# River Channel Characteristics in the San Miguel Watershed

A Product of the San Miguel Pilot Project

Submitted: 3/22/21

lotic

**Prepared For:**

**Prepared By:**

Lotic Hydrological, LLC
P.O. Box 1524
Carbondale, CO 81623

Cover Photo Credit: The Nature Conservancy

## Table of Contents



## List of Figures

## List of Tables

# 1 Introduction

Stakeholders participating in the San Miguel Pilot Project requested an evaluation of channel forms and dynamics in the San Miguel watershed. Relationships between channel characteristics, aquatic biology, and riparian community structure on the San Miguel River (Figure 1) are discussed by others [1]–[5] and known, anecdotally, by stakeholders. Channel dynamics encompass the fluvial and geomorphological processes that interact to control channel form and evolution across a range of spatial and temporal scales. Channel dynamics respond to interactions between patterns of rainfall and runoff, catchment-scale physical attributes (e.g. surficial geology, topography), riparian community structure, and local use practices (e.g. transportation corridor alignment, grazing practices).

In a preferred state, channel dynamics maintain aquatic habitat quality and provide the disturbance template upon which riparian vegetation thrives. Modification of the hydrological regime, altered patterns of erosion, adjustments to the structure of the channel bed, or changes in riparian community composition and extent may yield fundamental shifts in the geometry and behavior of the stream at the channel (tens of yards) or reach (hundreds of yards) scale. These changes may reduce the stability or reliability of critical infrastructure within the watershed (e.g. surface water diversion structures, bridges, highways) and may negatively impact the quality of aquatic habitat and riparian communities. Participants in the San Miguel Pilot Project specifically requested a summarization of existing information and collection of new data necessary to identify important streamflow characteristics that mediate the way that channels behave.

# 2 Conditional Assessment

This assessment summarized and built upon the long history of data collection and analysis in the San Miguel watershed by federal agencies, local governments, and non-governmental organizations. Specifically, consideration of river channel characteristics by the San Miguel Pilot Project included an assessment of surficial geology, classification of river channels throughout the watershed using the River Styles framework, a coarse examination of fluvial geomorphological condition, and an evaluation of sediment transport dynamics at selected locations of the mainstem San Miguel River and two tributaries.

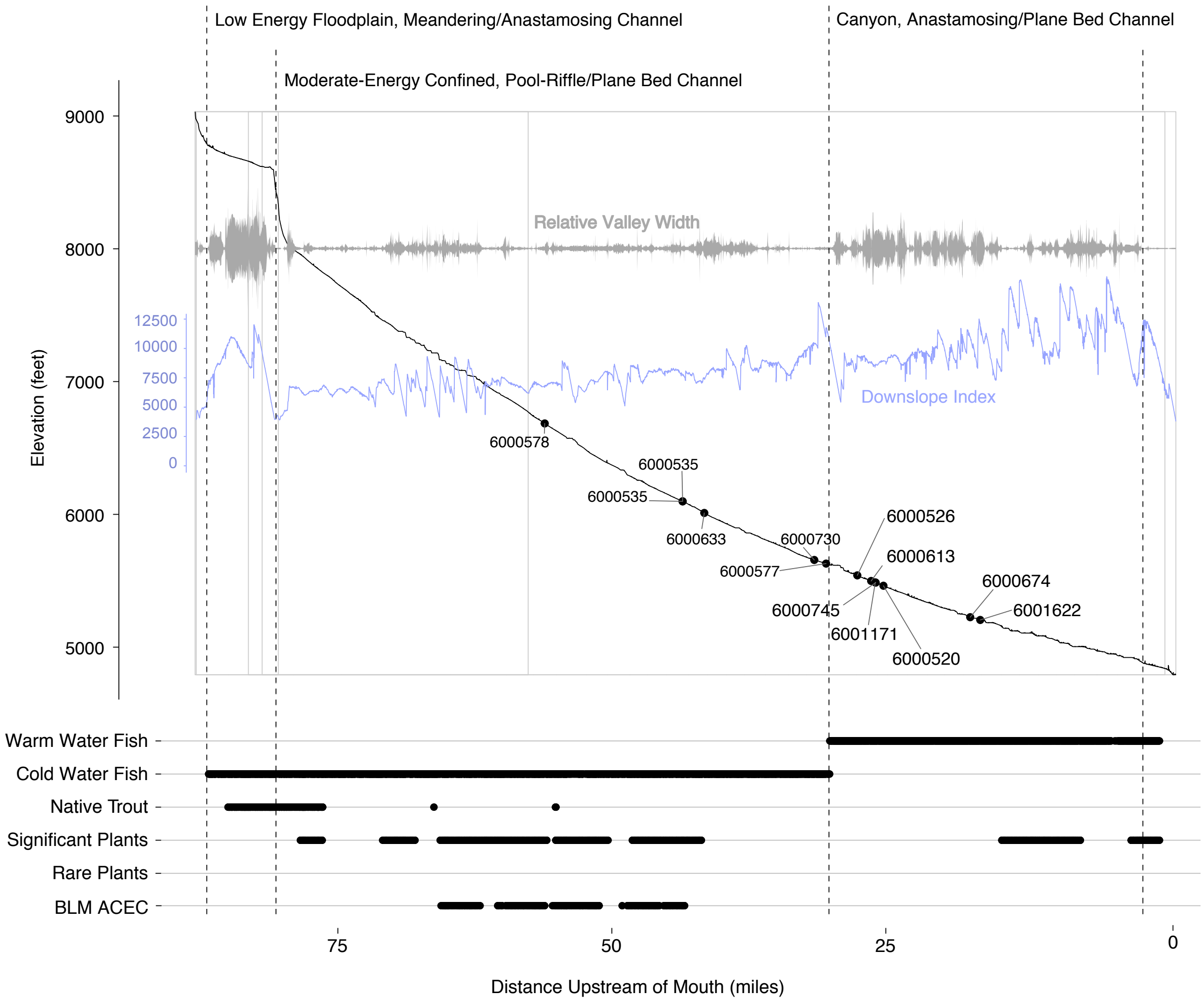



*Figure 1. Geomorphic characteristics of the San Miguel River corridor between Telluride and the confluence with the Dolores River are an important physical control for the arrangement and distribution of aquatic and riparian communities. The relative position of hydrological simulation model nodes are indicated as black dots with corresponding IDs along on the elevation profile.*

## 2.1 Geological Setting

Surficial rock and soils vary widely in the watershed, owing to the variety of geological processes at work. The same Tertiary volcanic rocks that are common across the San Juan Mountain Range dominate in high elevation headwaters tributaries. These rocks, formed between 66 and 2.6 million years ago, are frequently underlain by Mancos Shale. Descending from the San Juan Mountains, streams enter the Colorado Plateau physiographic province, incising narrow, deep canyons into the sandstone, siltstones and shales common in the middle watershed (Figure 2). Resistant sandstone layers prevent erosive siltstone and shale embedded within from crumbling, maintaining steep canyon walls along many valleys. In the lower basin, streams flow through sedimentary rocks of the Jurassic and Triassic Age [1], [6].

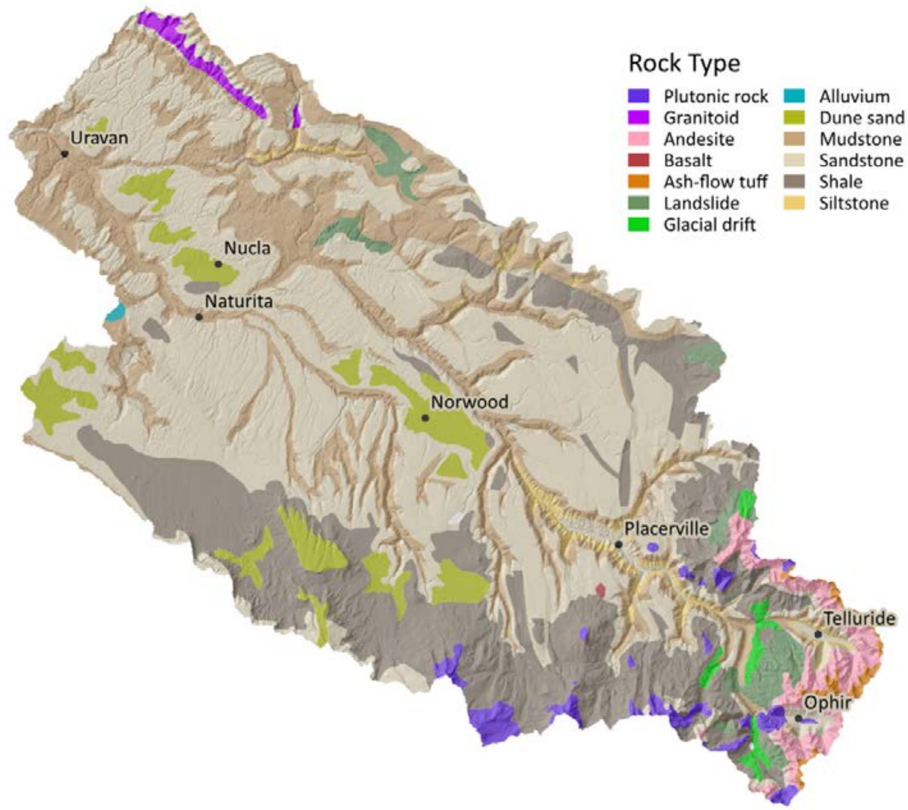



*Figure 2. Surficial geology of the San Miguel watershed.*

Side-slope processes largely control patterns in fluvial geomorphology across the watershed. Heavy glaciation during the Pleistocene (2.5 million to 11 thousand years ago) left the upper basin vulnerable to landslides, evidenced by large debris flow deposits in the steep tributary channels. Where the San Miguel River canyon is the deepest and narrowest near Placerville, frequent alluvial fans and colluvial slide deposits dictate channel location on the valley floor, as well as local channel geometry and erosion/aggradation processes (Figure 3). Alluvial fan size and frequency decreases where the canyon widens near Nucla. Planform channel dynamics are most apparent near Uravan, where the channel has actively migrated across the valley floor during the last 50 years (Figure 4) [1], [6].

Streams originating in alpine and subalpine headwaters feature confined channel types, steep profiles, narrow riparian bands and variable substrates. These streams are more resilient to changes in hydrology such as alteration of runoff timing, increasing peak flows, or decreasing baseflows. Such changes are unlikely to initiate large shifts in channel geometry and/or problematic rates of sediment transport. However, major land use shifts, such as alteration to hillslope conditions from timber harvest, fire, road development, increased impervious area, or climate-induced shifts in vegetation communities, can trigger significant sediment inputs, alter the frequency and magnitude of land or mudslides, or disrupt the supply of woody debris and organic matter to the stream. Each type of land use shift may result in local responses in channel form and riverine ecosystem structure.

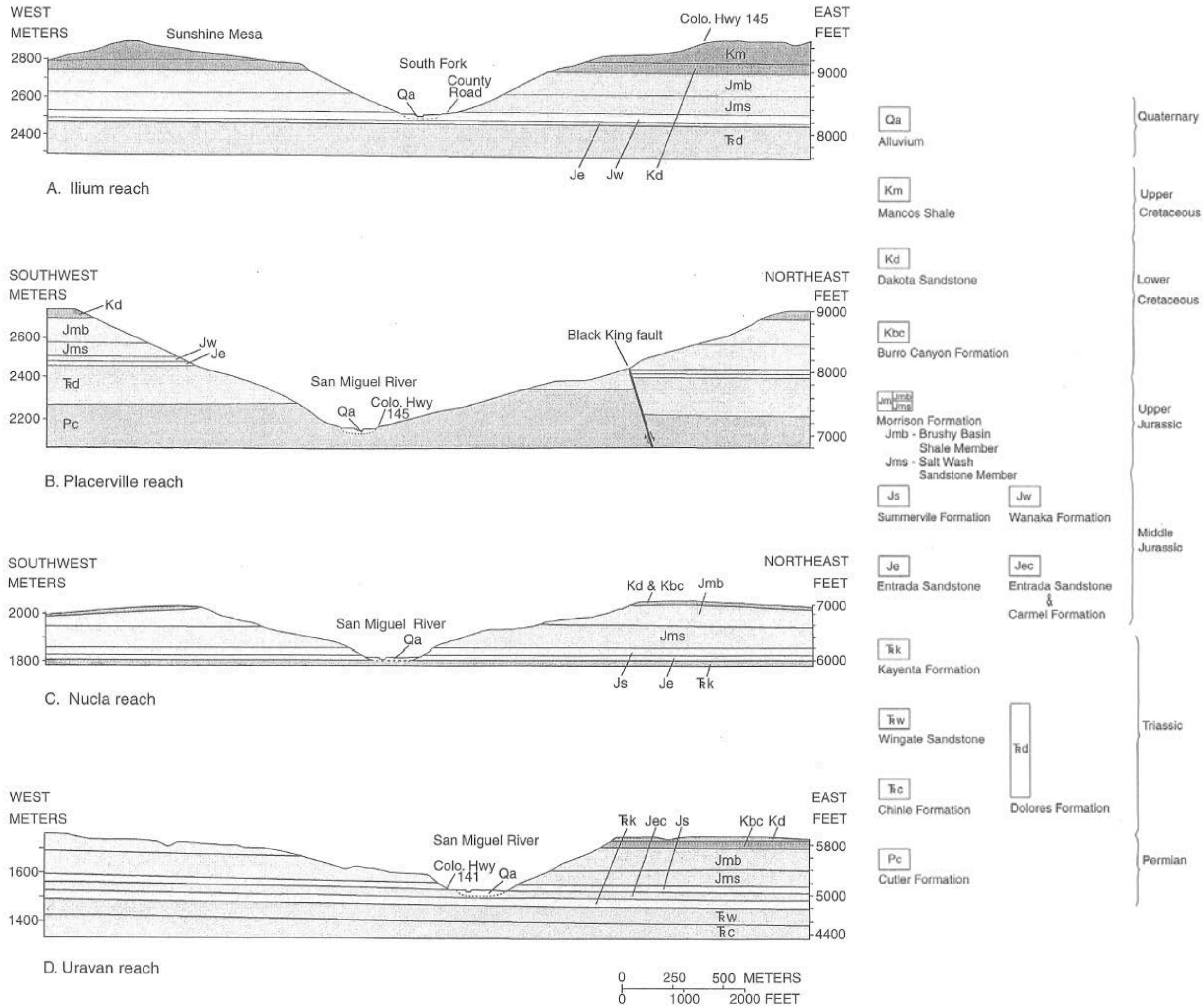



*Figure 3. Geological formations mapped by Madole and VanSistine [1] underlying the river channel on the South Fork San Miguel River in the Ilium valley (A) and on the San Miguel River near Placerville (B), near Cottonwood Creek (C), and near Uravan (D).*

Lower in the San Miguel watershed, bedrock and canyon walls still provide strong controls on channel planforms, but wider valley bottoms facilitate development of more continuous and well-developed floodplains and riparian corridors. Channel geometries migrate within the alluvial plain but are frequently constrained in lateral movement by valley margins. Riparian corridors often occupy the full extent of the floodplain up to the confining margin, which can be either the valley wall or elevated terraces and colluvial deposits or alluvial fans. Short reaches in the lower basin exhibit channel morphologies of completely unconfined valley types, with well-developed meanders fully contained in the active floodplain. Unconfined and partly-confined channel segments in this region are likely to be more sensitive to change in flow regimes than upstream reaches. Changing regimes may result in shifts to channel structure and aquatic habitat. Human-caused changes to riparian corridors may also trigger significant localized changes in channel form.

## 2.2 Channel Morphology

Geomorphological processes in the San Miguel watershed help create and alter the basin's landforms, channel forms, and aquatic ecosystems. Stream channel morphology and evolution tend to reflect the dominant boundary conditions present in a given landscape. Distinct channel patterns are observed at different positions in the San Miguel watershed (Figure 4). The San Miguel River is relatively sinuous and actively meanders throughout the valley bottom near Uravan. Channel patterns become less complex and exhibit less migration near Cottonwood Creek. Strong side-slope controls on river form and low rates of channel change are evident near Placerville.

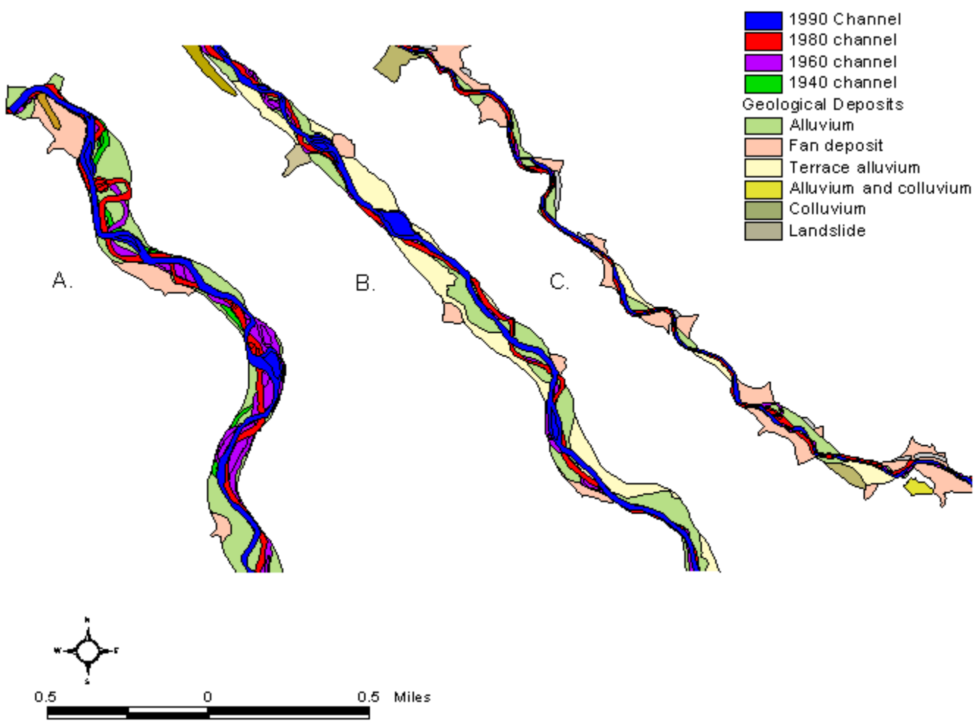



*Figure 4. Geological deposits and channel alignments mapped by Madole and VanSistine [1] for the San Miguel River near Uravan (A), near Cottonwood Creek (B), and near Placreville (C).*

Channels respond in varying degrees to regional and local conditions, including: local topography, patterns of hillslope erosion, wildlife browsing in riparian areas, precipitation regimes, and patterns of peak- and low-flow discharges. Additionally, local channel dynamics frequently reflect recent changes in land use/land cover or water management. Classifying river channel types provides a useful framework to understand dominant physical processes and ecosystem functions at different locations in the watershed. River classification simplifies communication about active physical processes and floodplain/riparian conditions, and helps with evaluation of potential management action outcomes. Understanding predictable relationships between local channel form and the physical and biological processes that govern that form allows river classification schemes to be useful in resource use decision-making.

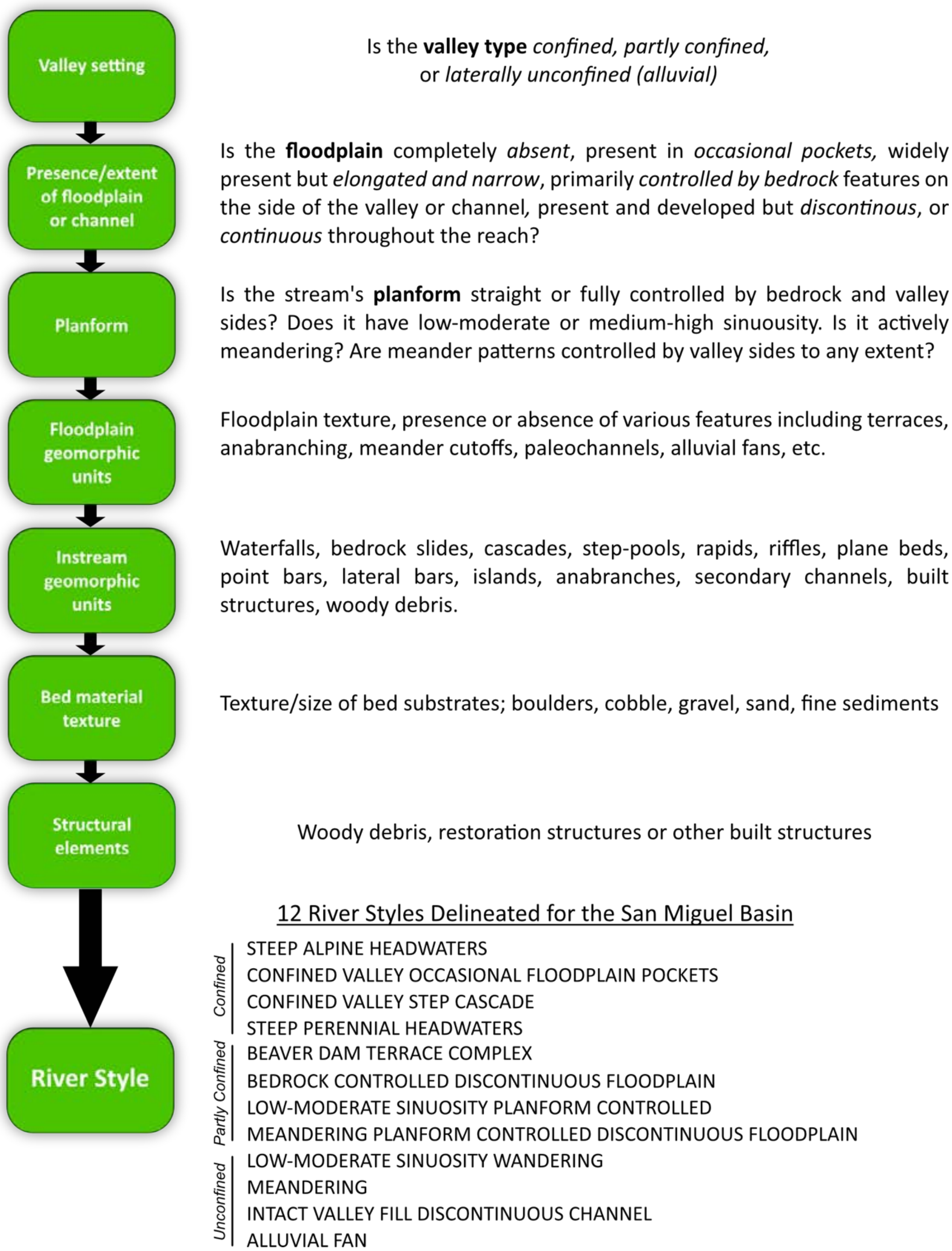



*Figure 5. River Styles classification workflow*

The River Styles framework [7] uses stream geometry, planform, and geomorphic features of the floodplain and instream segments to classify stream reaches in terms of channel character and behavior. The framework is a hierarchy classification tree, beginning broadly with valley characteristics and increasing specificity with floodplain geomorphic features, in-stream geomorphic features, and substrate (Table 1).

*Table 1. Modified River Styles classification descriptions, as applied to the San Miguel watershed.*

| Characteristics | River Style | Key features |
|---|---|---|
| Confined valley setting. High-energy streams closely coupled to hillslopes. Narrow riparian zones. Very sensitive to upland land use activities. | Steep alpine headwaters | High gradient, low-order streams exhibiting waterfalls, cascades, no floodplain, and substrate ranging from bedrock and boulders to sand and gravel. |
| | Steep perennial headwaters | High gradient, low-order streams exhibiting cascades, extensive wood debris/log jams, no floodplain, and substrate consisting of colluvium, boulders, and gravel. |
| | Confined valley step cascade | High gradient, predominantly steep cascades and occasional steep runs and waterfalls. Increasing amounts of cobble and gravel deposits with partially recognizable recurring step structure and frequency. Substrate includes bedrock, boulders and colluvium. |
| | Confined valley occasional floodplain pockets | Small and discontinuous floodplain pockets, riffles, runs and rapids with occasional larger wood-generated or step pools. Median substrate decreasing in size compared to headwaters; fewer boulders and more sands and gravels. Occasional but irregular instream bar formations. |
| Partially confined valley setting. Moderate energy streams exhibiting some floodplain development and weak connections to hillslopes. Variable riparian zone widths. Somewhat sensitive to both land and water use activities. | Beaver dam terrace complexes | Lower order streams exhibiting low and moderate gradients completely dominated by beaver communities. Impoundments create fine sediment fills and discontinuous step-terrace complexes. Difficult to identify primary channel locations. |
| | Elongate discontinuous floodplain, bedrock confined | Low to moderate sinuosity reaches in partially confined valleys; channel bed in predominately alluvial materials; various bar types, run and pool complexes, well-developed floodplain typically on one side of river; lateral channel movements occur but are largely confined by valley margins for a majority but not all of linear channel distance. Confining margins variously include bedrock, terraces, alluvial fans, and extensive colluvium stretches. |
| | Low-moderate sinuosity planform-controlled | Similar to elongate discontinuous floodplain but with slightly increased sinuosity and tendency to exhibit active meandering activity in planform. Channel still abuts confining valley margins frequently. Increased presence of meander-related geomorphic floodplain and channel features including paleo channels, meander cutoffs, cutbanks; multiple instream bar types. Substrate ranging from cobbles to silt. |
| | Meandering planform-controlled discontinuous floodplain | Active channel abuts confining margins for a minority of linear valley distance but is not fully unconfined. Floodplain and instream geomorphic features characteristic of meandering and lateral migration including multiple bar forms, especially point bars, cutoffs and cutbanks. Substrate ranging from cobble to silt. |

| Characteristics | River Style | Key features |
|---|---|---|
| Laterally unconfined valley setting. Low-energy alluvial streams exhibiting well-developed floodplains. Very weak connections to hillslopes and strong interactions with overbank areas. Well-developed riparian zones. Sensitive to land use changes in floodplains and water use activities. | Low-moderate sinuosity wandering | Unconfined, planform-controlled channel with low-moderate sinuosity, poorly developed meandering and associated geomorphic forms. |
| | Meandering | Unconfined, planform-controlled channel with moderate to high sinuosity, well-developed meandering and associated channel and floodplain geomorphic forms. Range of bar types, floodplain features and textures, substrate sizes tending towards gravels and sand; substrate variability depends on habitat-scale geomorphic features such as location in bend, pool, or riffle |
| | Intact valley-fill discontinuous channel | Low-order stream form in very low-gradient headwaters reaches, typically related to landscape-scale structural elements that promote high-elevation valley fills; may alternate with steep headwaters styles. Slow water runs and overflow channels, potential for multiple small flow paths; fine textured sediments. |
| | Alluvial fan | Unconfined, distributary channel form with potential for multiple channels, lateral migration, and frequent location shift. Typically occurs only for short distances at the mouths of steep, lower-order tributaries to the mainstem San Miguel. Where developed by humans, channel location may be artificially confined and no longer shift laterally (i.e., tributaries entering the Telluride valley floor or San Miguel mainstem in the lower watershed). |

Application of a modified River Styles framework to the San Miguel watershed yields insight into the likely physical responses of different stream reaches to existing management practices or anticipated flow regime or land use changes. For example, steep confined streams may undergo little geomorphologic change as a result of flow regime modification, while meandering unconfined streams can experience rapid shifts in channel form and ecosystem function following human-induced changes to flow or riparian integrity. Characterization of geomorphological behavior is also useful when predicting channel response to human infrastructure like bridges, culverts, and surface water diversion structures. Due to project constraints and paucity of existing data on tributaries, San Miguel watershed streams were classified down to a level of floodplain and instream geomorphic features whenever possible. Substrate data were not used to support further style-type delineation (Table 1, Figure 6).

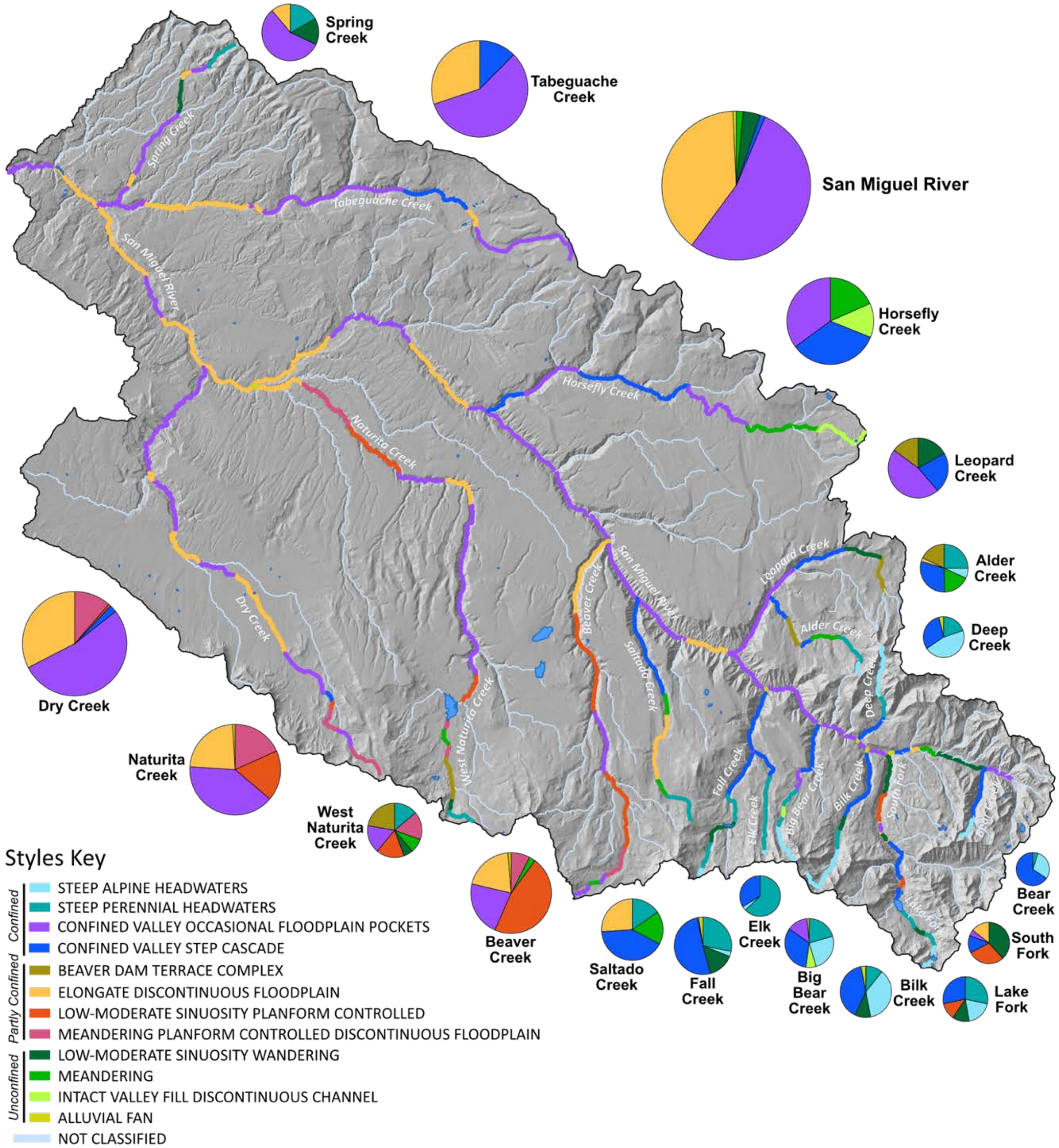



*Figure 6. River Styles mapped for streams segments in the San Miguel watershed.*

## 2.3 Sediment Transport Capacity

Alteration of sediment supply, channel forming flows, or streambank vegetation may lead to complex interactive effects that result in reduced resiliency of local channel forms, changes in sediment transport capacity, or altered connectivity between the stream and the floodplain. For example, in unconfined alluvial streams, degradation of riparian forests frequently results in diminished bank cohesion, an increased rate of channel avulsion, and a progressive widening and filling of the stream channel itself. These highly-dynamic channel states generally provide poor aquatic habitat and present a risk to streamside property and infrastructure. Review of existing conditions and consideration of the dominant processes governing channel dynamics in various biophysical settings led stakeholders to identify alluvial segments of the mainstem San Miguel River as the most critical for assessments of channel structure and sediment transport.

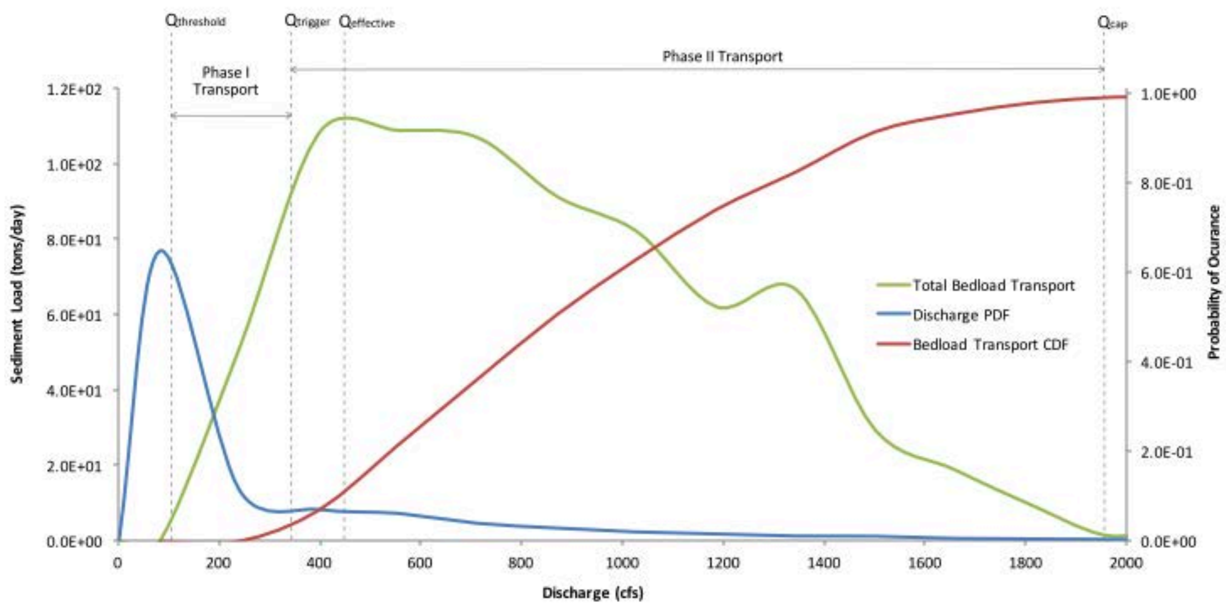



*Figure 7. Flow recommendations for a particular reach correspond to the range of flows that occur between the trigger discharge ($Q_{trigger}$) and the effective discharge ($Q_{effective}$), as these flows may be more directly impacted by human management activities in the San Miguel watershed than extremely large flood events.*

Local channel hydraulics and sediment size distributions control two dominant phases of sediment transport on the alluvial reaches of the San Miguel River [8]. These phases are responsible for mobilizing small and large particle size fractions along the streambed (Figure 7). Phase I transport typically includes sand and fine gravel. This phase of transport is often supply limited in gravel-bedded mountain streams. Phase II transport mobilizes gravel and larger substrate sizes. This phase of transport is typically transport limited. Channel maintenance work is expected to occur between the discharge where the majority of sediment transport work begins ($Q_{trigger}$) and the peak flow observed in the system ($Q_{cap}$). Optimal rates of sediment transport occur near the effective discharge ($Q_{effective}$): an intermediate flow rate with a higher probability of occurrence than $Q_{cap}$.

*Table 2. Calculations of Phase I ($Q_{threshold}$) and Phase II ($Q_{effective}$) sediment transport thresholds on the San Miguel River (SMR), lower Naturita Creek, and lower Tabeguache Creek.*

| **Location** | **$Q_{THRESHOLD}$** | **$Q_{EFFECTIVE}$** | **Reach Type** |
|---|---|---|---|
| South Fork of SMR at Illium Valley | - | 636* | Unconfined |
| Lower South Fork of SMR | 712 | 851 | Unconfined |
| SMR below Bear Creek | 457 | 542 | Unconfined |
| SMR above Mill Creek | 91 | 263 | Unconfined |
| SMR above South Fork SMR | 57 | 160 | Unconfined |
| SMR above Leopard Creek | 778 | 1325 | Confined |
| SMR at Placerville | - | 1660* | Confined |
| SMR below Leopard Creek | 1858 | 2536 | Partly-Confined |
| SMR at Cottonwood Campground | 1482 | 2311 | Partly-Confined |
| SMR at Rockhouse Campground | 2228 | 2323 | Partly-Confined |
| SMR near Nucla | - | 2472* | Partly-Confined |
| SMR at Nucla Power Plant | 2323 | 2323 | Partly-Confined |
| SMR above Tabeguache | 3129 | 4489 | Partly-Confined |
| SMR at Uravan | - | 4097* | Partly-Confined |
| Lower Naturita Creek | 147 | 201 | Partly-Confined |
| Lower Tabeguache Creek | 184 | 207 | Partly-Confined |

*Estimates provided by USGS [6]

Hydrological time series data and one-dimensional sediment transport models constructed using cross-sectional channel geometry and particle size distributions evaluated the magnitude and recurrence interval of flow events important for sediment transport on the South Fork of the San Miguel River and at various locations along the mainstem San Miguel River below Telluride. Conclusions provided by previous investigations into sediment transport [6], [4] were verified and augmented through collection of new data in 2016. Bed sediment particle size distributions were assessed using the Wolman Pebble Count method [9]. Hydraulic models were created through use of cross-sectional channel geometry information collected previously by CWCB, CPW, or BLM or through collection of new channel geometry data where necessary. Hydrological time series from a water rights and streamflow simulation model were used to drive the hydraulic models and the Meyer-Peter Muller method [10] was used to calculate thresholds and rates of sediment transport (Table 2). Effective discharge was computed using six arithmetic bins (5, 10, 15, 25, and 30) at most locations. Logarithmic class divisions were used when the computed effective discharge occurred within the first arithmetic bin.

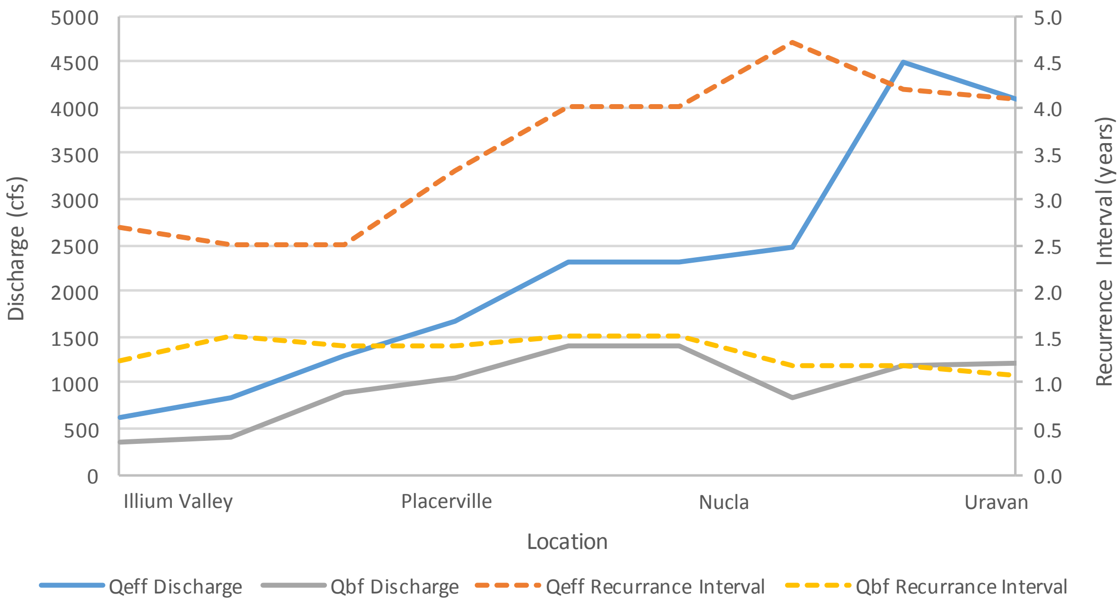



*Figure 8. Longitudinal patterns in effective discharges along the mainstem San Miguel River. The magnitude of flows required for channel maintenance increases in the downstream direction, corresponding to increasing watershed size, changing channel dimensions, and changing patterns in sediment input.*

*Table 3. Recurrence intervals for simulated streamflows at various locations along the San Miguel River and selected tributaries. The upper and lower bound of the 2- and 4-year peak flows correspond to the 90% confidence intervals computed for a Log-Pearson III distribution of simulated annual peak flows at each location.*

| Reach | Lower Bound 2-Year Peak Flow (cfs) | Upper Bound 4-Year Peak Flow (cfs) |
|---|---|---|
| Lower South Fork San Miguel River | 575 | 712 |
| San Miguel River below Bear Creek | 488 | 577 |
| San Miguel River near Placerville | 1173 | 1483 |
| San Miguel River below Leopard Creek | 1490 | 1807 |
| San Miguel River below Cottonwood Creek | 2236 | 2689 |
| San Miguel River near Uravan | 3358 | 4598 |
| Lower Naturita Creek | 166 | 238 |
| Lower Tabeguache Creek | 226 | 391 |

Observed and simulated flood recurrence intervals for the San Miguel River, Naturita Creek and Tabeguache Creek appear sufficient to mobilize both fine sediment ($Qt_{hreshold}$) and coarse sediment ($Q_{effective}$) at recurrence intervals necessary to maintain aquatic habitat and drive dynamic channel forms in pocket- and elongate-floodplain channel segments (Table 3). Flood flows on the lower South Fork San Miguel River corresponding to the 2- and 4-year recurrence intervals are slightly lower than the calculated $Q_{threshold}$ and $Q_{effective.}$ This may reflect a reduction in sediment transport capacity due to peak flow modification by upstream reservoirs. Conversely, this channel exhibits characteristics of advancing aggradation, which may be driven by the local valley slope and delivery of high fluvial and colluvial sediment loads from steep mountain drainages.

## 2.4 Ice Floes

Some concern existed historically in the watershed for the impact of ice floes on rates of erosion and cannel form on the mainstem San Miguel River. Floes typically begin in the South Fork San Miguel River, 2.5 miles from confluence with mainstem. Floes can transit all the way to the Dolores River. Ice jamming and flooding in the lower watershed usually occur in the spring. Ice growth usually occurs immediately following hydropower surges, and ice floe surges are triggered by sustained cold temperatures. Previous investigations were unsuccessful in associating ice floes with rates of increased channel erosion or instabilities [11]. Observations indicate that the size of a given ice flow is roughly proportional to number of preceding degree days below freezing.

Previous investigations were unsuccessful in associating ice floes with rates of increased channel erosion or instabilities[1]; however, local residents remain concerned about the potential impact of scour produced by ice movement to impair the fishery, macroinvertebrate communities and near-shore vegetation. Recent data collection efforts by CPW indicate potential impacts of ice floes on overwintering fish on the mainstem San Miguel River. A study conducted by BLM suggests that certain flow management activities at Trout Lake and the Ames Power Plant may promote ice floe formation on the South Fork San Miguel[2]. However, impacts on ice formation in the middle San Miguel watershed are more difficult to assess[3]. Ice floes have been documented to occur on the San Miguel River since at least 1909 (Figure 9).

---

[1] D. P. Groeneveld, "An Overview of Recent Bank Instability on San Miguel River.," Hydro-Biological Consulting, San Miguel County, 2000.

[2] Ice Accumulation Downstream of the Ames Powerhouse; Quality of the Sport Fishery Potentially Affected by the Project; Quality and Health of the Native Fish Communities, Ames Water/Terrestrial RWG Issue Nos. 1-2-4 Initial Study Plan Draft 09/08/2005

[3] Beltaos, S. (2008). Progress in the study and management of river ice jams. Cold regions science and technology, 51(1), 2-19.

In September of that year, a large flood breached the Trout Lake dam and it wasn't rebuilt until the summer of 1910[4]. Thus, the ice floe event documented in the winter of 1909 was likely a natural event. A lack of ice floe records before this period and the fact that reservoir construction and hydropower plant operation in the upper watershed began in the late 1800s significantly complicates the task of understanding the degree to which ice floes are exacerbated (or not) by water management activities in the upper watershed. An evaluation of reservoir/hydropower facility operation on frazil ice formation in the South Fork San Miguel River in the FERC permit renewal for the AMES Power Plant recommended reservoir release ramping rates, minimum bypass flows, and installation of water column mixers to cool hypolimnetic water in Trout Lake—all strategies intended to promote stable ice cover on the South Fork San Miguel River and, thereby, limit downstream ice accumulation.[5]

*Figure 9. An ice floe on the San Miguel River near Placerville in 1909. Photo courtesy of the Denver Public Library.*

[4] https://en.wikipedia.org/wiki/Trout_Lake_(Colorado)

[5] State of The San Miguel Annual Report, 2008, San Miguel Watershed Coalition.

## 2.5 Existing Condition Ranking

Consideration of the concepts of connectivity, capacity, and complexity are useful for process-level understanding of patterns and distribution of different morphological river states across the San Miguel watershed. Interplay between these critical components of the physical system govern a stream or river's resilience to perturbation. There are no ideal targets for the degree to which a stream reach is connected to adjacent hillslopes or floodplains, for its capacity to move water, sediment, and woody debris, or for the complexity of longitudinal and planform channel structures. Rather, the manifestation of connectivity, capacity, and complexity play out on stream reaches differently depending on landscape position, climate, hydrology, etc. Where these considerations are useful is in understanding existing conditions and natural or management-induced changes to one of the three concepts that may trigger rapid or dramatic changes in system and different—and, potentially, undesirable—fluvial geomorphic state.

Qualitative ranking of connectivity, capacity, and complexity on streams reaches throughout the San Miguel River—given their existing state of dynamic equilibrium—highlights areas that may require special land or water management consideration (Figure 7). Lower scores indicate reaches in a degraded state or at higher risk for change in channel form and behavior following some alteration of sediment supply or hydrological regime behavior. Assignment of conditional assessment rankings relied on published literature, data collected by this effort, and expert evaluation of the processes affecting the existing condition of a stream reach and consideration of potential evolutionary pathways that various channel morphologies may progress along.

The most pronounced impacts to channel morphology and dynamics exist in and around Telluride where historical straightening and diking of the San Miguel River alters sediment and water transport capacity and continues to limit connectivity to the floodplain. Examination of sediment transport analysis results for the San Miguel River near Telluride indicates that historical modification of stream structure through town increases conveyance of sediment. The calculated effective discharge at Mill Creek (263 cfs) is lower above than at an upstream location below Bear Creek (542 cfs). The section of straightened channel between these locations appears to be transporting sediment at a much faster rate than it receives loads from upstream. This likely results in some down-cutting, streambed and bank armoring, and reduced likelihood for lateral channel movement through the straightened reach. These changes produce a channel that is out of alignment with its biophysical setting and likely limit habitat quality and riparian function on the San Miguel River near Telluride. Ongoing restoration efforts in the Telluride area appear well-suited to addressing this issue.

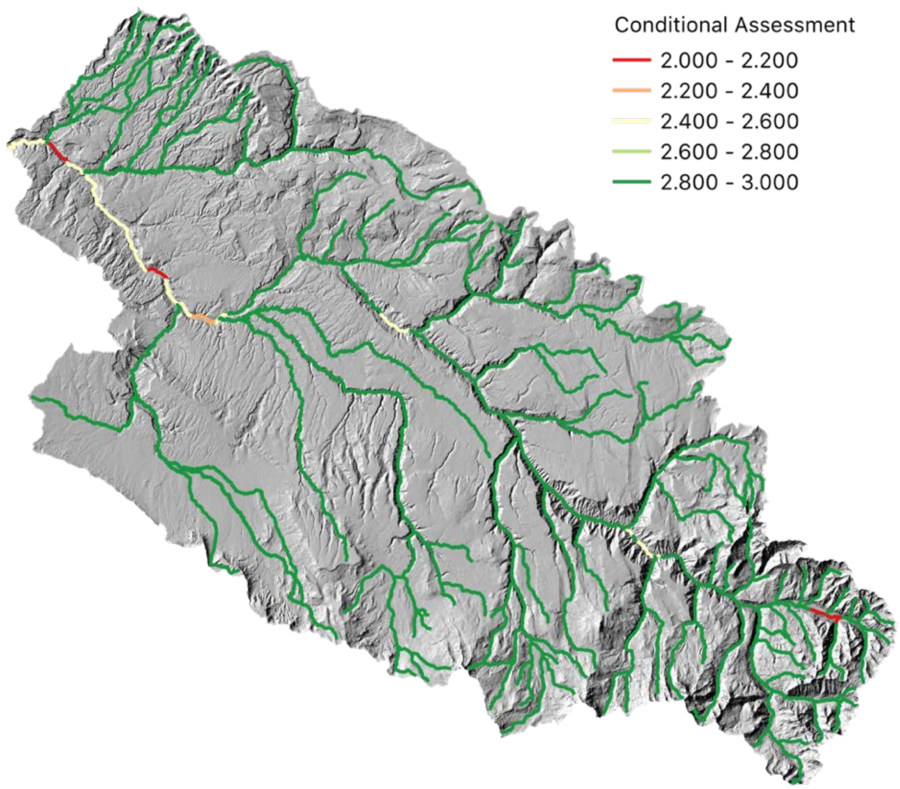



*Figure 10. Geomorphic condition assessment ranking results from across the San Miguel watershed.*

A coarse-scale examination of stream and river conditions across the San Miguel watershed indicates the greatest sensitivities to changes in hydrology and sediment transport dynamics along the alluvial reaches of the South Fork of the San Miguel River and along the mainstem of the San Miguel River between Naturita and the Dolores River. Along these reaches, the relationship between peak flow magnitude and frequency and the particle size distribution of sediment in the streambed exerts significant control on channel geometry and rates of change. Most other streams in the watershed exhibit steep gradients and strong process-based connections with adjacent hillslopes. These reaches are likely much more sensitive to land use development and natural disturbances in upland areas (e.g. forest fire) that alter the frequency and magnitude of woody debris inputs, hillslope sediment yields and/or landslide activity.

## 3 Potential for Future Change

In most parts of the San Miguel watershed, channel morphologies and behaviors appear to reflect the characteristics expected in the local biophysical setting. Low-order stream channels are well connected to adjacent hillslopes and vulnerable to alterations in hillslope vegetated cover type and density. Stream channel dynamics in these areas remain sensitive to urban development, wildfires, beetle-kill and other events affecting forest succession. Examination of channel forms and sediment transport dynamics on the mainstem San Miguel River indicates an increasing sensitivity to changes in peak flow magnitude and frequency moving from Placerville to the Dolores River. While this sensitivity is not accompanied by symptoms of functional degradation, it does suggest that future activities that modify peak flows in the lower watershed (e.g. reservoir construction) may produce long-term change in channel structure and behavior.

Sediment transport investigation results and previous studies conducted by USGS and others [6] indicate a pattern of increasing divergence between the recurrence intervals associated with bankfull and effective discharges moving from upstream near the confluence with the South Fork San Miguel River ($Q_{eff}$ ~ 2 year recurrence interval) to downstream near Uravan ($Q_{eff}$ ~ 4 year recurrence interval) (Figure 8). This pattern seems to suggest that sediment moving from the upper watershed is accumulating in the lower watershed. However, associated evidence of advancing aggradation or lateral channel movement is somewhat lacking in this area. Another possibility is that colluvial inputs to the river in the lower watershed or sediment loads carried by ephemeral tributaries during large monsoonal events consist of somewhat larger particle-size fractions than the normal load carried downstream from the upper watershed. If this is the case, then it may be possible that the recurrence interval of colluvial or flood events that contribute these larger particle sizes to the river are lower than the recurrence interval of the flows required to mobilize them on the mainstem San Miguel. This would result in relatively short and infrequent periods of sediment deposition and accumulation in the lower river, followed by large transport events that would move the accumulated sediment out of the system. This may help explain why evidence of sediment aggradation is somewhat lacking. Regardless of the explanation, the increasing dissimilarity between bankfull discharge and the dominant sediment transporting flows as one moves from the upper watershed to the lower watershed indicates a reduced capacity for sediment transport and a greater sensitivity to changes in peak flow magnitude and frequencies in the downstream direction.

The characteristics of hydrology most directly related to the structure and behavior of the stream channel are those that relate to the scour, movement, and deposition of sediment along the river corridor. The scenario modeling conducted as part of this planning process yielded predictions for flood recurrence intervals at locations across the watershed under a variety of planning scenarios (see Appendix C for more information). Scenarios A and B do not diverge significantly from baseline (i.e. current conditions). Scenarios C, D, and E indicate varying degrees of departure form current conditions at locations on the mainstem San Miguel River (Figure 11) and the mouths of tributaries to the San Miguel. The flows responsible for mobilizing and transporting the greatest amount sediment on the San Miguel mainstem historically occurred at a 2.5 to 4-year frequency.

A review of the flood recurrence interval curves associated with hydrological scenario modeling indicates that floods of those magnitudes occur less frequently under climate change. The impact is particularly pronounced at Telluride and Placerville. As sediment transporting flows become less frequent, the channel may become more sensitive to episodic or transient inputs of sediment (e.g. sediment loading produced by wildfire). A reduction in the frequency of floods capable of mobilizaing a large fraction of bed sediment may lead to channel bed aggradation, reduction in aquatic habitat quality, and rapid or incremental shifts in channel alignment along the valley floor.

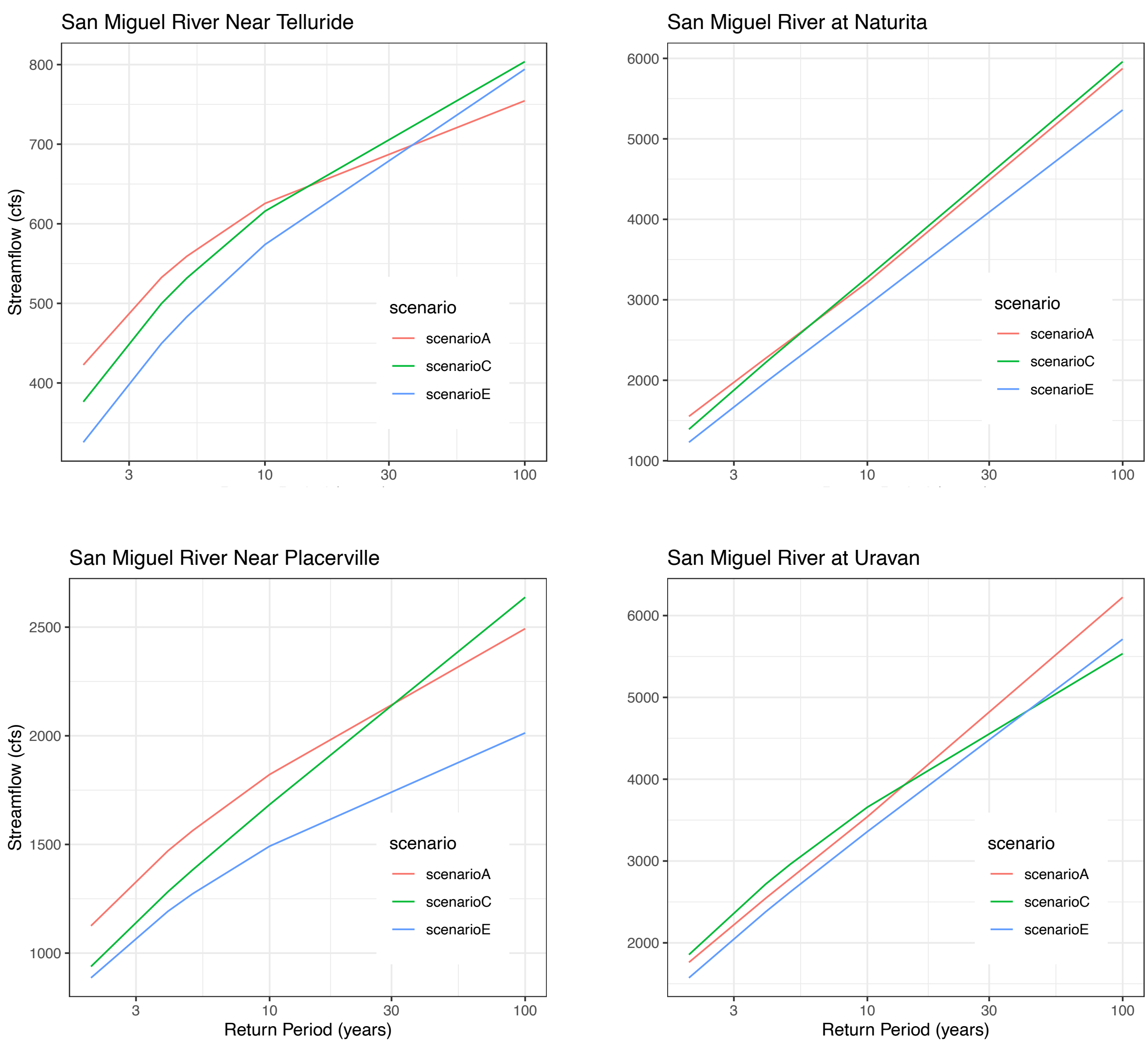



*Figure 11. Flood magnitude return intervals predicted under Scenarios A, B, and C at locations in the upper, middle, and lower watershed.*

Climate futures that change the composition and extent of riparian communities may alter the way that riparian vegetation interacts with channel hydraulics to mediate channel form and movement. The potential impact of a changing climate and hydrological regime on riparian communities is discussed in Appendix E.

As a drying climate increases the risk for high-intensity wildfire in the lower watershed, the risk for increased erosion and transport of hillslope soils to the river channel also increases. Drainages that experience high-intensity fires generally produce large yields of sediment in the years following the fire. This may be particularly relevant in areas like the lower San Miguel watershed where the risk of high-severity fire is high (Figure 12) and high-intensity monsoonal rainstorms are a common occurrence. Sediment mobilized by precipitation events can quickly move downslope to streams and rivers where it can cause rapid aggradation of the stream channel, changes in the alignment of the river, and significant damage to transportation infrastructure, water diversion infrastructure, homes, and businesses. Further discussion of fire risk is provided in Attachment 1.

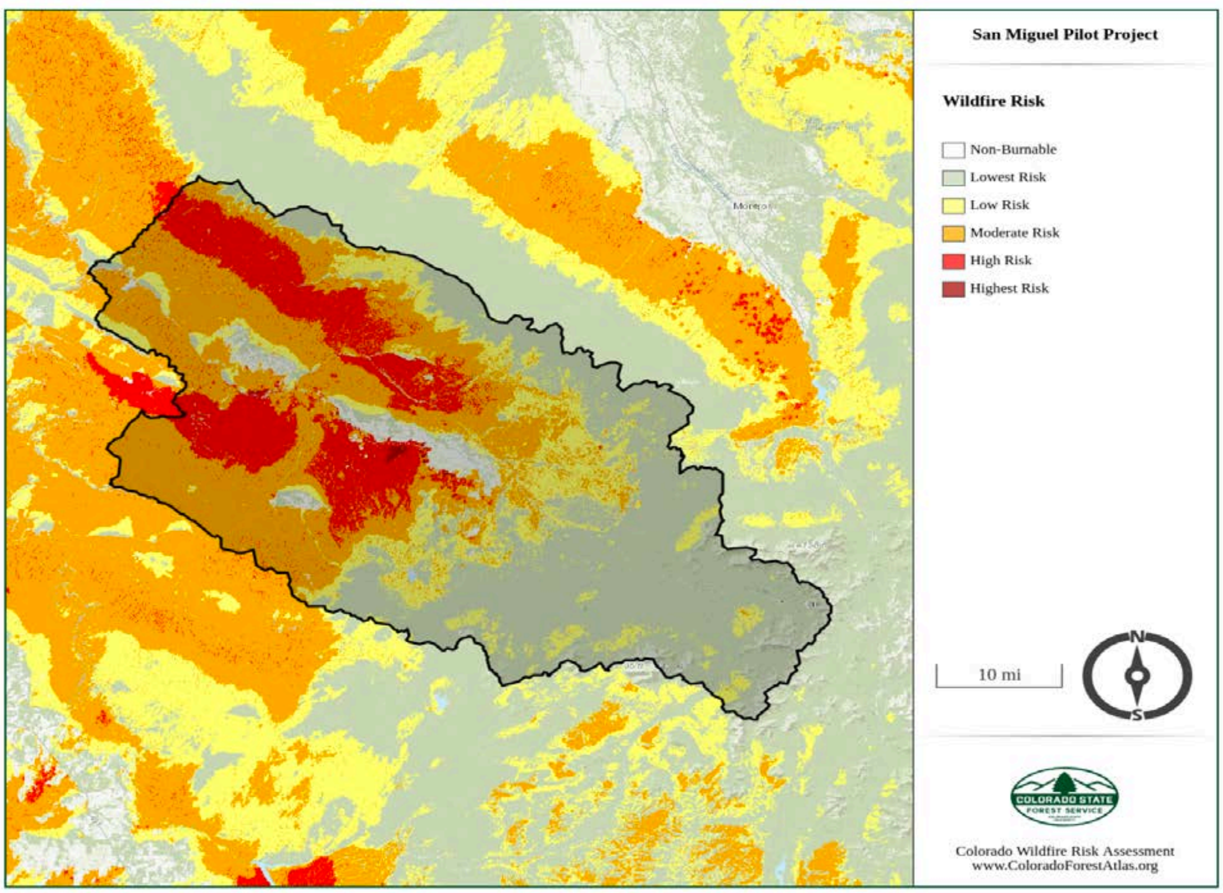



*Figure 12. Wildfire risk in the San Miguel watershed.*

Potential exists in the San Miguel watershed for changes in channel dynamics either by way of increased sediment inputs or decreased flood magnitudes. The greatest sensitivity to the former exists in the middle and lower watershed, while the greatest sensitivity to the latter exists in the middle and upper watershed. Any rapid shift in the form and behavior of stream channels may negatively impact aquatic communities, riparian areas, and human infrastructure.

# 4 Conclusions

Modification of the hydrological regime, altered patterns of erosion, adjustments to the structure of the channel bed, or changes in riparian community composition and extent may yield fundamental shifts in the geometry and behavior of the stream channel. Changes in sediment supply, peak flow magnitude and duration, or the extent of streambank vegetation may lead to changes in local channel forms, reductions in aquatic habitat quality, altered connectivity between the stream and the floodplain, and the stability and reliability of local infrastructure (e.g. surface water diversion structures, bridges, roadways). Primary findings produced by this assessment include:

- Structural modification of the channel on the San Miguel River near Telluride increases sediment transport capacity and limits floodplain development and maintenance in what would otherwise be a depositional zone hosting a well-connected alluvial channel. Ongoing restoration work in this area should address this condition.
- Peak flows required to perform channel maintenance activities on the mainstem San Miguel River (e.g. between 3300-4600 cfs at Uravan) historically occurred at least once every 2-4 years.
- Shifts in either the peak flow characteristics of the San Miguel River or in the delivery of sediment to the river channel from hillslopes and tributary streams can lead to shifts in channel form and behavior and corresponding impacts on aquatic/riparian habitat and water delivery and transportation infrastructure located in the river corridor.
- Scenario modeling indicates that under a "Business as Usual" future, flows require to perform channel maintenance activities will continue to occur at least once every 2-4 years. Scenarios that consider the potential impacts of change scenarios (i.e. scenarios C, D and E) indicate a decline in magnitude of floods with 2-4 year recurrence intervals. If these flood magnitudes are decreased and sediment inputs to the system remain unchanged, altered channel form and behavior on some sections of the San Miguel River is likely. The largest change in mainstem peak flow behavior under climate change is expected on reaches above Naturita. Pocket floodplains in Norwood Canyon and alluvial valley bottoms near Telluride and at the confluence with the South Fork San Miguel may be the first places changes to channel form and behavior will manifest following diminished peak flow magnitudes.
- San Miguel mainstem segments below Cottonwood Creek appear more vulnerable to changes in sediment delivery produced by wildfire. This portion of the watershed is at higher risk for wildfire than the rest of the watershed and the historical record indicates that monsoonal rainfall is capable of producing major runoff responses in lower-watershed tributaries and, subsequently, in the lower reaches of the mainstem San Miguel River. High-intensity rainfall events on burn areas are known to mobilize massive amounts of sediment in similar geographic settings.

Increased sediment delivery to the river channel may lead to rapid channel migration across valley bottoms, degradation of aquatic habitat, and impacts to water diversion infrastructure.

- The risk for synergistic impacts of decreased peak flow magnitudes due to climate change and increased sediment delivery following wildfire appear greatest in reaches of the San Miguel River between Placerville and Naturita. This section of the river corridor is home to unique riparian forests, both warm-water and cold-water fish, and is regularly used by anglers and whitewater boaters. Numerous important irrigation water diversions also exist along this section. Thus, changes in channel form and behavior in this reach of river may impact both consumptive and non-consumptive water uses.

# 5 References


[1] R. F. Madole and D. P. VanSistine, "Geology and Recent History of the San Miguel River Valley, Southwestern Colorado," Bureau of Land Management, Montrose District Office, 2000.

[2] J. M. Friedman *et al.*, "Transverse and Longitudinal Variation in Woody Riparian Vegetation along a Montane River," *West. North Am. Nat.*, vol. 66, no. 1, pp. 78–91, Jan. 2006.

[3] Auble, Gregor T., J. M. Friedman, and M. L. Scott, "Relating Riparian Vegetation to Present and Future Streamflows," *Ecol. Appl.*, vol. 4, no. 3, pp. 544–554, 1994.

[4] G. B. Fleener, "Hydrologic and Geomorphic Aspects of Riparian Forest Ecology on the Lower San Miguel River, Colorado," University of Colorado, 1997.

[5] Bureau of Reclamation, "San Miguel River Instream Flow Assessment." 1996.

[6] Allred, Tyler M. and E. D. Andrews, "Hydrology, Geomorphology, and Sediment Transport of the San Miguel River, Southwest Colorado." U.S. Geological Survey.

[7] G. J. Brierley and K. Fryirs, "River styles, a geomorphic approach to catchment characterization: Implications for river rehabilitation in Bega catchment, New South Wales, Australia.," *Environ. Manage.*, vol. 25, no. 6, pp. 661–679, 2000.

[8] L. J. Schmidt and J. P. Potyondy, "Quantifying Channel Maintenance Instream Flows: An Approach for Gravel-Bed Streams in the Western United States," U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ft. Collins, CO, 2004.

[9] Wolman, M. G., "A method of sampling coarse river-bed material.," *EOS Trans. Am. Geophys. Union*, vol. 35, no. 6, pp. 951–956, 1954.

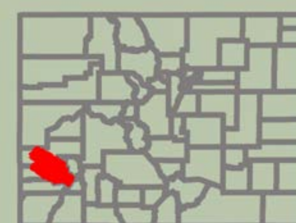
[10] P. Meyer and R. Meuler, "Formulas for bed-load transport.," in *Proc., 2nd Meeting of International Association for Hydraulic Research*, Stockholm, 1948, p. 26.

[11] D. P. Groeneveld, "An Overview of Recent Bank Instability on San Miguel River.," Hydro-Biological Consulting, San Miguel County, 2000.

**Attachment 1**

*San Miguel Pilot Project*

# 2017 Colorado Wildfire Risk Assessment Summary Report



COLORADO STATE FOREST SERVICE
COLORADO STATE UNIVERSITY

**Report was generated using**

**www.ColoradoForestAtlas.org**

**Report version: 1.1.0**

**Report generated: 2021-01-13**

# Table of Contents

# Disclaimer

Colorado State Forest Service makes no warranties or guarantees, either expressed or implied as to the completeness, accuracy, or correctness of the data portrayed in this product nor accepts any liability, arising from any incorrect, incomplete or misleading information contained therein. All information, data and databases are provided "As Is" with no warranty, expressed or implied, including but not limited to, fitness for a particular purpose.

User should also note that property boundaries included in any product do not represent an on-the-ground survey suitable for legal, engineering, or surveying purposes. They represent only the approximate relative locations.

# Introduction

## Colorado Wildfire Risk Assessment Report

Welcome to the Colorado Wildfire Risk Assessment Summary Reporting Tool.

This tool allows users of the Risk Reduction Planner application of the Colorado Forest Atlas web portal to define a specific project area and generate information for this area. A detailed risk summary report can be generated using a set of predefined map products developed by the Colorado Wildfire Risk Assessment project which have been summarized explicitly for the user defined project area. The report is generated in PDF format.

The report has been designed so that information from the report can be copied and pasted into other specific plans, reports, or documents depending on user needs. Examples include, but are not limited to, Community Wildfire Protection Plans, Local Fire Plans, Fuels Mitigation Plans, Hazard Mitigation Plans, Homeowner Risk Assessments, and Forest Management or Stewardship Plans. Example templates for some of these reports are available for download on the Colorado Forest Atlas web portal.

The Colorado WRA provides a consistent, comparable set of scientific results to be used as a foundation for wildfire mitigation and prevention planning in Colorado.

Results of the assessment can be used to help prioritize areas in the state where mitigation treatments, community interaction and education, or tactical analyses might be necessary to reduce risk from wildfires.

The Colorado WRA products included in this report are designed to provide the information needed to support the following key priorities:

- Identify areas that are most prone to wildfire
- Plan and prioritize hazardous fuel treatment programs
- Allow agencies to work together to better define priorities and improve emergency response, particularly across jurisdictional boundaries
- Increase communication with local residents and the public to address community priorities and needs

# Products

Each product in this report is accompanied by a general description, table, chart and/or map. A list of available Colorado WRA products in this report is provided in the following table.

| COWRA Product | Description |
|---|---|
| **Wildfire Risk** | The overall composite risk occurring from a wildfire derived by combining Burn Probability and Values at Risk Rating |
| **Burn Probability** | Annual probability of any location burning due to wildfire |
| **Fire Intensity Scale** | Quantifies the potential fire intensity by orders of magnitude |
| **Wildland Urban Interface** | Housing density depicting where humans and their structures meet or intermix with wildland fuel |
| **Wildland Urban Interface Risk** | Annual probability of any location burning due to wildfire |
| **Values at Risk Rating** | A composite rating of values and assets that would be adversely impacted by a wildfire by combining the four main risk outputs |
| **Suppression Difficulty Rating** | Reflects the difficulty or relative cost to suppress a fire given the terrain and vegetation conditions that may impact machine operability |
| **Drinking Water Risk Index** | A measure of the risk to Drinking Water Risk Index Areas (DWIA) based on the potential negative impacts from wildfire |
| **Forest Assets Risk Index** | A measure of the risk to forested areas based on the potential negative impacts from wildfire |
| **Riparian Assets Risk Index** | A measure of the risk to riparian areas based on the potential negative impacts from wildfire |
| **Characteristic Flame Length** | A measure of the expected flame length of a potential fire |

| COWRA Product | Description |
|---|---|
| **Characteristic Rate of Spread** | A measure of the expected rate of spread of a potential fire |
| **Fire Type Extreme Weather** | Represents the potential fire type under the extreme percentile weather category |
| **Surface Fuels** | A measure of the expected rate of spread of a potential fire |
| **Characteristic Rate of Spread** | Characterization of surface fuel models that contain the parameters for calculating fire behavior outputs |
| **Vegetation** | General vegetation and landcover types |
| **Forest Assets** | Identifies forested land categorized by susceptibility or response to fire |
| **Riparian Assets** | Forested riparian areas characterized by functions of water quantity and quality, and ecology |
| **Drinking Water Importance Areas** | A measure of quality and quantity of public surface drinking water categorized by watershed |

# Wildland Urban Interface

## Description

Colorado is one of the fastest growing states in the Nation, with much of this growth occurring outside urban boundaries. This increase in population across the state will impact counties and communities that are located within the Wildland Urban Interface (WUI). The WUI is described as the area where structures and other human improvements meet and intermingle with undeveloped wildland or vegetative fuels. Population growth within the WUI substantially increases the risk from wildfire.

For the **San Miguel Pilot Project** project area, it is estimated that **9,586** people or **99.9 %** percent of the total project area population (9,596) live within the WUI.

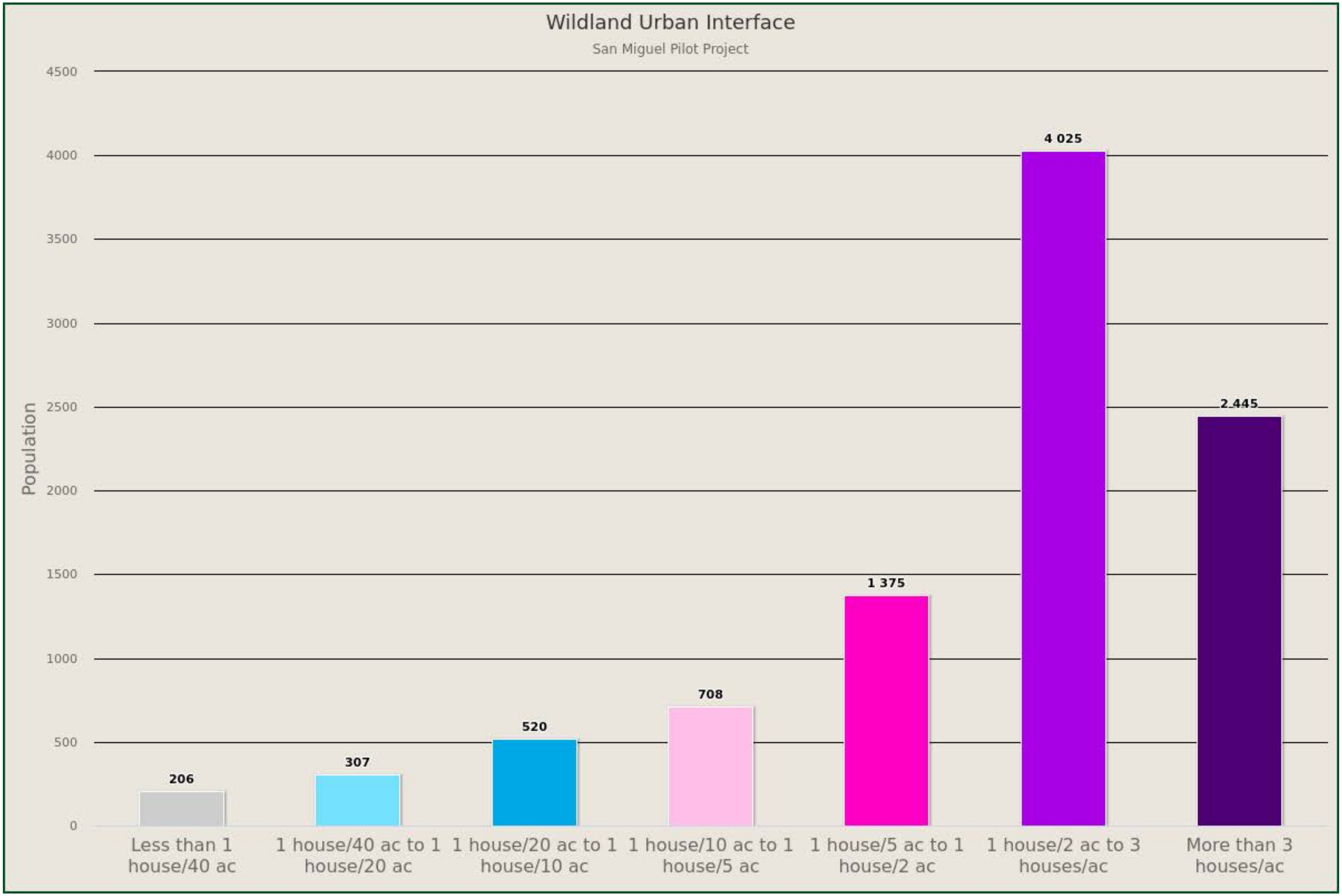
**The Wildland Urban Interface (WUI) layer reflects housing density depicting where humans and their structures meet or intermix with wildland fuels.** In the past, conventional wildland-urban interface datasets, such as USFS SILVIS, have been used to reflect these concerns. However, USFS SILVIS and other existing data sources did not provide the level of detail needed by the Colorado State Forest Service and local fire protection agencies.

The new WUI dataset is derived using advanced modeling techniques based on the Where People Live dataset and 2016 LandScan USA population count data available from the Department of Homeland Security, HSIP dataset. WUI is simply a subset of the Where People Live dataset. The primary difference is populated areas surrounded by sufficient non-burnable areas (i.e. interior urban areas) are removed from the Where People Live dataset, as these areas are not expected to be directly impacted by a wildfire. This accommodates WUI areas based on encroachment into urban areas where wildland fire is likely to spread.

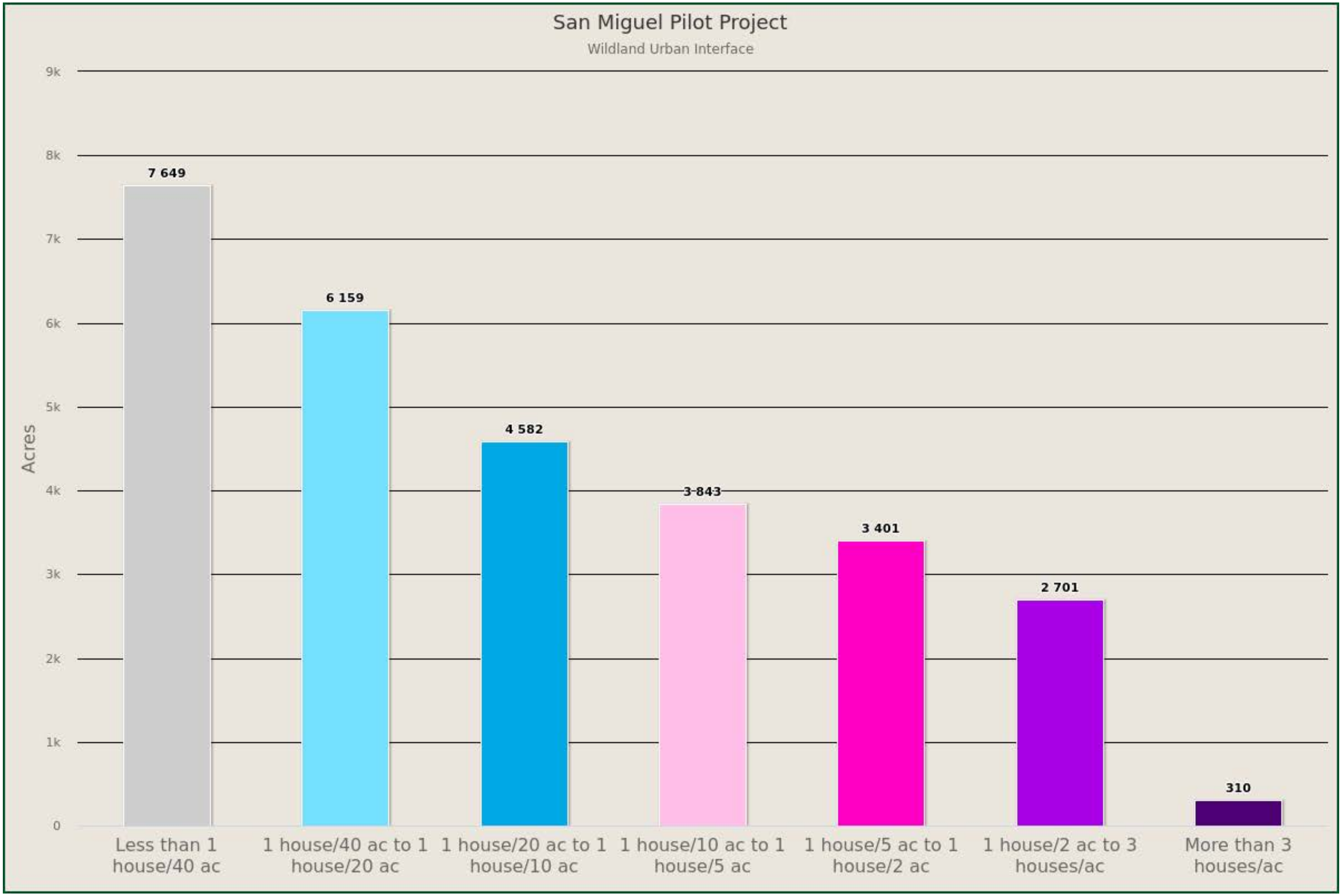
A more detailed description of the risk assessment algorithms is provided in the Colorado Wildfire Risk Assessment (Colorado WRA) Final Report, which can be downloaded from www.ColoradoForestAtlas.org.

Data are modeled at a 30-meter cell resolution (30 m2 or 900 m area per map cell), which is consistent with other Colorado WRA layers. The WUI classes are based on the number of houses per acre. Class breaks are based on densities understood and commonly used for fire protection planning.

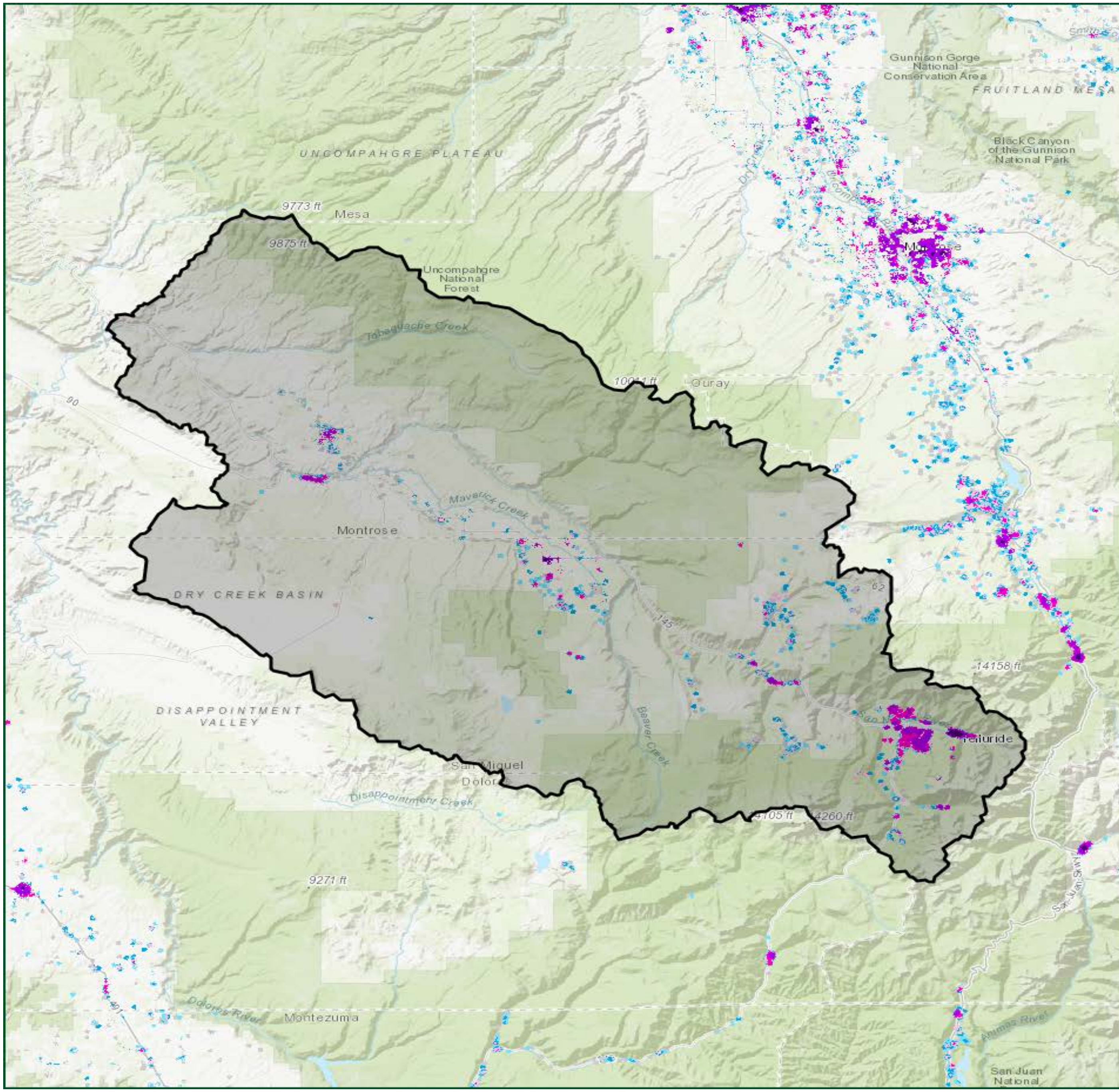
| Housing Density | WUI Population | Percent of WUI Population | WUI Acres | Percent of WUI Acres |
|---|---|---|---|---|
| Less than 1 house/40 ac | 206 | 2.2 % | 7,649 | 26.7 % |
| 1 house/40 ac to 1 house/20 ac | 307 | 3.2 % | 6,159 | 21.5 % |
| 1 house/20 ac to 1 house/10 ac | 520 | 5.4 % | 4,582 | 16.0 % |
| 1 house/10 ac to 1 house/5 ac | 708 | 7.4 % | 3,843 | 13.4 % |
| 1 house/5 ac to 1 house/2 ac | 1,375 | 14.4 % | 3,401 | 11.9 % |
| 1 house/2 ac to 3 houses/ac | 4,025 | 42.3 % | 2,701 | 9.4 % |
| More than 3 houses/ac | 2,445 | 31.2 % | 310 | 1.1 % |
| **Total** | **9,586** | **100.0 %** | **28,644** | **100.0 %** |



Wildland Urban Interface
San Miguel Pilot Project
Population
4500
4000
3500
3000
2500
2000
1500
1000
500
0
206
307
520
708
1 375
4 025
2 445
Less than 1 house/40 ac
1 house/40 ac to 1 house/20 ac
1 house/20 ac to 1 house/10 ac
1 house/10 ac to 1 house/5 ac
1 house/5 ac to 1 house/2 ac
1 house/2 ac to 3 houses/ac
More than 3 houses/ac



San Miguel Pilot Project
Wildland Urban Interface
Acres
9k
8k
7k
6k
5k
4k
3k
2k
1k
0
7 649
6 159
4 582
3 843
3 401
2 701
310
Less than 1 house/40 ac
1 house/40 ac to 1 house/20 ac
1 house/20 ac to 1 house/10 ac
1 house/10 ac to 1 house/5 ac
1 house/5 ac to 1 house/2 ac
1 house/2 ac to 3 houses/ac
More than 3 houses/ac




## San Miguel Pilot Project

### Wildland Urban Interface

- Less than 1 house/40 ac
- 1 house/40 ac to 1 house/20 ac
- 1 house/20 ac to 1 house/10 ac
- 1 house/10 ac to 1 house/5 ac
- 1 house/5 ac to 1 house/2 ac
- 1 house/2 ac to 3 houses/ac
- More than 3 houses/ac

10 mi

N S

COLORADO STATE FOREST SERVICE

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Wildland Urban Interface (WUI) Risk Index

## Description

**The Wildland-Urban Interface (WUI) Risk Index layer is a rating of the potential impact of a wildfire on people and their homes.** The key input, WUI, reflects housing density (houses per acre) consistent with Federal Register National standards. The location of people living in the wildland-urban interface and rural areas is essential for defining potential wildfire impacts to people and homes.

The WUI Risk Index is derived using a response function modeling approach. Response functions are a method of assigning a net change in the value to a resource or asset based on susceptibility to fire at different intensity levels, such as flame length.

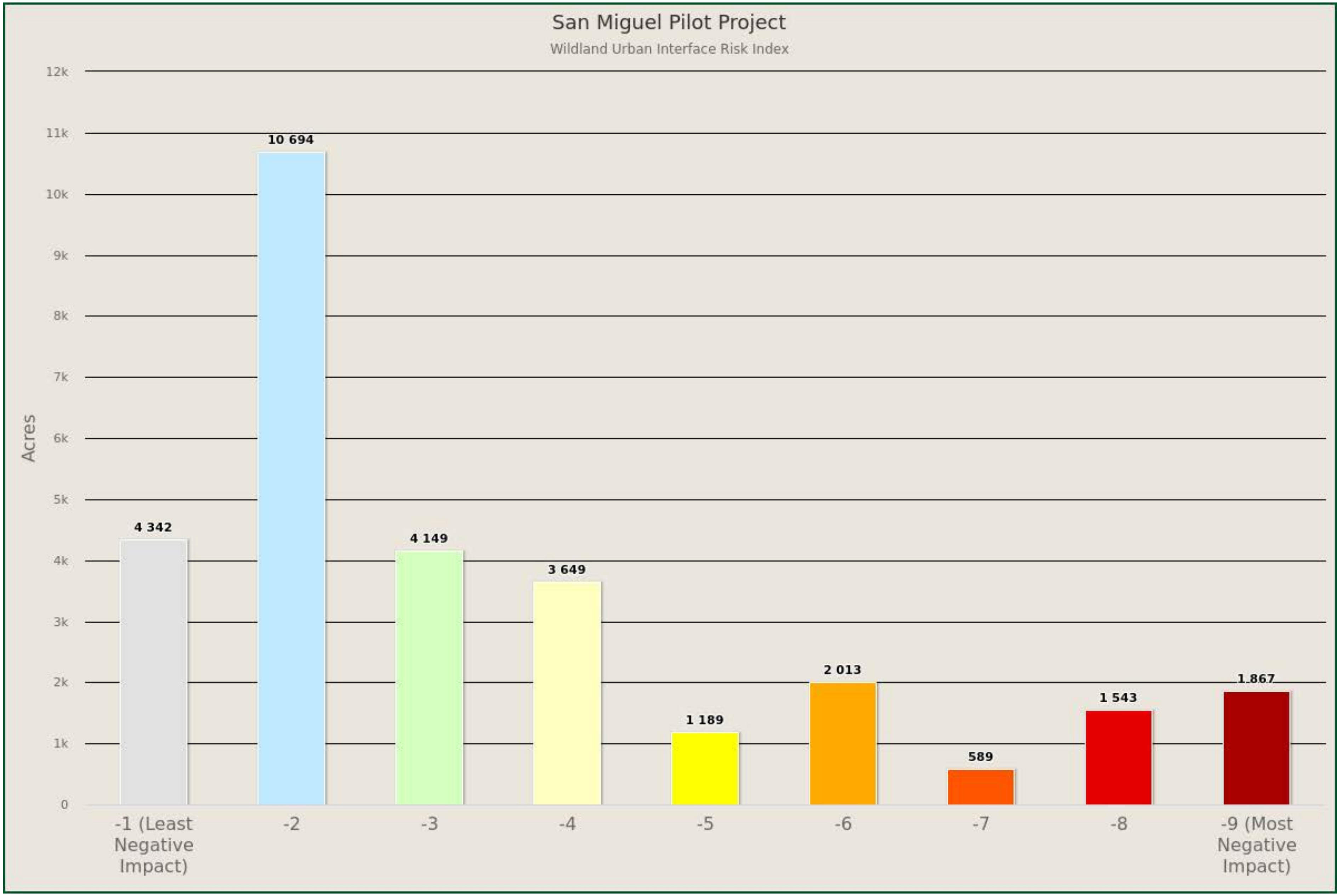
To calculate the WUI Risk Index, the WUI housing density data were combined with flame length data and response functions were defined to represent potential impacts. The response functions were defined by a team of experts led by Colorado State Forest

Service mitigation planning staff. By combining flame length with the WUI housing density data, it is possible to determine where the greatest potential impact to homes and people is likely to occur.

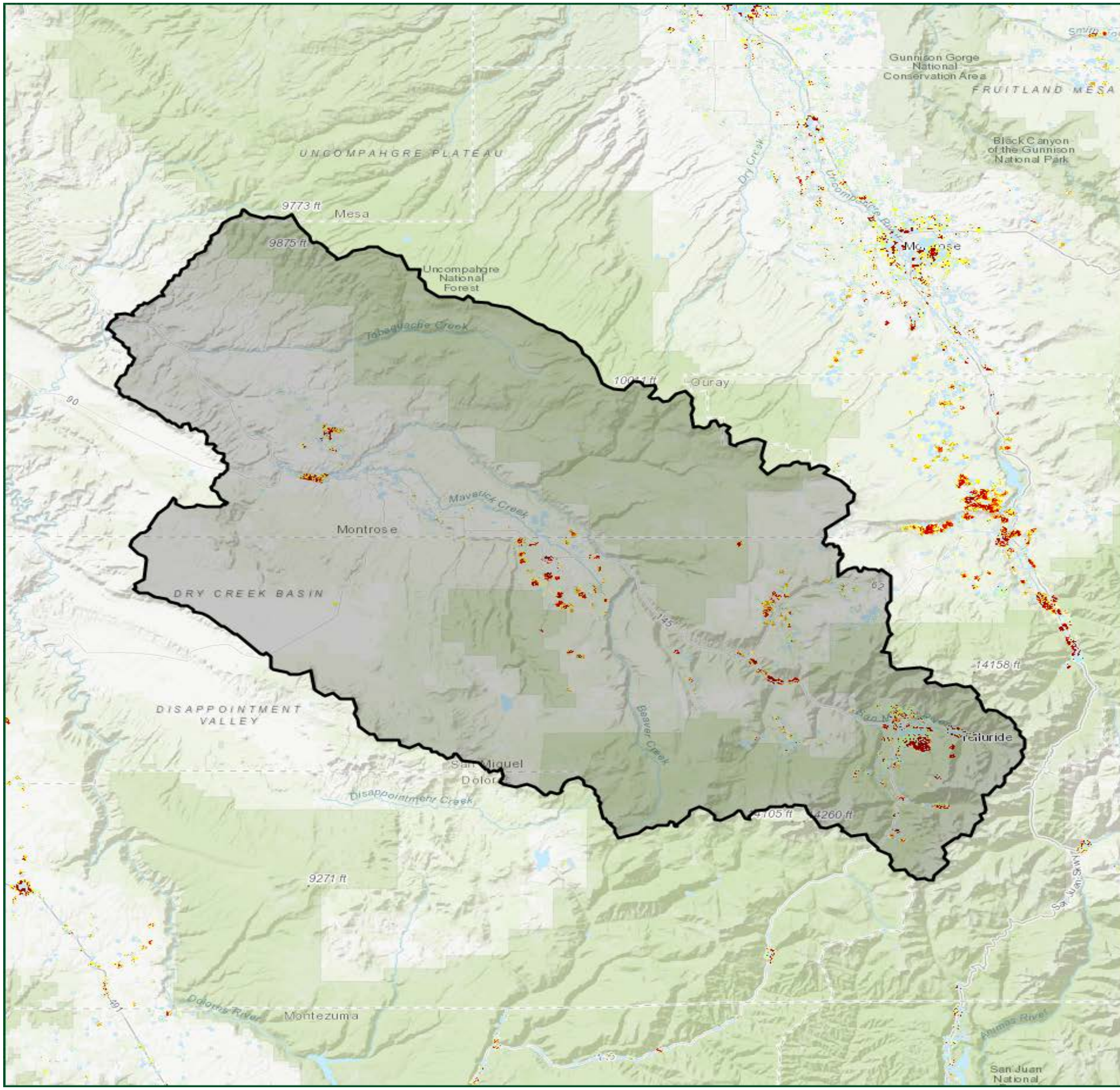
The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact. For example, areas with high housing density and high flame lengths are rated -9, while areas with low housing density and low flame lengths are rated -1.

The WUI Risk Index has been calculated consistently for all areas in Colorado, which allows for comparison and ordination of areas across the entire state. Data are modeled at a 30-meter cell resolution, which is consistent with other Colorado WRA layers.

| WUI Risk Class | Acres | Percent |
|---|---|---|
| -1 (Least Negative Impact) | 4,342 | 14.5 % |
| -2 | 10,694 | 35.6 % |
| -3 | 4,149 | 13.8 % |
| -4 | 3,649 | 12.1 % |
| -5 | 1,189 | 4.0 % |
| -6 | 2,013 | 6.7 % |
| -7 | 589 | 2.0 % |
| -8 | 1,543 | 5.1 % |
| -9 (Most Negative Impact) | 1,867 | 6.2 % |
| **Total** | **30,035** | **100 %** |



San Miguel Pilot Project
Wildland Urban Interface Risk Index
Acres
12k
11k
10k
9k
8k
7k
6k
5k
4k
3k
2k
1k
0
4 342
10 694
4 149
3 649
1 189
2 013
589
1 543
1 867
-1 (Least Negative Impact)
-2
-3
-4
-5
-6
-7
-8
-9 (Most Negative Impact)




**San Miguel Pilot Project**

**Wildland Urban Interface Risk**

- -1 (Least Negative Impact)
- -2
- -3
- -4
- -5
- -6
- -7
- -8
- -9 (Most Negative Impact)

10 mi

N
S

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Community Wildfire Protection Plans (CWPPs)

## Description

A Community Wildfire Protection Plan (CWPP) is a document developed and agreed upon by a community to identify how the community will reduce its wildfire risk. CWPPs identify areas where fuels reduction is needed to reduce wildfire threats to communities and critical infrastructure, address protection of homes and other structures, and plan for wildfire response capability. The Colorado State Forest Service (CSFS) supports the development and implementation of CWPPs and provides resources, educational materials and information to those interested in developing CWPPs.

The CWPP dataset represents the boundaries of those areas that have developed a CWPP. Note that CWPPs can be developed by different groups at varying scales, such as county, Fire Protection District (FPD), community/subdivision, HOA, etc., and as such, can overlap. In addition, the CWPPs can be from different dates. Often a county CWPP is completed first with subsequently more detailed CWPPs done for local communities within that county or FPD. CO-WRAP provides a tool that allows the user to select the CWPP area and retrieve the CWPP document for review (PDF).

At a minimum, a CWPP should include:

- The wildland-urban interface (WUI) boundary, defined on a map, where people, structures and other community values are most likely to be negatively impacted by wildfire
- The CSFS, local fire authority and local government involvement and any additional stakeholders
- A narrative that identifies the community's values and fuel hazards
- The community's plan for when a wildfire occurs
- An implementation plan that identifies areas of high priority for fuels treatments

**Community input is the foundation of a Community Wildfire Protection Plan that identfies community needs and garners community support.**

CWPPs are not shelf documents and should be reviewed, tracked and updated. A plan stays alive when it is periodically updated to address the accomplishments of the community. Community review of progress in meeting plan objectives and determining areas of new concern where actions must be taken to reduce wildfire risk helps the community stay current with changing environment and wildfire mitigation priorities.

If your community is in an area at risk from wildfire, now is a good time to start working with neighbors on a CWPP and preparing forfuture wildfires. Contact your local CSFS district to learn how to start this process and create a CWPP for your community: http://csfs.colostate.edu/pages/your-local-forester.html

For the San Miguel Pilot Project test project area, there are 6 CWPPs areas that are totally or partially in the defined project area.

| Community CWPP Name | CWPP Type | CSFS District | Acres inside project area | Total Acres |
|---|---|---|---|---|
| Mesa County | County | Grand Junction | 995 | 2,140,867 |
| Ouray County | County | Montrose | 1,466 | 347,305 |
| Montrose County | County | Montrose | 436,280 | 1,436,974 |
| San Juan County | County | Durango | 37 | 248,650 |
| Dolores County | County | Durango | 3,740 | 684,650 |
| San Miguel County | County | Montrose | 551,869 | 825,795 |
| **Total Acres** | | | **994,387** | **5,684,242** |

# Wildfire Risk

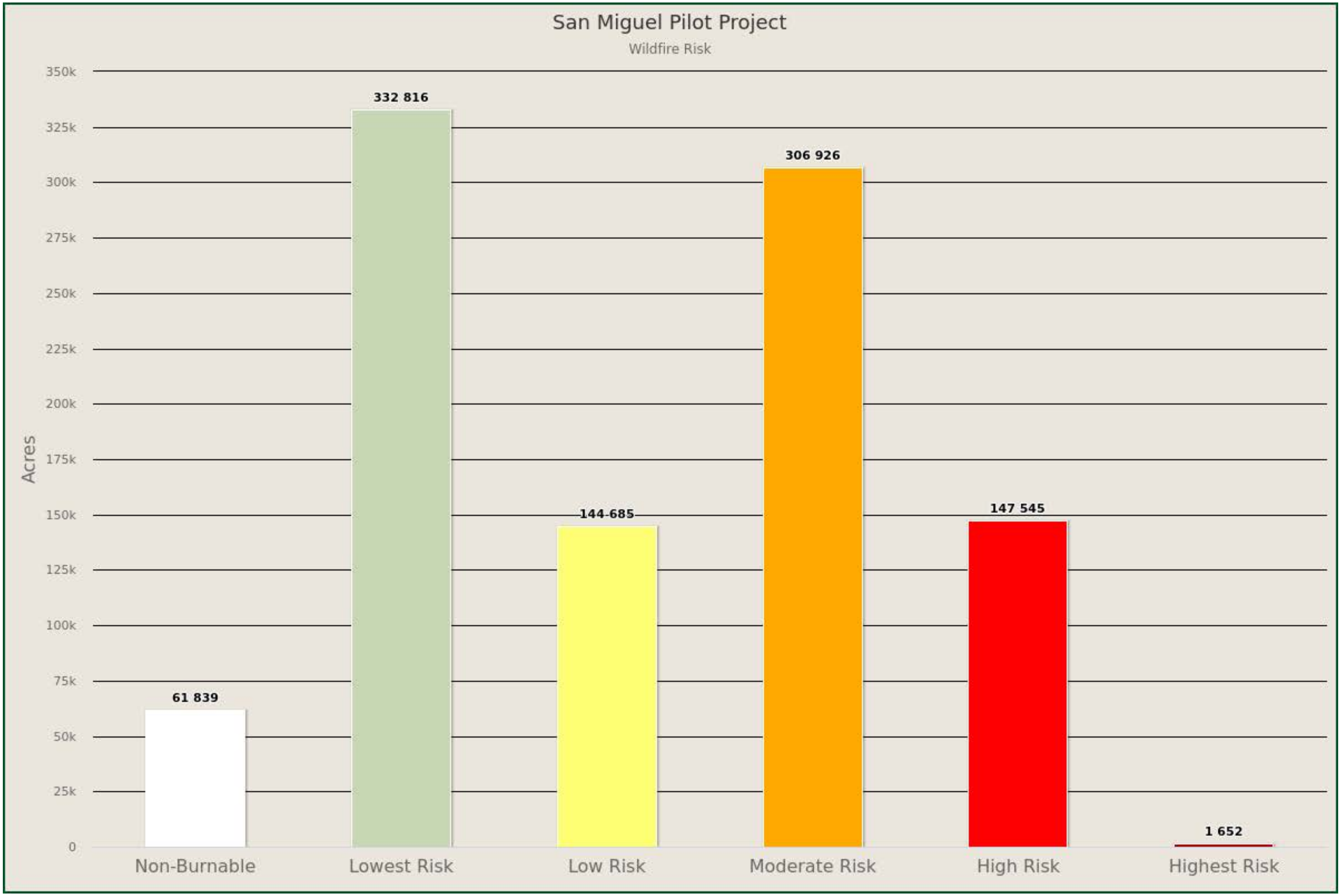
## Description

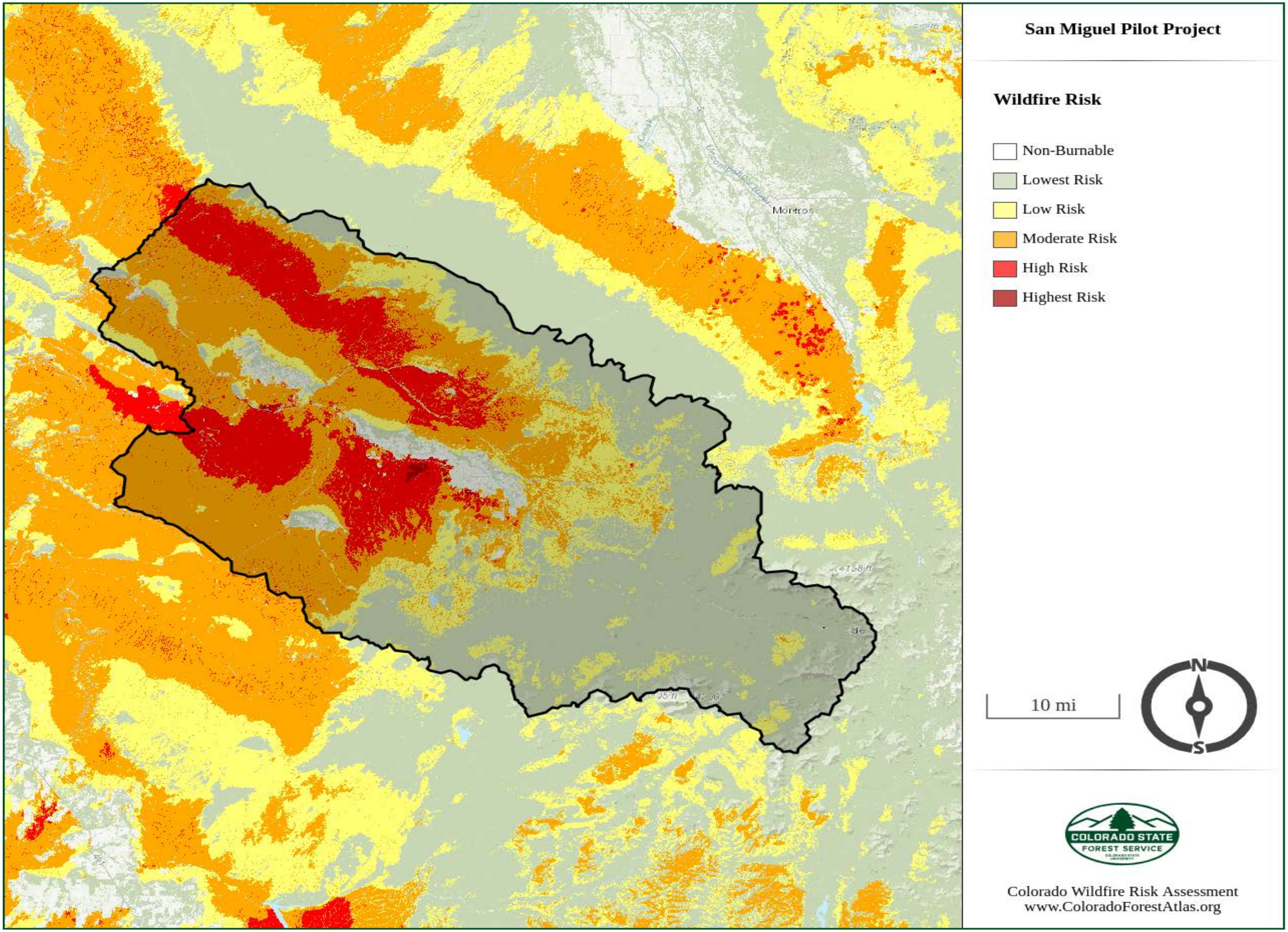
**Wildfire Risk is a composite risk rating obtained by combining the probability of a fire occurring with the individual values at risk layers.** Risk is defined as the possibility of loss or harm occurring from a wildfire. It identifies areas with the greatest potential impacts from a wildfire – i.e. those areas most at risk - considering all values and assets combined together – WUI Risk, Drinking Water Risk, Forest Assets Risk and Riparian Areas Risk.

Since all areas in Colorado have risk calculated consistently, it allows for comparison and ordination of areas across the entire state. The Values at Risk Rating is a key component of Wildfire Risk. The Values at Risk Rating is comprised of several inputs focusing on values and assets at risk. This includes Wildland Urban Interface, Forest Assets, Riparian Assets and Drinking Water Importance Areas (watersheds).

To aid in the use of Wildfire Risk for planning activities, the output values are categorized into five (5) classes. These are given general descriptions from Lowest to Highest Risk.

| Wildfire Risk Class | | Acres | Percent |
|---|---|---|---|
| | Non-Burnable | 61,839 | 6.2 % |
| | Lowest Risk | 332,816 | 33.4 % |
| | Low Risk | 144,685 | 14.5 % |
| | Moderate Risk | 306,926 | 30.8 % |
| | High Risk | 147,545 | 14.8 % |
| | Highest Risk | 1,652 | 0.2 % |
| **Total** | | **995,463** | **100 %** |


San Miguel Pilot Project
Wildfire Risk
Acres
350k
325k
300k
275k
250k
225k
200k
175k
150k
125k
100k
75k
50k
25k
0
61 839
332 816
144 685
306 926
147 545
1 652
Non-Burnable
Lowest Risk
Low Risk
Moderate Risk
High Risk
Highest Risk


San Miguel Pilot Project
Wildfire Risk
Non-Burnable
Lowest Risk
Low Risk
Moderate Risk
High Risk
Highest Risk
10 mi
N
S
COLORADO STATE
FOREST SERVICE
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Burn Probability

## Description

**Burn Probability (BP) is the annual probability of any location burning due to a wildfire.** BP is calculated as the number of times that a 30-meter cell on the landscape is burned from millions of fire simulations. The annual BP was estimated by using a stochastic (Monte Carlo) wildfire simulation approach with Technosylva's Wildfire Analyst software (www.WildfireAnalyst.com).

A total number of 3,200,000 fires were simulated across the state, including those fires outside the Colorado border which were used in a buffer area around the state, to compute BP with a mean ignition density of 8.68 fires/km2. The simulation ignition points were spatially distributed evenly every 500 meters across the state. Only high and extreme weather conditions were used to run the simulations. All fires simulations had a duration of 10 hours.

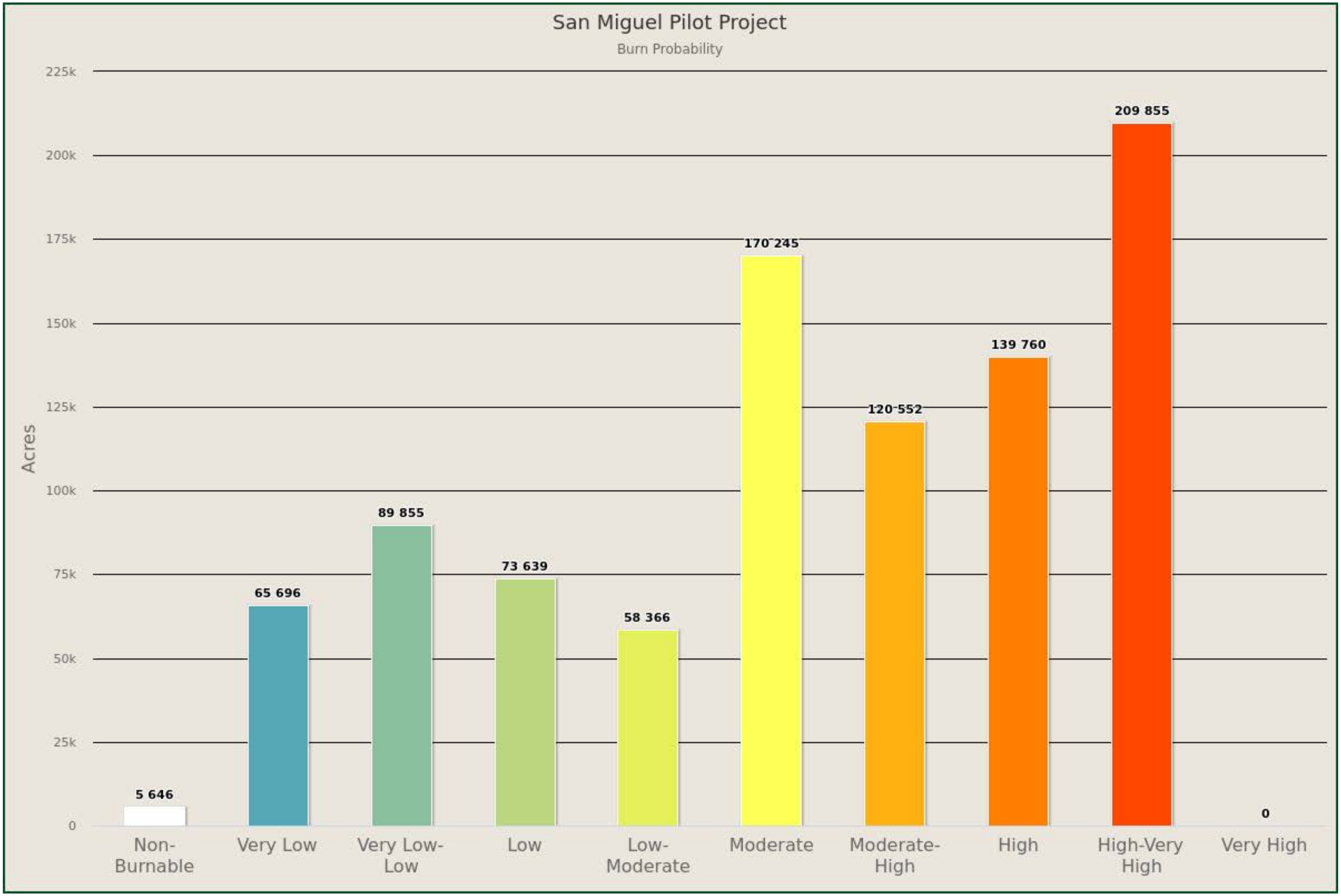
The Wildfire Analyst fire simulator considered the number of times that the simulated fires burned each cell. After that, results were weighted by considering the historical fire occurrence of those fires that burned in high and extreme weather conditions. The weighting was done by assessing the relationship between the annual historical fire ignition density in Colorado and the total number of simulated fires with varying input data in the different weather scenarios and the historical spatial distribution of the ignition points.

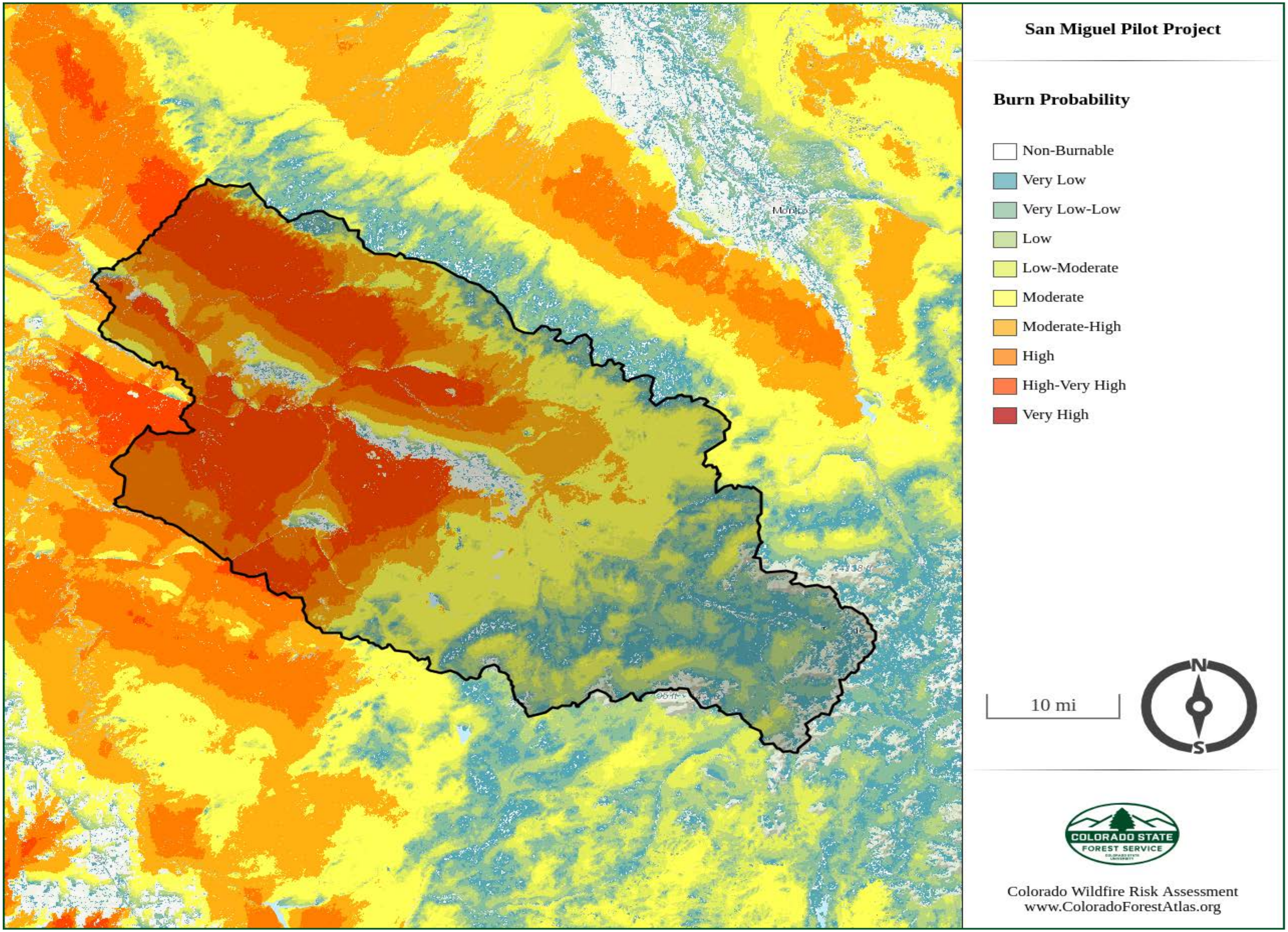
The probability map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not appropriate for site specific analysis, it is appropriate for regional, county or local protection mitigation or prevention planning.

To aid in the use of Burn Probability for planning activities, the output values are categorized into 10 (ten) classes. These are given general descriptions from Lowest to Highest Probability.

A more detailed description of the risk assessment algorithms is provided in the Colorado WRA Final Report, which can be downloaded from www.ColoradoForestAtlas.org.

| Burn Probability Class | Acres | Percent |
|---|---|---|
| Non-Burnable | 5,646 | 0.6 % |
| Very Low | 65,696 | 7.0 % |
| Very Low-Low | 89,855 | 9.6 % |
| Low | 73,639 | 7.9 % |
| Low-Moderate | 58,366 | 6.3 % |
| Moderate | 170,245 | 18.2 % |
| Moderate-High | 120,552 | 12.9 % |
| High | 139,760 | 15.0 % |
| High-Very High | 209,855 | 22.5 % |
| Very High | 0 | 0 % |
| **Total** | **933,615** | **100 %** |


San Miguel Pilot Project
Burn Probability
Acres
225k
200k
175k
150k
125k
100k
75k
50k
25k
0
5 646
65 696
89 855
73 639
58 366
170 245
120 552
139 760
209 855
0
Non-Burnable
Very Low
Very Low-Low
Low
Low-Moderate
Moderate
Moderate-High
High
High-Very High
Very High


San Miguel Pilot Project
Burn Probability
Non-Burnable
Very Low
Very Low-Low
Low
Low-Moderate
Moderate
Moderate-High
High
High-Very High
Very High
10 mi
N
S
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Values at Risk Rating

## Description

**Represents those values or assets that would be adversely impacted by a wildfire.** The Values at Risk Rating is an overall rating that combines the risk ratings for Wildland Urban Interface (WUI), Forest Assets, Riparian Assets, and Drinking Water Importance Areas into a single measure of values-at-risk. The individual ratings for each value layer were derived using a Response Function approach.

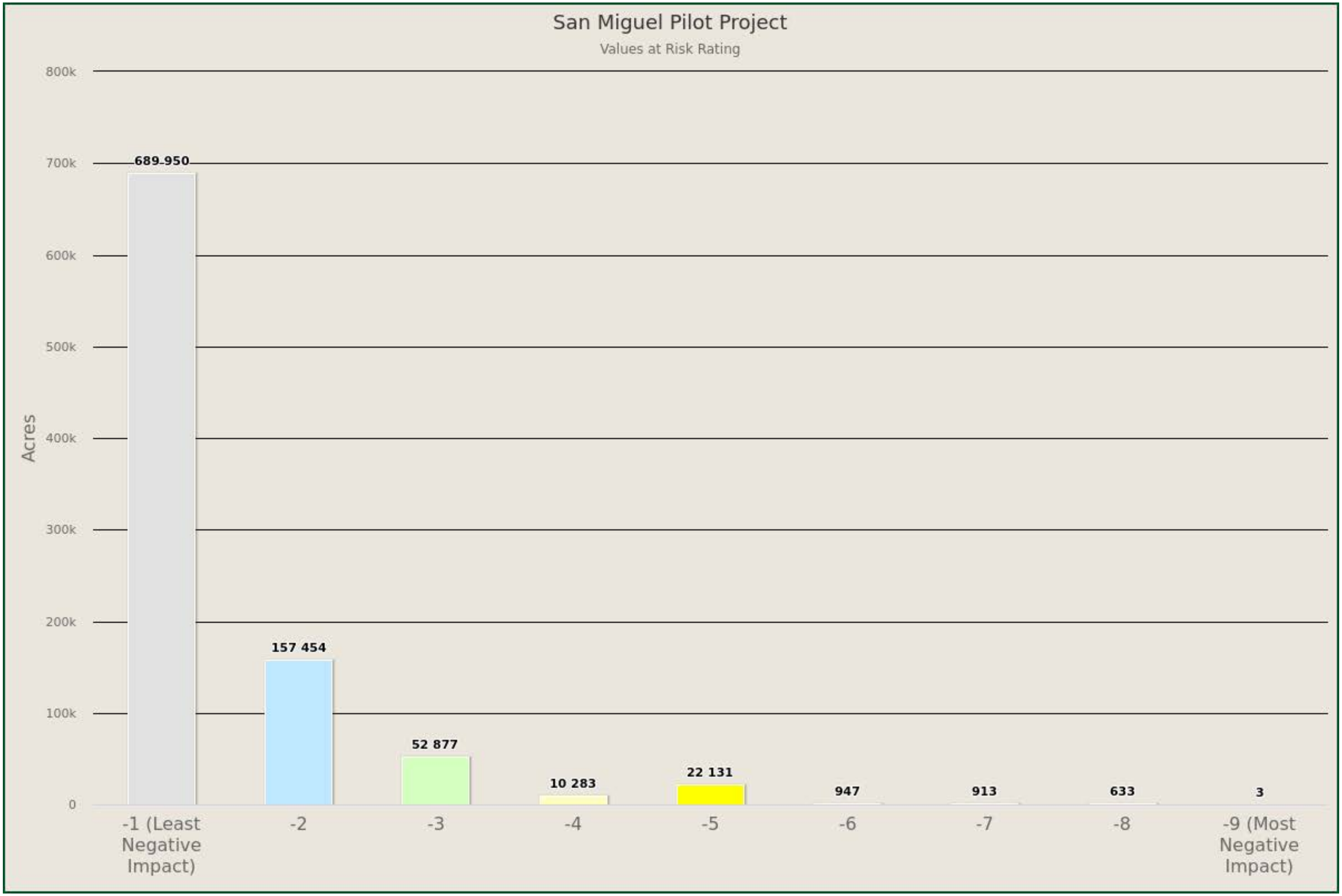
Response functions are a method of assigning a net change in the value to a resource or asset based on susceptibility to fire at different intensity levels. A resource or asset is any of the Fire Effects input layers, such as WUI, Forest Assets, etc. These net changes can be adverse (negative) or positive (beneficial).

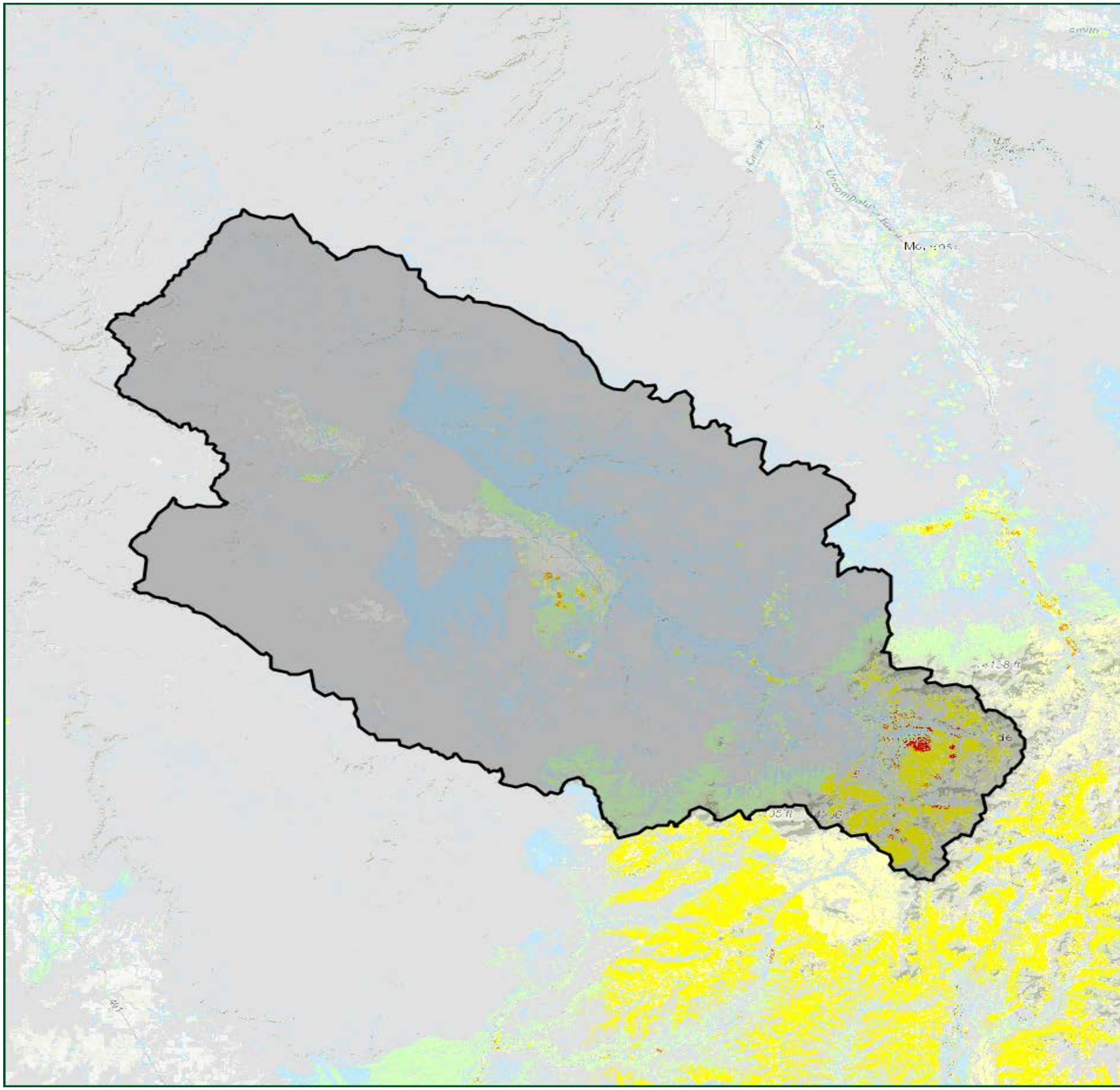
Calculating the Values at Risk Rating at a given location requires spatially defined estimates of the intensity of fire integrated with the identified resource value. This interaction is quantified through the use of response functions that estimate expected impacts to resources or assets at the specified fire intensity levels. The measure of fire intensity level used in the Colorado assessment is flame length for a location. Response Function outputs were derived for each input dataset and then combined to derive the Values Impacted Rating.

Different weightings are used for each of the input layers with the highest priority placed on protection of people and structures (i.e. WUI). The weightings represent the value associated with those assets. Weightings were developed by a team of experts during the assessment to reflect priorities for fire protection planning in Colorado. Refer to the Colorado WRA Final Report for more information about the layer weightings.

Since all areas in Colorado have the Values at Risk Rating calculated consistently, it allows for comparison and ordination of areas across the entire state. The data were derived at a 30-meter resolution.

| Values at Risk Class | Acres | Percent |
|---|---|---|
| -1 (Least Negative Impact) | 689,950 | 73.8 % |
| -2 | 157,454 | 16.8 % |
| -3 | 52,877 | 5.7 % |
| -4 | 10,283 | 1.1 % |
| -5 | 22,131 | 2.4 % |
| -6 | 947 | 0.1 % |
| -7 | 913 | 0.1 % |
| -8 | 633 | 0.1 % |
| -9 (Most Negative Impact) | 3 | 0.0 % |
| **Total** | **935,193** | **100 %** |


San Miguel Pilot Project
Values at Risk Rating
Acres
800k
700k
600k
500k
400k
300k
200k
100k
0
689 950
157 454
52 877
10 283
22 131
947
913
633
3
-1 (Least Negative Impact)
-2
-3
-4
-5
-6
-7
-8
-9 (Most Negative Impact)



**San Miguel Pilot Project**

**Values at Risk Rating**

- Non-Categorized
- -1 (Least Negative Impact)
- -2
- -3
- -4
- -5
- -6
- -7
- -8
- -9 (Most Negative Impact)

10 mi

N
S

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Suppression Difficulty Rating

## Description

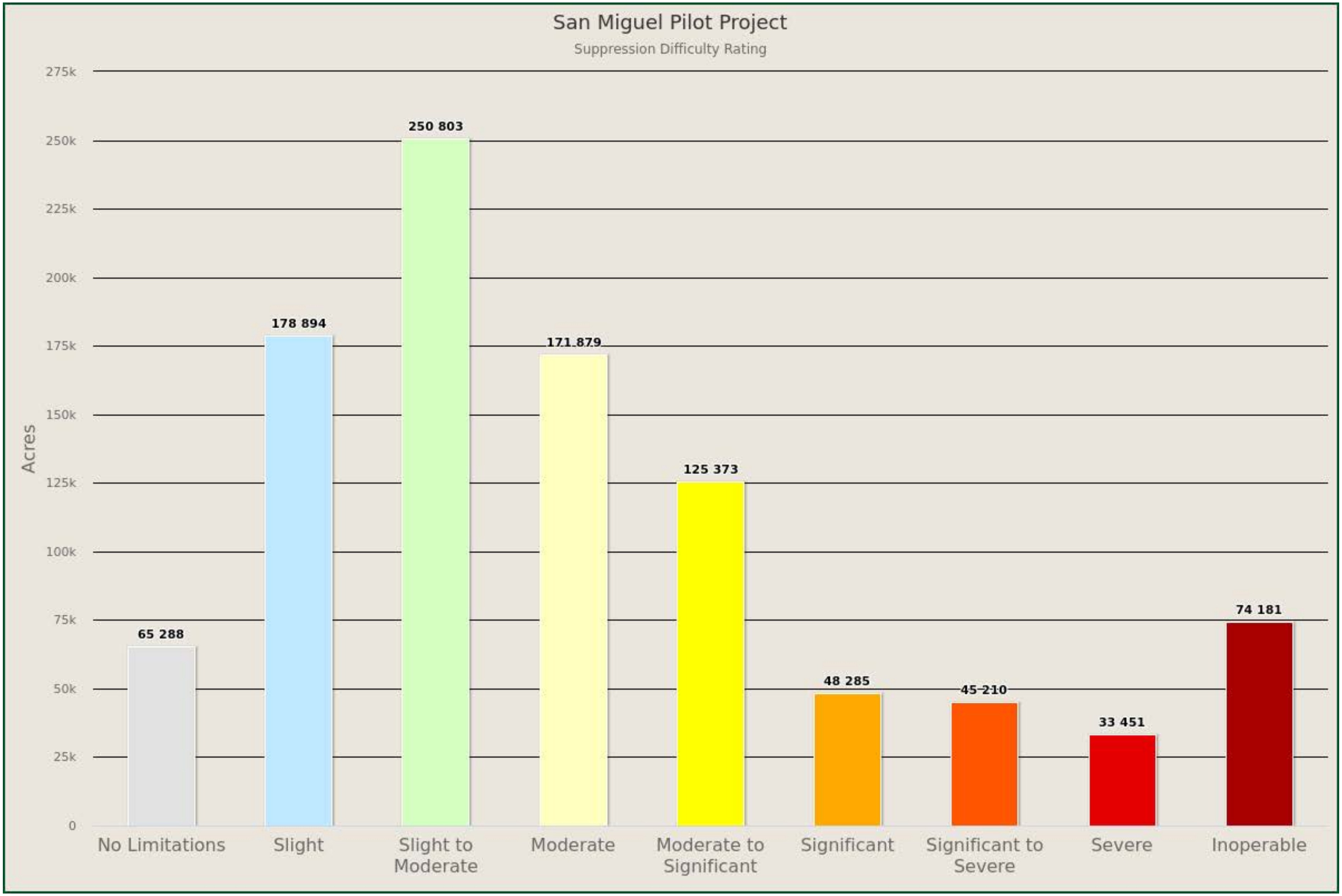
**Reflects the difficulty or relative cost to suppress a fire given the terrain and vegetation conditions that may impact machine operability.** This layer is an overall index that combines the slope steepness and the vegetation/fuel type characterization to identify areas where it would be difficult or costly to suppress a fire due to the underlying terrain and vegetation conditions that would impact machine operability (in particular Type II dozer).

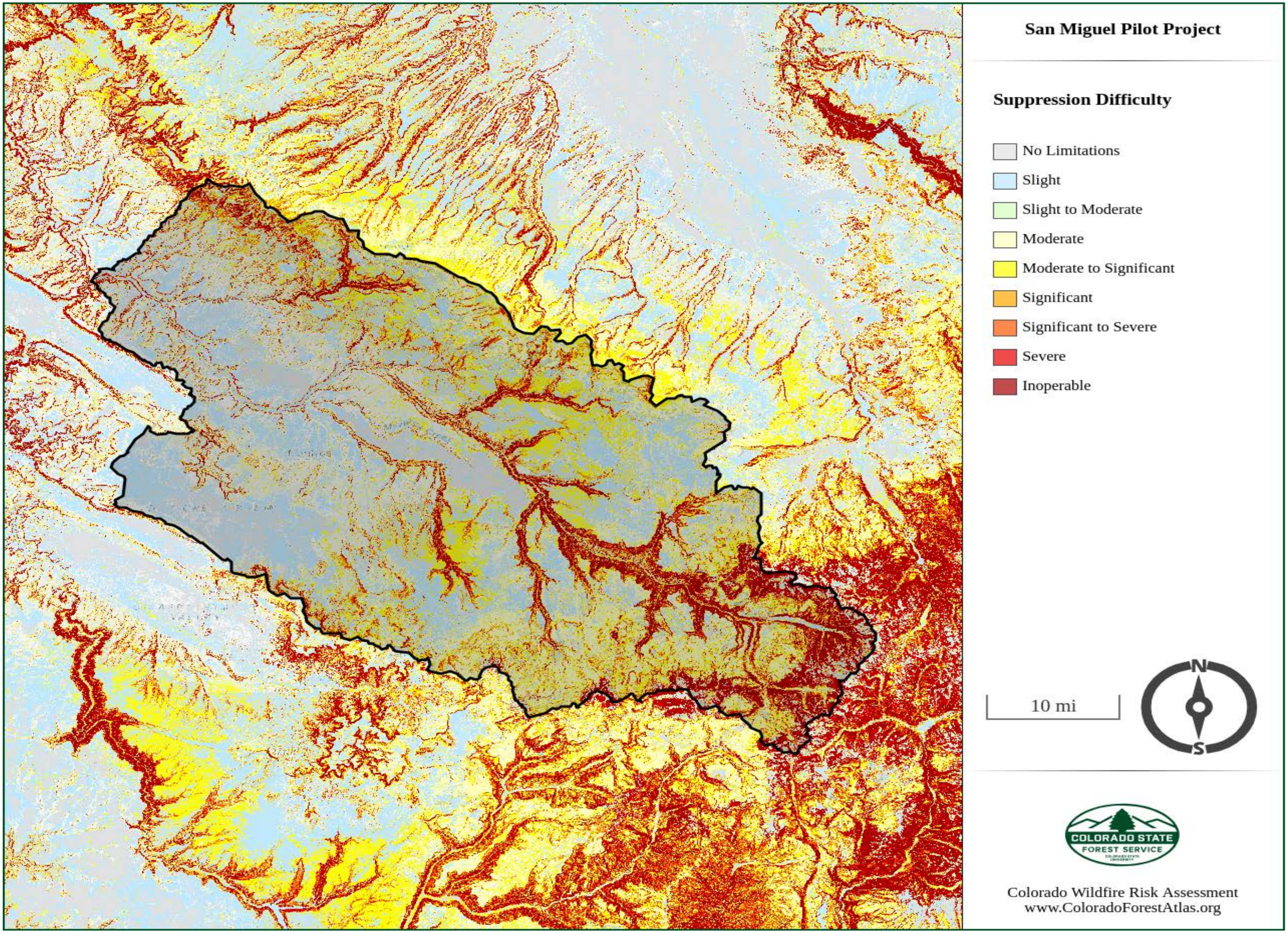
The rating was calculated based on the fireline production rates for hand crews and engines with modifications for slope, as documented in the NWCG Fireline Handbook 3, PMS 401-1.

The burnable fuel models in the Colorado WRA were grouped into ten categories: Grass, Grass/Shrub, Shrub/Regeneration, Moderate Forest, Heavy Forest, Swamp/Marsh, Agriculture, Barren, Urban/Developed, Water/Ice.

Fireline production capability on six slope classes was used as the basic reference to obtain the suppression difficulty score. The response function category is assigned to each combination of fuel model group and slope category.

| SDR Class | Acres | Percent |
|---|---|---|
| No Limitations | 65,288 | 6.6 % |
| Slight | 178,894 | 18.0 % |
| Slight to Moderate | 250,803 | 25.2 % |
| Moderate | 171,879 | 17.3 % |
| Moderate to Significant | 125,373 | 12.6 % |
| Significant | 48,285 | 4.9 % |
| Significant to Severe | 45,210 | 4.6 % |
| Severe | 33,451 | 3.4 % |
| Inoperable | 74,181 | 7.5 % |
| **Total** | **993,364** | **100 %** |


San Miguel Pilot Project
Suppression Difficulty Rating
Acres
275k
250k
225k
200k
175k
150k
125k
100k
75k
50k
25k
0
65 288
178 894
250 803
171 879
125 373
48 285
45 210
33 451
74 181
No Limitations
Slight
Slight to Moderate
Moderate
Moderate to Significant
Significant
Significant to Severe
Severe
Inoperable


San Miguel Pilot Project
Suppression Difficulty
No Limitations
Slight
Slight to Moderate
Moderate
Moderate to Significant
Significant
Significant to Severe
Severe
Inoperable
10 mi
N
S
COLORADO STATE
FOREST SERVICE
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Fire Occurrence

## Description

**Fire Occurrence is an ignition density that represents the likelihood of a wildfire starting based on historical ignition patterns.** Occurrence is derived by modeling historic wildfire ignition locations to create an ignition density map.

Historic fire report data were used to create the ignition points for all Colorado fires. The compiled fire occurrence database was cleaned to remove duplicate records and to correct inaccurate locations. The database was then modeled to create a density map reflecting historical fire ignition rates.

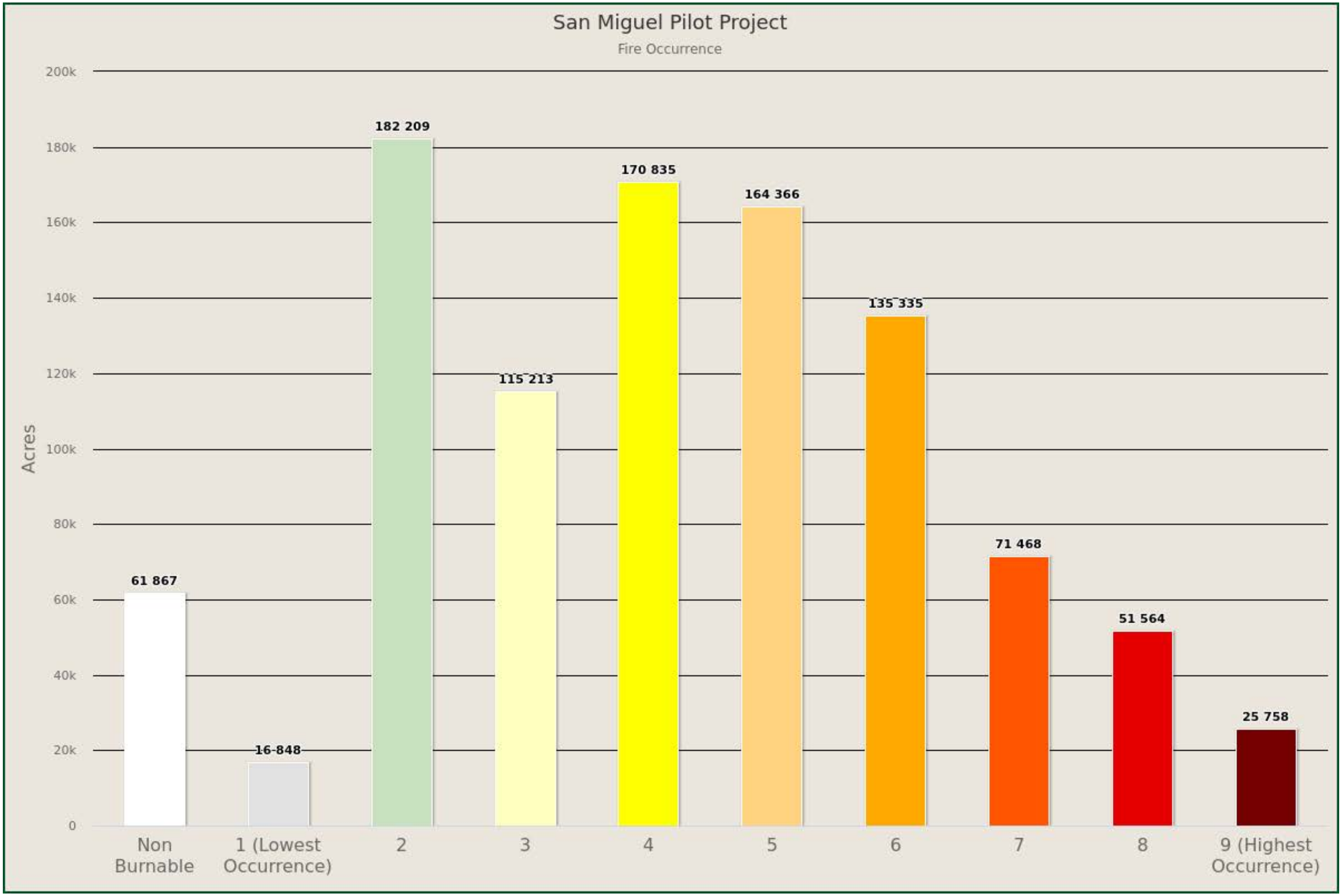
Historic fire report data were used to create the ignition points for all Colorado fires. This included both federal and non-federal fire ignition locations.

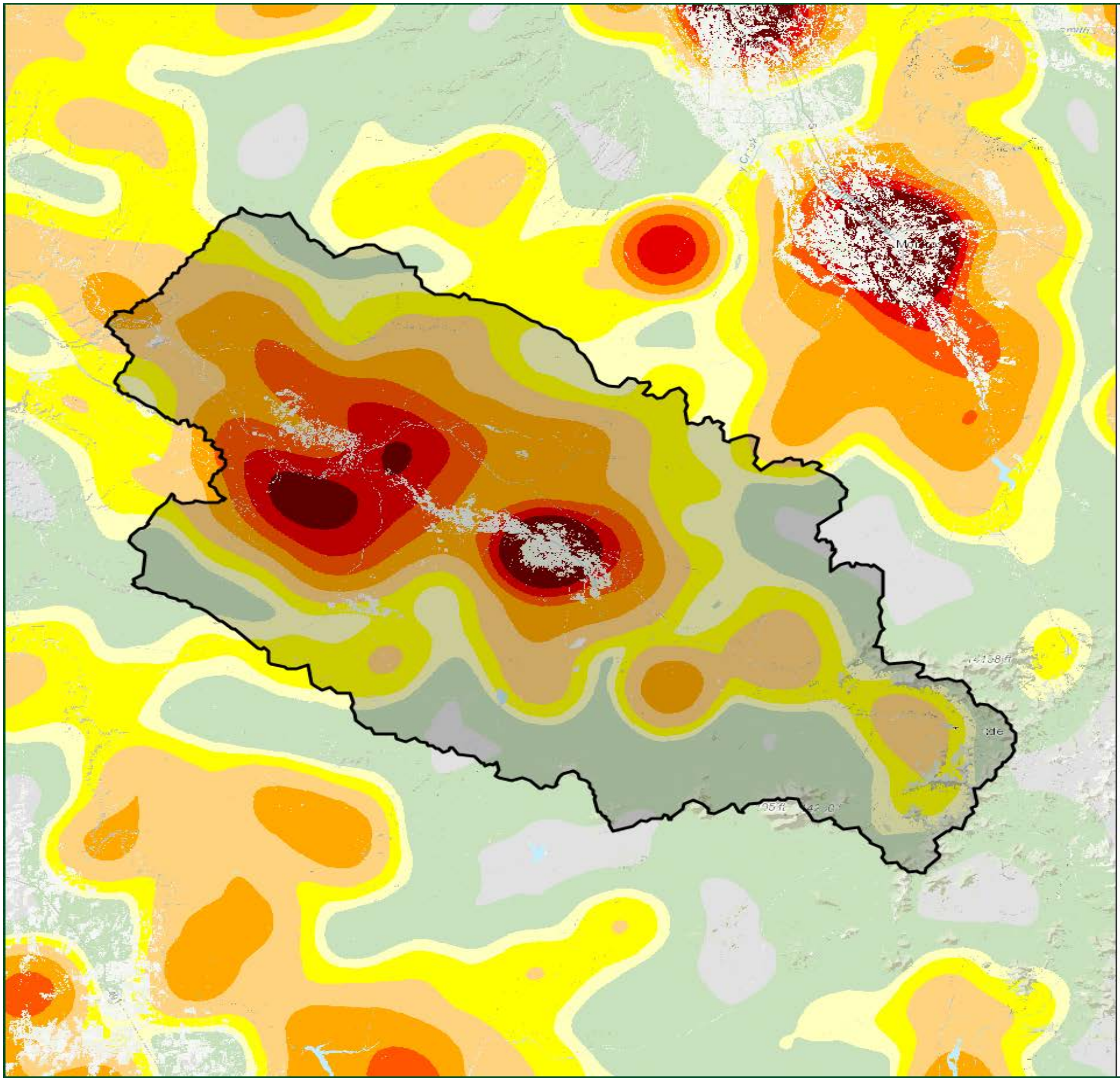
The class breaks are determined by analyzing the Fire Occurrence output values for the entire state and determining cumulative percent of acres (i.e. Class 9 has the top 1.5% of acres with the highest occurrence rate). Refer to the Colorado WRA Final Report for a more detailed description of the mapping classes and the methods used to derive these.

The Fire Occurrence map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not sufficient for site specific analysis, it is appropriate for regional, county or local protection mitigation or prevention planning.

A more detailed description of the risk assessment algorithms is provided in the Colorado WRA Final Report, which can be downloaded from www.ColoradoForestAtlas.org.

| Fire Occurrence Class | Acres | Percent |
|---|---|---|
| Non Burnable | 61,867 | 6.2 % |
| 1 (Lowest Occurrence) | 16,848 | 1.7 % |
| 2 | 182,209 | 18.3 % |
| 3 | 115,213 | 11.6 % |
| 4 | 170,835 | 17.2 % |
| 5 | 164,366 | 16.5 % |
| 6 | 135,335 | 13.6 % |
| 7 | 71,468 | 7.2 % |
| 8 | 51,564 | 5.2 % |
| 9 (Highest Occurrence) | 25,758 | 2.6 % |
| **Total** | **995,463** | **100 %** |


San Miguel Pilot Project
Fire Occurrence
Acres
200k
180k
160k
140k
120k
100k
80k
60k
40k
20k
0
61 867
16 848
182 209
115 213
170 835
164 366
135 335
71 468
51 564
25 758
Non Burnable
1 (Lowest Occurrence)
2
3
4
5
6
7
8
9 (Highest Occurrence)



San Miguel Pilot Project

Fire Occurrence

Non Burnable
1 (Lowest Occurrence)
2
3
4
5
6
7
8
9 (Highest Occurrence)

10 mi

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Fire Behavior

## Description

**Fire behavior is the manner in which a fire reacts to the following environmental influences:**

1. **Fuels**
2. **Weather**
3. **Topography**


Fire behavior characteristics are attributes of wildland fire that pertain to its spread, intensity, and growth. Fire behavior characteristics utilized in the Colorado WRA include fire type, rate of spread, flame length and fireline intensity (fire intensity scale). These metrics are used to determine the potential fire behavior under different weather scenarios. Areas that exhibit moderate to high fire behavior potential can be identified for mitigation treatments, especially if these areas are in close proximity to homes, business, or other assets.

**Fuels**

The Colorado WRA includes composition and characteristics for both surface fuels and canopy fuels. Assessing canopy fire potential and surface fire potential allows identification of areas where significant increases in fire behavior affects the potential of a fire to transition from a surface fire to a canopy fire.

Fuel datasets required to compute both surface and canopy fire potential include:

1. **Surface Fuels** are typically categorized into one of four primary fuel types based on the primary carrier of the surface fire: 1) grass, 2) shrub/brush, 3) timber litter, and 4) slash. They are generally referred to as fire behavior fuel models and provide the input parameters needed to compute surface fire behavior. The 2017 assessment uses the latest 2017 calibrated fuels for Colorado.
2. **Canopy Cover** is the horizontal percentage of the ground surface that is covered by tree crowns. It is used to compute wind-reduction factors and shading.
3. **Canopy Ceiling Height/Stand Height** is the height above the ground of the highest canopy layer where the density of the crown mass within the layer is high enough to support vertical movement of a fire. A good estimate of canopy ceiling height is the average height of the dominant and co-dominant trees in a stand. It is used to compute wind reduction to mid-flame height, and spotting distances from torching trees.
4. **Canopy Base** Height is the lowest height above the ground above which sufficient canopy fuel exists to vertically propagate fire (Scott & Reinhardt, 2001). Canopy base height is a property of a plot, stand or group of trees, not an individual tree. For fire modeling, canopy base height is an effective value that incorporates ladder fuels, such as tall shrubs and small trees. Canopy base height is used to determine whether a surface fire will transition to a canopy fire.

5. **Canopy Bulk Density** is the mass of available canopy fuel per unit canopy volume (Scott & Reinhardt, 2001). Canopy bulk density is a bulk property of a stand, plot or group of trees, not an individual tree. Canopy bulk density is used to predict whether an active crown fire is possible.

**Weather**

Environmental weather parameters needed to compute fire behavior characteristics include 1-hour, 10-hour and 100-hour time-lag fuel moistures, herbaceous fuel moisture, woody fuel moisture and the 20-foot, 10-minute average wind speed. To collect this information, Weather data (1988-2017) from NCEP (National Center for Environmental Prediction) was used to analyse potential weather scenarios in which assessing fire behavior and spread. In particular, the North American Regional Reanalysis (NARR) product from NCEP was selected because of it provides high resolution weather data for all of Colorado. The following percentiles (97th, 90th, 50th and 25th) were analysed for each variable in each 30km NARR point to create four weather scenarios to run the fire behavior analysis: “Extreme”, “High”, “Moderate” and “Low”. After computing the weather percentiles of the NARR variables, an IDW algorithm was used to derive 30m resolution data to match the surface fuels dataset.

The four percentile weather categories are intended to represent low, moderate, high and extreme fire weather days. Fire behavior outputs are computed for each percentile weather category to determine fire potential under different weather scenarios.

For a detailed description of the methodology, refer to the 2017 Colorado Wildfire Risk Assessment Final Report at www.ColoradoForestAtlas.org.

**Topography**

Topography datasets required to compute fire behavior characteristics are elevation, slope and aspect.

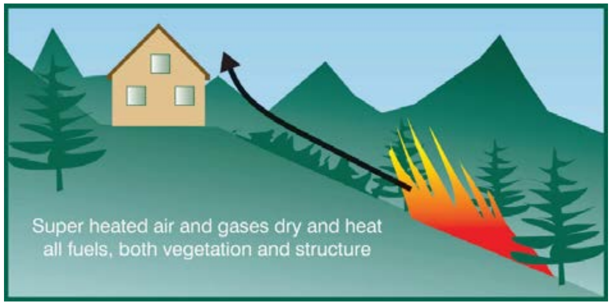
## FIRE BEHAVIOR CHARACTERISTICS

Fire behavior characteristics provided in this report include:

- **Characteristic Rate of Spread**
- **Characteristic Flame Length**
- **Fire Intensity Scale**
- **Fire Type – Extreme Weather**

# Characteristic Rate of Spread

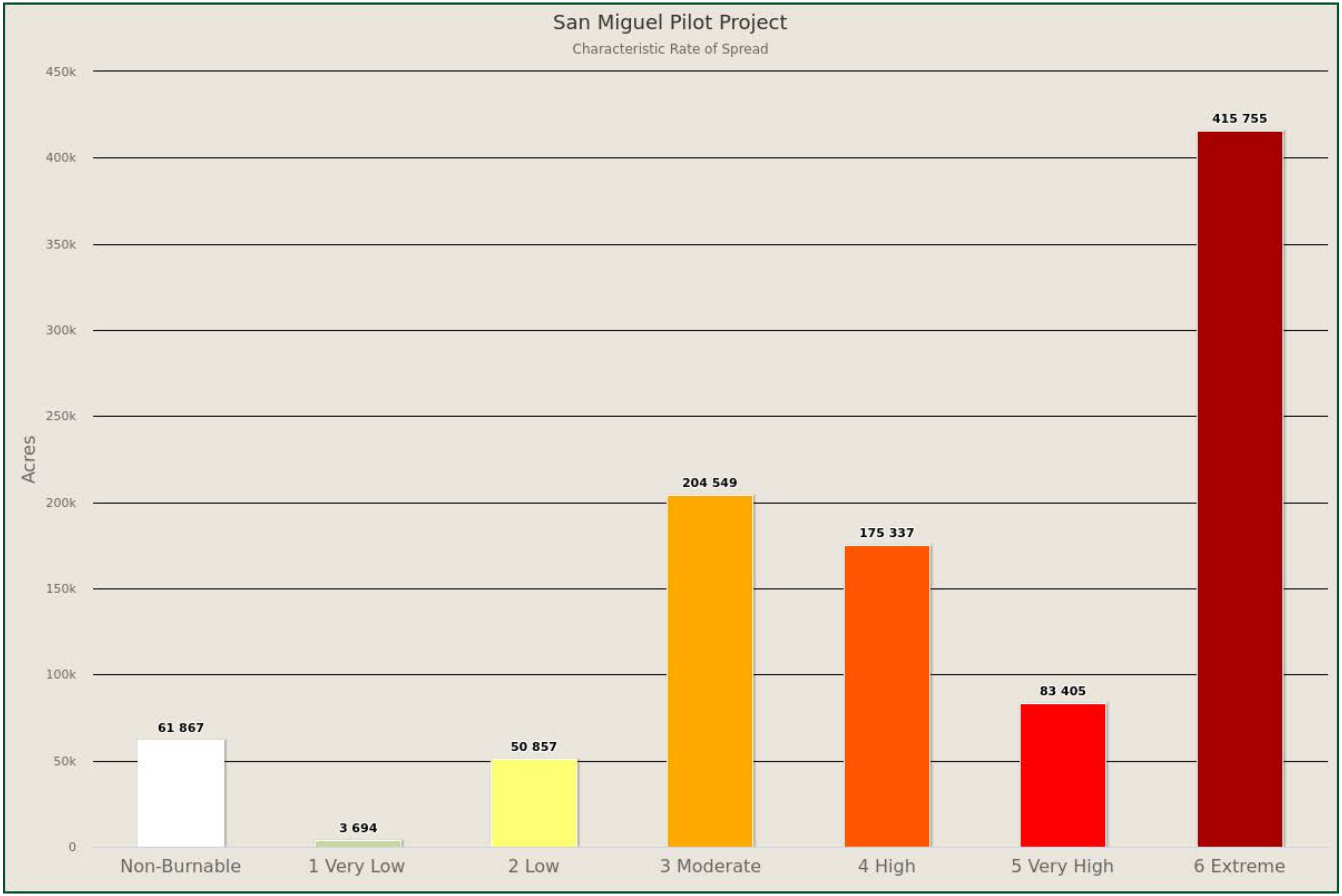
**Characteristic Rate of Spread is the typical or representative rate of spread of a potential fire based on a weighted average of four percentile weather categories.** Rate of spread is the speed with which a fire moves in a horizontal direction across the landscape, usually expressed in chains per hour (ch/hr) or feet per minute (ft/min). For purposes of the Colorado WRA, this measurement represents the maximum rate of spread of the fire front. Rate of Spread is used in the calculation of Wildfire Threat in the Colorado WRA.




Rate of spread is a fire behavior output, which is influenced by three environmental factors - fuels, weather, and topography. Weather is by far the most dynamic variable as it changes frequently. To account for this variability, four percentile weather categories were created from historical weather observations to represent low, moderate, high, and extreme weather days for each 30-meter cell in Colorado. Thirty (30) meter resolution is the baseline for the Colorado WRA, matching the source surface fuels dataset.

The "characteristic" output represents the weighted average for all four weather percentiles. While not shown in this report, the individual percentile weather ROS outputs are available in the Colorado WRA data.

| Rate of Spread | Acres | Percent |
|---|---|---|
| Non-Burnable | 61,867 | 6.2 % |
| 1 Very Low | 3,694 | 0.4 % |
| 2 Low | 50,857 | 5.1 % |
| 3 Moderate | 204,549 | 20.5 % |
| 4 High | 175,337 | 17.6 % |
| 5 Very High | 83,405 | 8.4 % |
| 6 Extreme | 415,755 | 41.8 % |
| **Total** | **995,463** | **100 %** |


San Miguel Pilot Project
Characteristic Rate of Spread
Acres
450k
400k
350k
300k
250k
200k
150k
100k
50k
0
61 867
3 694
50 857
204 549
175 337
83 405
415 755
Non-Burnable
1 Very Low
2 Low
3 Moderate
4 High
5 Very High
6 Extreme

**San Miguel Pilot Project**

**Characteristic Rate of Spread**

- 1 Very Low
- 2 Low
- 3 Moderate
- 4 High
- 5 Very High
- 6 Extreme

10 mi

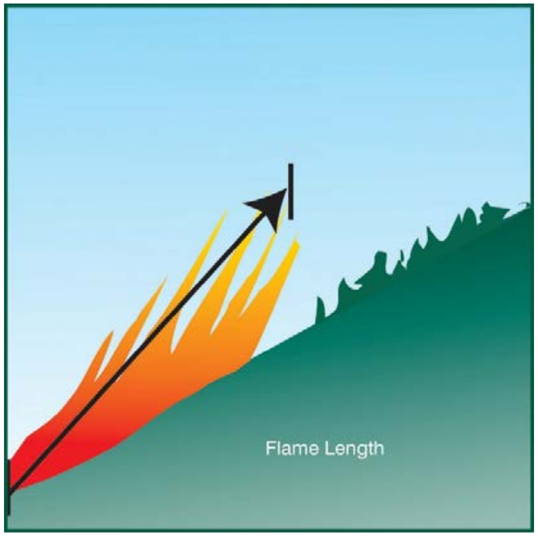
N
S

COLORADO STATE FOREST SERVICE

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Characteristic Flame Length

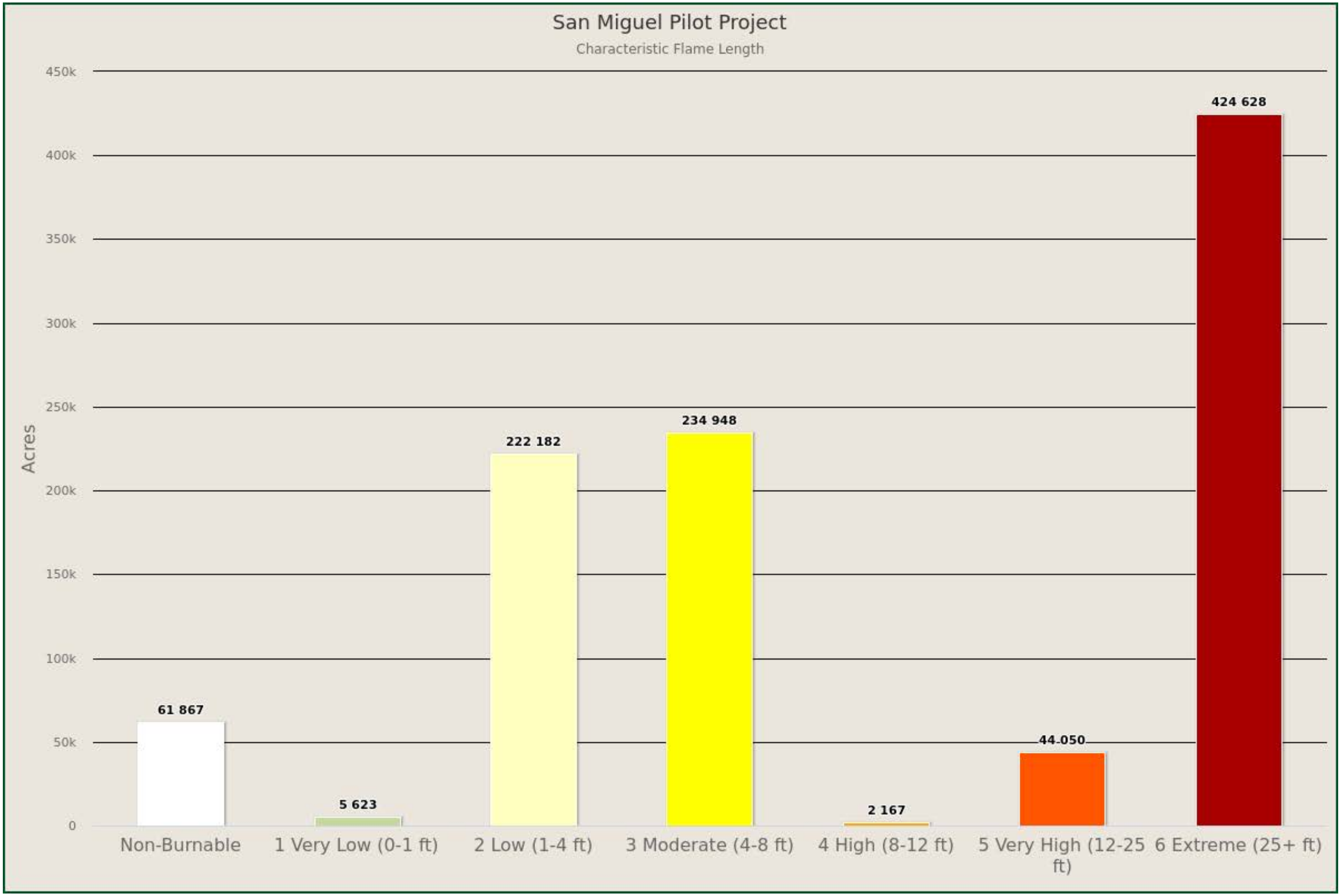
**Characteristic Flame Length is the typical or representative flame length of a potential fire based on a weighted average of four percentile weather categories.** Flame Length is defined as the distance between the flame tip and the midpoint of the flame depth at the base of the flame, which is generally the ground surface. It is an indicator of fire intensity and is often used to estimate how much heat the fire is generating. Flame length is typically measured in feet (ft). Flame length is the measure of fire intensity used to generate the Fire Effects outputs for the Colorado WRA.



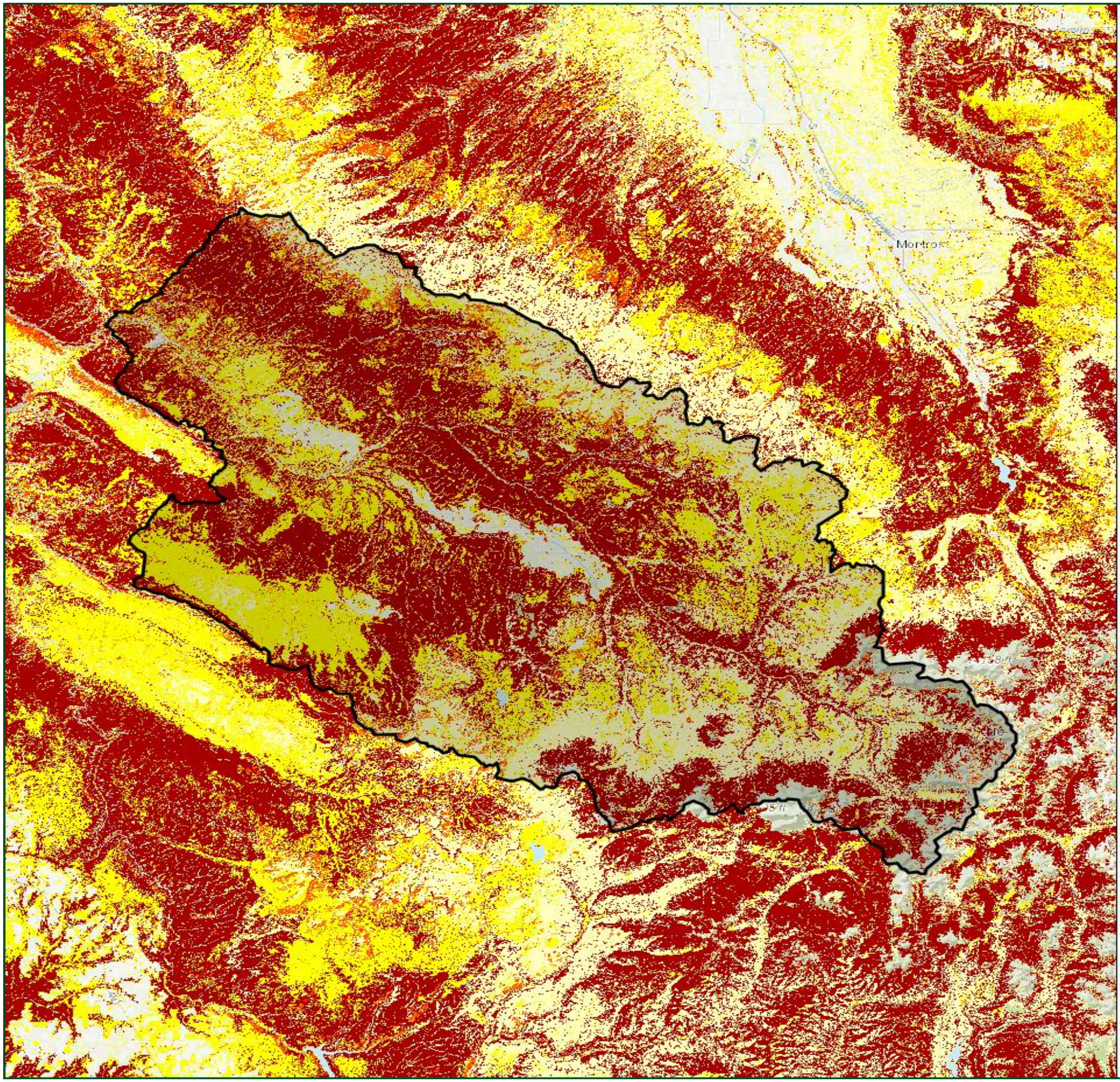

Flame length is a fire behavior output, which is influenced by three environmental factors - fuels, weather, and topography. Weather is by far the most dynamic variable as it changes frequently. To account for this variability, four percentile weather categories were created from historical weather observations to represent low, moderate, high, and extreme weather days for each 30-meter cell in Colorado.

This output represents the weighted average for all four weather percentiles. While not shown in this report, the individual percentile weather Flame Length outputs are available in the Colorado WRA data.

| Flame Length | Acres | Percent |
|---|---|---|
| Non-Burnable | 61,867 | 6.2 % |
| 1 Very Low (0-1 ft) | 5,623 | 0.6 % |
| 2 Low (1-4 ft) | 222,182 | 22.3 % |
| 3 Moderate (4-8 ft) | 234,948 | 23.6 % |
| 4 High (8-12 ft) | 2,167 | 0.2 % |
| 5 Very High (12-25 ft) | 44,050 | 4.4 % |
| 6 Extreme (25+ ft) | 424,628 | 42.7 % |
| **Total** | **995,463** | **100 %** |



San Miguel Pilot Project
Characteristic Flame Length
Acres
450k
400k
350k
300k
250k
200k
150k
100k
50k
0
424 628
234 948
222 182
61 867
44 050
5 623
2 167
Non-Burnable
1 Very Low (0-1 ft)
2 Low (1-4 ft)
3 Moderate (4-8 ft)
4 High (8-12 ft)
5 Very High (12-25 ft)
6 Extreme (25+ ft)




**San Miguel Pilot Project**

**Characteristic Flame Length**

- Non-Burnable
- 1 Very Low (0-1 ft)
- 2 Low (1-4 ft)
- 3 Moderate (4-8 ft)
- 4 High (8-12 ft)
- 5 Very High (12-25 ft)

10 mi

N
S

COLORADO STATE FOREST SERVICE

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Fire Intensity Scale

## Description

**Fire Intensity Scale (FIS) specifically identifies areas where significant fuel hazards and associated dangerous fire behavior potential exist.** Similar to the Richter scale for earthquakes, FIS provides a standard scale to measure potential wildfire intensity. FIS consist of five (5) classes where the order of magnitude between classes is ten-fold. The minimum class, Class 1, represents very low wildfire intensities and the maximum class, Class 5, represents very high wildfire intensities.

1. **Class 1, Lowest Intensity:**

   Very small, discontinuous flames, usually less than 1 foot in length; very low rate of spread; no spotting. Fires are typically easy to suppress by firefighters with basic training and non-specialized equipment.

2. **Class2, Low:**

   Small flames, usually less than two feet long; small amount of very short-range spotting possible. Fires are easy to suppress by trained firefighters with protective equipment and specialized tools.

3. **Class 3, Moderate:**

   Flames up to 8 feet in length; short-range spotting is possible. Trained firefighters will find these fires difficult to suppress without support from aircraft or engines, but dozer and plows are generally effective. Increasing potential for harm or damage to life and property.

4. **Class 4, High:**

   Large Flames, up to 30 feet in length; short-range spotting 1. common; medium range spotting possible. Direct attack by trained firefighters, engines, and dozers is generally ineffective, indirect attack may be effective. Significant potential for harm or damage to life and property.

5. **Class 5, Highest Intensity:**

   Very large flames up to 150 feet in length; profuse short-range spotting, frequent long-range spotting; strong fire-induced winds. Indirect attack marginally effective at the head of the fire. Great potential for harm or damage to life and property.

Burn Probability and Fire Intensity Scale are designed to complement each other. The Fire Intensity Scale does not incorporate historical occurrence information. It only evaluates the potential fire behavior for an area, regardless if any fires have occurred there in the past. This additional information allows mitigation planners to quickly identify areas where dangerous fire behavior potential exists in relationship to nearby homes or other valued assets.

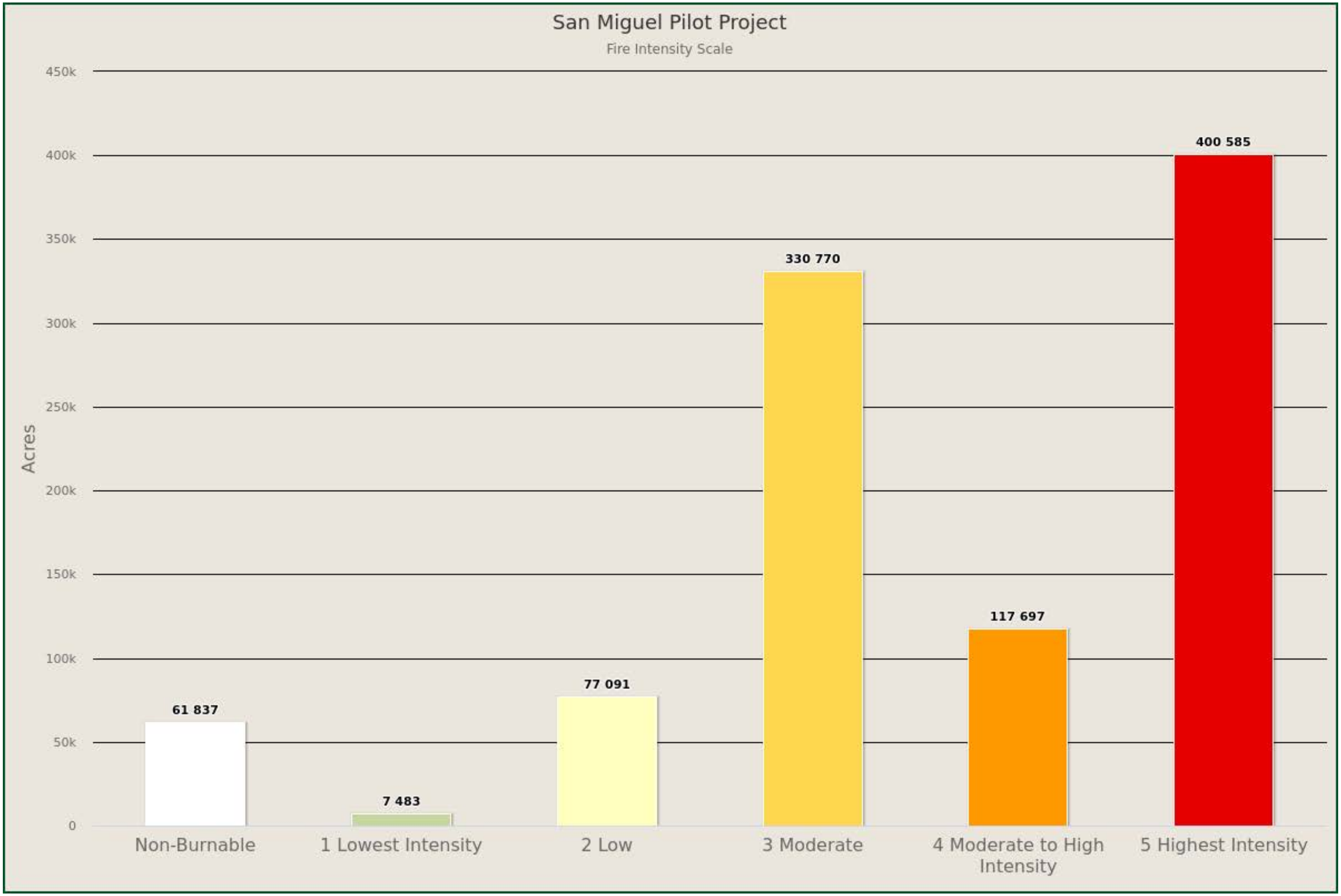
Since all areas in Colorado have fire intensity scale calculated consistently, it allows for comparison and ordination of areas across the entire state. For example, a high fire intensity area in Eastern Colorado is equivalent to a high fire intensity area in Western Colorado.

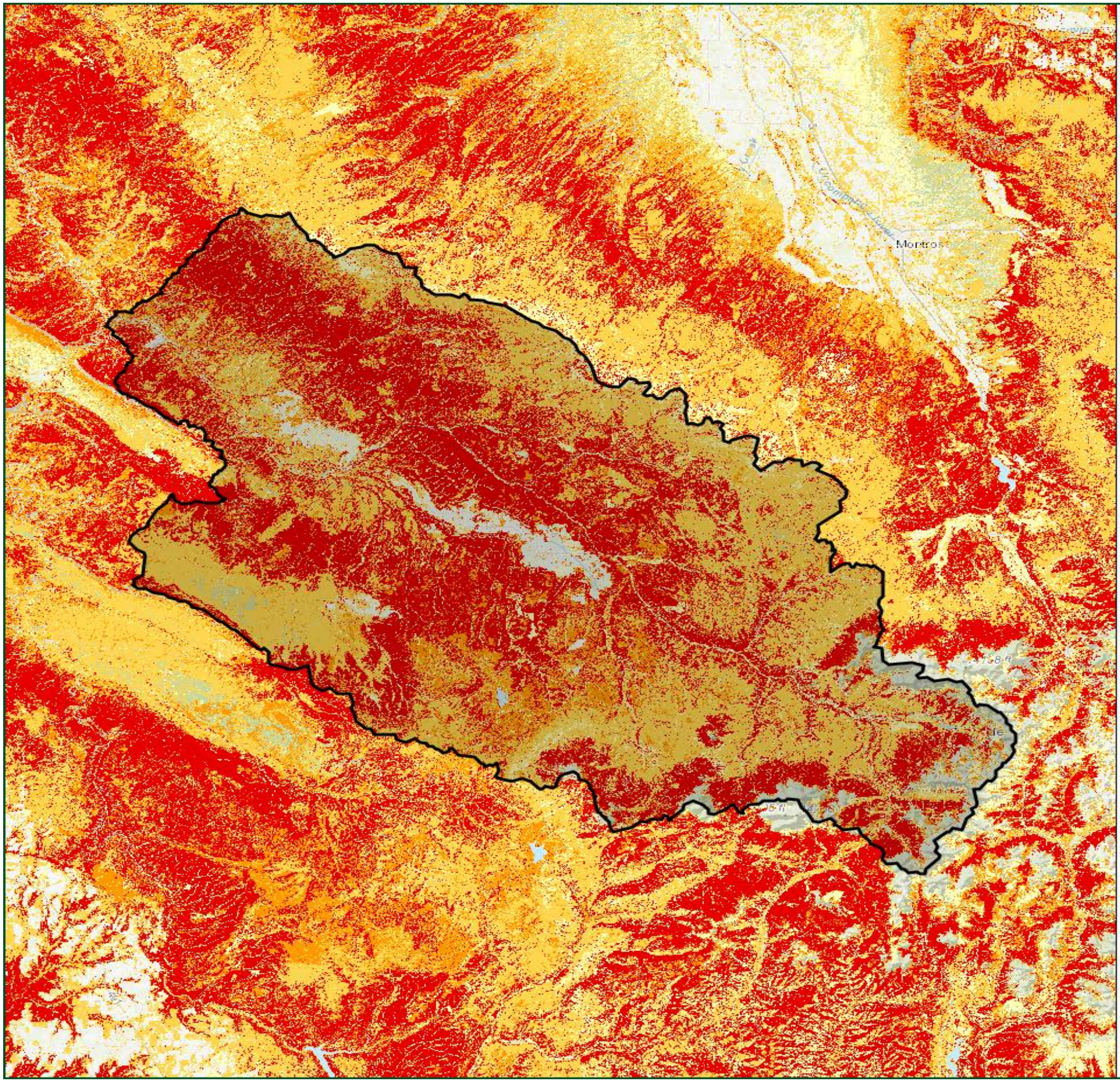
Fire intensity scale is a fire behavior output, which is influenced by three environmental factors - fuels, weather, and topography. Weather is by far the most dynamic variable as it changes frequently.

To account for this variability, four percentile weather categories were created from historical weather observations to represent low, moderate, high, and extreme weather days for each 30-meter cell in Colorado. The FIS represents the weighted average for all four weather percentiles.

The fire intensity scale map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not appropriate for site specific analysis, it is appropriate for regional, county or local planning efforts.

| FIS Class | Acres | Percent |
|---|---|---|
| Non-Burnable | 61,837 | 6.2 % |
| 1 Lowest Intensity | 7,483 | 0.8 % |
| 2 Low | 77,091 | 7.7 % |
| 3 Moderate | 330,770 | 33.2 % |
| 4 Moderate to High Intensity | 117,697 | 11.8 % |
| 5 Highest Intensity | 400,585 | 40.2 % |
| **Total** | **995,463** | **100 %** |


San Miguel Pilot Project
Fire Intensity Scale
Acres
450k
400k
350k
300k
250k
200k
150k
100k
50k
0
61 837
7 483
77 091
330 770
117 697
400 585
Non-Burnable
1 Lowest Intensity
2 Low
3 Moderate
4 Moderate to High Intensity
5 Highest Intensity



**San Miguel Pilot Project**

**Fire Intensity Scale**

- Non-Burnable
- 1 Lowest Intensity
- 2 Low
- 3 Moderate
- 4 Moderate to High Intensity
- 5 Highest Intensity

10 mi

N
S

COLORADO STATE FOREST SERVICE

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Fire Type – Extreme Weather

**Fire Type – Extreme represents the potential fire type under the extreme percentile weather category.** The extreme percentile weather category represents the average weather based on the top three percent fire weather days in the analysis period. It is not intended to represent a worst-case scenario weather event. Accordingly, the potential fire type is based on fuel conditions, extreme percentile weather, and topography.

Canopy fires are very dangerous, destructive and difficult to control due to their increased fire intensity. From a planning perspective, it is important to identify where these conditions are likely to occur on the landscape so that special preparedness measure can be taken if necessary. Typically canopy fires occur in extreme weather conditions. The Fire Type – Extreme layer shows the footprint of where these areas are most likely to occur. However, it is important to note that canopy fires are not restricted to these areas. Under the right conditions, it can occur in other canopied areas.

There are two primary fire types – surface fire and canopy fire. Canopy fire can be further subdivided into passive canopy fire and active canopy fire. A short description of each of these is provided below.

**Surface Fire**

A fire that spreads through surface fuel without consuming any overlying canopy fuel. Surface fuels include grass, timber litter, shrub/brush, slash and other dead or live vegetation within about 6 feet of the ground.

**Passive Canopy Fire**

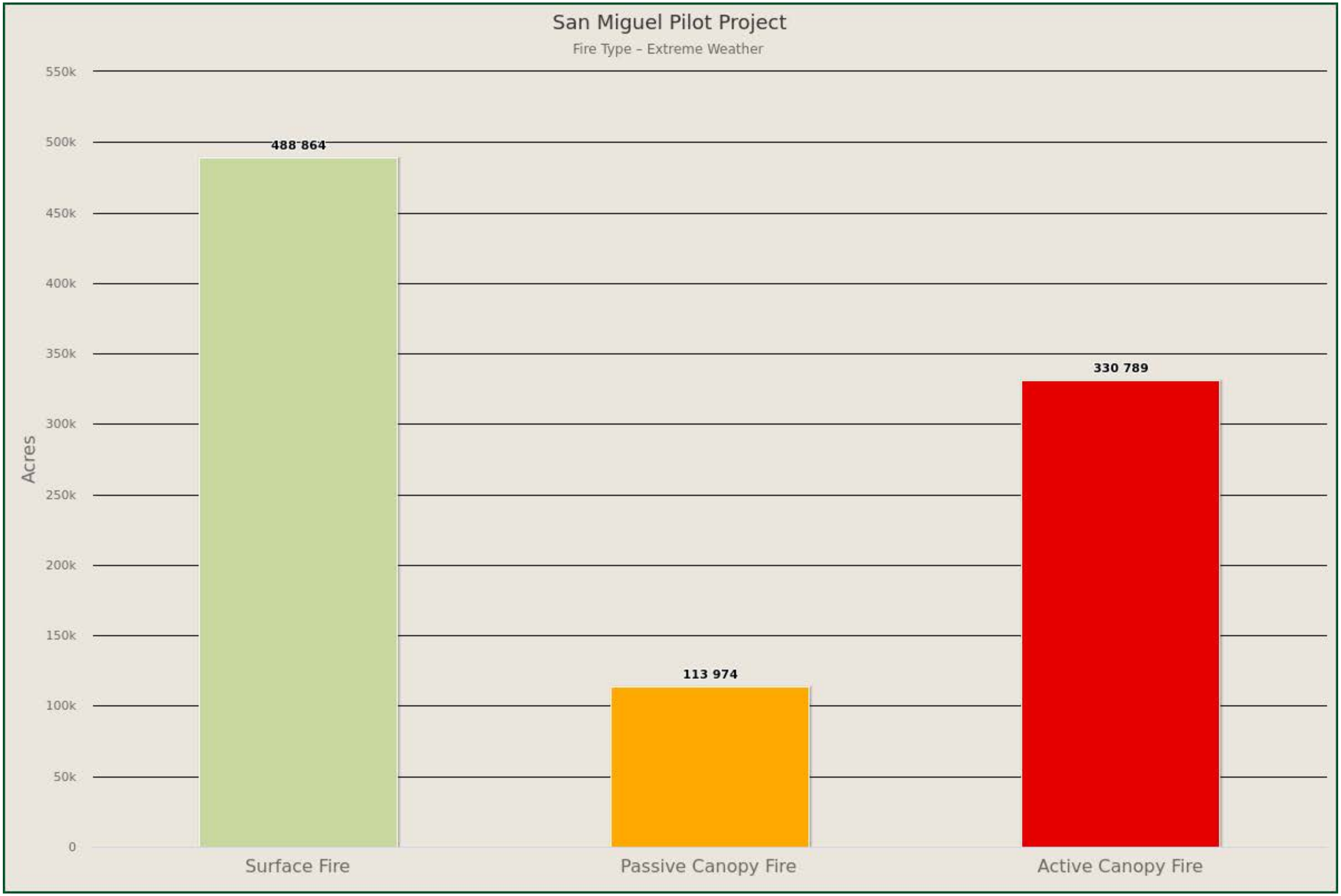
A type of crown fire in which the crowns of individual trees or small groups of trees burn, but solid flaming in the canopy cannot be maintained except for short periods (Scott & Reinhardt, 2001).

**Active Canopy Fire**

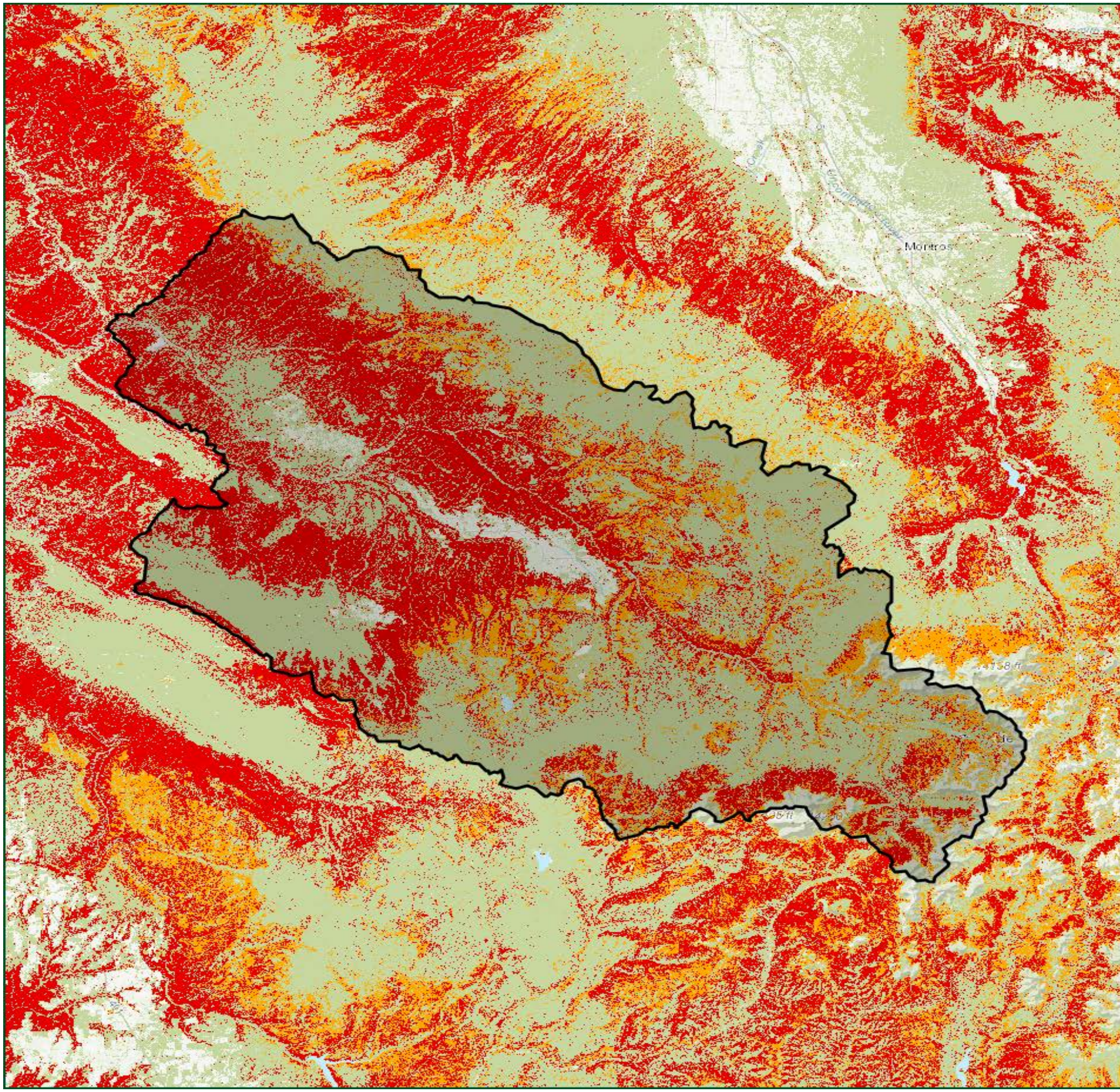
A crown fire in which the entire fuel complex (canopy) is involved in flame, but the crowning phase remains dependent on heat released from surface fuel for continued spread (Scott & Reinhardt, 2001).

The Fire Type - Extreme Weather map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not appropriate for site specific analysis, it is appropriate for regional, county or local planning efforts.

| Fire Type - Extreme Weather | Acres | Percent |
|---|---|---|
| Surface Fire | 488,864 | 52.4 % |
| Passive Canopy Fire | 113,974 | 12.2 % |
| Active Canopy Fire | 330,789 | 35.4 % |
| **Total** | **933,627** | **100 %** |


San Miguel Pilot Project
Fire Type – Extreme Weather
Acres
550k
500k
450k
400k
350k
300k
250k
200k
150k
100k
50k
0
488 864
113 974
330 789
Surface Fire
Passive Canopy Fire
Active Canopy Fire

## San Miguel Pilot Project




**Fire Type Extreme Weather**

- Surface Fire
- Passive Canopy Fire
- Active Canopy Fire

10 mi

N
S

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Surface Fuels

## Description

Surface fuels, or fire behavior fuel models as they are technically referred to, contain the parameters required by the Rothermel (1972) surface fire spread model to compute surface fire behavior characteristics, including rate of spread, flame length, fireline intensity and other fire behavior metrics. As the name might suggest, surface fuels account only for surface fire potential. Canopy fire potential is computed through a separate but linked process. The Colorado WRA accounts for both surface and canopy fire potential in the fire behavior outputs. However, only surface fuels are shown in this risk report.

Surface fuels typically are categorized into one of four primary fuel types based on the primary carrier of the surface fire: 1) grass, 2) shrub/brush, 3) timber litter, and 4) slash. Two standard fire behavior fuel model sets have been published. The Fire Behavior Prediction System 1982 Fuel Model Set (Anderson, 1982) contains 13 fuel models, and the Fire Behavior Prediction System 2005 Fuel Model Set (Scott & Burgan, 2005) contains 40 fuel models. The Colorado WRA uses fuel models from the 2005 Fuel Model Set.

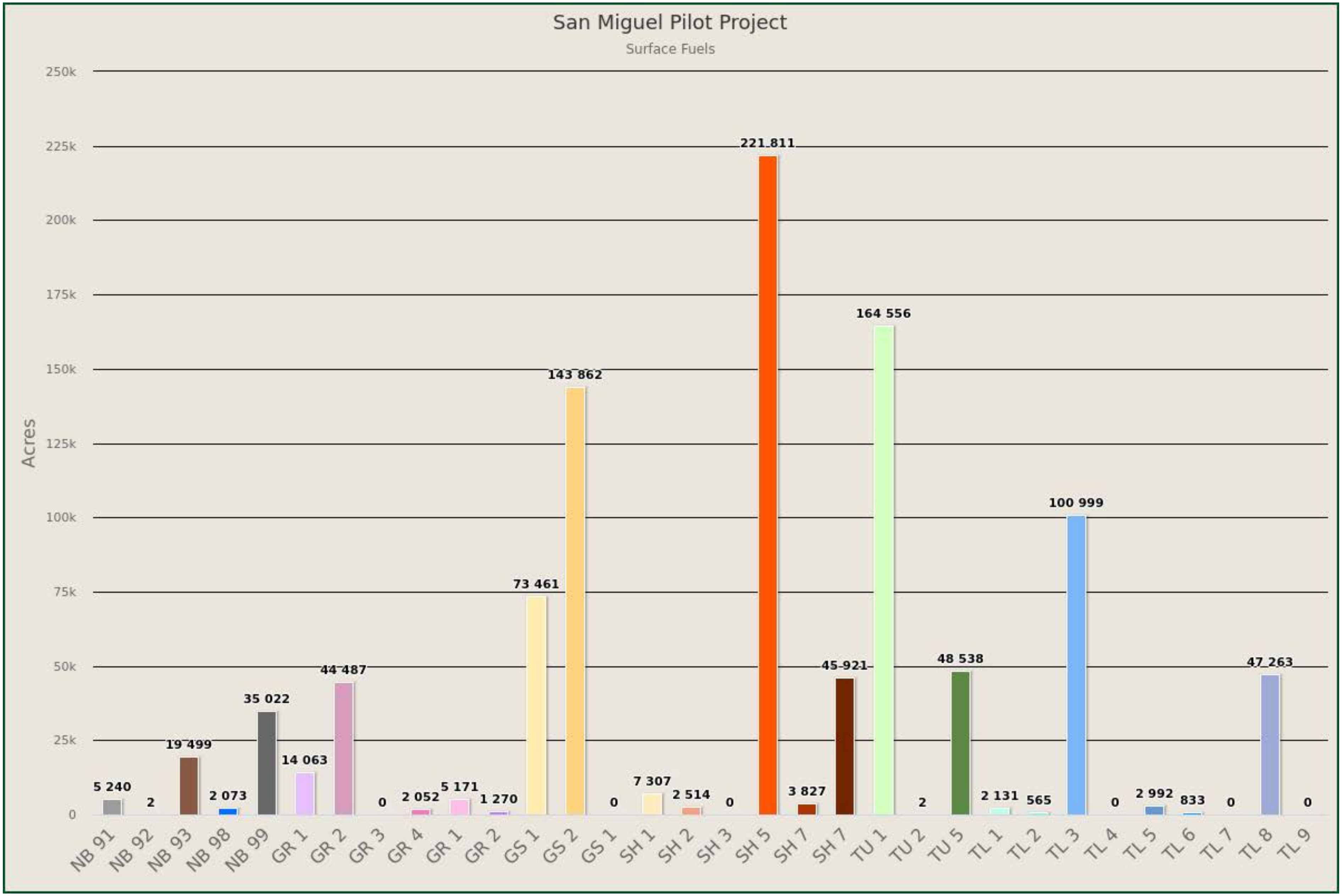
Unmanaged forest with dead and downed trees and branches

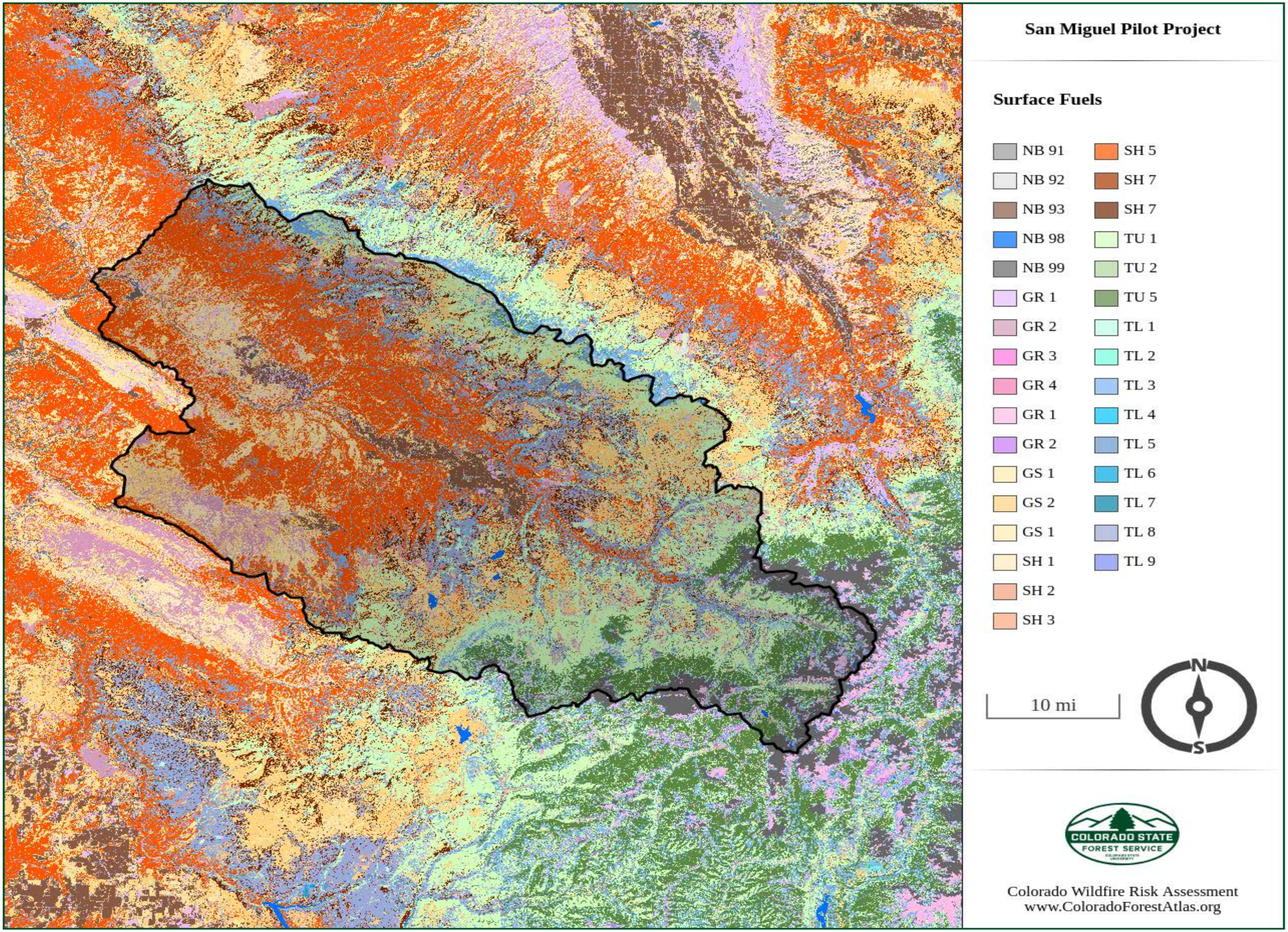
Slash on the ground indicates that forest management treatments have occurred in this area

The 2017 Colorado Surface Fuels were derived by enhancing the baseline LANDFIRE 2014 products with modifications to reflect local conditions and knowledge. A team of fuels and fire behavior experts, led by the CSFS, conducted a detailed calibration of the LANDFIRE 2014 fuels datasets. This calibration involved correcting LANDFIRE mapping zone seamlines errors; adding recent disturbances from 2013 to 2017 for fires, insect and disease, and treatments; correcting fuels for high elevations; adjusting fuels for oak-shrublands and pinyon-juniper areas; and modifying SH7 fuel designations. This calibration effort resulted in an accurate and up-to-date surface fuels dataset that is the basis for the fire behavior and risk calculations in the 2017 Colorado Wildfire Risk Assessment Update.

A detailed description of the fuels calibration methods and results is provided in the CSFS 2017 Fuels Calibration Final Report (July 2018).

| Surface Fuels | | Description | Acres | Percent |
|---|---|---|---|---|
| | NB 91 | Urban/Developed | 5,240 | 0.5 % |
| | NB 92 | Snow/Ice | 2 | 0.0 % |
| | NB 93 | Agriculture | 19,499 | 2.0 % |
| | NB 98 | Water | 2,073 | 0.2 % |
| | NB 99 | Barren | 35,022 | 3.5 % |
| | GR 1 | Short, sparse, dry climate grass | 14,063 | 1.4 % |
| | GR 2 | Low load, dry climate grass | 44,487 | 4.5 % |
| | GR 3 | Low load, very coarse, humid climate grass | 0 | 0 % |
| | GR 4 | Moderate load, dry climate grass | 2,052 | 0.2 % |
| | GR 1 | GT 10,000 ft elevation | 5,171 | 0.5 % |
| | GR 2 | GT 10,000 ft elevation | 1,270 | 0.1 % |
| | GS 1 | Low load, dry climate grass-shrub | 73,461 | 7.4 % |
| | GS 2 | Moderate load, dry climate grass-shrub | 143,862 | 14.5 % |
| | GS 1 | GT 10,000 ft elevation | 0 | 0 % |
| | SH 1 | Low load, dry climate shrub | 7,307 | 0.7 % |
| | SH 2 | Moderate load, dry climate shrub | 2,514 | 0.3 % |
| | SH 3 | Moderate load, humid climate shrub | 0 | 0 % |
| | SH 5 | High load, humid climate shrub | 221,811 | 22.3 % |
| | SH 7 | Very high load, dry climate shrub | 3,827 | 0.4 % |
| | SH 7 | Oak Shrubland without changes | 45,921 | 4.6 % |
| | TU 1 | Light load, dry climate timber-grass-shrub | 164,556 | 16.5 % |
| | TU 2 | Moderate load, humid climate timber-shrub | 2 | 0.0 % |
| | TU 5 | Very high load, dry climate timber-shrub | 48,538 | 4.9 % |
| | TL 1 | Low load, compact conifer litter | 2,131 | 0.2 % |
| | TL 2 | Low load, broadleaf litter | 565 | 0.1 % |
| | TL 3 | Moderate load, conifer litter | 100,999 | 10.1 % |
| | TL 4 | Small downed logs | 0 | 0 % |
| | TL 5 | High load, conifer litter | 2,992 | 0.3 % |
| | TL 6 | Moderate load, broadleaf litter | 833 | 0.1 % |
| | TL 7 | Large downed logs | 0 | 0 % |
| | TL 8 | Long-needle litter | 47,263 | 4.7 % |
| | TL 9 | Very high load, broadleaf litter | 0 | 0.0 % |
| **Total** | | | **995,463** | **100 %** |


San Miguel Pilot Project
Surface Fuels
Acres
250k
225k
200k
175k
150k
125k
100k
75k
50k
25k
0
5 240
2
19 499
2 073
35 022
14 063
44 487
0
2 052
5 171
1 270
73 461
143 862
0
7 307
2 514
0
221 811
3 827
45 921
164 556
2
48 538
2 131
565
100 999
0
2 992
833
0
47 263
0
NB 91
NB 92
NB 93
NB 98
NB 99
GR 1
GR 2
GR 3
GR 4
GR 1
GR 2
GS 1
GS 2
GS 1
SH 1
SH 2
SH 3
SH 5
SH 7
SH 7
TU 1
TU 2
TU 5
TL 1
TL 2
TL 3
TL 4
TL 5
TL 6
TL 7
TL 8
TL 9


San Miguel Pilot Project
Surface Fuels
NB 91
NB 92
NB 93
NB 98
NB 99
GR 1
GR 2
GR 3
GR 4
GR 1
GR 2
GS 1
GS 2
GS 1
SH 1
SH 2
SH 3
SH 5
SH 7
SH 7
TU 1
TU 2
TU 5
TL 1
TL 2
TL 3
TL 4
TL 5
TL 6
TL 7
TL 8
TL 9
10 mi
N
S
COLORADO STATE
FOREST SERVICE
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Vegetation

## Description

**The Vegetation map describes the general vegetation and landcover types across the state of Colorado**. In the Colorado WRA, the Vegetation dataset is used to support the development of the Surface Fuels, Canopy Cover, Canopy Stand Height, Canopy Base Height, and Canopy Bulk Density datasets.

The LANDFIRE 2014 version of data products (Existing Vegetation Type) was used to compile the Vegetation data for the Colorado WRA. This reflects data current to 2014. The LANDFIRE EVT data were classified to reflect general vegetation cover types for representation with CO-WRAP.

Oak shrublands are commonly found along dry foothills and lower mountain slopes, and are often situated above Piñyon-juniper.

Piñyon-juniper woodlands are common in southern and southwestern Colorado.

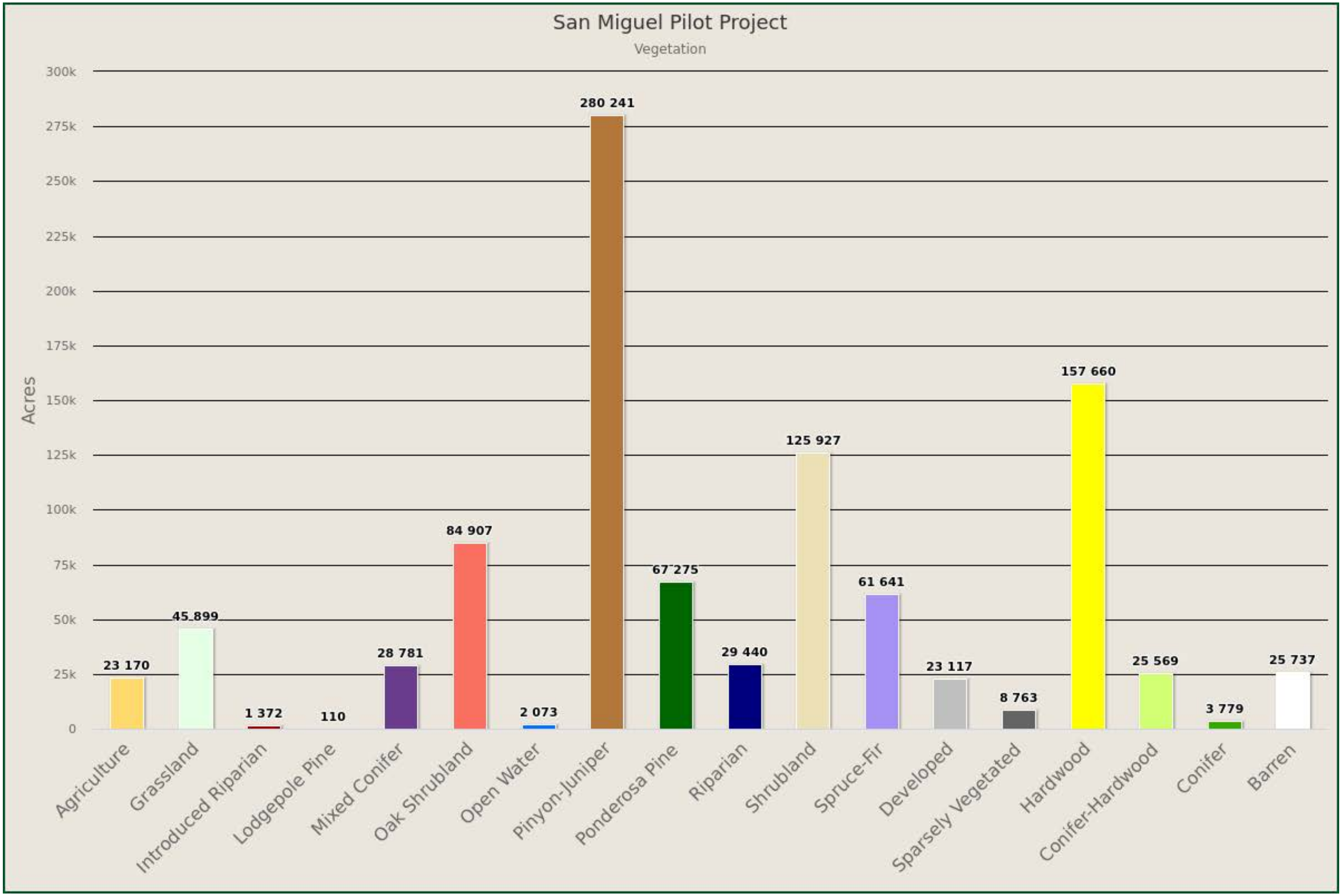
Douglas-fir understory in a ponderosa pine forest.

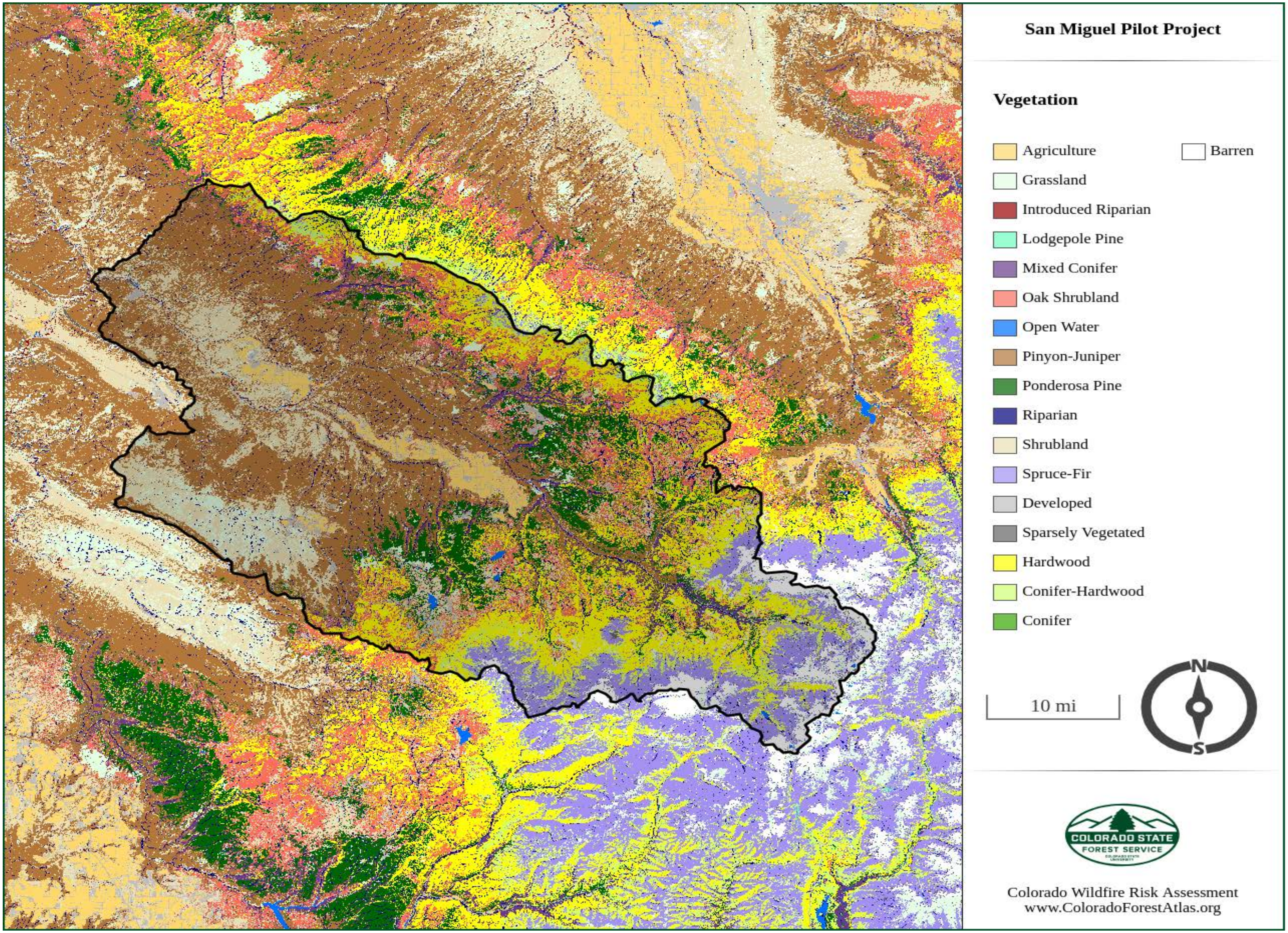
Grasslands occur both on Colorado's Eastern Plains and on the Western Slope.

Wildland fire threat increases in lodgepole pine as the dense forests grow old.

Overly dense ponderosa pine, a dominant species of the montane zone.

| Vegetation Class | | Acres | Percent |
|---|---|---|---|
| | Agriculture | 23,170 | 2.3 % |
| | Grassland | 45,899 | 4.6 % |
| | Introduced Riparian | 1,372 | 0.1 % |
| | Lodgepole Pine | 110 | 0.0 % |
| | Mixed Conifer | 28,781 | 2.9 % |
| | Oak Shrubland | 84,907 | 8.5 % |
| | Open Water | 2,073 | 0.2 % |
| | Pinyon-Juniper | 280,241 | 28.2 % |
| | Ponderosa Pine | 67,275 | 6.8 % |
| | Riparian | 29,440 | 3.0 % |
| | Shrubland | 125,927 | 12.7 % |
| | Spruce-Fir | 61,641 | 6.2 % |
| | Developed | 23,117 | 2.3 % |
| | Sparsely Vegetated | 8,763 | 0.9 % |
| | Hardwood | 157,660 | 15.8 % |
| | Conifer-Hardwood | 25,569 | 2.6 % |
| | Conifer | 3,779 | 0.4 % |
| | Barren | 25,737 | 2.6 % |
| **Total** | | **995,463** | **100 %** |


San Miguel Pilot Project
Vegetation
Acres
300k
275k
250k
225k
200k
175k
150k
125k
100k
75k
50k
25k
0
23 170
45 899
1 372
110
28 781
84 907
2 073
280 241
67 275
29 440
125 927
61 641
23 117
8 763
157 660
25 569
3 779
25 737
Agriculture
Grassland
Introduced Riparian
Lodgepole Pine
Mixed Conifer
Oak Shrubland
Open Water
Pinyon-Juniper
Ponderosa Pine
Riparian
Shrubland
Spruce-Fir
Developed
Sparsely Vegetated
Hardwood
Conifer-Hardwood
Conifer
Barren


San Miguel Pilot Project
Vegetation
Agriculture
Barren
Grassland
Introduced Riparian
Lodgepole Pine
Mixed Conifer
Oak Shrubland
Open Water
Pinyon-Juniper
Ponderosa Pine
Riparian
Shrubland
Spruce-Fir
Developed
Sparsely Vegetated
Hardwood
Conifer-Hardwood
Conifer
10 mi
N
S
COLORADO STATE FOREST SERVICE
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Drinking Water Importance Areas

## Description

**Drinking Water Importance Areas is the measure of quality and quantity of public surface drinking water categorized by watershed.** This layer identifies an index of surface drinking water importance, reflecting a measure of water quality and quantity, characterized by Hydrologic Unit Code 12 (HUC 12) watersheds. The Hydrologic Unit system is a standardized watershed classification system developed by the USGS. Areas that are a source of drinking water are of critical importance and adverse effects from fire are a key concern.

The U.S. Forest Service Forests to Faucets (F2F) project is the primary source of the drinking water data set. This project used GIS modeling to develop an index of importance for supplying drinking water using HUC 12 watersheds as the spatial resolution. Watersheds are ranked from 1 to 100 reflecting relative level of importance, with 100 being the most important and 1 the least important.

Several criteria were used in the F2F project to derive the importance rating including water supply, flow analysis, and downstream drinking water demand. The final model of surface drinking water importance used in the F2F project combines the drinking water protection model, capturing the flow of water and water demand, with a model of mean annual water supply.

The values generated by the drinking water protection model are simply multiplied by the results of the model of mean annual water supply to create the final surface drinking water importance index.

Water is critical to sustain life. Human water usage has further complicated nature's already complex aquatic system. Plants, including trees, are essential to the proper functioning of water movement within the environment. Forests receive precipitation, utilize it for their sustenance and growth, and influence its storage and/or passage to other parts of the environment.

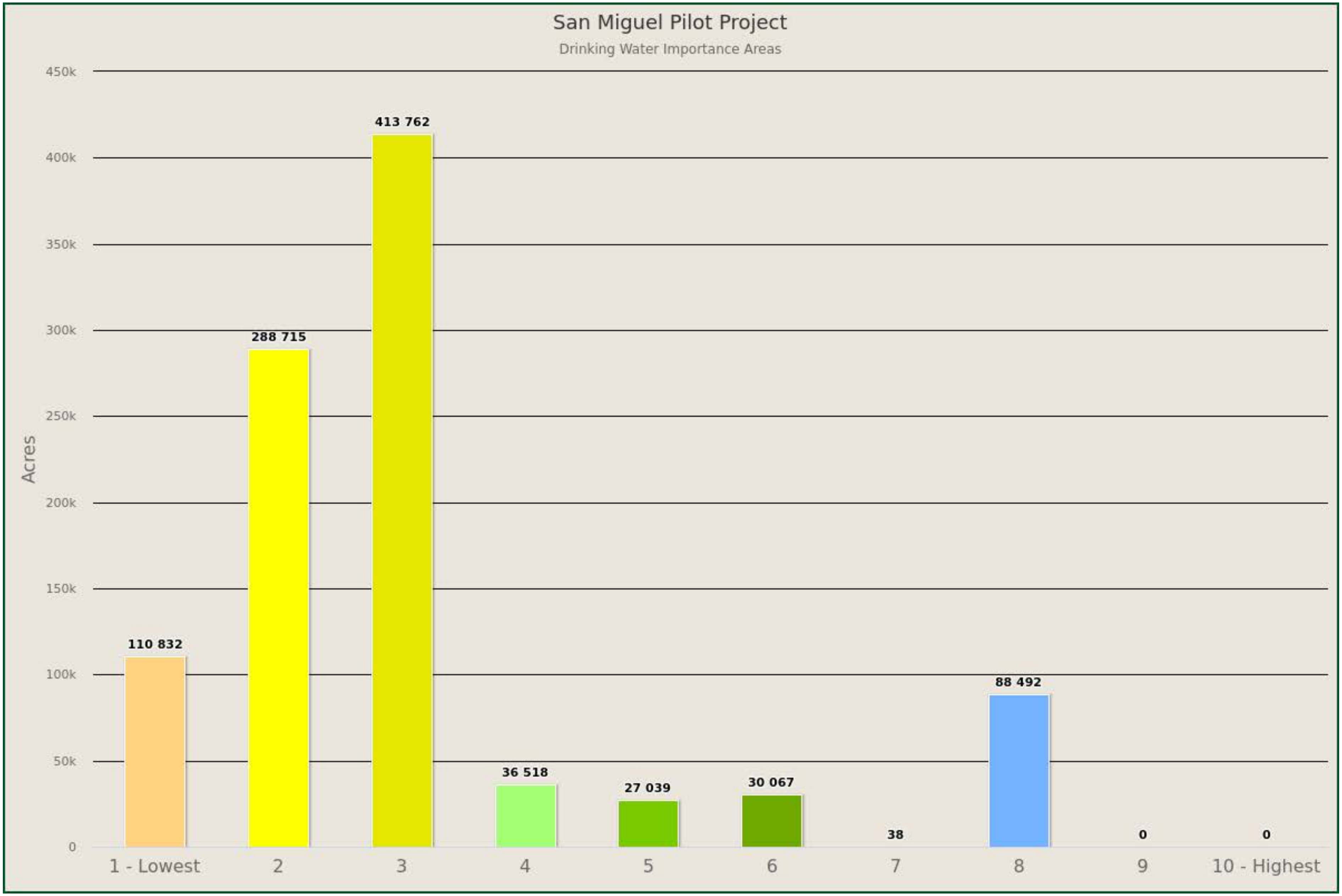
Four major river systems – the Platte, Colorado, Arkansas and Rio Grande – originate in the Colorado mountains and fully drain into one-third of the landmass of the lower 48 states. Mountain snows supply 75 percent of the water to these river systems.

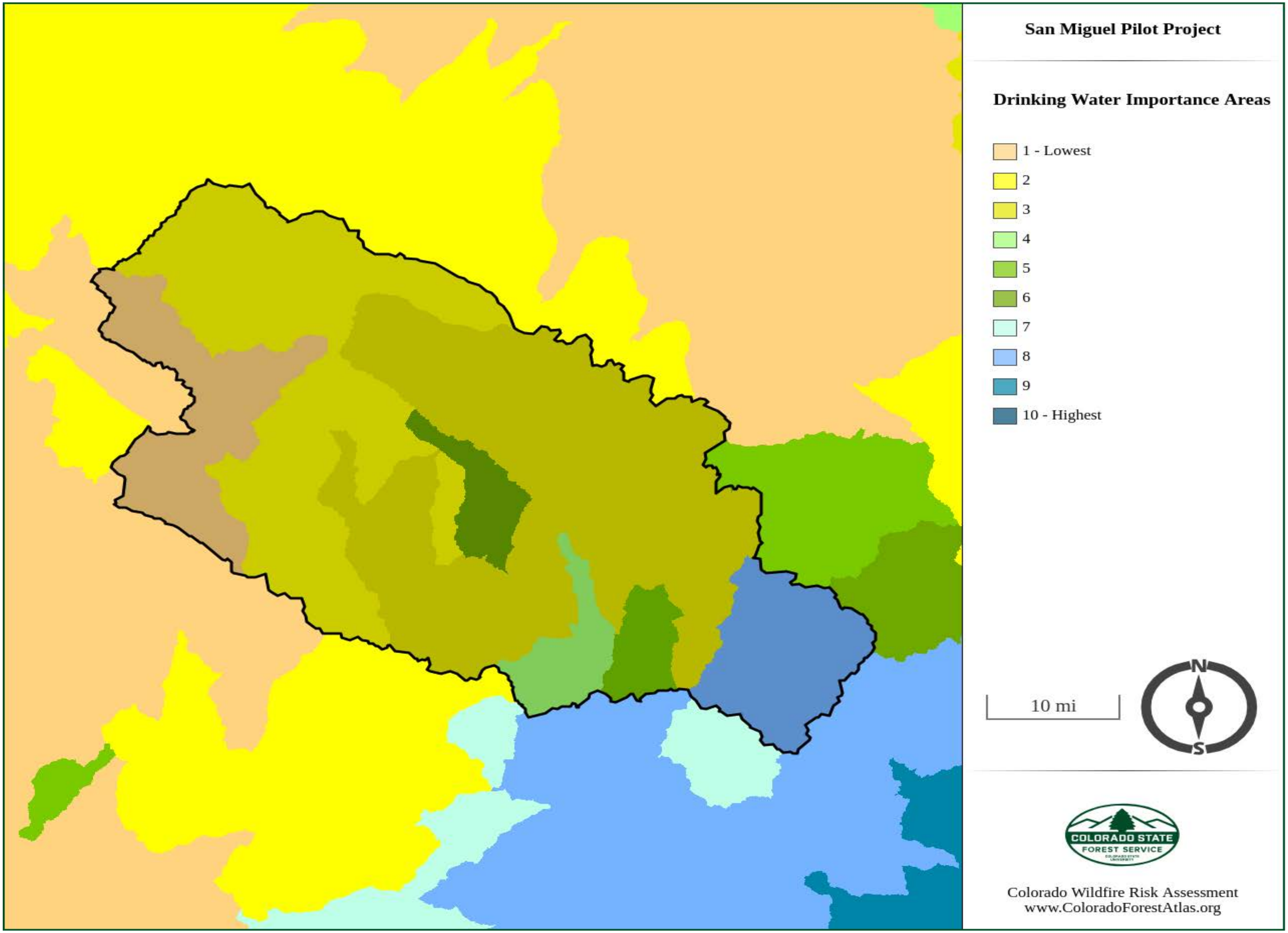
Virtually all of Colorado's drinking water comes from snowmelt carried at some point by a river.

The headwaters of the Animas River begin near Silverton, CO at elevations greater than 12,000 feet.

Approximately 40 percent of the water comes from the highest 20 percent of the land, most of which lies in national forests. National forests yield large portions of the total water in these river systems. The potential is great for forests to positively and negatively influence the transport of water over such immense distances.

| Drinking Water Class | Acres | Percent |
|---|---|---|
| 1 - Lowest | 110,832 | 11.1 % |
| 2 | 288,715 | 29.0 % |
| 3 | 413,762 | 41.6 % |
| 4 | 36,518 | 3.7 % |
| 5 | 27,039 | 2.7 % |
| 6 | 30,067 | 3.0 % |
| 7 | 38 | 0.0 % |
| 8 | 88,492 | 8.9 % |
| 9 | 0 | 0 % |
| 10 - Highest | 0 | 0 % |
| **Total** | **995,463** | **100 %** |


San Miguel Pilot Project
Drinking Water Importance Areas
Acres
450k
400k
350k
300k
250k
200k
150k
100k
50k
0
110 832
288 715
413 762
36 518
27 039
30 067
38
88 492
0
0
1 - Lowest
2
3
4
5
6
7
8
9
10 - Highest


San Miguel Pilot Project
Drinking Water Importance Areas
1 - Lowest
2
3
4
5
6
7
8
9
10 - Highest
10 mi
N
S
COLORADO STATE
FOREST SERVICE
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Drinking Water Risk Index

## Description

**Drinking Water Risk Index is a measure of the risk to DWIAs based on the potential negative impacts from wildfire.**

In areas that experience low-severity burns, fire events can serve to eliminate competition, rejuvenate growth and improve watershed conditions. But in landscapes subjected to high, or even moderate-burn severity, the post-fire threats to public safety and natural resources can be extreme.

High-severity wildfires remove virtually all forest vegetation – from trees, shrubs and grasses down to discarded needles, decomposed roots and other elements of ground cover or duff that protect forest soils. A severe wildfire also can cause certain types of soil to become hydrophobic by forming a waxy, water-repellent layer that keeps water from penetrating the soil, dramatically amplifying the rate of runoff.

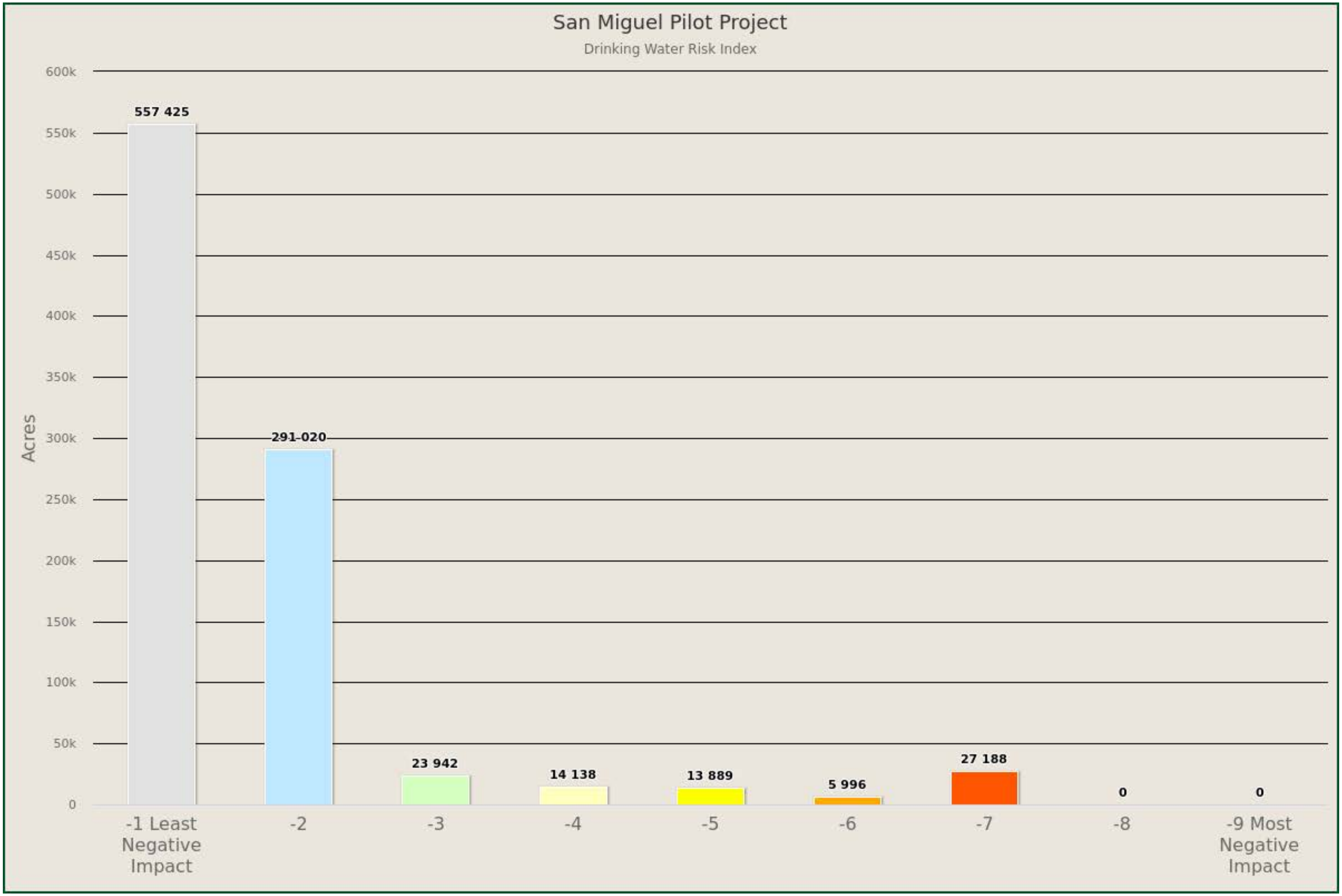
The loss of critical surface vegetation leaves forested slopes extremely vulnerable to large-scale soil erosion and flooding during subsequent storm events. In turn, these threats can impact the health, safety and integrity of communities and natural resources downstream. The likelihood that such a post-fire event will occur in Colorado is increased by the prevalence of highly erodible soils in several parts of the state, and weather patterns that frequently bring heavy rains on the heels of fire season.

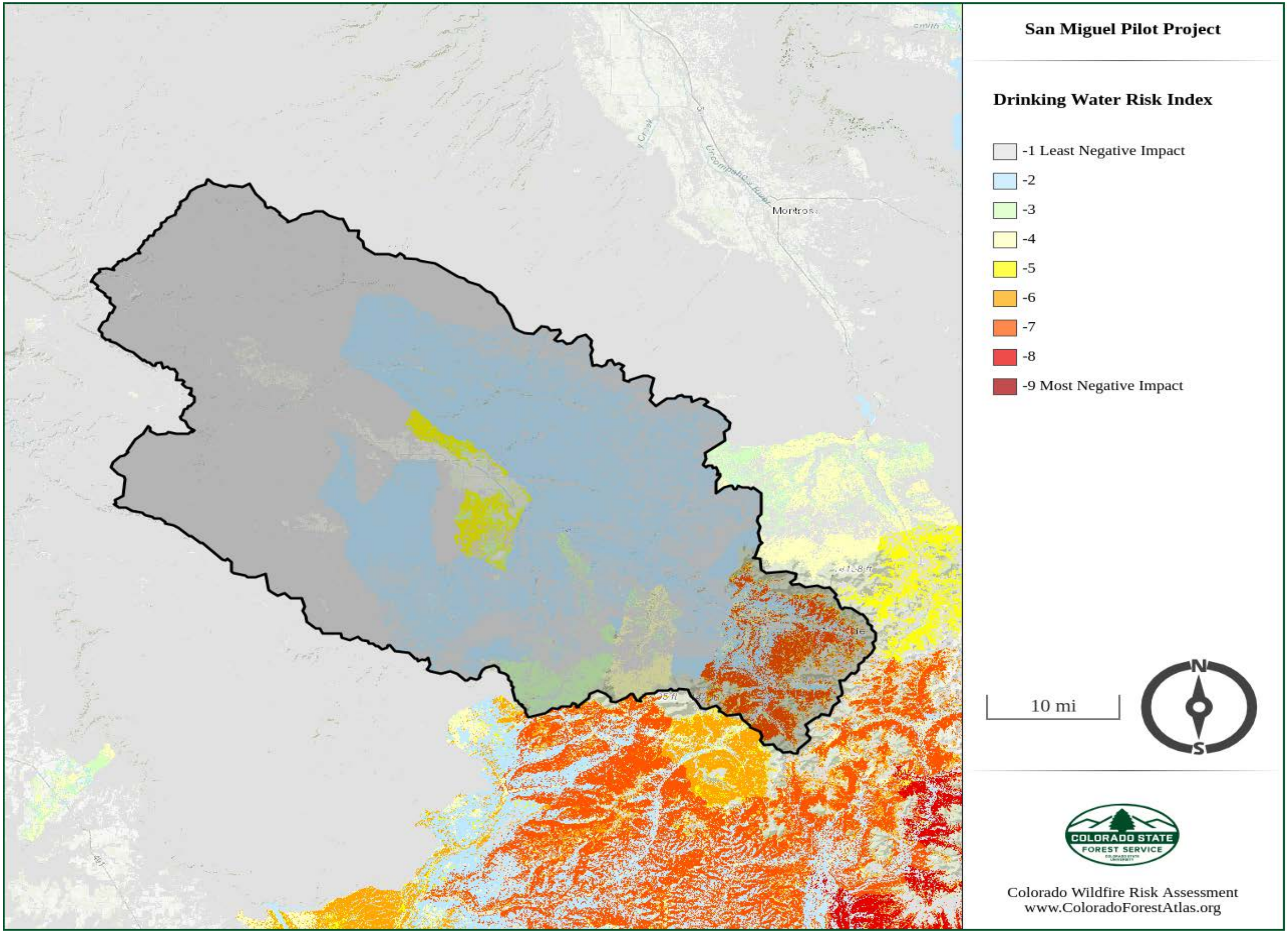
In the aftermath of the 2002 fire season, the Colorado Department of Health estimated that 26 municipal water storage facilities were shut down due to fire and post-fire impacts.

The potential for severe soil erosion is a consequence of wildfire because as a fire burns, it destroys plant material and the litter layer. Shrubs, forbs, grasses, trees and the litter layer disperse water during severe rainstorms. Plant roots stabilize the soil, and stems and leaves slow the water to give it time to percolate into the soil profile. Fire can destroy this soil protection.

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

| Class | Acres | Percent |
|---|---|---|
| -1 Least Negative Impact | 557,425 | 59.7 % |
| -2 | 291,020 | 31.2 % |
| -3 | 23,942 | 2.6 % |
| -4 | 14,138 | 1.5 % |
| -5 | 13,889 | 1.5 % |
| -6 | 5,996 | 0.6 % |
| -7 | 27,188 | 2.9 % |
| -8 | 0 | 0 % |
| -9 Most Negative Impact | 0 | 0 % |
| **Total** | **933,597** | **100 %** |


San Miguel Pilot Project
Drinking Water Risk Index
Acres
600k
550k
500k
450k
400k
350k
300k
250k
200k
150k
100k
50k
0
557 425
291 020
23 942
14 138
13 889
5 996
27 188
0
0
-1 Least Negative Impact
-2
-3
-4
-5
-6
-7
-8
-9 Most Negative Impact


Montrose
Uncompahgre River
San Miguel Pilot Project
Drinking Water Risk Index
-1 Least Negative Impact
-2
-3
-4
-5
-6
-7
-8
-9 Most Negative Impact
10 mi
N
S
COLORADO STATE FOREST SERVICE
Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Riparian Assets

## Description

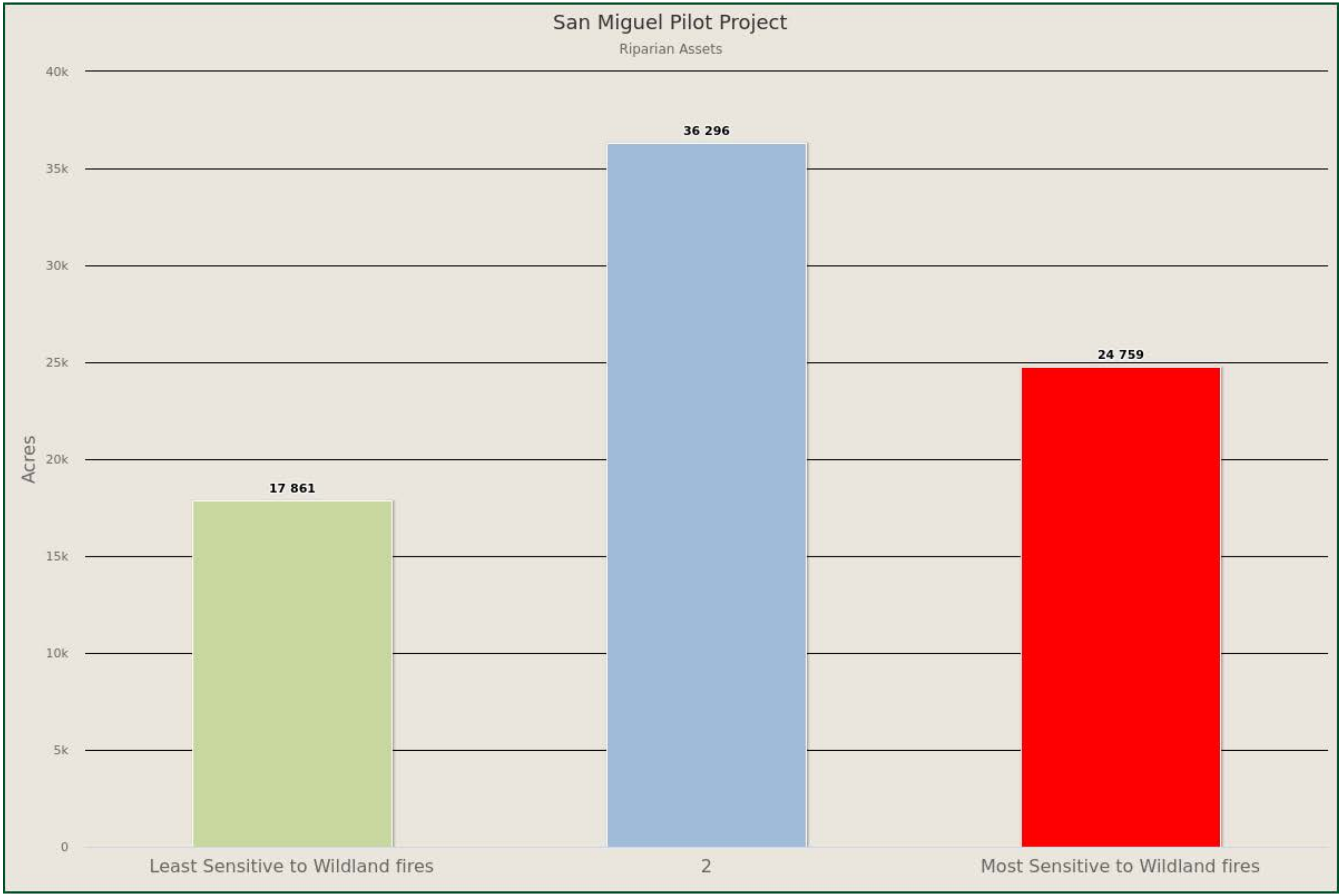
**Riparian Assets are forested riparian areas characterized by functions of water quantity and quality, and ecology**. This layer identifies riparian areas that are important as a suite of ecosystem services, including both terrestrial and aquatic habitat, water quality, water quantity, and other ecological functions. Riparian areas are considered an especially important element of the landscape in the west. Accordingly, riparian assets are distinguished from other forest assets so they can be evaluated separately.

The process for defining these riparian areas involved identifying the riparian footprint and then assigning a rating based upon two important riparian functions – water quantity and quality, and ecological significance. A scientific model was developed by the West Wide Risk Assessment technical team with in-kind support from CAL FIRE state representatives. Several input datasets were used in the model including the National Hydrography Dataset and the National Wetland Inventory.

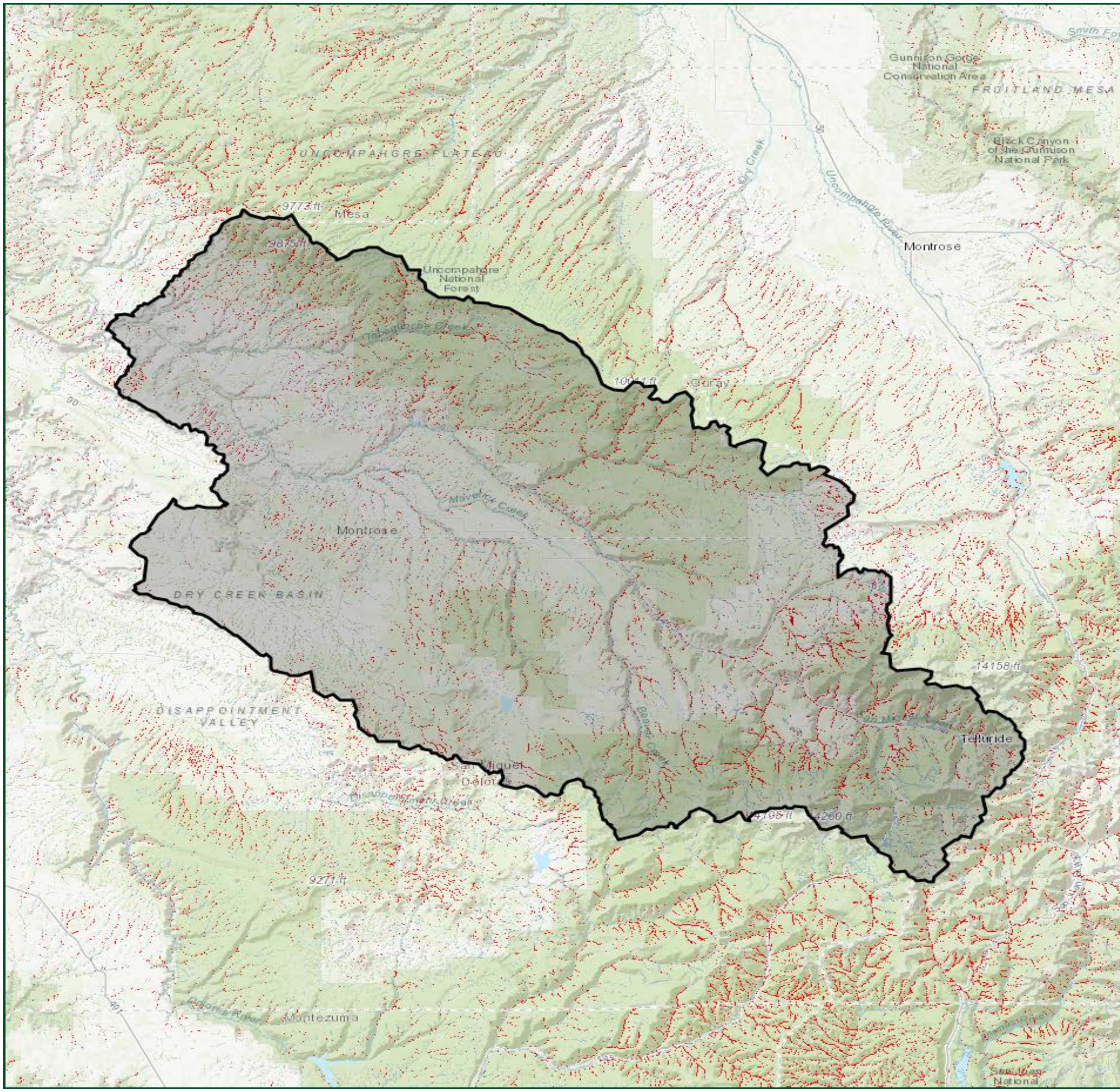
The National Hydrography Data Set (NHD) was used to represent hydrology. A subset of streams and water bodies, which represents perennial, intermittent, and wetlands, was created. The NHD water bodies dataset was used to determine the location of lakes, ponds, swamps, and marshes (wetlands).

To model water quality and quantity, erosion potential (K-factor) and annual average precipitation was used as key variables. The Riparian Assets data are an index of class values that range from 1 to 3 representing increasing importance of the riparian area as well as sensitivity to fire-related impacts on the suite of ecosystem services.

| Riparian Assets Class | Acres | Percent |
|---|---|---|
| Least Sensitive to Wildland fires | 17,861 | 22.6 % |
| 2 | 36,296 | 46.0 % |
| Most Sensitive to Wildland fires | 24,759 | 31.4 % |
| **Total** | **78,916** | **100 %** |


San Miguel Pilot Project
Riparian Assets
Acres
40k
35k
30k
25k
20k
15k
10k
5k
0
17 861
36 296
24 759
Least Sensitive to Wildland fires
2
Most Sensitive to Wildland fires

## San Miguel Pilot Project




### Riparian Assets

- Least Sensitive to Wildland fires
- 2
- Most Sensitive to Wildland fires

10 mi

N S

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Riparian Assets Risk Index

## Description

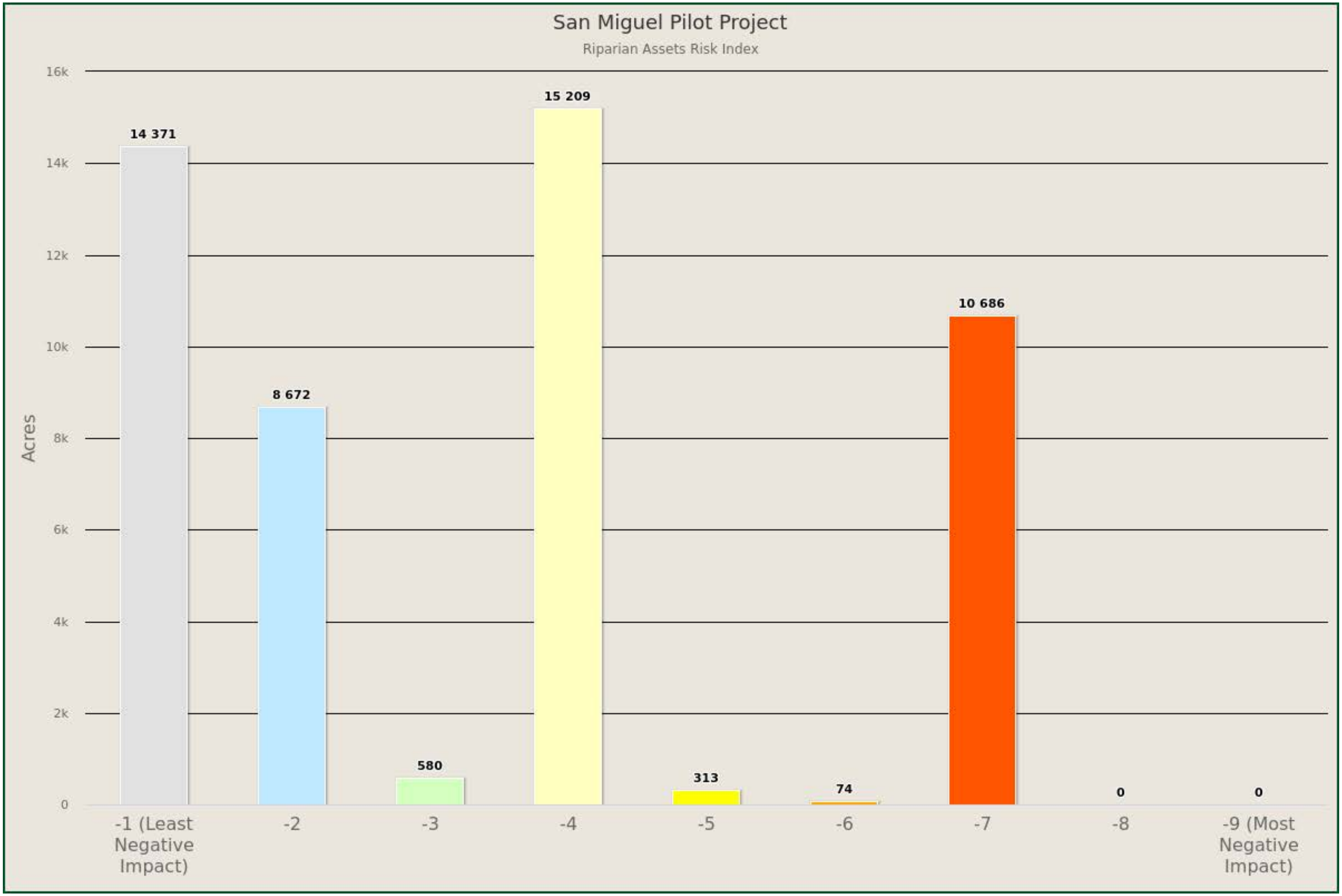
**Riparian Assets Risk Index is a measure of the risk to riparian areas based on the potential negative impacts from wildfire.** This layer identifies those riparian areas with the greatest potential for adverse effects from wildfire.

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

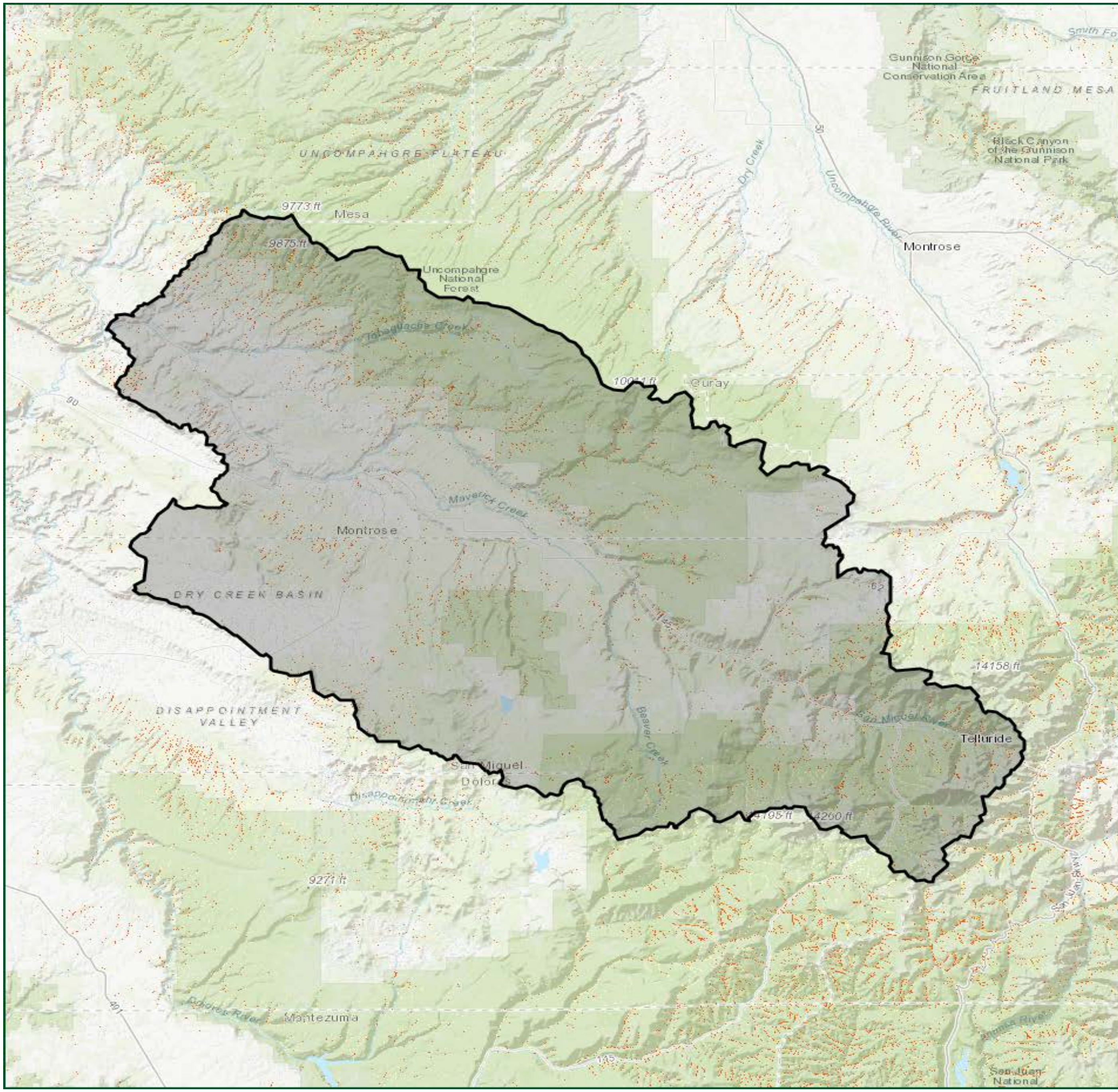
The risk index has been calculated by combining the Riparian Assets data with a measure of fire intensity using a Response Function approach. Those areas with the highest negative impact (-9) represent areas with high potential fire intensity and high importance for ecosystem services. Those areas with the lowest negative impact (-1) represent those areas with low potential fire intensity and a low importance for ecosystem services.

This risk output is intended to supplement the Drinking Water Risk Index by identifying wildfire risk within the more detailed riparian areas.

| Riparian Assets Risk Class | Acres | Percent |
|---|---|---|
| -1 (Least Negative Impact) | 14,371 | 28.8 % |
| -2 | 8,672 | 17.4 % |
| -3 | 580 | 1.2 % |
| -4 | 15,209 | 30.5 % |
| -5 | 313 | 0.6 % |
| -6 | 74 | 0.1 % |
| -7 | 10,686 | 21.4 % |
| -8 | 0 | 0 % |
| -9 (Most Negative Impact) | 0 | 0 % |
| **Total** | **49,905** | **100 %** |



San Miguel Pilot Project
Riparian Assets Risk Index
Acres
16k
14k
12k
10k
8k
6k
4k
2k
0
14 371
8 672
580
15 209
313
74
10 686
0
0
-1 (Least Negative Impact)
-2
-3
-4
-5
-6
-7
-8
-9 (Most Negative Impact)




## San Miguel Pilot Project

### Riparian Assets Risk Index

- -1 (Least Negative Impact)
- -2
- -3
- -4
- -5
- -6
- -7
- -8
- -9 (Most Negative Impact)

10 mi

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Forest Assets

## Description

**Forest Assets are forested areas categorized by height, cover, and susceptibility/response to fire.** This layer identifies forested land categorized by height, cover and susceptibility or response to fire. Using these characteristics allows for the prioritization of landscapes reflecting forest assets that would be most adversely affected by fire. The rating of importance or value of the forest assets is relative to each state's interpretation of those characteristics considered most important for their landscapes.

Canopy cover from LANDFIRE 2014 was re-classified into two categories, open or sparse and closed. Areas classified as open or sparse have a canopy cover less than 60%. Areas classified as closed have a canopy cover greater than 60%.

Canopy height from LANDFIRE 2014 was re-classified into two categories, 0-10 meters and greater than 10 meters.

Response to fire was developed from the LANDFIRE 2014 existing vegetation type (EVT) dataset. There are over 1,000 existing vegetation types in the project area. Using a crosswalk defined by project ecologists, a classification of susceptibility and response to fire was defined and documented by fire ecologists into the three fire response classes.

These three classes are sensitive, resilient and adaptive.

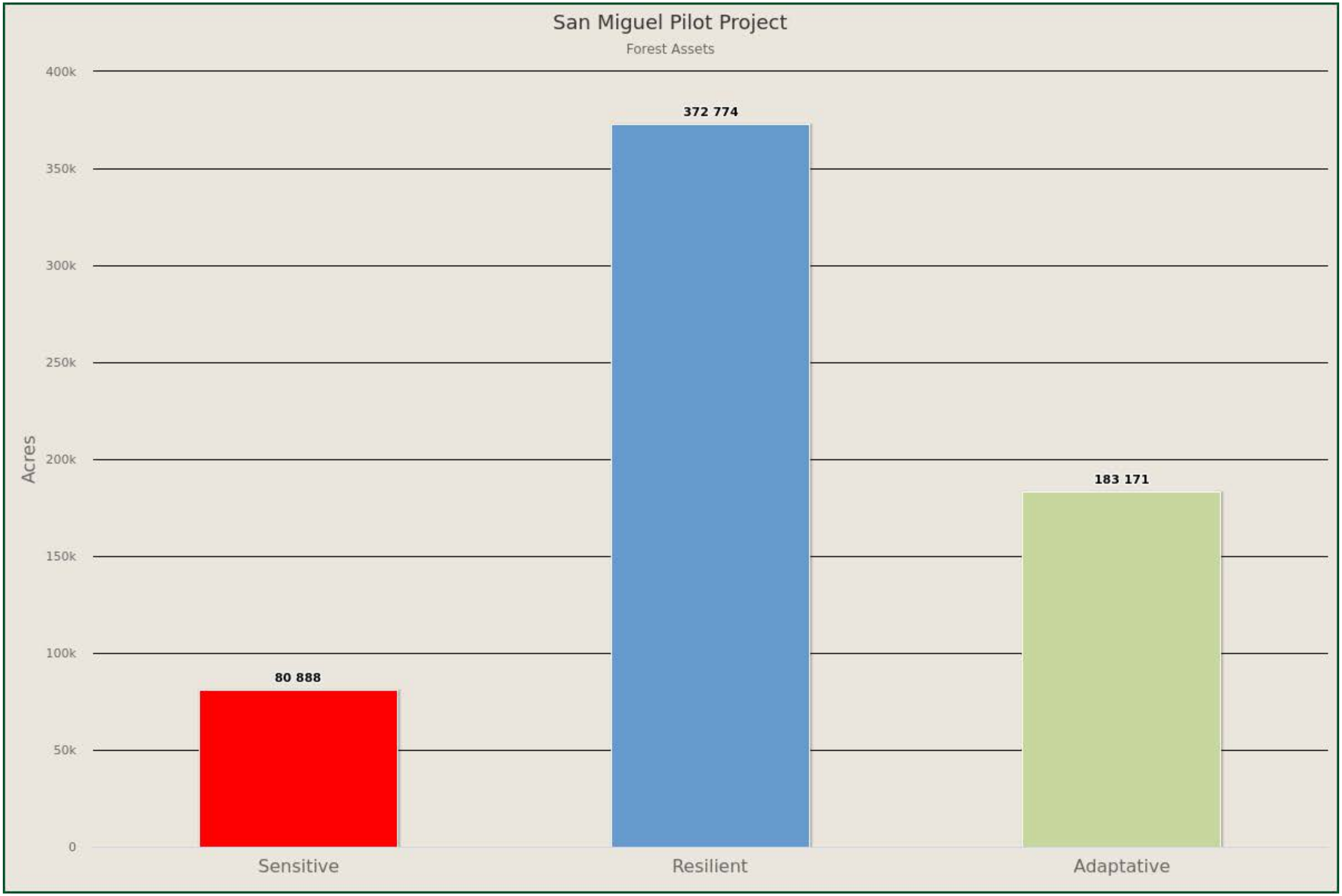
- **Sensitive** = These are tree species that are intolerant or sensitive to damage from fire with low intensity.
- **Resilient** = These are tree species that have characteristics that help the tree resist damage from fire and whose adult stages can survive low intensity fires.
- **Adaptive** = These are tree species adapted with the ability to regenerate following fire by sprouting or serotinous cones

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

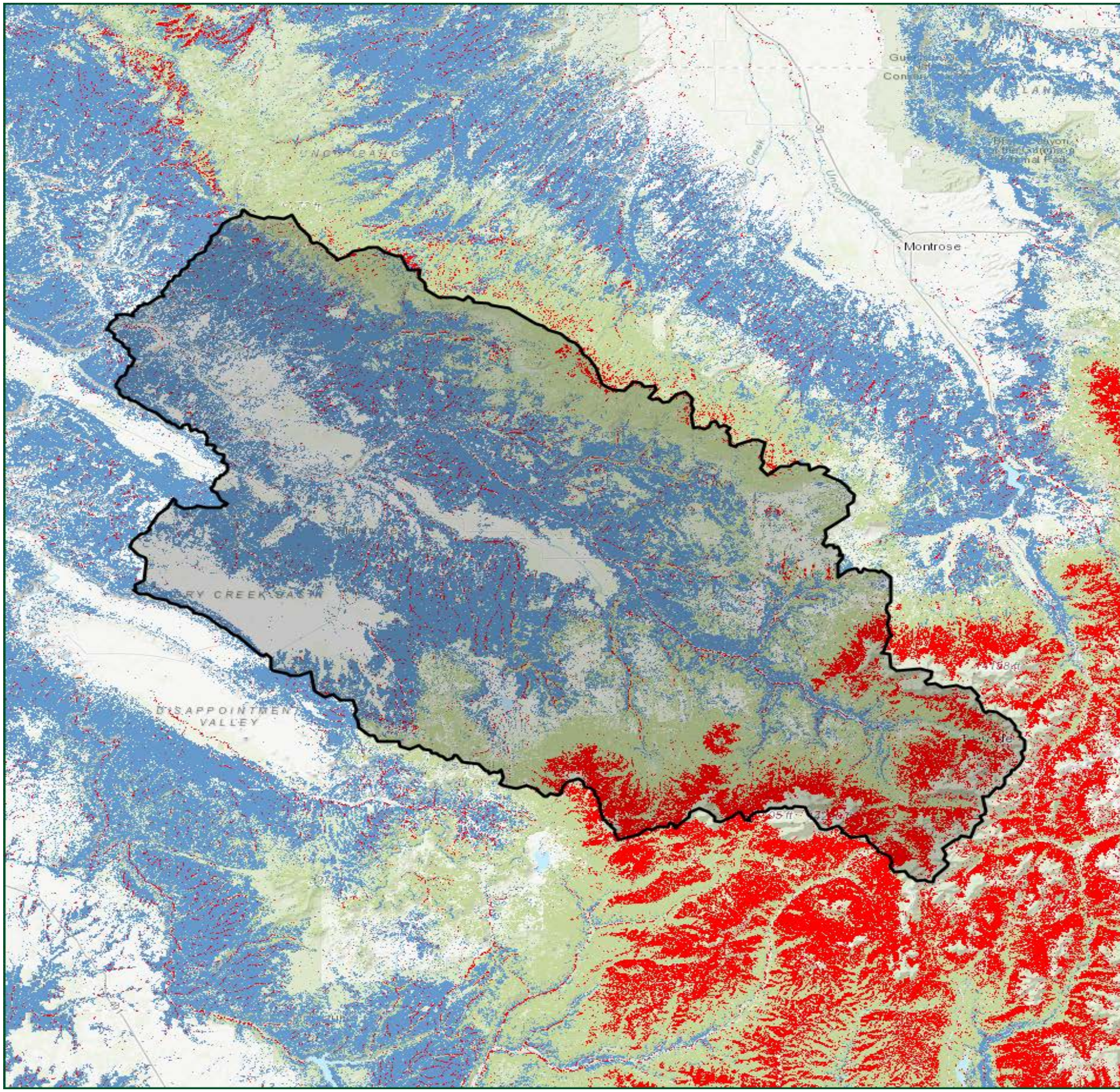
The risk index has been calculated by combining the Forest Assets data with a measure of fire intensity using a Response Function approach. Those areas with the highest negative impact (-9) represent areas with high potential fire intensity and low resilience or adaptability to fire. Those areas with the lowest negative impact (-1) represent those areas with low potential fire intensity and high resilience or adaptability to fire.

This risk output is intended to provide an overall forest index for potential impact from wildfire. This can be applied to consider aesthetic values, ecosystem services, or economic values of forested lands.

| Forest Assets | Acres | Percent |
|---|---|---|
| Sensitive | 80,888 | 12.7 % |
| Resilient | 372,774 | 58.5 % |
| Adaptative | 183,171 | 28.8 % |
| **Total** | **636,833** | **100 %** |


San Miguel Pilot Project
Forest Assets
Acres
400k
350k
300k
250k
200k
150k
100k
50k
0
80 888
372 774
183 171
Sensitive
Resilient
Adaptative

## San Miguel Pilot Project




**Forest Assets**

- Sensitive
- Resilient
- Adaptative

10 mi

N
S

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# Forest Assets Risk Index

## Description

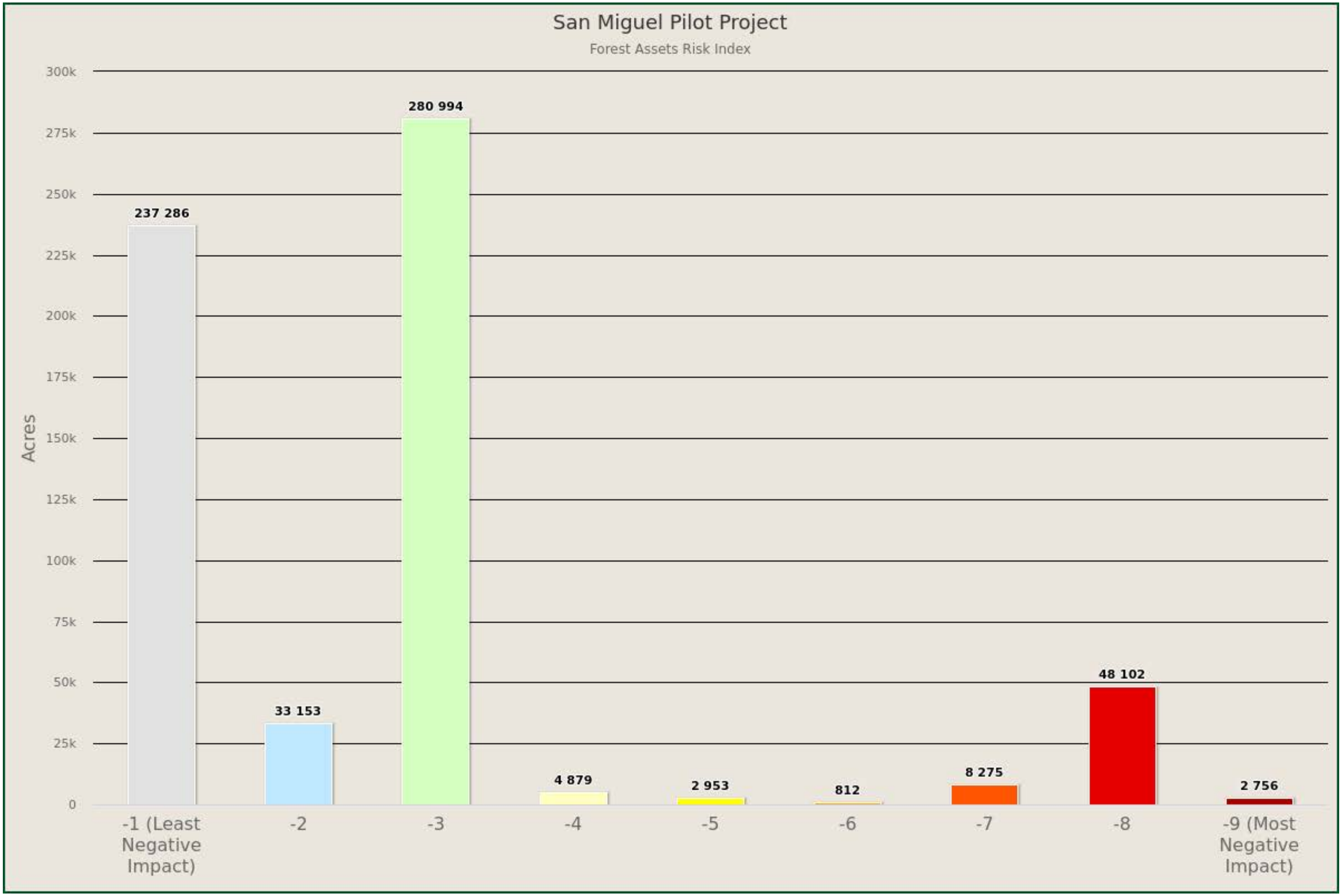
**Forest Assets Risk Index is a measure of the risk to forested areas based on the potential negative impacts from wildfire.** This layer identifies those forested areas with the greatest potential for adverse effects from wildfire.

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

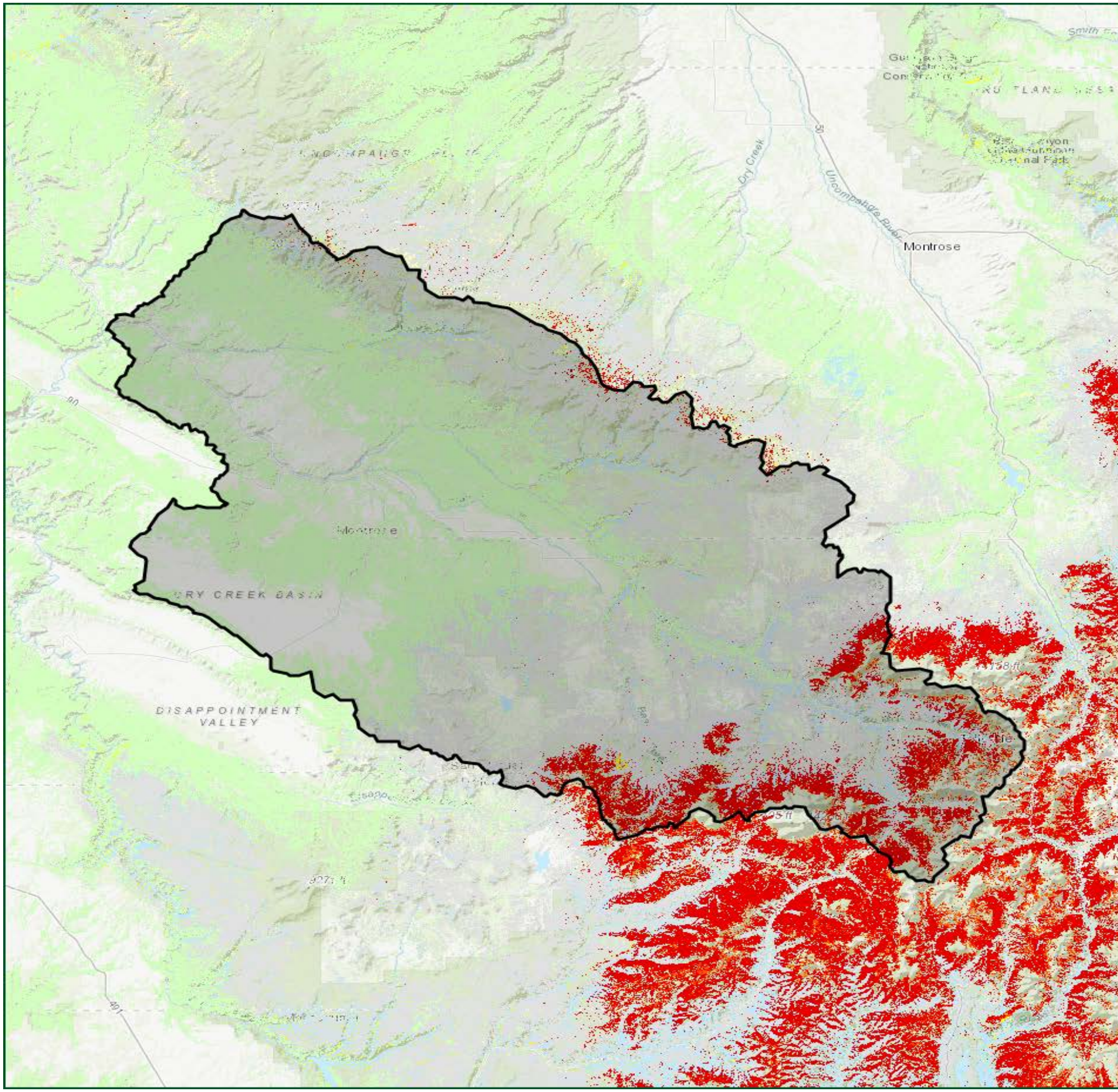
The risk index has been calculated by combining the Forest Assets data with a measure of fire intensity using a Response Function approach. Those areas with the highest negative impact (-9) represent areas with high potential fire intensity and low resilience or adaptability to fire. Those areas with the lowest negative impact (-1) represent those areas with low potential fire intensity and high resilience or adaptability to fire.

This risk output is intended to provide an overall forest index for potential impact from wildfire. This can be applied to consider aesthetic values, ecosystem services, or economic values of forested lands.

| Forest Assets Risk Class | Acres | Percent |
|---|---|---|
| -1 (Least Negative Impact) | 237,286 | 38.3 % |
| -2 | 33,153 | 5.4 % |
| -3 | 280,994 | 45.4 % |
| -4 | 4,879 | 0.8 % |
| -5 | 2,953 | 0.5 % |
| -6 | 812 | 0.1 % |
| -7 | 8,275 | 1.3 % |
| -8 | 48,102 | 7.8 % |
| -9 (Most Negative Impact) | 2,756 | 0.4 % |
| **Total** | **619,212** | **100 %** |



San Miguel Pilot Project
Forest Assets Risk Index
Acres
300k
275k
250k
225k
200k
175k
150k
125k
100k
75k
50k
25k
0
237 286
33 153
280 994
4 879
2 953
812
8 275
48 102
2 756
-1 (Least Negative Impact)
-2
-3
-4
-5
-6
-7
-8
-9 (Most Negative Impact)




## San Miguel Pilot Project

### Forest Assets Risk Index

- -1 (Least Negative Impact)
- -2
- -3
- -4
- -5
- -6
- -7
- -8
- -9 (Most Negative Impact)

10 mi

N
S

Colorado Wildfire Risk Assessment
www.ColoradoForestAtlas.org

# References


Anderson, H. E. (1982). Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-122.

Colorado State Forest Service (November 2018). Colorado Wildfire Risk Assessment Final Report. A final report developed by CSFS and Technosylva Inc. (La Jolla, CA) documenting the technical methods and results for the Colorado wildfire risk assessment update project.

Colorado State Forest Service (July 2018). Fuels Calibration Final Report. A final report developed by CSFS and Technosylva Inc. (La Jolla, CA) documenting the technical methods and results for the Colorado fuels calibration project.

Colorado State Forest Service (2012). Colorado Wildfire Risk Assessment 2012 Final Report. A final report developed by CSFS and DTS (Fort Collins, CO) documenting the technical methods and specifications for the Colorado WRA project.

National Wildfire Coordinating Group (NWCG). (2008). Glossary of Wildland Fire Terminology. Publication Management System document PMS-205.

National Wildfire Coordinating Group (2004). Fireline Handbook. NWCG Handbook 3. PMS 410-1. NFES 0065. National Interagency Fire Center. Boise, Idaho 83705.

Scott, J. H., & Burgan, R. E. (2005). Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model. Ft. Collins, CO, Rocky Mountain Research Station: USDA Forest Service, Gen. Tech. Rpt. RMRS-GTR-153.

Scott, J. H., & Reinhardt, E. D. (2001). Assessing the Crown Fire Potential by Linking Models of Surface and Crown Fire Behavior. Ft. Collins, CO, Rocky Mountain Research Station: USDA Forest Service, Research Paper RMRS-RP-29.


COLORADO STATE FOREST SERVICE
COLORADO STATE UNIVERSITY