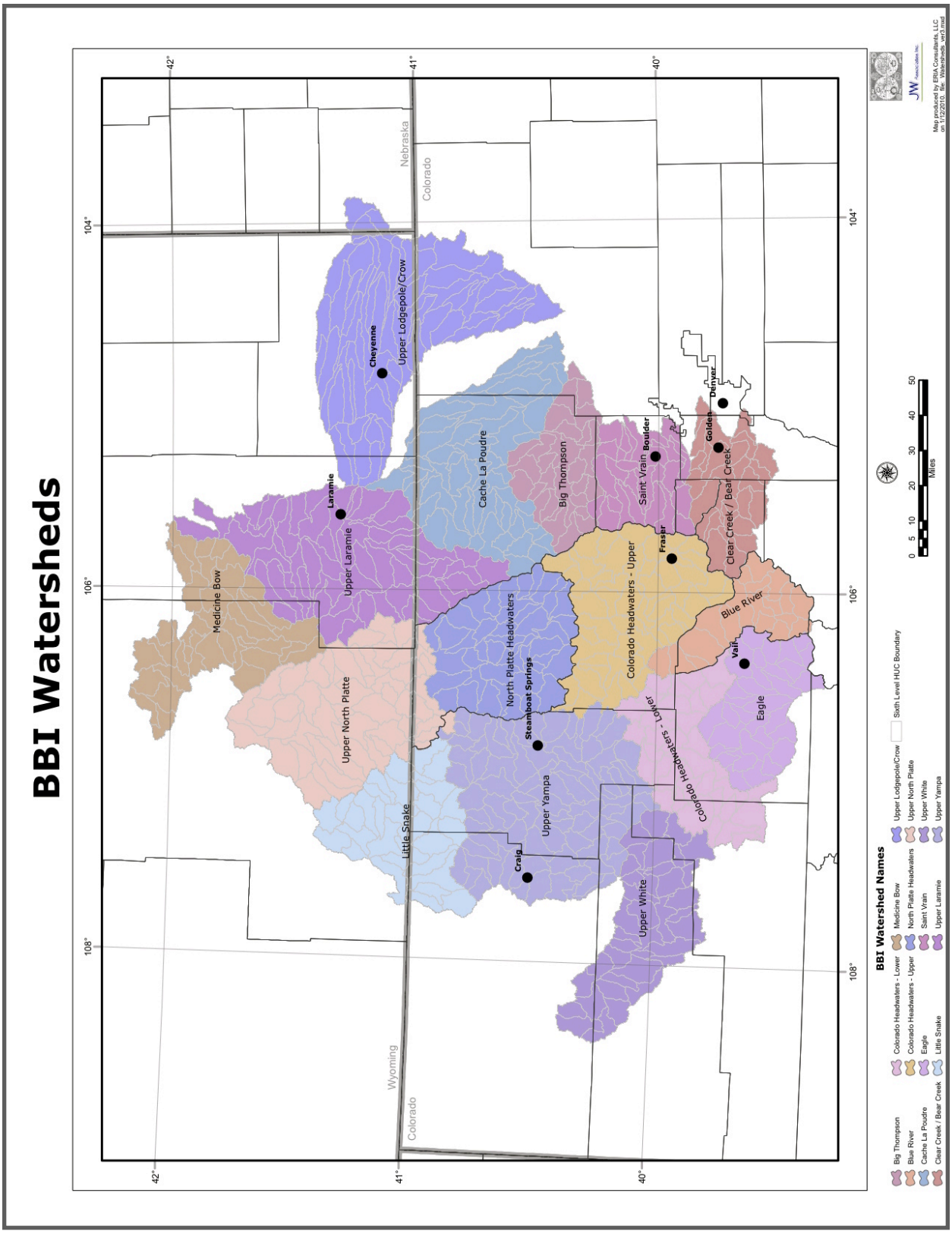


Figure 1. Bark Beetle Incident Phase 1 Watersheds

WATERSHED DESCRIPTION

The Saint Vrain 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 contains five separate streams that come together to form the Saint Vrain before its confluence with 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. For this assessment the Saint Vrain Watershed is approximately 500,529 acres in area and is composed of one fourth-level[1] (eight-digit) watershed (HUC 10190005).

The Saint Vrain watershed contains seven fifth-level watersheds and 28 sixth-level watersheds, which are the analysis units for this watershed assessment (Front Range Watershed Protection Data Refinement Work Group 2009). The Saint Vrain 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.

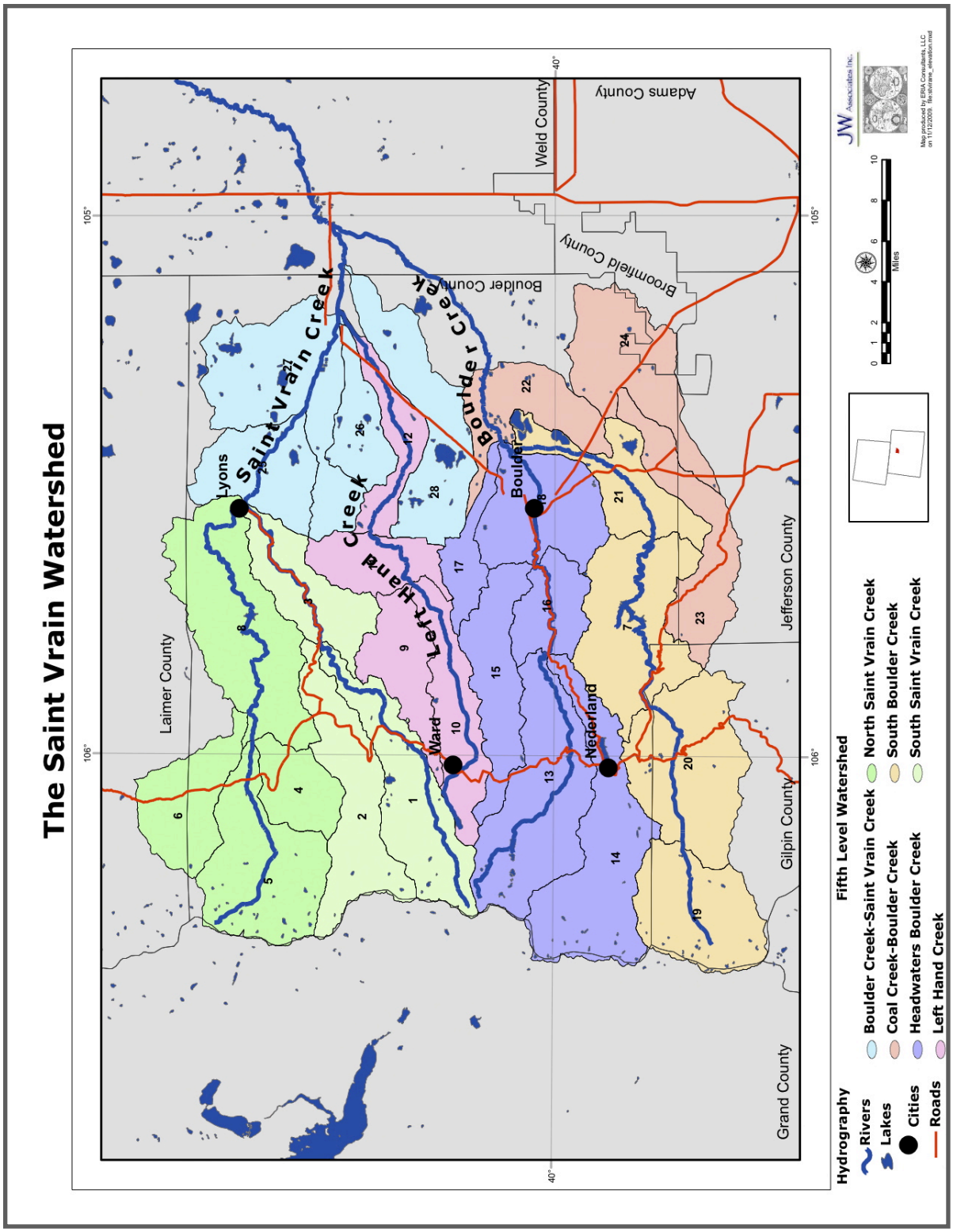


Figure 2. Saint Vrain Watershed Analysis Area[2]

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

Table 1. Fifth-level and Sixth-level Watersheds in Saint Vrain Watershed

Fifth-level Watershed	Watershed Map Number	Sixth-level Watershed	Watershed Area (acres)	Hydrologic Unit Code (HUC)
South Saint Vrain Creek	1	Headwaters South Saint Vrain Creek	21,839	101900050101
HUC 1019000501	2	Middle Saint Vrain Creek	20,944	101900050102
	3	Outlet South Saint Vrain Creek	14,358	101900050103
North Saint Vrain Creek	4	Rock Creek	9,428	101900050201
HUC 1019000502	5	Headwaters North Saint Vrain Creek	24,238	101900050202
	6	Cabin Creek	14,498	101900050203
	8	Outlet North Saint Vrain Creek	31,351	101900050204
Left Hand Creek	9	James Creek[3]	11,917	101900050301
HUC 1019000503	10	Upper Left Hand Creek	14,839	101900050302
	11	Middle Left Hand Creek	10,290	101900050303
	12	Lower Left Hand Creek	9,484	101900050304
Headwaters Boulder Creek	13	North Boulder Creek	28,612	101900050401
HUC 1019000504	14	Middle Boulder Creek	28,334	101900050402
	15	Fourmile Creek	15,528	101900050403
	16	Boulder Creek Canyon	9,783	101900050404
	17	Fourmile Canyon Creek	6,495	101900050405
	18	City of Boulder-Boulder Creek	18,556	101900050406
South Boulder Creek	19	Headwaters South Boulder Creek	19,430	101900050501
HUC 1019000505	20	Upper South Boulder Creek	26,124	101900050502
	7	Middle South Boulder Creek	25,637	101900050503
	21	Lower South Boulder Creek	14,534	101900050504
Coal Creek-Boulder Creek	22	Dry Creek-Boulder Creek	14,059	101900050601
HUC 1019000506	23	Upper Coal Creek	16,423	101900050602
	24	Middle Coal Creek	19,799	101900050603
Boulder Creek-Saint Vrain Creek	25	Indian Mountain-Saint Vrain Creek	14,972	101900050701
HUC 1019000507	26	Dry Creek	8,958	101900050702
	27	McIntosh Lake-Saint Vrain Creek	28,617	101900050703
	28	Boulder Reservoir	21,482	101900050704
		Total Area	500,529	

[3] The James Creek watershed is named Little James Creek in the database. It has been renamed in this assessment because Little James Creek is a tributary stream to James Creek which is the main stream in this watershed.

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 - Saint Vrain 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 categories are used in this analysis for the purpose of comparing watersheds to each other within the Saint Vrain 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 Saint Vrain Watershed Assessment are the wildfire hazard based on existing forest conditions. The wildfire hazard was determined using the FlamMap model (http://www.firemodels.org/content/view/14/28/). The basic data was derived from the LANDFIRE (http://www.landfire.gov/) database updated for bark beetle mortality conditions using USDA Forest Service, Rocky Mountain Region Aerial Detection Survey Data (http://www.fs.fed.us/r2/resources/fhm/aerialsurvey/). The details for the FlamMap model inputs and runs are presented in Appendix A.

The FlamMap analysis results in four categories of wildfire hazard ranging from lowest (Category 1) to highest (Category 4). Figure 3 shows the results of the FlamMap modeling. Sixth-level watersheds were then rated for wildfire hazard based on the percentage of their area in the highest category. The results were categorized by sixth-level watershed into five categories that are used throughout the analysis (see Table B-1 in Appendix B).

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: Boulder Creek Canyon, Outlet North Saint Vrain, Outlet South Saint Vrain, Rock Creek, and Upper Coal Creek. Eleven watersheds were ranked as Category 4, which is the next highest category. Therefore, more than one-half of the watersheds were rated as Category 4 or 5.

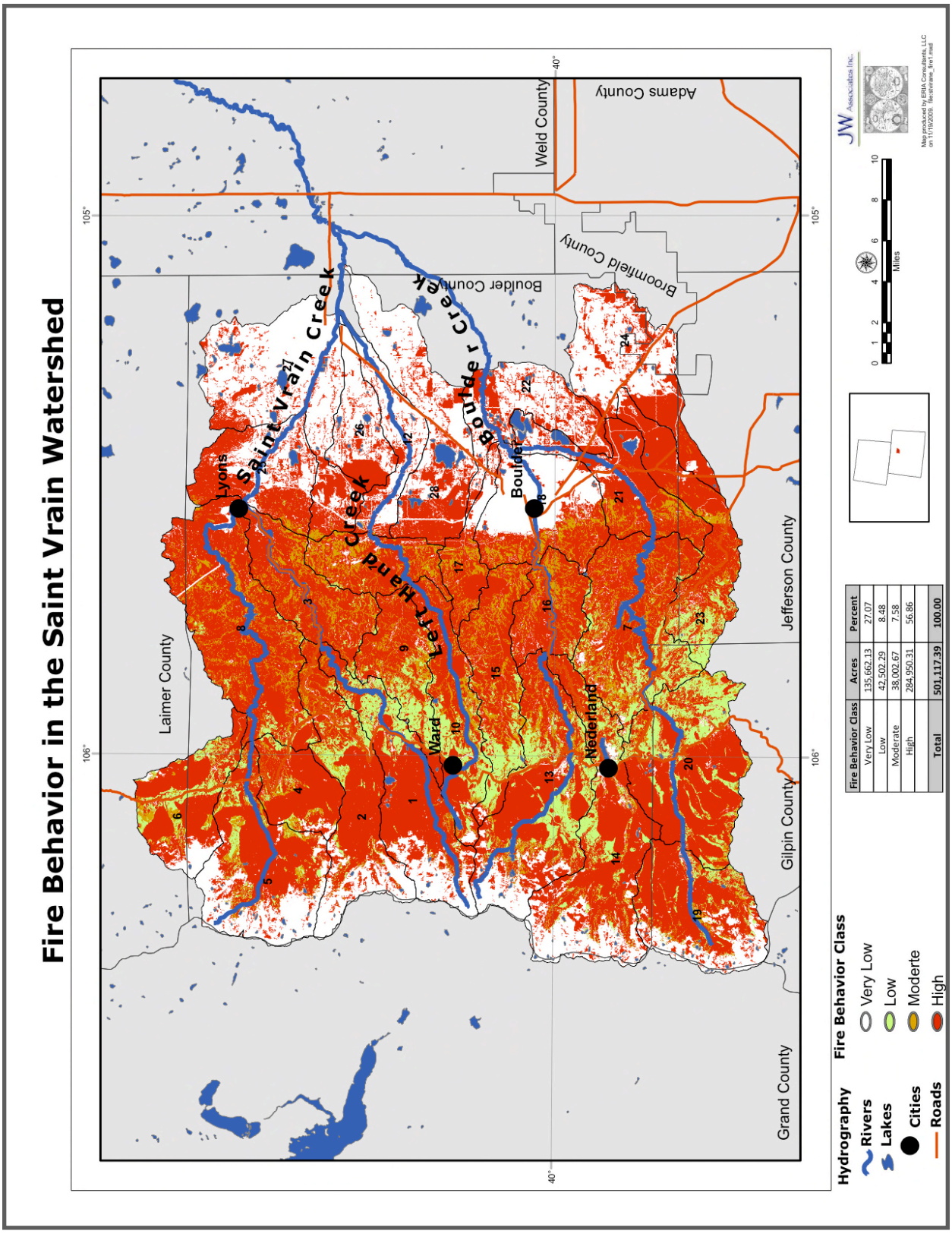


Figure 3. Saint Vrain Watershed FlamMap Modeling Results

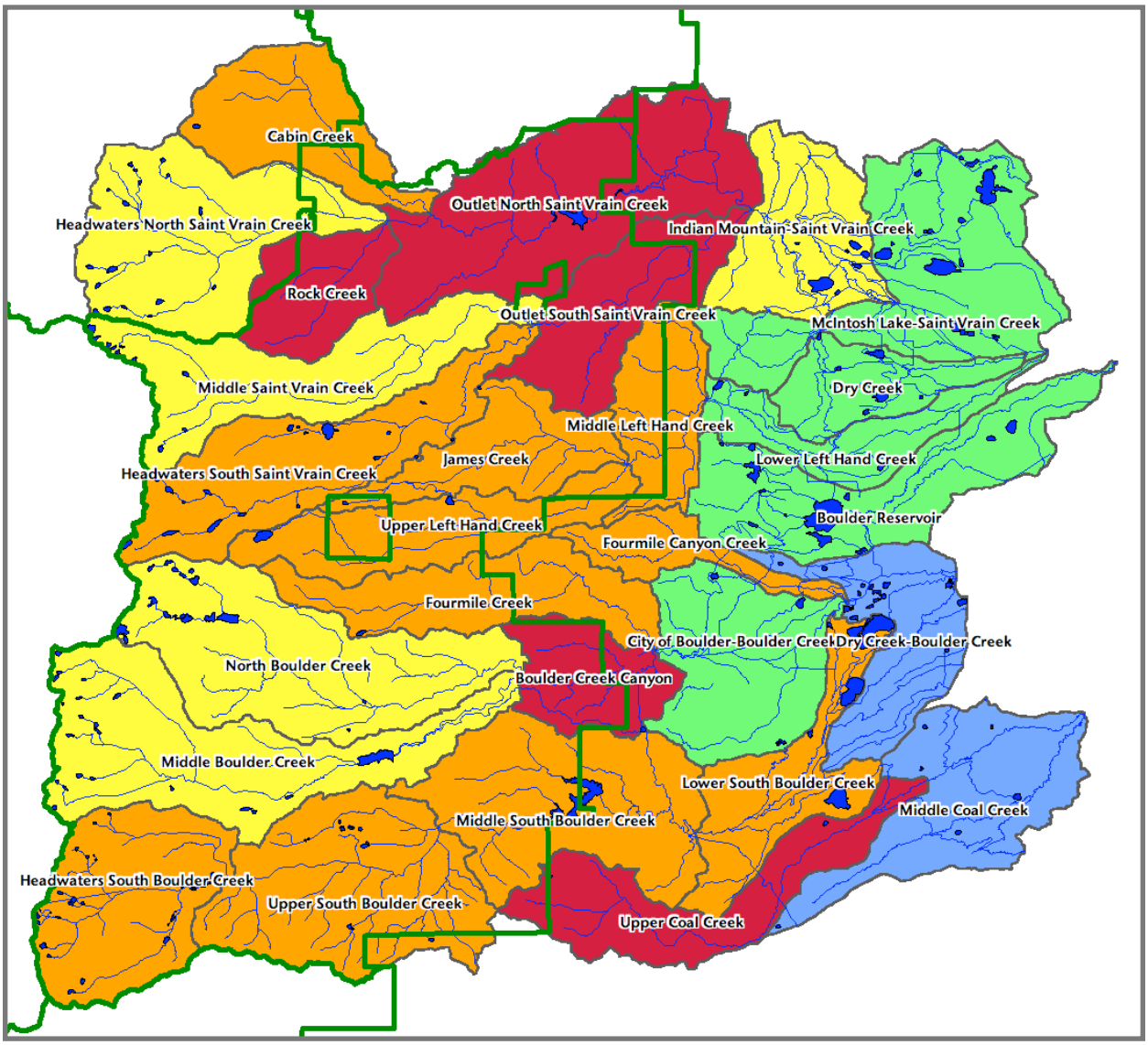


Figure 4. Saint Vrain Watershed Wildfire Hazard Ranking

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 and H_b is basin height measured from the point of highest elevation along the watershed divide to the outlet.

Figure 5 displays the categorized ruggedness for the Saint Vrain Watershed. The map generally shows that while much of the watershed is quite steep, the watersheds east of the foothills are much flatter than the others. 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 Cabin Creek, Fourmile Creek, Headwaters North Saint Vrain Creek, Headwaters South Saint Vrain Creek, Middle Saint Vrain Creek, Rock Creek, and Upper Left Hand Creek. The upper portions of the watershed are steeper than the lower portions in general.

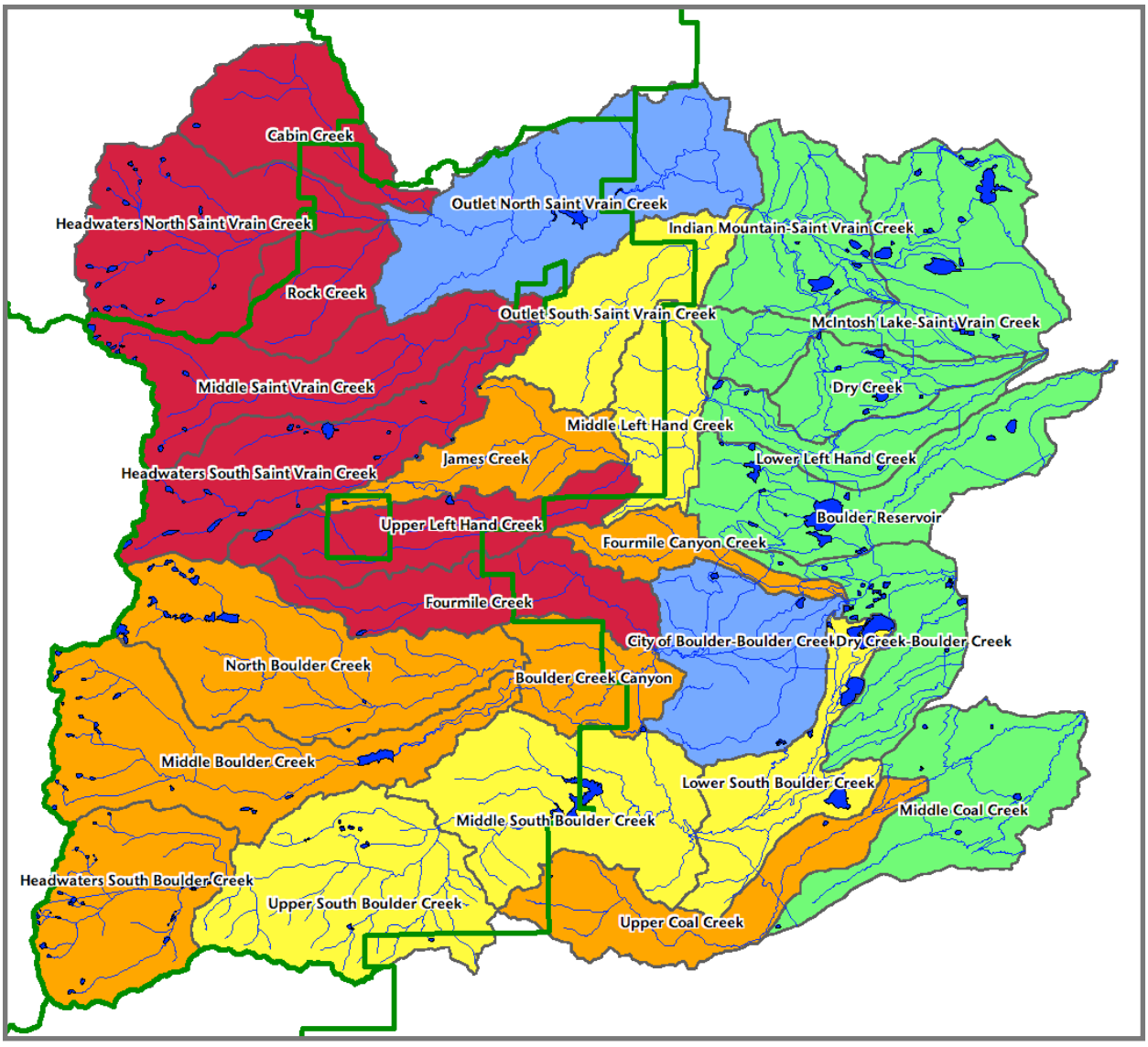


Figure 5. Saint Vrain Watershed Ruggedness Ranking

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. Roads data need to be consistent within the entire watershed to allow for appropriate comparisons during prioritization. Therefore, the U.S. Census Bureau's Tiger database was used as a consistent roads data layer (Figure 6).

The road density ranking was adjusted to account for watersheds in certain areas that were heavily skewing the results. The largest density of roads in the Saint Vrain Watershed are in towns and other developed areas. The roads that are of interest in this analysis are those roads that would increase the risk of flooding following wildfires in forested areas. Roads in towns and housing developments would not affect hydrologic changes following wildfires in the forest, where this analysis is focused. It was found that there was a high road density in several watersheds due to towns or housing developments. Road density in Boulder Reservoir, City of Boulder-Boulder Creek, Dry Creek-Boulder Creek, Dry Creek, Indian Mountain-Saint Vrain Creek, MacIntosh Lake-Saint Vrain Creek, and Middle Coal Creek watersheds were all adjusted by manually replacing the road length within each watershed with one mile because they are located on the plains and contain towns or housing developments that display very high road density. These watersheds were skewing the road density categorization; therefore the road density in those seven watersheds was adjusted down manually. The adjustments are displayed on Table B-3 in Appendix B.

Other watersheds in the project area were also examined to evaluate the appropriateness of the road density rankings. Several different roads layers were examined and various methods of adjusting the roads analysis were also evaluated. The Tiger roads data was compared with conditions on the ground. This was done by looking at vegetation type mapping to eliminate roads in developed areas. Then digital images including Google Earth were used to look for roads that were not in the roads data and identify roads that were in subdivisions and towns. Two watersheds were adjusted using this method - Fourmile Canyon Creek and Lower South Boulder Creek. The road lengths in those watersheds were reduced based upon an estimate of the percentage of roads within the forested area.

Figure 7 displays the categorized road density for the Saint Vrain Watershed and tabular results are presented in Appendix B (Table B-3). It displays some expected differences in road density throughout the watershed. Figure 7 shows that the highest rankings are in the Boulder Creek Canyon, Fourmile Canyon Creek, Fourmile Creek, Upper Coal Creek, and Upper South Boulder Creek watersheds.

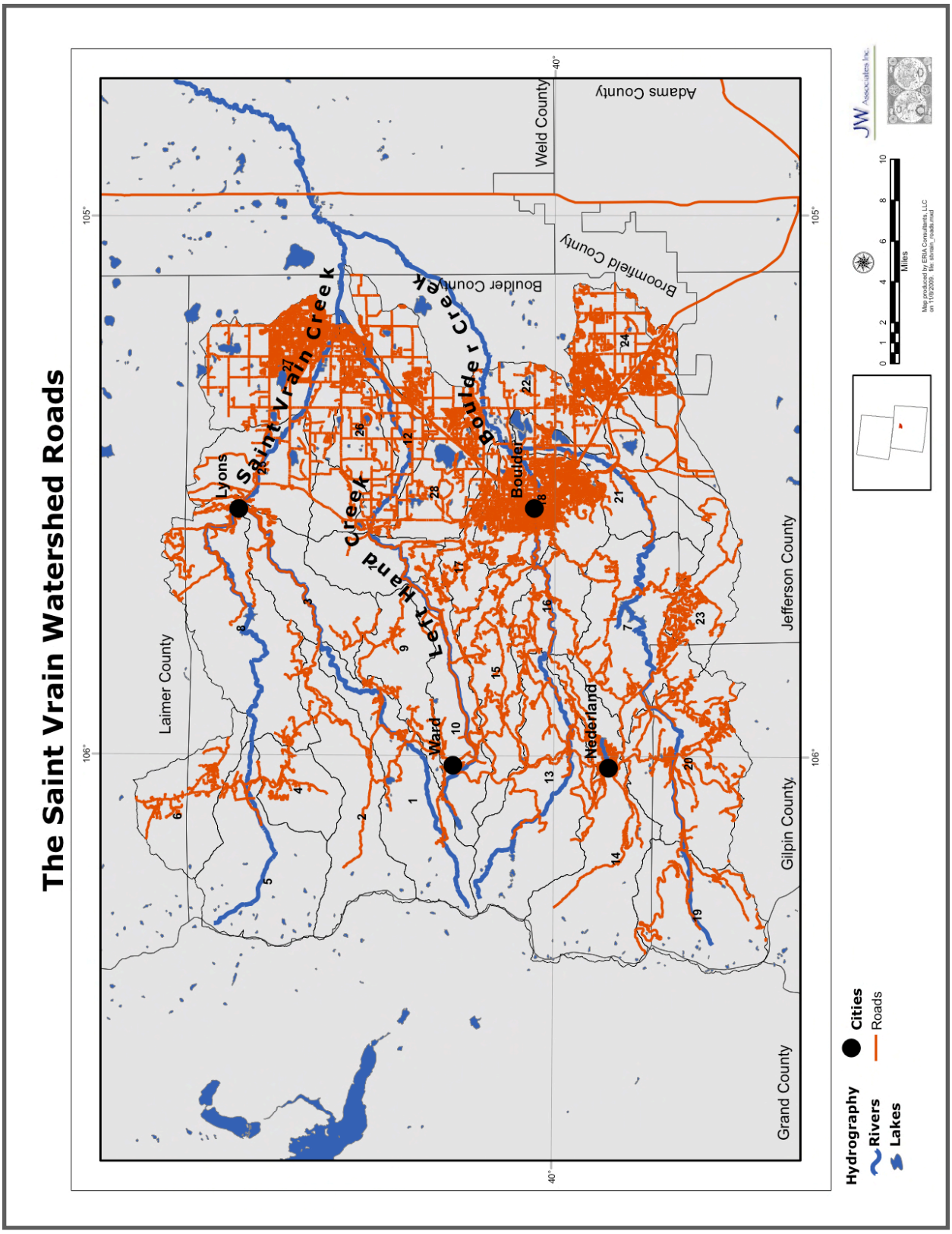


Figure 6. Saint Vrain Watershed Tiger Roads Map

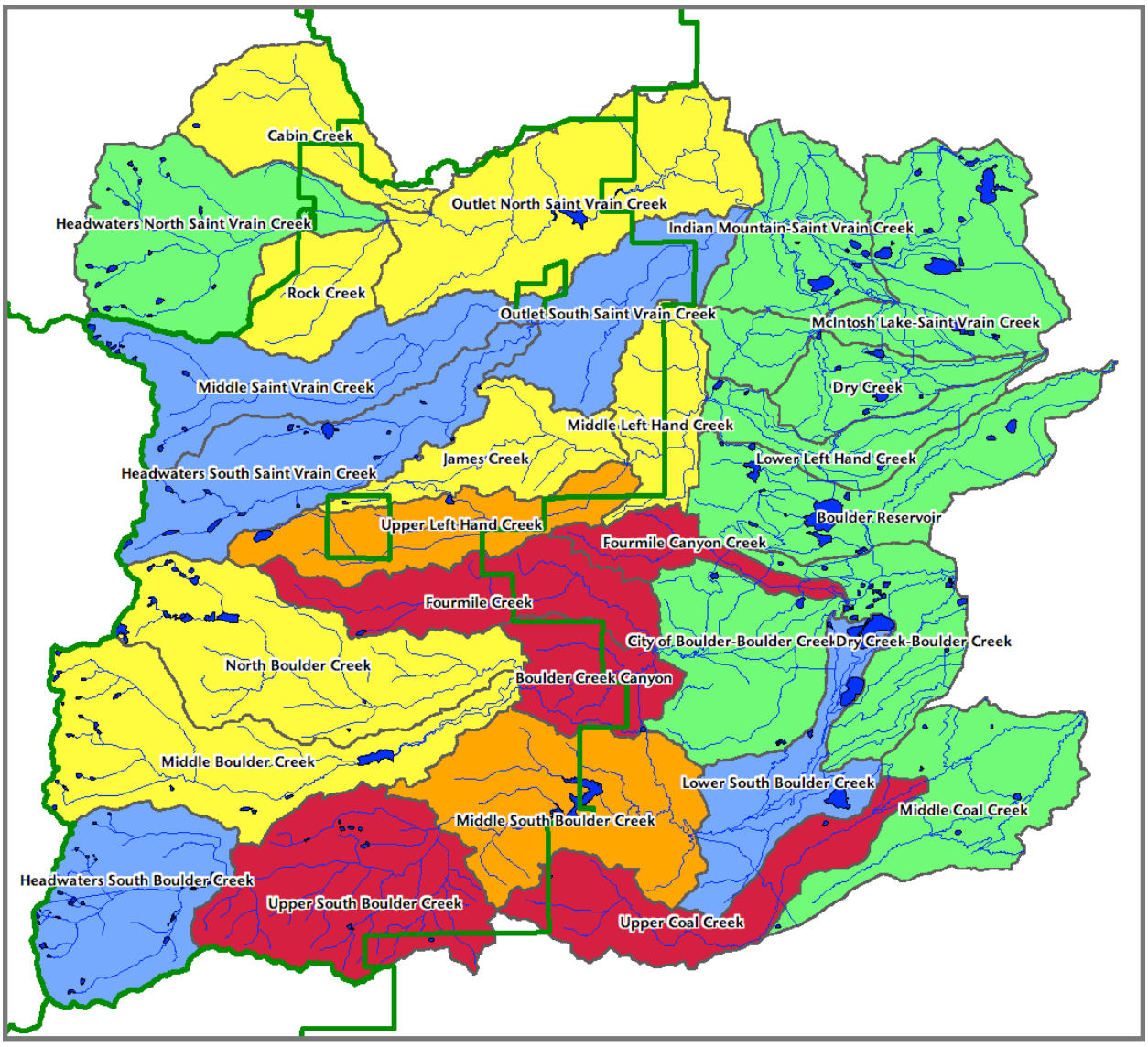
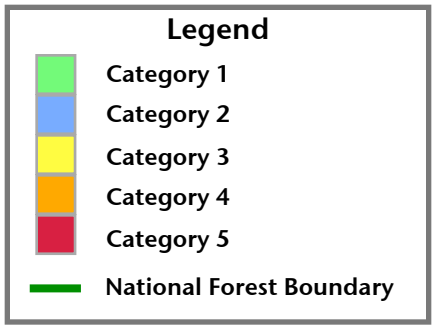


Figure 7. Saint Vrain Watershed Road Density Ranking



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) determined that ruggedness should have a higher value than road density in this ranking. In this assessment, the effect of road density on post-wildfire effects was determined to be more variable than ruggedness. For example, an area with a low ruggedness and high road density would have little influence on post-wildfire erosion. The determination that ruggedness would have a higher value than road density was based on professional judgment, experience, and the results of the Upper South Platte Watershed Assessment Test Case completed by the Front Range Watershed Work Group (2009). The analysis for flooding or debris flow hazard for the Saint Vrain 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 Cabin Creek, Fourmile Canyon Creek, Fourmile Creek, Upper Coal Creek and Upper Left Hand Creek.

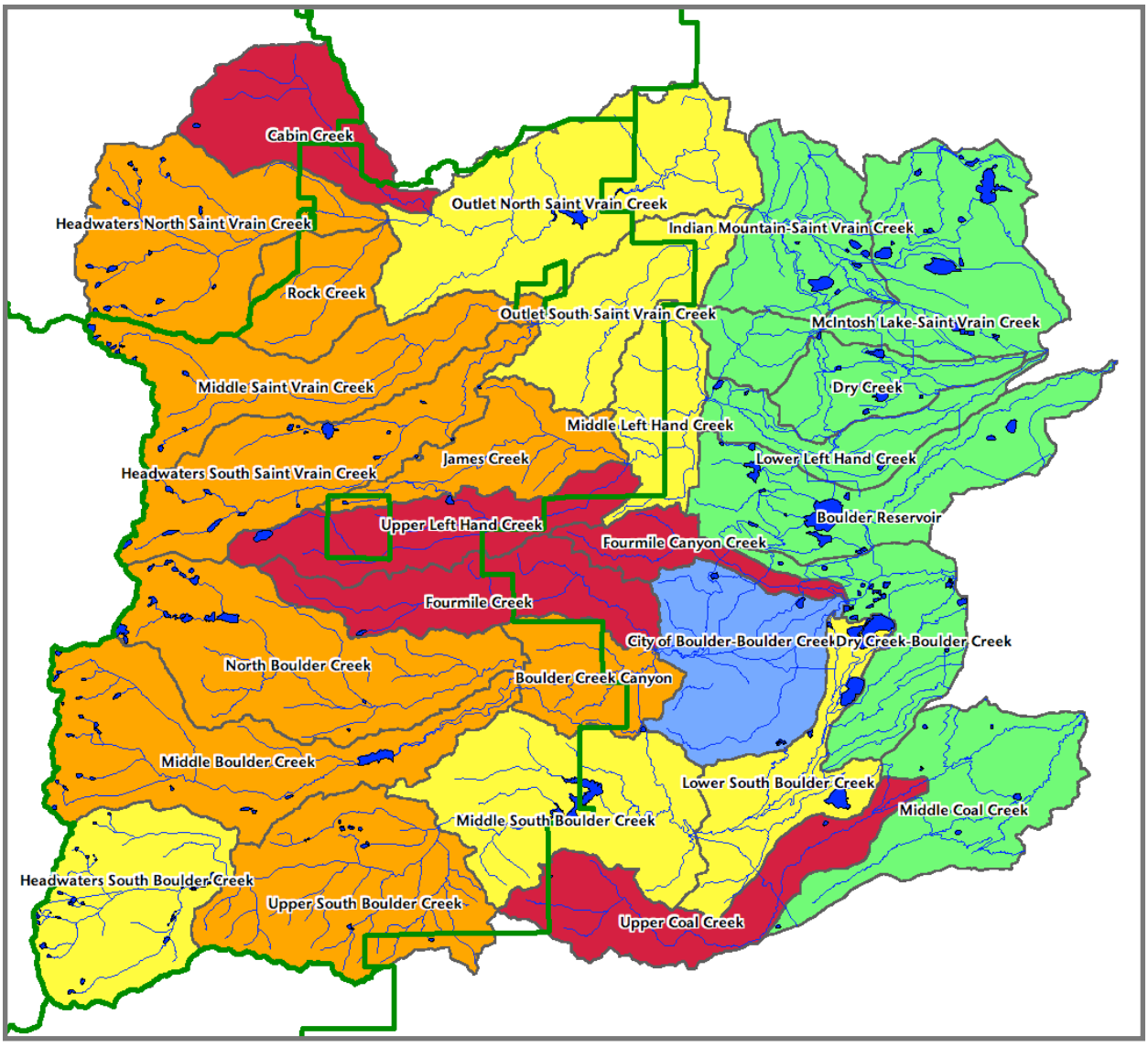


Figure 8. Saint Vrain Watershed Flooding/Debris Flow Hazard Ranking

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 STATSGO data (Figure 9) were used in this analysis and provide a consistent soils data layer that can be used in the absence of more site-specific data.

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 STATSGO 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

There is one soil map unit that runs along the edge of the foothills that has a very high K Factor (Figure 9). This soil type was skewing the distribution of the soil erodibility ranking analysis. Therefore, four watersheds (Upper Left Hand Creek, Middle Left Hand Creek, Boulder Creek Canyon, and Indian Mountain-Saint Vrain Creek) that were skewing the results because of that soil type were assigned a ranking of Category 5. The resulting 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 are Boulder Creek Canyon, City of Boulder-Boulder Creek, Fourmile Canyon Creek, Indian Mountain-Saint Vrain Creek, Lower South Boulder Creek, Middle Left Hand Creek, Middle South Boulder Creek, Upper Coal Creek, and Upper Left Hand Creek.

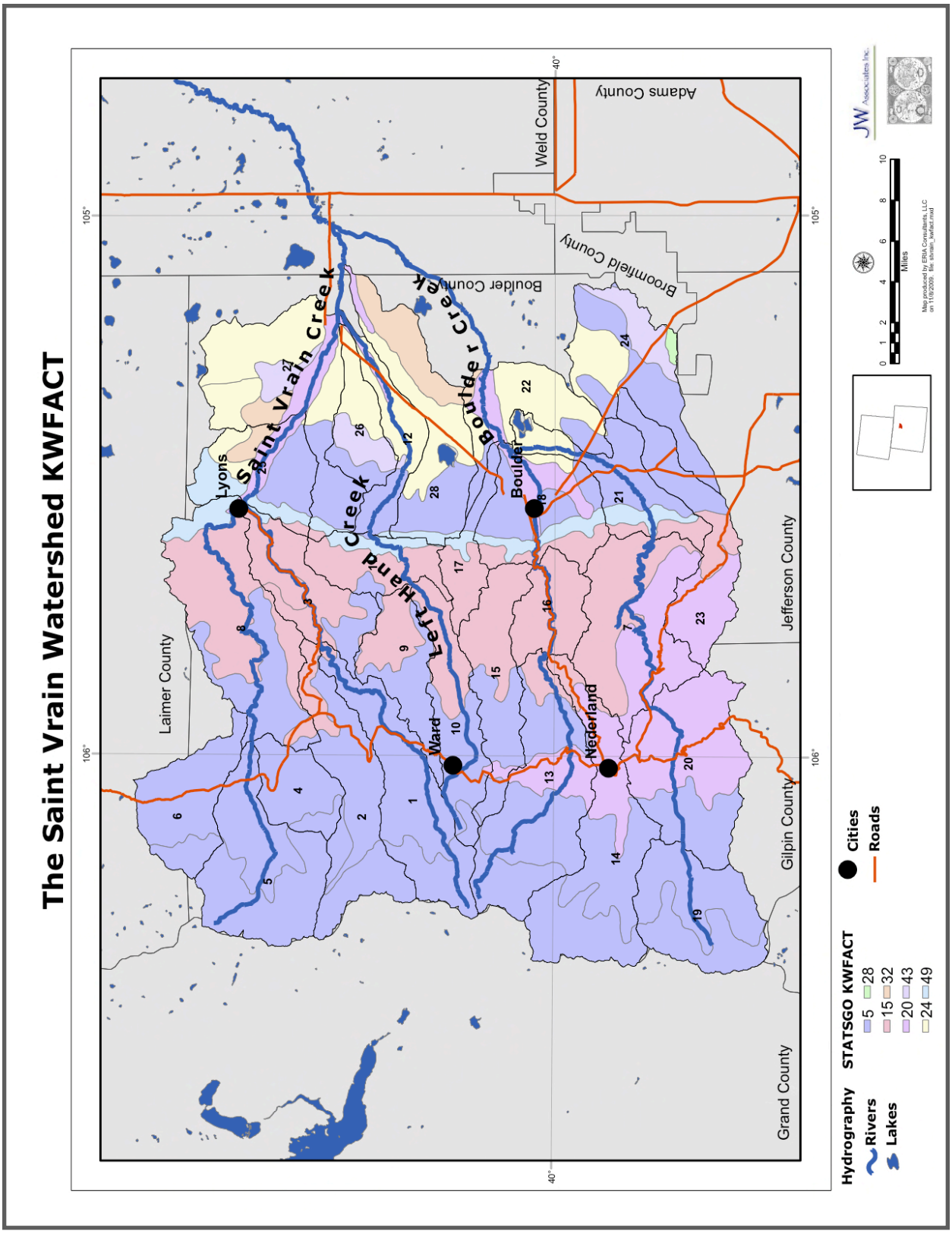


Figure 9. Saint Vrain Watershed STATSGO K-Factor Map

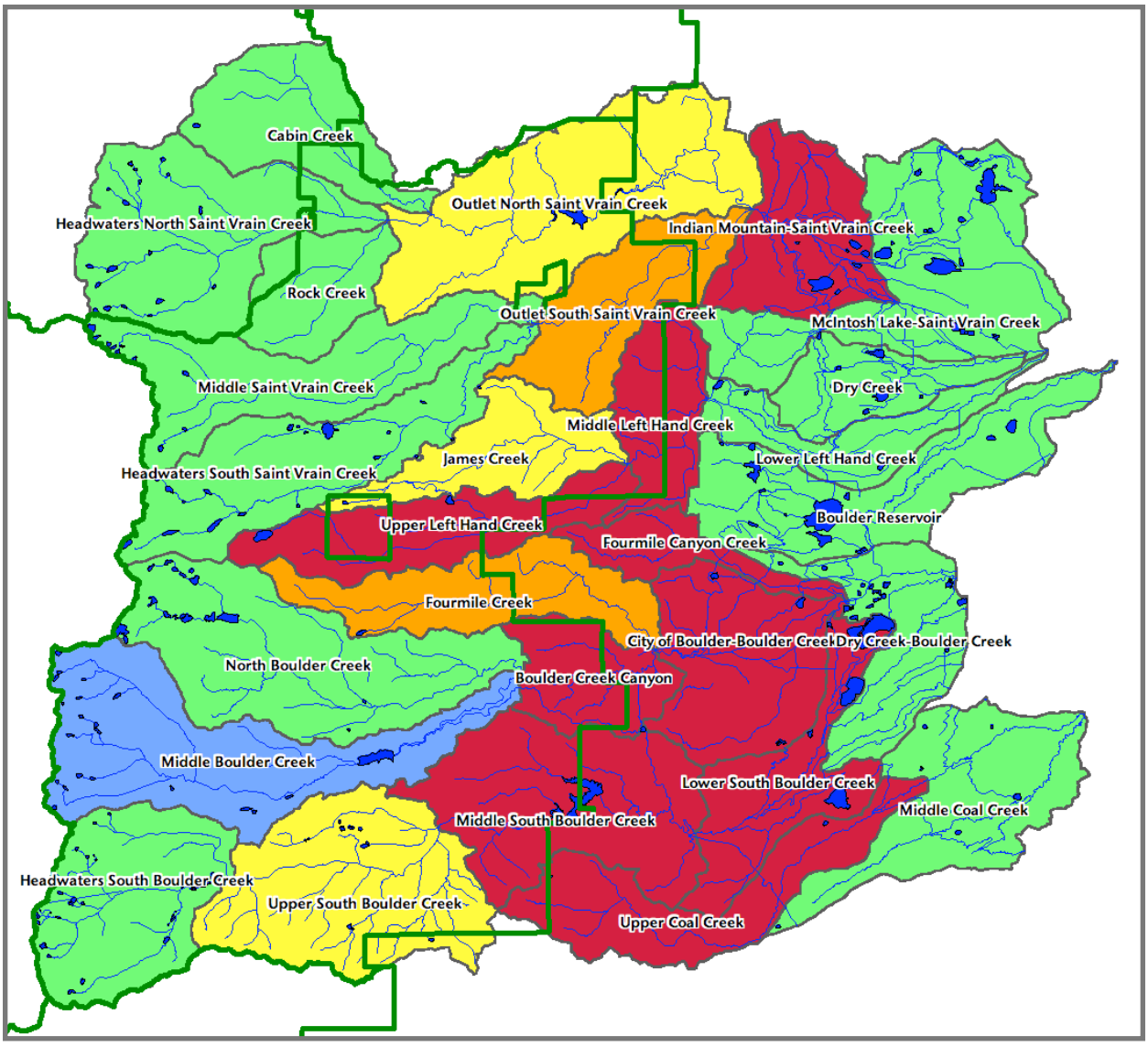


Figure 10. Saint Vrain Watershed Potential Soil Erodibility Hazard Ranking

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 Saint Vrain 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 Boulder Creek Canyon, Fourmile Canyon Creek, Fourmile Creek, Lower South Boulder Creek, Middle Left Hand Creek, MIddle South Boulder Creek, Outlet South Saint Vrain Creek, Upper Coal Creek, and Upper Left Hand Creek. Additionally, there are six watersheds in Category 4.

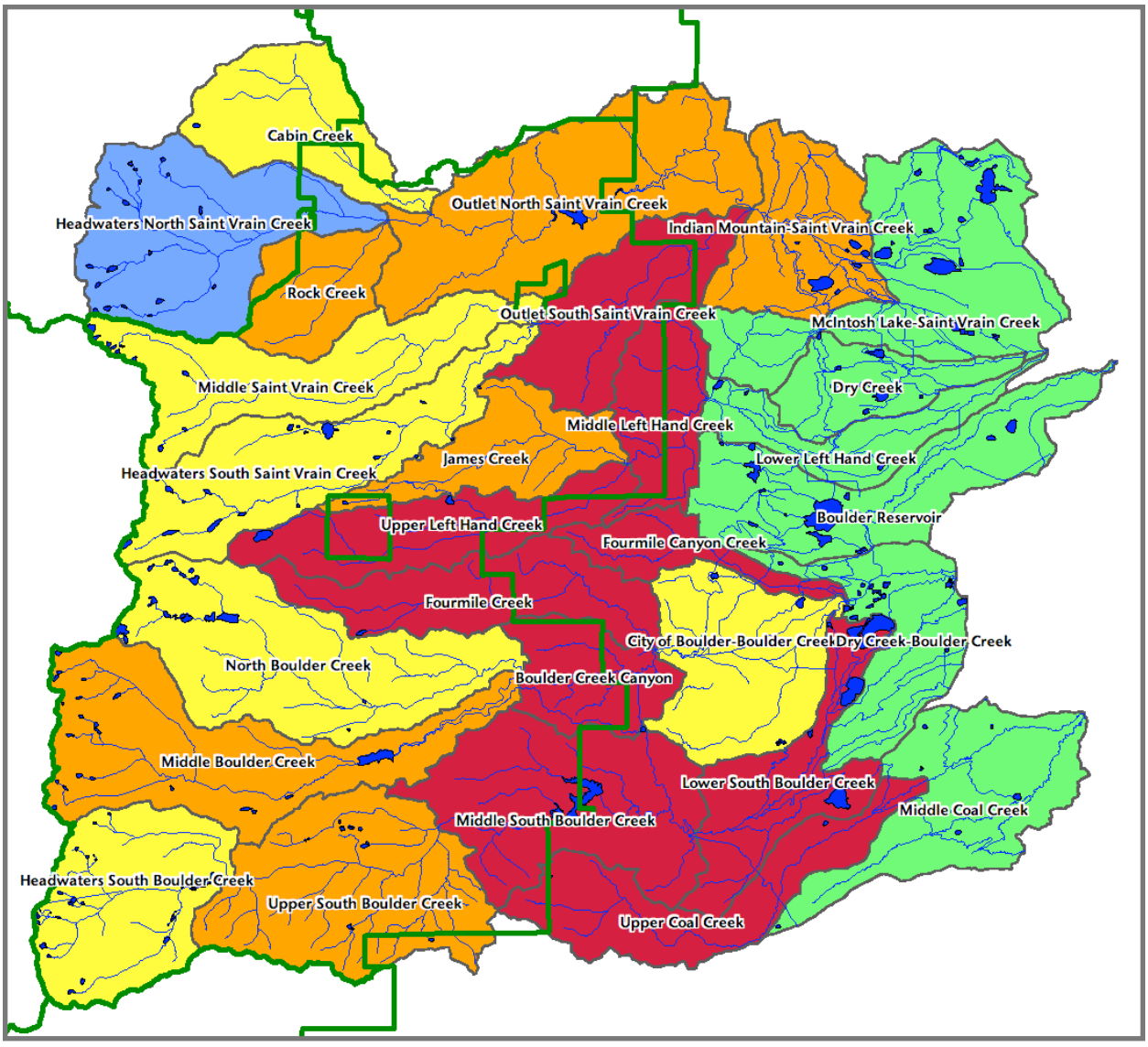


Figure 11. Saint Vrain Watershed Composite Hazard Ranking

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. For this assessment, water nodes were defined as coordinate points corresponding to surface water intakes, upstream diversion points and classified drinking water reservoirs.

Nodes 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 were not identified in the SWAP database but were identified by the stakeholders. The Water Supply map was modified to include the Middle Left Hand Creek watershed. There is a water intake just downstream of the watershed boundary.

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

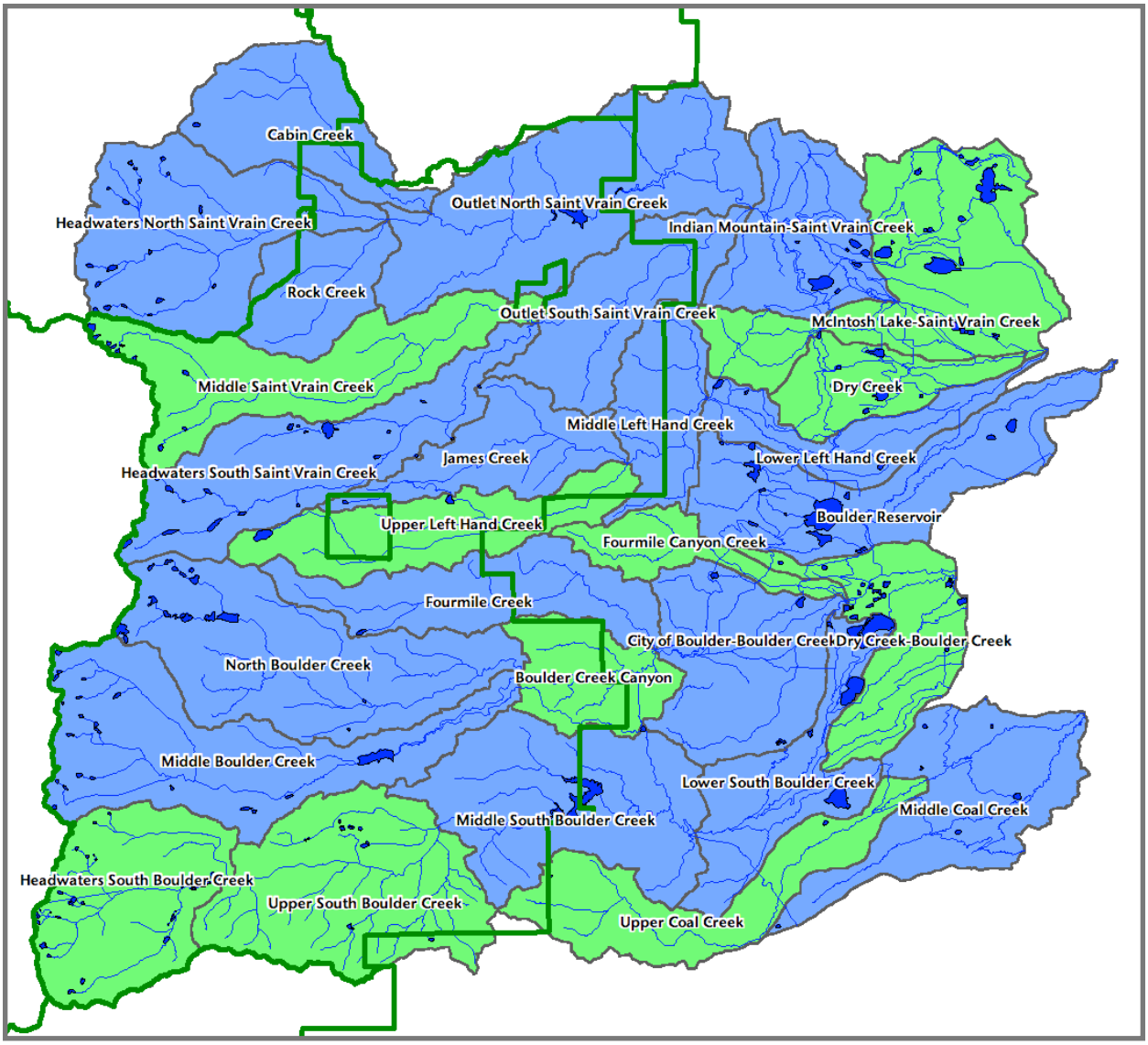


Figure 12. Saint Vrain Watershed Water Supply Map

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APPENDIX A

SAINT VRAIN FLAMMAP MODEL INPUTS

Fire Behavior Assessment Tool Parameter File

Path: C:\WorkSpace\projects\watershed_assessment\fbat_outputs\st_vrain\first_run\param.txt

Run Date: 11/19/2009 3:22:07 PM

Inputs

Spatial Inputs

ARCGrids

Elevation: svrain_elv_5

Fuel Model: svrain_fbfm5 (Scott and Burgan 2005)

Canopy Cover: svrain_cc_5 (MPB mortality 2002 - 2006 = 10%)

Canopy Height: svrain_ch5

Canopy Base Height: svrain_cbh_5 (MPB mortality 2002 - 2006 = 25% and MPB mortality 2007 = 0%)

Canopy Bulk Density: svrain_cbd_5 (MPB mortality 2002 - 2006 = 50%)

Fuel Moisture File: C:\temp\east_side_default.FMS

Wind Speed: 40

Wind Direction: Uphill

Crown Fire Calculation: Scott & Reinhardt (2001)

Foliar Moisture Content: 100

Outputs

Wildland Fire Intensity

Fire Behavior Simple Query

Flame Length: 1.2

Rate of Spread: 1.7

Fire Type: 2

And/Or: OR2

Fire Behavior Classification Query

Level	Flame Len	ROS	Fire Type
3	3.7	16.8	3
2	1.2	1.7	2
1	0.1	0.1	1

And/Or: OR

Output Folder: C:\WorkSpace\projects\watershed_assessment\fbat_outputs\st_vrain\first_run

Additional modification

1 Hour fuels = 4% moisture, 10 Hour fuels = 5%, 100 Hour Fuels = 9%, Herb = 18%, Large Woody = 68%

Run Date: 11/19/2009 3:29:09 PM

APPENDIX B

DETAILED SAINT VRAIN WATERSHED ASSESSMENT RESULTS

Table B-1. Saint Vrain Watershed Wildfire Hazard Ranking

Sixth-level Watershed Name	Watershed Area (acres)	Wildfire Hazard Calculation	Wildfire Rank
Rock Creek	9,428	80.4%	*5.5*
Outlet North Saint Vrain Creek	31,351	78.5%	*5.3*
Outlet South Saint Vrain Creek	14,358	76.4%	*5.1*
Boulder Creek Canyon	9,783	75.6%	*5.1*
Upper Coal Creek	16,423	69.9%	*4.5*
Lower South Boulder Creek	14,534	68.8%	*4.4*
Middle Left Hand Creek	10,290	68.1%	*4.4*
Upper South Boulder Creek	26,124	67.5%	*4.3*
Middle South Boulder Creek	25,637	64.2%	*4.0*
Cabin Creek	14,498	63.8%	*4.0*
Fourmile Creek	15,528	63.1%	*3.9*
Headwaters South Boulder Creek	19,430	62.7%	*3.9*
Fourmile Canyon Creek	6,495	62.3%	*3.8*
Upper Left Hand Creek	14,839	61.2%	*3.7*
Headwaters South Saint Vrain Creek	21,839	61.2%	*3.7*
James Creek	11,917	60.6%	*3.7*
North Boulder Creek	28,612	58.4%	*3.5*
Middle Saint Vrain Creek	20,944	58.3%	*3.5*
Indian Mountain-Saint Vrain Creek	14,972	58.0%	*3.4*
Middle Boulder Creek	28,334	56.4%	*3.3*
Headwaters North Saint Vrain Creek	24,238	52.3%	*2.9*
Dry Creek-Boulder Creek	14,059	40.7%	*1.9*
Middle Coal Creek	19,799	38.4%	*1.6*
Boulder Reservoir	21,482	35.6%	*1.4*
Dry Creek	8,958	34.3%	*1.3*
City of Boulder-Boulder Creek	18,556	34.2%	*1.3*
Lower Left Hand Creek	9,484	28.6%	*0.8*
McIntosh Lake-Saint Vrain Creek	28,617	25.8%	*0.5*

Table B-2. Saint Vrain Watershed Ruggedness Ranking[1]

Sixth-level Watershed Name	Watershed Area (acres)	Maximum Elevation	Minimum Elevation	Difference Elevation	Ruggedness	Rank
Cabin Creek	14,498	13,556	7,629	5,927	0.2359	5.5
Fourmile Creek	15,528	11,467	5,766	5,701	0.2192	5.1
Headwaters South Saint Vrain Creek	21,839	13,369	6,973	6,396	0.2074	4.8
Upper Left Hand Creek	14,839	11,513	6,317	5,196	0.2044	4.7
Headwaters North Saint Vrain Creek	24,238	14,252	7,718	6,534	0.2011	4.7
Middle Saint Vrain Creek	20,944	13,117	7,091	6,026	0.1995	4.6
Rock Creek	9,428	11,631	7,649	3,982	0.1965	4.6
Upper Coal Creek	16,423	10,496	5,455	5,041	0.1885	4.4
Fourmile Canyon Creek	6,495	8,295	5,169	3,126	0.1858	4.3
Middle Boulder Creek	28,334	13,389	6,918	6,471	0.1842	4.3
North Boulder Creek	28,612	13,504	7,108	6,396	0.1812	4.2
James Creek (1)	11,917	10,047	6,416	3,631	0.1594	3.7
Headwaters South Boulder Creek	19,430	13,291	8,843	4,448	0.1529	3.5
Boulder Creek Canyon	9,783	8,863	5,724	3,139	0.1521	3.5
Lower South Boulder Creek	14,534	8,731	5,150	3,581	0.1423	3.3
Middle Left Hand Creek	10,290	8,554	5,648	2,906	0.1373	3.1
Outlet South Saint Vrain Creek	14,358	8,574	5,320	3,254	0.1301	3.0
Middle South Boulder Creek	25,637	10,384	6,117	4,267	0.1277	2.9
Upper South Boulder Creek	26,124	10,886	8,082	2,804	0.1176	2.7
City of Boulder-Boulder Creek	18,556	8,220	5,159	3,061	0.1077	2.4
Outlet North Saint Vrain Creek	31,351	9,243	5,346	3,897	0.1055	2.4
Lower Left Hand Creek	9,484	6,271	4,923	1,348	0.0663	1.5
Indian Mountain-Saint Vrain Creek	14,972	6,754	5,071	1,683	0.0659	1.4
Boulder Reservoir	21,482	6,665	4,887	1,778	0.0581	1.3
McIntosh Lake-Saint Vrain Creek	28,617	6,803	4,930	1,873	0.0530	1.1
Middle Coal Creek	19,799	6,334	5,120	1,214	0.0413	0.9
Dry Creek	8,958	5,596	4,940	656	0.0332	0.7
Dry Creek-Boulder Creek	14,059	5,707	5,061	646	0.0261	0.5

[1] Ruggedness is based on Melton (1957)

Table B-3. Saint Vrain Watershed Road Density Ranking[2]

Sixth-level Watershed Name	Roads (miles)	Roads Adjusted [2] (miles)	Watershed Area (sq. mi.)	Road density (miles/sq. mi.)	Rank
Fourmile Canyon Creek	14.3	7.0	10.1	0.69	5.5
Upper Coal Creek	16.5	16.5	25.7	0.64	5.1
Upper South Boulder Creek	26.0	26.0	40.8	0.64	5.1
Fourmile Creek	15.4	15.4	24.3	0.63	5.1
Boulder Creek Canyon	9.4	9.4	15.3	0.61	4.9
Upper Left Hand Creek	12.5	12.5	23.2	0.54	4.4
Middle South Boulder Creek	17.9	17.9	40.1	0.45	3.7
James Creek	7.2	7.2	18.6	0.39	3.2
Middle Boulder Creek	16.6	16.6	44.3	0.37	3.1
Cabin Creek	8.1	8.1	22.7	0.36	3.0
Rock Creek	5.1	5.1	14.7	0.35	2.9
Outlet North Saint Vrain Creek	16.2	16.2	49.0	0.33	2.8
Middle Left Hand Creek	5.3	5.3	16.1	0.33	2.8
North Boulder Creek	13.6	13.6	44.7	0.30	2.6
Outlet South Saint Vrain Creek	6.4	6.4	22.4	0.29	2.5
Headwaters South Boulder Creek	8.1	8.1	30.4	0.27	2.3
Lower South Boulder Creek	12.6	6.0	22.7	0.26	2.3
Middle Saint Vrain Creek	7.1	7.1	32.7	0.22	2.0
Headwaters South Saint Vrain Creek	6.9	6.9	34.1	0.20	1.9
Headwaters North Saint Vrain Creek	3.2	3.2	37.9	0.09	1.0
Dry Creek	18.7	1.0	14.0	0.07	0.9
Lower Left Hand Creek	20.5	1.0	14.8	0.07	0.8
Dry Creek-Boulder Creek	26.1	1.0	22.0	0.05	0.7
Indian Mountain-Saint Vrain Creek	11.0	1.0	23.4	0.04	0.7
City of Boulder-Boulder Creek	89.4	1.0	29.0	0.03	0.6
Middle Coal Creek	65.0	1.0	30.9	0.03	0.6
Boulder Reservoir	36.1	1.0	33.6	0.03	0.6
McIntosh Lake-Saint Vrain Creek	72.8	1.0	44.7	0.02	0.5

[2] The road density rank was adjusted based upon the procedure discussed in the report (p. 12) for several watersheds.

Table B-4. Saint Vrain Watershed Flooding/Debris Flow Hazard Ranking[3]

Sixth-level Watershed Name	Ruggedness Ranking	Road Density Ranking	Combined Ranking	Rank
Fourmile Creek	5.1	5.1	15.29	5.5
Fourmile Canyon Creek	4.3	5.5	14.12	5.1
Cabin Creek	5.5	3.0	14.00	5.0
Upper Coal Creek	4.4	5.1	13.88	5.0
Upper Left Hand Creek	4.7	4.4	13.87	5.0
Rock Creek	4.6	2.9	12.06	4.3
Boulder Creek Canyon	3.5	4.9	11.92	4.3
Middle Boulder Creek	4.3	3.1	11.67	4.2
Headwaters South Saint Vrain Creek	4.8	1.9	11.50	4.1
Middle Saint Vrain Creek	4.6	2.0	11.23	4.0
North Boulder Creek	4.2	2.6	11.00	3.9
James Creek (1)	3.7	3.2	10.58	3.8
Upper South Boulder Creek	2.7	5.1	10.47	3.7
Headwaters North Saint Vrain Creek	4.7	1.0	10.32	3.7
Middle South Boulder Creek	2.9	3.7	9.52	3.4
Headwaters South Boulder Creek	3.5	2.3	9.38	3.3
Middle Left Hand Creek	3.1	2.8	9.11	3.2
Lower South Boulder Creek	3.3	2.3	8.85	3.1
Outlet South Saint Vrain Creek	3.0	2.5	8.43	3.0
Outlet North Saint Vrain Creek	2.4	2.8	7.60	2.7
City of Boulder-Boulder Creek	2.4	0.6	5.48	1.9
Lower Left Hand Creek	1.5	0.8	3.76	1.3
Indian Mountain-Saint Vrain Creek	1.4	0.7	3.55	1.2
Boulder Reservoir	1.3	0.6	3.08	1.0
McIntosh Lake-Saint Vrain Creek	1.1	0.5	2.78	0.9
Middle Coal Creek	0.9	0.6	2.30	0.7
Dry Creek	0.7	0.9	2.21	0.7
Dry Creek-Boulder Creek	0.5	0.7	1.67	0.5

[3] Combined Ranking is Ruggedness Ranking times 2 plus the Road Density Ranking

Table B-5. Saint Vrain Watershed Soil Erodibility Ranking[4]

Sixth-level Watershed Name	Severe	Very Severe	Soil Erodibility Value	Soil Erodibility Rank
Middle South Boulder Creek	17.0%	7.7%	32.5%	5.5
Upper Left Hand Creek[5]	66.1%	0.1%		5.0
Middle Left Hand Creek[5]	26.1%	10.6%		5.0
Boulder Creek Canyon[5]	49.6%	0.0%		5.0
City of Boulder-Boulder Creek[5]	8.0%	71.1%		5.0
Indian Mountain-Saint Vrain Creek[5]	13.7%	66.5%		5.0
Upper Coal Creek	16.4%	6.2%	28.8%	4.9
Lower South Boulder Creek	16.2%	6.3%	28.7%	4.9
Fourmile Canyon Creek	16.0%	5.7%	27.4%	4.7
Fourmile Creek	25.2%	0.2%	25.7%	4.5
Outlet South Saint Vrain Creek	22.4%	0.4%	23.3%	4.1
Outlet North Saint Vrain Creek	13.9%	2.1%	18.1%	3.3
James Creek	15.8%	0.0%	15.8%	2.9
Upper South Boulder Creek	8.4%	3.3%	15.1%	2.8
Middle Boulder Creek	5.1%	2.8%	10.8%	2.2
Lower Left Hand Creek	0.7%	2.6%	5.9%	1.4
Boulder Reservoir	1.9%	1.7%	5.3%	1.3
North Boulder Creek	2.4%	0.6%	3.6%	1.1
McIntosh Lake-Saint Vrain Creek	1.4%	0.5%	2.3%	0.9
Middle Coal Creek	1.5%	0.0%	1.5%	0.7
Middle Saint Vrain Creek	1.3%	0.0%	1.3%	0.7
Dry Creek	1.2%	0.0%	1.3%	0.7
Headwaters South Saint Vrain Creek	0.6%	0.0%	0.6%	0.6
Dry Creek-Boulder Creek	0.1%	0.0%	0.1%	0.5
Rock Creek	0.0%	0.0%	0.0%	0.5
Headwaters North Saint Vrain Creek	0.0%	0.0%	0.0%	0.5
Cabin Creek	0.0%	0.0%	0.0%	0.5
Headwaters South Boulder Creek	0.0%	0.0%	0.0%	0.5

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

[5] These five watersheds had results that were so high that they were skewing the categorization. They were manually given the highest category value of 5 to minimize their effect on the categorization of the other watersheds.

Table B-6. Saint Vrain Watershed Composite Hazard Ranking[6]

Sixth-level Watershed Name	Wildfire Hazard Rank	Flooding/Debris Flow Rank	Soil Erodibility Rank	Composite Hazard Rank
Upper Coal Creek	4.5	5.0	4.9	5.5
Boulder Creek Canyon	5.1	4.3	5.0	5.4
Fourmile Creek	3.9	5.5	4.5	5.3
Upper Left Hand Creek	3.7	5.0	5.0	5.2
Fourmile Canyon Creek	3.8	5.1	4.7	5.2
Middle South Boulder Creek	4.0	3.4	5.5	4.9
Middle Left Hand Creek	4.4	3.2	5.0	4.7
Lower South Boulder Creek	4.4	3.1	4.9	4.7
Outlet South Saint Vrain Creek	5.1	3.0	4.1	4.6
Outlet North Saint Vrain Creek	5.3	2.7	3.3	4.2
Upper South Boulder Creek	4.3	3.7	2.8	4.0
James Creek (1)	3.7	3.8	2.9	3.8
Rock Creek	5.5	4.3	0.5	3.8
Indian Mountain-Saint Vrain Creek	3.4	1.2	5.0	3.5
Middle Boulder Creek	3.3	4.2	2.2	3.5
Cabin Creek	4.0	5.0	0.5	3.5
North Boulder Creek	3.5	3.9	1.1	3.0
Headwaters South Saint Vrain Creek	3.7	4.1	0.6	3.0
Middle Saint Vrain Creek	3.5	4.0	0.7	2.9
City of Boulder-Boulder Creek	1.3	1.9	5.0	2.9
Headwaters South Boulder Creek	3.9	3.3	0.5	2.7
Headwaters North Saint Vrain Creek	2.9	3.7	0.5	2.5
Boulder Reservoir	1.4	1.0	1.3	1.1
Lower Left Hand Creek	0.8	1.3	1.4	1.0
Middle Coal Creek	1.6	0.7	0.7	0.8
Dry Creek-Boulder Creek	1.9	0.5	0.5	0.8
Dry Creek	1.3	0.7	0.7	0.7
McIntosh Lake-Saint Vrain Creek	0.5	0.9	0.9	0.5

[6] The Composite Hazard Rank is the average of the Wildfire Hazard Rank, Flooding/Debris Flow Rank, and Soil Erodibility Rank that is re-categorized into 5 categories using the procedure described in Front Range Watershed Protection Data Refinement Work Group (2009).