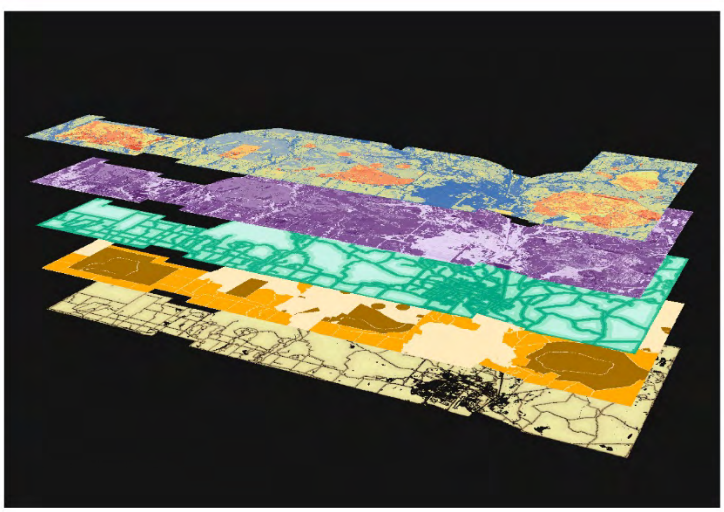
Type 2 Wildfire Risk Assessment

United States Army

March 2017

Installation Management Command



Type 2 Wildfire Risk Assessment

Prepared for:

United States Army
Installation Management Command

Andrew M. Beavers
Jena A. Ferrarese
Amy M. Burzynski

The Wildland Fire Support Center
The Center for Environmental Management of Military Lands
Colorado State University
Fort Collins, CO

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

This analysis triages installations into high, moderate and low risk. To accomplish this, a metric of wildfire hazard, defined by the probability and severity of fire, was compared with the frequency with which that outcome was observed at any installation. Each installation was then categorized based on data groupings.

This risk assessment was executed due to a lack of comprehensive, comparable wildfire information with which to determine wildfire risk exposure across the Army Installation Management Command (IMCOM). Determining wildfire risk is important in order to properly fund and support wildfire risk mitigation efforts at installations where such efforts are necessary. Historic fire occurrence data would be the ideal source of information for such an analysis, but recording of wildland fire data has historically been handled at the installation level and varies dramatically in scope and accuracy from one installation to the next, making it impossible to estimate risk within IMCOM as a whole or to identify acute risk exposure of any given installation. This risk assessment was developed to alleviate this gap in knowledge and to help determine where risk is most pronounced within IMCOM.

The wildfire hazard, defined in this study as the potential likelihood, severity, and spatial extent of fire, at 53 IMCOM installations was evaluated using an internally relative assessment in which installations were compared to each other across a suite of contributing components. The assessment incorporated ignition likelihood from military and non-military sources, fire behavior, and suppression resource effectiveness as major factors. Spatially explicit hazard values were calculated for each installation and used to assign installations to one of three classifications representing the exposure to wildfire. The results of this study are intended for use at the national scale to compare potential wildfire hazard among installations and use that information during wildfire-related strategic decision making.

Of the 53 installations, 15 were classified as high hazard, 17 as moderate, and 21 as low hazard. Very generally, high hazard installations have high volumes of live-fire training, hot and dry weather, heavy or flashy fuels, or a combination of the three. High hazard installations are listed below. High hazard installations occur throughout much of the country, although no installations in the Northeast or Midwest are in the high category. High hazard installations have the potential to experience major wildfire events with some regularity, possibly as often as once every 10 years, though an estimation of large fire recurrence is very difficult.

Table ES1. High hazard IMCOM installations.

• Fort Benning	• Fort Riley	• USAG Hawaii Schofield
• Fort Bragg	• Fort Sill	• White Sands Missile Range
• Fort Carson	• Fort Stewart	• Yakima Training Center
• Fort Hunter Liggett	• Fort Wainwright	
• Fort Polk	• Pinon Canyon MA	

Installations in the moderate category generally still represent a significant hazard and should plan, prepare, and resource accordingly. Many of the moderate category installations in the east are only lacking the weather conditions necessary to produce wide-spread and/or high intensity fires. Such conditions can be expected to occur during droughts which, though infrequent, can be expected to occur at any given installation in the South, or Southeast. Many of the moderate category installations in the west are only lacking the contiguous fuels to allow for widespread fires. These fuels can be produced by unusually high rainfall, such as occurred in 2005. All of these installations have the potential to experience a major wildfire event, but the frequency of such events is considerably lower than at high hazard installations.

Installations classified as low hazard generally lack fire-prone fuels, weather supportive of significant fire spread, fire-prone military training, or some combination of these factors. These installations may not merit consideration

for wildfire mitigation resourcing and/or funding, though there may be reasons to support wildland fire programs at these installations that are not specifically related to wildfire risk reduction.

This risk assessment applies only to wildfire, it does not address or consider prescribed fire. While this risk assessment may be used to inform funding decisions, it is important to note that wildland fire, and usually the funds associated with it, includes both prescribed fire and wildfire. There are many reasons to fund and implement prescribed fire that have no relation to wildfire risk mitigation, such as maintenance of a desired landscape for training purposes or habit restoration. Thus, installations rated as low risk in this assessment may still require significant wildland fire funding to support their prescribed fire programs and may, in fact, achieve low risk due to the risk mitigation effects of frequent prescribed burning, primarily the effects on vegetation buildup.

Six exceptionally large installations were evaluated individually as outliers from the remaining dataset: Dugway Proving Ground, Fort Bliss, Fort Irwin, Fort Wainwright, White Sands Missile Range, and Yuma Proving Ground. The classification of each outlier installation was reevaluated, considering supplemental information available from the Type 1 and Type 3 Wildland Fire Risk Assessments as well as evaluation of the fuels data and expert knowledge of the area.

INTRODUCTION

Wildfire size and severity have increased dramatically nation-wide over the past several decades (Figure 1), more than doubling from their averages in the 1980's. The Department of Defense (DOD) is not immune from these trends as the trends are driven by factors that are just as likely to occur on DOD lands as elsewhere. These include long-term fire suppression which leads to fuels buildups on installations where prescribed fire is not extensively applied, climate change which in many portions of the country exacerbates fire weather, and invasive species which can increase fuel loads and fill in vegetation gaps allowing fires to spread more broadly and/or burn more intensely.

Trends specific to the DOD are currently unknown. To date, neither the Army nor the DOD has a policy or a mechanism by which to consistently and comprehensively track wildfire ignitions, size, severity, outcome, or any other measure of wildfire occurrence. Decision makers at the national level are generally aware of the largest and most expensive fires, but lack fundamental information about routine fire occurrence. Even at the installation level, typically no one individual is aware of all fires that occur at the installation as they may be reported and/or responded to by more than one entity within the installation.

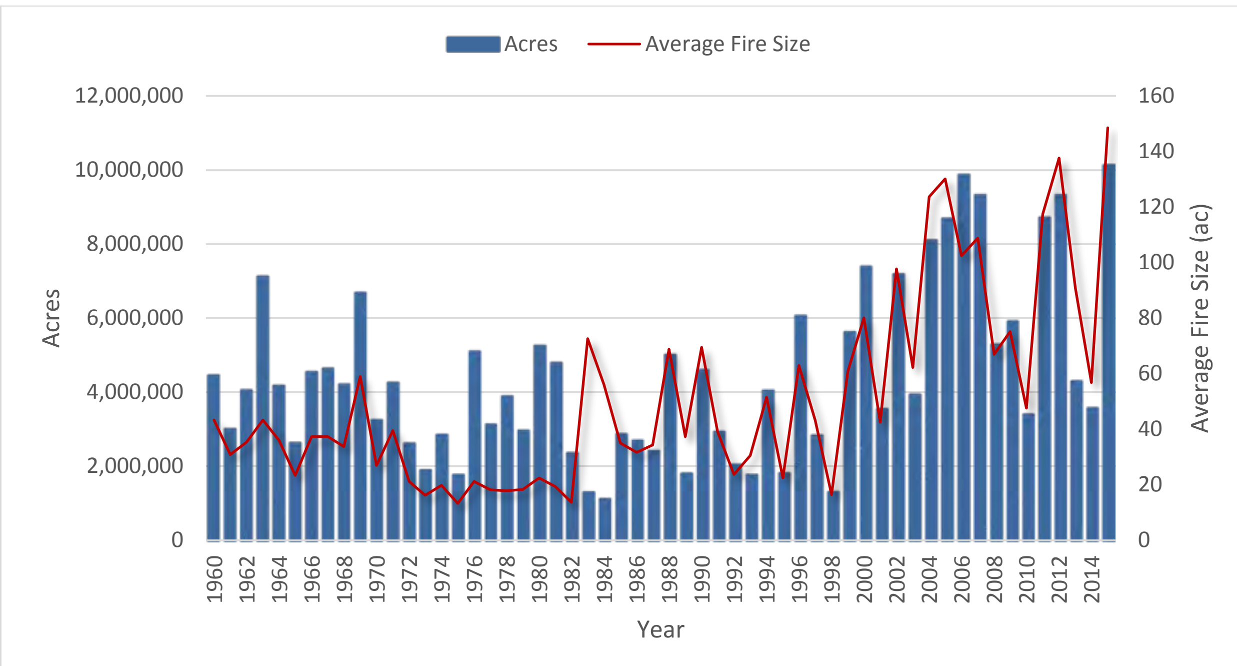


Figure 1. National fire statistics by year 1960 to present. Total burned acreage and average fire size have both increased in the past two decades.

As a result, the Army has a limited understanding of the full scope of wildfire impacts to installations and its exposure to wildfire risk. Without metrics with which to measure the scope, acuity, or location of wildfire hazards, either strategically or at the installation level, it is impossible to mitigate those threats. These threats include potential interruptions to and constraints on the mission, damage to military training assets and defense infrastructure, loss of natural or cultural resources or housing, as well as the potential for damage to neighboring properties and other values at risk.

Recognizing that significant gaps exist in wildland fire management, the Army convened a Wildfire Working Group in 2013 to make an initial subjective assessment of the state of wildland fire management and risk throughout the Army. Some of the findings of that group, finalized in May of 2014, are summarized below:

- Many installations are highly exposed to wildfire risk as exemplified by recent major fires at Forts Sill, Huachuca, Wainwright, and Carson (and more recently Yakima Training Center).
- There are significant costs incurred to the Army almost every year through suppression expenses, asset losses, and legal claims. Negative publicity often follows a major wildfire event as well.
- It is estimated that 85% of wildfire responses by IMCOM firefighting personnel are to wildfires caused by military training.
- There is no uniform reporting method or mechanism by which to record wildfire occurrence.
- At the time it was estimated that IMCOM responded to two to three thousand fires annually. Work by the Wildland Fire Support Center at CEMML has since indicated that the true number is as much as an order of magnitude higher, with data demonstrating that on average 2,203 fires are ignited each year at just 11 IMCOM installations. Five of these eleven installations recorded over 100 wildfires annually.
- In 2011 alone, payouts directly related to only four fires resulting from Army activities totaled $8.95 million in claims, lost assets, and suppression costs. This exemplifies the potential financial burden represented by wildfire.

These factors, when taken in aggregate, suggest that IMCOM Headquarters lacked sufficient situational awareness of fire occurrence and fire outcomes to make informed decisions regarding wildland fire management at both the national and installation level. Decisions regarding wildland fire management at the national level have multi-million dollar repercussions as well as consequences at each installation for the mission, natural and cultural resource protection, and on-post and neighboring infrastructure and assets. The Army recognizes it is critical to make decisions that are informed and data driven, neither of which is possible under the status quo.

Part of the first recommendation of the working group was to “determine the risk to the Army by individual garrison”. The Army has since embarked on a program, in collaboration with the U.S. Air Force, to identify and enumerate the risk through a series of risk assessments that collectively provide reliable information with which to make informed decisions at the national down to the installation level. These are termed the Type 1, 2, and 3 Risk Assessments. The Type 1 Wildfire Risk Assessment uses satellite detected fires to determine historic fire probability, location, and threat in an effort to define risk at the national scale. The Type 3 Risk assessment is carried out at the installation scale and provides much greater detail, accuracy, and nuance, as well as predictions of the potential for future fire occurrences. Its outputs are intended for use at both the national and installation scale.

The Type 2 Wildfire Risk Assessment provided here classifies each installation in the Army IMCOM’s portfolio into low, moderate, or high risk classifications. The Type 2 Wildfire Risk Assessment (hereafter Type 2 Risk Assessment) uses datasets with national coverage to assess risk at each installation via a series of models using national datasets with the intent of allowing meaningful comparisons across all 53 installations included in the study. The resulting data is intended to aid in strategic national wildland fire management planning.

METHODS

A set of 53 installations from within the Army IMCOM (hereafter 'IMCOM') were selected in collaboration with and with approval from the IMCOM G-4 Directorate of Public Works, Environmental Division, Resourcing and Environmental Planning Branch Chief. These 53 installations represent virtually all of the training land capacity managed by IMCOM as well as the bulk of the wildfire risk potential (Appendix 1).

In this analysis, we accounted for all factors that could reasonably be assessed on a commensurable basis across all installations. The requirement to measure all factors using equivalent data across all installations reduces the number of factors for which data exists and, generally speaking, the detail and nuance available in the data. However, sufficient data does exist to carry out an analysis that effectively triages installations in regard to exposure to wildfire.

The installations were compared on an internally relative scale, meaning the risk associated with each installation can be compared proportionately to all the others. Thus, the scale is effectively an index on which all of the installations are measured against one another. The flowchart in Figure 3 on page 7 shows the step-wise integration of data through the risk assessment process. Risk is made up of three primary components, each of which is comprised of several sub-components, which may vary depending on exactly how the risk assessment is carried out, that can each be analyzed on their own as well as in aggregate through the risk measurement. The primary components of risk are event probability, event magnitude, and potential event outcomes. In wildfire events, these are the ignition probability, the fire behavior magnitude, and the values at risk respectively. Each of these components was calculated independently, and then combined to produce a metric of risk per standard risk analysis methodology (Kaplan and Garrick 1981, Ostrom and Wilhelmsen 2012, Rausand 2011).

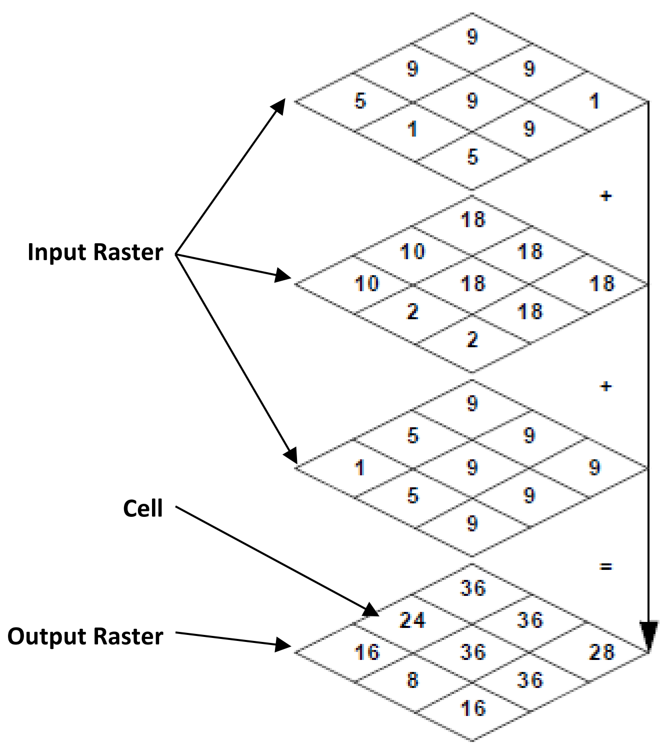


Figure 2. Example of raster math used throughout the analysis to combine two or more rasters. Each raster consists of multiple cells and each cell contains a value. In this simple example, adding the numbers in the top corner of each of the three input rasters results in the summed value in the top corner of the output raster. This process is carried out for every cell in the raster to produce a new output raster of the resulting data. Any mathematical or logical function can be used to combine rasters.

Data sets were obtained from several sources (Table 1), constituting the breadth and diversity required for wildfire (hereafter 'fire') risk analysis. Each data set was pre-processed as necessary to prepare it to meet its purpose in the analysis. They were then combined in a series of calculations based upon known relationships and expert opinion to reflect the interactions among factors that influence ignition probability, fire behavior magnitude, and values at risk. Finally, those three elements were combined to produce the overall risk for each cell (see Glossary of Terms and Figure 2) in each installation (see process diagram in Figure 3). The final product is an aggregation of all the cells in each installation into a single metric and a subsequent triage of these outputs.

Because this is a *relative* risk assessment, the absolute values for each element considered are not important, only their relative value is meaningful. Each data element was therefore standardized to a common scale of 0 – 1000, regardless of the native units. Standardization occurred by identifying the smallest and largest value of the given factor anywhere in the 53 installation dataset and scaling the data proportionately across that range. Because the analysis is relative, units are not necessary. Unitless standardization allowed data such as fire response effectiveness to be combined with ignition likelihood for example, two factors that do not otherwise share a common unit of measure. When any two factors in the risk analysis were combined, a weighting scheme was developed based upon the best available information. That information included established fire behavior systems like FlamMap (Finney, 2006), reviews of the literature, using subject matter expertise, and other resources. The specific weights used when combining each set of factors are provided in the relevant sections of this report.

All data in this model were processed inside of a 3 km buffer around the installation to avoid edge effects and to account for information important to risk that lies outside the installation boundary. The final risk and hazard data were clipped to each installation boundary before calculating summary statistics and triage. Installations are triaged into three categories. Further splicing of the data is suspect as the precision of the analysis is somewhat limited given the challenges of compiling comprehensive and comparable data across the entire U.S. While it is possible to separate installations into three triage categories, it is much more difficult to reliably separate two installations within the same triage category. Those decisions are best made with a more robust set of data and the intuition of wildland fire managers.

RAW DATA INPUTS

Table 1 lists the source of the raw data for each dataset, as well as the pre-processing applied before further analysis. A detailed description of how each dataset was used is included in the following sections. All data was processed in the UTM zone in which the installation occurs.

Table 1. Sources for datasets used in the analysis.

Dataset	Source	Pre-processing
Installation Boundaries	Army Mapper	None
Training Areas	Army Mapper and Manual Digitizing	Range shapefiles were extracted from the installation geodatabase, weighted by use category (live-fire or non-live-fire), and converted to raster with use type as pixel value. Visual comparisons were made with aerial imagery, and notable absences were manually digitized.
Roads	ESRI North America Detailed Streets	Rasterized roads and applied Arterial Classification Code (ACC - a usage factor) as pixel value for use in estimates of ignition probability. Calculated Euclidean distance rasters for use in estimates of suppression effectiveness.
Fire Records	National Fire and Aviation Management	Combined records from all agencies into a single, national dataset, individual records were not pre-processed.
Lightning - CONUS	Vaisala, Inc.	Converted 2003-2012 strike point data to raster using kernel density, used stroke attribute (equivalent to multiplicity in AK dataset) for each strike.
Lightning – AK	Alaska Interagency Coordination Center	Converted 2003 – 2012 strike point data to raster using kernel density, used multiplicity attribute (equivalent to strokes in CONUS dataset) for each strike.
Lightning – HI and Puerto Rico	NASA Lightning Imaging Sensor	Geo-located and converted satellite-originated lightning values to match CONUS and Alaska units; assigned values to installations and smoothed boundaries of lightning raster cells if multiple cells occurred in one installation
LANDFIRE Landscape File (fuels, canopy, terrain, etc.)	LANDFIRE	None.
Weather	Western Regional Climate Center/Iowa State University	Remote Automated Weather Station (RAWS) data was imported into Fire Family Plus. Where National Weather Service data was used in place of RAWS, it was processed using multiple stations to account for State of the Weather, then imported into Fire Family Plus.
Water Sources	USGS National Hydrography Dataset (NHD)	Selected relevant categories from NHD Flowline and Waterbody data (e.g. streams but not pipelines) and created Euclidean distance rasters from water features.
Fire Stations	USGS National Map	Created Euclidean distance rasters from national fire station location shapefile.
Building Footprints and Tower Points	Army Mapper	Converted building footprints and tower location shapefiles to raster.

INSTALLATION BOUNDARIES

Installation boundaries in this analysis were acquired from Army Mapper. For the purposes of this assessment, these are considered the definitive boundary of each installation.

IGNITION CALCULATIONS

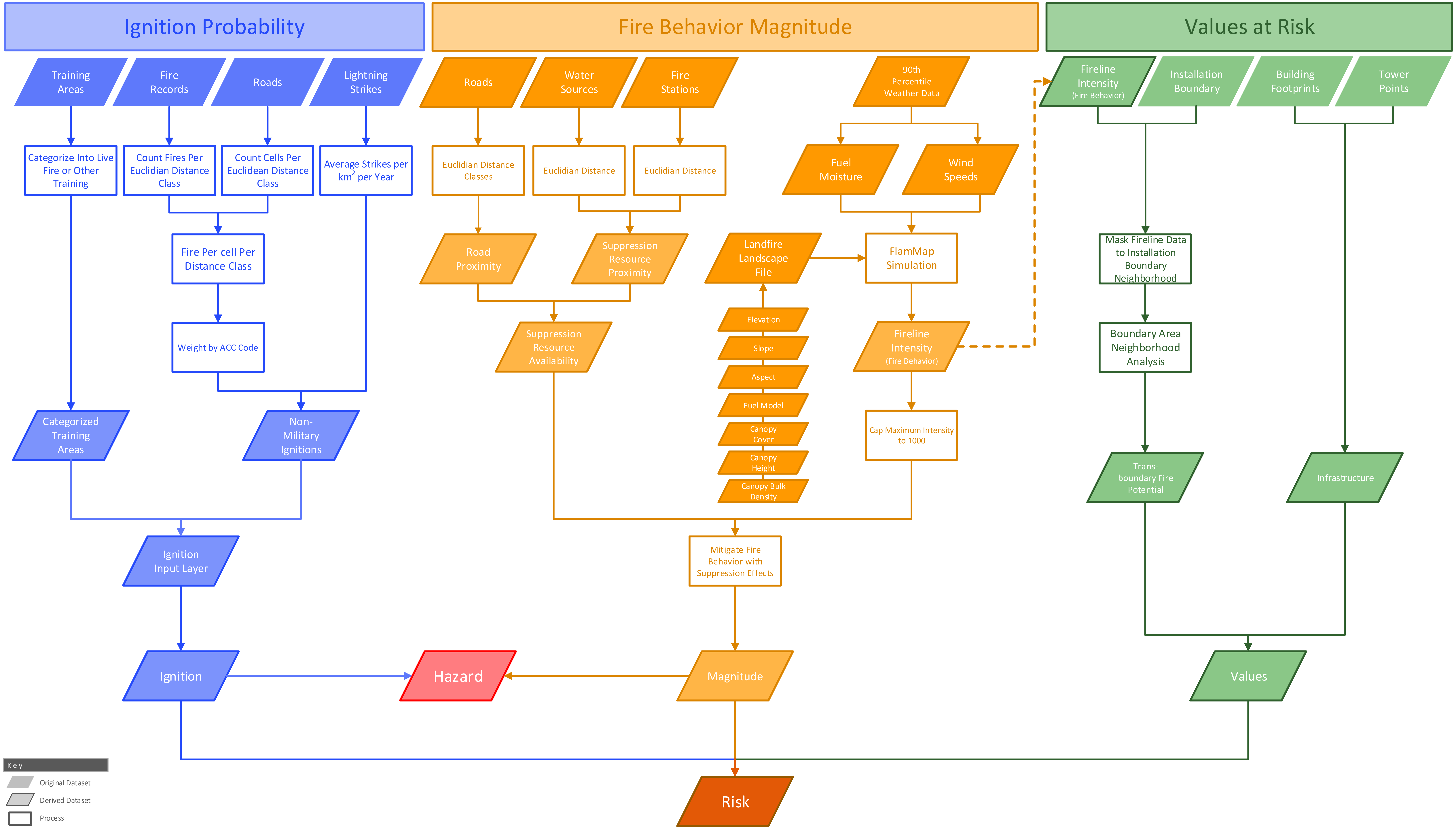
Wildfire ignitions come from three primary sources – civilian activities, lightning, and military operations. We first combined civilian and lightning ignitions into a non-military ignitions layer. We then integrated that with military ignitions to produce total ignition likelihood for the installation.

NON-MILITARY IGNITIONS

Because most non-military, human-caused fires are related to ease of access as defined by the availability of roads (Grala and Cooke, 2010; Maingi and Henry, 2007; Badia-Perpinyà and Pallares-Barbera, 2006), road proximity was used as a proxy for civilian ignitions. A database of all known fire records in the U.S. from the Fire and Aviation Management website (https://fam.nwcg.gov/fam-web/) was used to create a model of fire likelihood relative to distance from roads. This database included fires reported by the national and state agencies representing the bulk government managed lands in the U.S. – the Bureau of Indian Affairs, the Bureau of Land Management, the Bureau of Reclamation, the California Department of Forestry, the National Park Service, the U.S. Fish and Wildlife Service, U.S. Forest Service, as well as data for each state from the National Association of State Foresters. The data included a point location of each fire. Within a 3 km buffer of all installations in the study, the distance from each ignition in the fire records to the nearest road was calculated. These distances were binned in 30 m increments to produce a total count of fires per distance bin.

Euclidean distance rasters were created from the roads and reclassed into 30 m increments called 'bins' (e.g. a cell that was 52 m from a road would be reclassed into the 30-60 m distance bin). The total number of cells across all installations in each bin was calculated, excluding cells classified as unburnable as determined by LANDFIRE fuels data. Knowing the total count of ignitable cells per bin, and knowing the total count of fires per bin allowed calculation of the average fire count per ignitable cell in each bin. The per-cell average fire count by distance bin was then applied to the reclassed Euclidean distance raster, to proportionately allocate fires per cell.

This result was then weighted by each road's Arterial Classification Code (ACC), a traffic use index. The frequency of fire related to each ACC class was calculated nationally, thus describing the level of ignition probability associated with each road based on its ACC code. The ratio of ignition probability between ACC codes was calculated using the percentage of road length in each ACC code and the percentage of fires whose nearest road was in the same ACC code. If road usage was not related to fire frequency, then the percentage of fires adjacent to a road category would equal the percentage of road length in that category (e.g. if fires were spatially neutral, then if 10% of roads are in ACC class 2, one would expect 10% of fires to be closest to roads of class 2). When the percentages are not equal, a tendency in fire occurrence related to road ACC class was indicated. The ratio between expected and actual percentages was used to weight the number of fires per cell output from the distance binning. Thus, cells at the same distance from roads of different ACC classes would have different predicted fires per cell.


Ignition Probability
Fire Behavior Magnitude
Values at Risk
Training Areas
Fire Records
Roads
Lightning Strikes
Categorize Into Live Fire or Other Training
Count Fires Per Euclidian Distance Class
Count Cells Per Euclidean Distance Class
Average Strikes per km2 per Year
Fire Per cell Per Distance Class
Weight by ACC Code
Categorized Training Areas
Non-Military Ignitions
Ignition Input Layer
Ignition
Roads
Water Sources
Fire Stations
Euclidian Distance Classes
Euclidian Distance
Euclidian Distance
Road Proximity
Suppression Resource Proximity
Suppression Resource Availability
90th Percentile Weather Data
Fuel Moisture
Wind Speeds
Landfire Landscape File
FlamMap Simulation
Elevation
Slope
Aspect
Fuel Model
Canopy Cover
Canopy Height
Canopy Bulk Density
Fireline Intensity
(Fire Behavior)
Cap Maximum Intensity to 1000
Mitigate Fire Behavior with Suppression Effects
Magnitude
Hazard
Fireline Intensity
(Fire Behavior)
Installation Boundary
Building Footprints
Tower Points
Mask Fireline Data to Installation Boundary Neighborhood
Boundary Area Neighborhood Analysis
Trans-boundary Fire Potential
Infrastructure
Values
Risk
Key
Original Dataset
Derived Dataset
Process

The other component of non-military ignitions is natural ignitions from lightning. The number of lightning strokes per year from the lightning strike data was summed into a 10-year lightning strike value. This process was slightly different for the Continental United States, Alaska, Hawaii, and Puerto Rico due to slightly different raw data sources for each location (see Table 1), but the results are still comparable. The cumulative number of lightning strokes in each cell was used as the metric of potential for fire ignition from lightning and was scaled per the standard scaling methodology.

To combine civilian and natural ignitions, a variable weighting scheme was developed. For each Geographic Area Coordinating Center region (GACC), a ratio of lightning to human-caused fires was created from data accessible on the National Interagency Fire Center website (https://www.nifc.gov/fireInfo/fireInfo_stats_lightng-human.html). This provided a weight for the civilian versus lightning ignitions for each GACC. To offset sharp differences along these geographic boundaries, the ratios were blended using distance weighting from the edge. The resultant ratio was used to weight the civilian and lightning ignition values into a combined non-military ignition value for each cell. After combining, the non-military ignitions were scaled.

MILITARY IGNITIONS

Using information from Army Mapper, military lands were delineated into three categories – live fire areas, non-live fire training areas, and non-training areas which consisted primarily of cantonment areas but also of any other area on an installation that was not designated as a live-fire area or training area. Data acquired during the process of developing the Type 3 Risk Assessments, as well as from data acquired while developing past Integrated Wildland Fire Management Plans, allowed us to estimate that live fire areas produced approximately ten times as many ignitions as non-live fire training areas. Live fire areas were assigned a value of 1000, non-live fire training areas a value of 100, and areas that do not experience military training activities a value of zero. These values spanned 0 – 1000 naturally and needed no scaling.

OVERALL IGNITION

Military and non-military ignitions were weighted using information about military versus non-military ignition probability derived from 11 Type 3 Risk Assessments and past fire management planning at three other Army installations where fire ignition data allowed the differentiation of military from non-military ignition sources. This data allowed us to define a ratio of military to non-military ignition probability. Using this information, military ignitions were weighted by 0.8 and non-military ignitions by 0.2. After this combination was carried out, overall ignition values were scaled.

FIRE BEHAVIOR MAGNITUDE CALCULATIONS

The potential magnitude of a wildfire event was characterized by estimating potential fire behavior, as measured by fireline intensity. FlamMap, a spatial fire behavior simulation tool (Finney, 2006), was used for this purpose. Fireline intensity is a measure of heat output and is measured in units of British Thermal Units/Foot of fireline/Second (BTU/Ft/Sec). It is directly related to flame length. Flame length is commonly used by firefighters to gauge the level of effort that will be required to contain a wildfire, and/or whether a wildfire can feasibly be contained given current conditions. Thus, fireline intensity is a useful measure for determining the potential for escape from wildfire containment efforts.

Wildfire behavior is dependent on fuels, weather, and topography. However, it is also potentially offset by human efforts to suppress fires and in this study we offset the potential magnitude of the fire behavior by a factor associated with road, water, and fire station proximities, the three of which are used in conjunction to estimate potential fire suppression resources.

FUELS

The vegetation available to burn (hereafter 'fuels') is characterized by fuel models which have been mapped throughout the U.S. In this study we used the 40 standard fuel models as described by Scott & Burgan (2005). Each fuel model characterizes the vegetation via a set of numbers, each number representing a characteristic of the fuel (e.g. fuel load, fuel bed depth, surface area to volume ratio, etc.). A landscape file including all eight layers necessary to run spatial fire analysis was downloaded from LANDFIRE (Landscape Fire Resource Management Planning Tools Project, 2015) for each installation and its surrounding 3 km buffer. One of these eight layers is the layer representing the fuel models.

Although the fuels data from LANDFIRE, one of the eight landscape layers, is often prone to errors, LANDFIRE is the only national fuels dataset in existence and is used routinely at the national scale for a wide variety of strategic fire management. Adjusting fuels at the individual installation level as is done for the Type 3 Risk Assessments was not feasible given the national scale of the Type 2 Risk Assessment and the scale of the quality control that would be necessary.

WEATHER

Fire behavior is influenced by temperature, relative humidity, wind speed and direction, solar radiation, and rainfall. FlamMap requires estimation of the condition of the fuels as a result of the weather as well as a measure of wind speed to use in the calculations. In order to estimate these values, a Remote Automated Weather Station (RAWS) or National Weather Service (NWS) weather station was identified for use for each installation. Weather stations were selected based on proximity to the installation, as well as known weather gradients. These weather gradients can be caused by maritime influence, for example, or a weather station that is substantially higher or lower in elevation than the installation. The goal was to pick weather stations that best represent the weather of the installation. Appendix 2 includes a list of the weather stations used in the analysis. In most cases, a ten-year (2005-2014) period of record was used, although there were some stations that did not have complete records for the entire ten year period, either because the station had not been in place for 10 years, or because of erroneous or missing data. In those cases, the best available time period was used.

Based on those weather inputs, FireFamilyPlus (Bradshaw and McCormick, 2000) was used to calculate the 90th percentile value for either Burning Index (BI) or Energy Release Component (ERC) as appropriate to the fuels of the installation. Both of these are National Fire Danger Rating System (NFDRS) fire danger indices used to estimate daily fire potential. Generally speaking, BI is used by the NFDRS where fuels are light, such as installations dominated by grasses, and ERC is used where fuels are heavy, such as installations dominated by forest. The determination to use BI or ERC was made either by referring to the Weather Information Management System (WIMS) if the weather station was a RAWS. WIMS records information about the weather station, including which index is used for making fire danger decisions. For NWS stations, the choice between BI and ERC was made by a subject matter expert who determined whether the fuels were light or heavy. This decision was based on knowledge of the installations, the LANDFIRE data, and aerial imagery available through commercial products such as Google Earth.

The only weather data required by FlamMap are fuel moisture and wind speed. The data from these weather stations was analyzed to identify the 90th percentile index value. Every weather record meeting that value was extracted into a separate data set of weather that results in a 90th percentile BI or ERC. The average fuel moisture and wind speed were calculated from these data to produce average 90th percentile values for these two variables. These variables were then used as inputs into FlamMap.

FIRE BEHAVIOR

FlamMap is a spatial fire behavior prediction system. It calculates fire behavior for each cell on a landscape based on a given set of static inputs. While it does not account for fire spread over space or time, it does provide reliable estimation of the potential fire behavior for every location on the landscape based on weather and fuels and is used for that purpose for a wide variety of analyses at scales ranging from small to very large. FlamMap was used in this study to calculate 90th percentile fire behavior for each cell on each installation.

The spatial fuels data acquired from LANDFIRE, and the fuel moisture and wind inputs as determined through the process described in Weather, above, were input to FlamMap to calculate fireline intensity (BTUs/ft/sec). Canopy characteristics from LANDFIRE were also input into FlamMap which uses these data to determine wind reduction factors based on interference from trees, as well as fireline intensity associated with crown fire if crown fire were initiated.

Fireline intensities greater than 1000 represent fire behavior that is unlikely to be controlled by suppression efforts. From a risk management perspective what is most important is whether the fire is controllable, rather than the degree to which it has exceeded the ability to control it. Fireline intensity outputs from FlamMap were capped at 1000 BTU/ft/sec. Any value output from FlamMap that exceeded this value was reclassed to 1000, all other values remained as calculated by FlamMap. Coincidentally, the value of 1000 also represents the maximum value for scaled factors in this study, so the outputs were not rescaled.

This analysis calculated fire behavior values for individual cells, independent of neighbors, and did not consider fire spread between cells. The complexity of calculating fire spread over 53 installations and for many possible weather and ignition scenarios was beyond the scope of this study. However, fire spread is accounted for in the Type 1 Risk Assessment, a spatial analysis of all known past fires, and in the Type 3 Risk Assessments, which use the best available high resolution temporal and spatial analysis methodologies, including predicting fire spread and fire intensity potential, to predict fire risk.

SUPPRESSION EFFECT

Wildfire suppression is a complex operation, often involving multiple types of resources, competing financial considerations, and timely decisions in a rapidly evolving fire environment. Effectiveness of any given firefighting resource also depends upon competence, fuels, terrain, and a wide variety of other factors. Capturing the complete range of variability in the model was beyond the scope of this assessment. Instead, we used three key metrics as a proxy for potential suppression effectiveness: proximity to water, proximity to fire stations, and proximity to roads. Water provides a resource with which to extinguish the fire and is used extensively whenever it is available. Fire stations provide equipment and personnel. Roads provide access to the fire through the wildland landscape and can also be used as firebreaks. The potential growth of a fire is affected by the proximity of the fire to each of these items as firefighters will use any resource available to combat the fire. The closer the resource is, the more effectively it can be brought to bear.

Proximity to water was calculated by generating a Euclidean distance raster from the combined relevant NHD flowline and waterbody datasets, and then scaled. In wildland firefighting situations, there are usually no hydrants, water must be pumped from lakes, pond, streams or other water features. These are often not available, or a significant distance from the fire, often miles away and there are many fires where very little or even no water is used to fight the fire.

Proximity to fire stations was calculated by generating a Euclidean distance raster from the shapefile of fire station locations. Though not from a national fire data source, the fire station data appeared to be quite complete. It included a wide range of fire stations, from fully-outfitted city departments to rural volunteer organizations, and included many small, rural stations (those most likely to be missing from the dataset) known to the study authors.

Water and fire station proximity rasters were scaled, combined using weights of 0.2 and 0.8, respectively, and the combined proximity to suppression resources values were scaled again to maintain the consistent 0 – 1000 scale. This scale was then inverted to represent the fact that smaller distances represent greater suppression effectiveness. Thus, small distances from firefighting resources resulted in a value in this raster close to 1000.

The same initial roads dataset used for ignition calculation was also used here. Euclidean distance rasters were generated representing the distance from the nearest road, and distances categorized into <46 m (~150 ft), 46-152 m (~150-500 ft), 152-457 m (~500-1500 ft), and >457 m (~1500 ft). These categories were assigned values of 1000, 800, 300, and 0, respectively, assigning larger values to smaller distances based on typical hose length carried by typical wildland fire engines, typical hose lay capabilities of those engines, and subject matter expertise.

Road proximity calculated in this fashion was then combined with the standardized water/fire station proximity combination using a weight of 0.5 for each, and the output was scaled.

INTEGRATED FIRE BEHAVIOR AND SUPPRESSION EFFECT

As originally calculated, suppression resource proximity was positive numbers between 0-1000, with larger numbers representing closer proximities. However, because suppression offsets fire behavior, the suppression proximity numbers were converted from positive to negative before combining with fire behavior.

Suppression is much more effective at low fireline intensities than at high fireline intensities. At fireline intensities below 60 BTU/ft/sec (approximately 3 ft flames), fireline intensity was combined with suppression effect using a 5/95 ratio, respectively. If the fire behavior/suppression combined value was negative, reflecting suppression efforts outweighing fire behavior, the combined value was set to zero indicating no fire. Fireline intensities of 60-1000 BTU/ft/sec were combined with suppression effect using a function to scale the weight from 5/95 to 100/0. The function was based on subject matter expertise:

$$FLI_{\%} = 33.872 * \ln(FLI_C) - 134.7$$

Where $FLI_{\%}$ is the percentage of the weight of the fire behavior value in the ratio of fire behavior/suppression and FLI_C is the calculated fireline intensity. Again, if the combined value was calculated to be negative, it was set to zero. Fireline intensities greater than 1000 are considered largely uncontrollable and were capped at this level in the fire behavior calculations as a result. Wherever fireline intensity was calculated to be 1000 BTU/ft/sec, suppression effect was set to a constant of zero, meaning there was no offset to the fire behavior as a result of fire suppression. After combining fire intensity with fire suppression effect, the resulting mitigated fire behavior values were rescaled.

VALUES AT RISK CALCULATION

Only two values potentially at risk were available at the national scale, infrastructure and installation boundaries. Infrastructure consisted of building footprints (polygon shapefiles) and tower locations (point shapefiles) which were extracted from Army Mapper for each installation and rasterized. These were intended to represent potentially at risk infrastructure. All infrastructure was given a cell value of 1000 as there was no meaningful way to differentiate the value of one building from another.

In addition to infrastructure, fires crossing the installation boundary are a common concern. Using neighborhood statistics, the magnitude of the fire behavior of any fire crossing the boundary was calculated from the combined ignition and fire magnitude data.

To accomplish this, a decision tree model was used. If the fireline intensity (FlamMap output) of the boundary cell was zero, the trans-boundary fire likelihood was also zero as fire cannot burn across that cell either because the cell is unburnable or because the suppression effect completely outweighs the potential for fire behavior as described above. If the boundary cell itself was not zero, then its eight neighbors were considered. If they were all zero, then the average of the boundary cell and its immediate 8 neighbors was used (because the immediate neighbors being zero would block a larger neighborhood from influencing the boundary cell). In this scenario, the only possibility of fire crossing the boundary is if the fire ignition were on the boundary cell itself or if a fire elsewhere produced a spot fire on the boundary cell. If the boundary cell and at least one of its neighbors were non-zero, then the average was taken of all the cells in a 7x7 window. Because initial processing included cells within a 3 km buffer around each installation, the 7x7 window included both on- and off-installation data. Adjacent unburnable fuels, such as parking lots or highways, represent a situation in which a fire burning either way across installation boundary is of lower consequence than a scenario in which the fuels provide for wildfire spread some additional distance from the installation boundary.

Infrastructure and trans-boundary fire likelihood were combined as evenly weighted inputs (0.5 each) and scaled.

HAZARD CALCULATION

Hazard is defined here as the integration of likelihood (ignitions) and magnitude (the severity of fire behavior offset by suppression effectiveness). The standardized ignition and magnitude values were combined as evenly weighted inputs (0.5 each) and scaled. Any cell with a value of zero for either input value was set to zero in the output. Unlike preceding combinations where no one input invalidates another, a zero value in either of these inputs indicates zero hazard. An ignition must occur for fire behavior to exist, and if an ignition is possible, fire behavior must be non-zero in order to represent a hazard. For example, a cell near a fire station with light fuels may have a value associated with ignition probability, but its proximity to the fire station mitigates the potential fire behavior to zero. Even though an ignition is a possibility, the fire behavior is completely mitigated by the suppression effect and therefore there is no hazard. These results were then scaled.

RISK CALCULATION

Risk is the integration of hazard and value, and the greatest risk will occur when highest valued resources face severe hazards.

Standardized ignitions probability, magnitude (mitigated fire behavior), and values at risk were combined using weights of 0.33 for each dataset. However, like the combination of ignition and magnitude, if any of the three inputs to risk were zero, the risk was set to zero to reflect the requirement that all three factors be present to produce risk per standard risk analysis methodology.

After combination, the results were scaled. The risk rasters were clipped to installation boundaries, thus excluding the off-installation buffer used up to this point, before calculation of the assessment metrics, defined below, that were used to rank installations.

ASSESSMENT METRICS

Wildfire mitigation is largely focused on prevention of low probability, high consequence events – the large, high severity fires that occur infrequently. When quantified, generally a percentile is used that more broadly represents the high risk end of the spectrum. Therefore, this assessment focuses on the “typical” high risk an installation might face, not a single outlier cell value as may occur due to a very rare combination of factors, nor some measure of the average risk that represents run of the mill fires. Additionally, because the outcomes were not measured on any real-world scale, it was not possible to establish a real-world threshold value to separate high risk installations from low risk ones.

The purpose of this analysis was to triage installations into high, moderate, and low risk. To accomplish this, metrics of hazard and risk outcomes were compared with the frequency with which that outcome was observed at any installation. The results were then categorized based on data groupings.

The 95th percentile value was used as the evaluation criteria. The 95th percentile cell value was calculated for each installation using custom statistical scripting in python. This number represented the level of hazard or risk associated with each installation.

However, the 95th percentile risk or hazard cell value alone is insufficient to define the risk or hazard. The amount of area at high risk or hazard matters as well as the value itself to account for the fact that a large area of high hazard is more of a fire management issue than a small area with the same 95th percentile value. To represent this, the 95th percentile cell values were plotted against the number of cells greater than or equal to the 95th percentile, thus representing all cells within which the risk or hazard is high relative to the rest of the installation. This allowed differentiation among installations with similar percentile values but of notably different sizes. This process was carried out for both risk and hazard results. If the percentile value was zero (the lowest possible value), the area calculation only included those cells greater than the percentile value. Data were split into classes of high, moderate, and low concern using break points based on this metric (see Hazard section below for more detail).

RESULTS

The final triage of the installations into low, moderate, and high categories are displayed in Figure 6 and Table 3 below, with more detailed information available in Appendix 1 and 3. Intermediate calculations, such as those determining suppression resource availability or total non-military ignitions (see Figure 3 on page 7), are not provided in this report but are available from the authors. The results indicated that risk poorly represented exposure to damage from fire due to a lack of nationally available comparable values data. As a result, hazard, which represents the probability and potential magnitude of fires, was used as the metric for triaging installations into three classifications. This resulted in 15 installations being classified as high hazard, 17 as moderate hazard, and 21 as low hazard. Outliers were handled through individual analysis.

RISK

There was a lack of values at risk data that was comparable across the nation, making it very difficult to make any determinations about the actual risk posed to installations. Only two values with data that was reasonably commensurable across all installations were identified, infrastructure, represented by buildings and towers, and the installation boundary, representing trans-boundary fire potential. It is well known that voluminous other resources are at risk from wildfire. Based on experience gained from the Type 3 Risk Assessments, a project that results in extensive and detailed data regarding values at risk at individual installations, but not nationally, we know that installations have many more values at risk than basic infrastructure and fires burning across the installation boundary. During the Type 3 Risk Assessment process, installations typically identify 50 to 100 values of interest. We also know that the degree of concern for any given value, including infrastructure and fires burning across the installation boundary, varies considerably among installations. To try to represent risk using only two values that are equally valued at all installations was clearly inadequate.

Additionally, doing so resulted in large portions of the installations exhibiting no risk. Because risk is zero where there are no values, anywhere on an installation without buildings or not on the boundary was calculated to be at no risk. For most installations, this was a very large proportion of the installation, and resulted in 42 of the 53 installations receiving a 95th percentile risk value of zero. This lack of differentiation among installations does not lend itself to classification into risk groups and does not provide a means by which to achieve the goal of triaging installations for the purpose of informing strategic fire management decisions.

This analysis requires data that is consistent and commensurable across all installations in order to ensure comparisons are meaningful. Short of collecting data regarding values at risk at every installation individually, an untenable undertaking, there was no way to collect data regarding values at every installation in a consistent fashion. This is the reason only the buildings, towers, and boundaries were used in this analysis. That data is available for every installation and is reasonably consistent across installations. However, it limits the values at risk data to the degree that their inclusion in the analysis substantially weakens the study as a whole. As a result, we chose to abandon the use of risk as a classification metric and to use hazard in its place.

HAZARD

Hazard is a measurement of the combination of ignition probability and the potential fire behavior, including consideration of fire suppression effects. It represents a combination of how likely a fire is to occur and how severe the fire is likely to be. This makes it a good metric to use for differentiating the fire exposure of installations as it accounts for everything except values at risk. Please refer to the Ignition Calculations, Fire Behavior Magnitude Calculations, and Hazard Calculation sections for detail on how Hazard was calculated.

The 95th percentile hazard cell value was calculated for each installation. This is a representation of the upper end of hazard that is observed at the installation and thus is a measure of the maximum level of fire-related hazard the installation faces. As mentioned above, in addition to the potential hazard, a measurement of the amount of land exposed to the hazard was used. Large areas of high hazard present a greater threat than small areas of the same level of hazard. We incorporated these two values, the 95th percentile hazard and the area occupied by those cells greater than or equal to the 95th percentile hazard value, into a 'Hazard Metric' for use in this analysis. This is the metric by which installations were indexed in order to triage them across all 53 installations in the study.

Figure 4 shows the Hazard Metric for all 53 installations in the study. The 95th percentile hazard values range from 0 to 910.65. The area occupied at or above that value ranges from less than 5 acres to 109,852 acres.

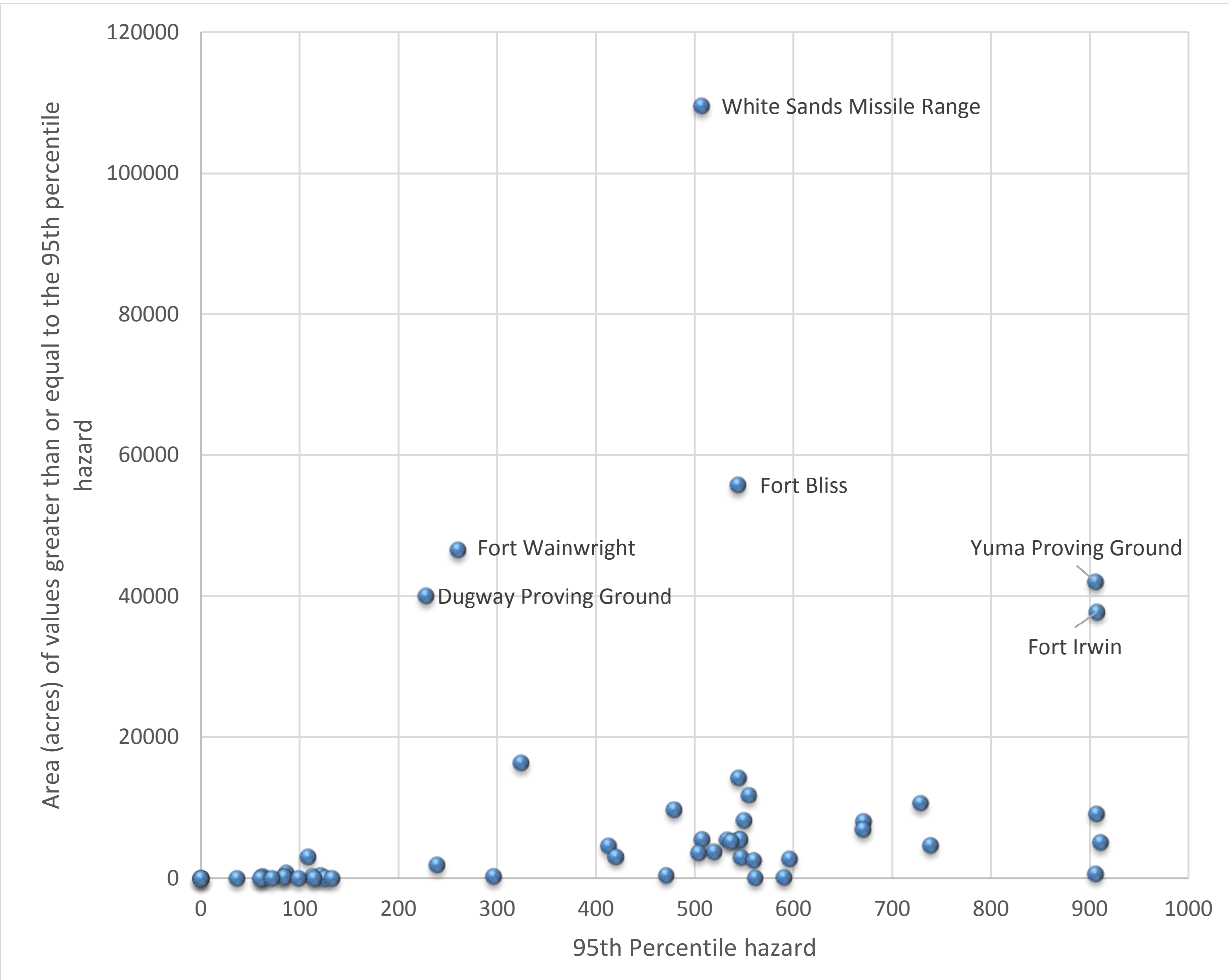


Figure 4. The Hazard Metric for each installation. The Hazard Metric is defined by each installation's 95th percentile hazard value versus the area occupied by cells greater than or equal to the 95th percentile hazard value. The six outlier installations are labeled.

In Figure 4, there are six points that have significantly larger areas than the remaining 47. Statistical analysis was used to demonstrate that these six installations are outliers from the rest of the data. This process is described in detail in the Outliers section. These installations were not removed from the analysis entirely, only from the process of establishing thresholds for triaging the installations into high, moderate and low categories. If left in the data set, they would vastly skew the outcomes. Instead, they are discussed individually in the Outliers section.

Removing the outliers left 47 installations in the threshold analysis. Figure 5 shows only these remaining installations but is otherwise the same data shown previously in Figure 4. The largest installation in the remaining 47 contains just over 16,000 acres at or above the 95th percentile hazard value.

Diagonal bands were used to divide installations into high, moderate, and low hazard. Because of the interplay between the hazard magnitude and acreage, a simple quadrant analysis was not appropriate. A high 95th percentile hazard value *or* a large area at or above that percentile each merit classification as a high hazard installation. Moderate values of either parameter warrant a moderate hazard classification, and only a combination of low values for both parameters should produce a low hazard classification. In accordance with these guidelines, the division between high and moderate values was drawn from the largest observed high hazard area as (y-intercept) to the largest observed 95th percentile (x-intercept). The moderate-low division was drawn using half of each of these values.

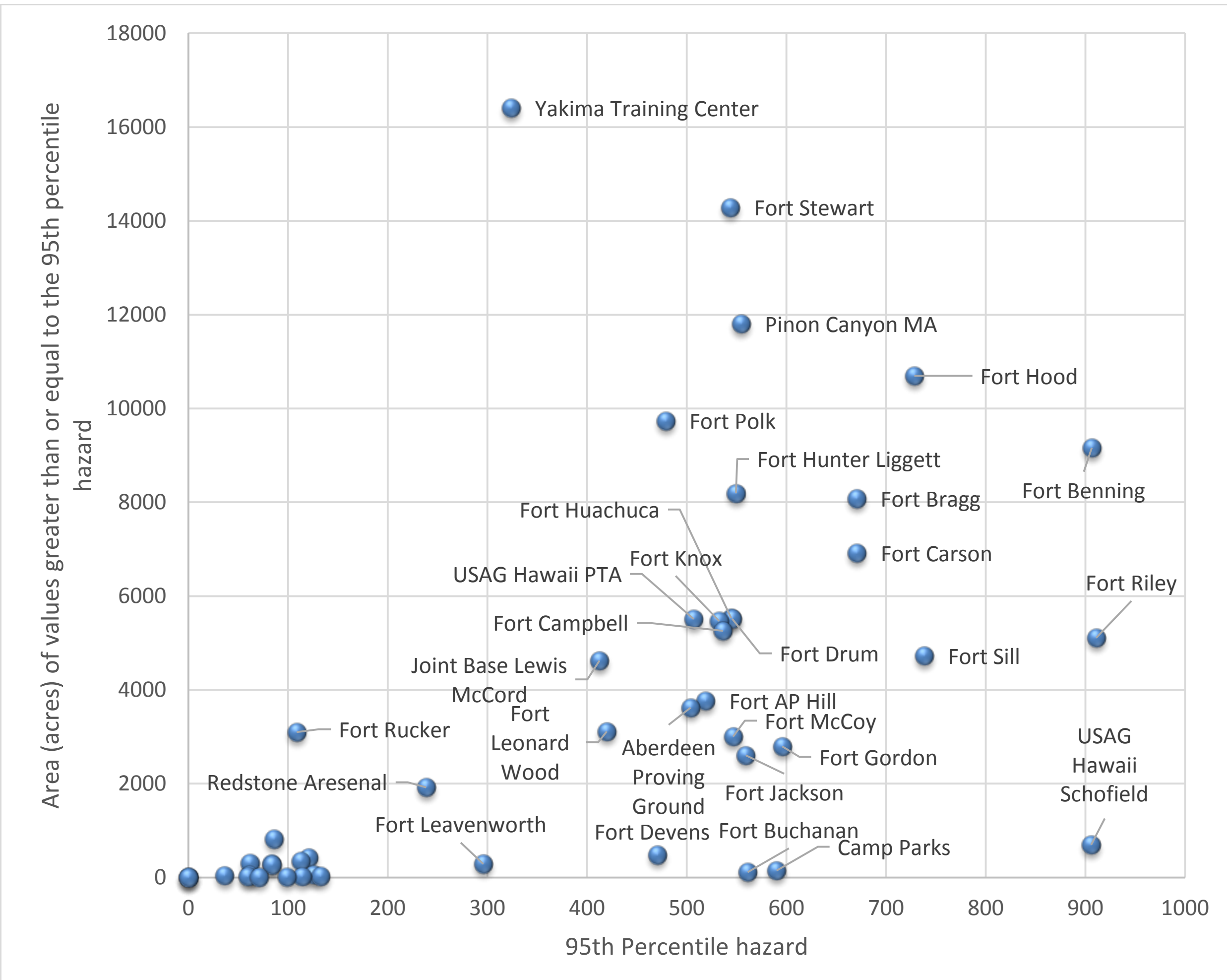


Figure 5. 95th percentile hazard value versus the area occupied by cells greater than or equal to the 95th percentile hazard value. In this figure, six installation that had extreme acreages have been removed from the comparison among installations and are considered separately.

Because the acreage greater than or equal to the 95th percentile hazard value will always be approximately 5% of the installation size, small installations in this analysis needed less area with elevated hazard values in order to be categorized into the moderate or high classifications. This is in keeping with the representation of the threat to the installation from fire. All else being equal, resources of concern are more likely to be impacted by wildfire at smaller installations than larger ones because a fire of a given size will affect a greater proportion of the land area of the smaller installation. Similarly, fires of the same size will be more likely to threaten the boundary of a smaller installation because a greater proportion of the installation is close to the boundary, and thus the fire is more likely to cross the boundary.

High, moderate, and selected low hazard installations are labelled in Figure 6. Table 2 provides preliminary hazard classifications for all installations based on these divisions. Classes for outliers are discussed in the next section.

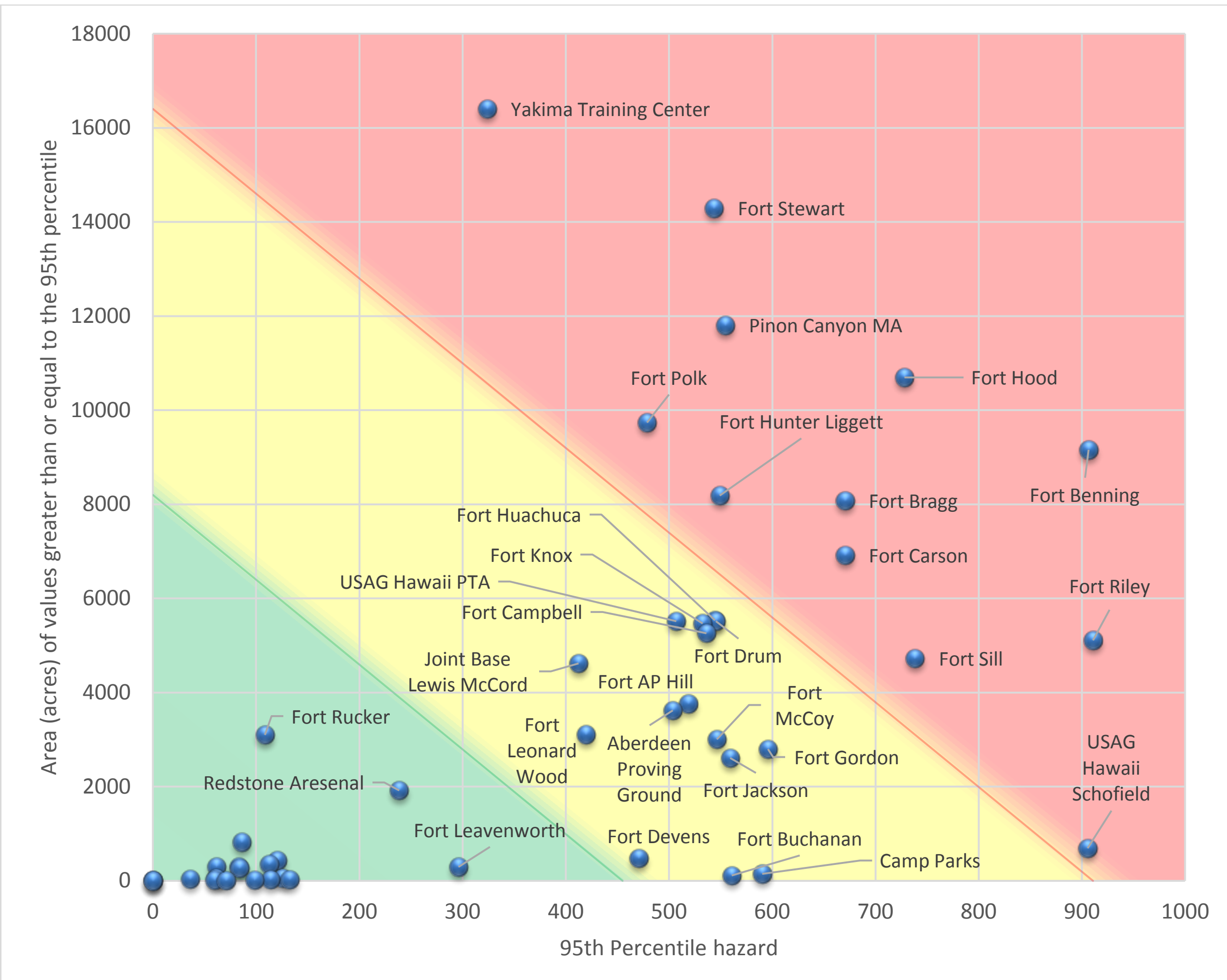


Figure 6. High (red), moderate (yellow), and low (green) hazard groupings with high and moderate installations labelled.

Table 2. Preliminary grouping of installations into triaged classes of the Hazard Metric. Outliers are not assigned a Hazard Metric class at this stage.

High Hazard	Moderate Hazard	Low Hazard	Undetermined Hazard (Outliers)
Fort Benning	Aberdeen Proving Ground	U.S. Army Laboratory	Dugway Proving Ground
Fort Bragg	Camp Parks	Carlisle Barracks	Fort Bliss
Fort Carson	Fort AP Hill	Detroit Arsenal	Fort Irwin
Fort Hood	Fort Buchanan	Fort Belvoir	Fort Wainwright
Fort Hunter Liggett	Fort Campbell	Fort Detrick	White Sands Missile Range
Fort Polk	Fort Devens	Fort Greeley	Yuma Proving Ground
Fort Riley	Fort Drum	Fort Hamilton	
Fort Sill	Fort Gordon	Fort Leavenworth	
Fort Stewart	Fort Huachuca	Fort Lee	
Pinon Canyon MA	Fort Jackson	Fort Meade	
USAG Hawaii Schofield	Fort Knox	Fort Myer McNair	
Yakima Training Center	Fort Leonard Wood	Fort Rucker	
	Fort McCoy	Natick	
	Joint Base Lewis McCord	Picatinny Arsenal	
	USAG Hawaii PTA	Presidio Of Monterey	
		Redstone Arsenal	
		Rock Island Arsenal	
		Sharpe Army Depot	
		USAG Miami	
		West Point	

OUTLIERS

Six of the 53 installations in this study had hazard acreage values so large they were effectively incomparable with the rest of the dataset. These are identified in Table 2 and discussed individually below where the appropriate hazard classification for each is determined.

Statistical tests were used to determine whether these six installations can be classified as outliers. Implementation of standard statistical tests for outliers (e.g. Grubb's Test or Tietjen-Moore Test) was not valid because the data did not have a normal or log normal distribution. However, Tukey's outlier test uses interquartile ranges and has some application to this highly skewed data. Using Tukey's method, we found that the six installations in question fit the criteria for outliers using either the 1.5 or 3 times the interquartile range definition.

Because the multiplier of interquartile ranges required to define an outlier in Tukey's method, in our case 1.5 or 3, is loosely based on normally distributed data, we also chose to use two supplemental mechanisms to aid in evaluating outliers. In the first, we examined the histogram of acreage exceeding 95th percentile hazard value, without reference to the value of the 95th percentile, shown in Figure 7. The majority of installations have areas at or above the 95th percentile hazard that are less than 20,000 acres. There are 5 values between 35,000 and 60,000 acres, and one greater than 105,000 acres. The single instance representing the largest acreage is clearly an outlier, and the degree of separation between the central five cases and the remaining installations is suggestive that they too merit consideration as outliers.

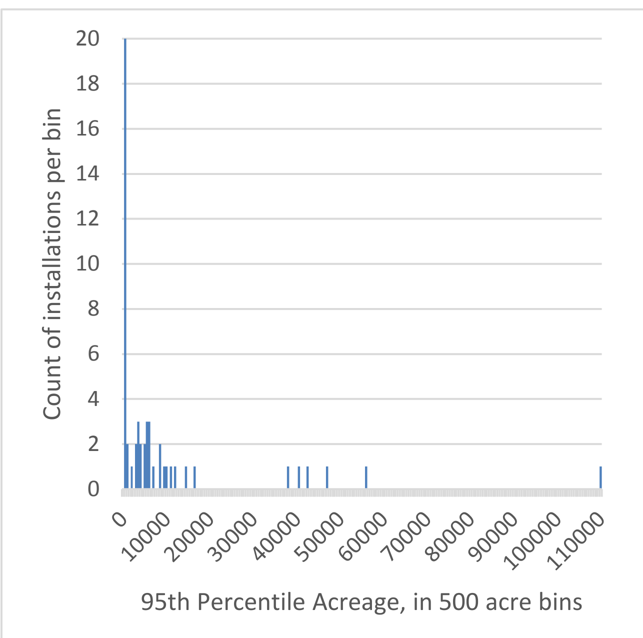


Figure 7. Histogram of acreage exceeding the 95th percentile hazard value in 500 acre bins.

To make a determination about the remaining five very large installations, we examined the standard five statistic summary (minimum, 1st quartile, median, 3rd quartile, and maximum) in a boxplot (Figure 8). Panel A shows the distribution when all the data is used. The long upper "whisker" (extending from the 3rd quartile to the maximum) is indicative of the great difference in value from the single largest acreage to the value below which lays three-quarters of the data (the 3rd quartile). If those six values are identified as outliers (Panel B), then the remaining data can be plotted as shown in Panel C. The difference between the interquartile range and the closest outlier is readily apparent in Panel B. In Panel C, the difference between the maximum and 3rd quartile is still greater than the other intervals (3rd quartile to median, median to 1st quartile, or 1st quartile to minimum), but the difference has been notably reduced (by over a factor of 5 as compared to the data in Panel A).

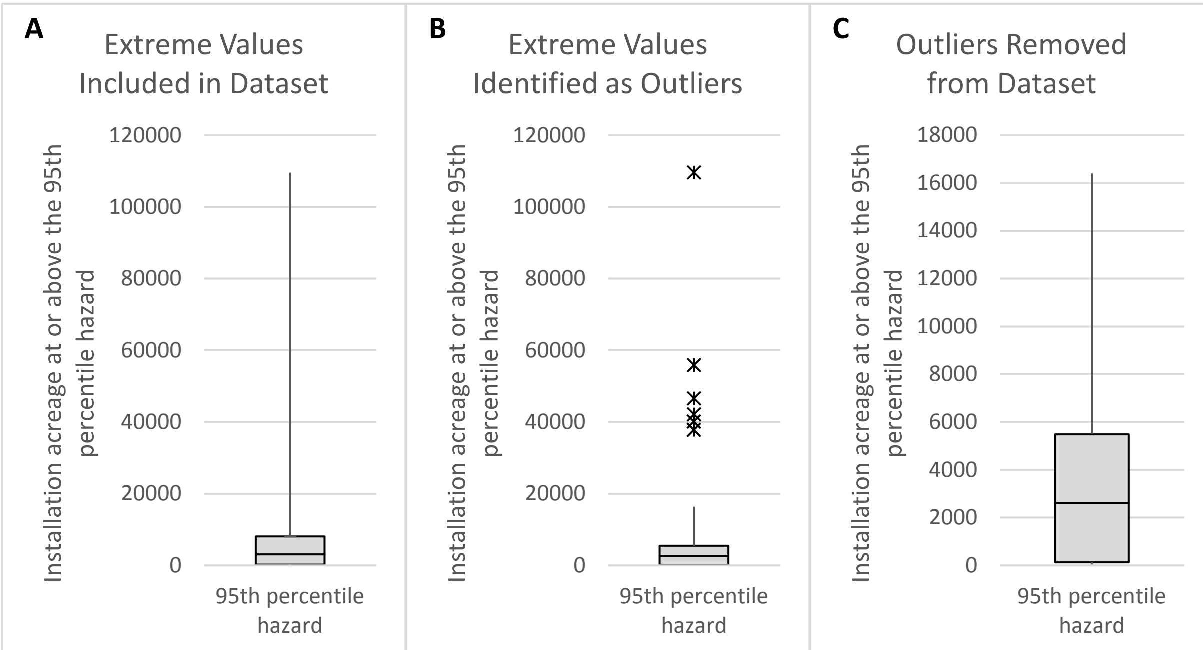


Figure 8. Box plots for 95th percentile acreage data. In all panels, the interior line marks the median, and the two boxes extend down to the 1st quartile, and up to the 3rd quartile, respectively. Panel A was created using the entire dataset of 95th percentile hazard data. Panel B displays all of the data, but excluded the extreme values (marked with asterisks) from the median, quartile, minimum and maximum calculations. Panel C excluded the points identified as outliers and only shows the summary outputs for the remaining data. Panel C is, effectively, a close-up of the bottom of Panel B.

Based on these evaluations, it was determined that these six installations are indeed statistically classifiable as outliers. After they were removed from the dataset for the purposes of defining low, moderate, and high thresholds of the hazard metric (Figure 6), they were considered individually and placed into a hazard category. In this way, they were evaluated for their categorical appropriateness without their extremely large areas overwhelming the hazard categorization process.

Additionally, four of the six outliers are located in the desert southwest. LANDFIRE fuel model data is known to have significant data errors in this region. Much of the desert southwest will not carry fire, the fuels are not contiguous enough to allow a fire to spread from one patch of fuels to the next. LANDFIRE has, however, classified much of this area as burnable, allowing simulated fires to burn in areas where fuels are insufficient to carry fire. This was confirmed during the Type 3 Risk Assessment of Yuma Proving Ground where the majority of the installation was found to be unburnable. Our experience there is further supported by a LANDFIRE report (LANDFIRE 2010) indicating lower accuracy in desert ecosystems and higher accuracies in forested ecosystems. Inaccuracies in LANDFIRE data can affect the accuracy of the expected fire behavior as areas that in reality cannot burn instead result in highly flammable FlamMap outputs due to the very dry conditions of the desert southwest. These erroneous outputs affect the hazard values in those cells which in turn increases the 95th percentile hazard value for the installation.

It should be noted that the desert southwest region experiences spikes in fire occurrence and spread after high rainfall periods. These periods produce a large volume of herbaceous vegetation that often fills in the gaps in fuels that are normally present. Fires can then carry across the landscape, and in many cases burn large acreages. The most recent event of this type occurred in 2005, but such events are rare, occurring on a scale of decades.

These concerns were addressed during the final categorization of the outlier installations using evaluation of the fuels data, expert knowledge of the area, and Type 1 and Type 3 Risk Assessment findings.

DUGWAY PROVING GROUND

Dugway Proving Ground is located in northern Utah, and totals over 800,000 acres. A large portion (roughly 60%) of the installation is part of the Great Salt Lake Desert and classified as unburnable fuels. It is the remaining ~320,000 acres that are important to determining hazard. Of the burnable area, 56.6% is a classified in LANDFIRE as sparse grass-shrub fuel model, 18.71% as a sparse shrub model, and 18.02% as a moderate grass model.

The authors have completed a Type 3 Risk Assessment, including quality control of LANDFIRE fuels data, for Utah Test and Training Range, an Air Force installation ~100 km north with very similar fuels. At that location, we found that the LANDFIRE classifications of sparse grass-shrub, sparse shrub and moderate grass models were all considerably overestimated. The predominant observed fuel was a sparse grass model. If we assume classification errors at the two sites are similar, then much of the 93.3% of burnable fuels classified as sparse grass-shrub, sparse shrub, or moderate grass should actually be sparse grass. Under dry conditions with a 10 mph 20 foot wind speed, the fireline intensity (BTU/ft/sec) of sparse grass is 21.5% that of sparse grass-shrub, 33.9% that of sparse shrub, and 11.7% that of moderate grass indicating a high likelihood of over-estimation of fire behavior magnitude.

The Type 1 Risk Assessment detected only 1.09 wildfires per year during the period 2004 – 2014. However, the mean fire size was the second largest of all of the 53 installations, 5353 acres, though this is in part driven by the small number of fires detected.

We also considered that a large proportion of Dugway Proving Ground is salt flats and is unburnable. When addressing only the potentially burnable portion of the installation, the 95th percentile hazard value was increased by 48%, but still fell in the low to middle range. The acreage where 95th percentile or greater hazard values are observed is reduced by 61%, but is still quite large at 15,674 acres. This would lead to a Hazard Metric in the high classification assuming the fuels data were accurate.

Based on the strong likelihood that the hazard is overestimated, possibly by a substantial amount, a small number of fires per year, but large fire acreages for those few fires, we placed Dugway Proving Ground in the moderate hazard category.

FORT BLISS

Fort Bliss is over 1.1 million acres, located in south-central New Mexico and extreme western Texas. In addition to expected desert fuel inaccuracies, examination of the LANDFIRE data shows specific data classification disjunctions that are not reflected in imagery of the same area. One example of this is shown in Figure 9.

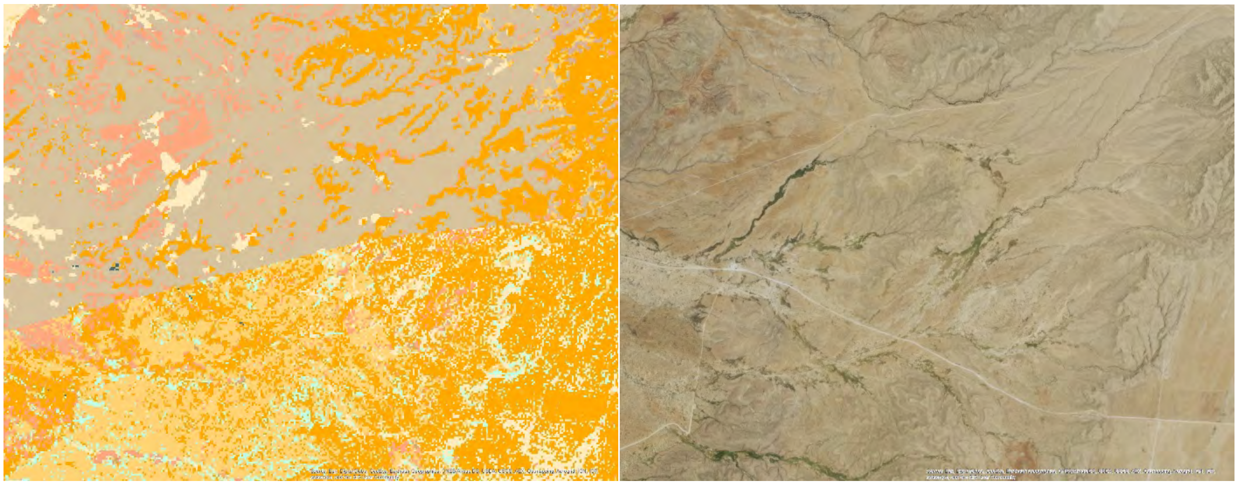


Figure 9. Fort Bliss LANDFIRE fuels classification disjunction (left) is not apparent in 1:30,000 imagery (right). Note the relatively straight line running approximately east/west across the center of the left image separating yellow and orange from a large area of grey and pink. The yellow and orange colors represent more flammable fuel models than the grey and pink colors which translates into an artificial result of more severe fire behavior in the yellow and orange areas. This suggests inconsistent fuels classification across the installation and demonstrates some of the considerations required when utilizing LANDFIRE data.

Fort Bliss straddles two LANDFIRE Zones (25 and 26), which are areas within which different sets of decision criteria are applied to LANDFIRE fuels data development. The classification disjunction observed in Figure 9 is a result of that boundary. Zone 25 is largely classified as sparse grass with some sparse shrub, whereas zone 26 is a mix of sparse grass-shrub, moderate grass, and moderate grass-shrub. Although the fuels would be expected to become heavier in the higher elevation portions of the installation, the zone boundary is not related to elevation, and overestimates the portion of the installation where anything other than sparse fuels can grow. The result is unrealistically high fire intensity values, which elevate the 95th percentile hazard for Fort Bliss. Fort Bliss recorded one of the highest average number of wildfires per year in the he Type 1 Risk Assessment. However, the mean wildfire size was an order of magnitude smaller than that of Dugway Proving Ground and fell in the middle of the group in the Type 1 Risk Assessment. Based on the likelihood that the 95th percentile hazard value is overestimated, but a high number of fires per year and moderate acreages for those fires, Fort Bliss was categorized as a high hazard installation.

FORT IRWIN

Fort Irwin covers over 750,000 acres in the Mojave desert of California. Of the slightly more than half the installation that is classified as burnable by LANDFIRE, 75.95% is a moderate fuel class (either moderate grass, moderate grass-shrub, or moderate shrub). Based on subject matter expertise, we determined that fuel loads are very likely overestimated by LANDFIRE, particularly in the lower elevation areas, and thus the 95th percentile hazard value is also an overestimation. A mean of 1.82 fires per year was recorded from the Type 1 Risk Assessment, and the mean fire size was 255 acres. Based on that information, Fort Irwin was recategorized as a moderate hazard installation.

FORT WAINWRIGHT

Fort Wainwright is the only outlier installation located in a forested ecosystem where LANDFIRE data is expected to be more reliable. We have detailed observations of fuels data for Fort Wainwright resulting from the Type 3 Risk Assessment of that installation, and its LANDFIRE fuels classifications are reasonably accurate. There is no reason to believe its hazard classification has been unduly influenced by an unwarranted input component, and based on those considerations, Fort Wainwright was left in the high Hazard Metric category.

WHITE SANDS MISSILE RANGE

At over two million acres, White Sands Missile Range is the largest installation in the analysis, almost twice as large as Fort Bliss, the next largest. It is also adjacent to Fort Bliss, although entirely within one LANDFIRE zone, so it is not subject to the same data disjunction. As is typical in a desert ecosystem, some of the lower elevation fuels are likely overestimated, particularly the areas classified as moderate grass-shrub. However, there are abundant high elevation areas where fuels classification is expected to be more reliable and where fuel loads are likely to be more than adequate to carry fires. This is supported by the Type 1 Risk Assessment findings, which show a mean fire size of 873 acres, and a mean of 2.45 fires per year. White Sands Missile Range merits a high Hazard Metric categorization.

YUMA PROVING GROUND

Detailed fuels data were collected at Yuma Proving Ground as part of a Type 3 Risk Assessment carried out there. Although the LANDFIRE classification is almost entirely a mix of sparse shrubs and moderate grass-shrub fuels, observations taken during a week-long site visit demonstrated the majority of this installation was, in fact, unburnable. The most common location in which fuels contiguous enough to carry fire were found in stream channels. Outside of these washes, vegetation was largely too sparse to allow fire spread. Based on that information, we classified Yuma Proving Ground in the low Hazard Metric class.

OTHER INSTALLATIONS WITH SPECIAL CONSIDERATIONS

Because Fort Huachuca is in the desert southwest, where the LANDFIRE fuels data is suspect, we investigated the fuels there as well. Though there is likely some level of over-estimation of fuel continuity, it does not appear to be nearly as widespread as at the other desert southwest installations, in large part because much of Fort Huachuca consists of mountainous, relatively high elevation terrain where LANDFIRE tends to be more accurate.

Fort Huachuca is also unusual because it is comprised of two properties, a northern property consisting almost entirely of sand and rock, and thus unburnable, and a southern property where virtually all of the installation infrastructure is located. We examined the statistics for Fort Huachuca's southern property separately and found that while the acreage diminished by approximately one third with the removal of the northern property, where fire spread is not possible, the hazard value remained nearly unchanged and the resulting Hazard Metric still fell firmly within the moderate category.

FINAL CLASSIFICATION AND DISCUSSION

This Risk Assessment suggests there are 15 installations within the U.S. Army IMCOM installation portfolio that may be of significant concern (Table 3, Figure 10). This assessment is validated by the fact that many of the high hazard installations have previously experienced large scale fires and/or fires producing significant damage to mission capability or property. Yakima Training Center recently experienced a 176,000 acre fire, most of which burned off of the installation. Fort Carson routinely has wildfires in excess of 1,000 acres. Fort Wainwright experiences large scale fires of 10,000 acres or more several times per decade due to the fire regime in which it occurs. Fort Bliss, Fort Wainwright, and Pinon Canyon Maneuver Area have all experienced at least five transboundary fires each in the past 10 years. Fort Bragg, Fort Sill, Fort Hood, Fort Polk, and Yakima Training Center each experience an average of four or more large fires (defined as greater than 300 acres) per year. Much of this information comes from the Type 1 Risk Assessment and bolsters the conclusions of this study. These installations typically experience both large fires and a high number of fires relative to other installations.

The installations in the low classification are also of interest as they likely do not require significant attention or mitigation assistance with respect to wildfire (but may still require attention regarding prescribed fire). Many of these installations support little or no field training, the primary source of ignitions on military installations. They also tend to be located in regions where fuels are not particularly fire prone, weather is not often supportive of significant fire behavior, and the fire season is relatively short, though there are exceptions. Some of these installations sustain significant training, but the type of training is not particularly fire prone. Fort Rucker's lands are used primarily for aviation training, for example. Of the installations classified as low hazard, Picatinny Arsenal may merit some further consideration given their mission requires the use of an unusually wide variety of explosives and other munitions and activities, some of which may be highly fire prone.

It should be noted that though the hazard at a given installation may be low, there are reasons other than wildfire risk and hazard to consider when determining the level of overall wildland fire support for an installation, which may include a prescribed fire program. For example, prescribed fire is often used to improve land for training purposes, increasing line of sight and both mounted and dismounted maneuverability. Ecological needs that require the application of prescribed fire may have little to do with risk or hazard mitigation, but may be important to maintaining desired ecosystem functions or individual species of significant concern, whose well-being may be required by regulatory statute. There are many other similar examples.

The moderate classification includes installations where there is some potential for relatively severe fire (e.g. Fort Gordon where fuels are conducive to intense fire behavior) and/or relatively widespread fire (e.g. Fort Campbell where there have been at least 43 large wildfires in the past 10 years). Fire at all of these installations represent a potential threat to the mission and on and off installation resources. While the likelihood of a significant fire at these installations may be lower than at installations in the high classification, there is still a measurable possibility of a fire of major significance occurring at any one of these installations. Indeed, Fort Huachuca and USAG Hawaii PTA have both experienced fires known to the authors that would be considered significant by nearly any measure. So while the frequency of such events is expected to be relatively low, major fire events can be expected to occur at the majority of these installations, it is simply a matter of how long it will be before such an event occurs.

Camp Parks is worthy of individual note as it is a small installation that may not have been thoroughly considered to date. Though less than 2,500 acres in size, it contains live-fire ranges in close proximity to its boundary. The grassy fuels provide light flashy fuels, the environment on occasion produces weather conducive to rapid fire spread, and the installation is nearly surrounded by residential development. Camp Parks also was rated amongst the top installations in a number of fire metrics in the Type 1 Risk Assessment. Considered together, this information suggest Camp Parks may represent a significant wildfire concern.

Many of the other moderate category installations support high loads of potentially highly flammable fuels and are only missing the weather and dry fuel conditions necessary to produce severe fire behavior. Such fire behavior could easily be realized during drought conditions when fuels would be far more receptive to an ignition. Such a period recently occurred in the fall of 2016 when the States of Georgia, Kentucky, and North Carolina experienced multiple fires greater than 10,000 acres while under exceptional drought conditions as defined by the National Drought Monitor. While the likelihood of observing conditions conducive to a major fire at these installations is lower than at installations in the high category, it is not zero, and most of these installations are likely to be subjected to drought conditions for at least some period of time within the next decade.

All of the moderate classification installations also support training that utilizes moderate to large volumes of ignition prone munitions and training aids. As a result, the possibility of an ignition is considerable. Given weather conducive to ignitions, the possibility of ignition at one of these installations is comparable to those in the high category. Many are simply lacking the weather to sustain large-scale fire events on a regular basis.

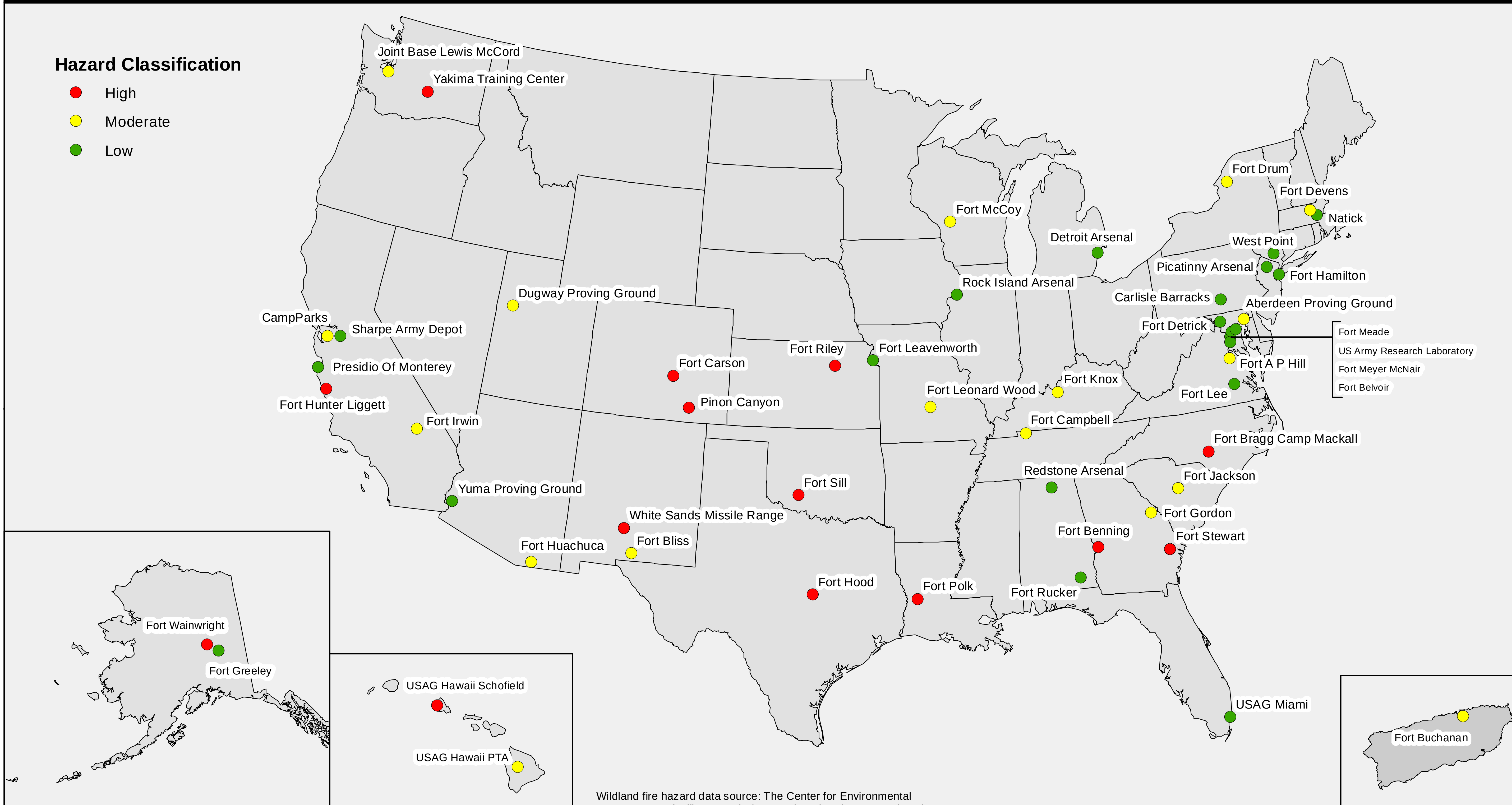
In summary, 15 of the 53 installations analyzed in this study were classified as high hazard. These installations deserve significant consideration for wildfire mitigation resources and funds. Another 17 installations were classified as moderate hazard. Many of these can be expected to experience a fire of major significance in the future, though it may be a decade or more before such an event occurs, and thus may justify some consideration for wildfire mitigation support. The remaining 21 installations were found to have little exposure to wildfire and likely require little assistance for wildfire mitigation, though there may be a wide variety of reasons to support prescribed fire not related to wildfire mitigation at any of these installations.

Table 3. Installations grouped by hazard class. Outliers have been assigned a hazard class based on individual considerations.

High	Moderate	Low
Fort Benning	Aberdeen Proving Ground	U.S. Army Laboratory
Fort Bliss	Camp Parks	Carlisle Barracks
Fort Bragg	Dugway Proving Ground	Detroit Arsenal
Fort Carson	Fort AP Hill	Fort Belvoir
Fort Hood	Fort Buchanan	Fort Detrick
Fort Hunter Liggett	Fort Campbell	Fort Greeley
Fort Polk	Fort Devens	Fort Hamilton
Fort Riley	Fort Drum	Fort Leavenworth
Fort Sill	Fort Gordon	Fort Lee
Fort Stewart	Fort Huachuca	Fort Meade
Fort Wainwright	Fort Irwin	Fort Myer McNair
Pinon Canyon MA	Fort Jackson	Fort Rucker
USAG Hawaii Schofield	Fort Knox	Natick
White Sands Missile Range	Fort Leonard Wood	Picatinny Arsenal
Yakima Training Center	Fort McCoy	Presidio Of Monterey
	Joint Base Lewis McCord	Redstone Arsenal
	USAG Hawaii PTA	Rock Island Arsenal
		Sharpe Army Depot
		USAG Miami
		West Point
		Yuma Proving Ground

Army IMCOM Installations **Wildfire Hazard Classification**

Type 2 Wildfire Risk Assessment Figure 10



Wildland fire hazard data source: The Center for Environmental Management of Military Lands (CEMML), Colorado State University.

GLOSSARY OF TERMS

Cell
This risk analysis process uses gridded data. The landscape is divided into squares, each one of which is a 'cell'. Cells vary in size in this analysis, but are generally 30 m by 30 m. Cells are also referred to as 'pixels'. A grid of cells is referred to as a 'raster'.

Fuel
Living and dead vegetation. Vegetation is referred to as fuel in the context of wildland fire because it is what burns and 'fuels' the wildfire.

Fire Behavior
The characteristics displayed by the fire(s) expressed in terms of flame length, rate of spread, and fireline intensity (heat per linear length of fire front per unit time) and other measures. More than one variable may be used to describe the fire behavior.

Hazard
In the context of wildland fire, hazard is a part of wildfire risk and is defined by the combination of ignition potential and the breadth of potential fire behavior. It does not account for the potential impacts to valued resources.

LANDFIRE
A national dataset that describes vegetation in terms of the fire behavior fuel models, canopy cover, elevation, slope, and many other variables. This data is used to support fire behavior simulations which require information about the vegetation in which the simulated fire is burning. In this analysis, LANDFIRE data has been quality controlled prior to use.

Percentiles
In a set of data, the 90th percentile value is that value where 90% of the values in the dataset will be smaller than that value, and only 10% will be larger. For example, we might be interested in the flame lengths of the most severe wildfires. If the 90th percentile flame length is eight feet, then 90% of the flame lengths observed are less than eight feet and only 10% are greater than eight feet. The 50th percentile is synonymous with the median value.

When describing the threat wildland fire poses to the human and natural environment, typically managers are interested in the more severe events, e.g. large, intense wildfires. These fires are low probability, but high consequence events and it is the nature of wildfire management to evaluate events that are unlikely, but highly undesirable if they were to occur. To address this focus on fires that are relatively unlikely, we use 'percentiles' to measure fire behavior and size within just the subset of fires that are very large and damaging.

Prescribed fire
A planned wildland fire, intentionally ignited for the purpose of achieving a specified management objective that is in accordance with applicable laws, policies, and regulations.

Probability
The likelihood of an event, typically expressed as decimal. Probabilities are cumulative across space and time. The probability of fire in any given 30 m by 30 m cell may be low in a given year, but when combined with other cells nearby, and/or over the course of several years, probability of fire can add up to a near certainty (probability of 1). Probabilities in this report are measured on an annual basis. A probability of one means that an occurrence is 100% certain in any given year and a probability of .2 means there is a 20% likelihood of occurrence in any given year.

Risk
A combination of the probabilities of event occurrence, magnitude, and outcome. In the case of wildfire, these are ignition potential, the breadth of potential fire behavior, and the values that may potentially be impacted.

Value at Risk
Anything considered valuable that could potentially be affected, positively or negatively, by wildfire. These are often not measurable, or very difficult to measure, in monetary terms (i.e., aesthetics, rare species, installation security).

Wildfire
An unplanned, unwanted wildland fire. These may be caused by human activities or natural occurrences such as lightning.

Wildland Fire
Any fire deliberately or unintentionally ignited in vegetation or natural fuels. Wildland fire includes both wildfires and prescribed fires

REFERENCES

Badia-Perpinyà A, Pallares-Barbera M. 2006. Spatial distribution of ignitions in Mediterranean periurban and rural areas: the case of Catalonia. International Journal of Wildland Fire, 15, 187-196.

Bradshaw L, McCormick E. 2000. FireFamilyPlus user's guide, Version 2.0. Gen. Tech. Rep. RMRS-GTR-67WWW. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://www.treesearch.fs.fed.us/pubs/4573

Finney MA. 2006. An overview of FlamMap modeling capabilities. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006 Fuels Management – How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 213-220. http://www.treesearch.fs.fed.us/pubs/25948

FireModels.org; Fire Behavior and Fire Danger Software. Missoula Fire Sciences Laboratory. http://www.firemodels.org/

Grala K, Cooke W. 2010. Spatial and temporal characteristics of wildfires in Mississippi, USA. International Journal of Wildland Fire, 19, 14-28.

Kaplan S, Garrick BJ. 1981. On the quantitative definition of risk. Risk Analysis, 1, 11-27.

LANDFIRE. 2010. LANDFIRE Product Assessment: National Western Milestone Agreement Assessment Super Zone Analysis and Report. http://www.landfire.gov/documents/LANDFIRE_WUS_SuperZone_Report.pdf

Landscape Fire and Resource Management Planning Tools Project (LANDFIRE). http://www.landfire.gov/index.php

Maingi J, Henry M. 2007. Factors influencing wildfire occurrence and distribution in eastern Kentucky, USA. International Journal of Wildland Fire, 16, 23-33.

Ostrom LT, Wilhelmsen CA. 2012. Risk assessment. Tools, techniques, and their applications. John Wiley and Sons Inc, Hoboken, New Jersey.

Rausand M. 2011. Risk Assessment. Theory, methods, and applications. John Wiley and Sons Inc, Hoboken, New Jersey.

Scott JH Burgan RE. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. General Technical Report RMRS-GTR-153, United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

CONTACT INFORMATION

This report was prepared by:

The Wildland Fire Support Center at
The Center for Environmental Management of Military Lands
1490 Campus Delivery
Colorado State University
Fort Collins, CO 80523-1490

Andrew Beavers
Wildland Fire Program Manager
cemml_fire_support@mail.colostate.edu
970-491-1005

This report was prepared for:

The United States Army Installation Management Command
Directorate of Public Works
Environmental Division
Resourcing and Environmental Planning Branch
San Antonio, TX

Craig Slebrch
Resourcing and Environmental Planning Branch Chief
craig.j.slebrch.civ@mail.mil

210-466-0570

APPENDIX 1 – IMCOM INSTALLATIONS INCLUDED IN THE TYPE 2 WILDFIRE RISK ASSESSMENT

Installation	State	UTM Zone	Acreage	Hazard Classification
Aberdeen Proving Ground	Maryland	18	71905.67	Moderate
Camp Parks	California	10	2480.13	Moderate
Carlisle Barracks	Pennsylvania	18	452.28	Low
Detroit Arsenal	Michigan	17	183.98	Low
Dugway Proving Ground	Utah	12	800949.65	Moderate
Fort AP Hill	Virginia	18	74612.13	Moderate
Fort Belvoir	Virginia	18	8321.90	Low
Fort Benning	Georgia	16	182415.48	High
Fort Bliss	Texas	13	1114781.01	High
Fort Bragg	North Carolina	17	160796.83	High
Fort Buchanan	Puerto Rico	19	756.04	Moderate
Fort Campbell	Tennessee	16	104682.19	Moderate
Fort Carson	Colorado	13	138035.48	High
Fort Detrick	Maryland	18	1149.15	Low
Fort Devens	Massachusetts	19	9248.20	Moderate
Fort Drum	New York	18	109756.96	Moderate
Fort Gordon	Georgia	17	55509.14	Moderate
Fort Greeley	Alaska	6	6836.52	Low
Fort Hamilton	New York	18	176.89	Low
Fort Hood	Texas	14	212578.05	High
Fort Huachuca	Arizona	12	110080.79	Moderate
Fort Hunter Liggett	California	10	162100.54	High
Fort Irwin	California	11	755338.34	Moderate
Fort Jackson	South Carolina	17	51906.83	Moderate
Fort Knox	Kentucky	16	108796.52	Moderate
Fort Leavenworth	Kansas	15	5740.46	Low
Fort Lee	Virginia	18	5685.28	Low
Fort Leonard Wood	Missouri	15	61934.73	Moderate
Fort McCoy	Wisconsin	15	59656.95	Moderate
Fort Meade	Maryland	18	5253.76	Low
Fort Myer McNair	Virginia	18	354.96	Low
Fort Polk	Louisiana	15	193314.08	High
Fort Riley	Kansas	14	101621.09	High
Fort Rucker	Alabama	16	61425.36	Low
Fort Sill	Oklahoma	14	94087.66	High
Fort Stewart	Georgia	17	285133.02	High
Fort Wainwright	Alaska	6	929616.95	High
Joint Base Lewis McCord	Washington	10	91386.77	Moderate
Natick	Massachusetts	19	79.17	Low
Picatinny Arsenal	New Jersey	18	5865.06	Low
Pinon Canyon MA	Colorado	13	235507.41	High
Presidio Of Monterey	California	10	400.99	Low
Redstone Arsenal	Alabama	16	38180.07	Low
Rock Island Arsenal	Illinois	15	898.46	Low
Sharpe Army Depot	California	10	720.09	Low
U.S. Army Laboratory	Maryland	18	201.37	Low
USAG Hawaii PTA	Hawaii	5	109694.58	Moderate

Installation	State	UTM Zone	Acreage	Hazard Classification
USAG Hawaii Schofield	Hawaii	4	13591.21	High
USAG Miami	Florida	17	6.52	Low
West Point	New York	18	16096.04	Low
White Sands Missile Range	New Mexico	13	2190480.65	High
Yakima Training Center	Washington	10	327117.43	High
Yuma Proving Ground	Arizona	11	838979.14	Low

APPENDIX 2 – WEATHER STATIONS USED FOR FIRE BEHAVIOR ESTIMATION.

Installation Name	State	Weather Station Name	Weather Station Code	Weather Station Type	Period of Record
Aberdeen Proving Ground	MD	Baltimore/Martin	MTN	NWS	2005-2014
Camp Parks	CA	Altamont	AATC1	RAWS	2009-2015
Carlisle Barracks	PA	Capital City Airport	CXY	NWS	2005-2014
Detroit Arsenal	MI	Detroit City Airport	DET	NWS	2005-2014
Dugway Proving Ground	UT	Aragonite	ARAU1	RAWS	2004-2013
Fort AP Hill	VA	Fredericksburg, Shannon Airport	EZF	NWS	2005-2014
Fort Belvoir	VA	Prince William	PWRV2	NWS	2005-2014
Fort Benning	GA	Lawson AAF Airport	LSF	NWS	2005-2014
Fort Bliss	TX	El Paso Int Airport	ELP	NWS	2005-2014
Fort Bragg + Camp Mackall	NC	Fort Bragg	N/A	RAWS	2005-2014
Fort Buchanan	PR	San Juan Fernando Luis Ribas Dominicci	TJIG	NWS	2005-2014
Fort Campbell	KY	Campbell AAF Airport	HOP	NWS	2006-2014
Fort Carson	CO	Fort Carson	N/A	RAWS	2005-2014
Fort Detrick	MD	Frederick Municipal Airport	FDK	NWS	2005-2014
Fort Devens	MA	Oxbow	OXBM3	RAWS	2012-2015
Fort Drum	NY	Fort Drum	GTB	NWS	2005-2014
Fort Gordon	GA	Daniel Field Airport	DNL	NWS	2005-2014
Fort Greely	AK	Allen AAF	PABI	NWS	2005-2014
Fort Hamilton	NY	JFK Airport	JFK	NWS	2005-2014
Fort Hood	TX	Hood AAF Airport	GRK	NWS	2005-2014
Fort Huachuca	AZ	Sierra Vista Municipal	FHU	NWS	2004-2014
Fort Hunter Ligget	CA	Hunter Ligget	N/A	RAWS	2006-2015
Fort Irwin	CA	Bicycle Lake AAF	BYS	NWS	2011-2014
Fort Jackson	SC	McEntire Air National Guard Weather	MMT	NWS	2005-2014
Fort Knox	KY	Fort Knox/Godman	FTK	NWS	2005-2014
Fort Leavenworth	MO	Kansas City Intl Airport	MCI	NWS	2005-2014
Fort Lee	VA	James River	N/A	RAWS	2006-2015
Fort Leonard Wood	MO	Waynesville Regional Airport	TBN	NWS	2005-2014
Fort McCoy	WI	Sparta Fort McCoy Airport	CMY	NWS	2005-2014
Fort Meade	MD	Cedarville	CVLM2	RAWS	2005-2014
Fort Myer/McNair	VA	Ronald Reagan Washington National Airport	DCA	NWS	2005-2014
Fort Polk	LA	Vernon	LEVL1	NWS	2005-2014
Fort Riley	KS	Fort Riley	FRI	NWS	2009-2014
Fort Rucker	AL	Fort Rucker	OZR	NWS	2005-2014
Fort Sill	OK	Fort Sill	FSI	NWS	2005-2014
Fort Stewart + HAAF	GA	Ft Stewart	LHW	NWS	2005-2014
Fort Wainwright	AK	Wainwright AAF	PAFB	NWS	2005-2014
Joint Base Lewis McCord	WA	Tacoma/McChord Airfield	KTCM	NWS	2005-2014
Natick	MA	Norwood Memorial Airport	OWD	NWS	2005-2014
Picatinny Arsenal	NJ	Ringwood	RAWN4	RAWS	2005-2014
Piñon Canyon	CO	Ute Canyon	UCNC2	RAWS	2007-2014
Presidio of Monterrey	CA	Monterey Peninsula	MRY	NWS	2005-2014

Installation Name	State	Weather Station Name	Weather Station Code	Weather Station Type	Period of Record
Redstone Arsenal	AL	Redstone Arsenal	HSV	NWS	2005-2014
Rock Island Arsenal	IL	Moline	MLI	NWS	2005-2014
Sharpe Army Depot	CA	Stockton Metro Airport	SCK	NWS	2005-2014
U.S. Army Research Lab	MD	Ronald Reagan Washington National Airport	DCA	NWS	2005-2014
USAG Hawaii - PTA	HI	Bradshaw AAF	PHSF	NWS	2000-2009
USAG Hawaii - Schofield	HI	Honolulu Intl Airport	PHNL	NWS	2005-2014
USAG Miami	FL	Miami Intl Airport	MIA	NWS	2005-2014
West Point	NY	StonyKill	BCHN6	RAWS	2005-2014
White Sands Missile Range	NM	Holloman AFB	HMN	NWS	2005-2014
Yakima Training Center	WA	Vagabond Army Airfield	YKM	NWS	2005-2014
Yuma Proving Ground	AZ	Yuma 27 ENE	NYL	NWS	2005-2014

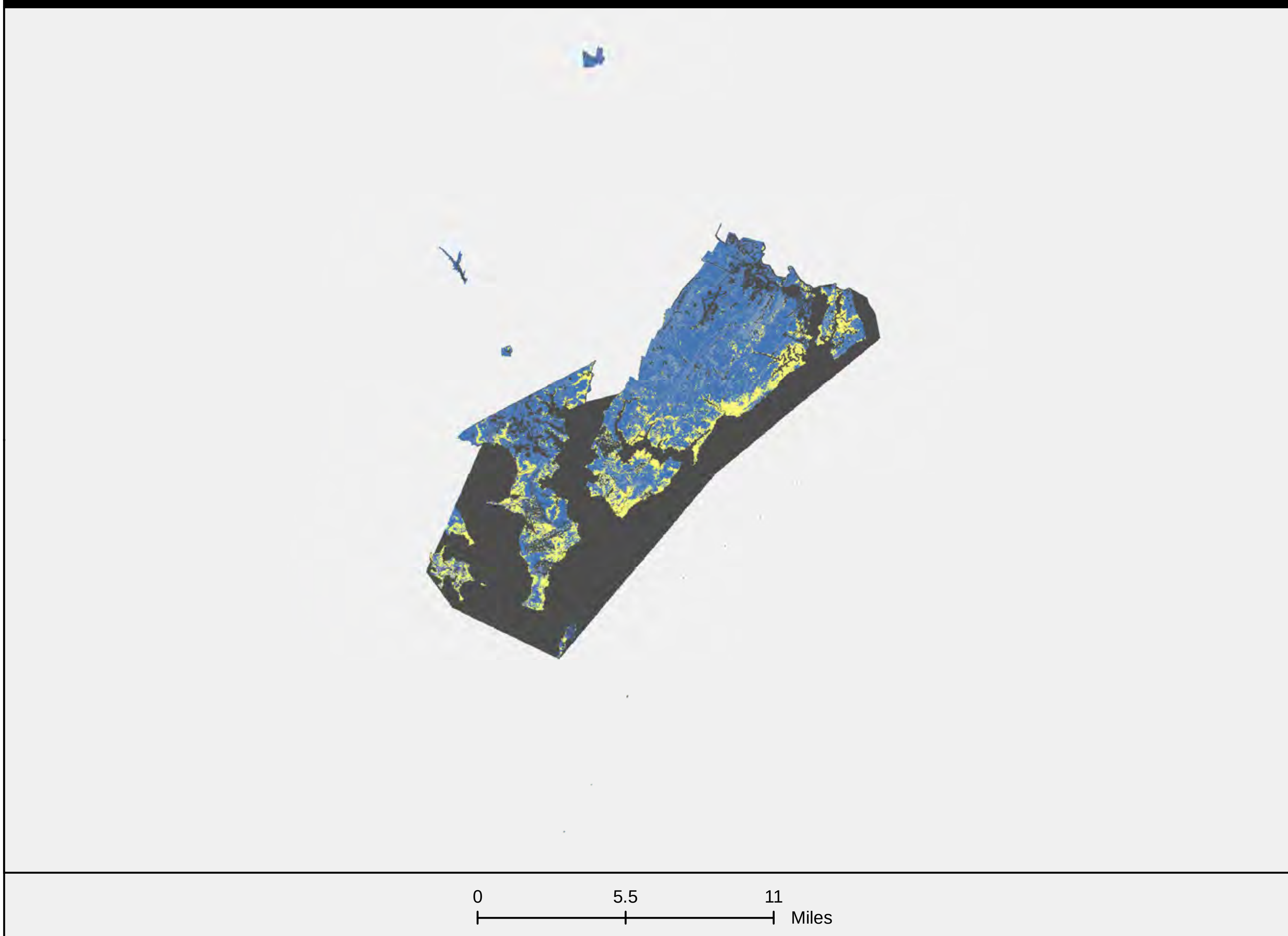
APPENDIX 3 – WILDFIRE HAZARD MAPS

The following maps for each installation represent the final hazard and the two inputs into hazard, ignition likelihood and fire behavior magnitude. The results from this study are intended for use at the national scale to compare potential wildfire hazard among installations rather than to provide any information about variation within hazard or its component parts across a single installation. Fine-scale risk assessment that effectively enumerates within installation variation in ignition potential, hazard, risk, and other fire management concerns is addressed by the Type 3 Risk Analysis.

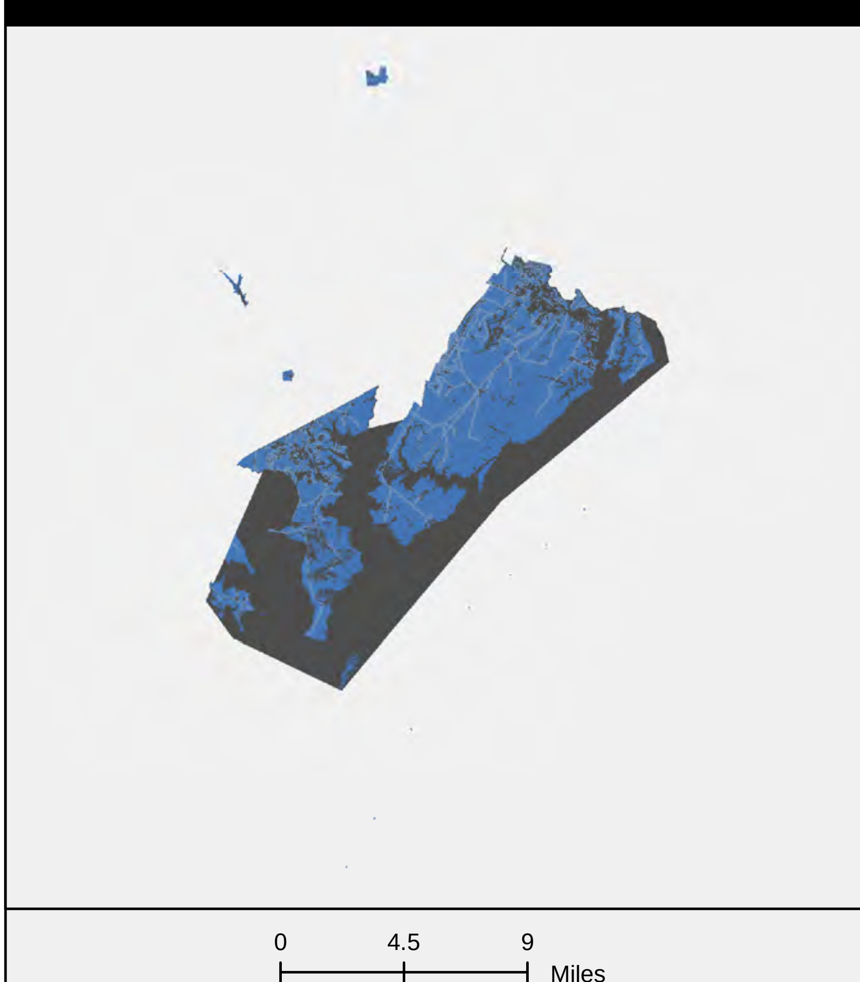
Aberdeen Proving Ground **Moderate**

Type 2 Wildfire Risk Assessment

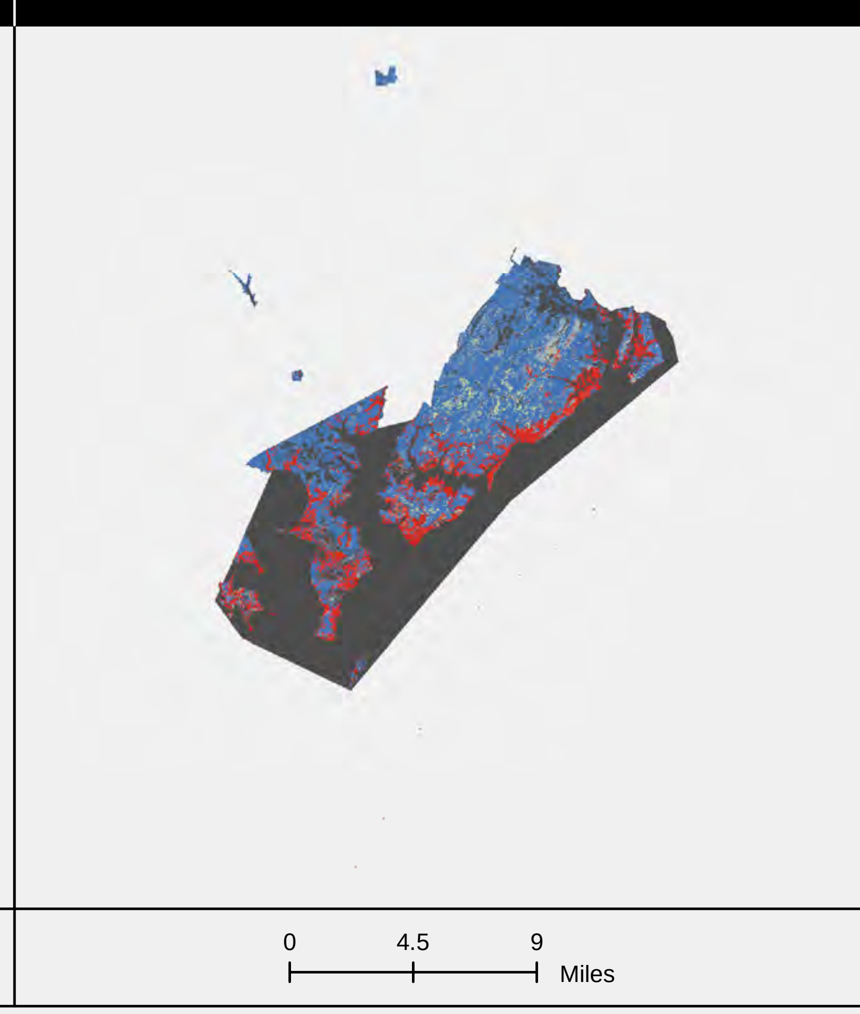
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

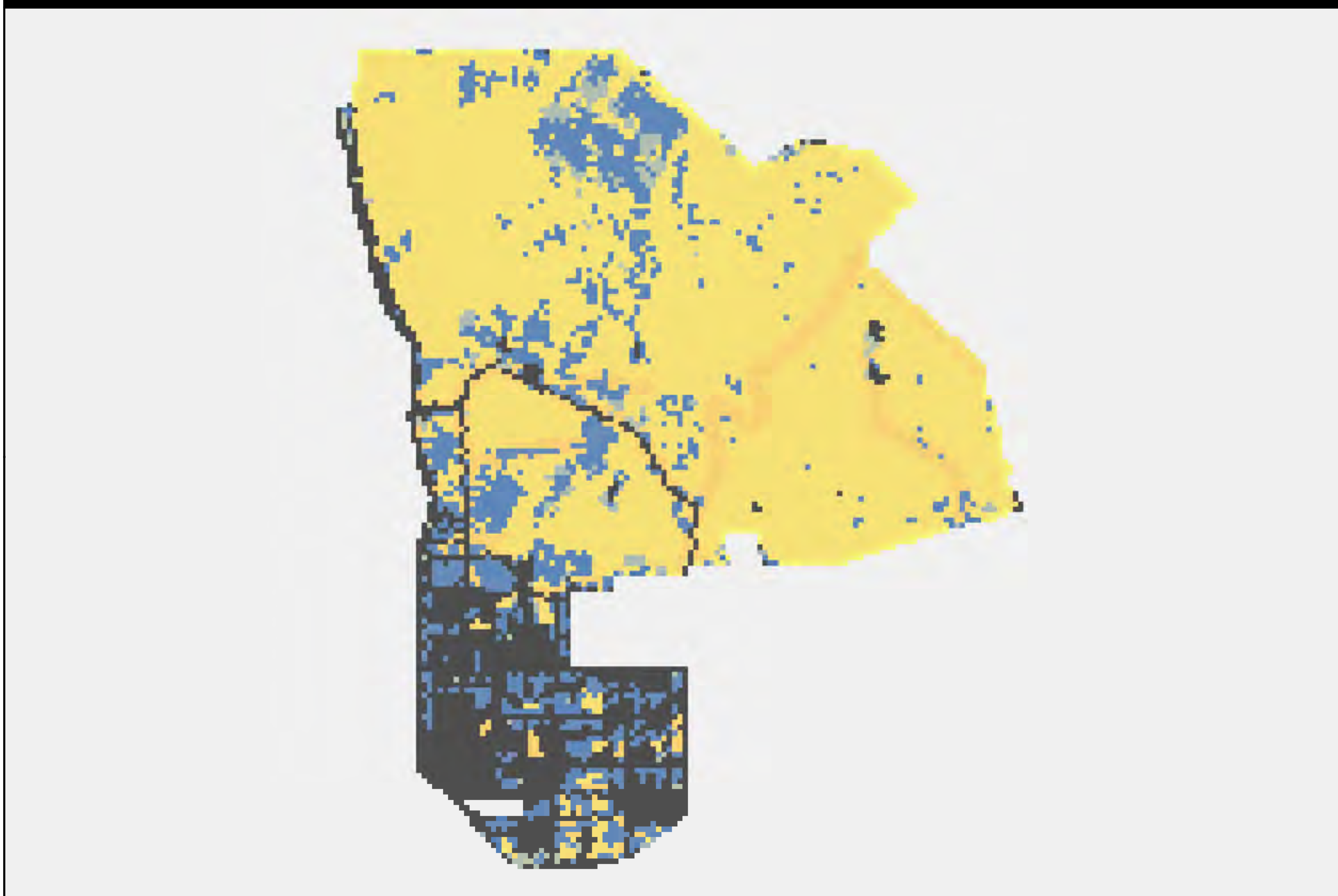
0, 1, 250, 500, 750, 1000

Camp Parks

Moderate

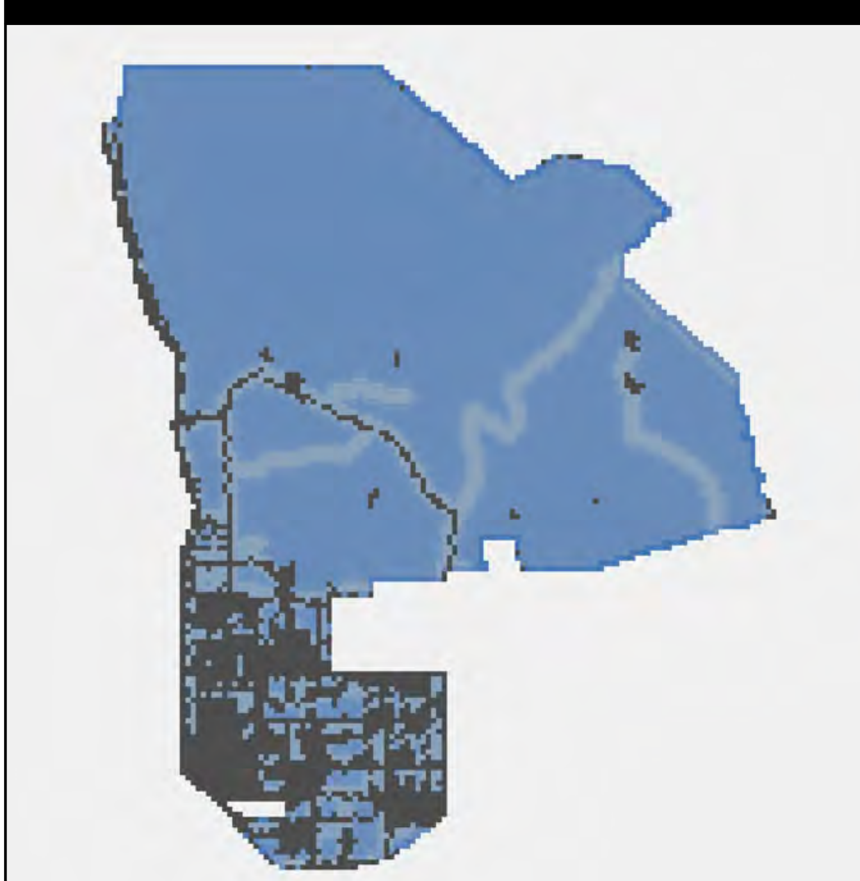
Type 2 Wildfire Risk Assessment

Hazard



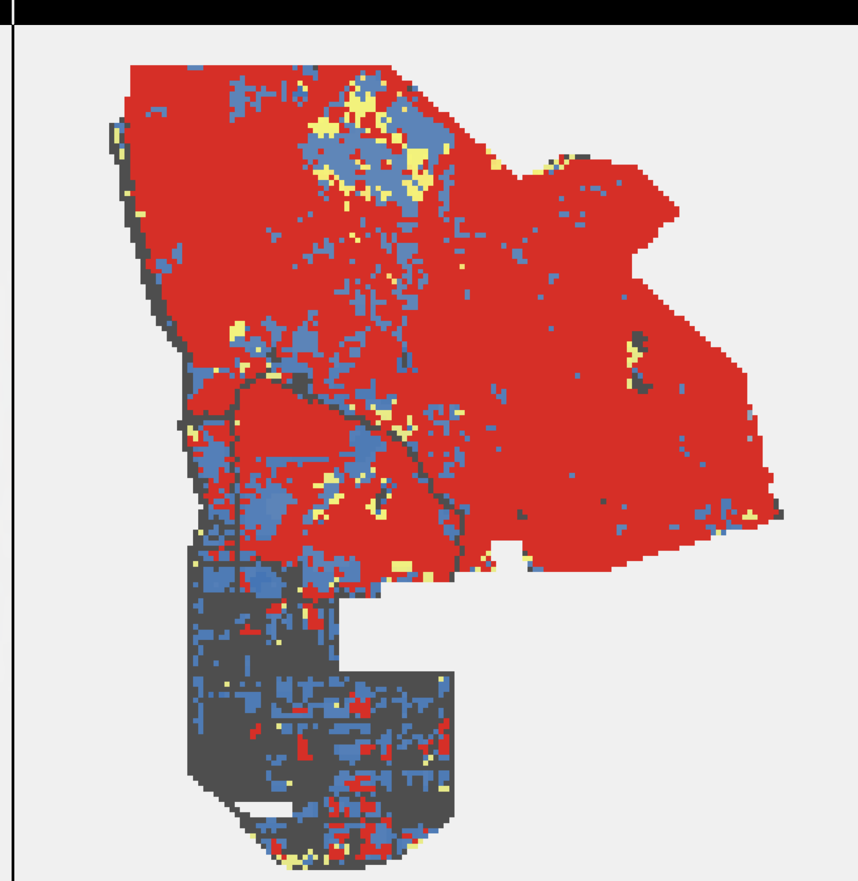
0 0.55 1.1 Miles

Ignition Likelihood



0 0.4 0.8 Miles

Fire Behavior Magnitude



0 0.4 0.8 Miles

Scaled Cell Values

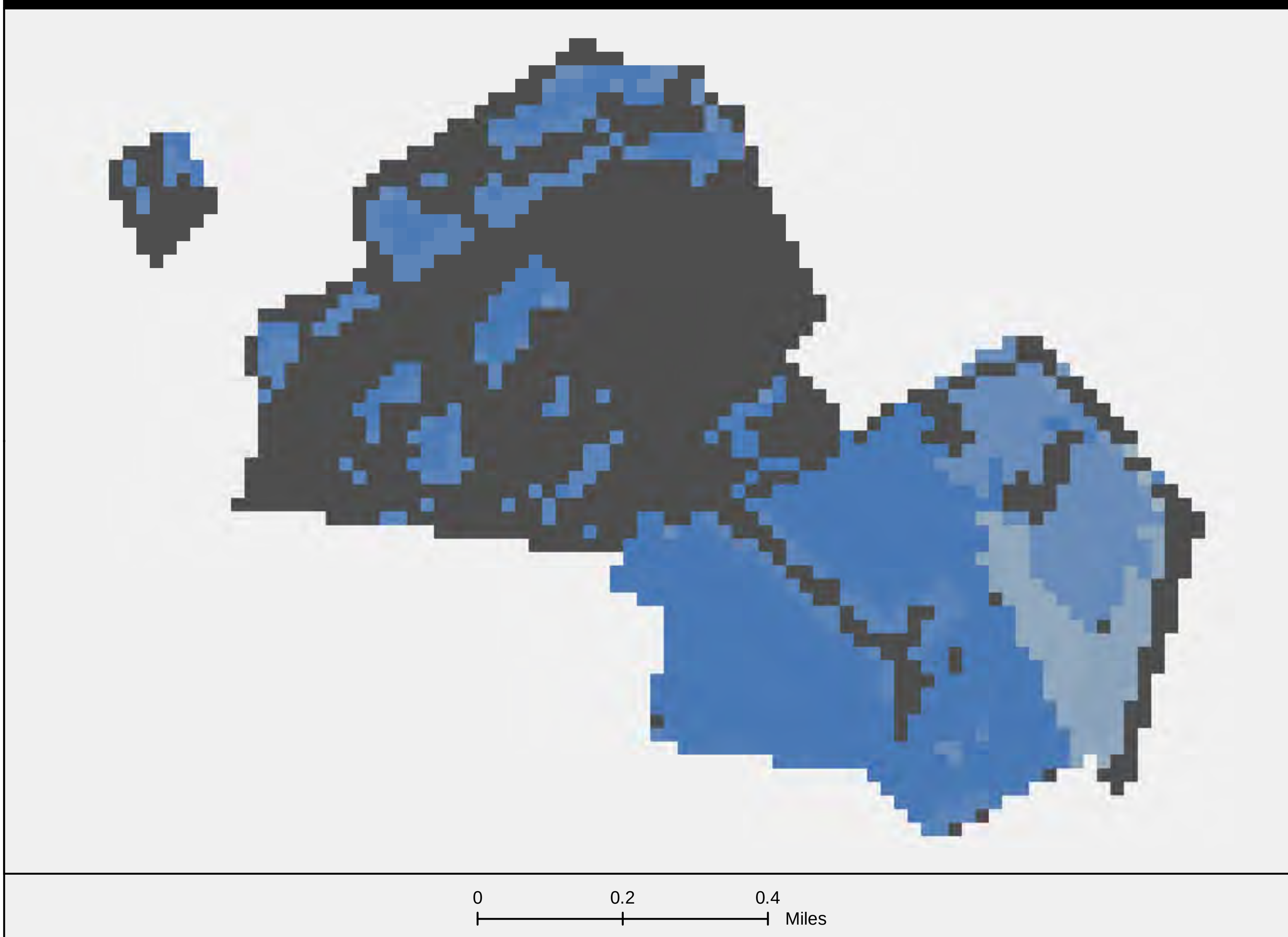
0	250
1	500
750	1000

Carlisle Barracks

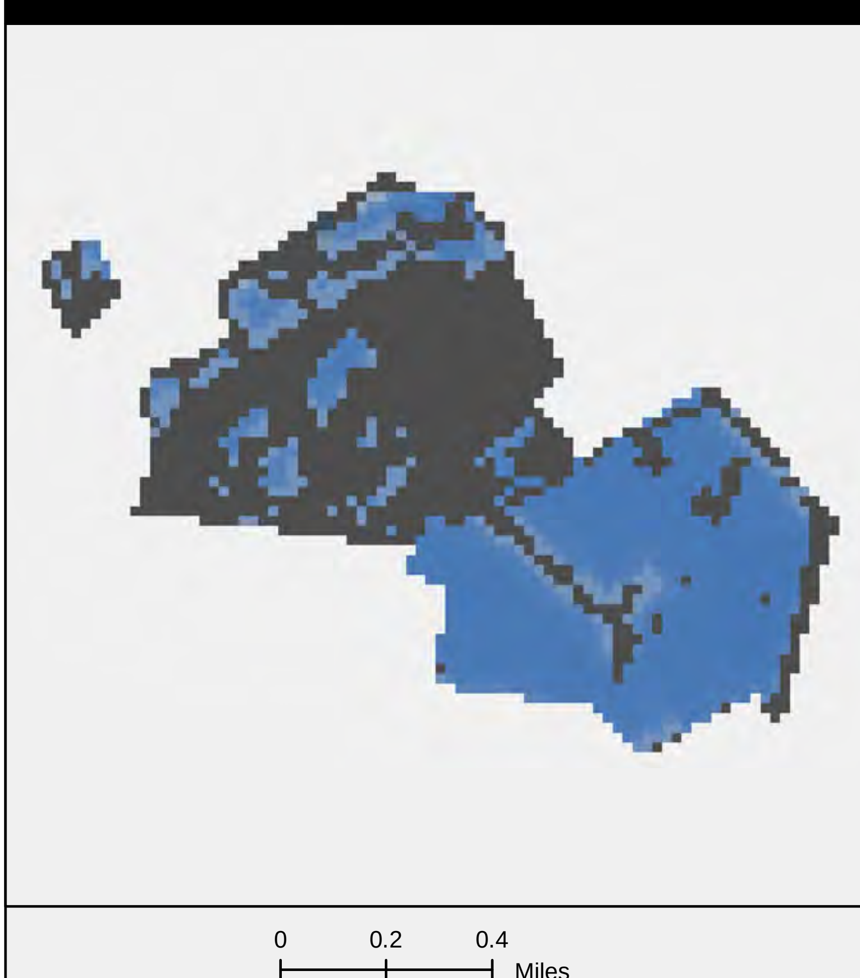
Low

Type 2 Wildfire Risk Assessment

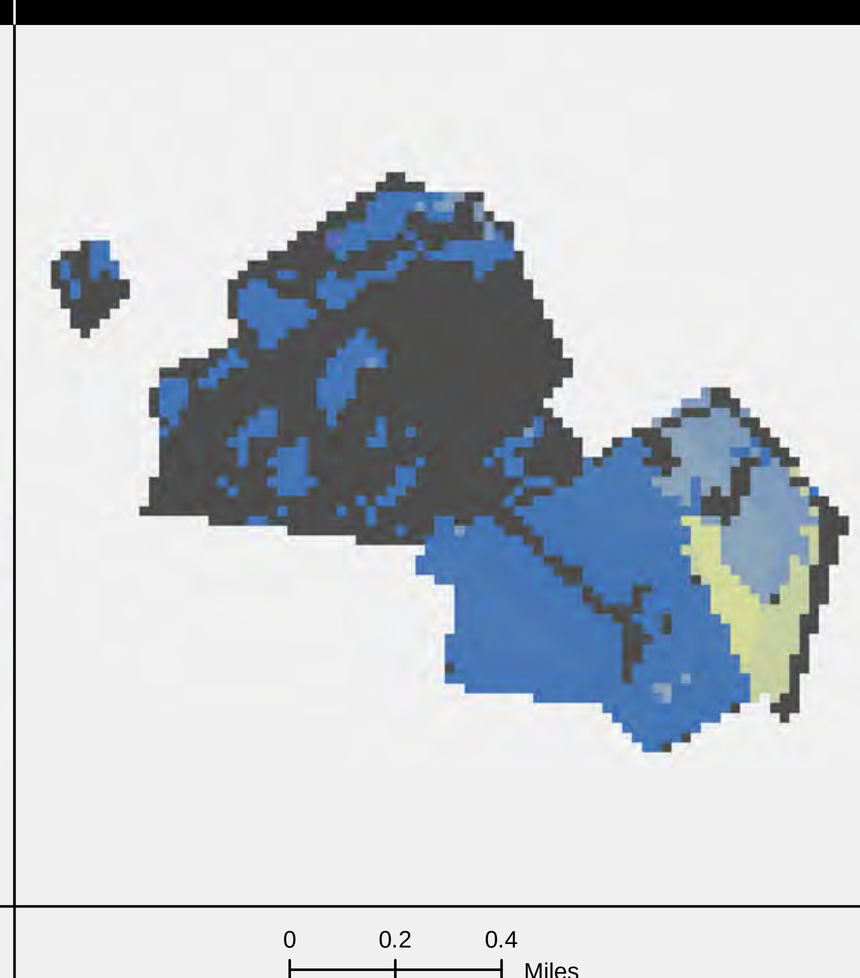
Hazard

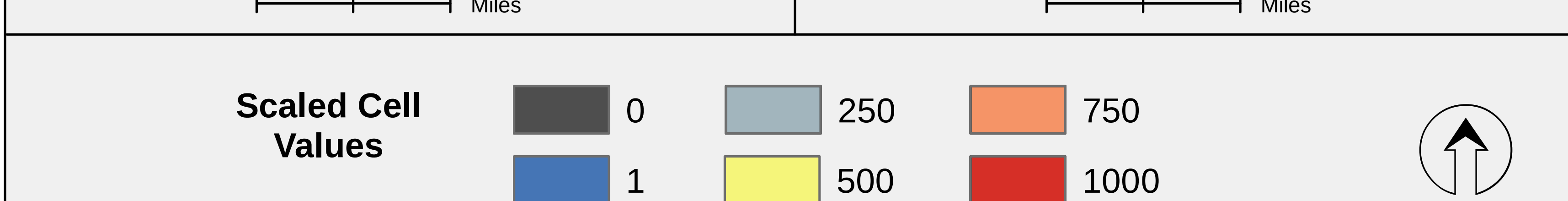


Ignition Likelihood



Fire Behavior Magnitude

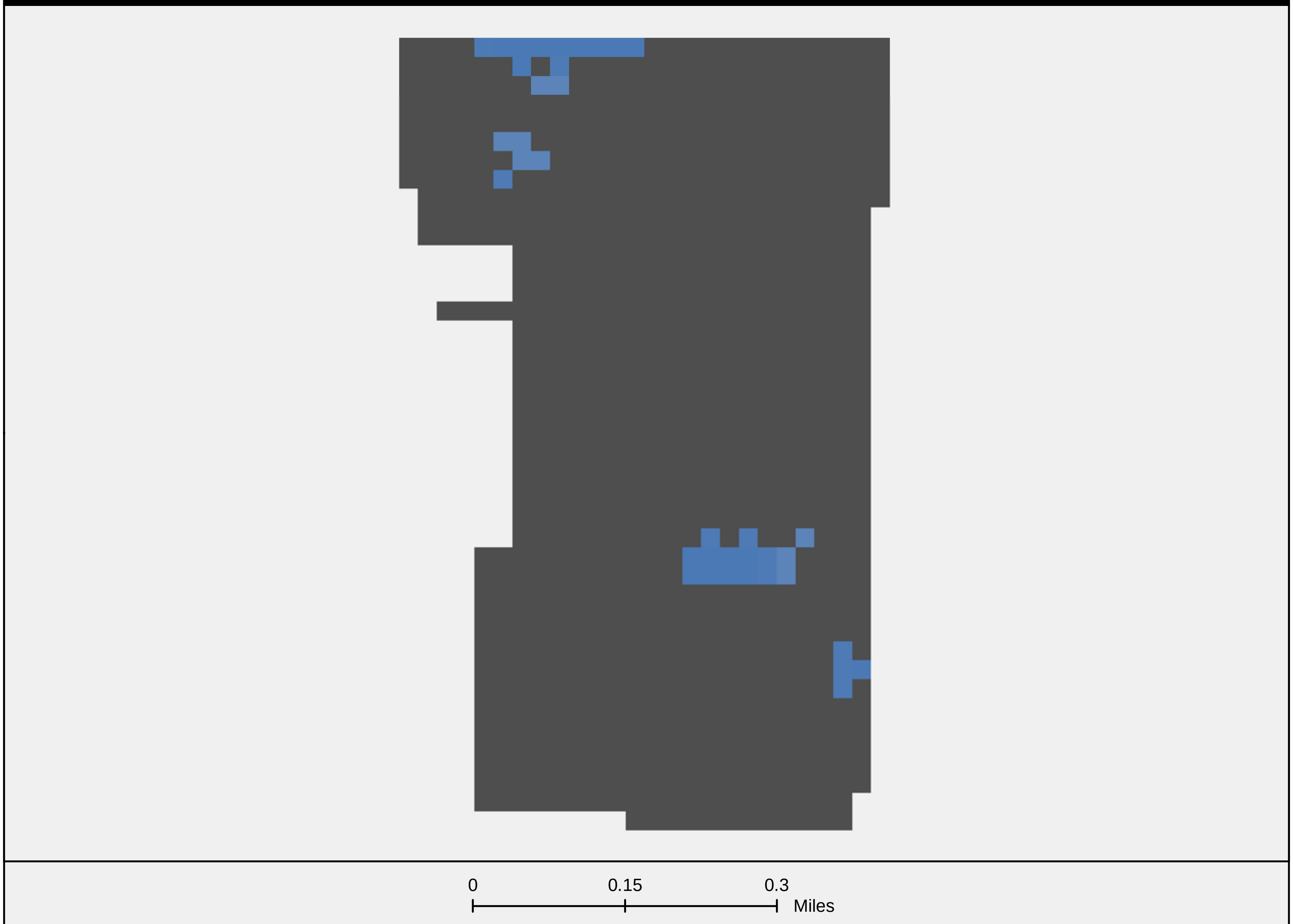




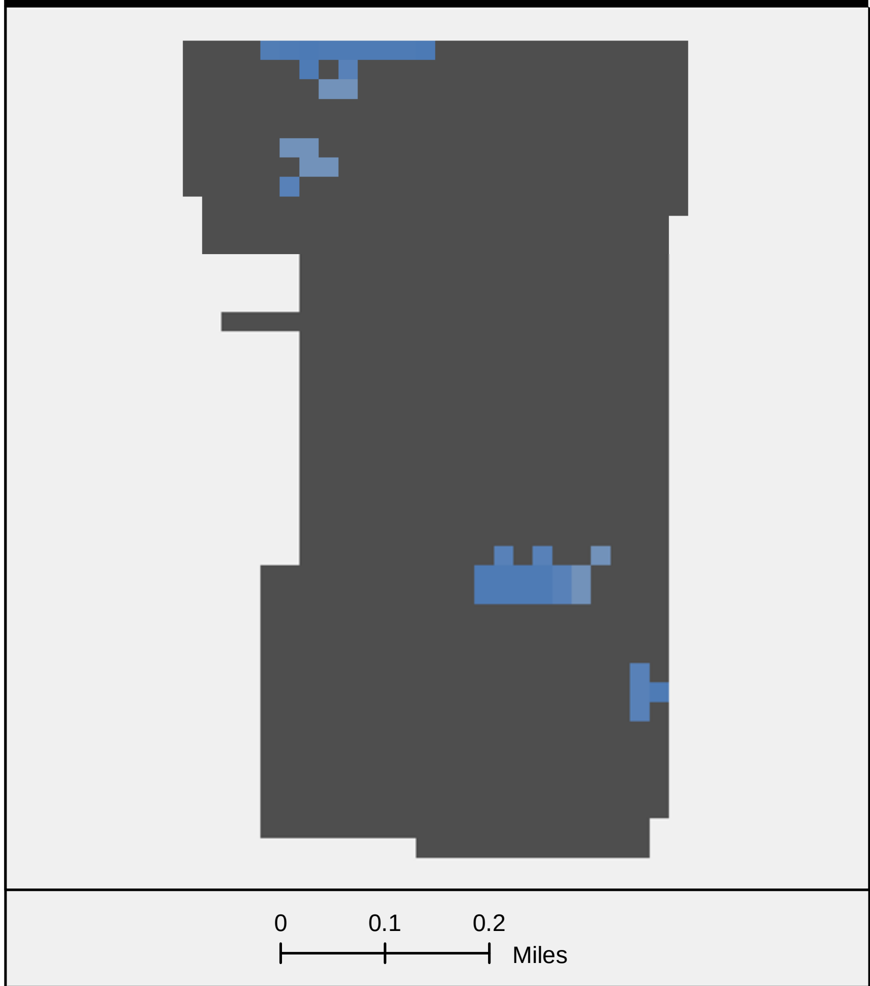
Detroit Arsenal — Low

Type 2 Wildfire Risk Assessment

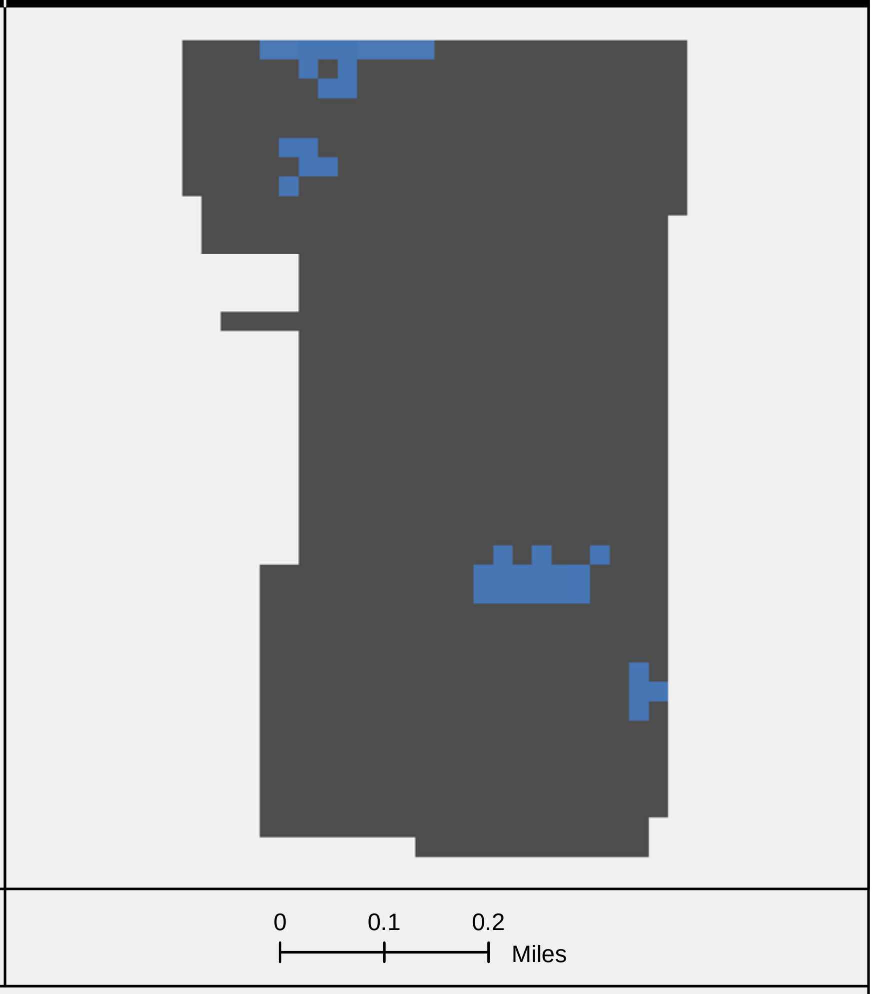
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

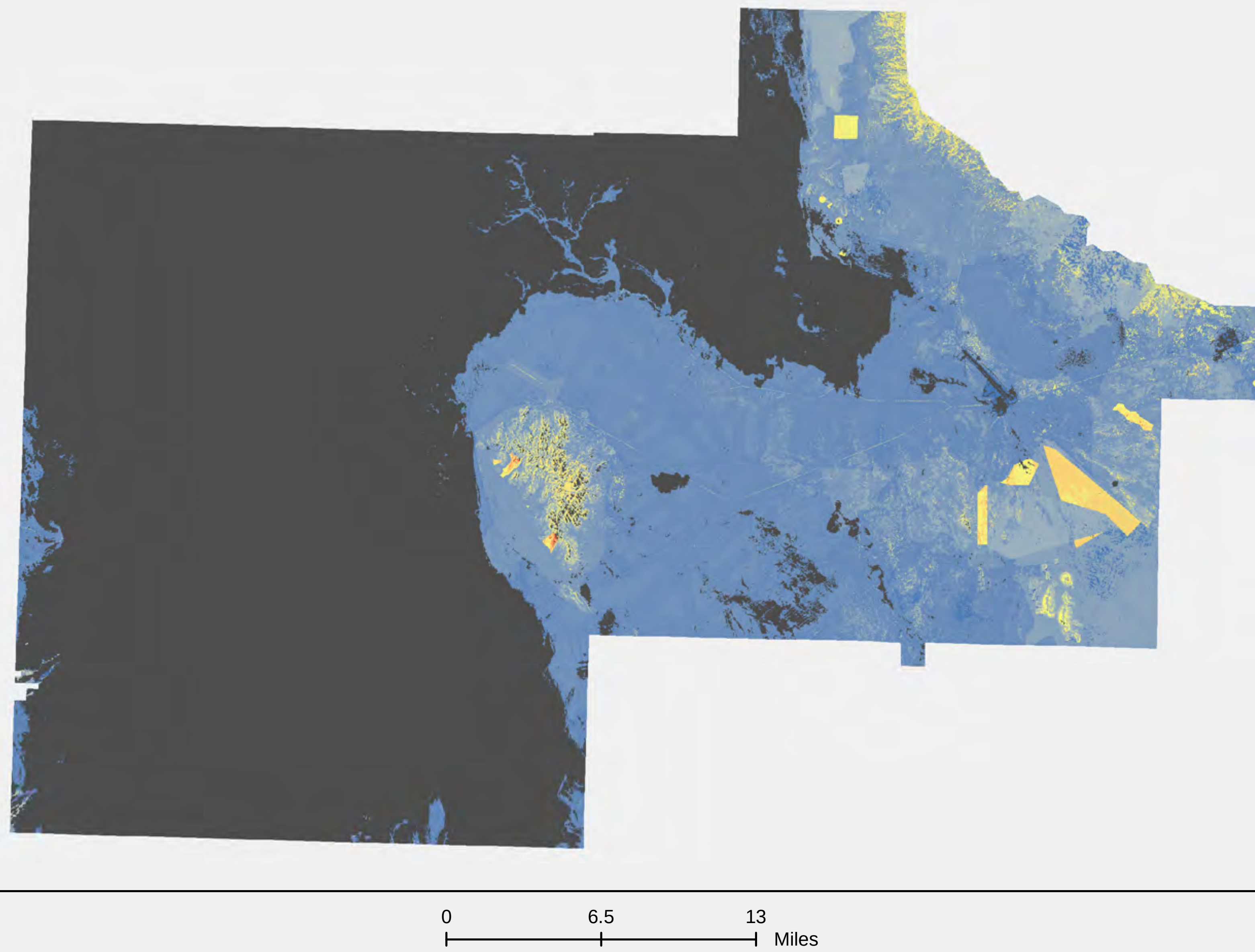
0 | 250 | 750
1 | 500 | 1000

Dugway Proving Ground

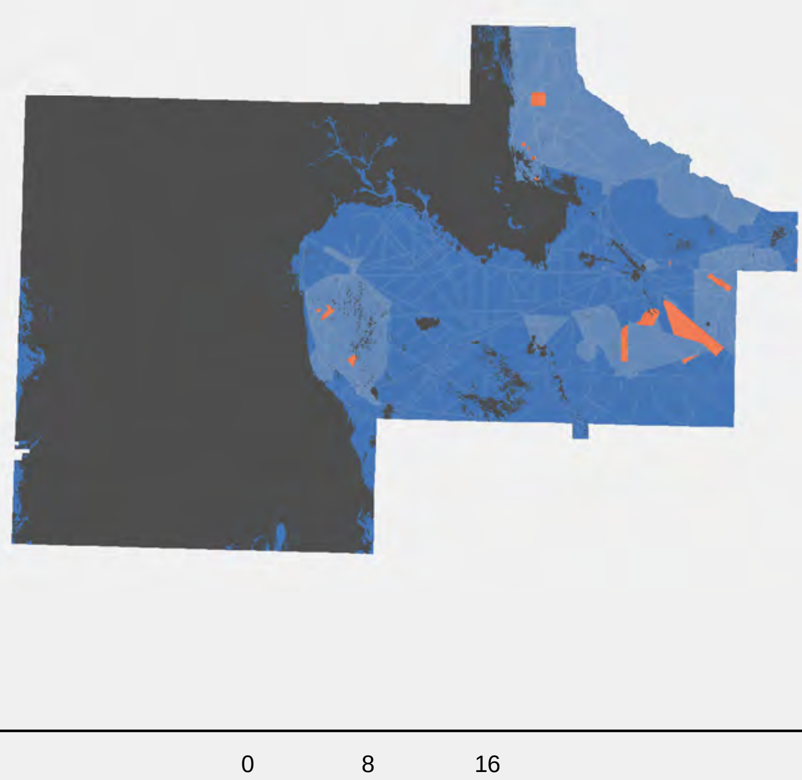
Moderate

Type 2 Wildfire Risk Assessment

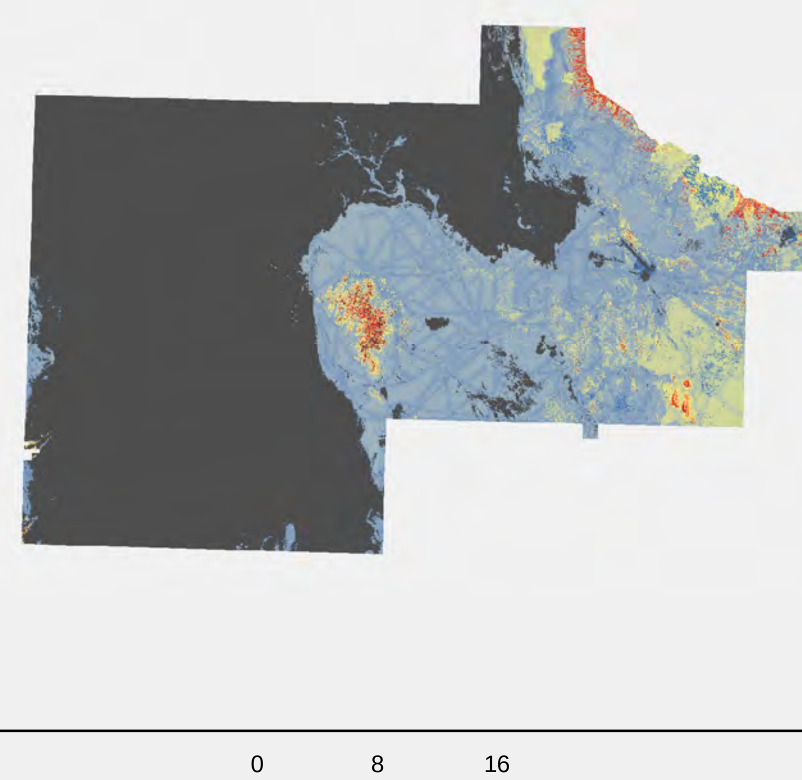
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

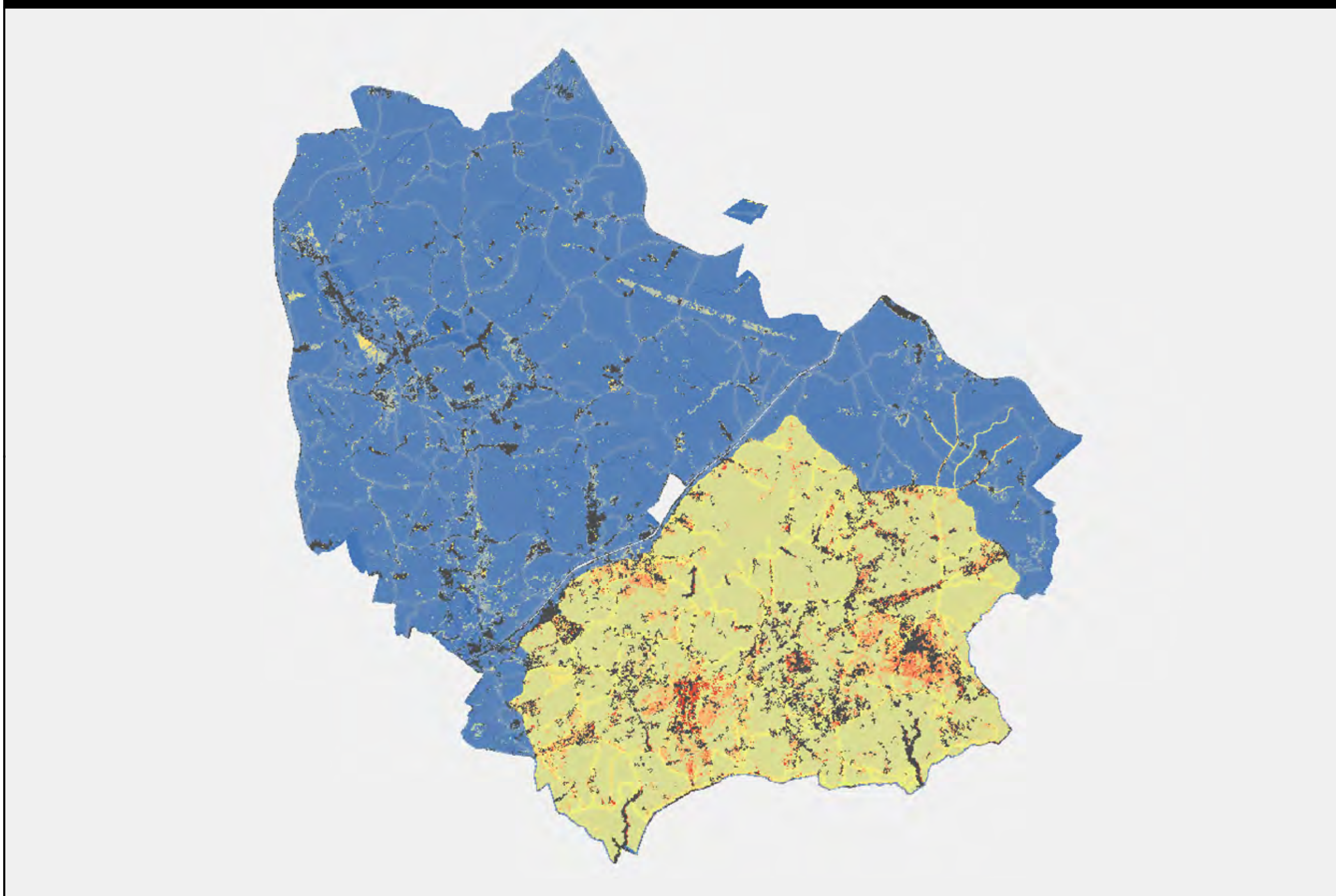
0, 1, 250, 500, 750, 1000

Fort AP Hill

Moderate

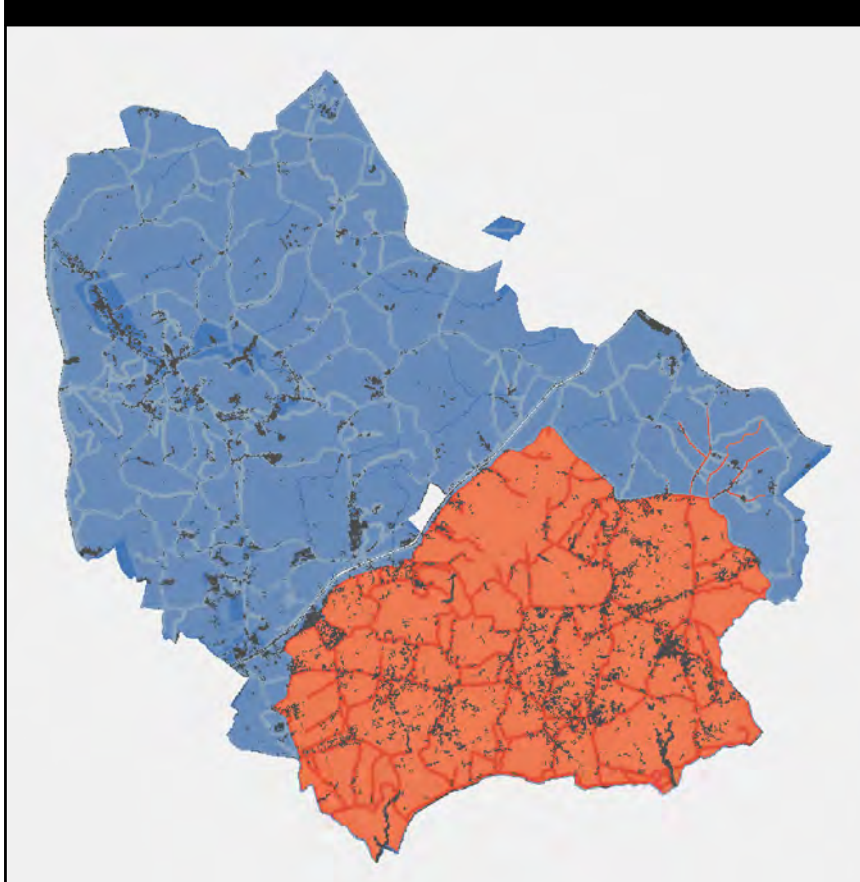
Type 2 Wildfire Risk Assessment

Hazard



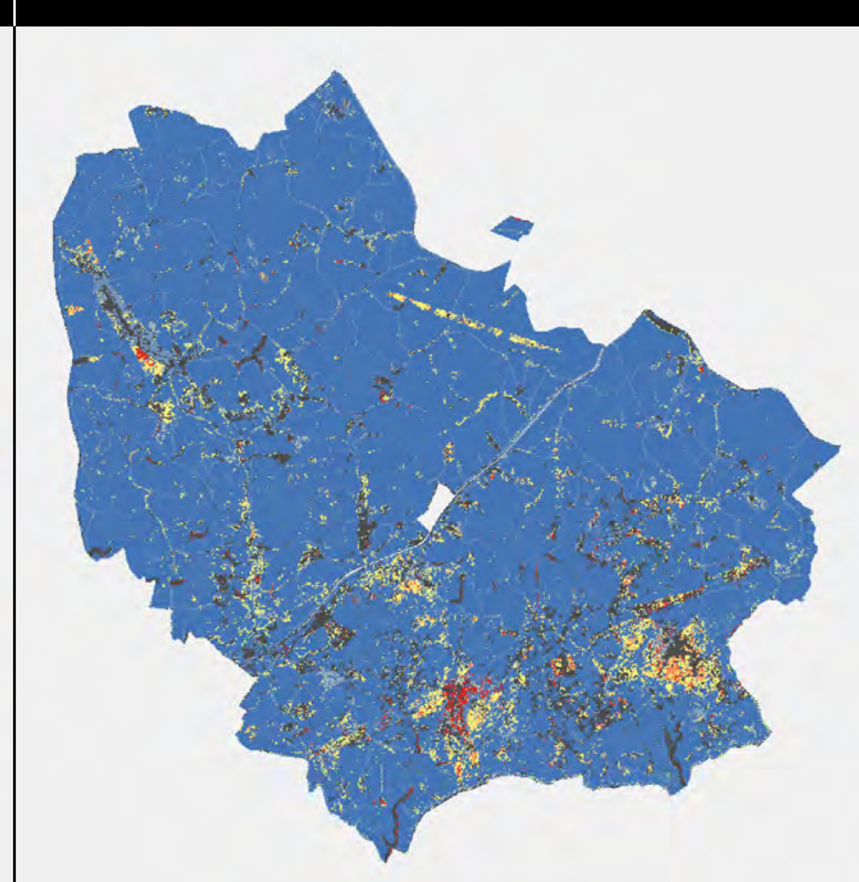
0 2.5 5 Miles

Ignition Likelihood



0 2 4 Miles

Fire Behavior Magnitude



0 2 4 Miles

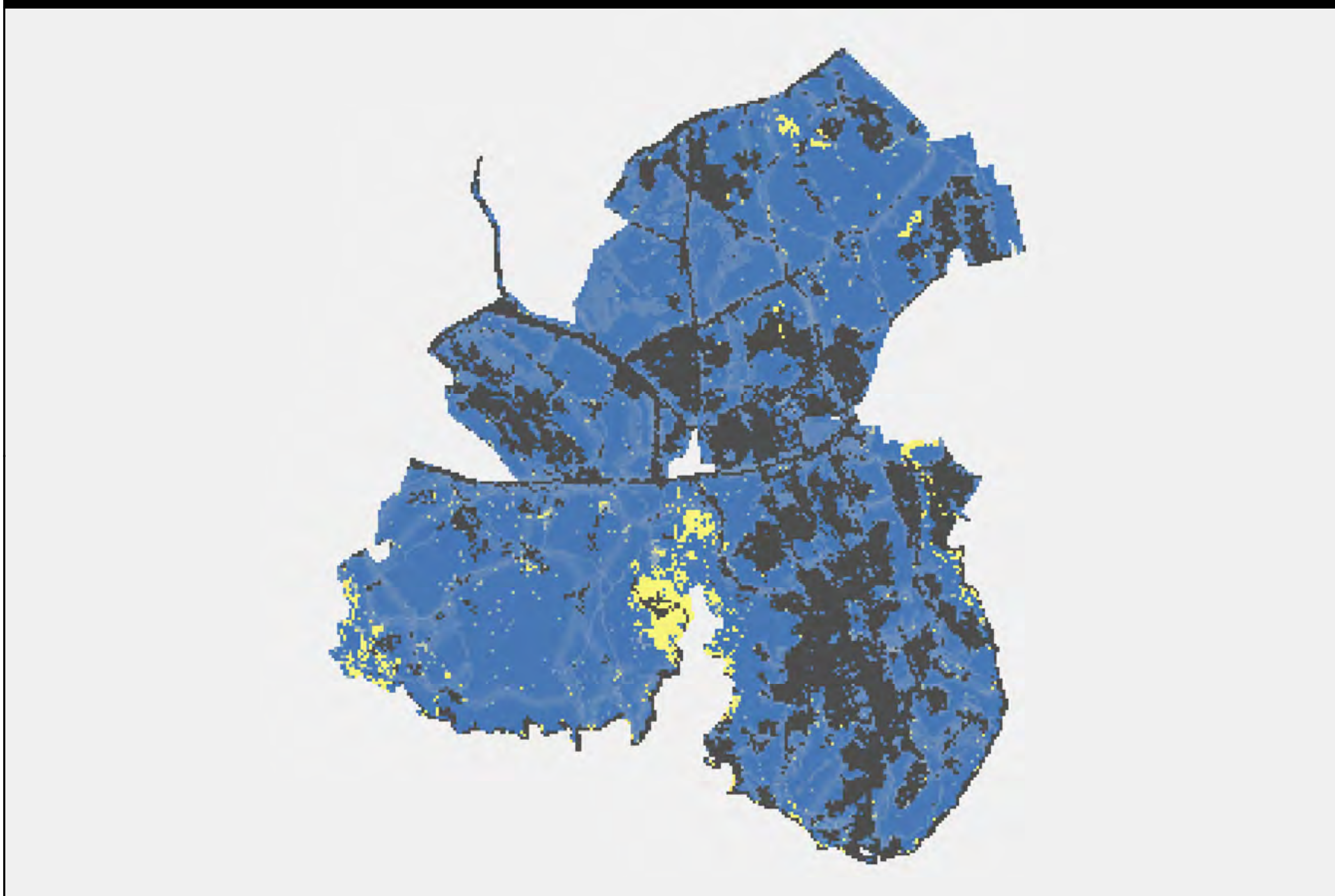
Scaled Cell Values

0, 1, 250, 500, 750, 1000

Fort Belvoir — Low

Type 2 Wildfire Risk Assessment

Hazard

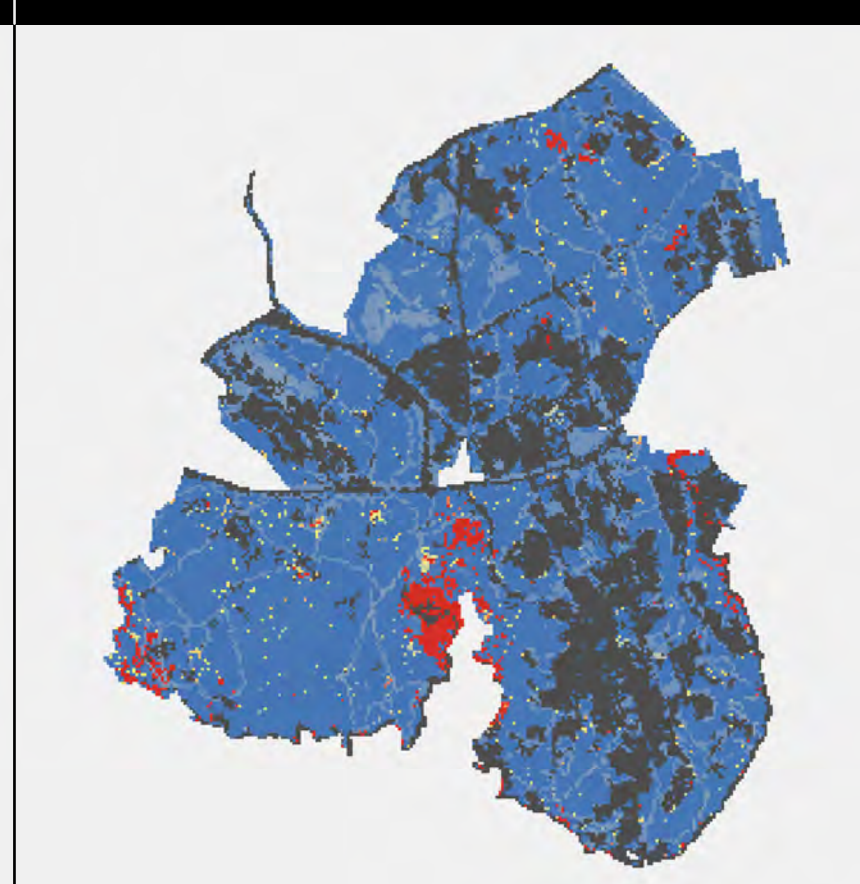


0 1 2 Miles

Ignition Likelihood

0 0.8 1.6 Miles

Fire Behavior Magnitude



0 0.8 1.6 Miles

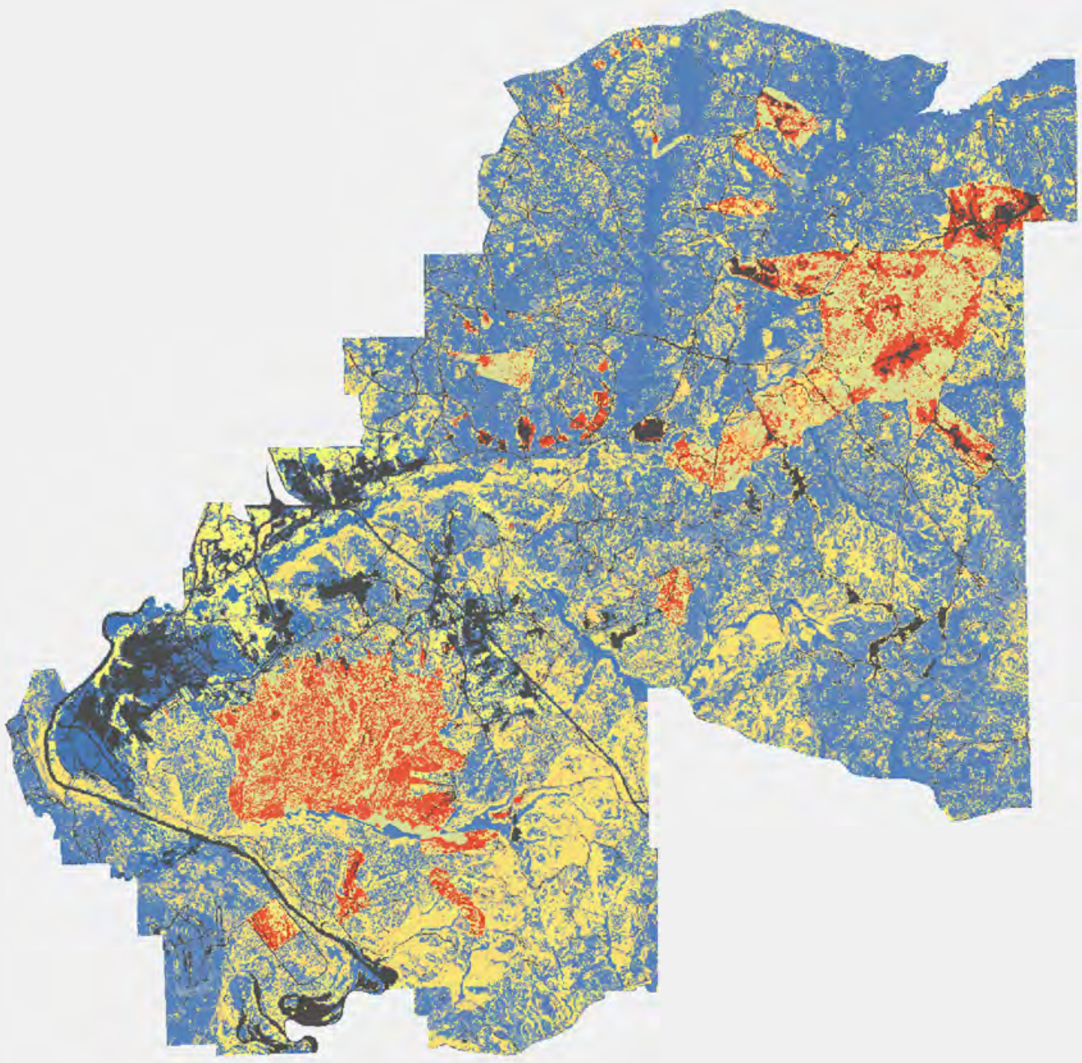
Scaled Cell Values

Dark gray	0
Blue	1
Light gray-blue	250
Yellow	500
Orange	750
Red	1000

Fort Benning High

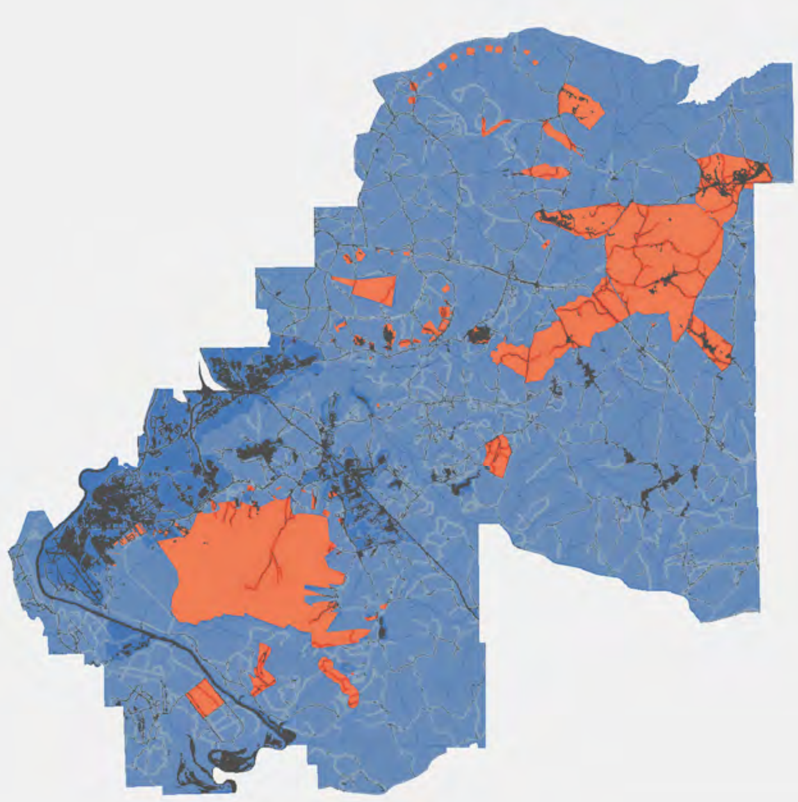
Type 2 Wildfire Risk Assessment

Hazard



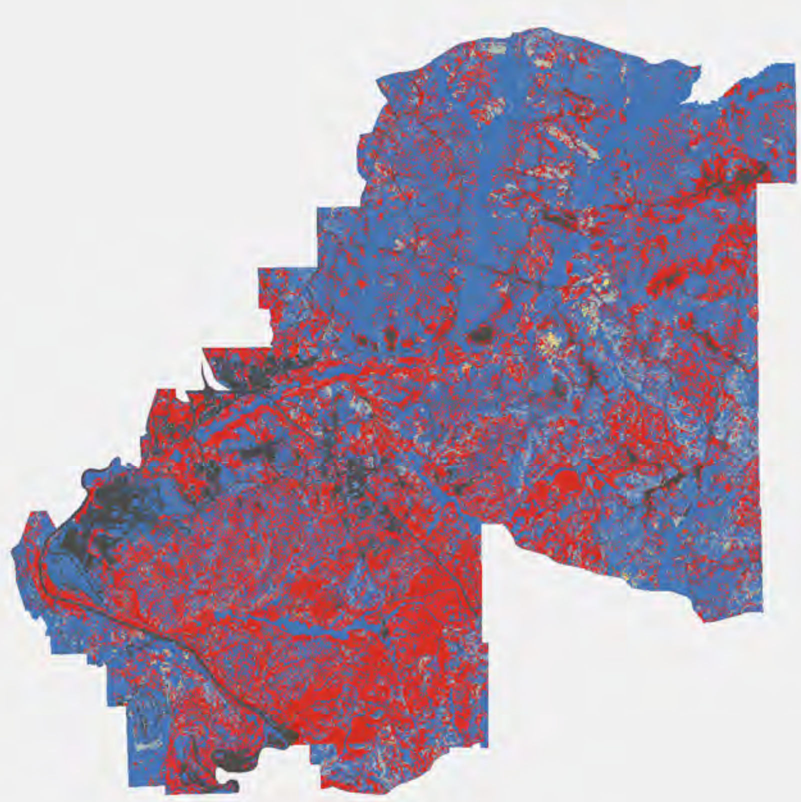
0 4 8 Miles

Ignition Likelihood



0 3.5 7 Miles

Fire Behavior Magnitude



0 3.5 7 Miles

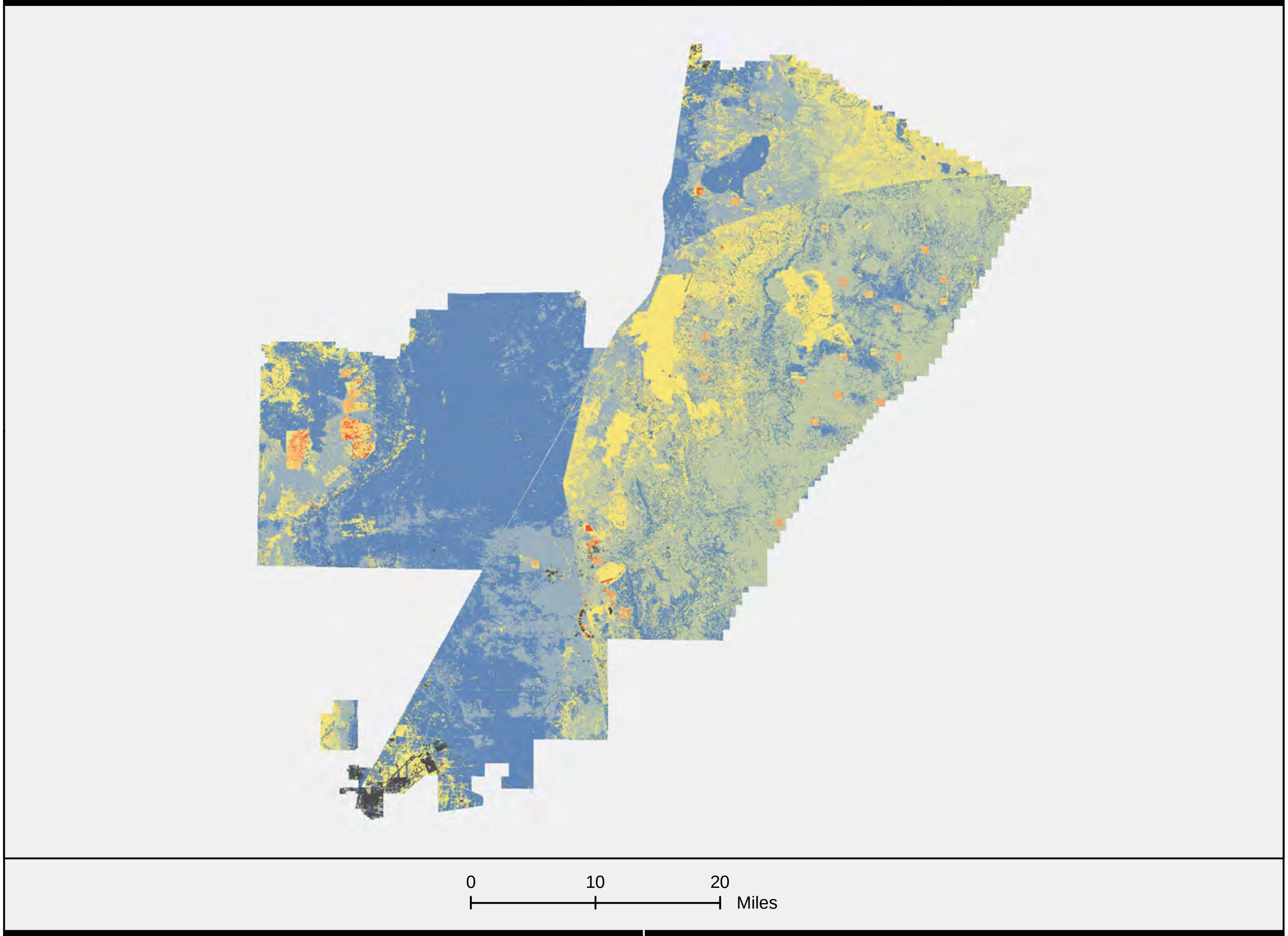
Scaled Cell Values

0	250	750
1	500	1000

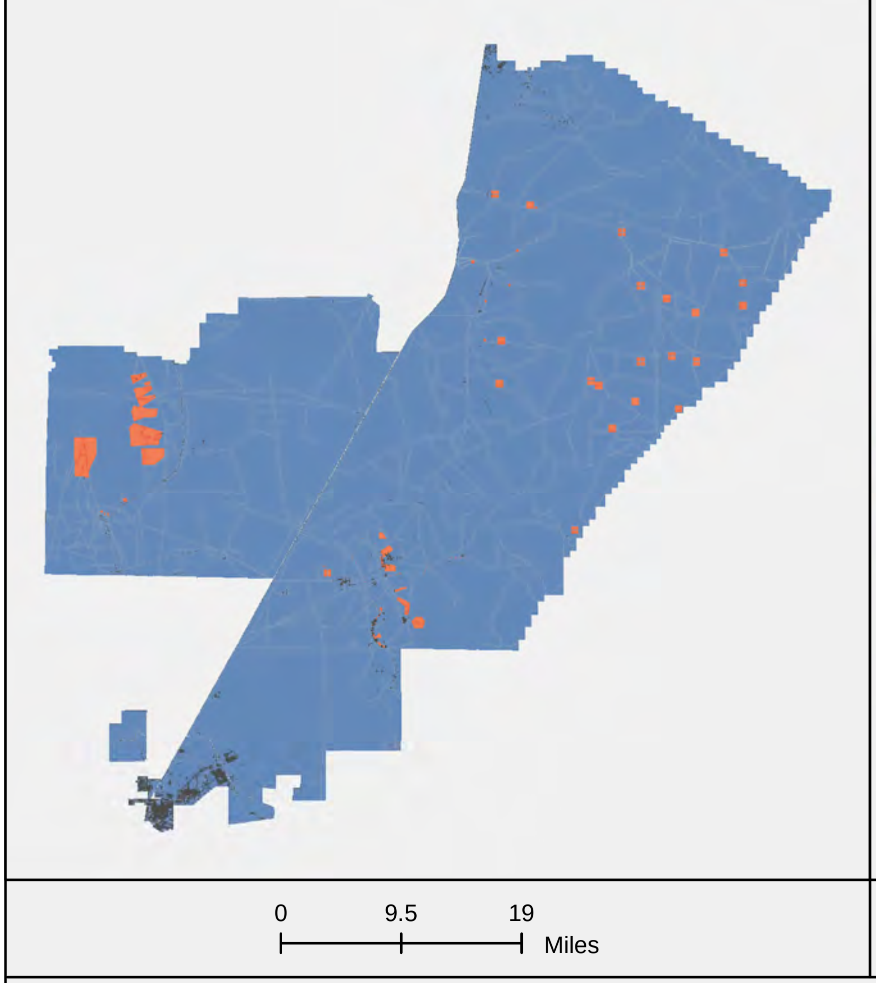
Fort Bliss High

Type 2 Wildfire Risk Assessment

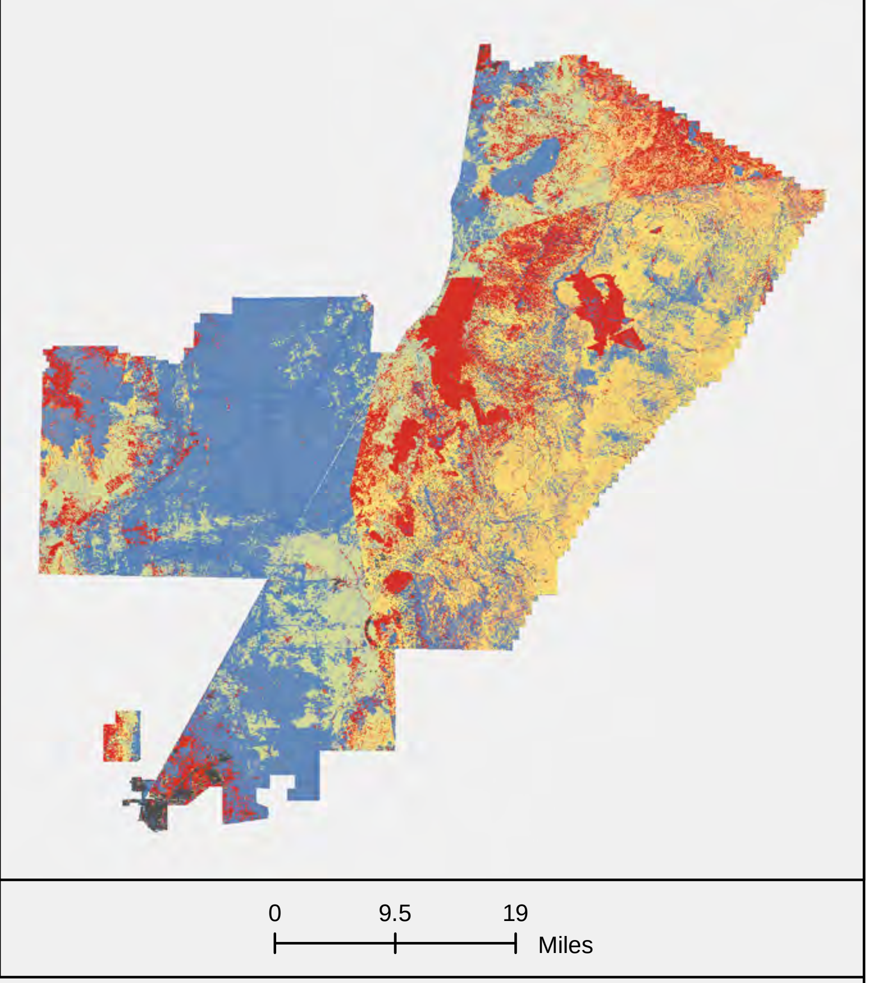
Hazard



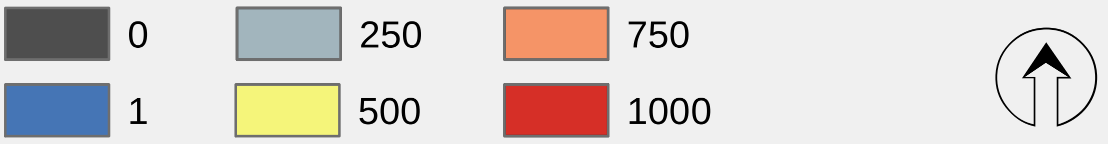
Ignition Likelihood



Fire Behavior Magnitude



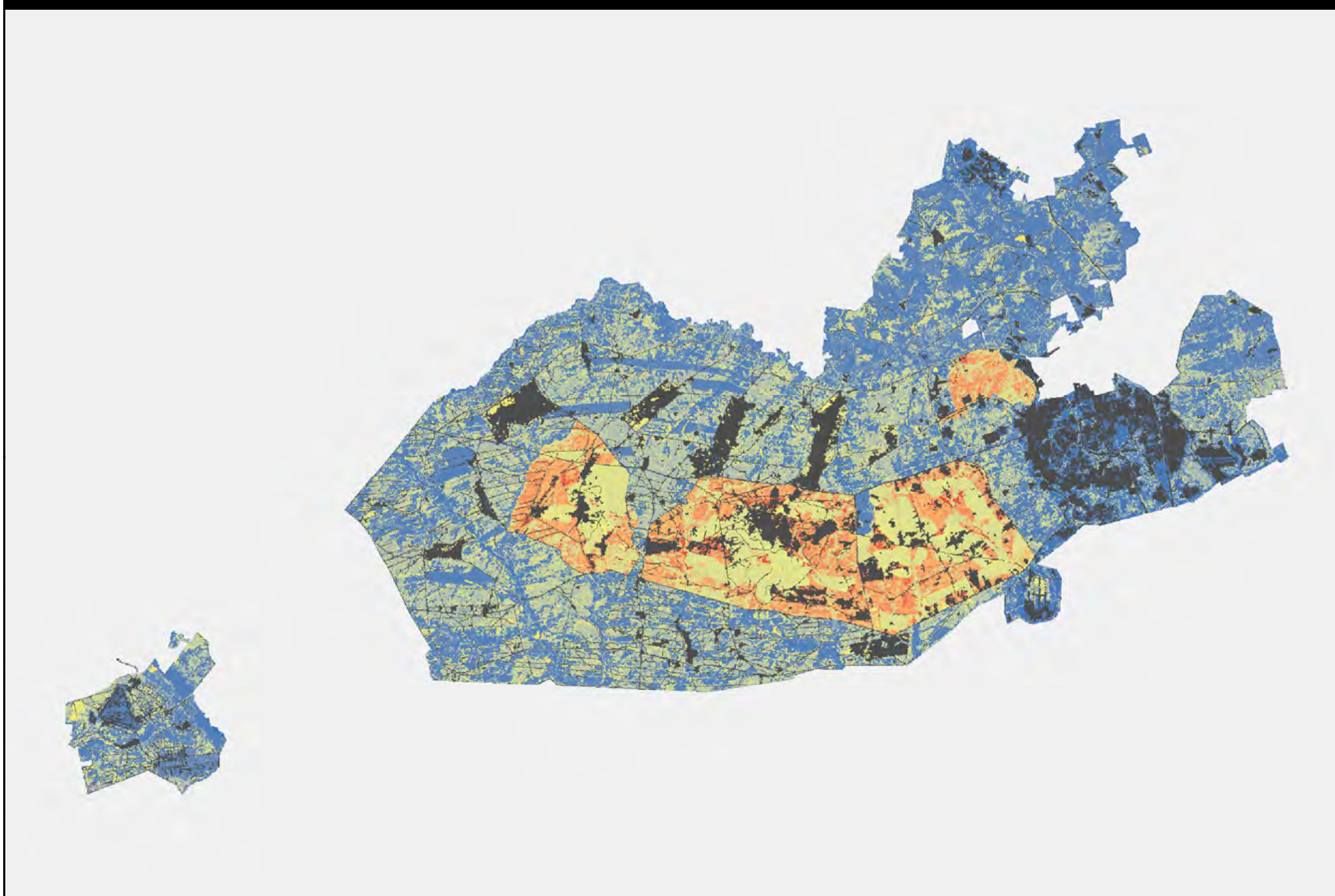
Scaled Cell Values



Fort Bragg High

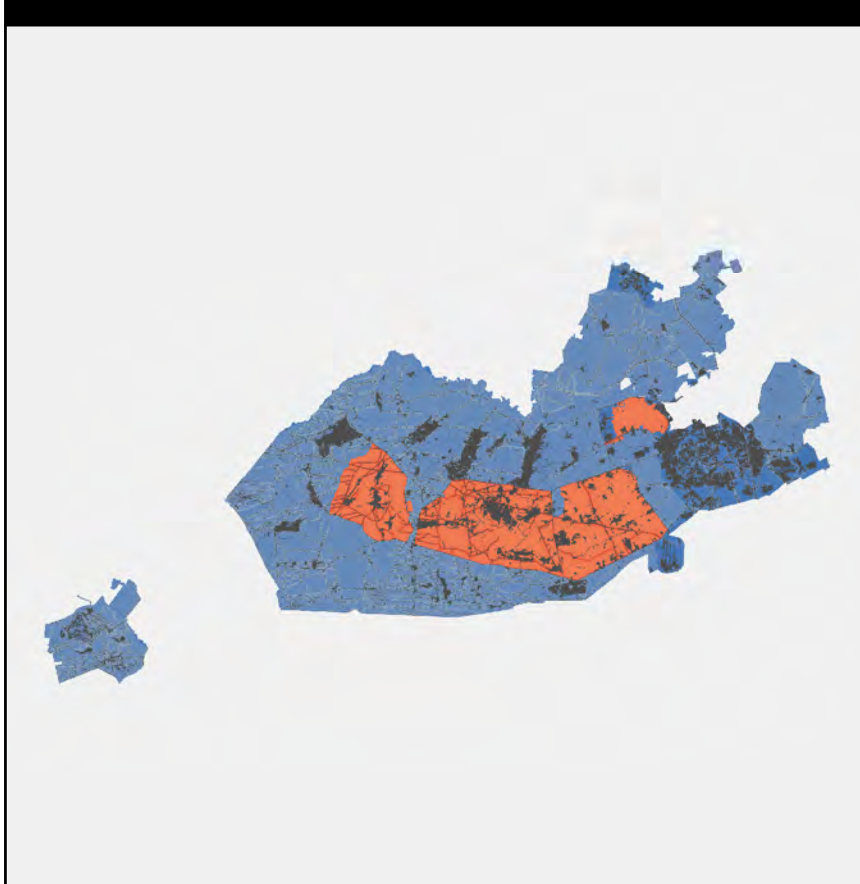
Type 2 Wildfire Risk Assessment

Hazard



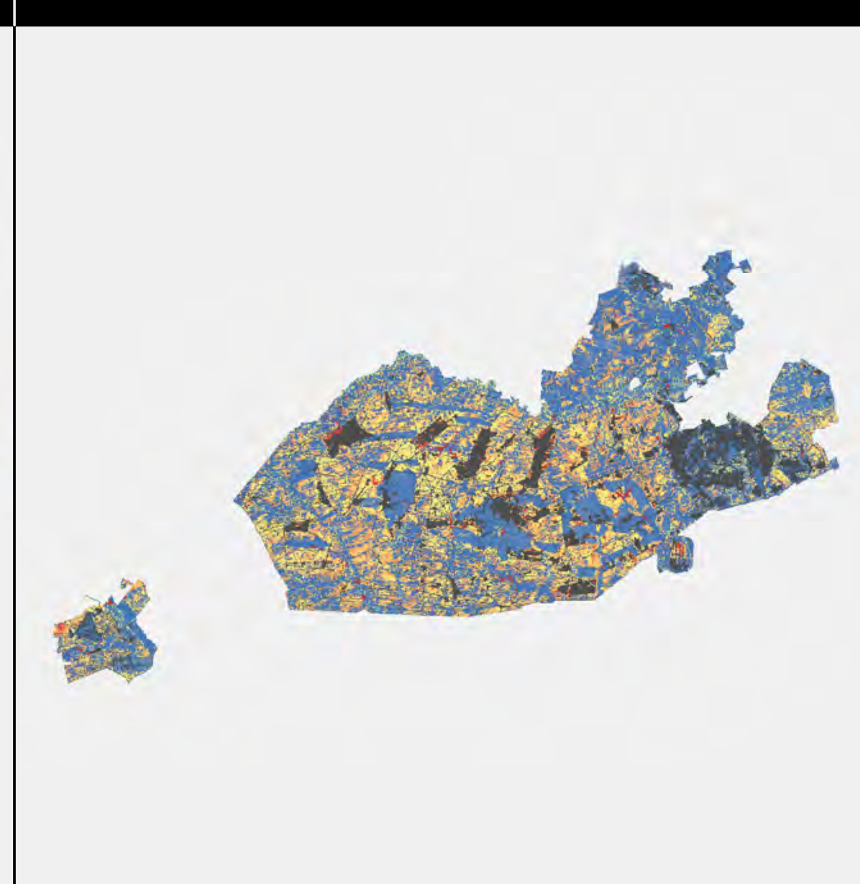
0 4.5 9 Miles

Ignition Likelihood



0 5.5 11 Miles

Fire Behavior Magnitude



0 5.5 11 Miles

Scaled Cell Values

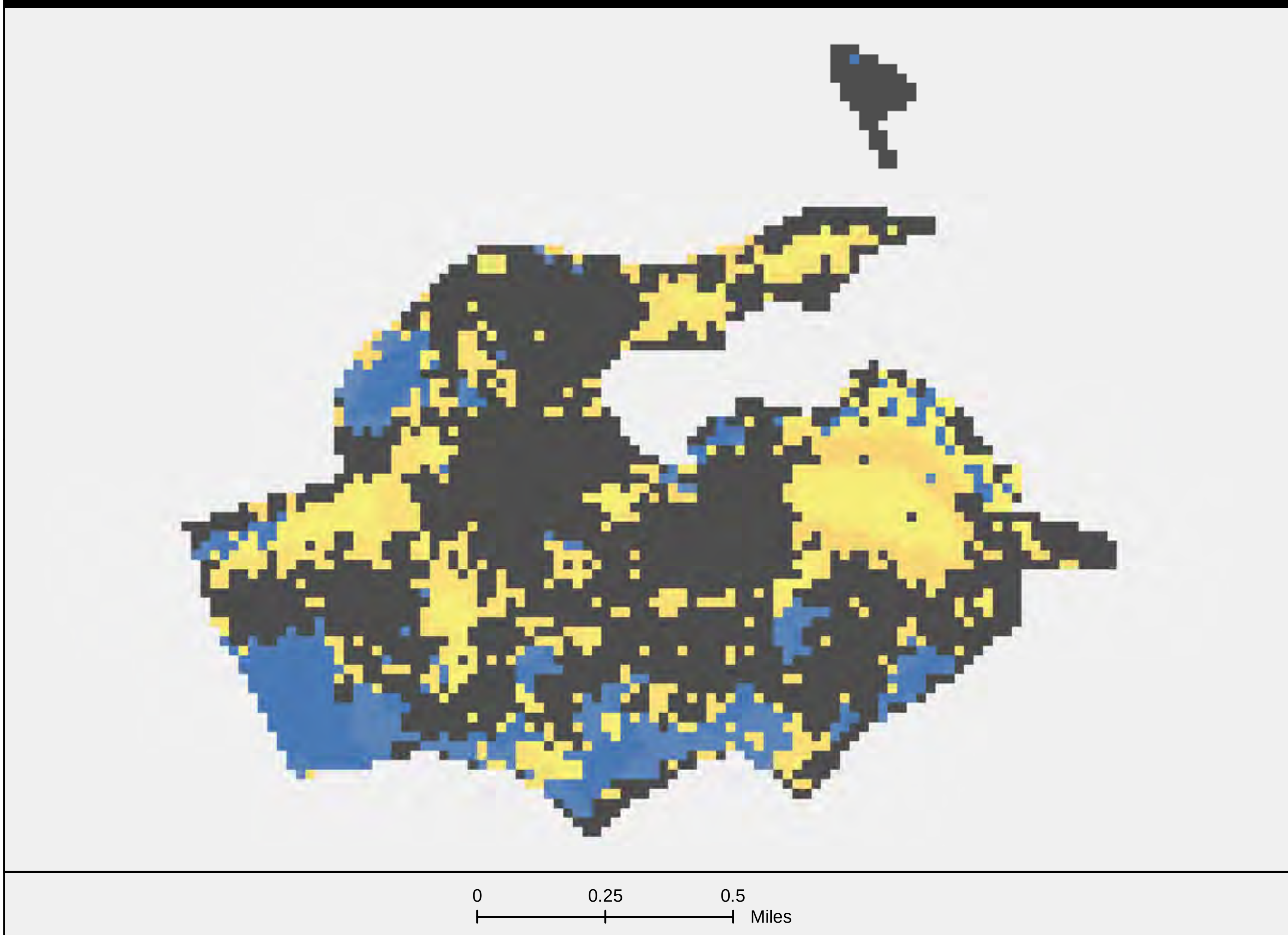
0, 1, 250, 500, 750, 1000

Fort Buchanan

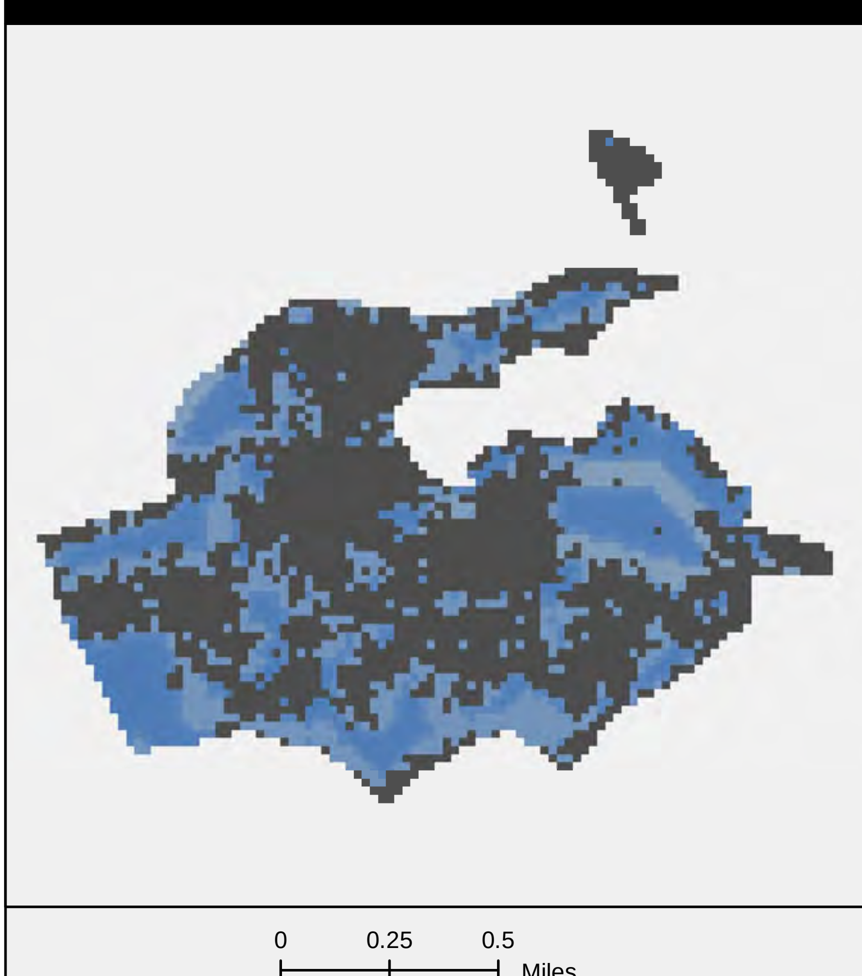
Moderate

Type 2 Wildfire Risk Assessment

Hazard



Ignition Likelihood



Fire Behavior Magnitude

Scaled Cell Values

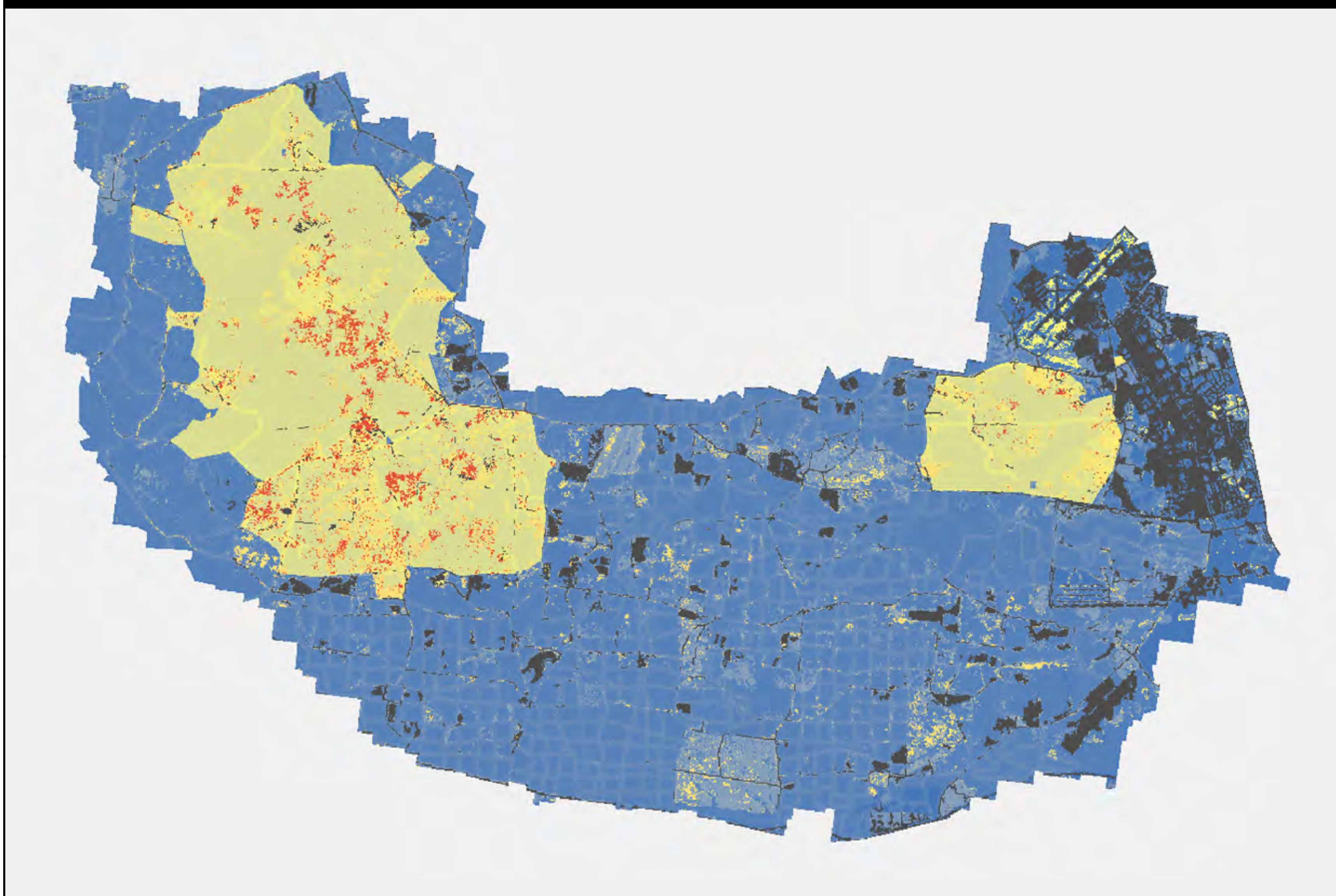
0
1
250
500
750
1000

Fort Campbell

Moderate

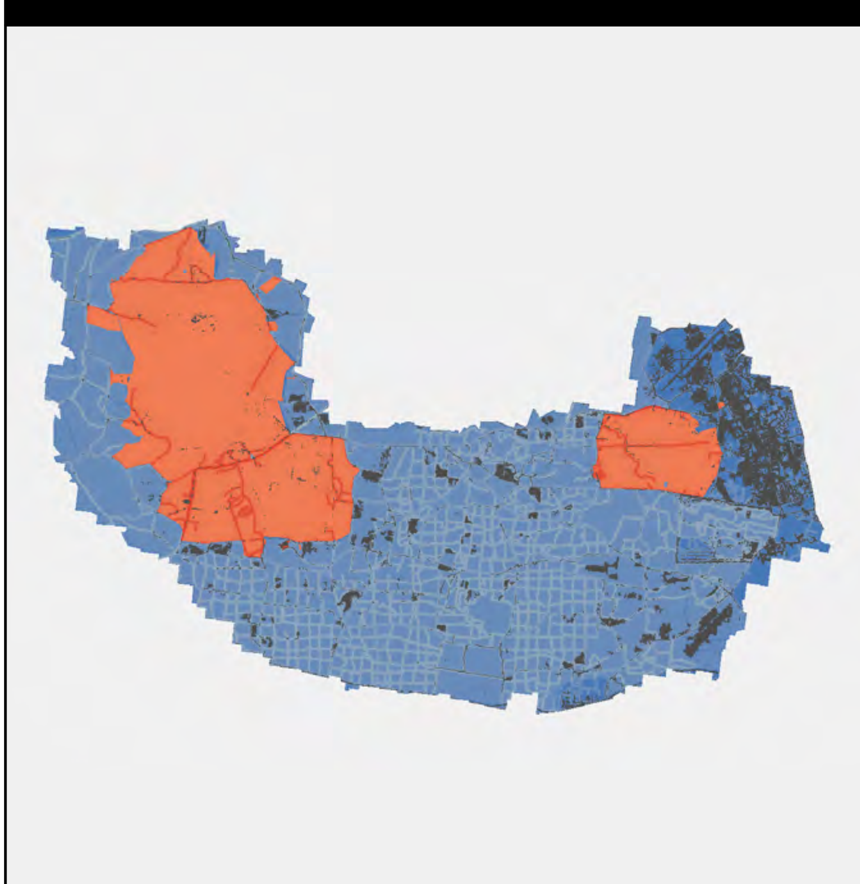
Type 2 Wildfire Risk Assessment

Hazard



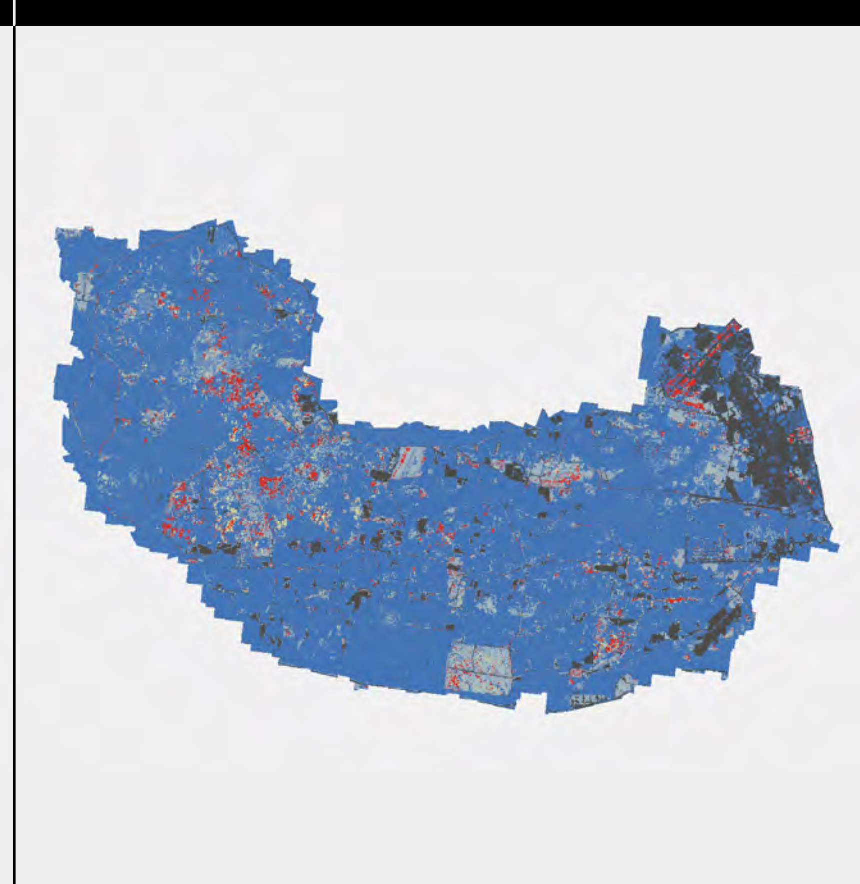
0 2.5 5 Miles

Ignition Likelihood



0 3 6 Miles

Fire Behavior Magnitude



0 3 6 Miles

Scaled Cell Values

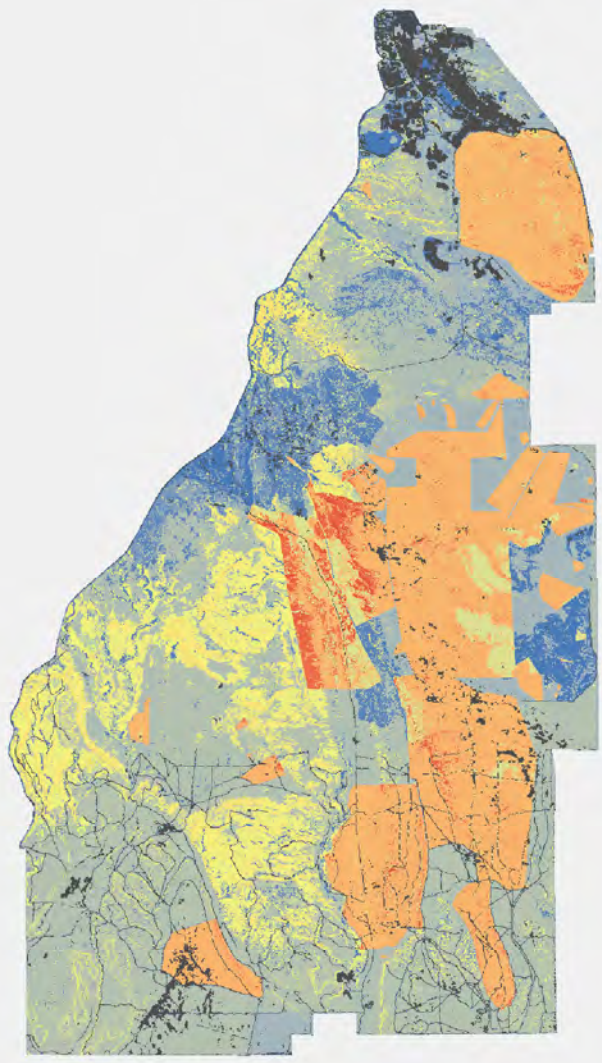
0, 1, 250, 500, 750, 1000

Fort Carson

High

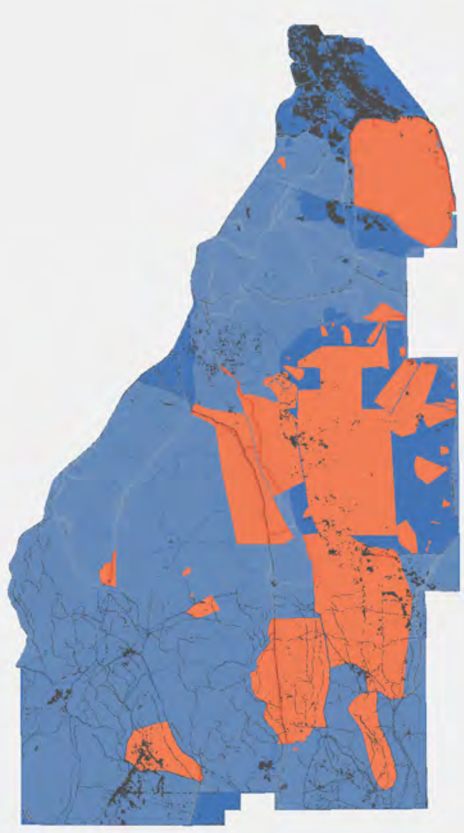
Type 2 Wildfire Risk Assessment

Hazard



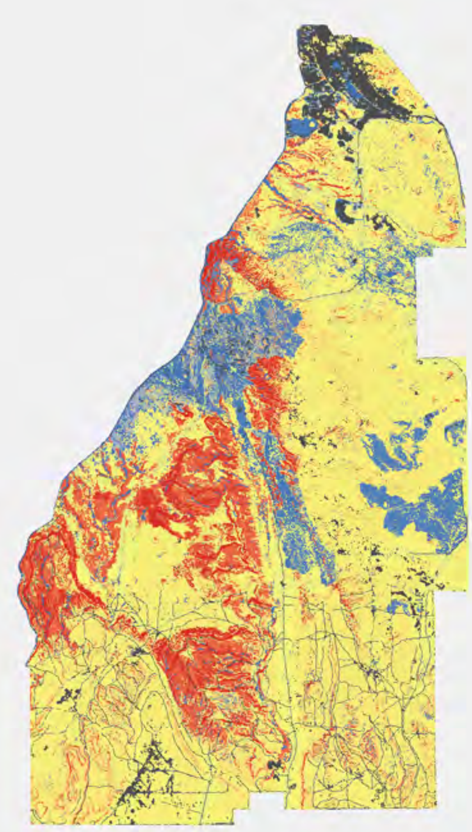
0 4.5 9 Miles

Ignition Likelihood



0 3.5 7 Miles

Fire Behavior Magnitude



0 3.5 7 Miles

Scaled Cell Values

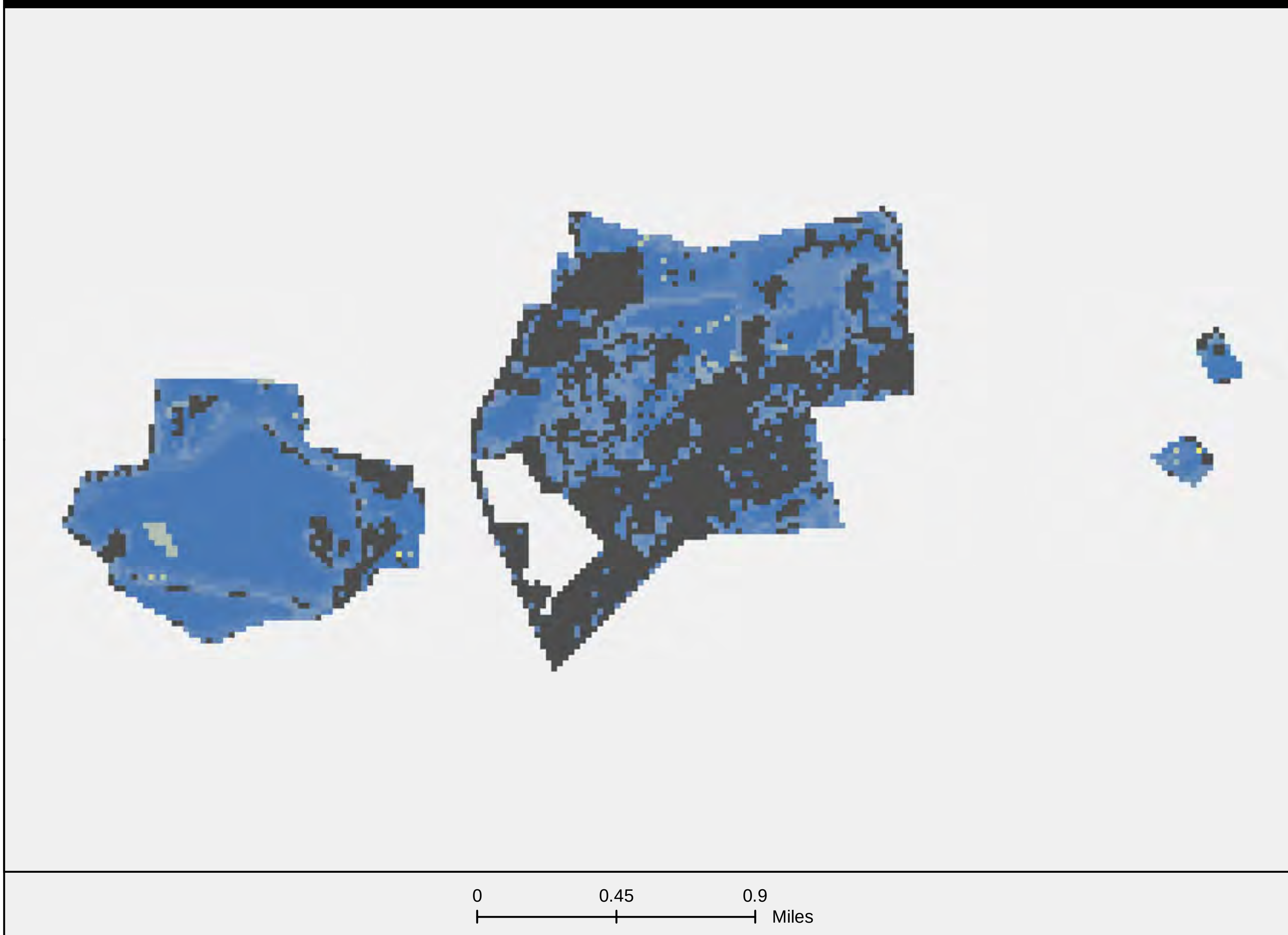
0	250	750
1	500	1000

Fort Detrick

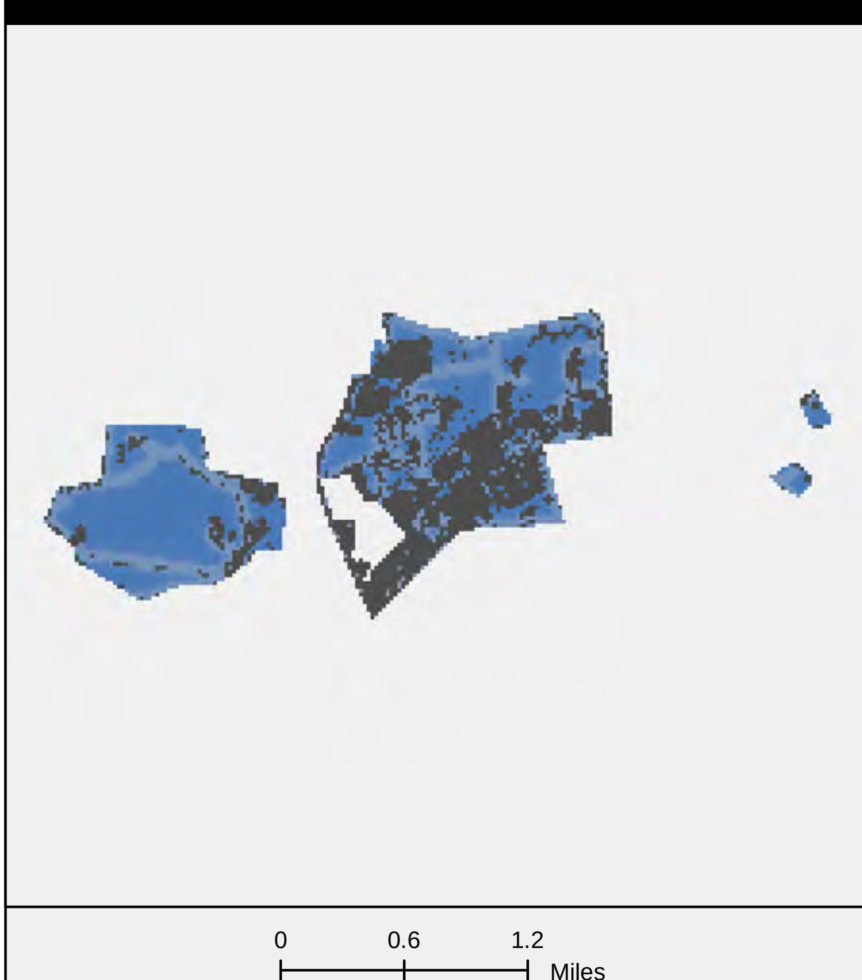
Low

Type 2 Wildfire Risk Assessment

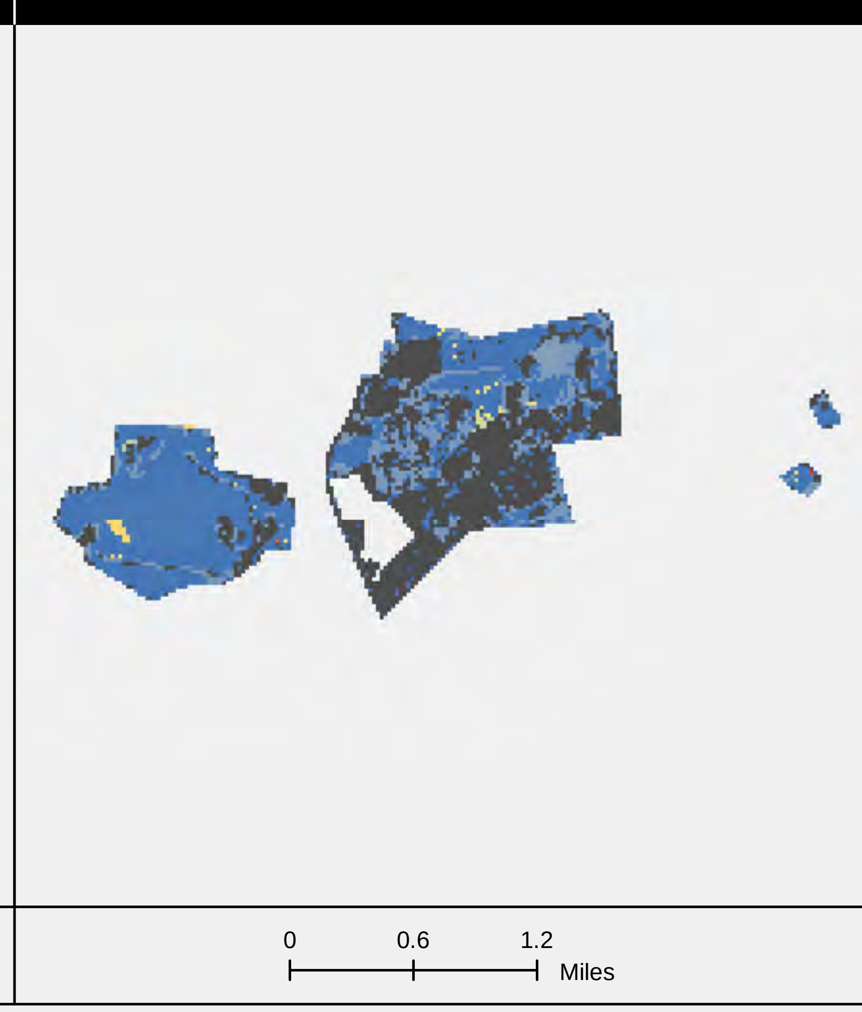
Hazard



Ignition Likelihood



Fire Behavior Magnitude



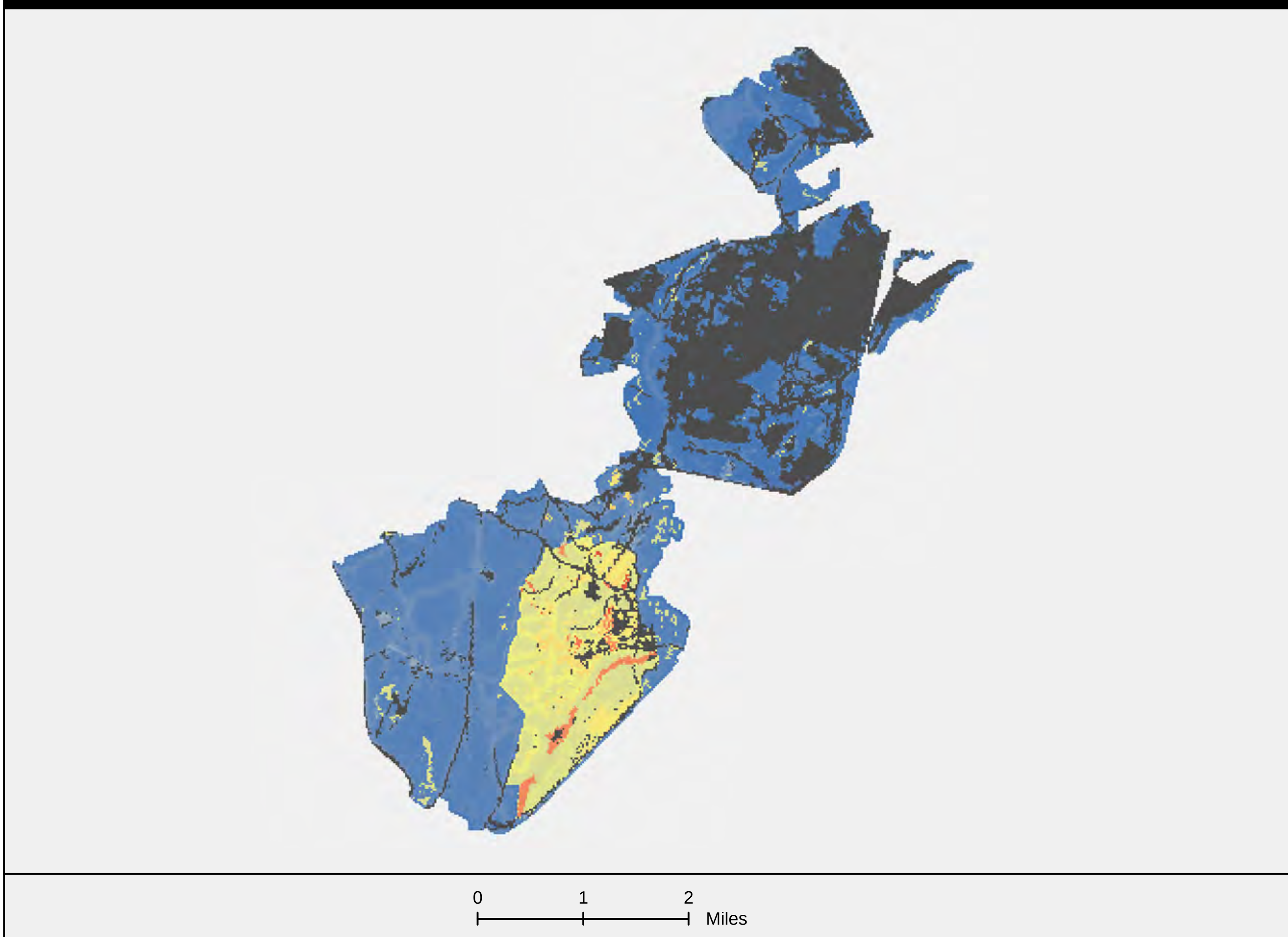
Scaled Cell Values

0, 1, 250, 500, 750, 1000

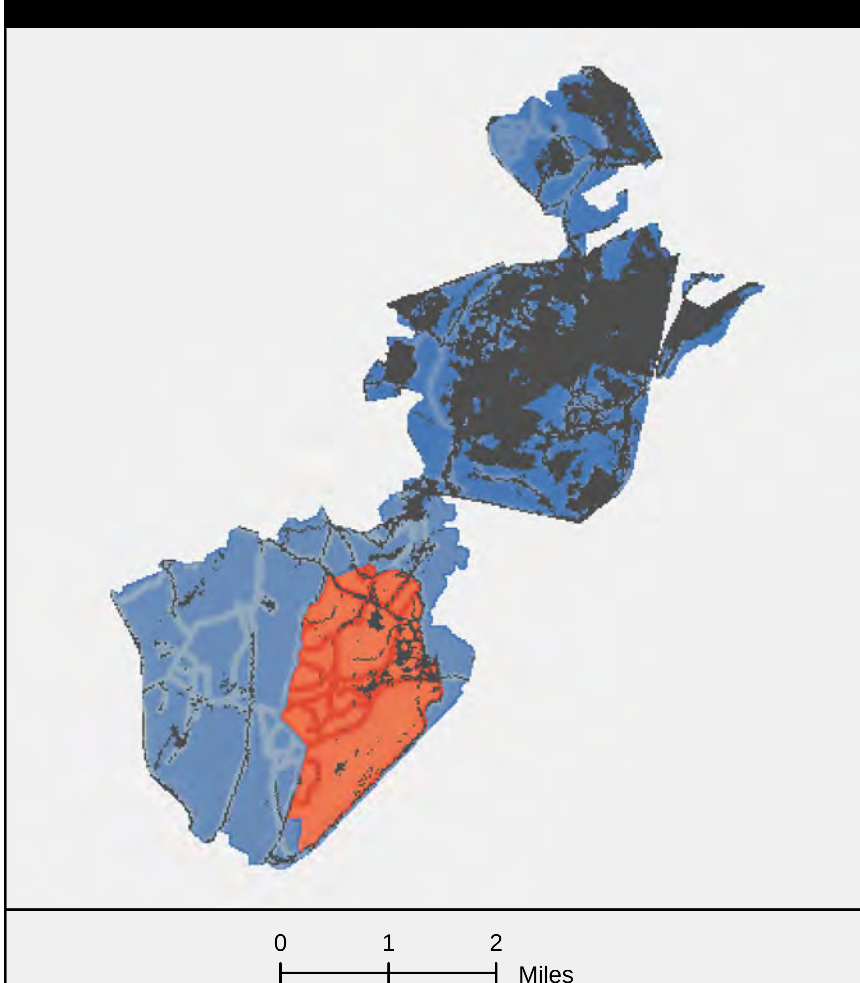
Fort Devens — Moderate

Type 2 Wildfire Risk Assessment

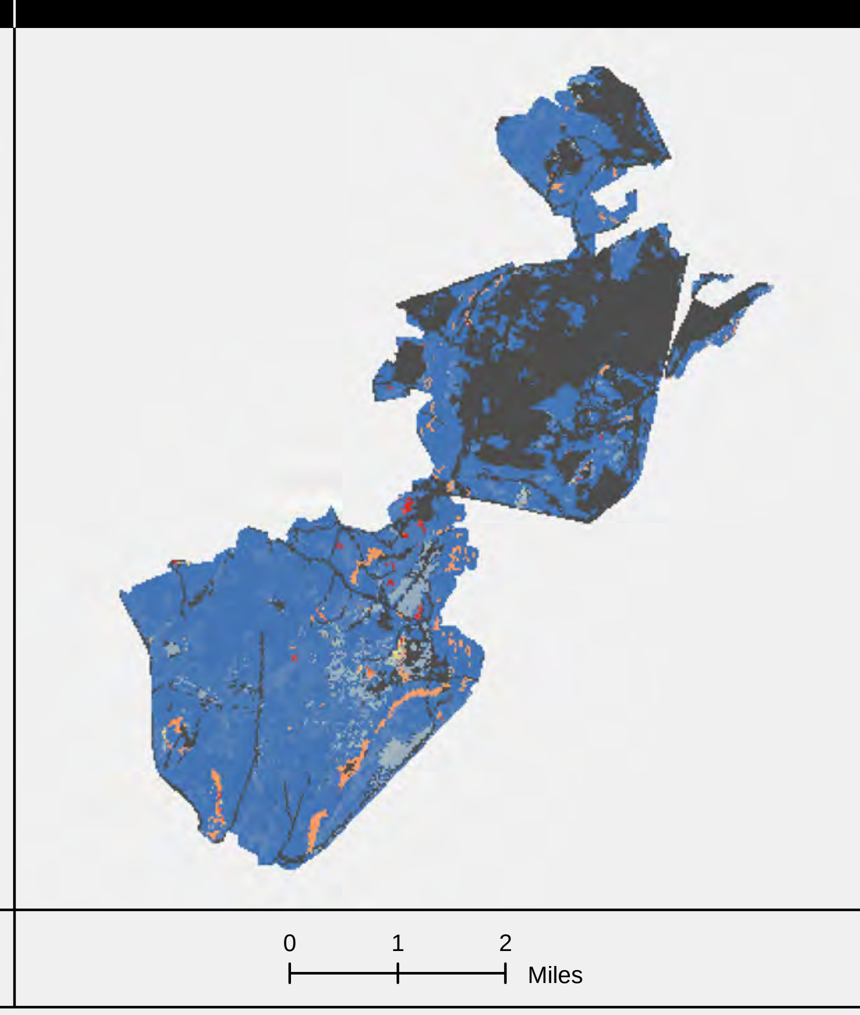
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

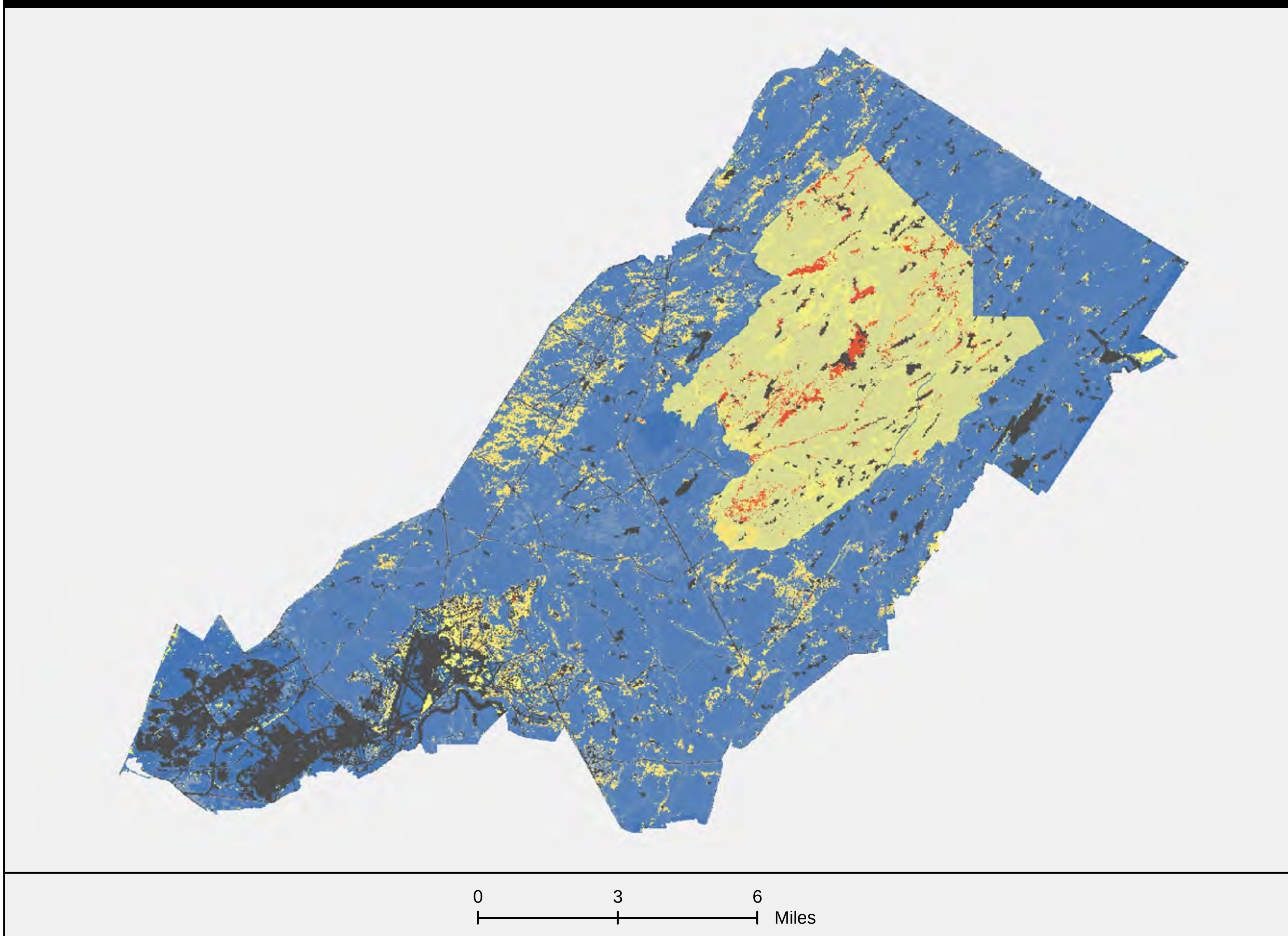
0, 1, 250, 500, 750, 1000

Fort Drum

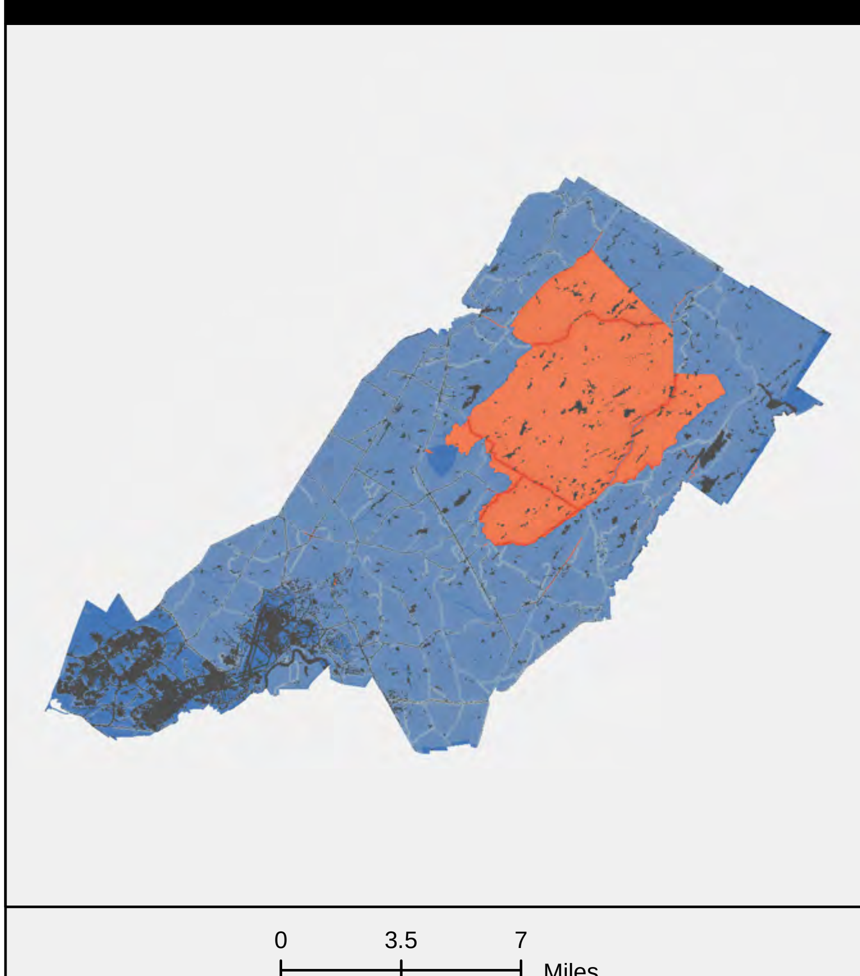
Moderate

Type 2 Wildfire Risk Assessment

Hazard



Ignition Likelihood



Fire Behavior Magnitude

Scaled Cell Values

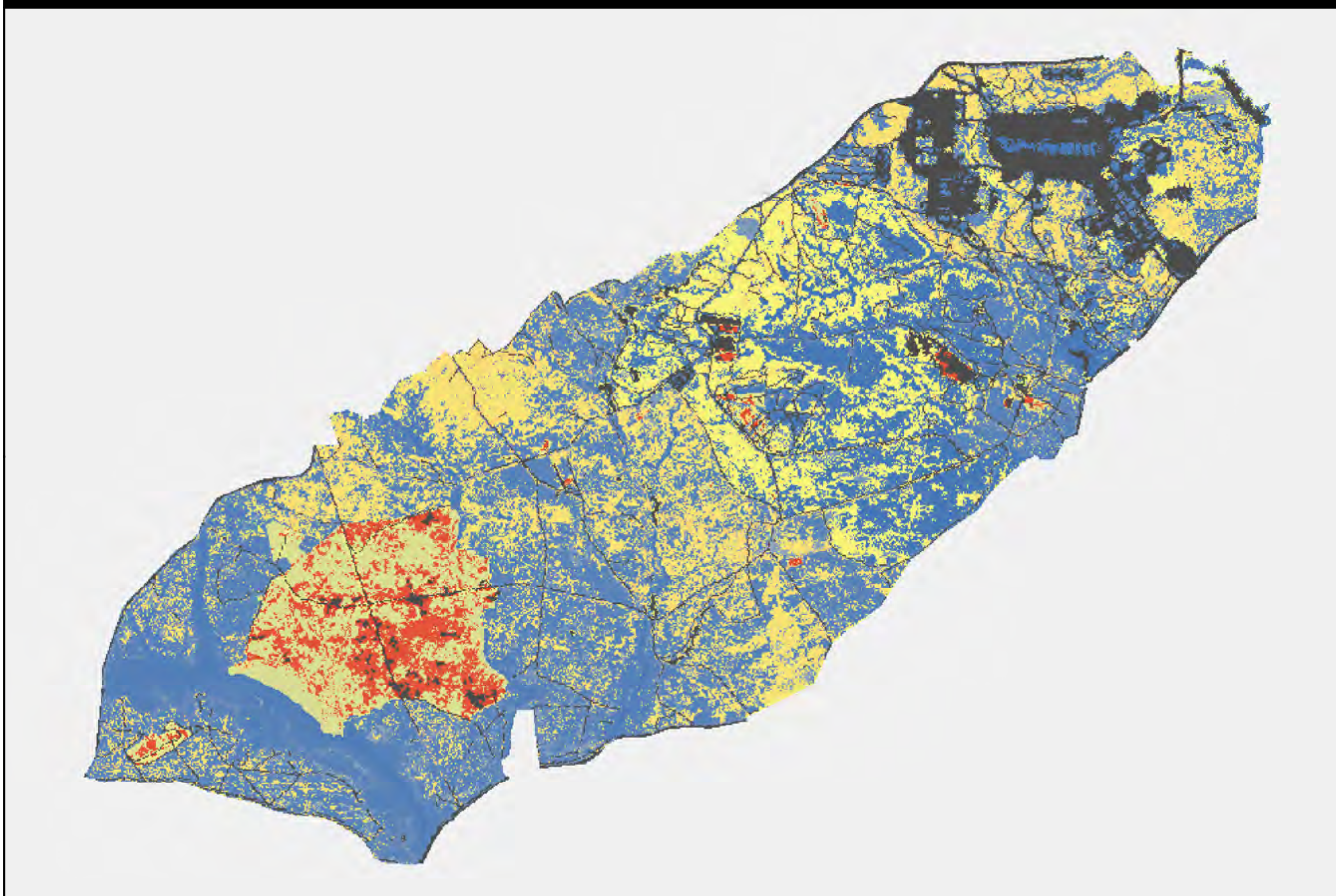
0, 1, 250, 500, 750, 1000

Fort Gordon

Moderate

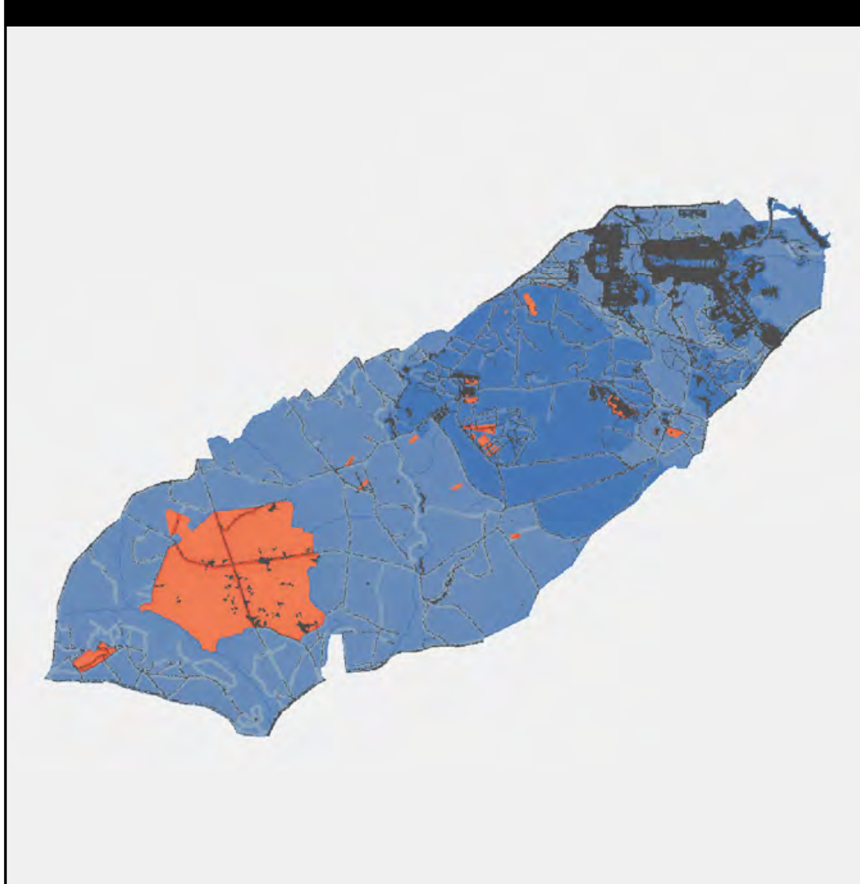
Type 2 Wildfire Risk Assessment

Hazard



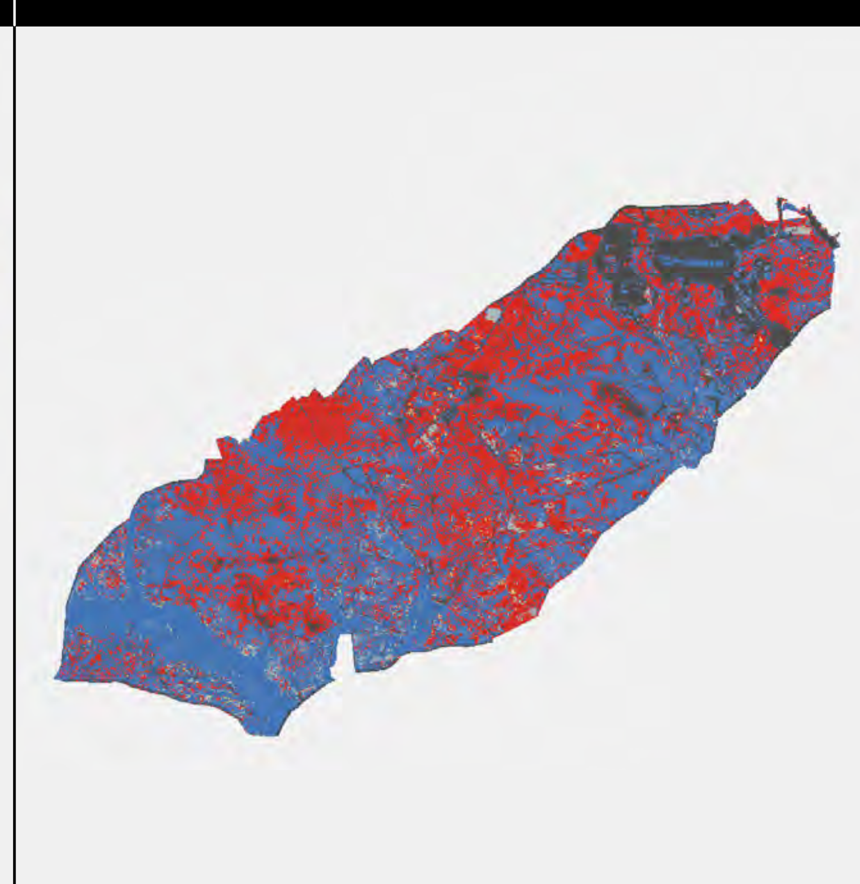
0 2 4 Miles

Ignition Likelihood



0 2.5 5 Miles

Fire Behavior Magnitude



0 2.5 5 Miles

Scaled Cell Values

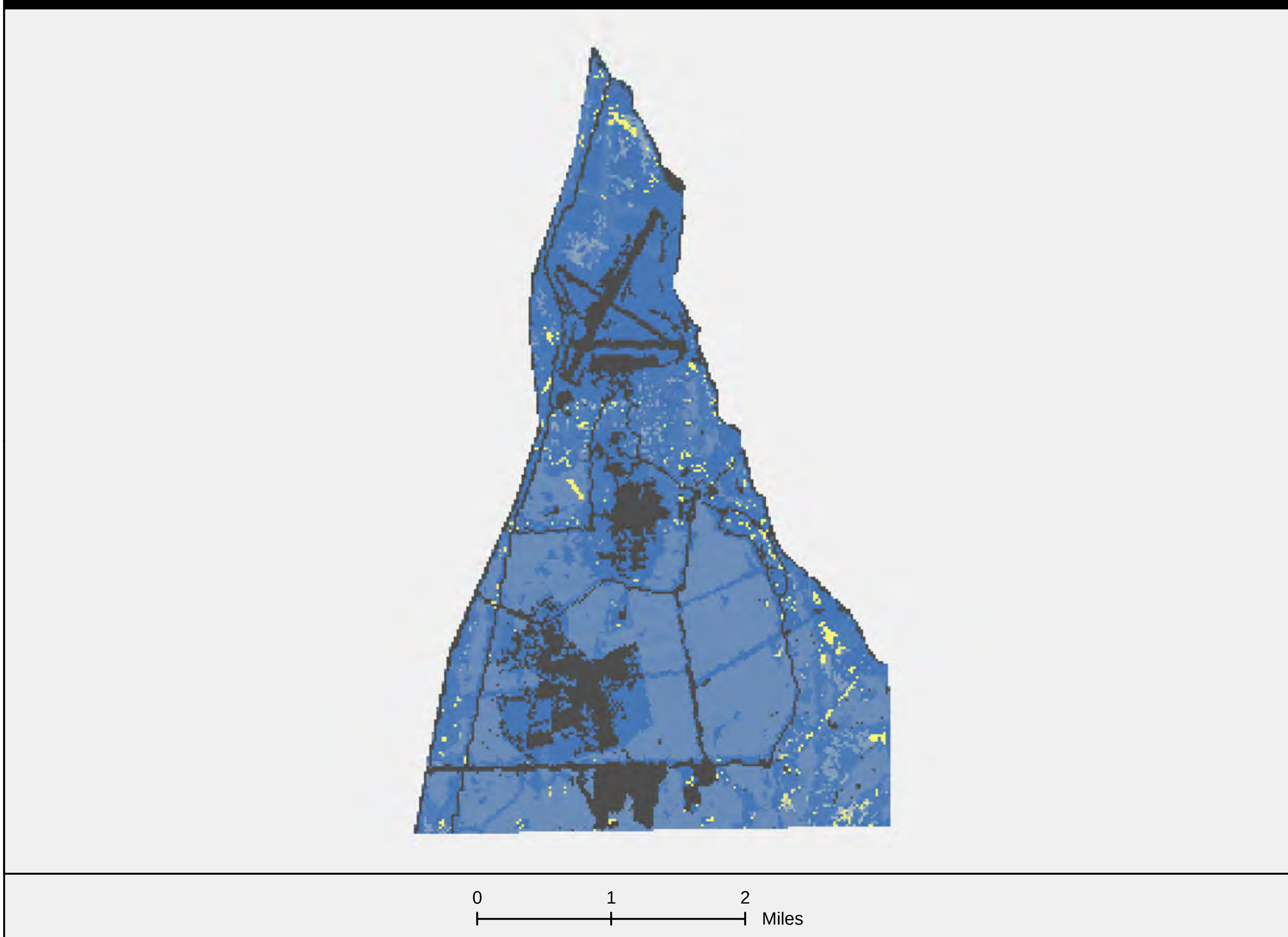
0, 1, 250, 500, 750, 1000

Fort Greeley

Low

Type 2 Wildfire Risk Assessment

Hazard



Ignition Likelihood

Fire Behavior Magnitude

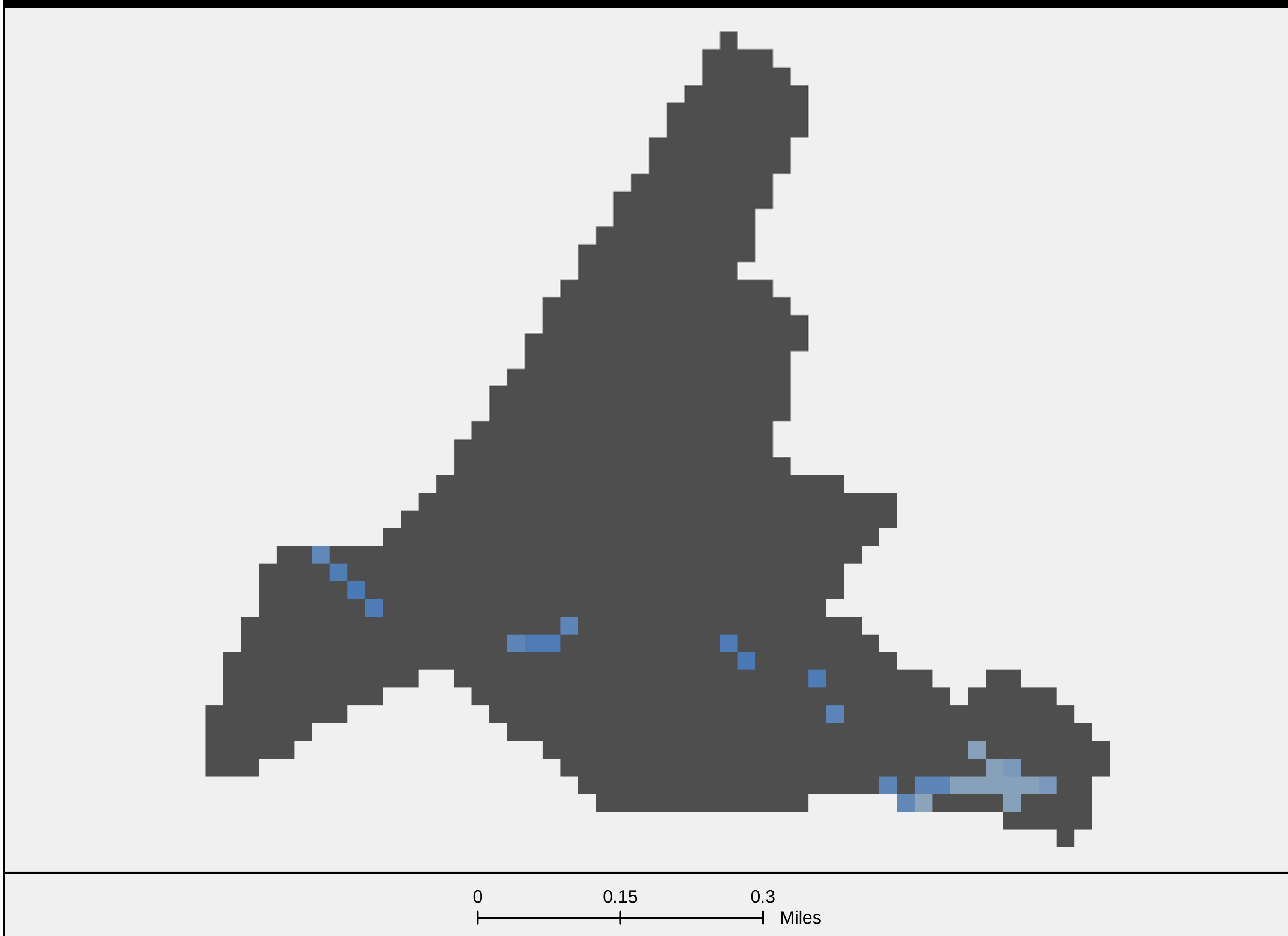
Scaled Cell Values

0, 1, 250, 500, 750, 1000

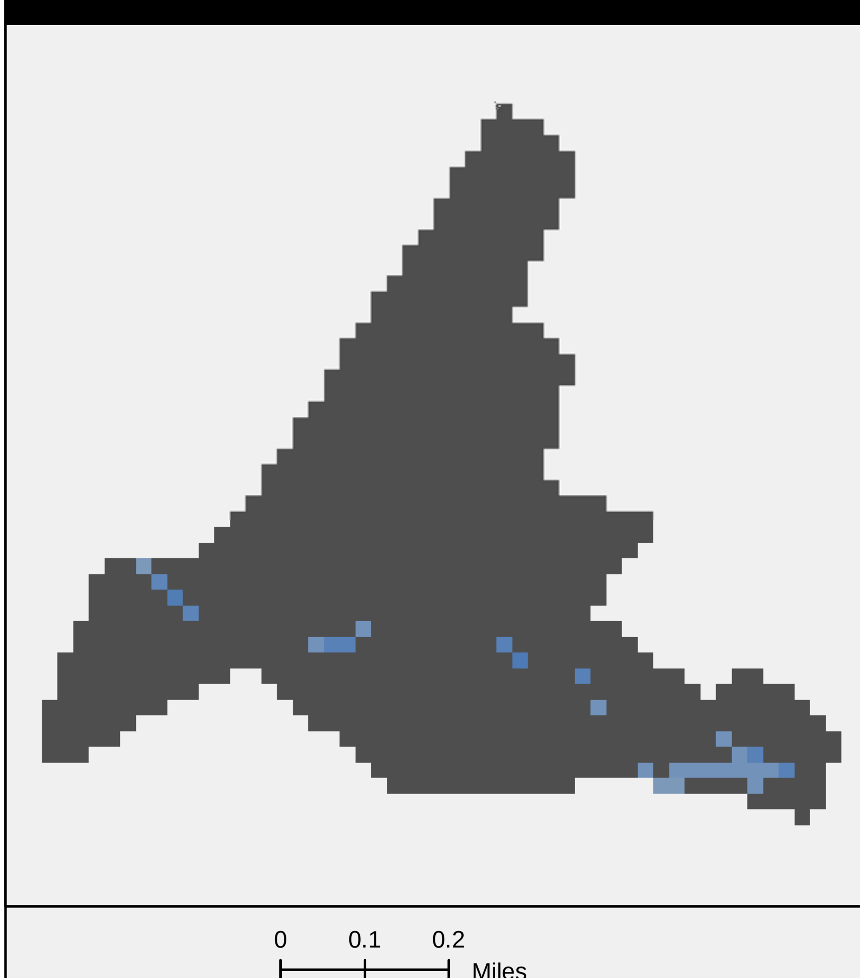
Fort Hamilton — Low

Type 2 Wildfire Risk Assessment

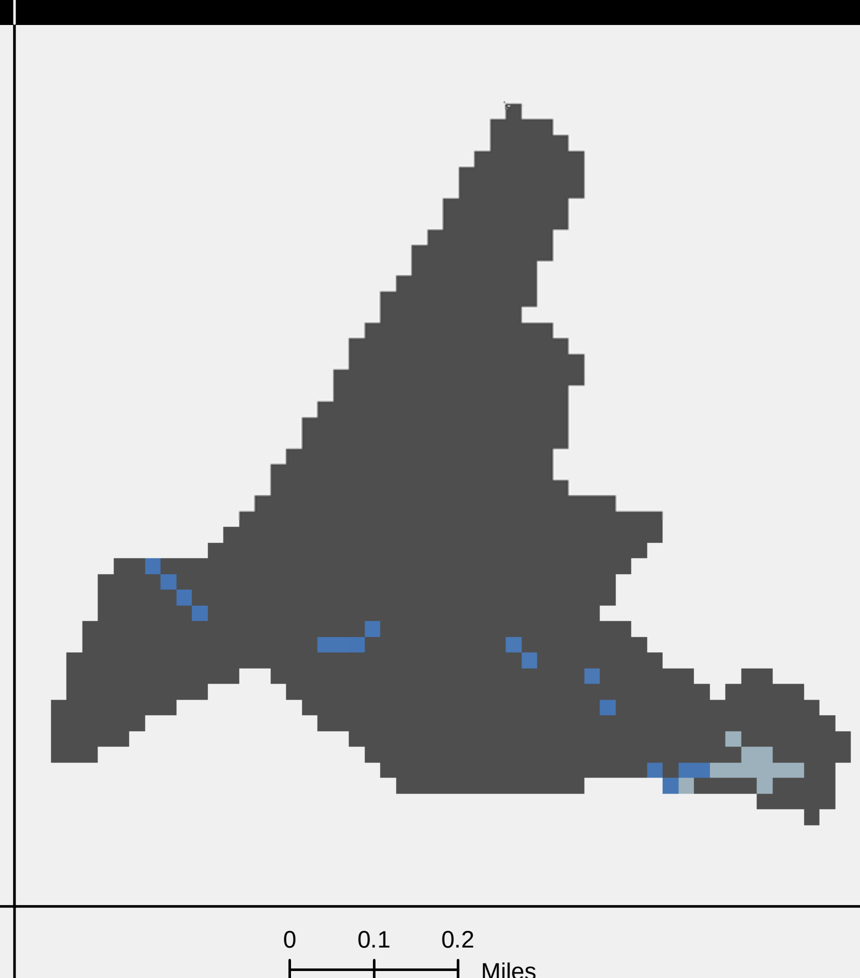
Hazard



Ignition Likelihood



Fire Behavior Magnitude



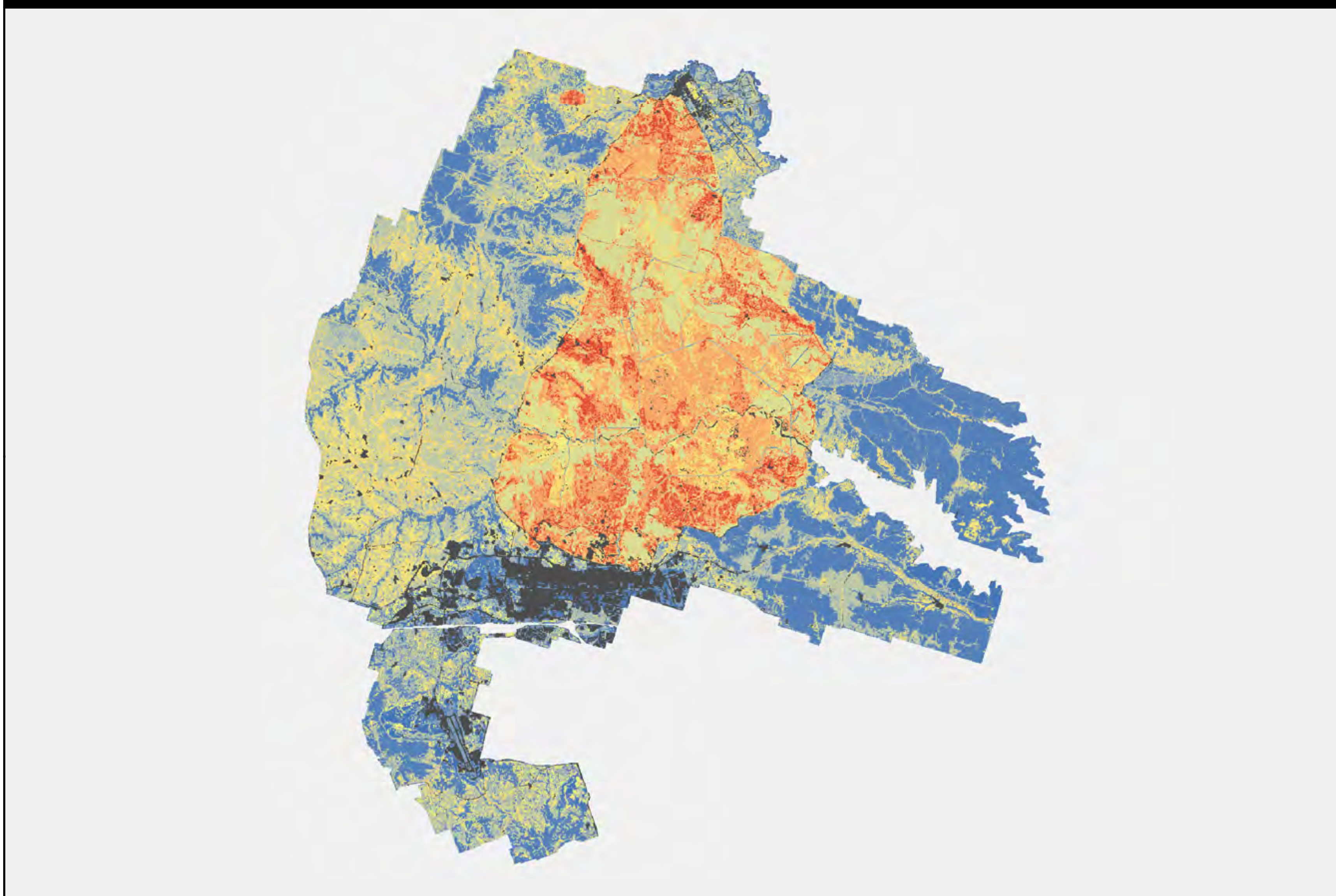
Scaled Cell Values

0	250	750
1	500	1000

Fort Hood — High

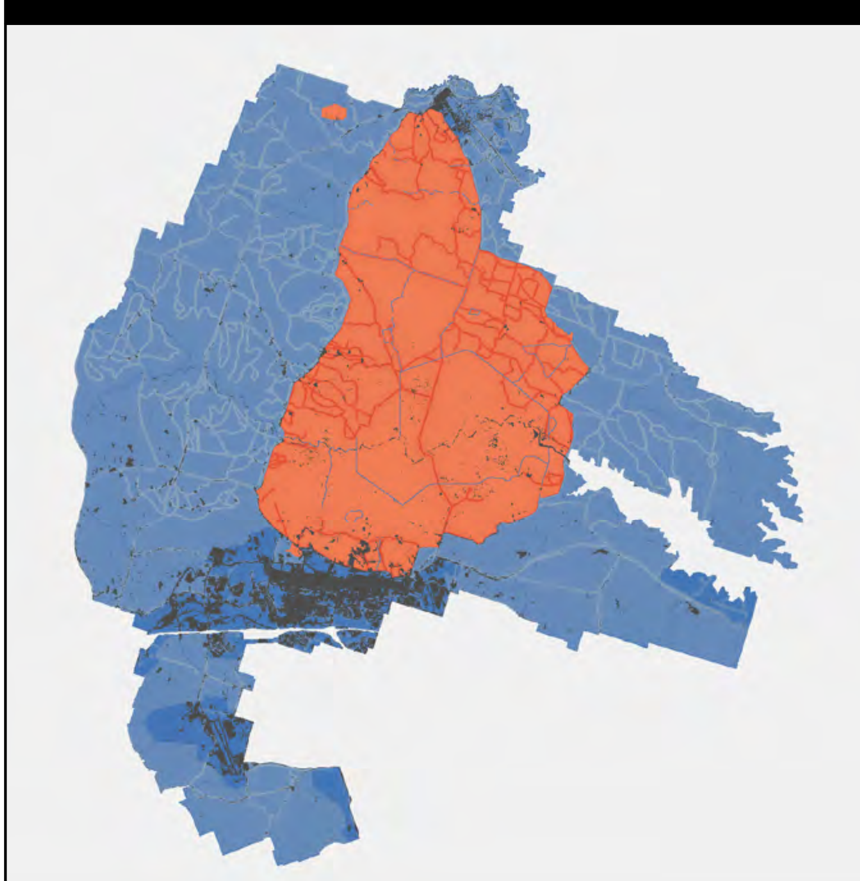
Type 2 Wildfire Risk Assessment

Hazard



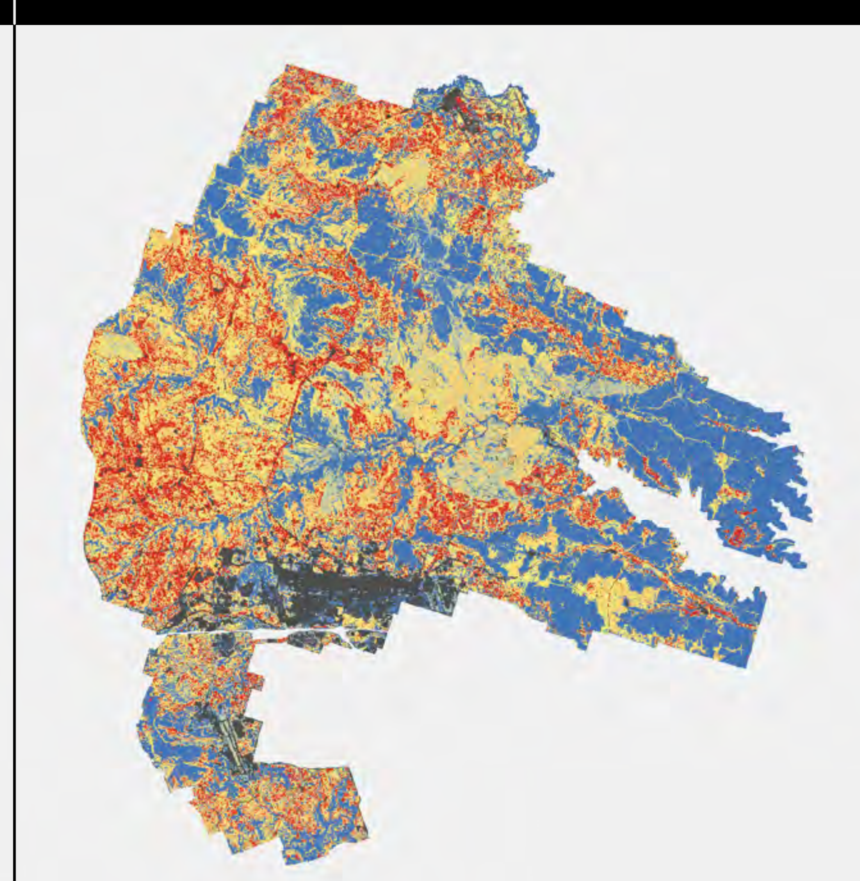
0 5 10 Miles

Ignition Likelihood



0 4 8 Miles

Fire Behavior Magnitude



0 4 8 Miles

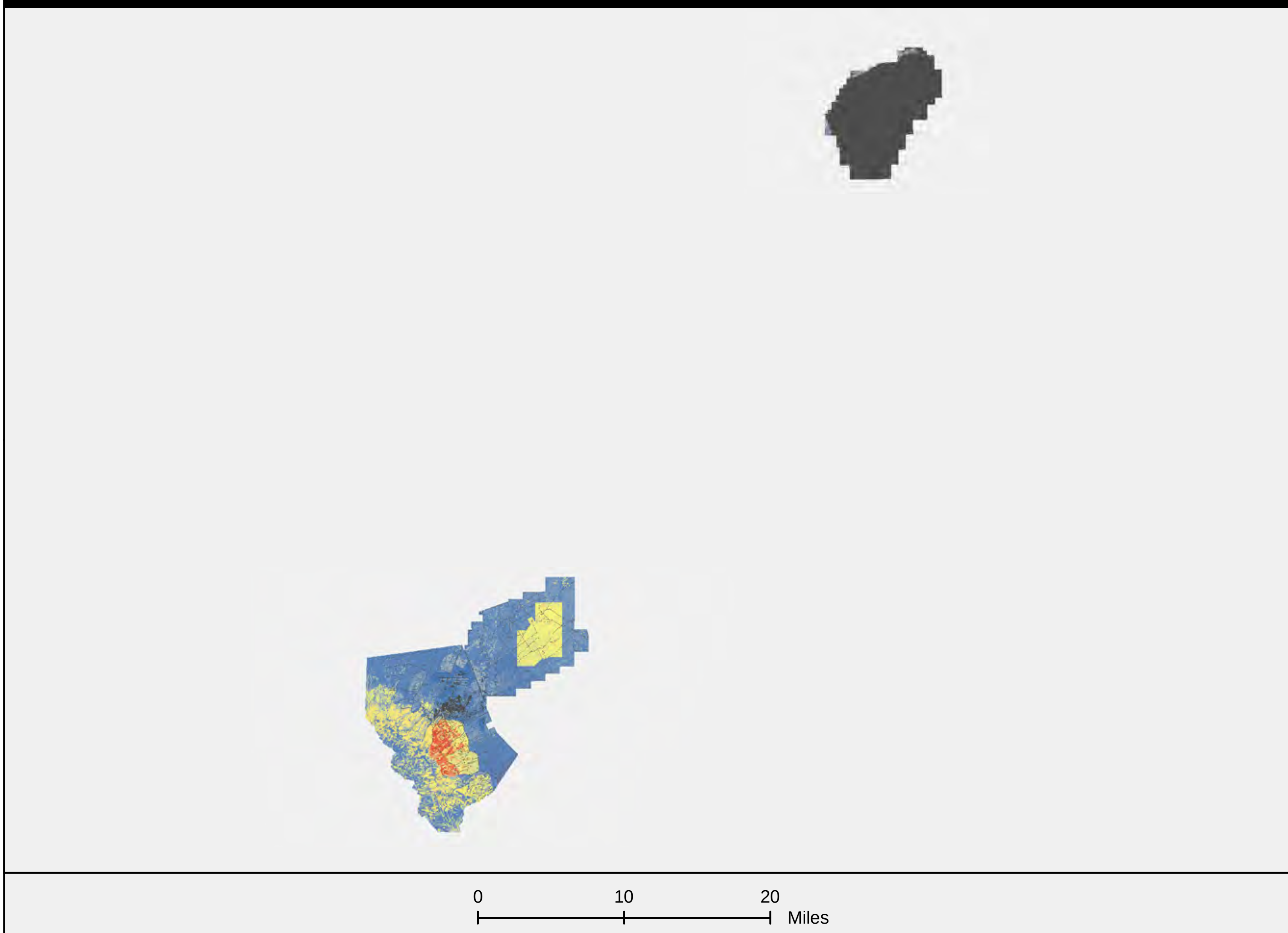
Scaled Cell Values

0	250	750
1	500	1000

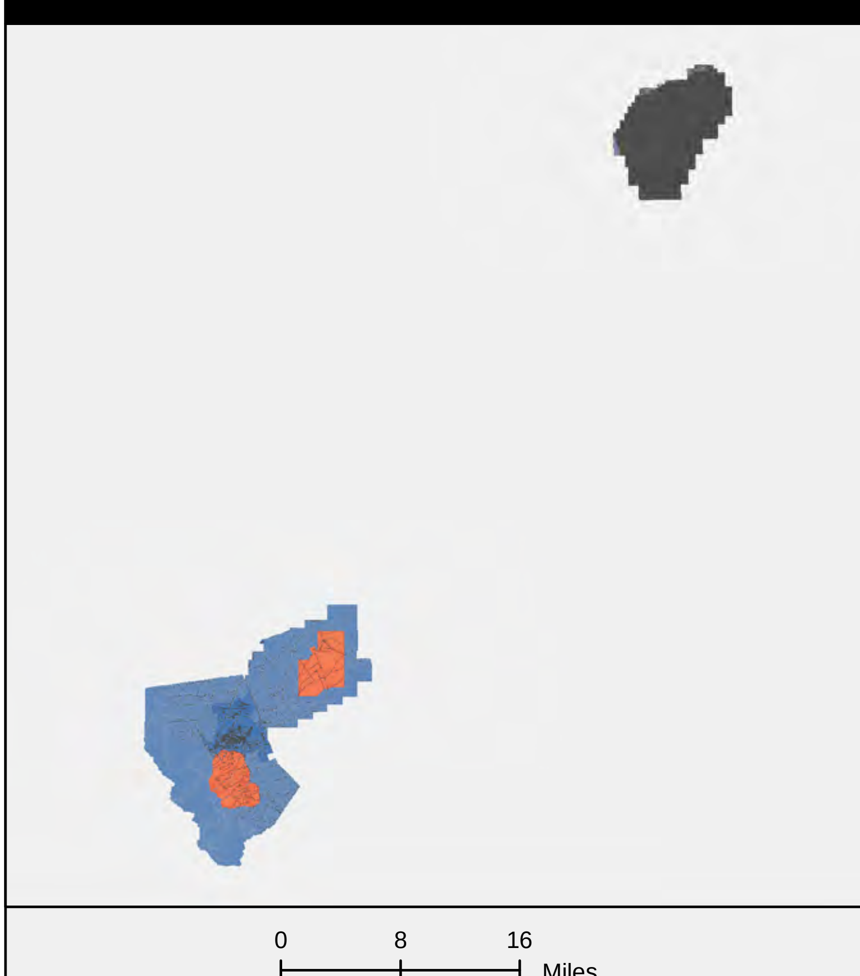
Fort Huachuca — Moderate

Type 2 Wildfire Risk Assessment

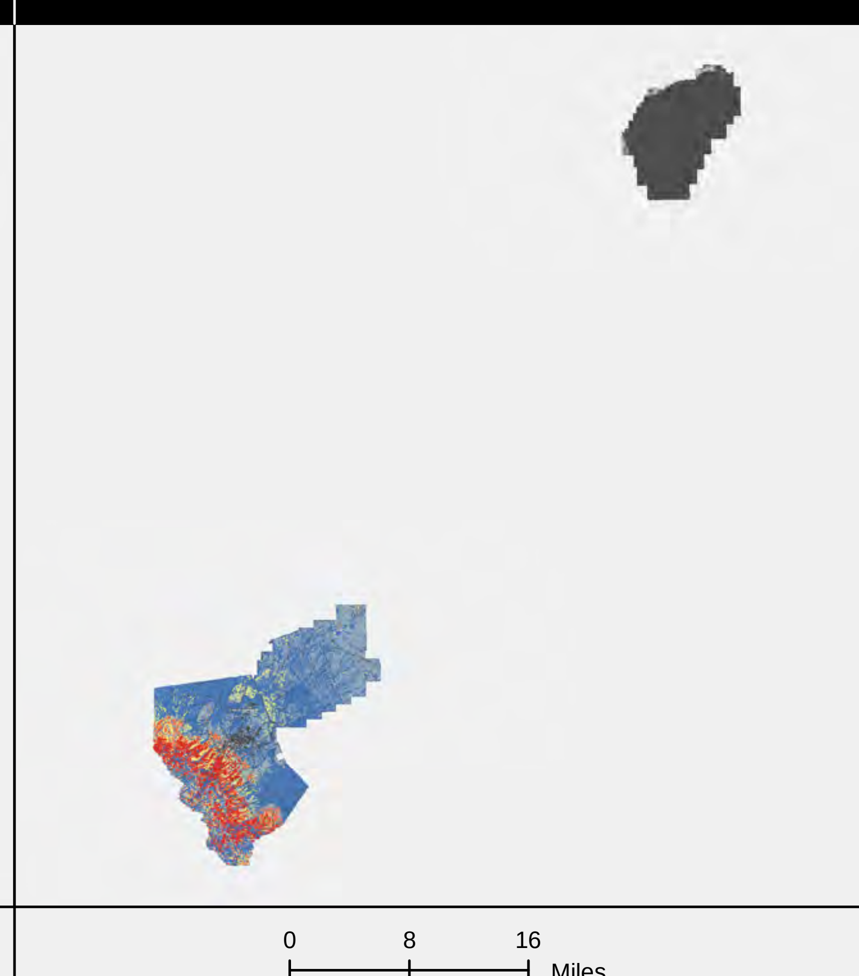
Hazard



Ignition Likelihood



Fire Behavior Magnitude



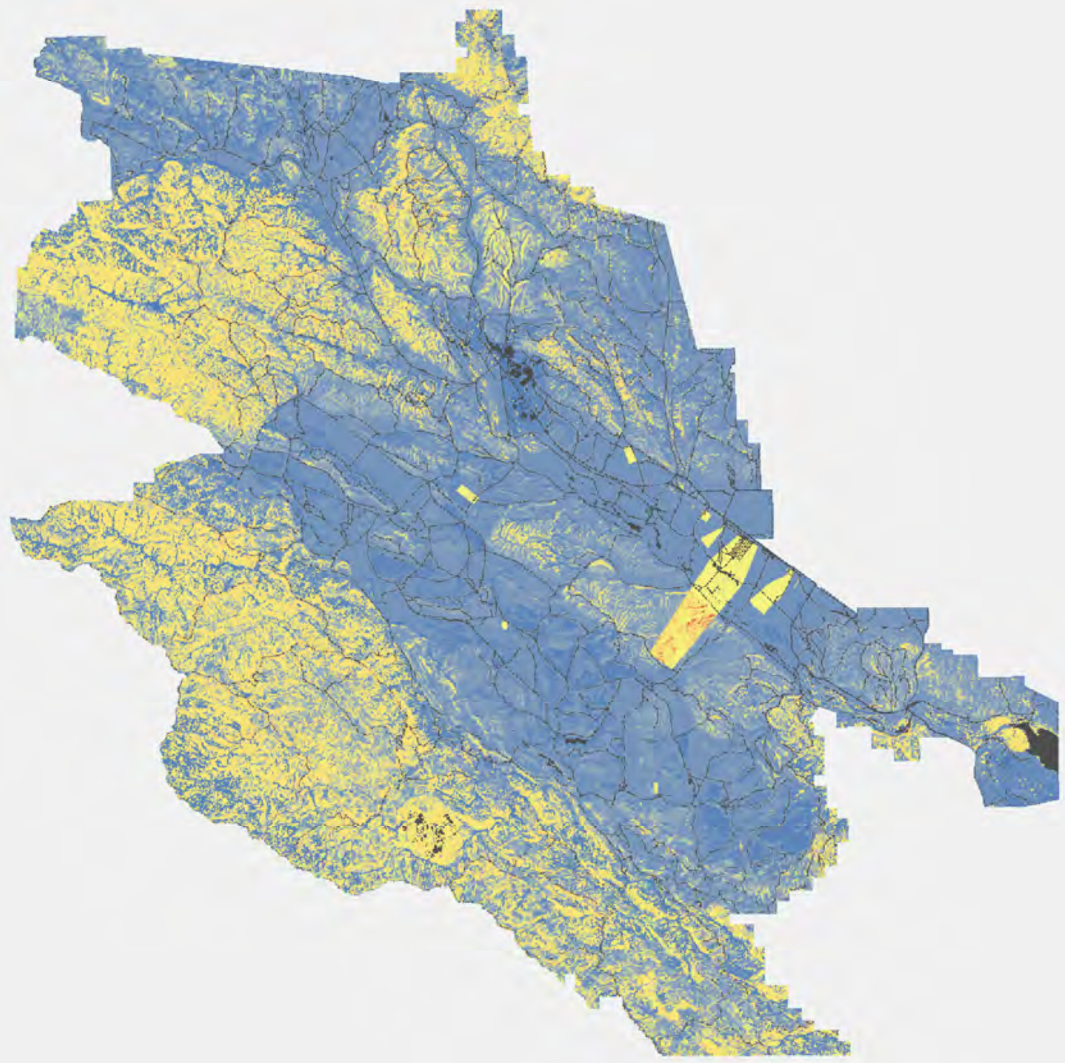
Scaled Cell Values

0	250	750
1	500	1000

Fort Hunter Liggett High

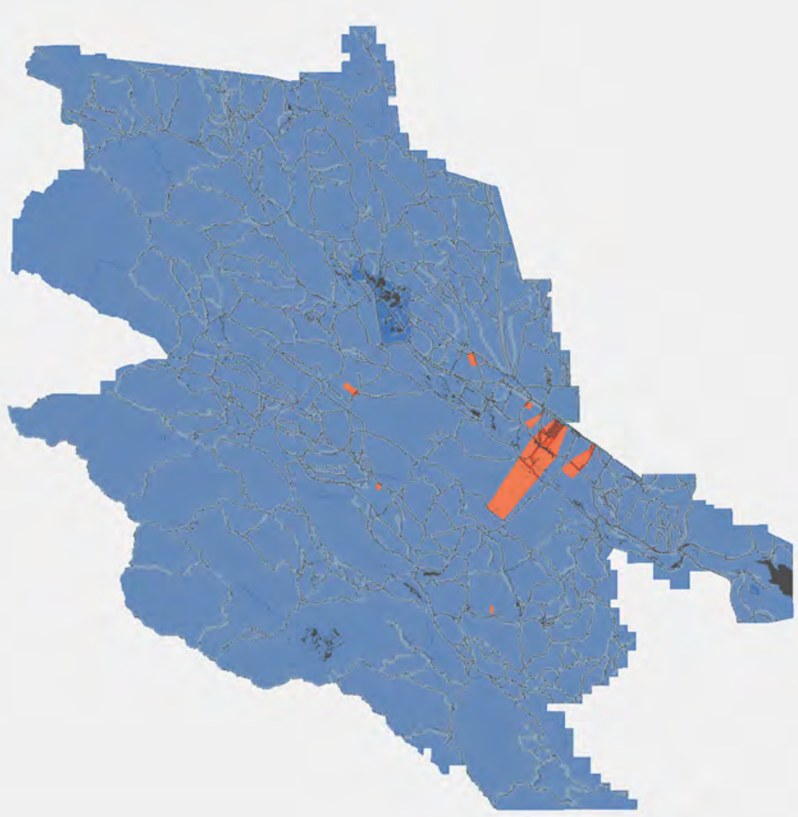
Type 2 Wildfire Risk Assessment

Hazard



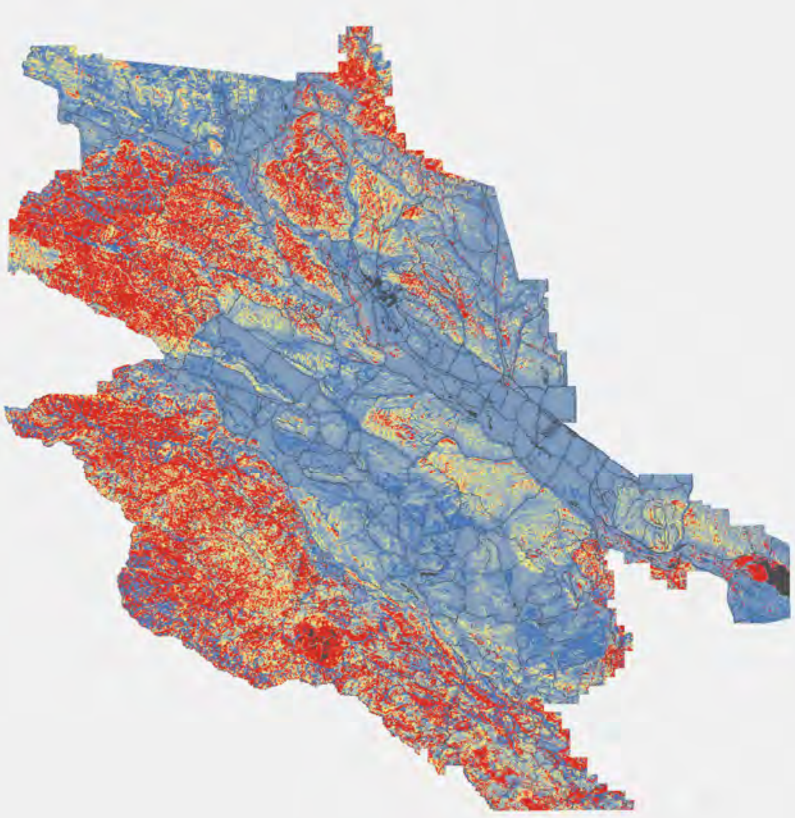
0 4 8 Miles

Ignition Likelihood



0 3 6 Miles

Fire Behavior Magnitude



0 3 6 Miles

Scaled Cell Values

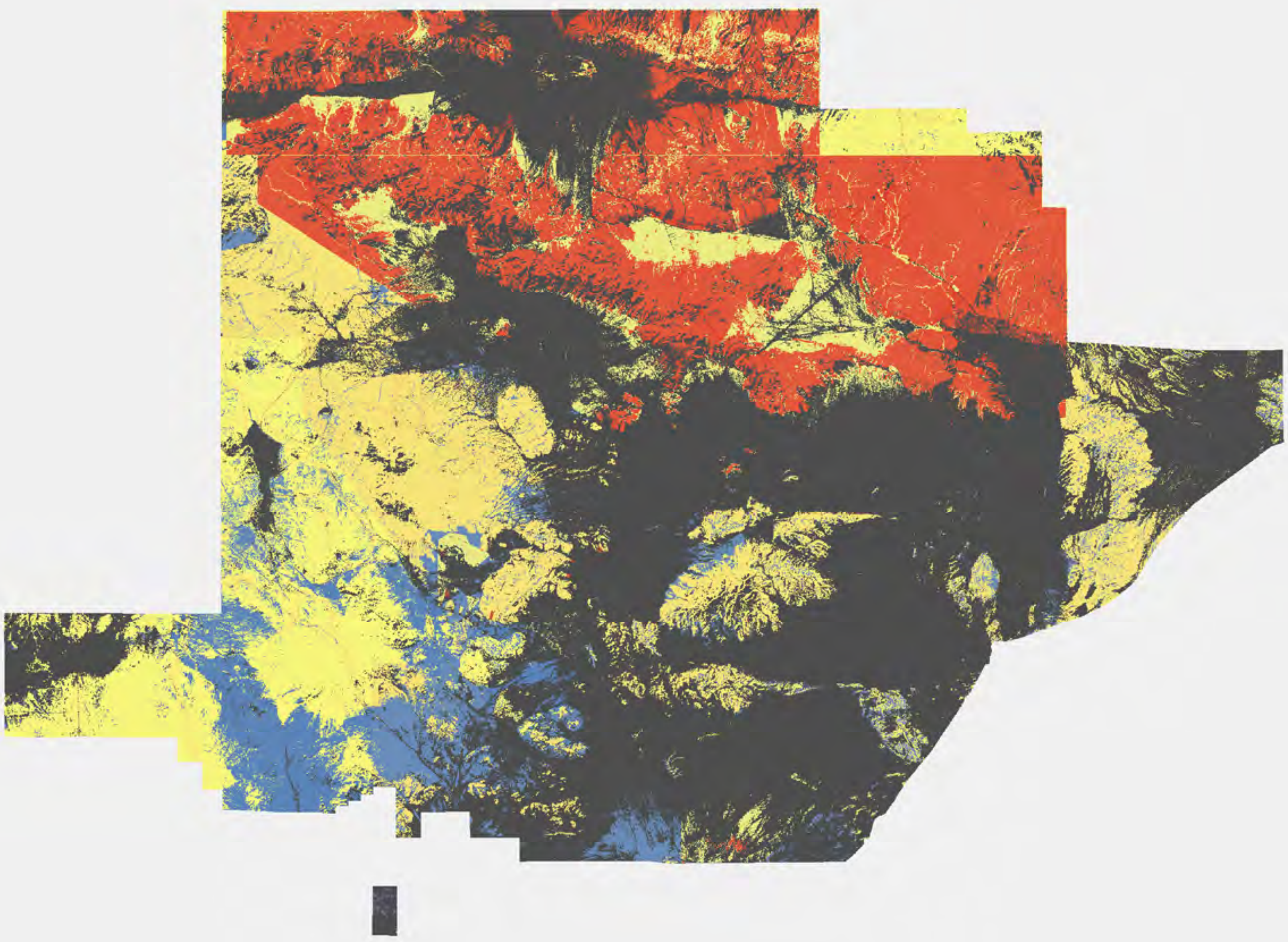
0 250 750
1 500 1000

Fort Irwin

Moderate

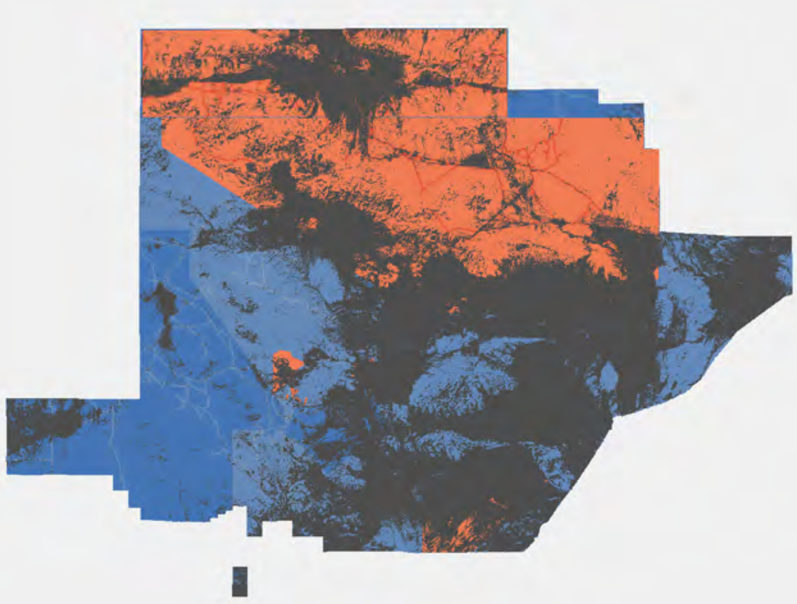
Type 2 Wildfire Risk Assessment

Hazard



0 7 14 Miles

Ignition Likelihood



0 8 16 Miles

Fire Behavior Magnitude

0 8 16 Miles

Scaled Cell Values

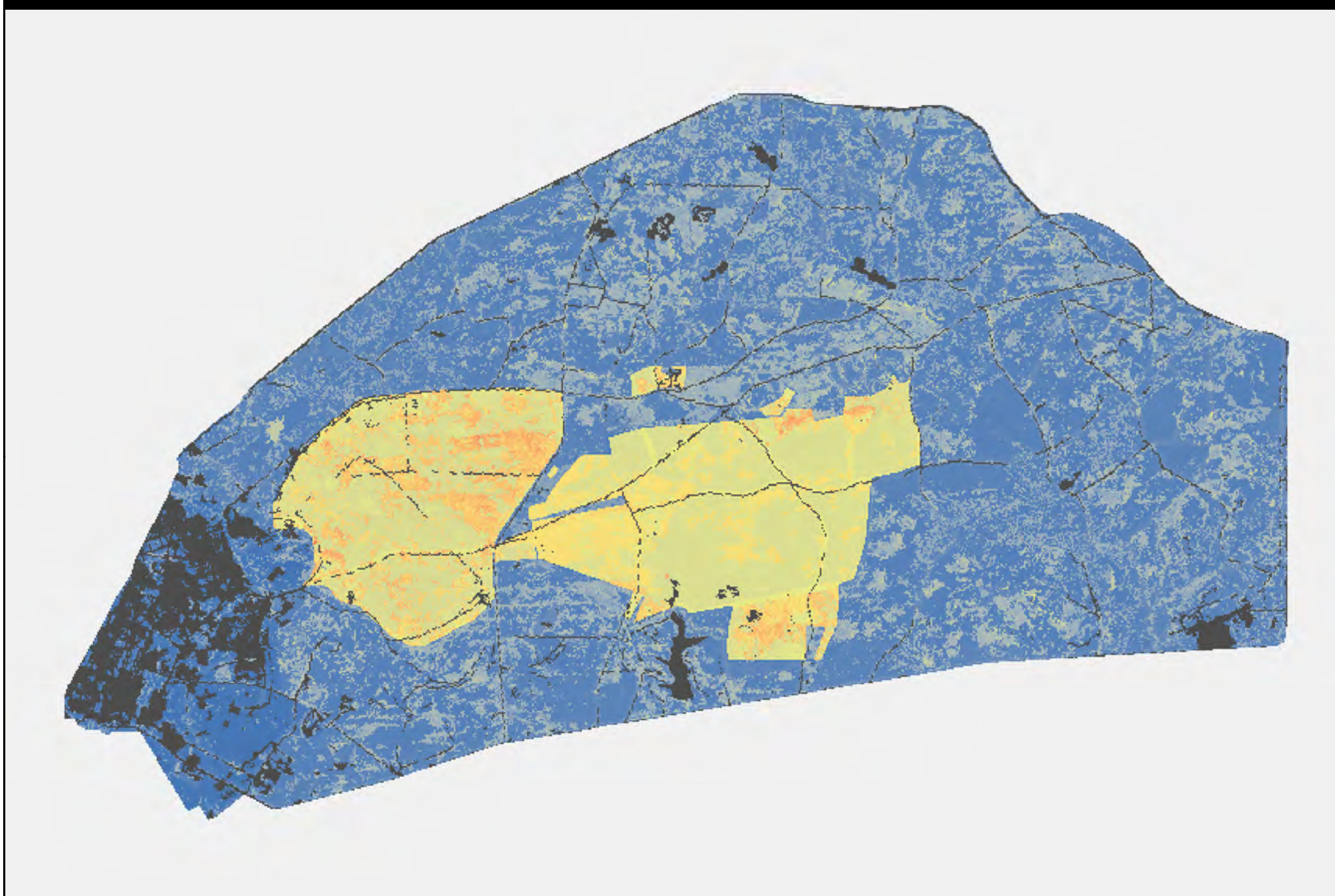
0, 1, 250, 500, 750, 1000

Fort Jackson

Moderate

Type 2 Wildfire Risk Assessment

Hazard

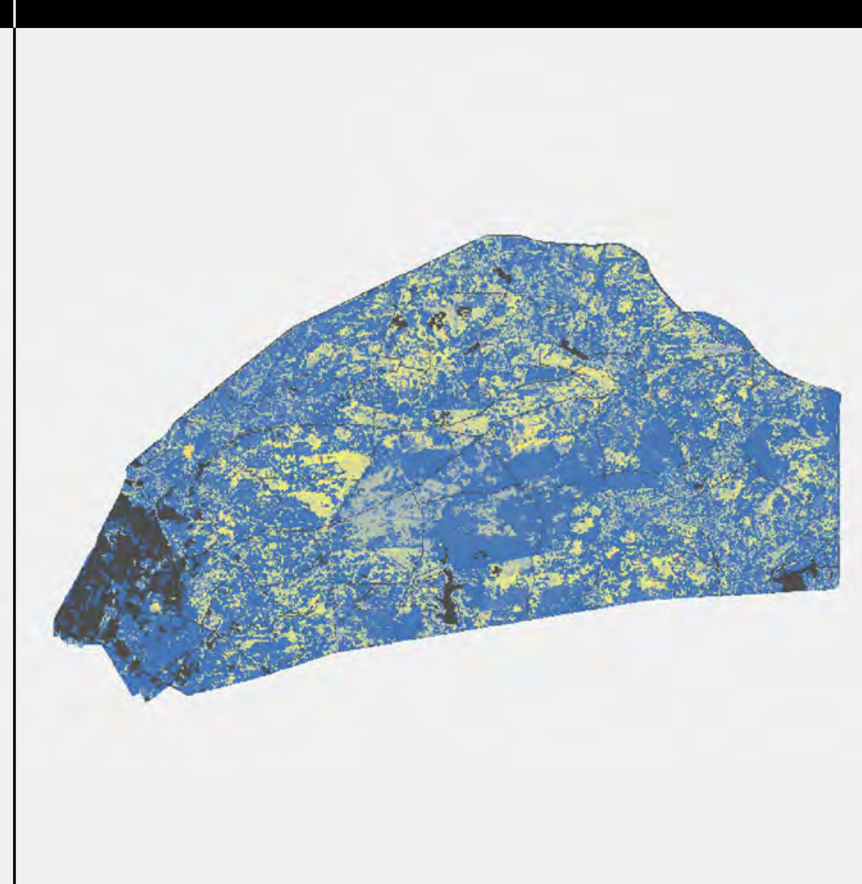


0 1.5 3 Miles

Ignition Likelihood

0 2 4 Miles

Fire Behavior Magnitude



0 2 4 Miles

Scaled Cell Values

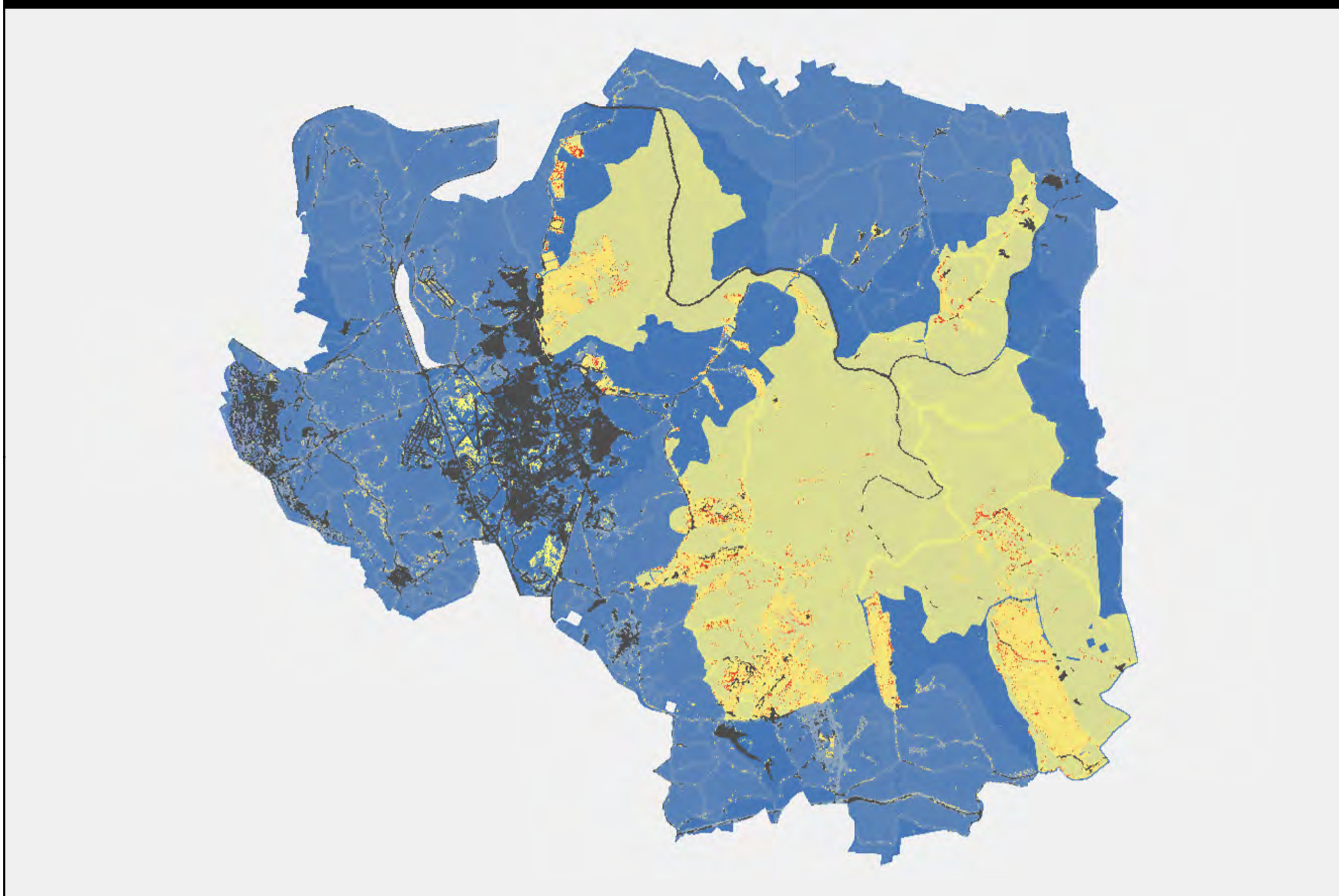
0
1
250
500
750
1000

Fort Knox

Moderate

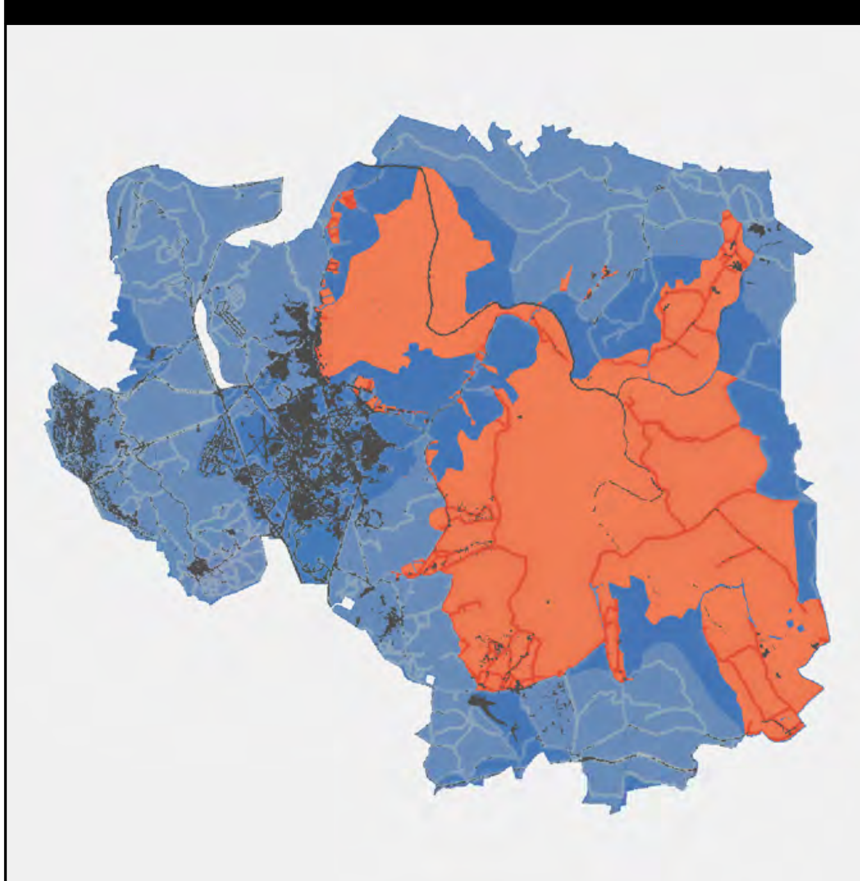
Type 2 Wildfire Risk Assessment

Hazard



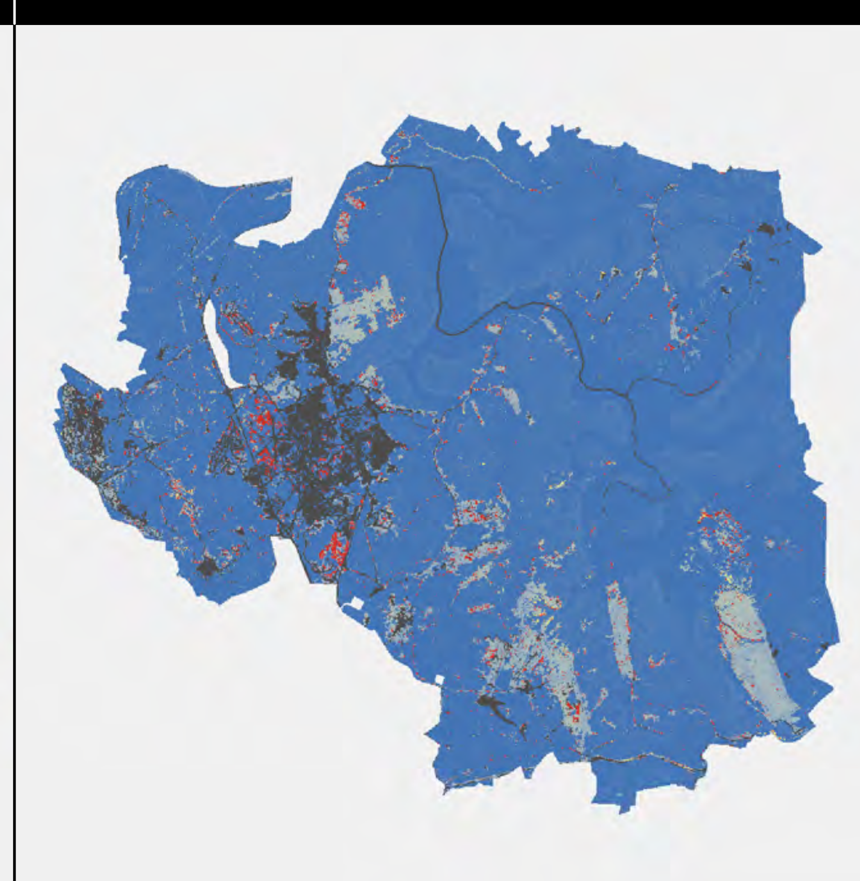
0 2.5 5 Miles

Ignition Likelihood



0 2.5 5 Miles

Fire Behavior Magnitude



0 2.5 5 Miles

Scaled Cell Values

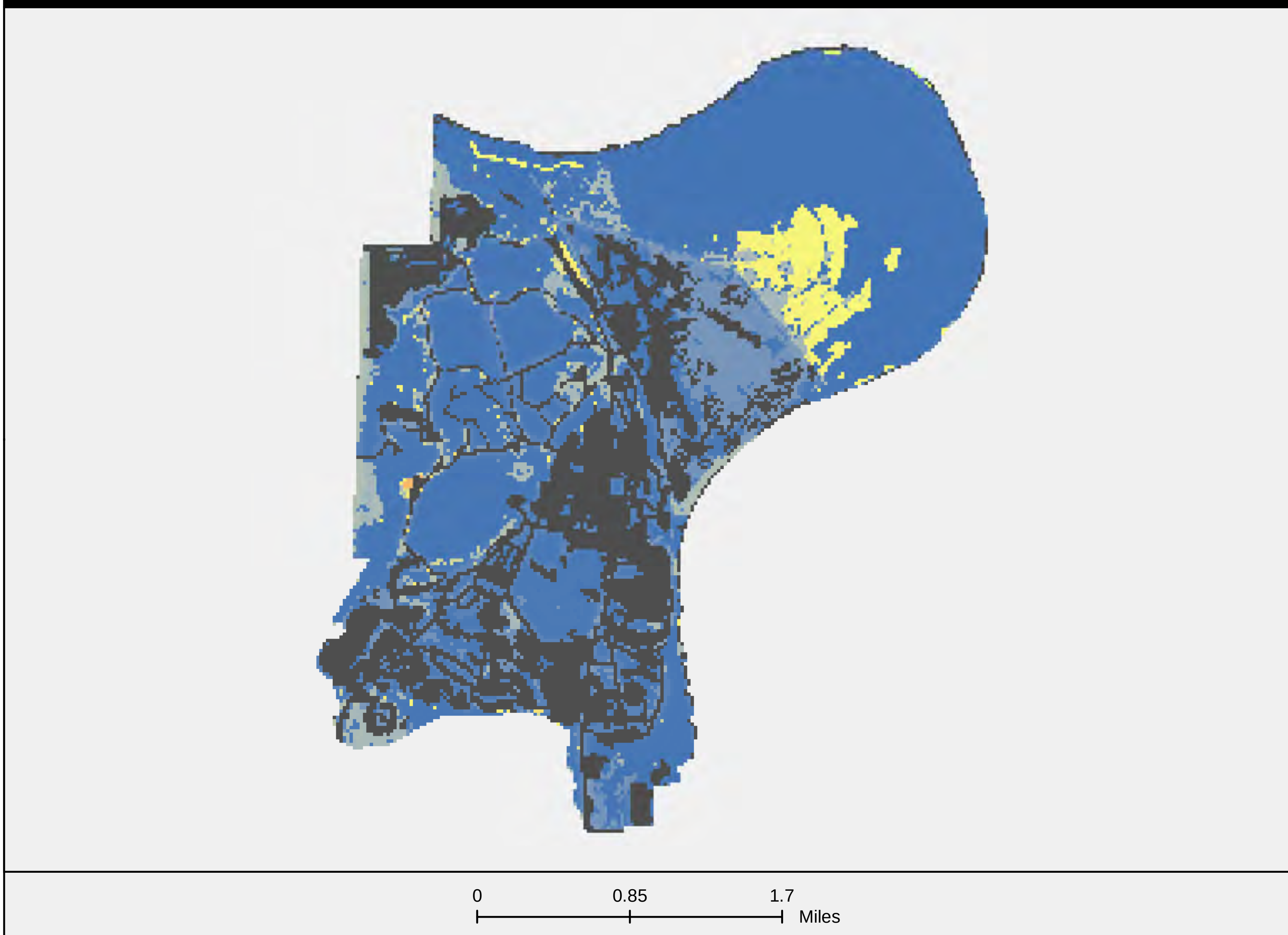
0, 1, 250, 500, 750, 1000

Fort Leavenworth

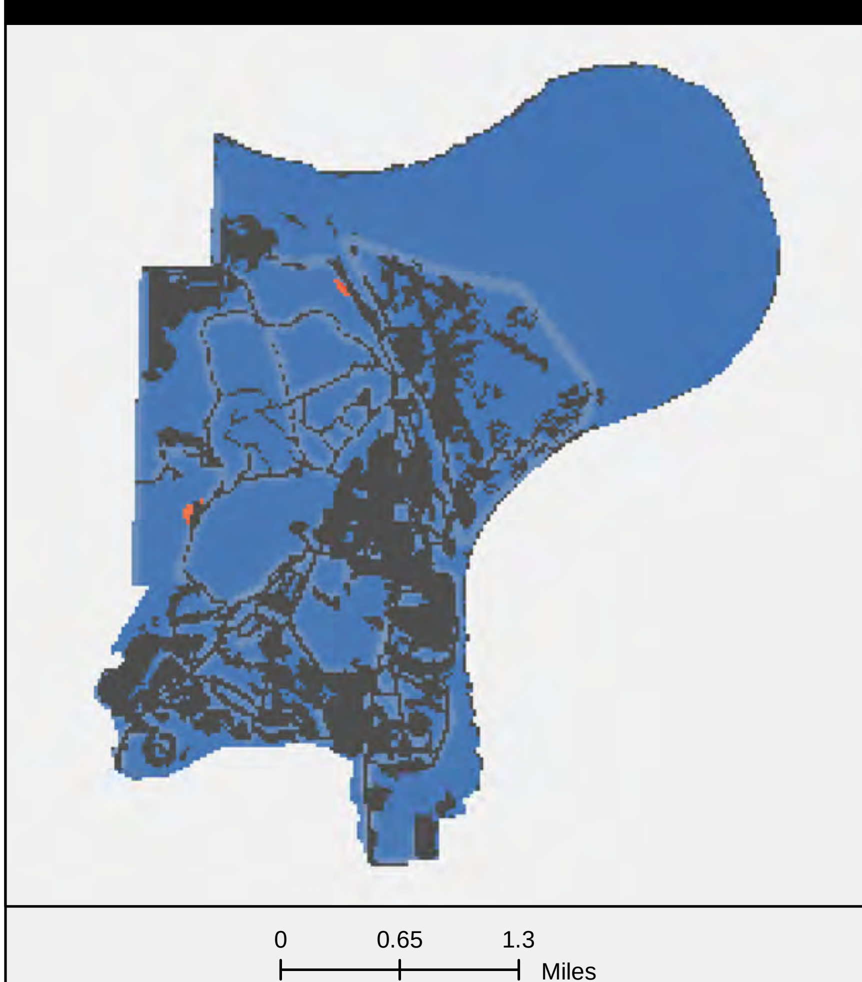
Low

Type 2 Wildfire Risk Assessment

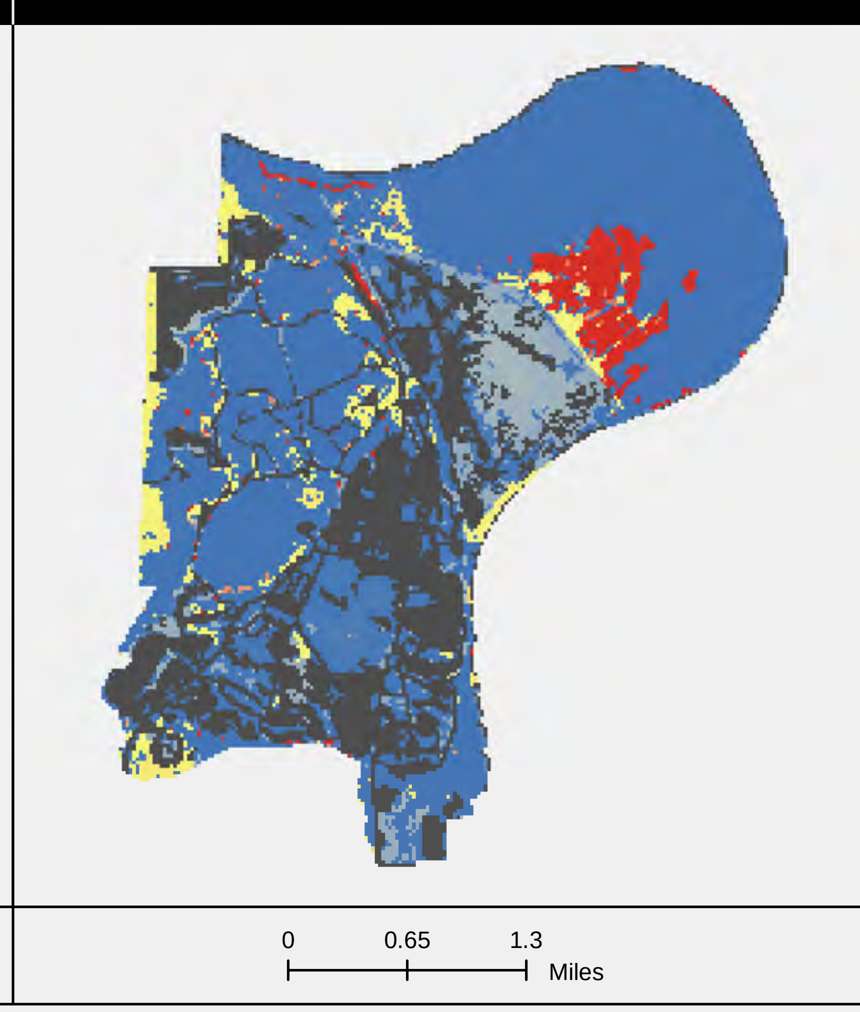
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

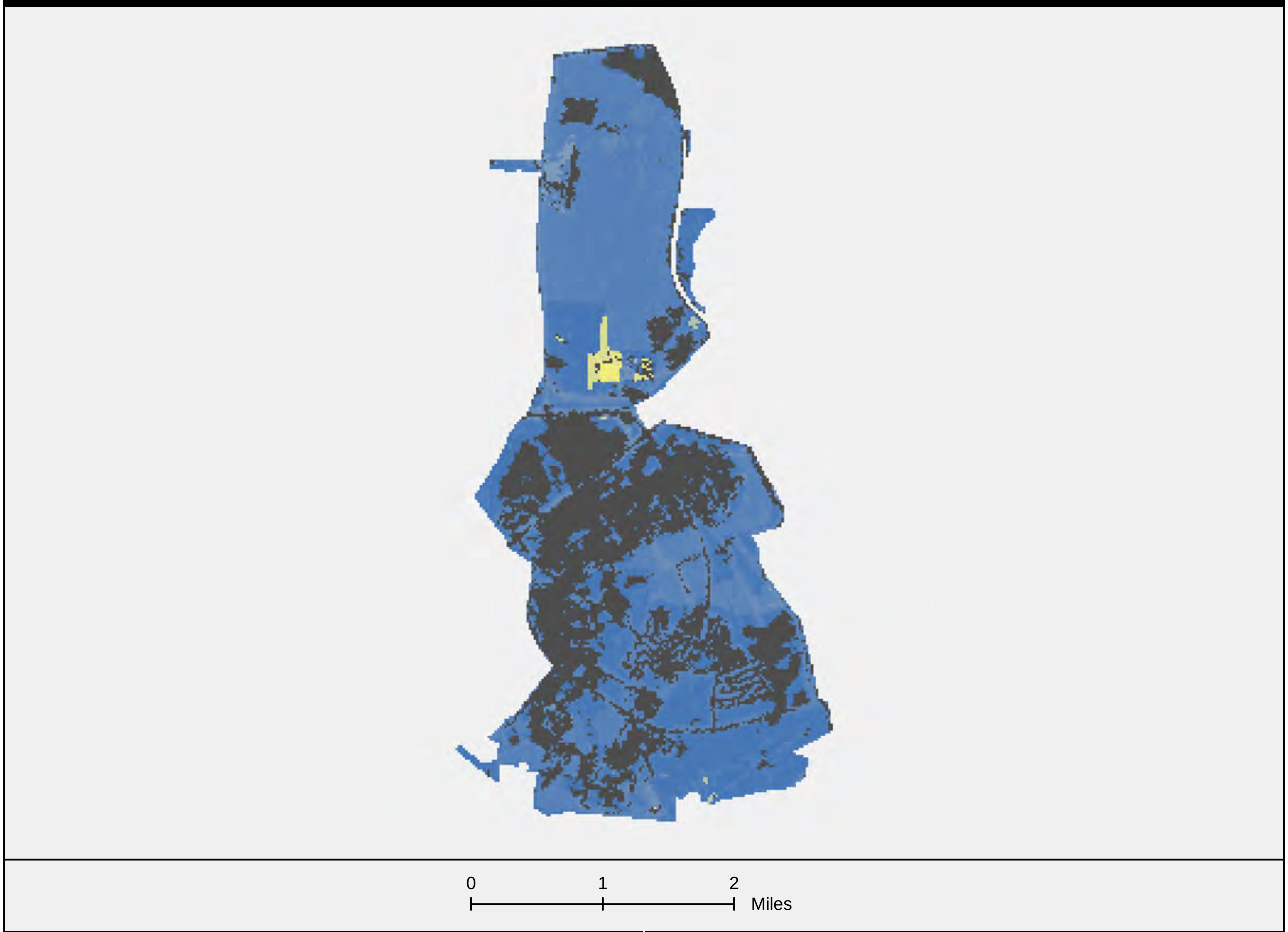
0
1
250
500
750
1000

Fort Lee

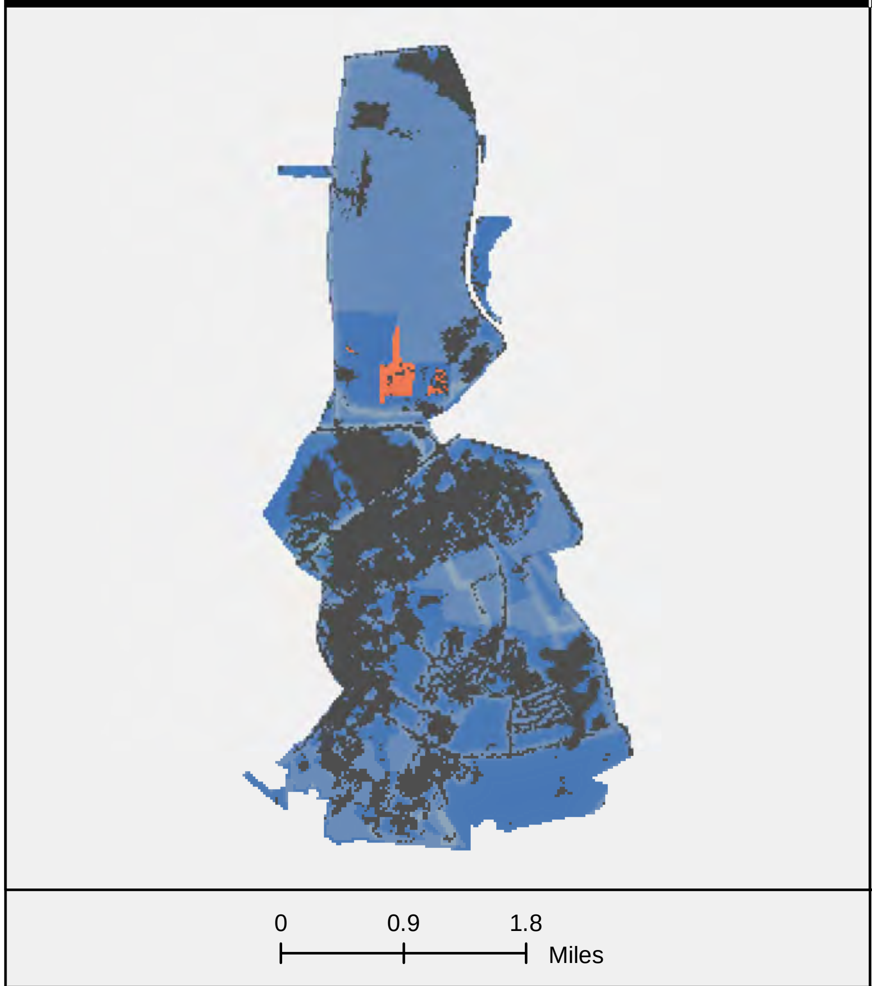
Low

Type 2 Wildfire Risk Assessment

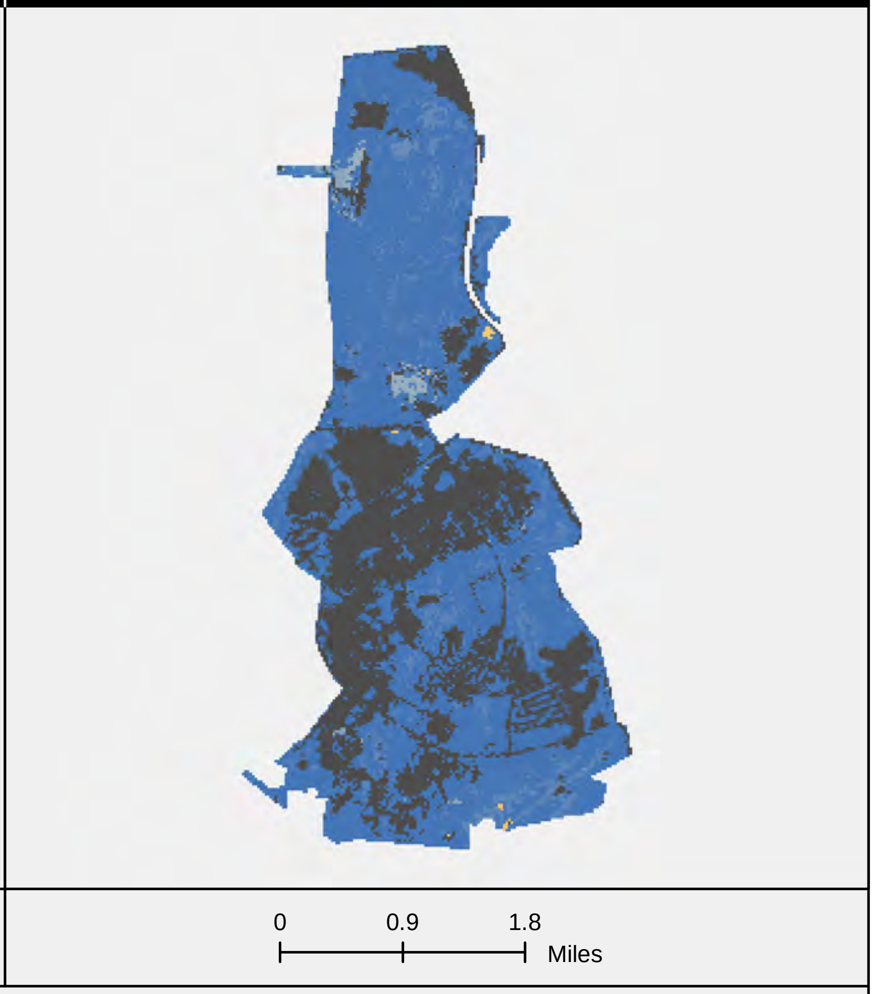
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

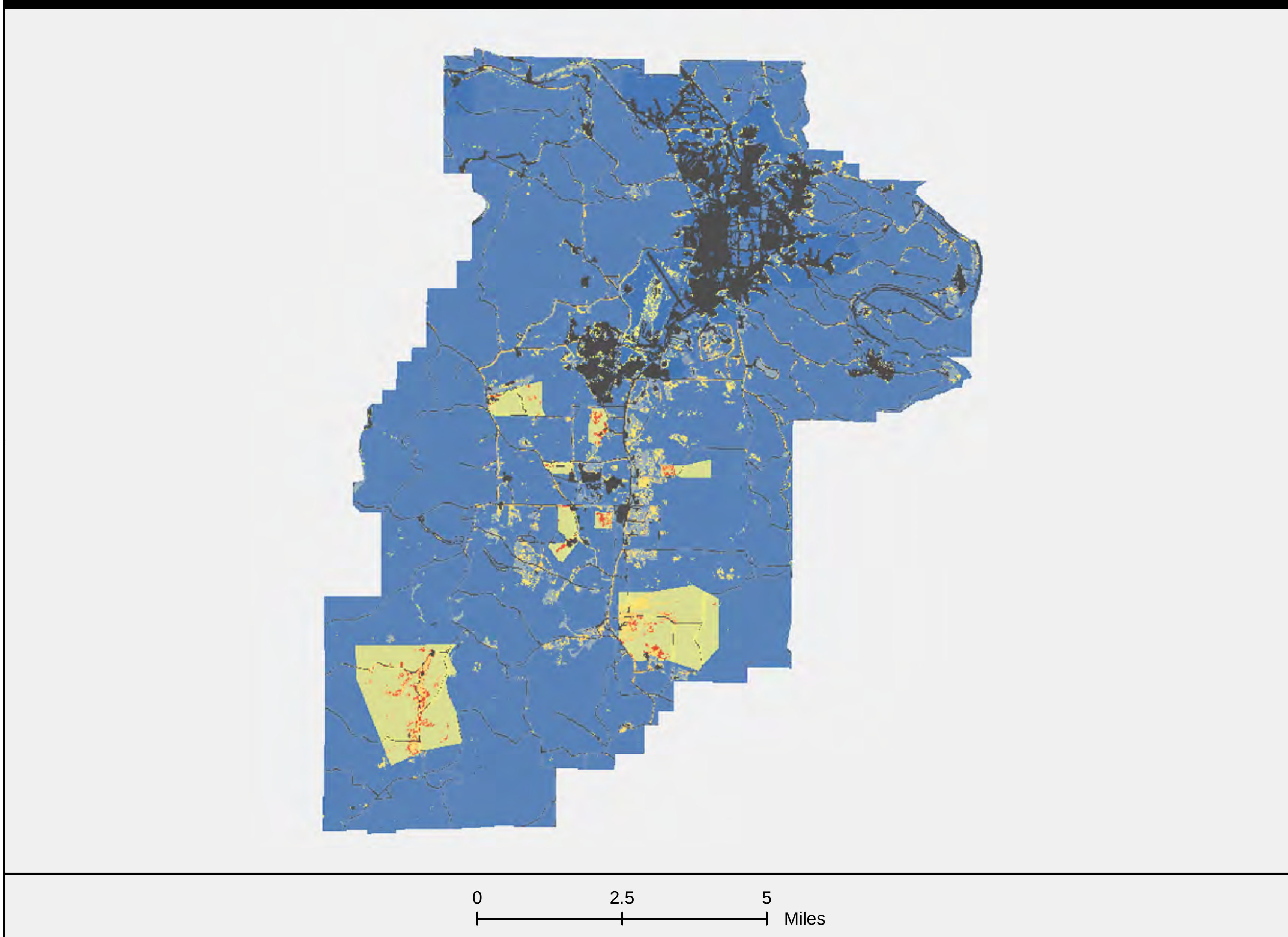
0	250
1	500
750	1000

Fort Leonard Wood

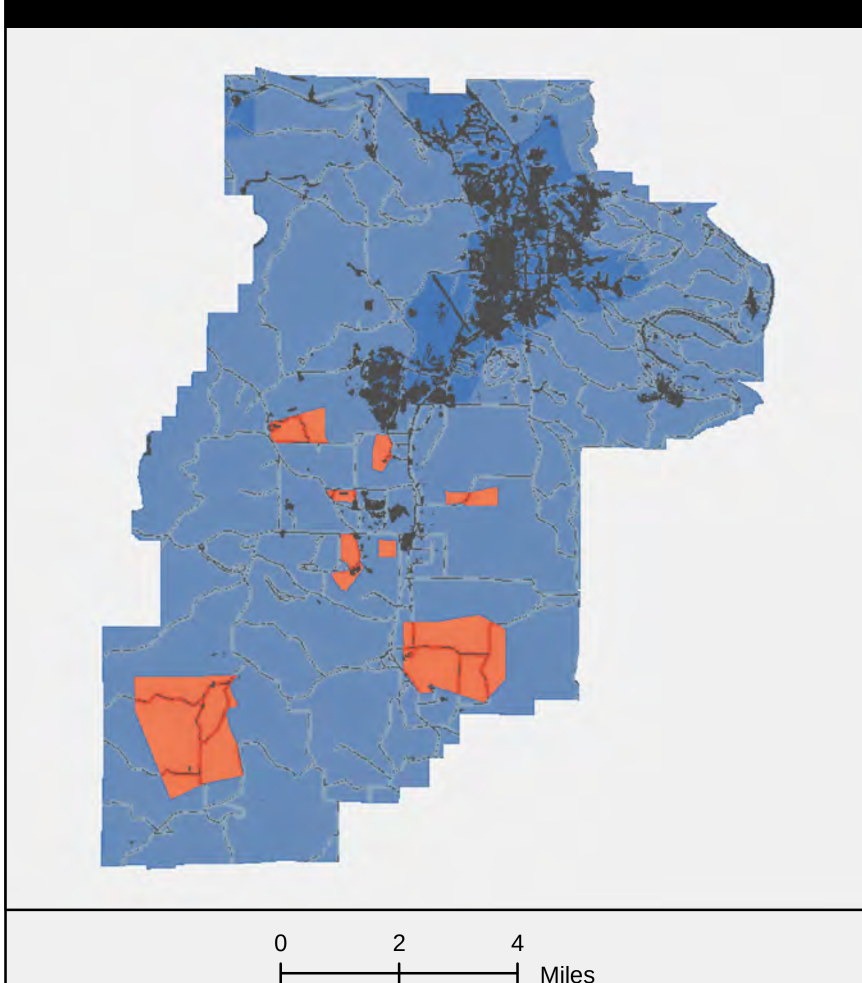
Moderate

Type 2 Wildfire Risk Assessment

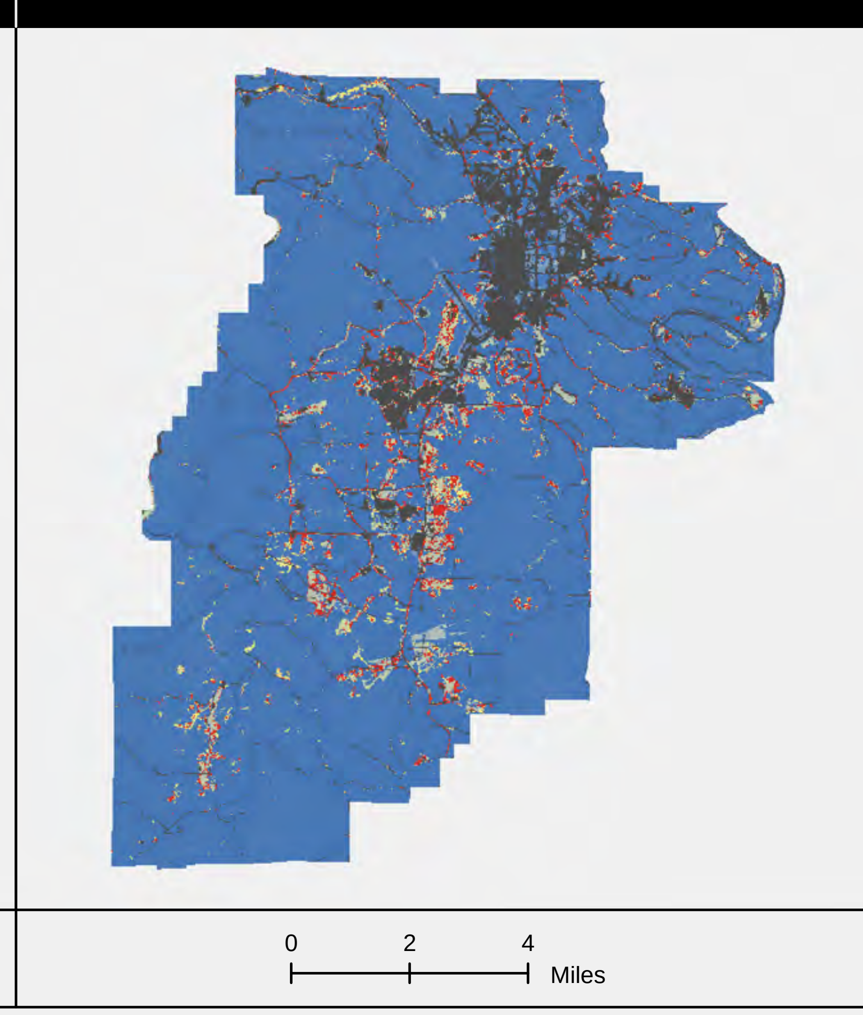
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

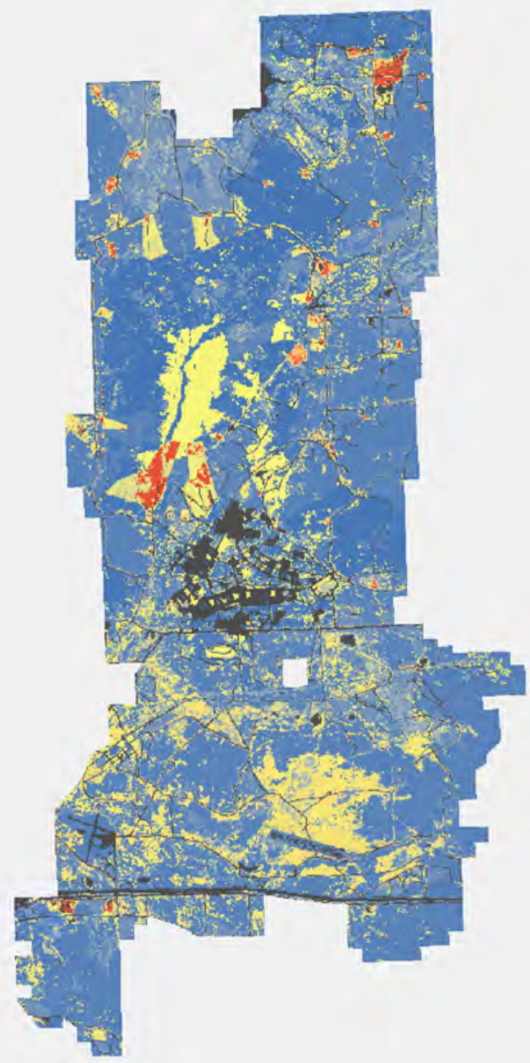
0 | 250 | 750
1 | 500 | 1000

Fort McCoy

Moderate

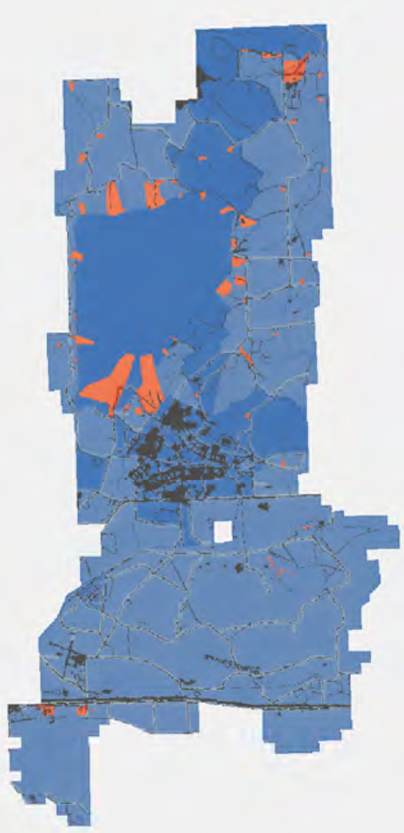
Type 2 Wildfire Risk Assessment

Hazard



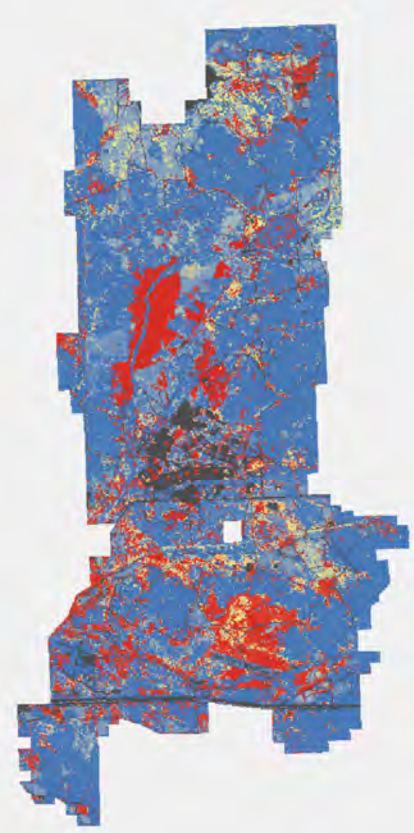
0 3.5 7 Miles

Ignition Likelihood



0 2.5 5 Miles

Fire Behavior Magnitude



0 2.5 5 Miles

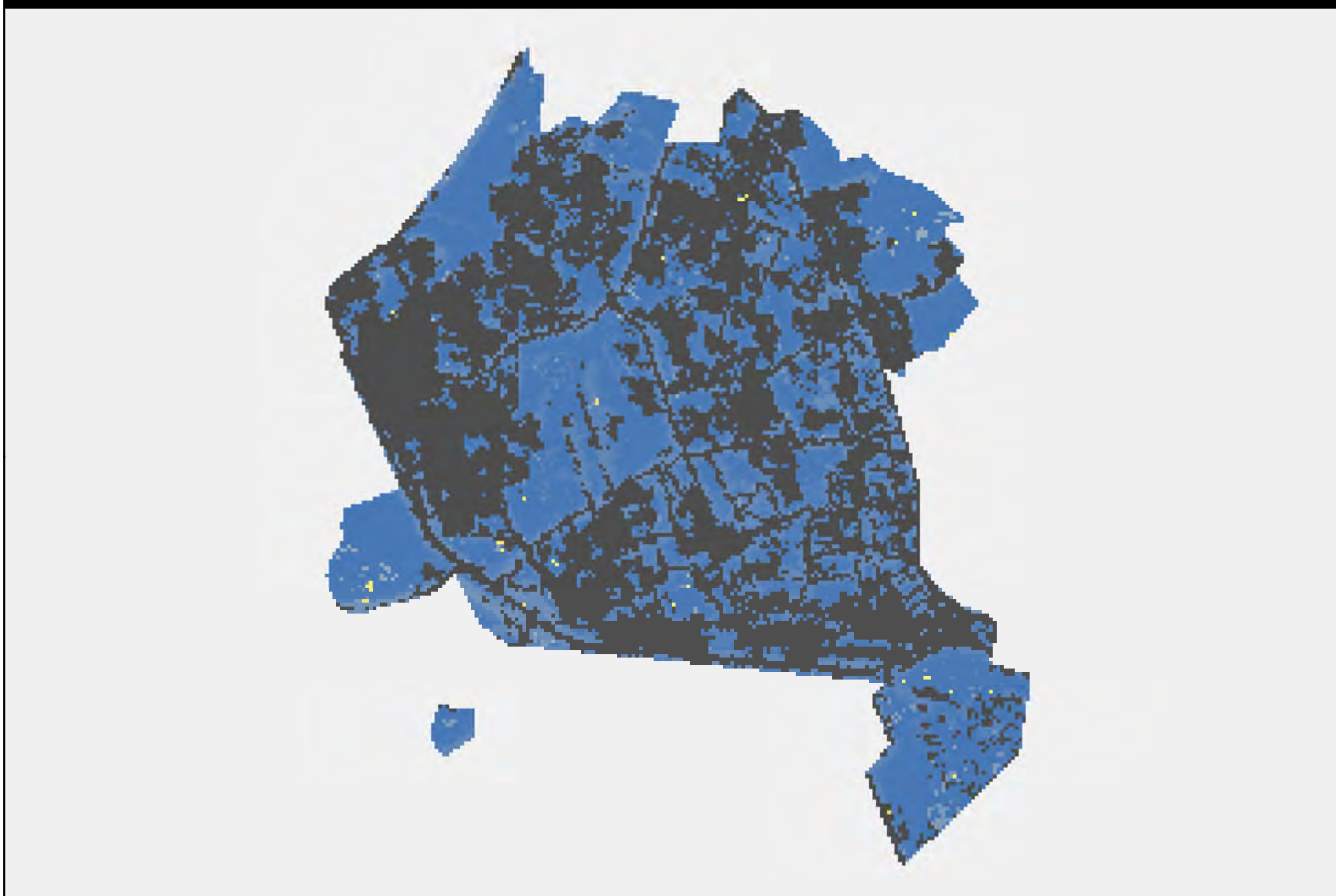
Scaled Cell Values

0, 1, 250, 500, 750, 1000

Fort Meade — Low

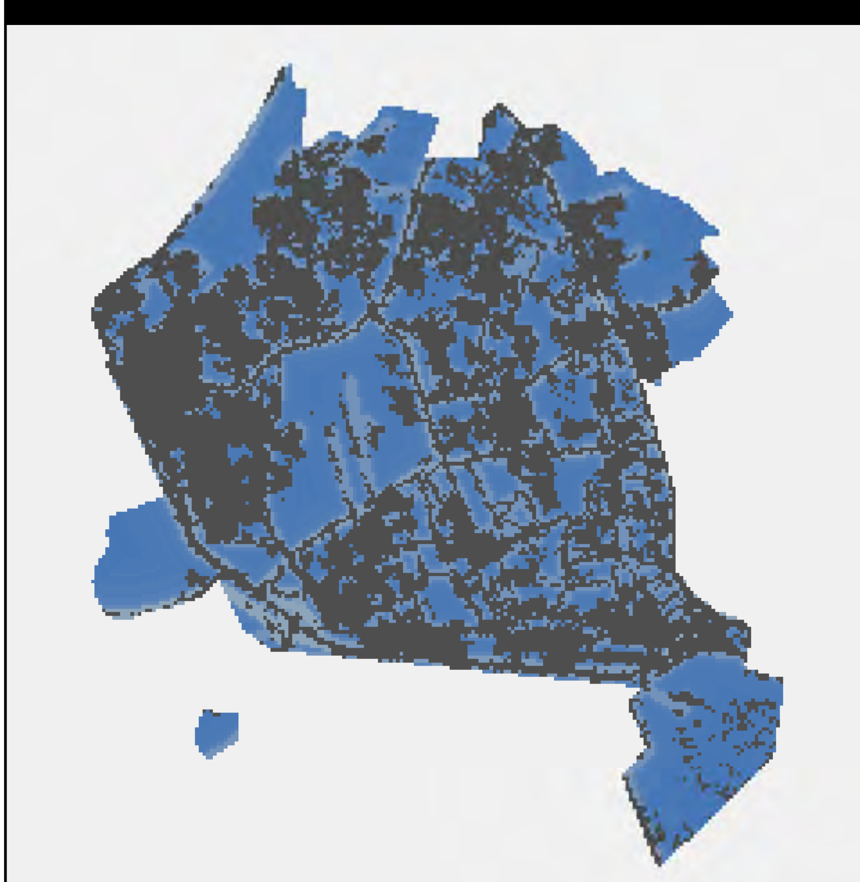
Type 2 Wildfire Risk Assessment

Hazard



0 0.8 1.6 Miles

Ignition Likelihood



0 0.6 1.2 Miles

Fire Behavior Magnitude

0 0.6 1.2 Miles

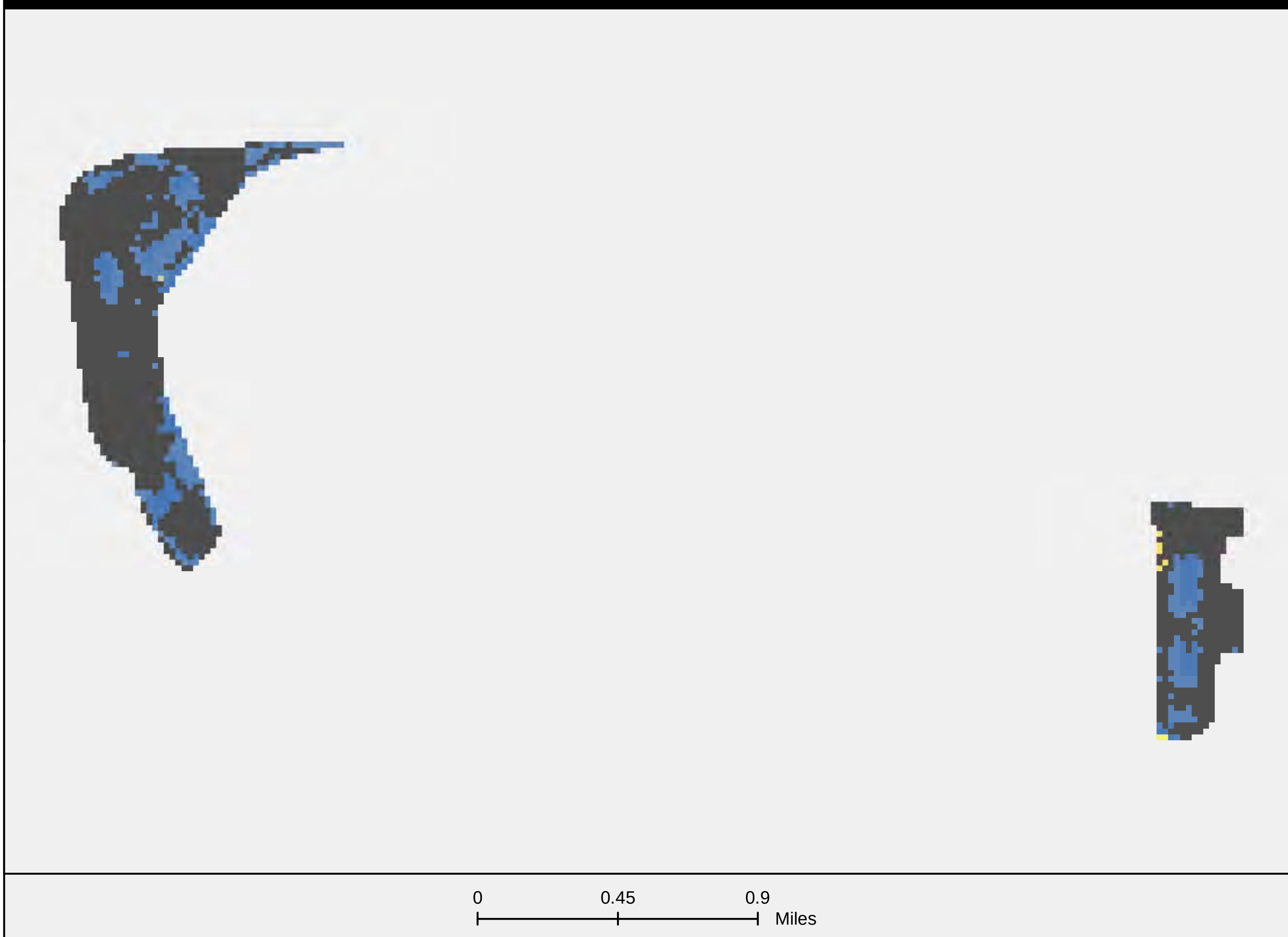
Scaled Cell Values

0	250	750
1	500	1000

Fort Myer McNair — Low

Type 2 Wildfire Risk Assessment

Hazard



Ignition Likelihood

Fire Behavior Magnitude

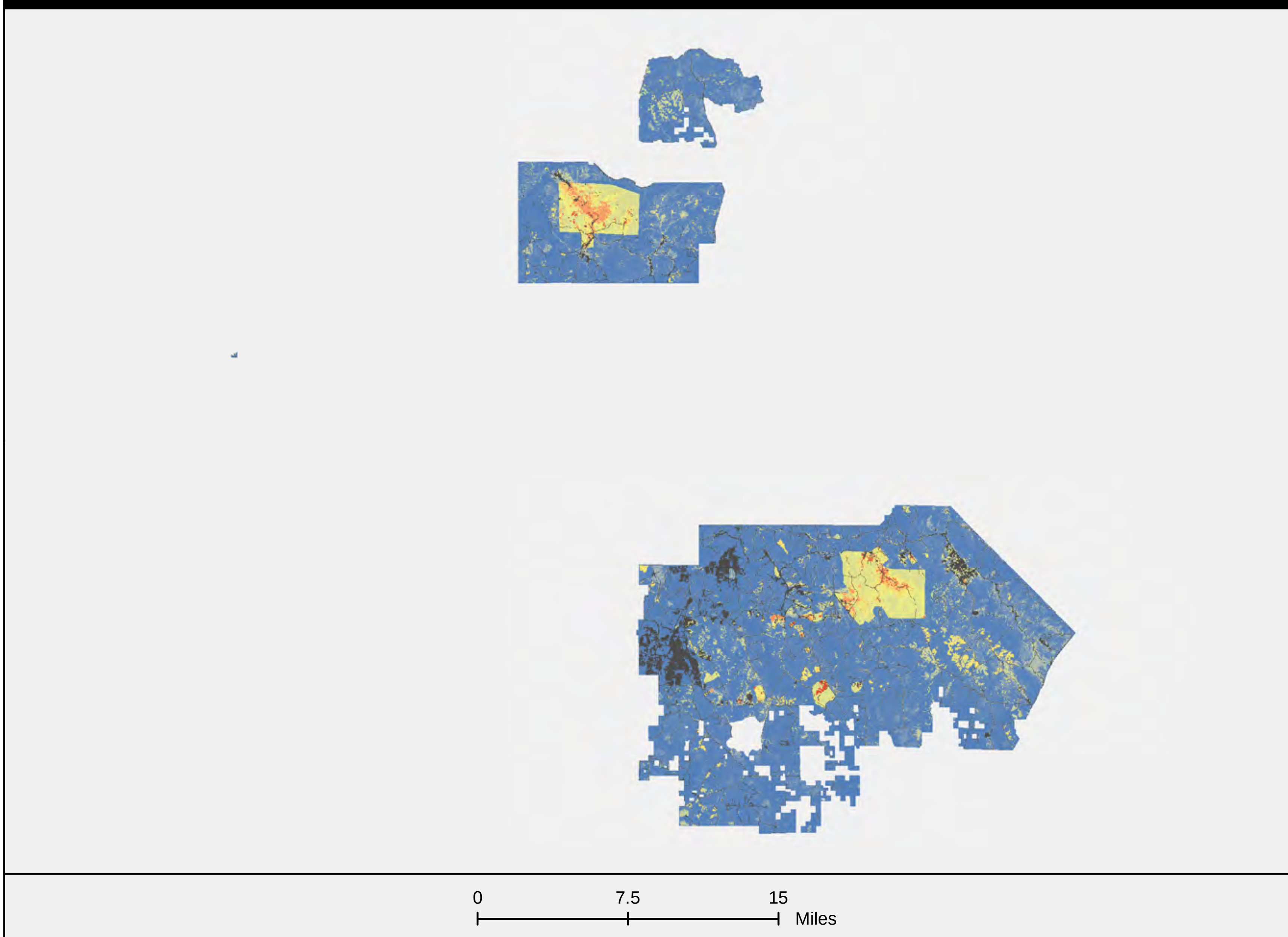
Scaled Cell Values

0 · 1 · 250 · 500 · 750 · 1000

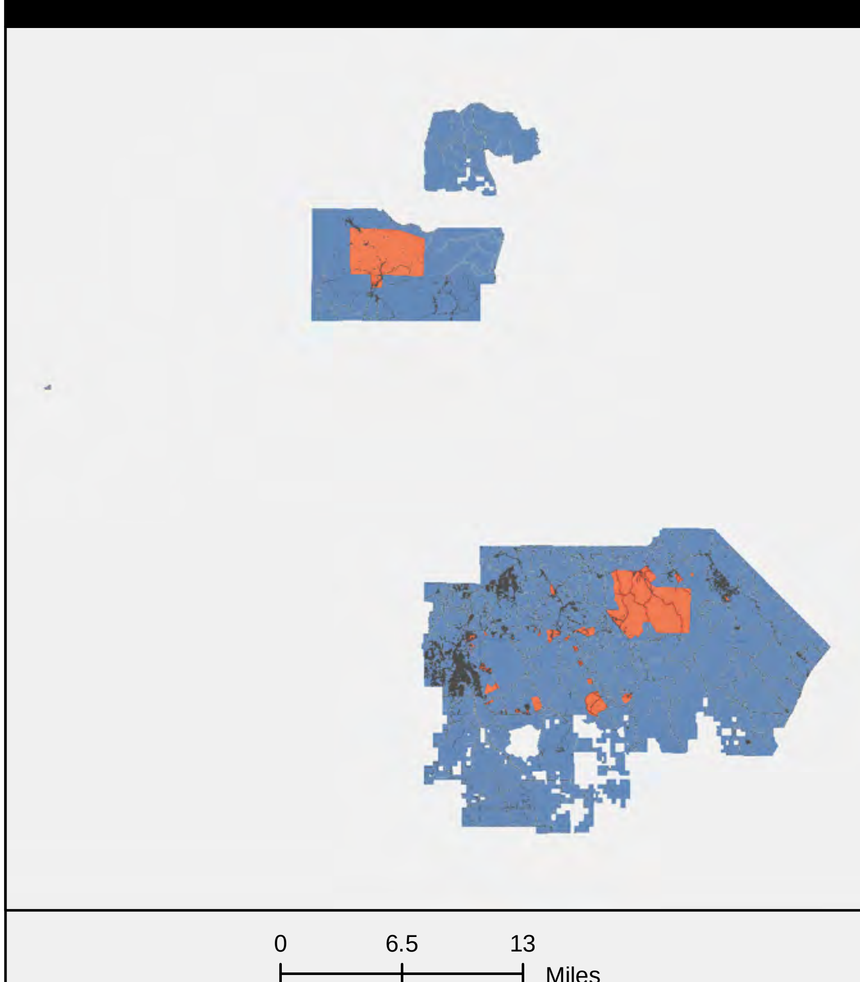
Fort Polk — High

Type 2 Wildfire Risk Assessment

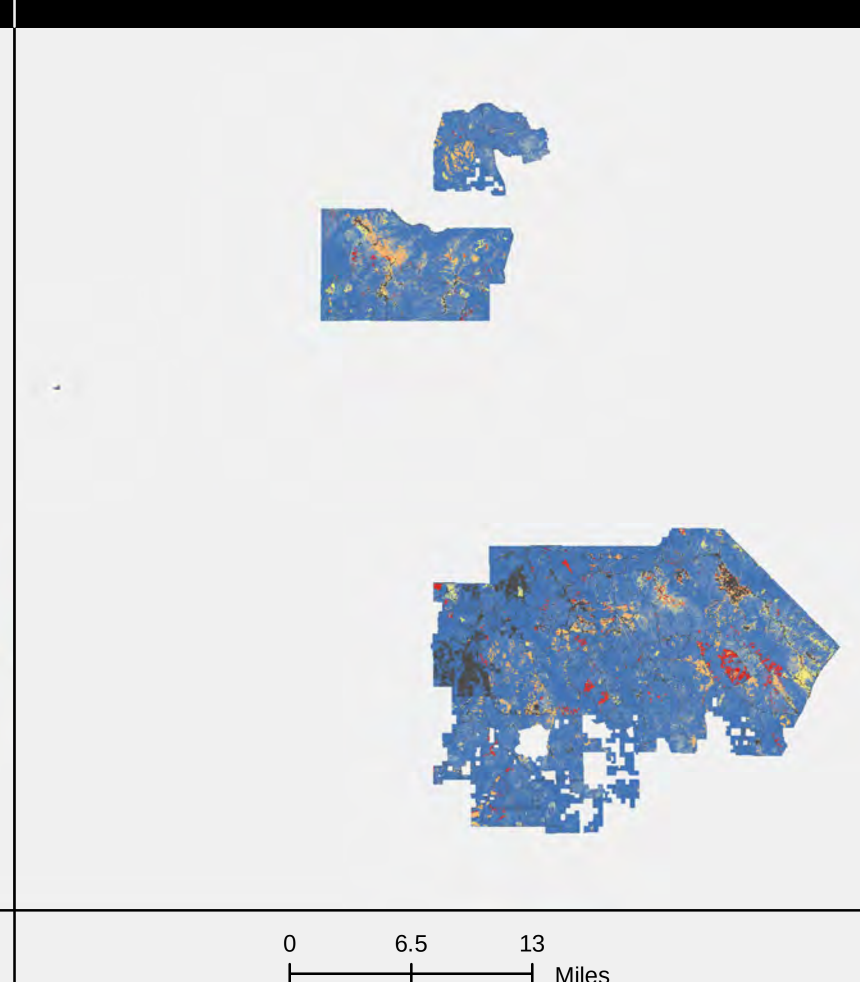
Hazard



Ignition Likelihood



Fire Behavior Magnitude



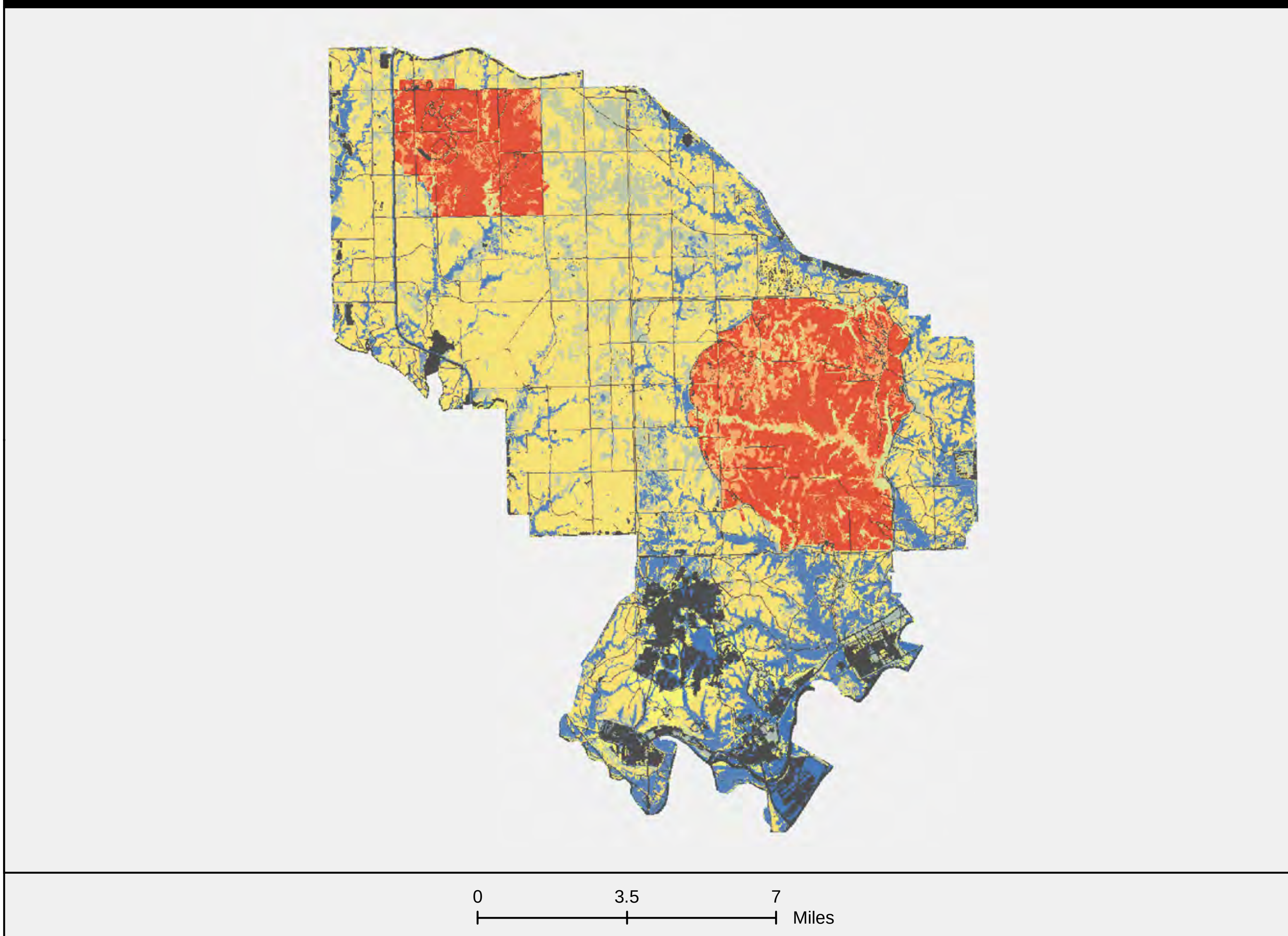
Scaled Cell Values

0, 1, 250, 500, 750, 1000

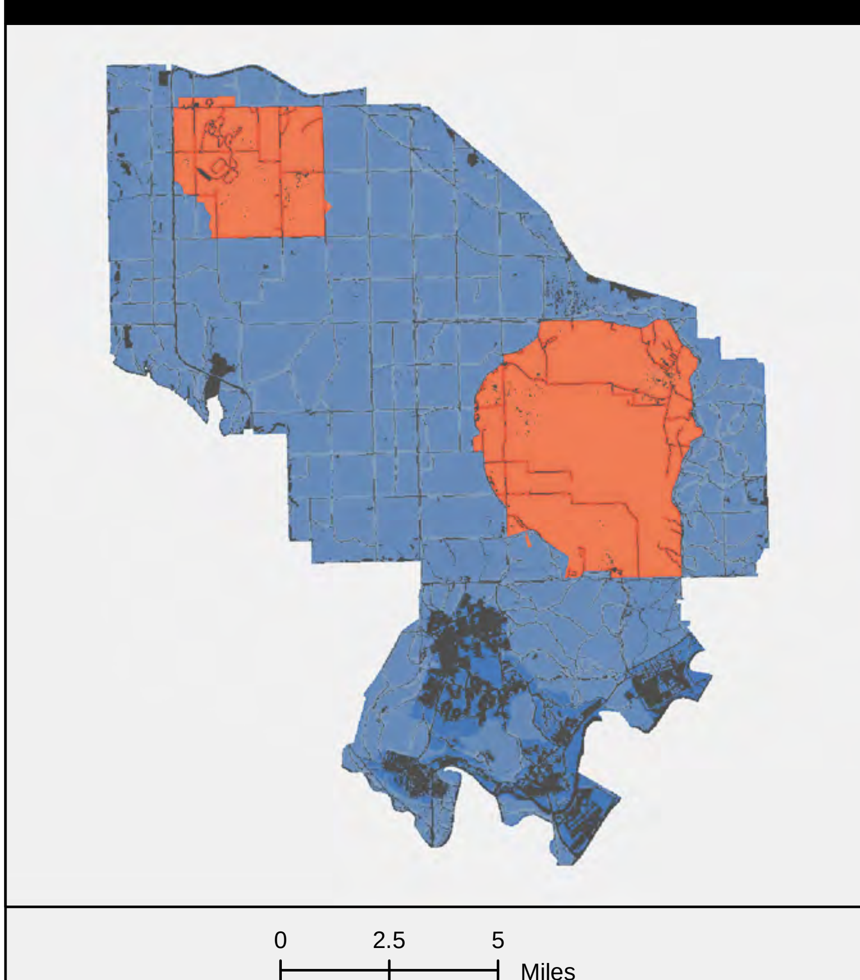
Fort Riley High

Type 2 Wildfire Risk Assessment

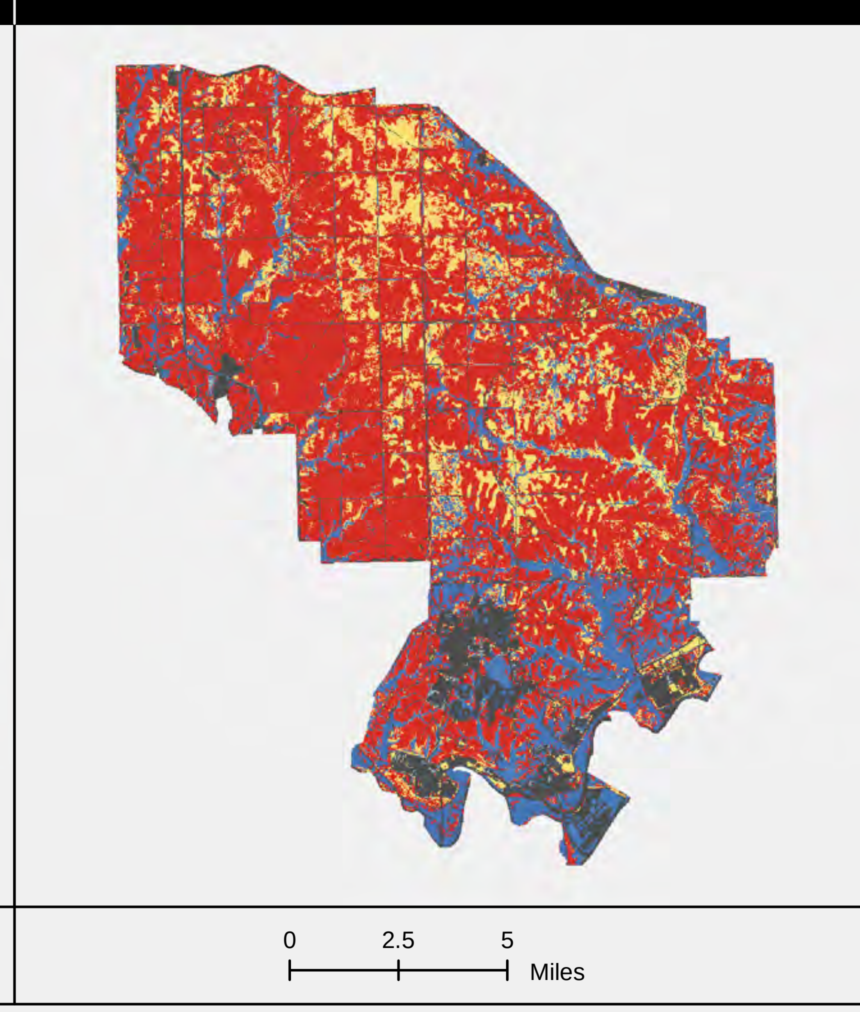
Hazard



Ignition Likelihood



Fire Behavior Magnitude



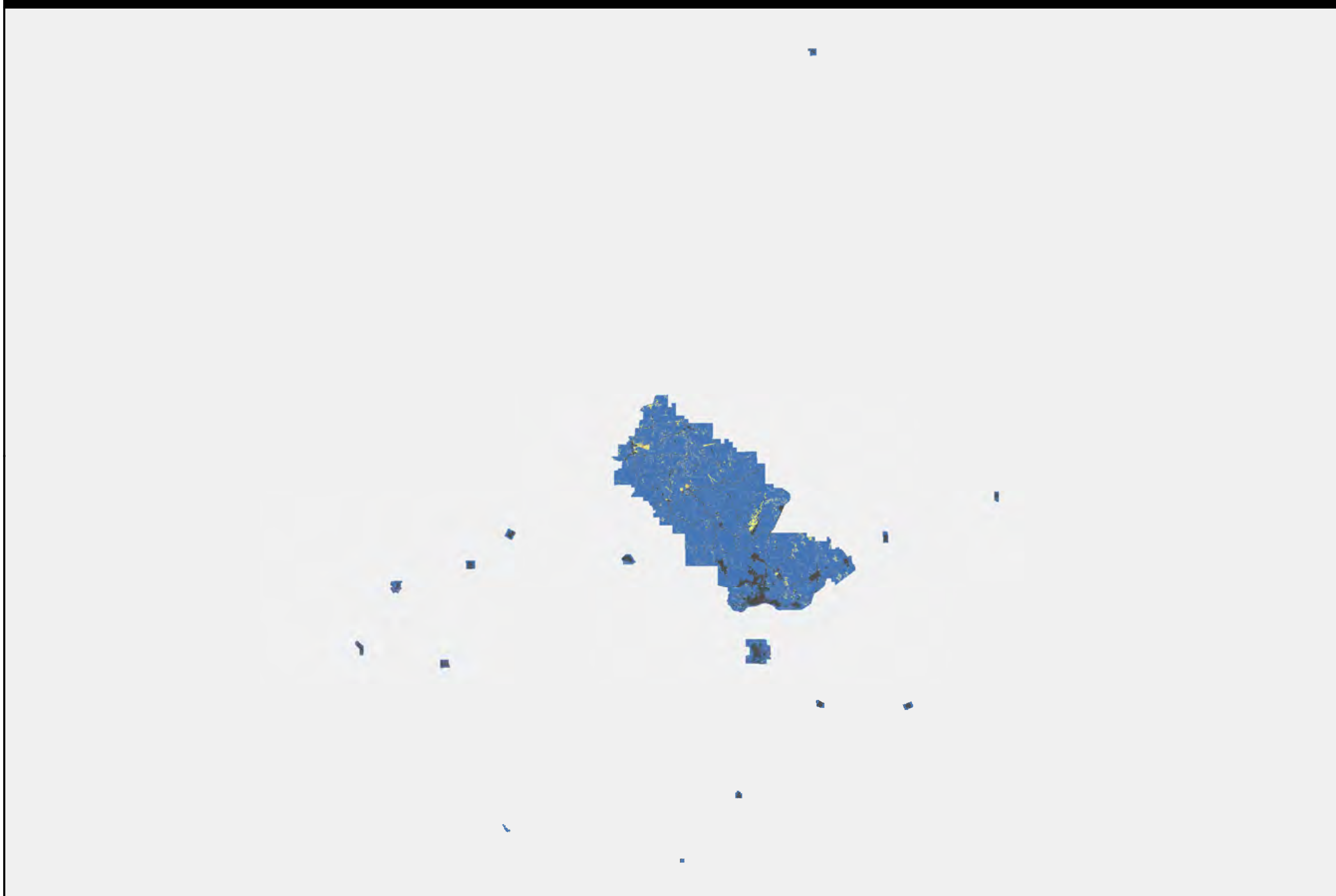
Scaled Cell Values

0	250	750
1	500	1000

Fort Rucker — Low

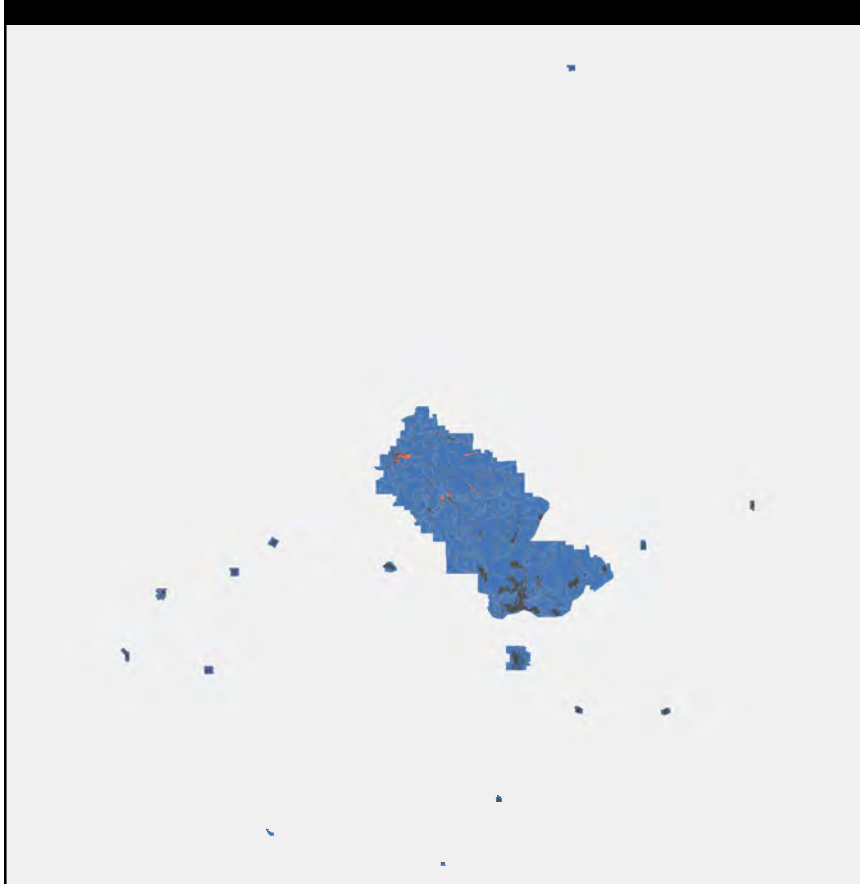
Type 2 Wildfire Risk Assessment

Hazard



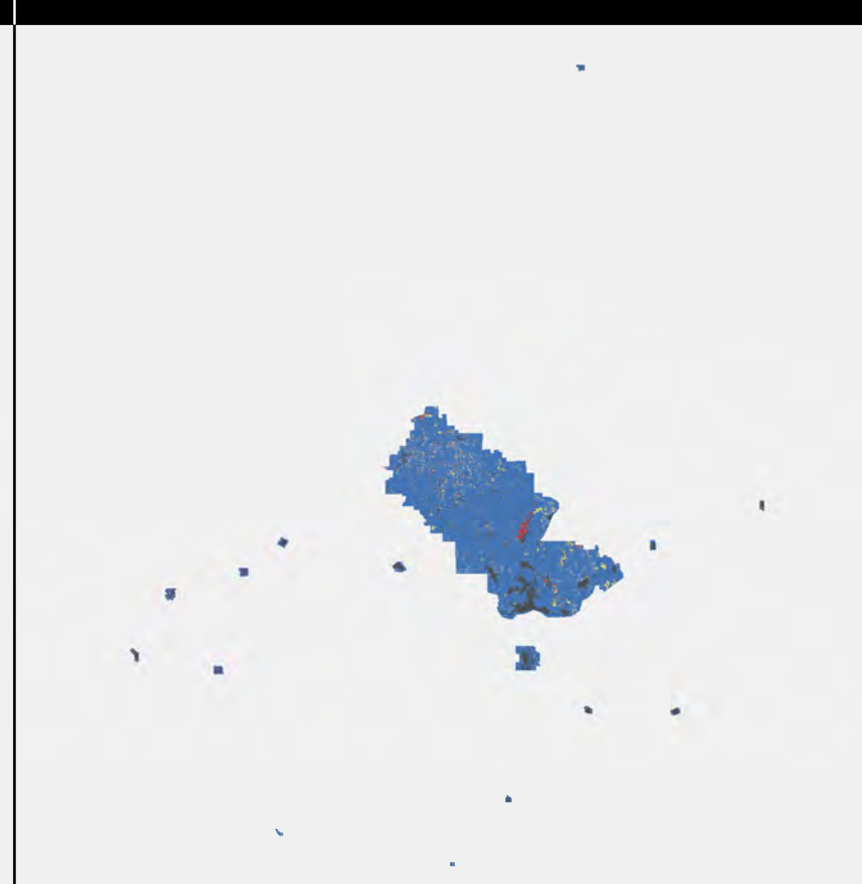
0 9.5 19 Miles

Ignition Likelihood



0 7.5 15 Miles

Fire Behavior Magnitude



0 7.5 15 Miles

Scaled Cell Values

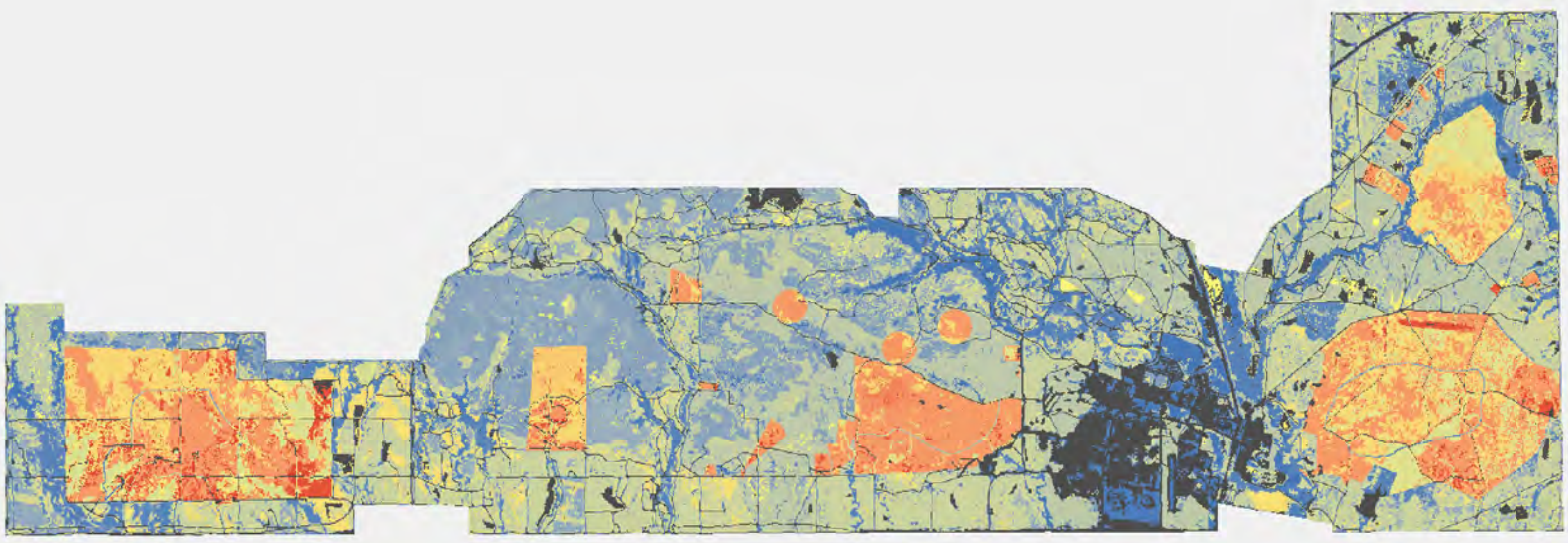
■	0	■	250	■	750
■	1	■	500	■	1000

Fort Sill

High

Type 2 Wildfire Risk Assessment

Hazard

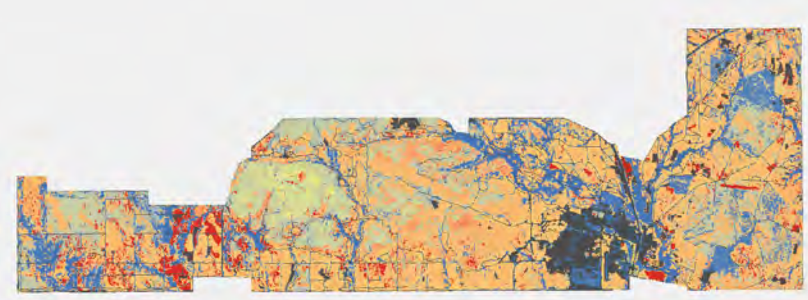


0 3.5 7 Miles

Ignition Likelihood

0 4 8 Miles

Fire Behavior Magnitude



0 4 8 Miles

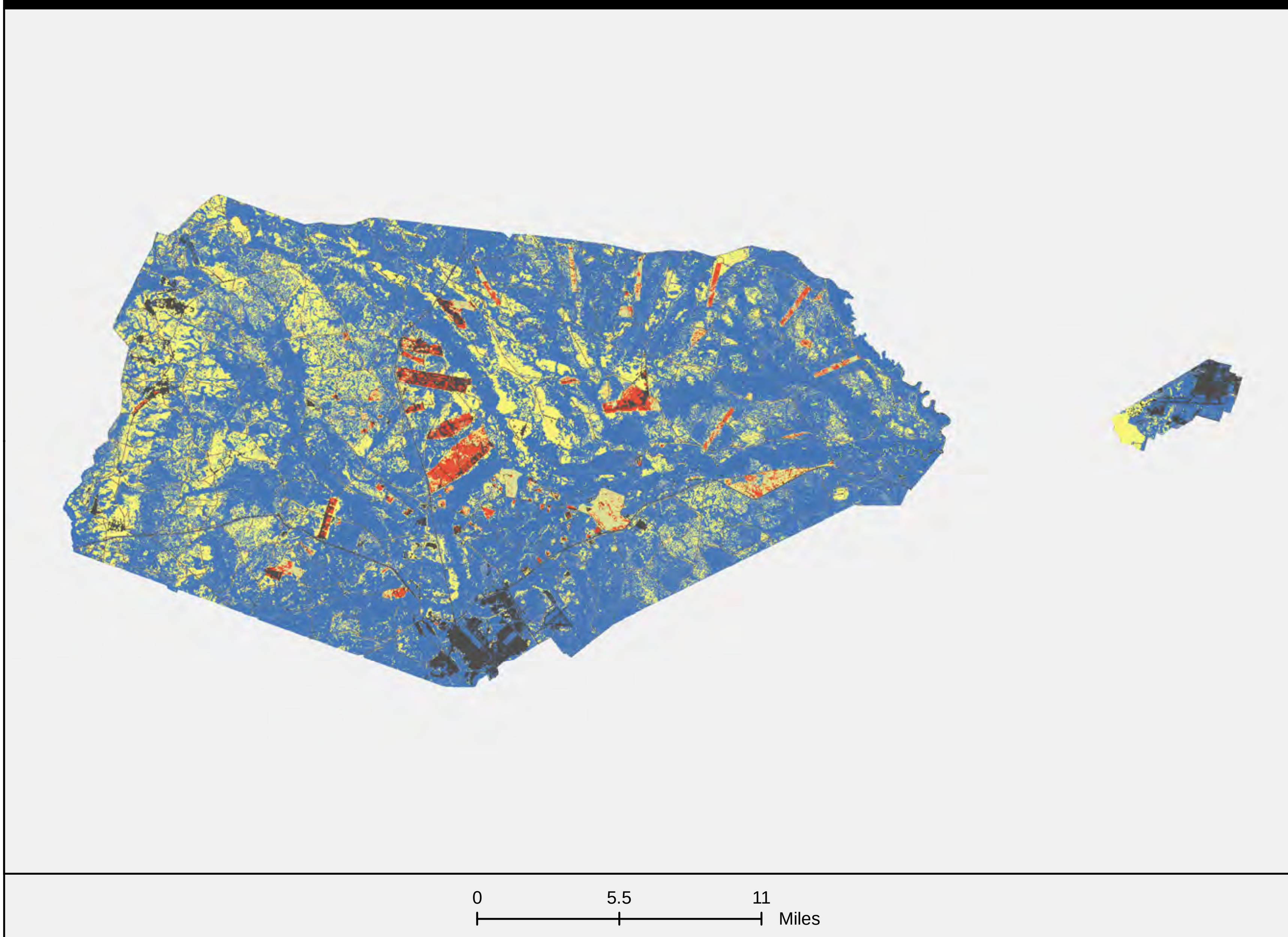
Scaled Cell Values

0	250	750
1	500	1000

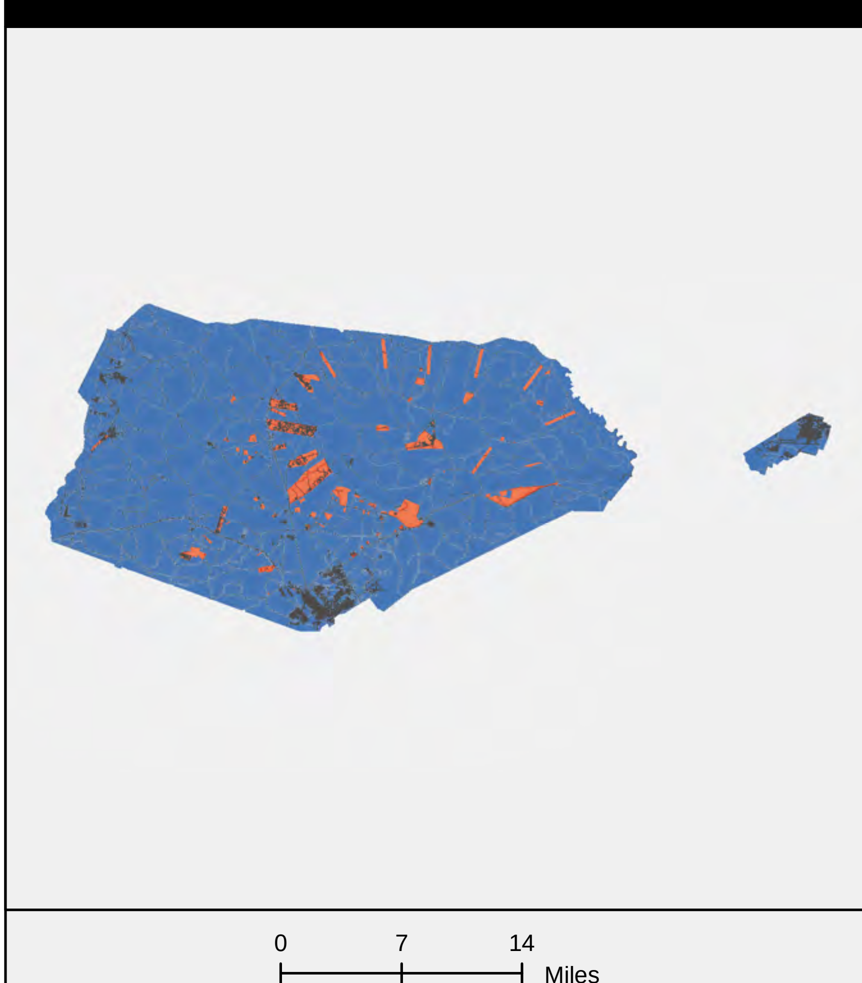
Fort Stewart High

Type 2 Wildfire Risk Assessment

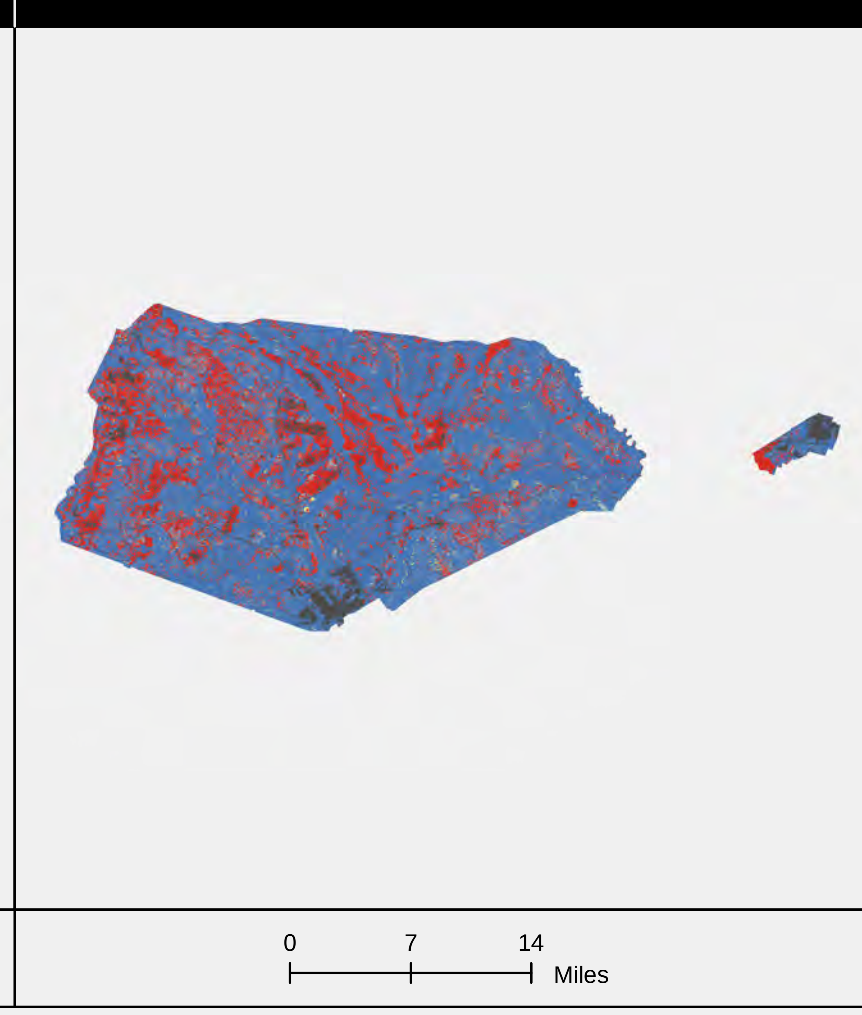
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

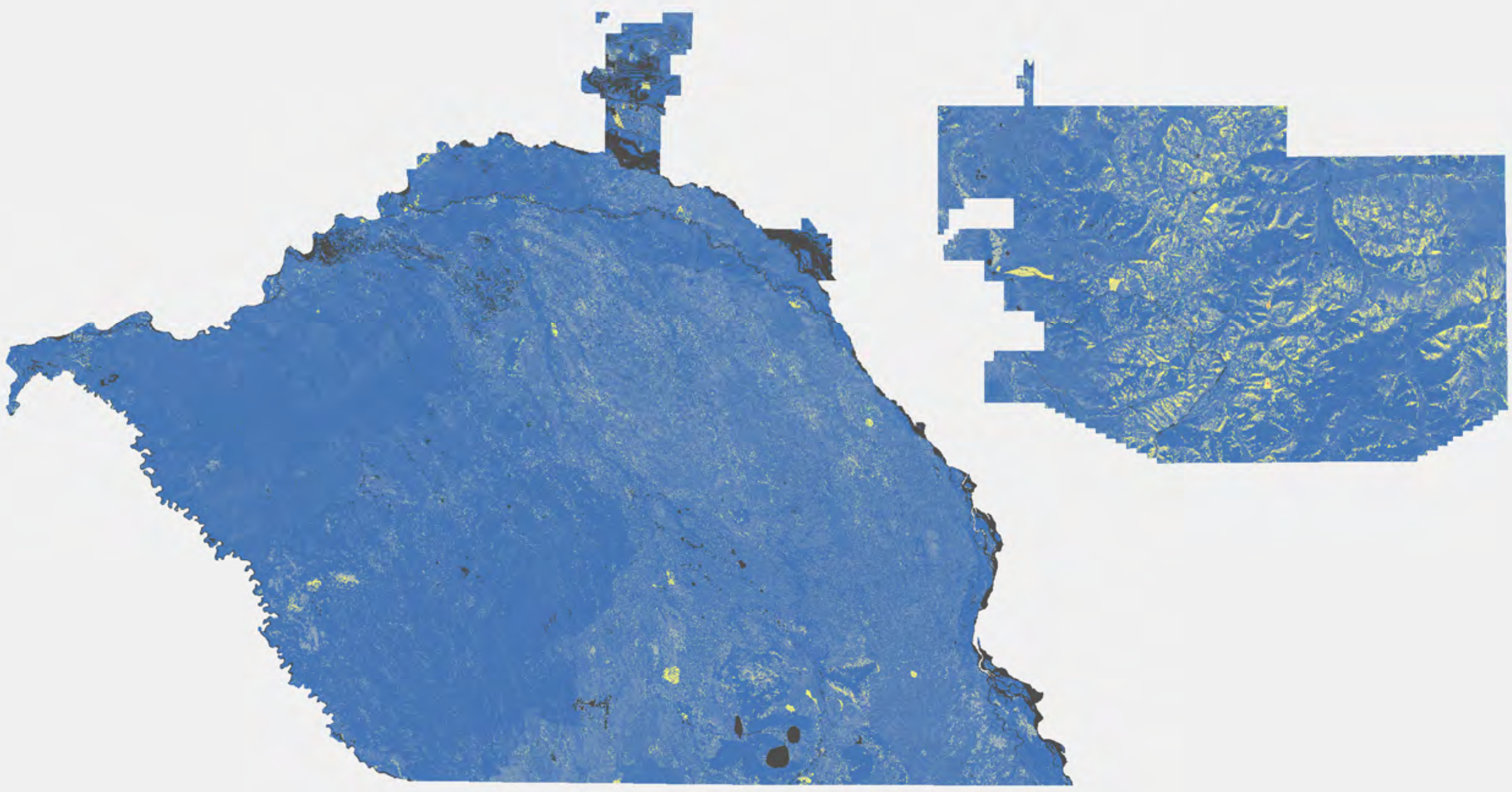
0 250 750
1 500 1000

Fort Wainwright

High

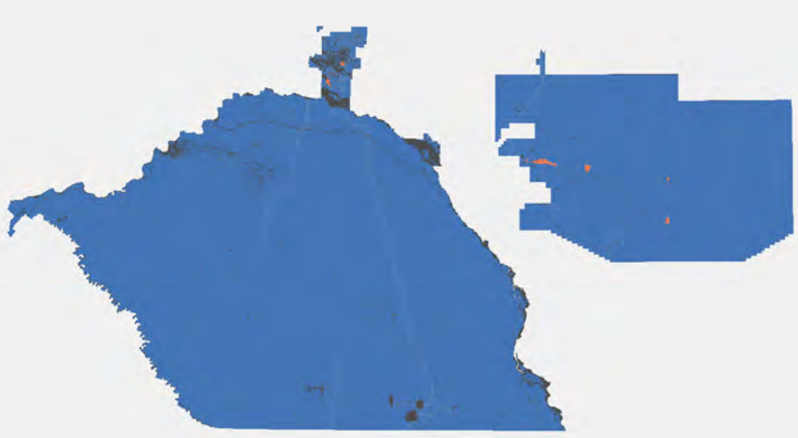
Type 2 Wildfire Risk Assessment

Hazard



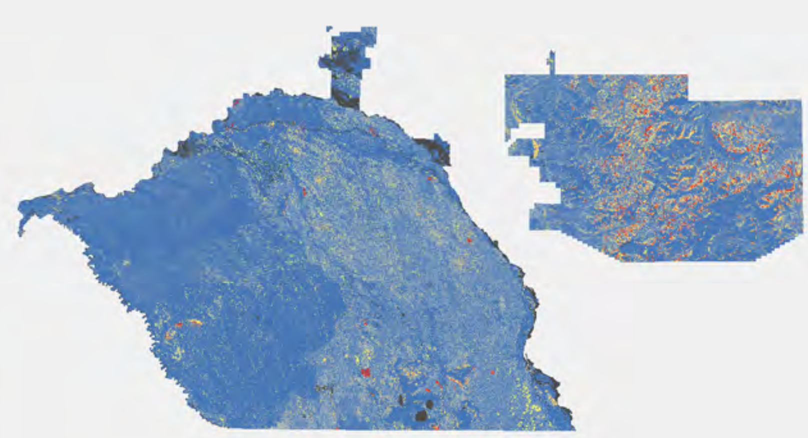
0 9.5 19 Miles

Ignition Likelihood



0 10 20 Miles

Fire Behavior Magnitude



0 10 20 Miles

Scaled Cell Values

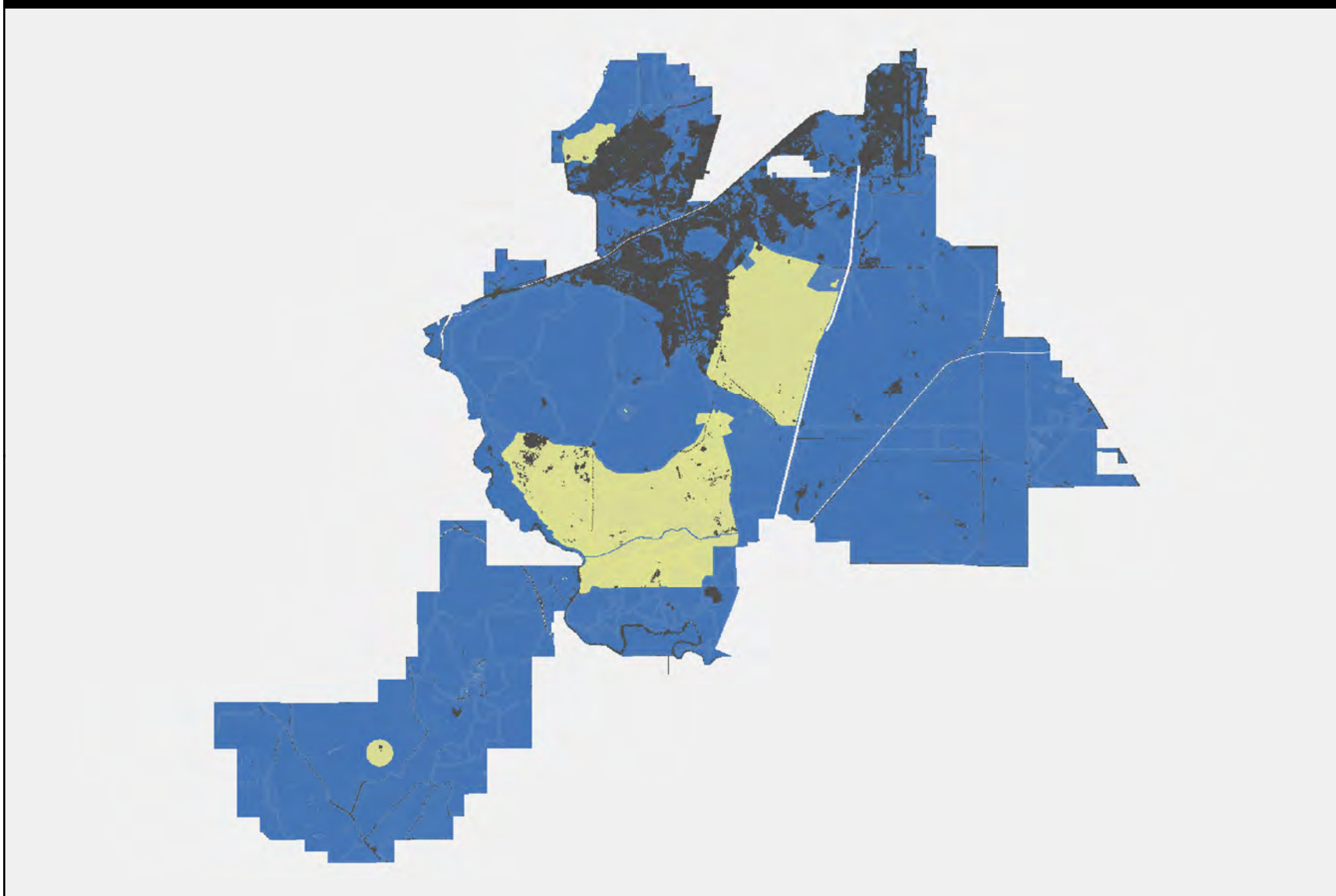
Dark gray	0
Blue	1
Gray-blue	250
Yellow	500
Orange	750
Red	1000

Joint Base Lewis McCord

Moderate

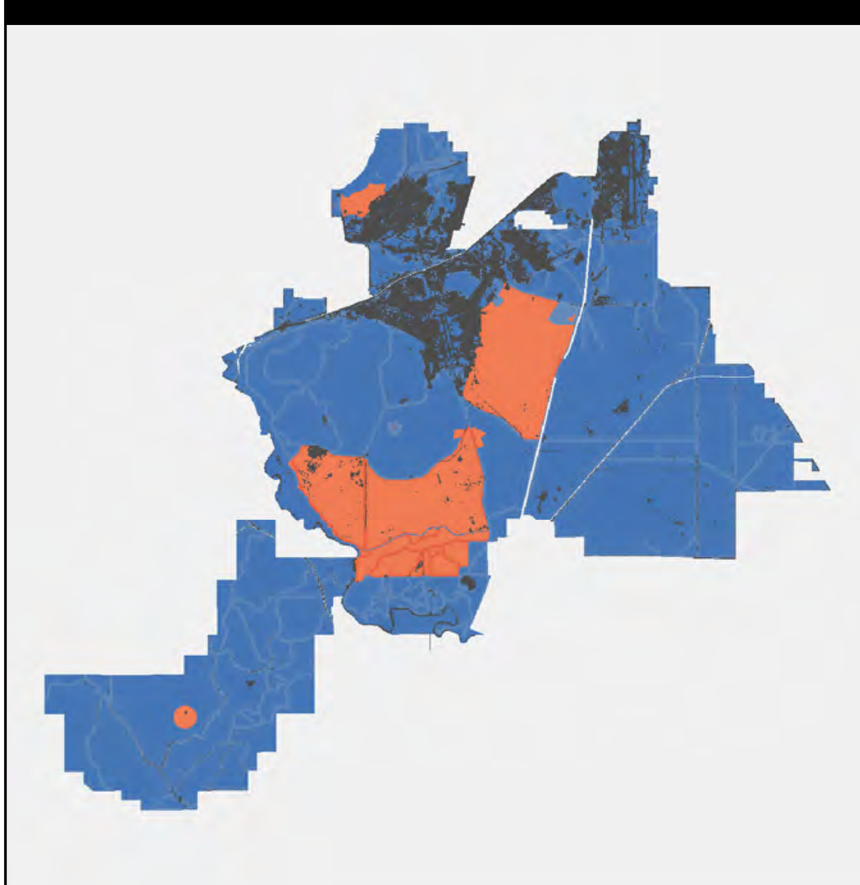
Type 2 Wildfire Risk Assessment

Hazard



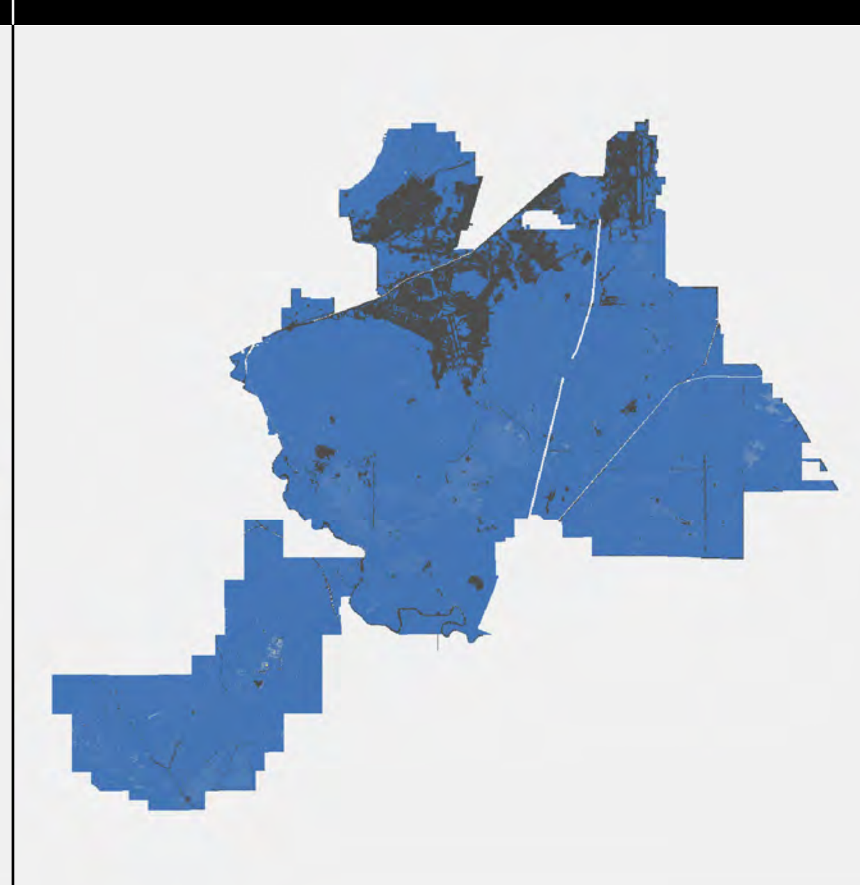
0 3.5 7 Miles

Ignition Likelihood



0 3 6 Miles

Fire Behavior Magnitude



0 3 6 Miles

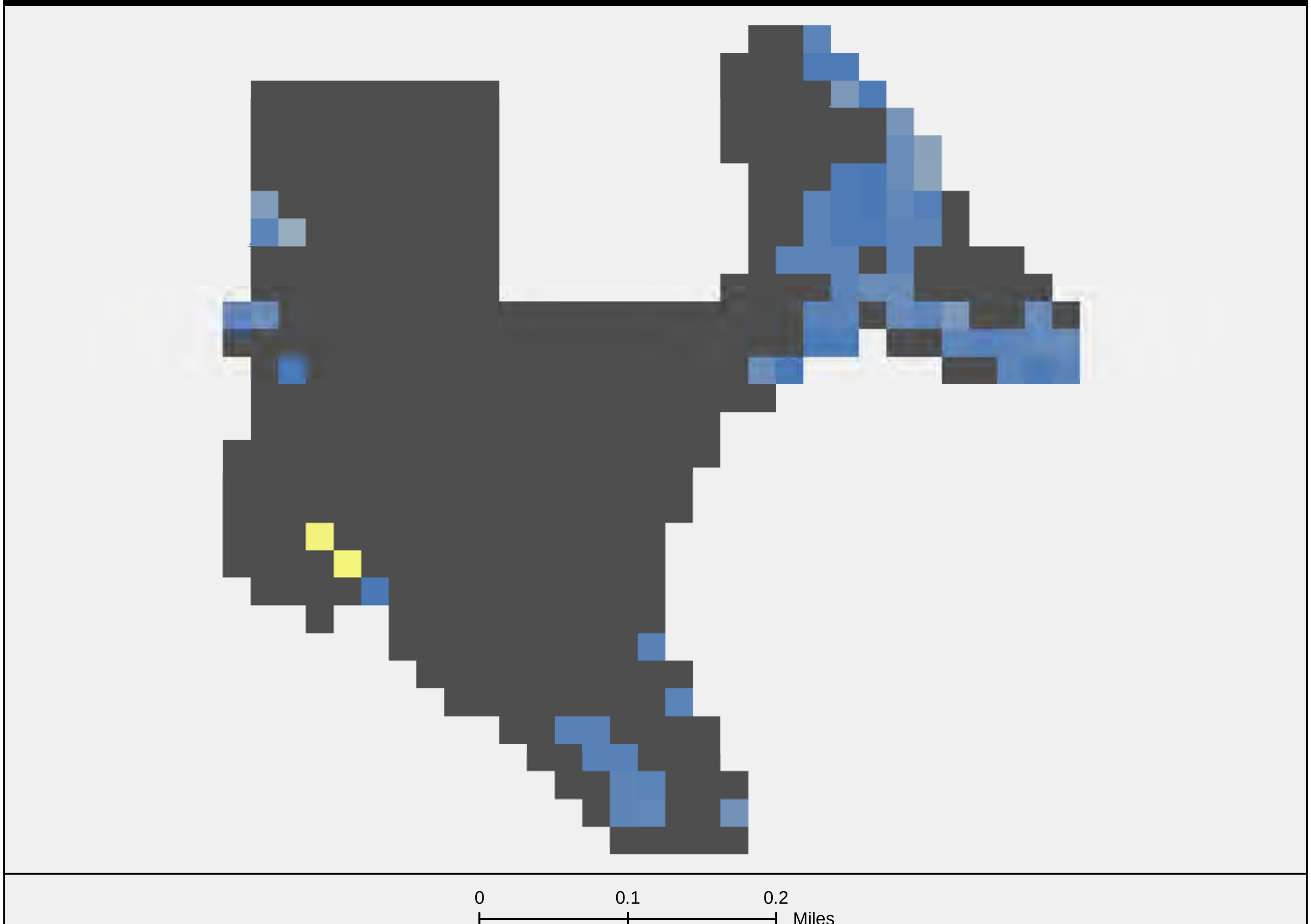
Scaled Cell Values

0
1
250
500
750
1000

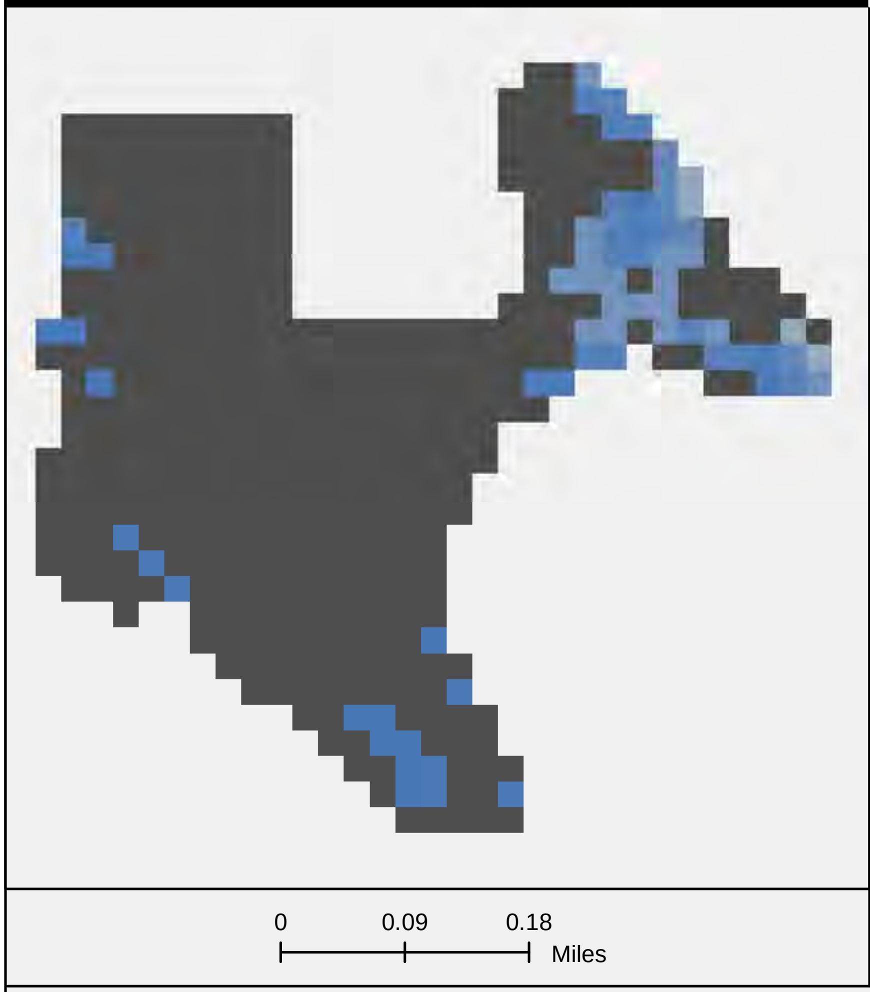
Natick — Low

Type 2 Wildfire Risk Assessment

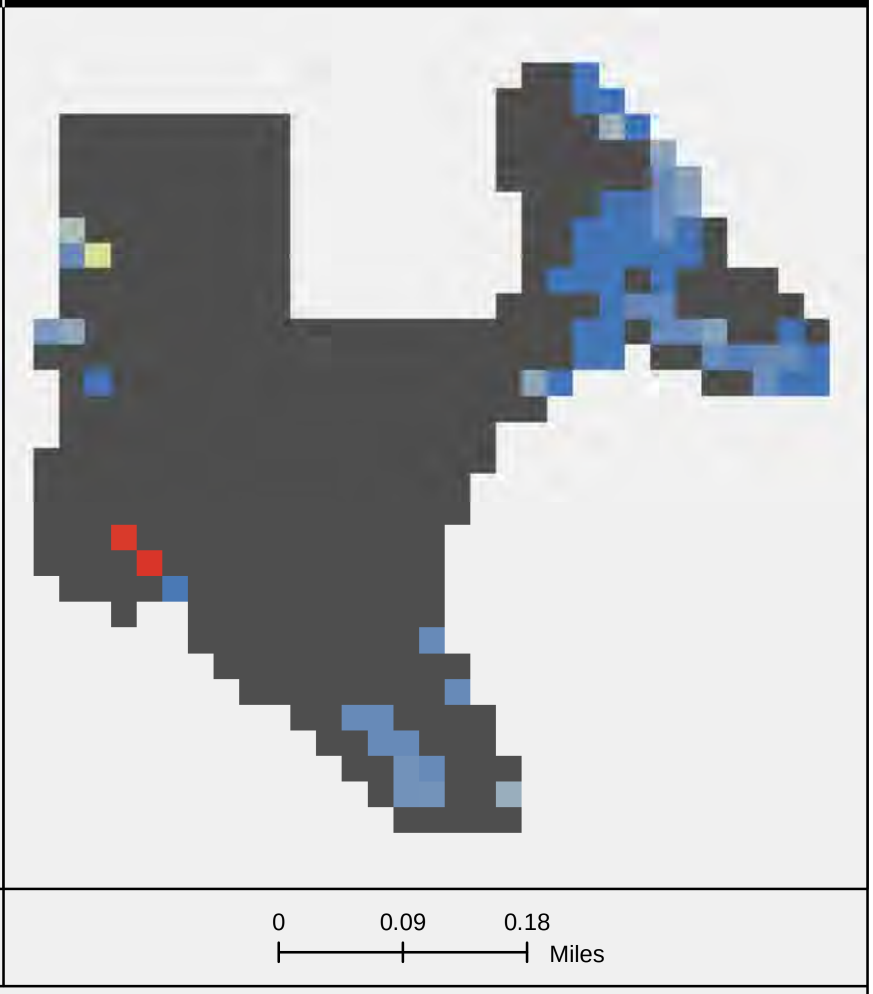
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

0 | 250 | 750
1 | 500 | 1000

Picatinny Arsenal Low

Type 2 Wildfire Risk Assessment

Hazard

0 1 2 Miles

Ignition Likelihood

0 0.85 1.7 Miles

Fire Behavior Magnitude

0 0.85 1.7 Miles

Scaled Cell Values

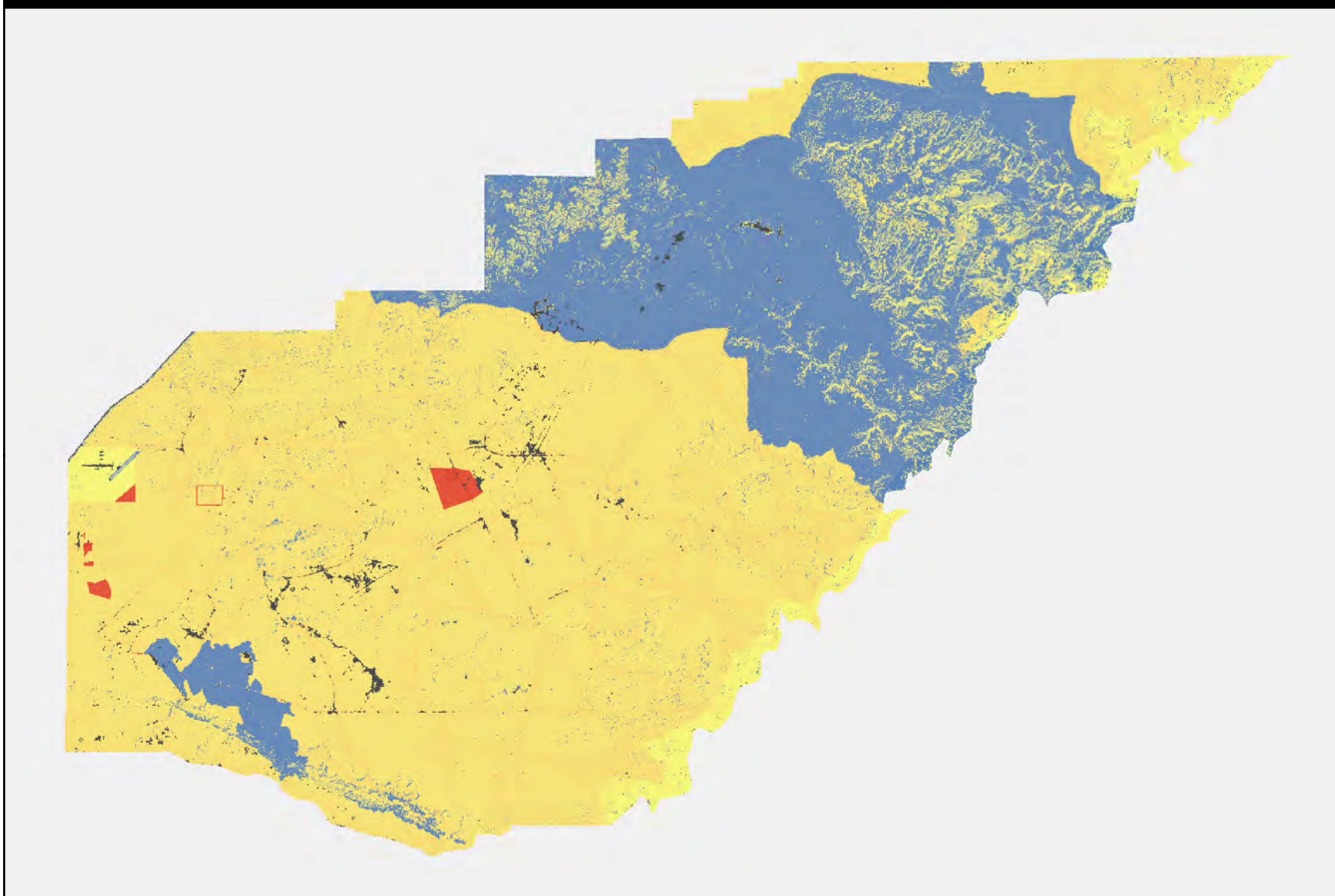
0	250	750
1	500	1000

Pinon Canyon MA

High

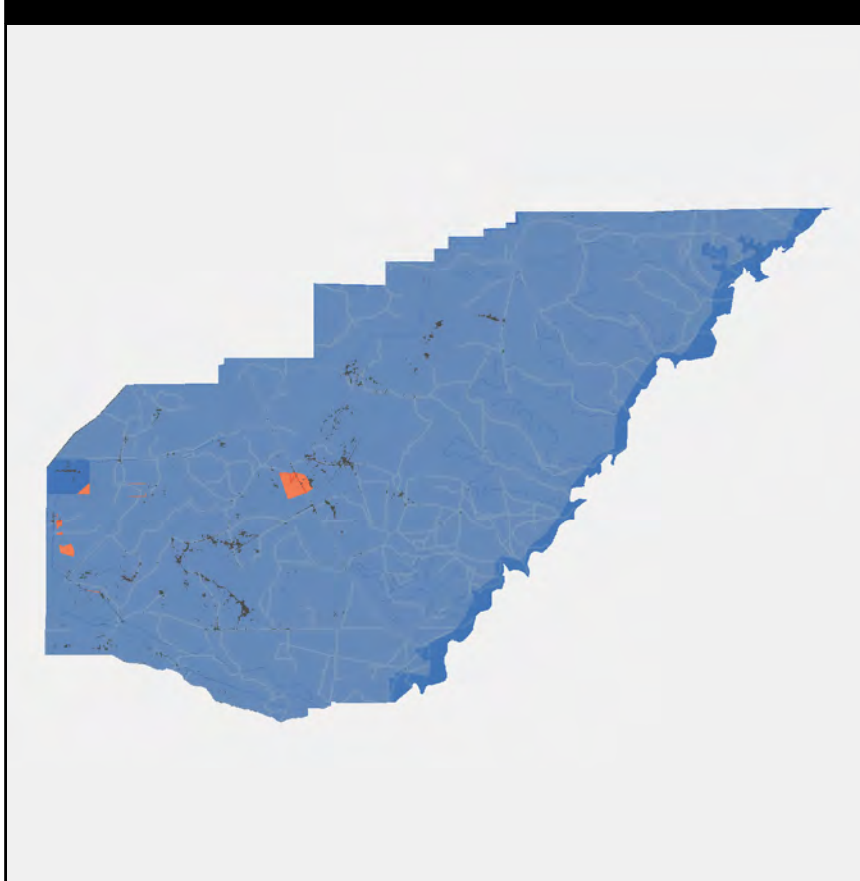
Type 2 Wildfire Risk Assessment

Hazard



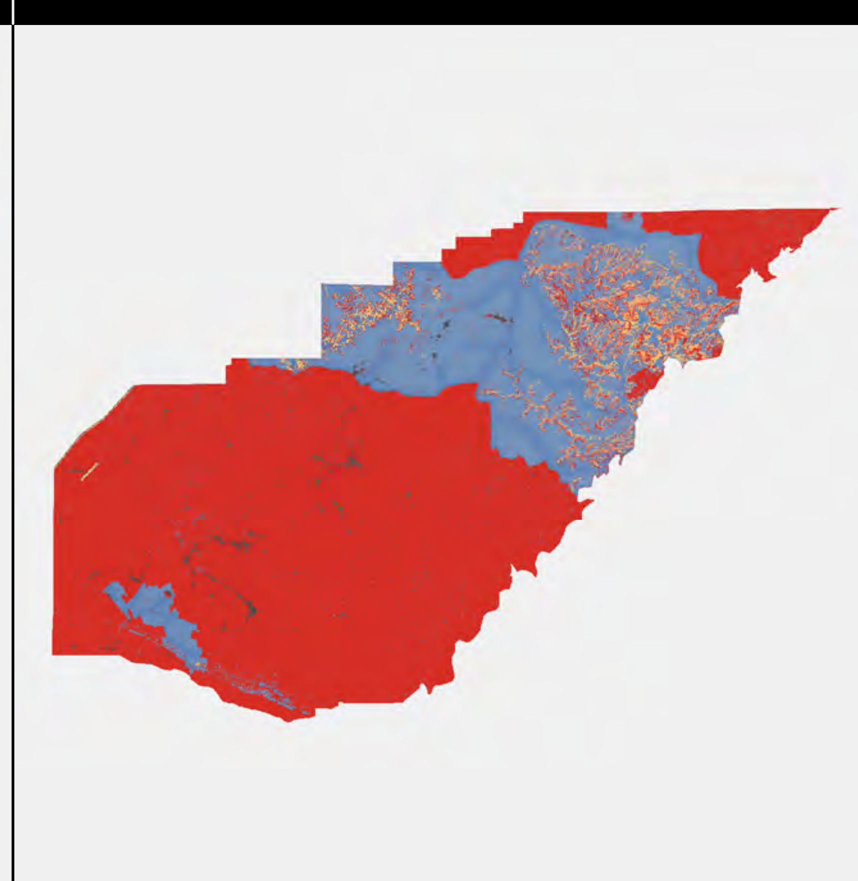
0 4 8 Miles

Ignition Likelihood



0 5 10 Miles

Fire Behavior Magnitude



0 5 10 Miles

Scaled Cell Values

0, 1, 250, 500, 750, 1000

Presidio Of Monterey

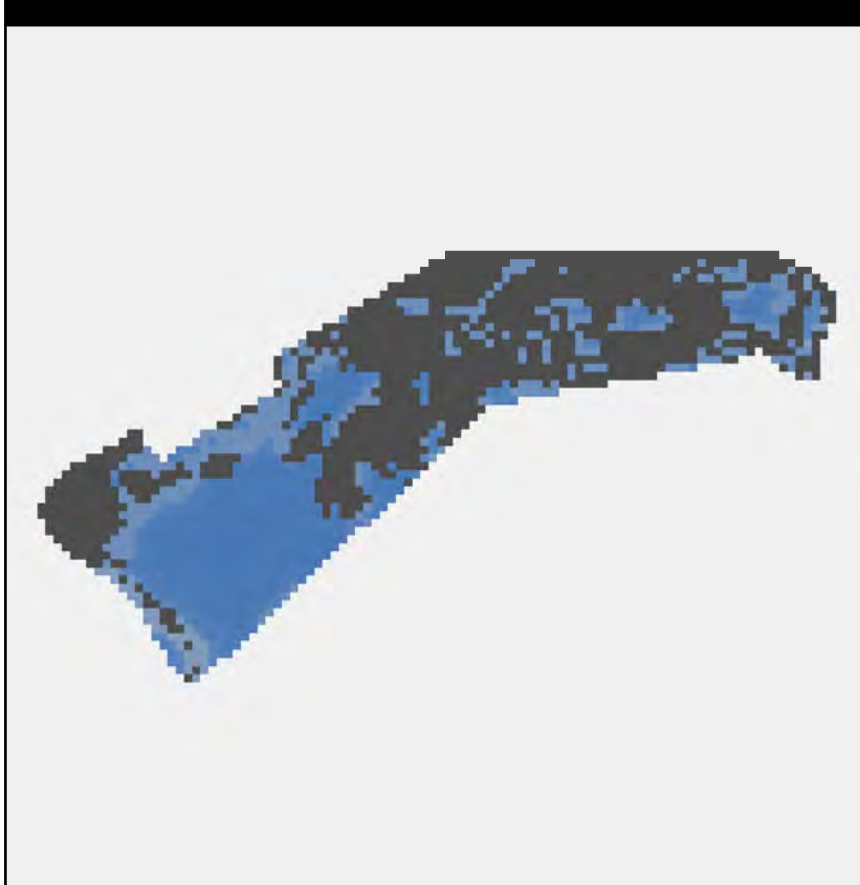
Low

Type 2 Wildfire Risk Assessment

Hazard

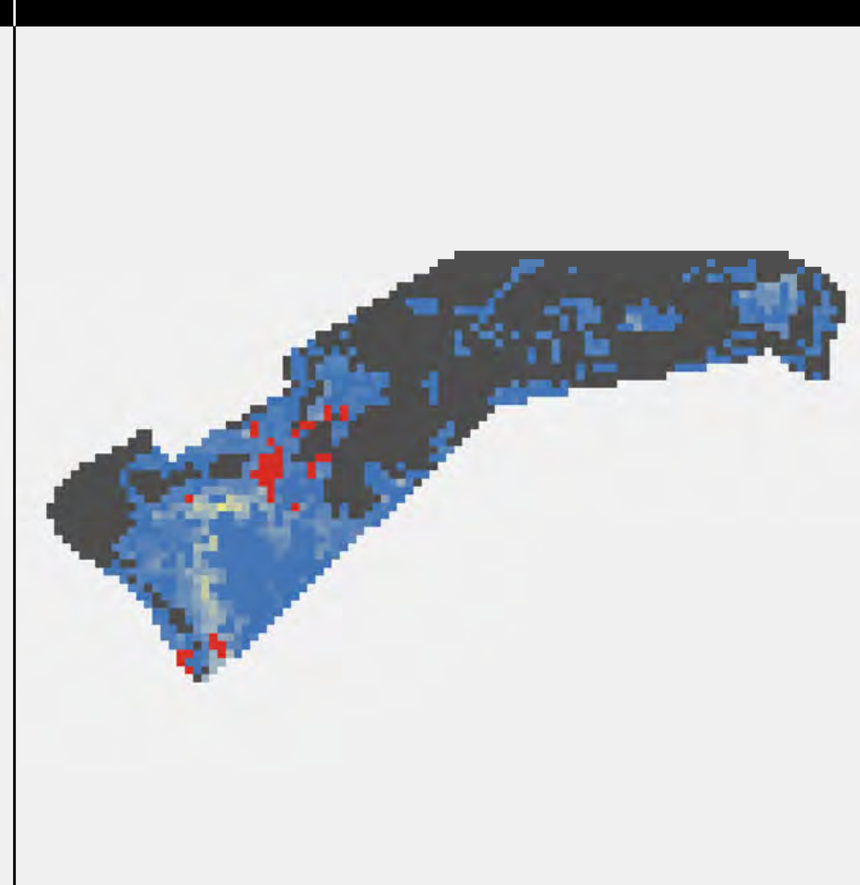
0 0.2 0.4 Miles

Ignition Likelihood



0 0.25 0.5 Miles

Fire Behavior Magnitude



0 0.25 0.5 Miles

Scaled Cell Values

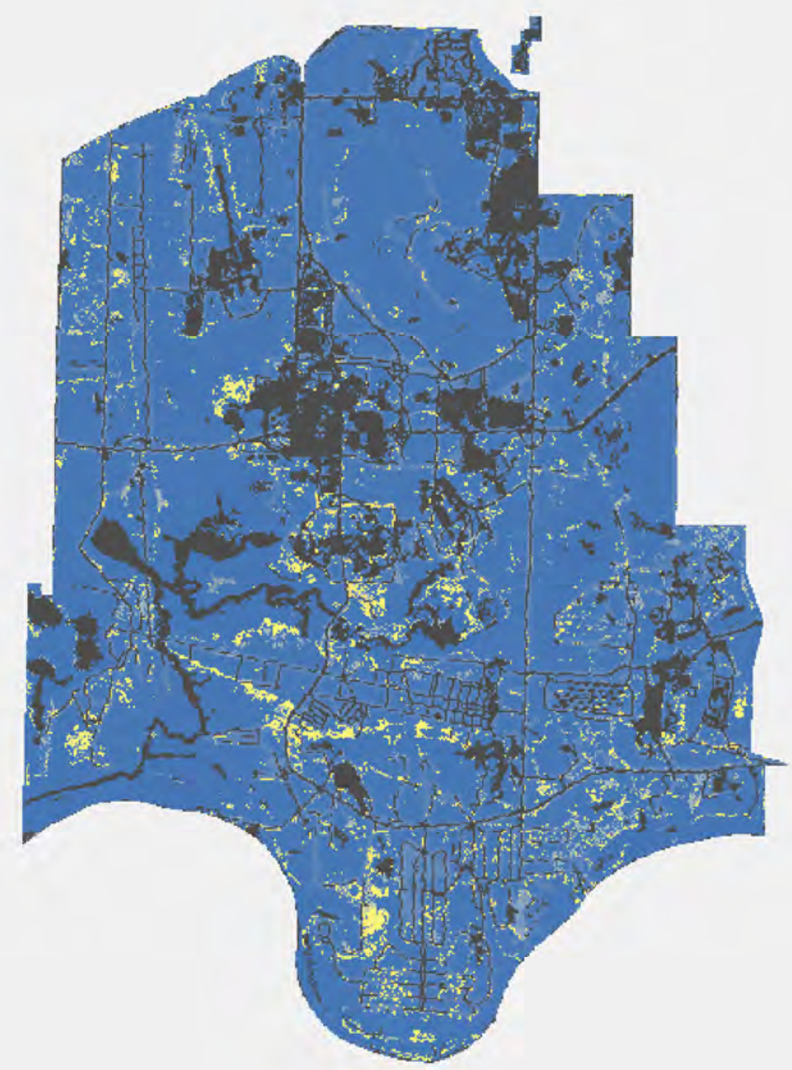
0	250	750
1	500	1000

Redstone Aresenal

Low

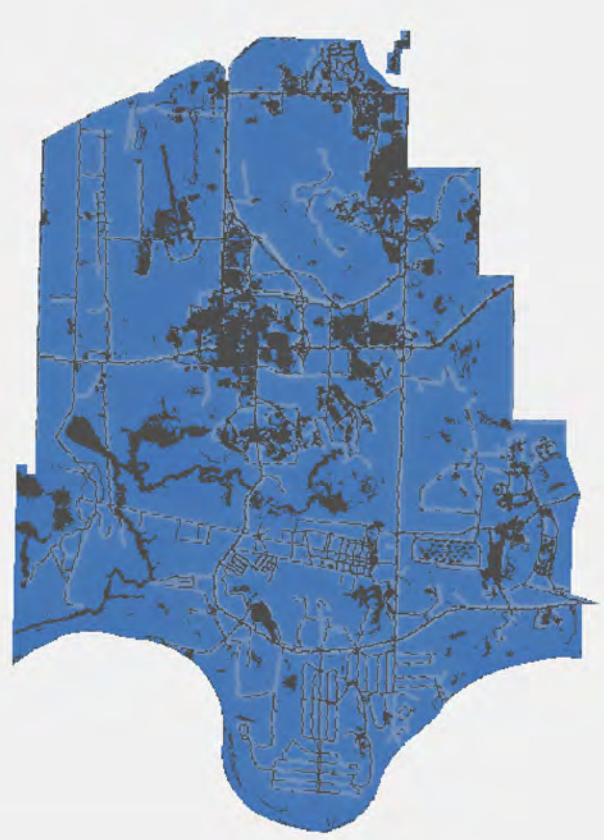
Type 2 Wildfire Risk Assessment

Hazard



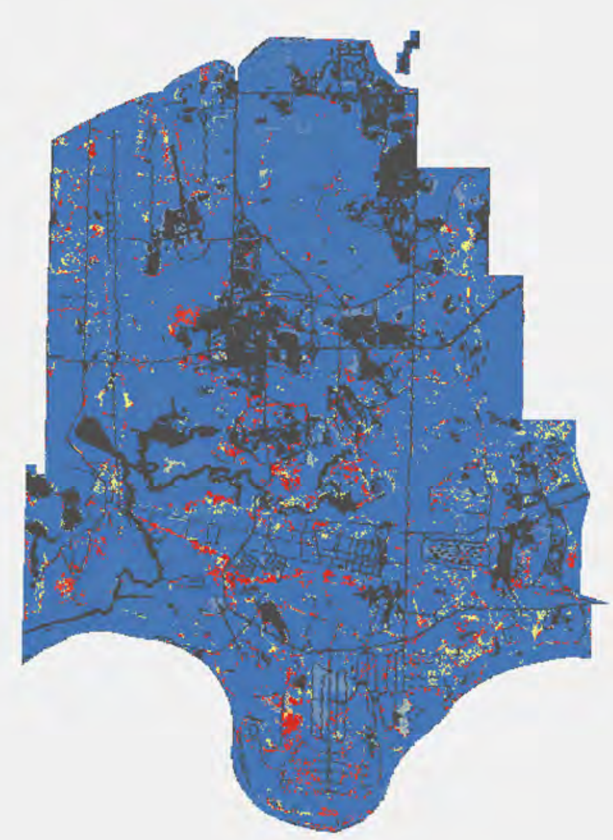
0 2 4 Miles

Ignition Likelihood



0 1.5 3 Miles

Fire Behavior Magnitude



0 1.5 3 Miles

Scaled Cell Values

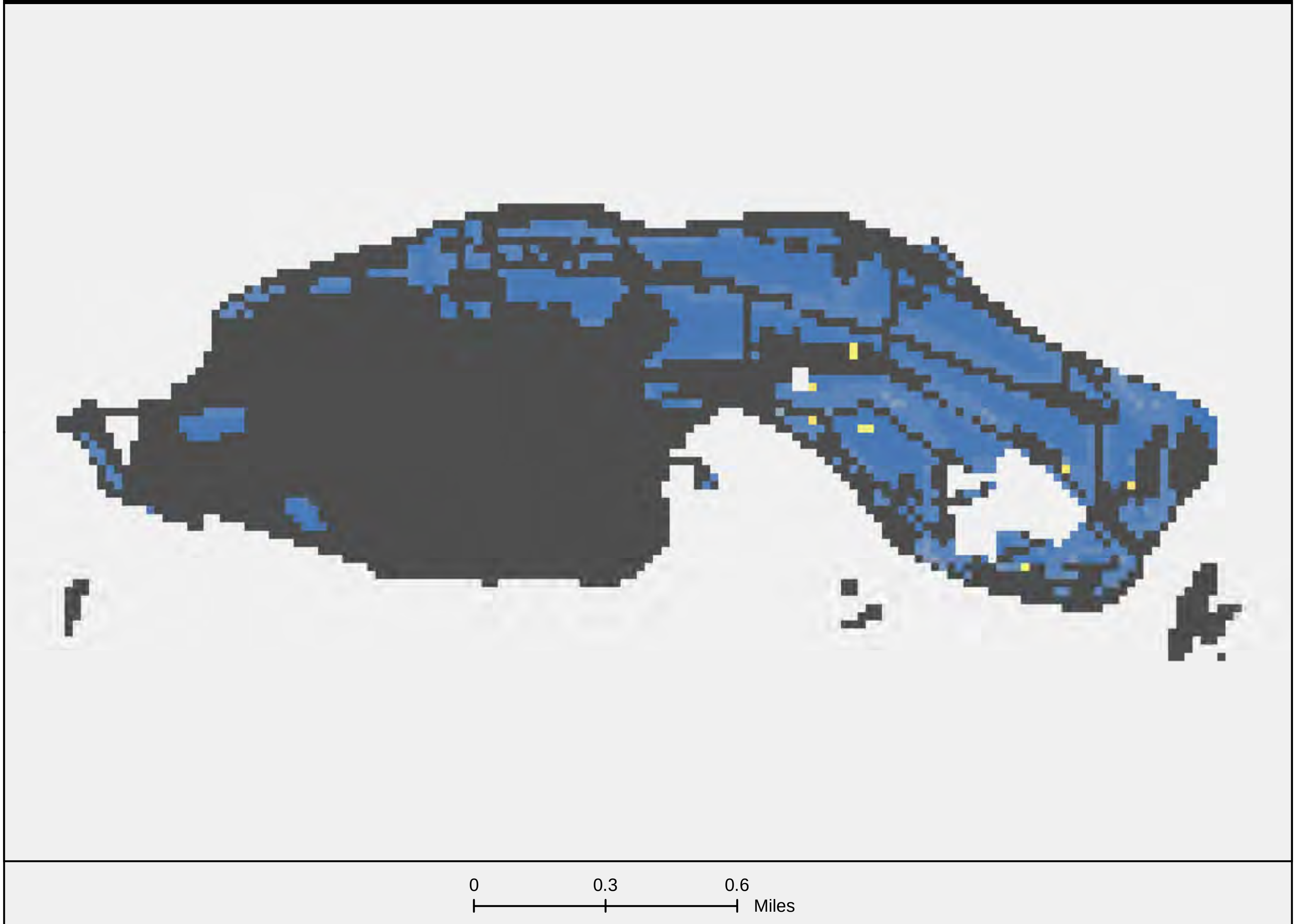
0	250	750
1	500	1000

Rock Island Arsenal

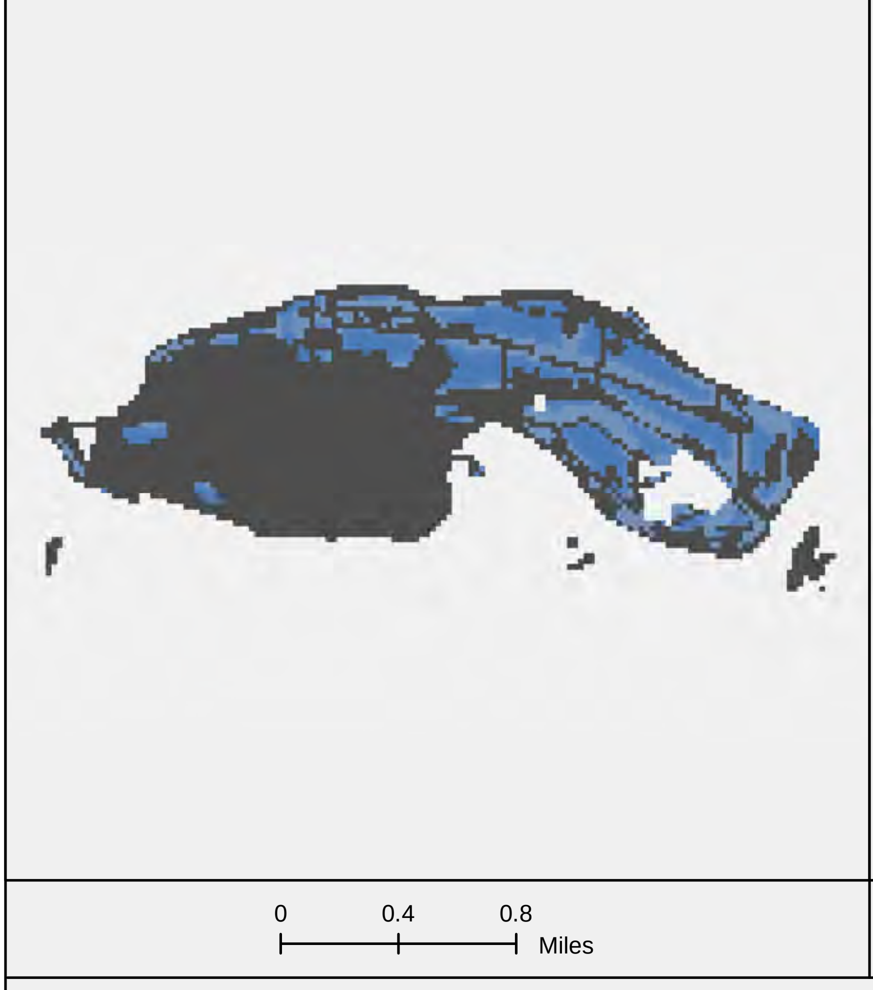
Low

Type 2 Wildfire Risk Assessment

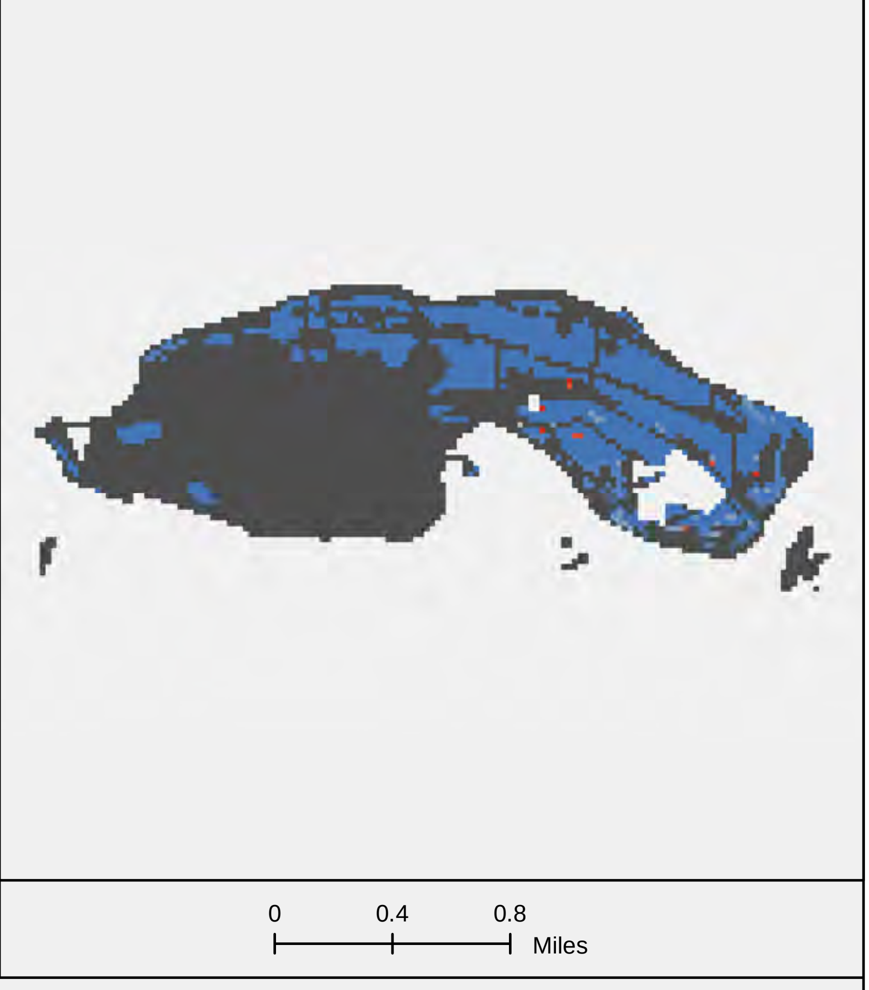
Hazard



Ignition Likelihood



Fire Behavior Magnitude



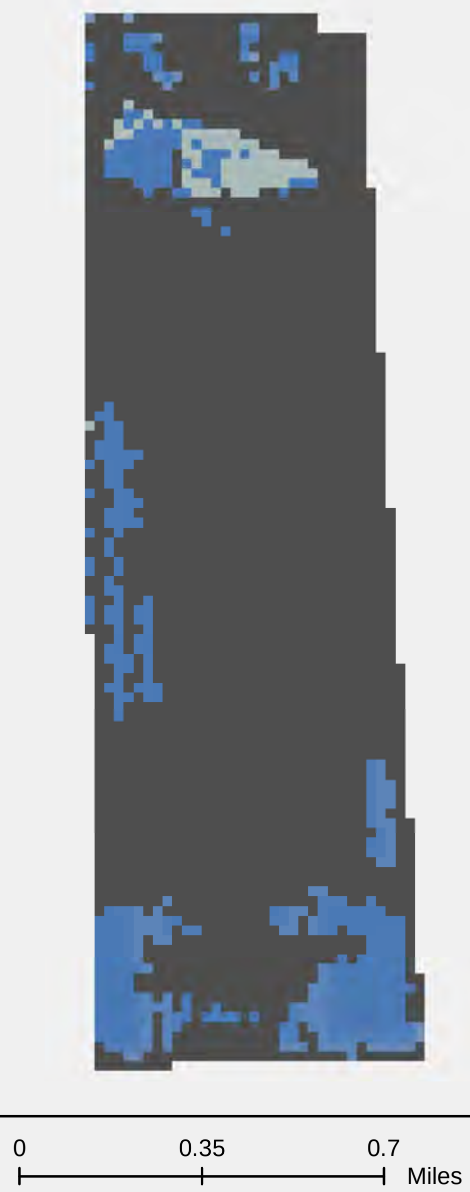
Scaled Cell Values

0, 1, 250, 500, 750, 1000

Sharpe Army Depot Low

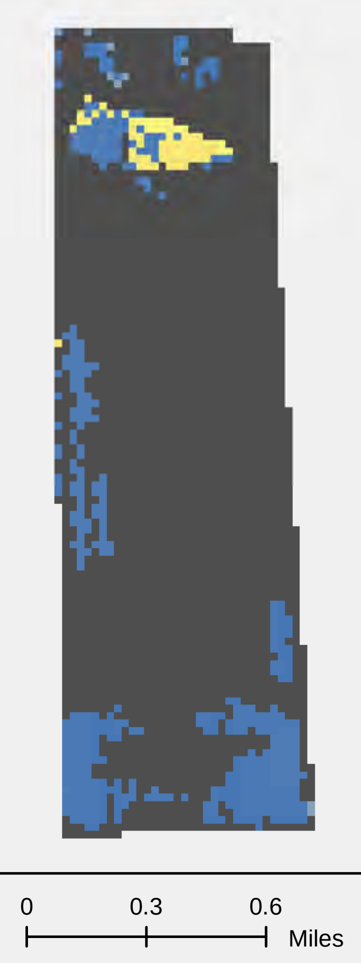
Type 2 Wildfire Risk Assessment

Hazard



Ignition Likelihood

Fire Behavior Magnitude



Scaled Cell Values

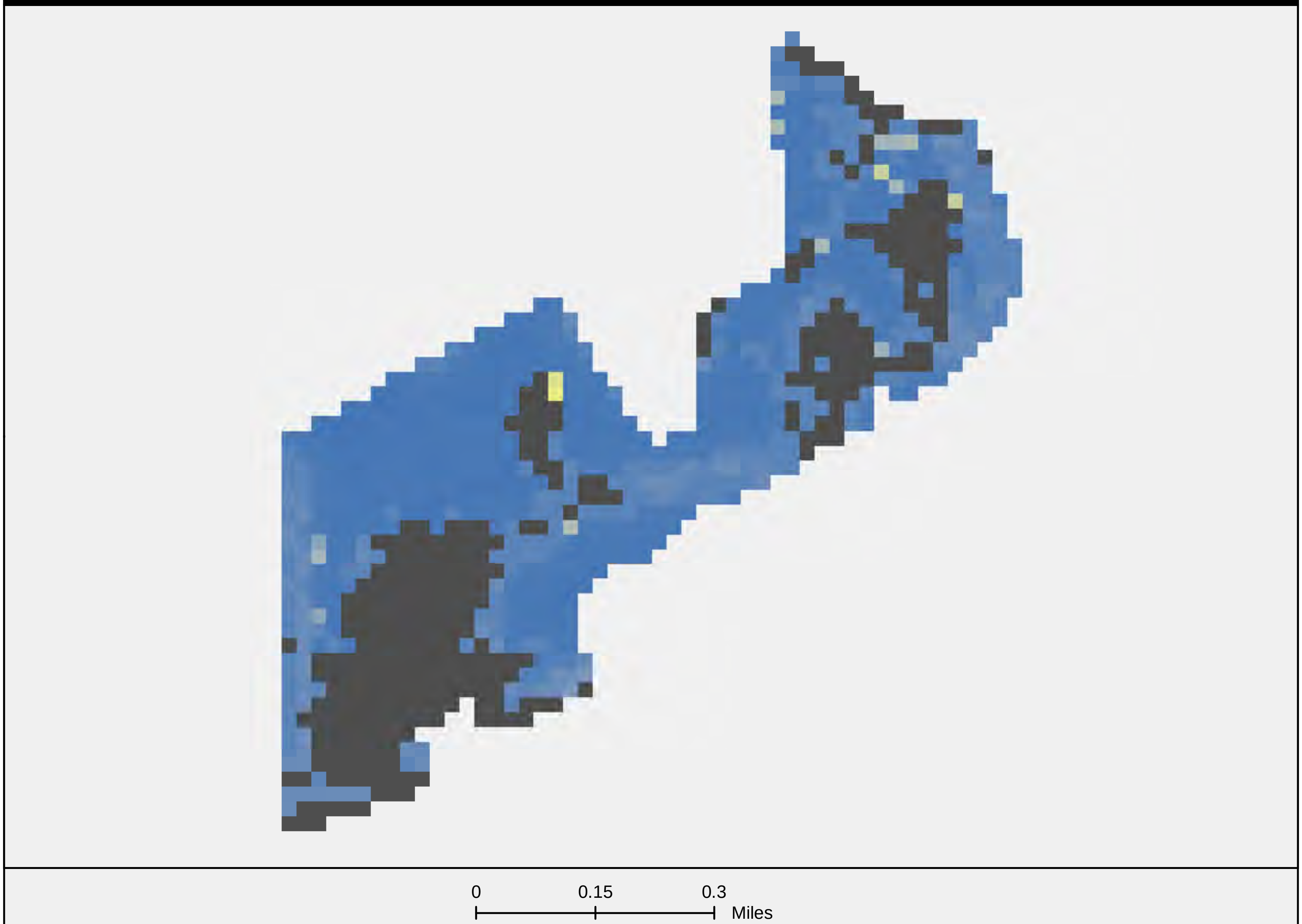
0	250	750
1	500	1000

US Army Research Laboratory

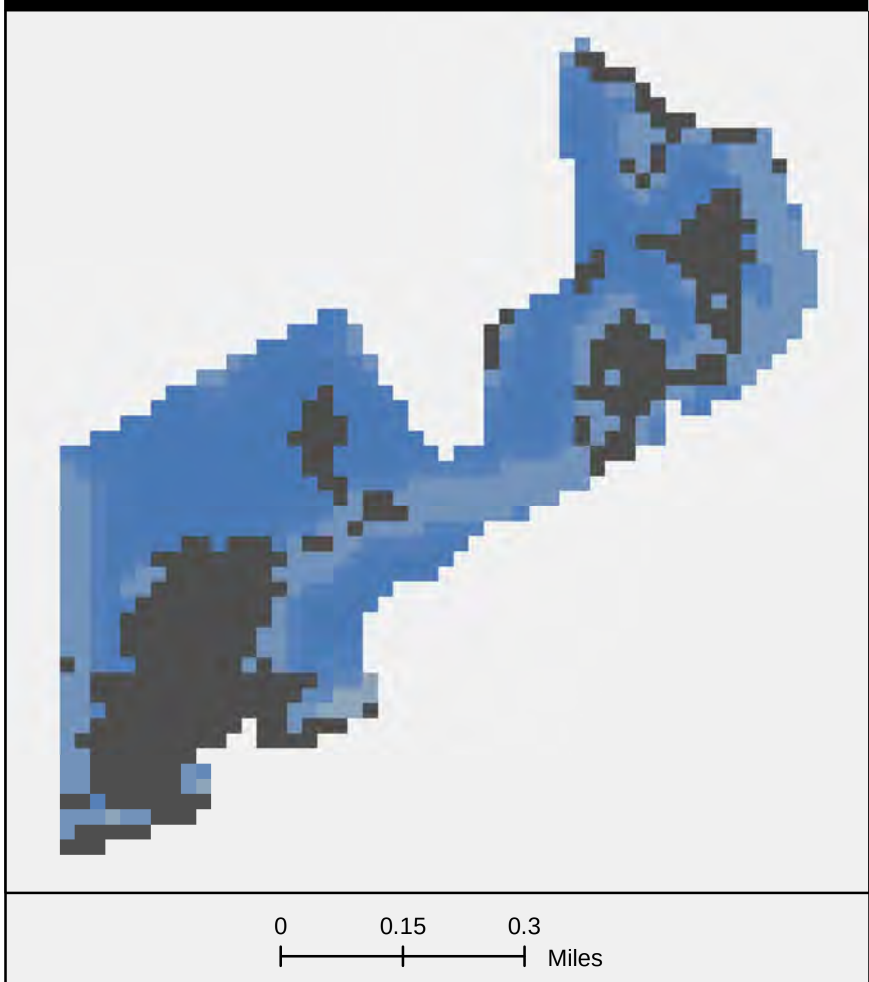
Low

Type 2 Wildfire Risk Assessment

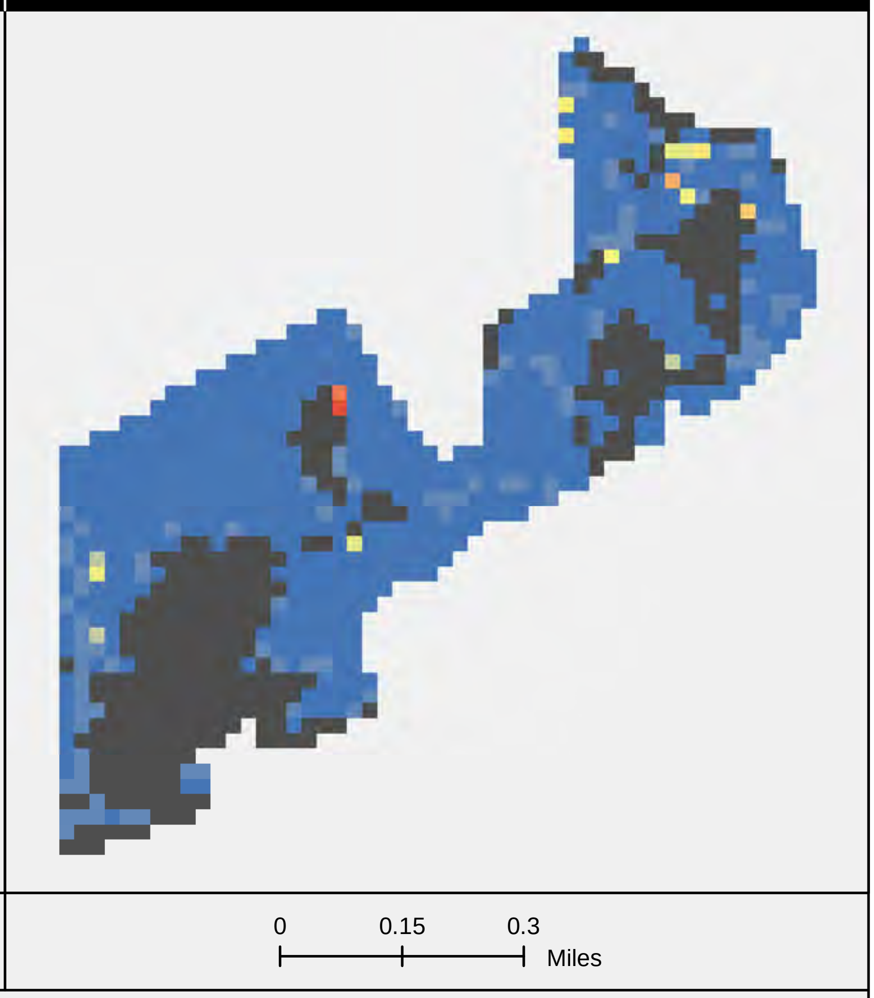
Hazard



Ignition Likelihood



Fire Behavior Magnitude



Scaled Cell Values

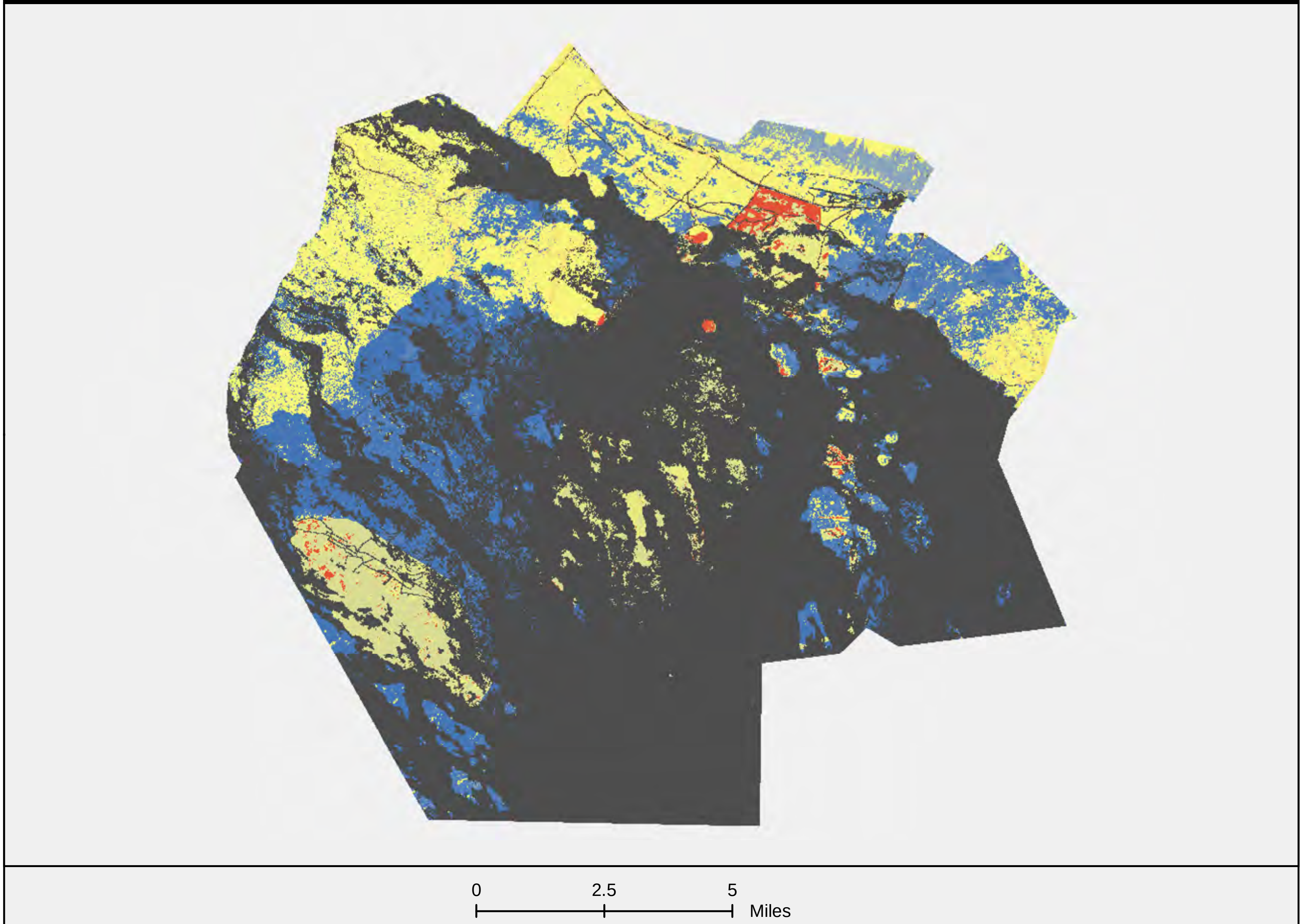
0	250
1	500
750	1000

USAG Hawaii PTA

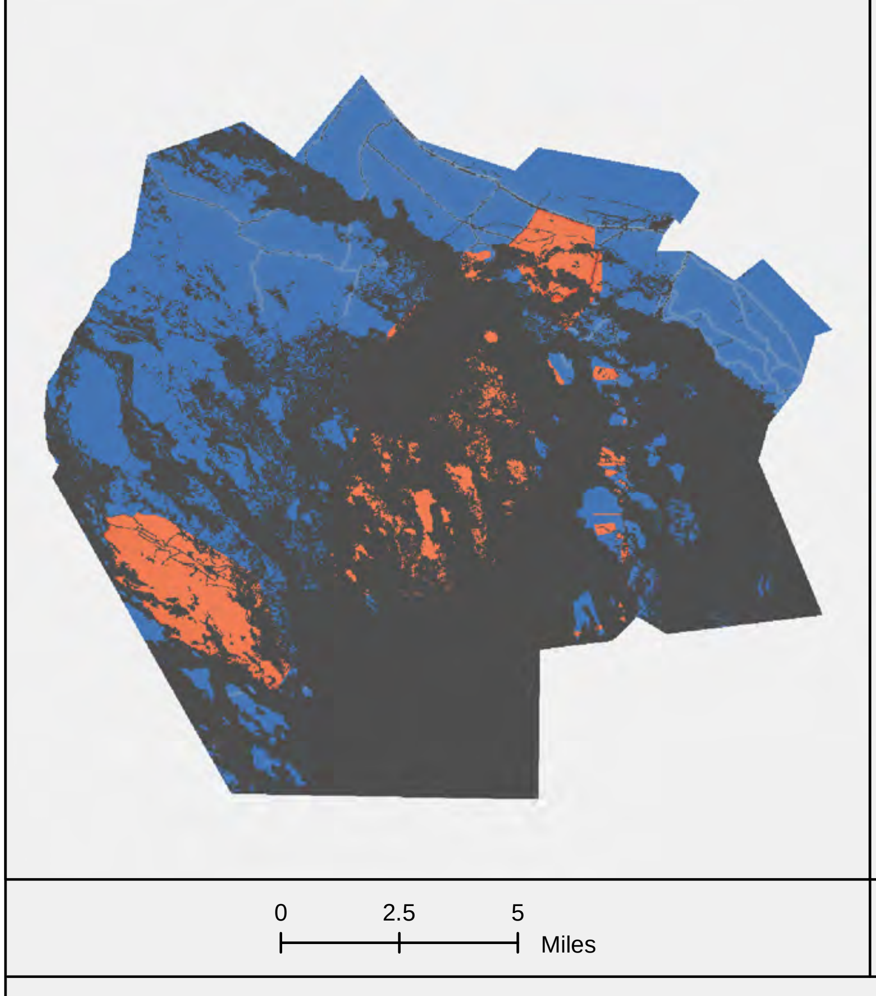
Moderate

Type 2 Wildfire Risk Assessment

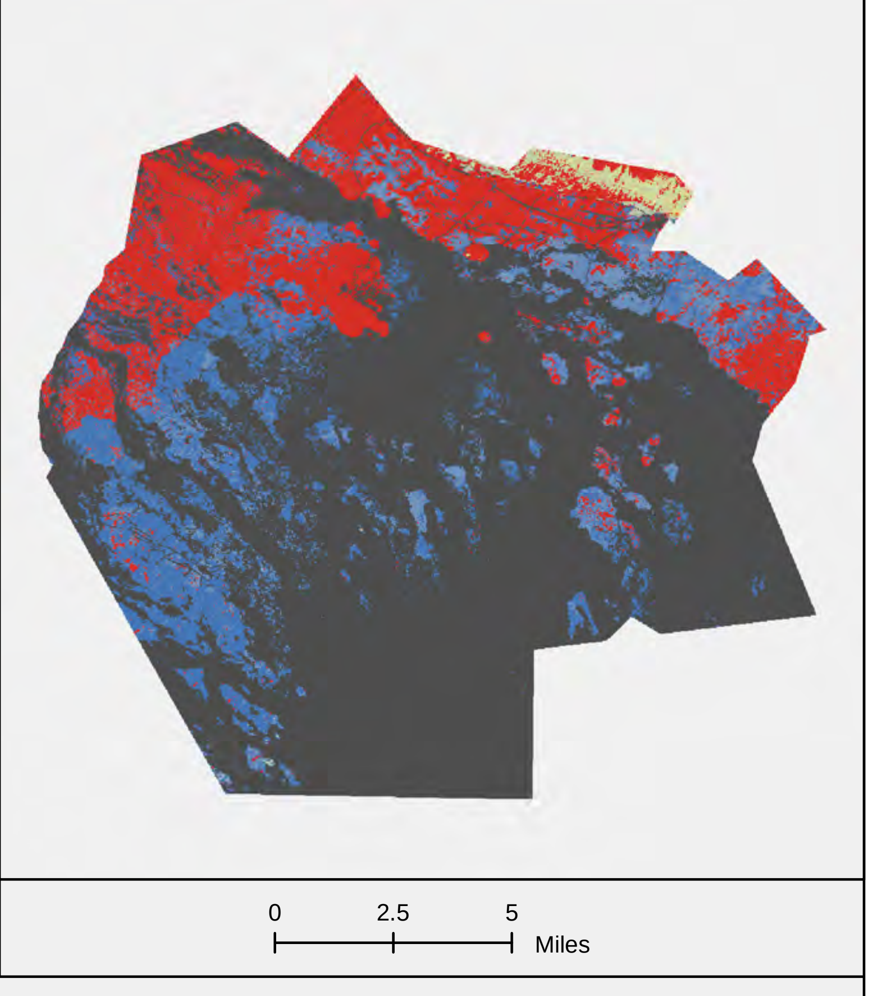
Hazard



Ignition Likelihood



Fire Behavior Magnitude



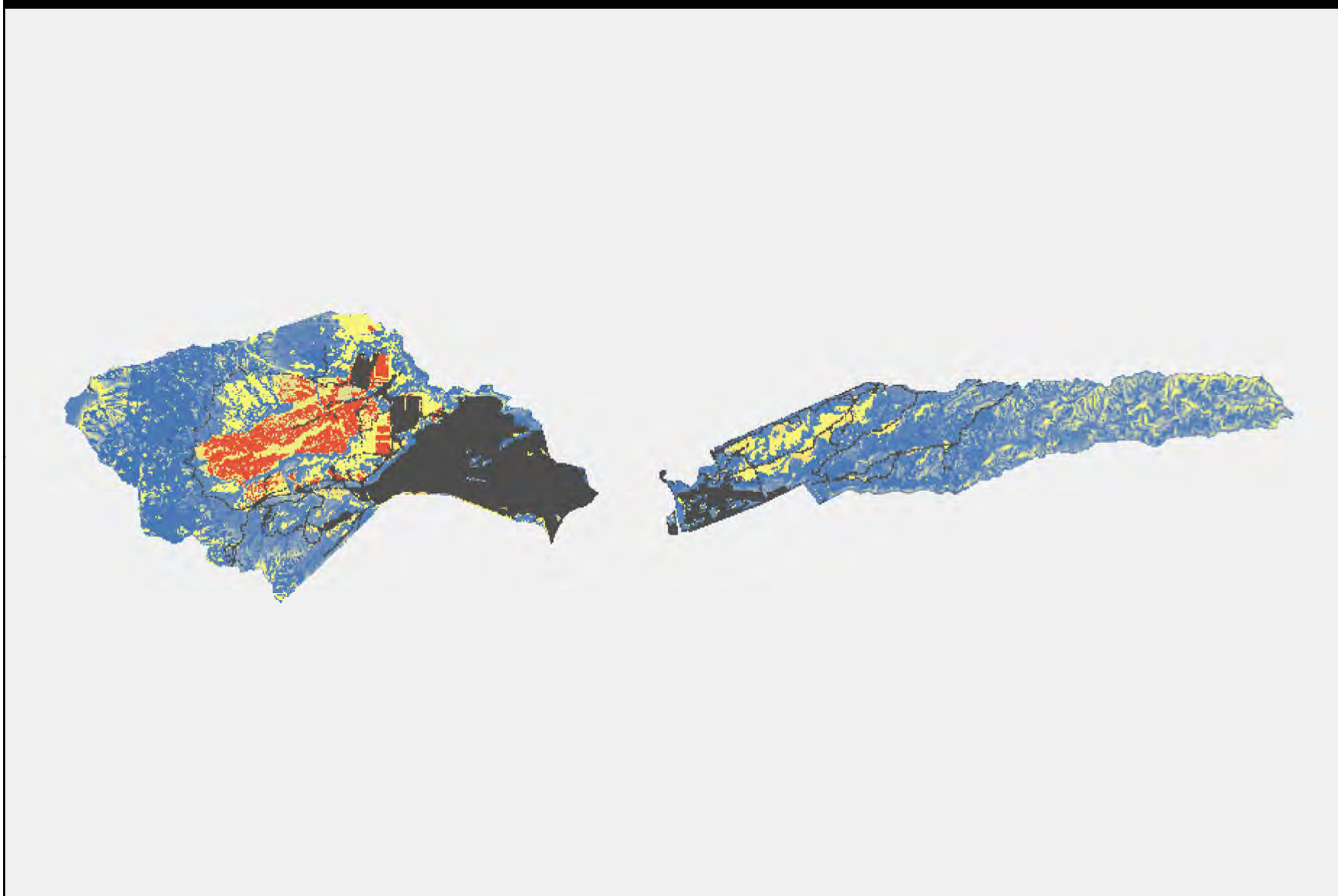
Scaled Cell Values

0
1
250
500
750
1000

USAG Hawaii Schofield — High

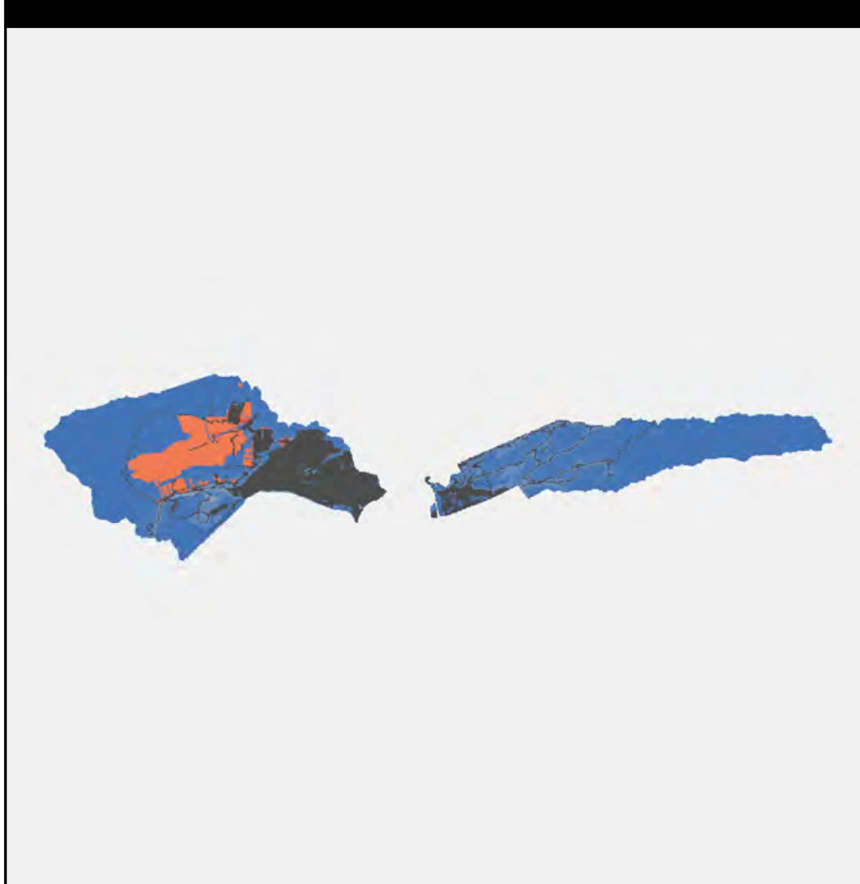
Type 2 Wildfire Risk Assessment

Hazard



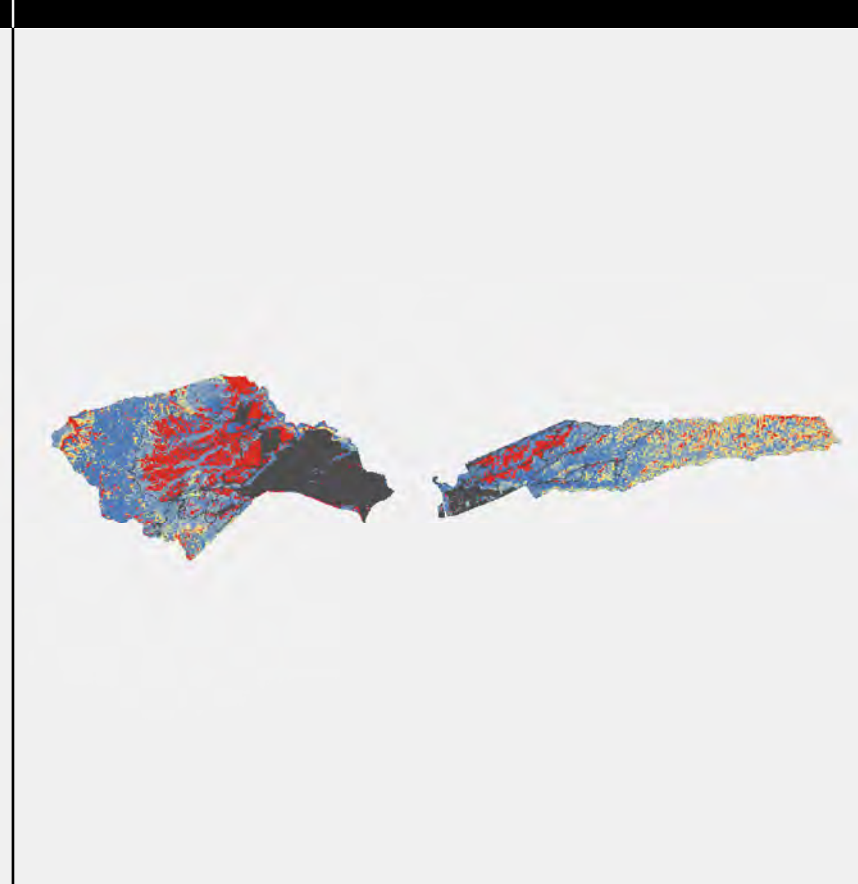
0 2 4 Miles

Ignition Likelihood



0 2 4 Miles

Fire Behavior Magnitude



0 2 4 Miles

Scaled Cell Values

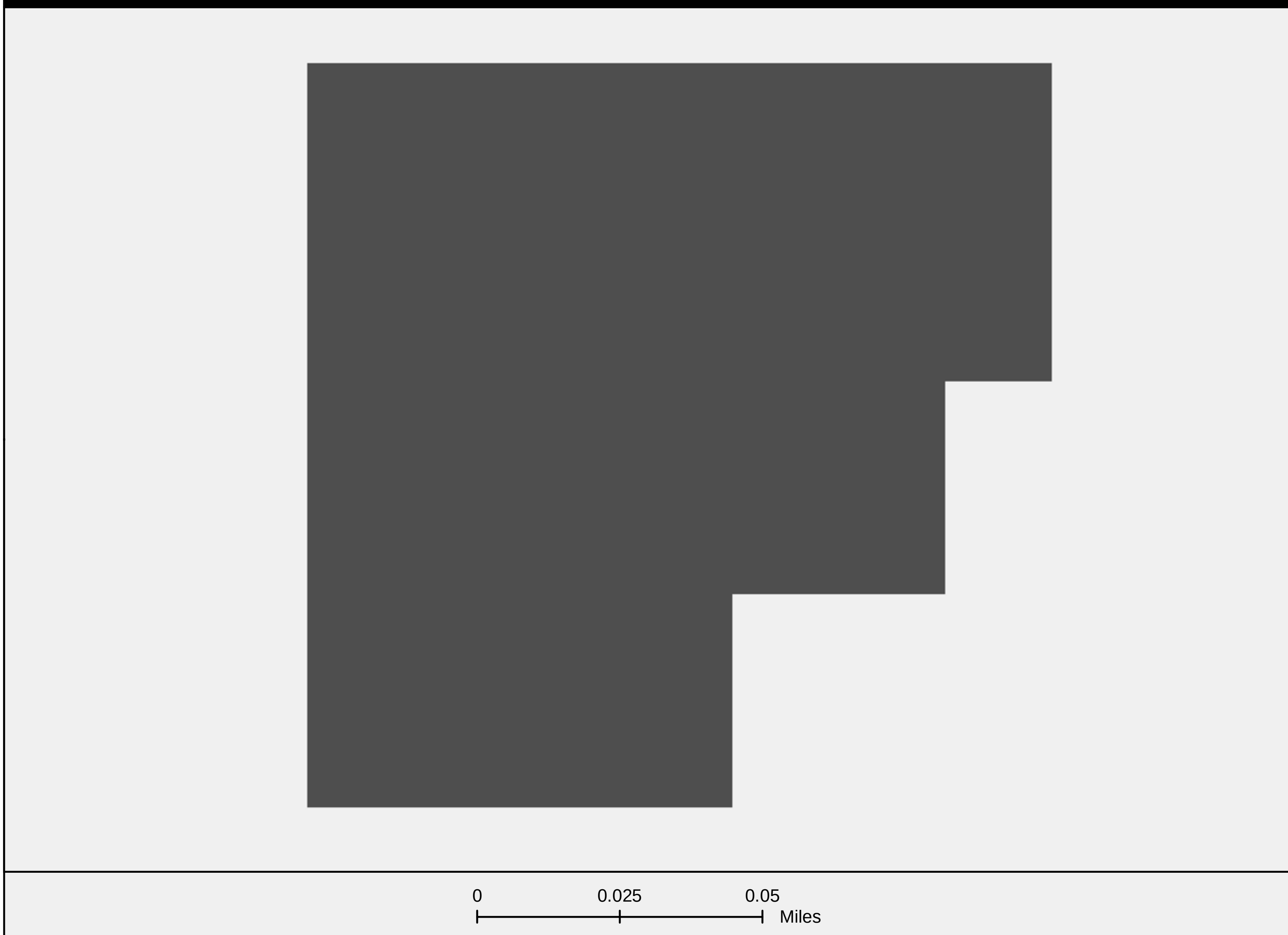
0	250	750
1	500	1000

USAG Miami

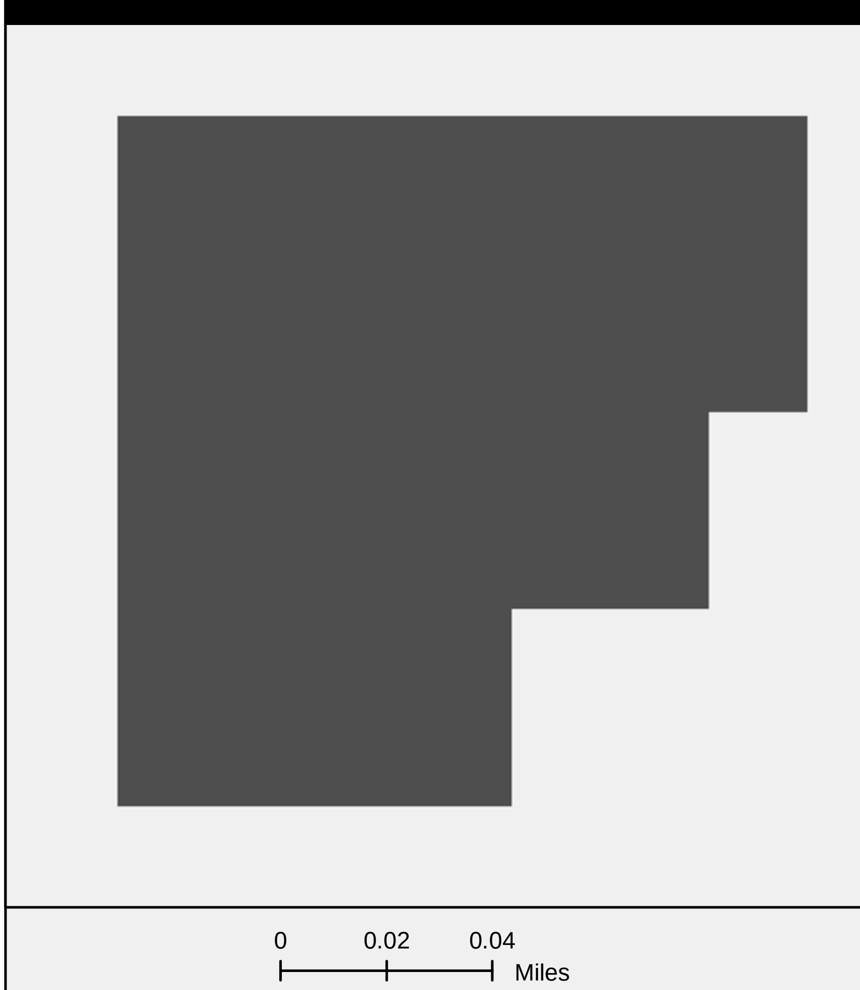
Low

Type 2 Wildfire Risk Assessment

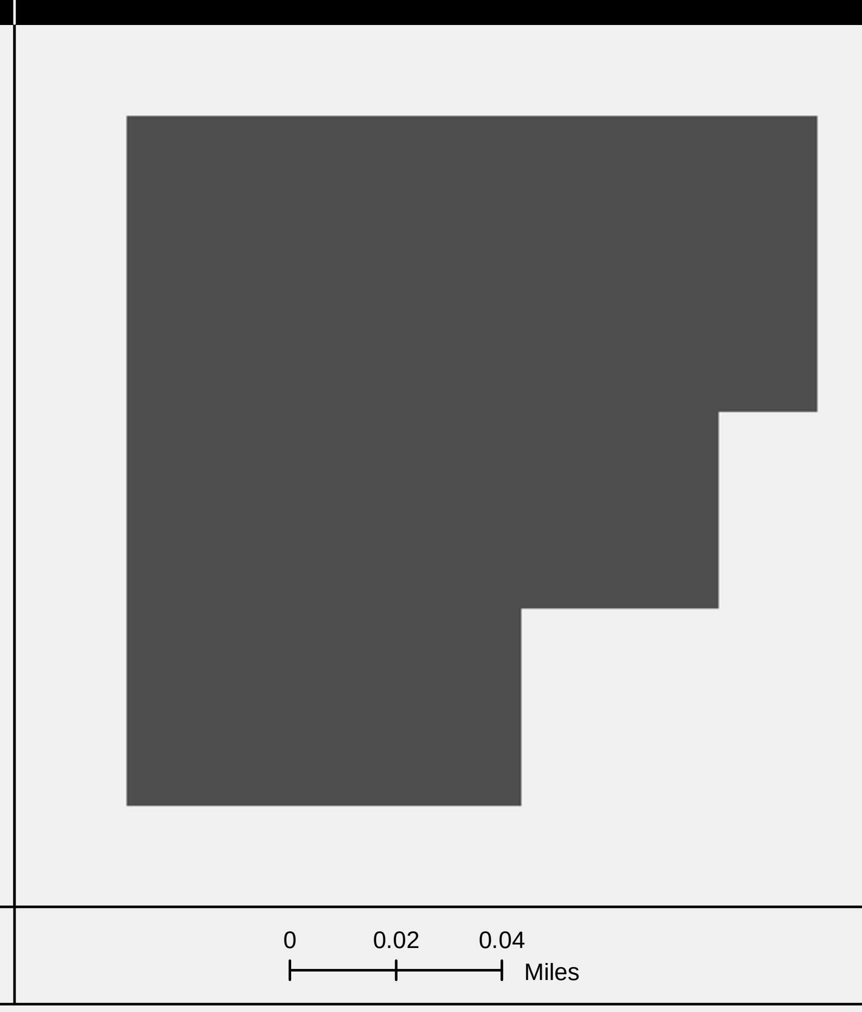
Hazard



Ignition Likelihood



Fire Behavior Magnitude



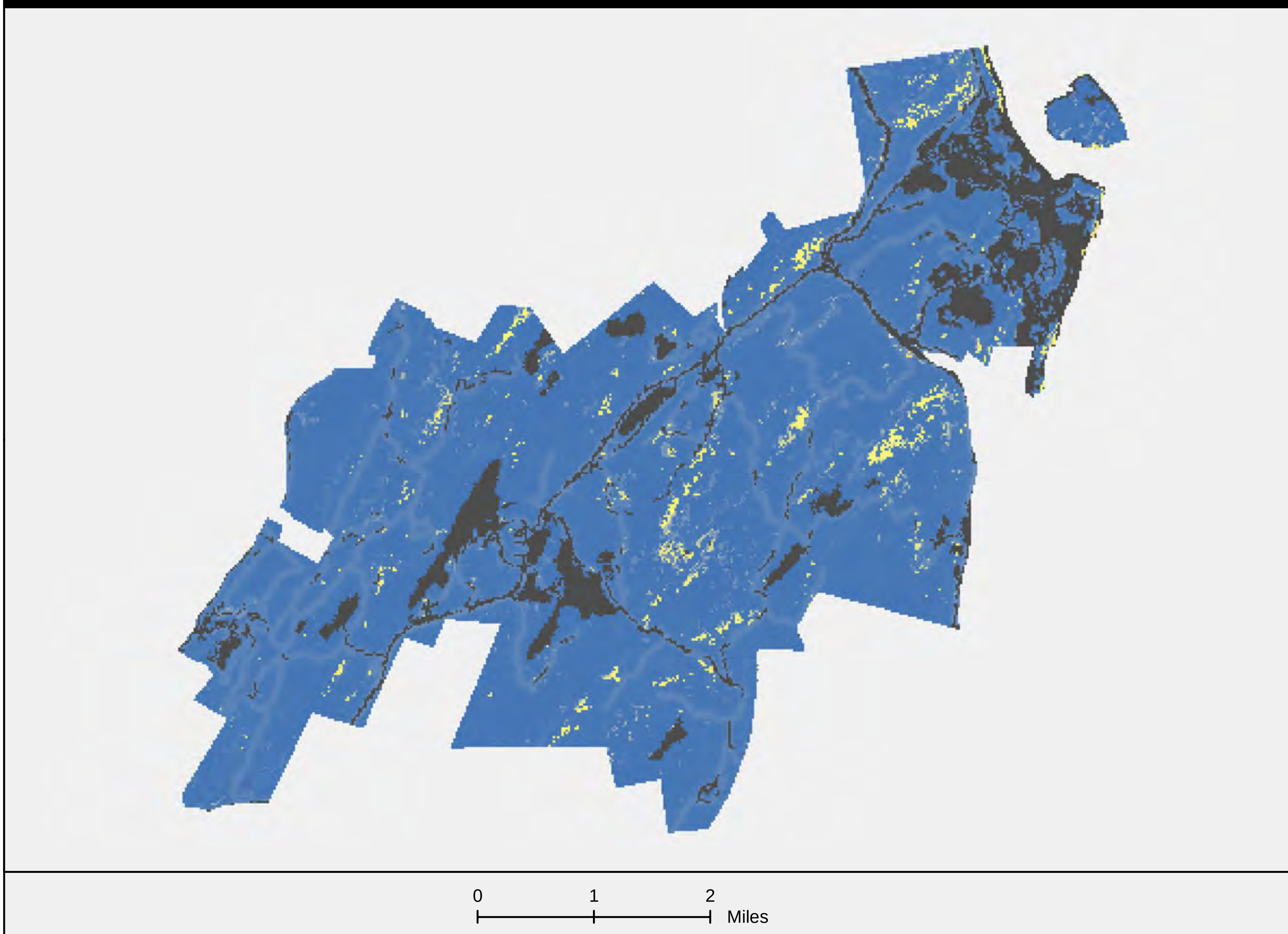
Scaled Cell Values

0
1
250
500
750
1000

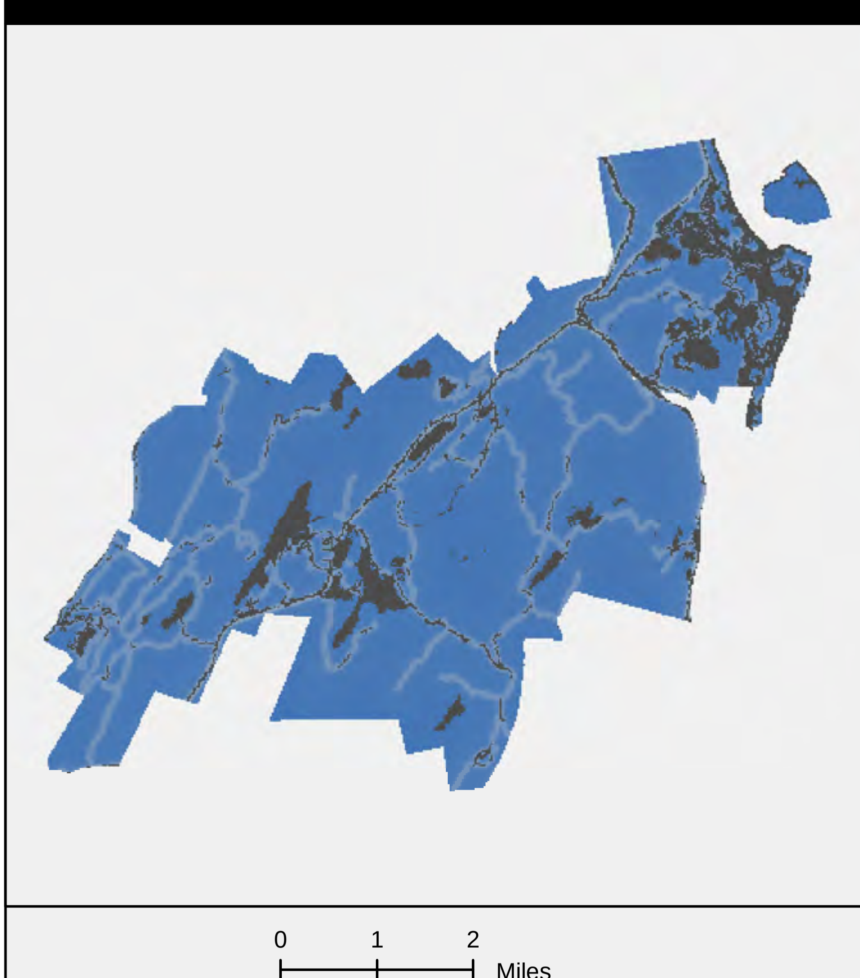
West Point — Low

Type 2 Wildfire Risk Assessment

Hazard



Ignition Likelihood



Fire Behavior Magnitude

Scaled Cell Values

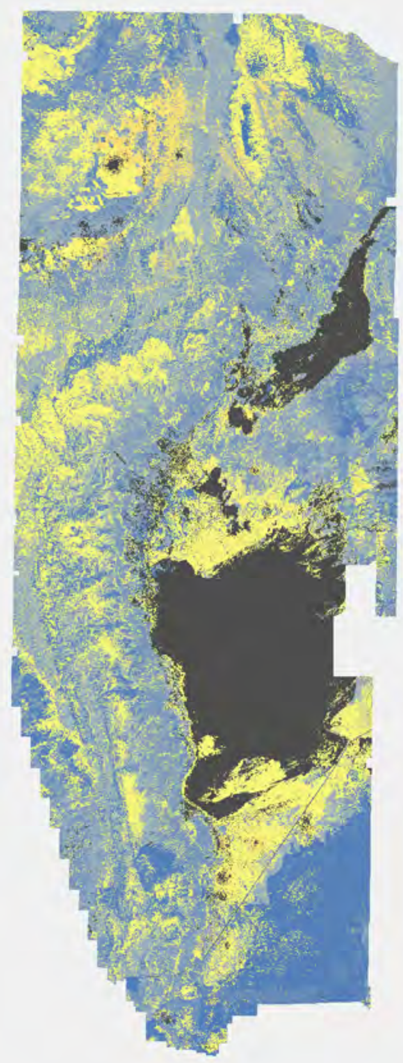
0, 250, 750
1, 500, 1000

White Sands Missile Range

High

Type 2 Wildfire Risk Assessment

Hazard

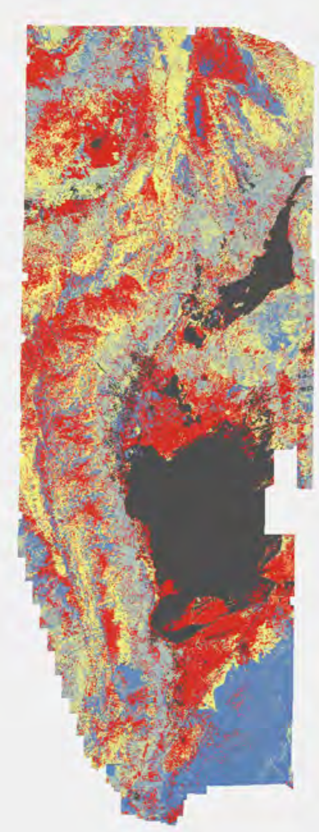


0 20 40 Miles

Ignition Likelihood

0 10 20 Miles

Fire Behavior Magnitude



0 10 20 Miles

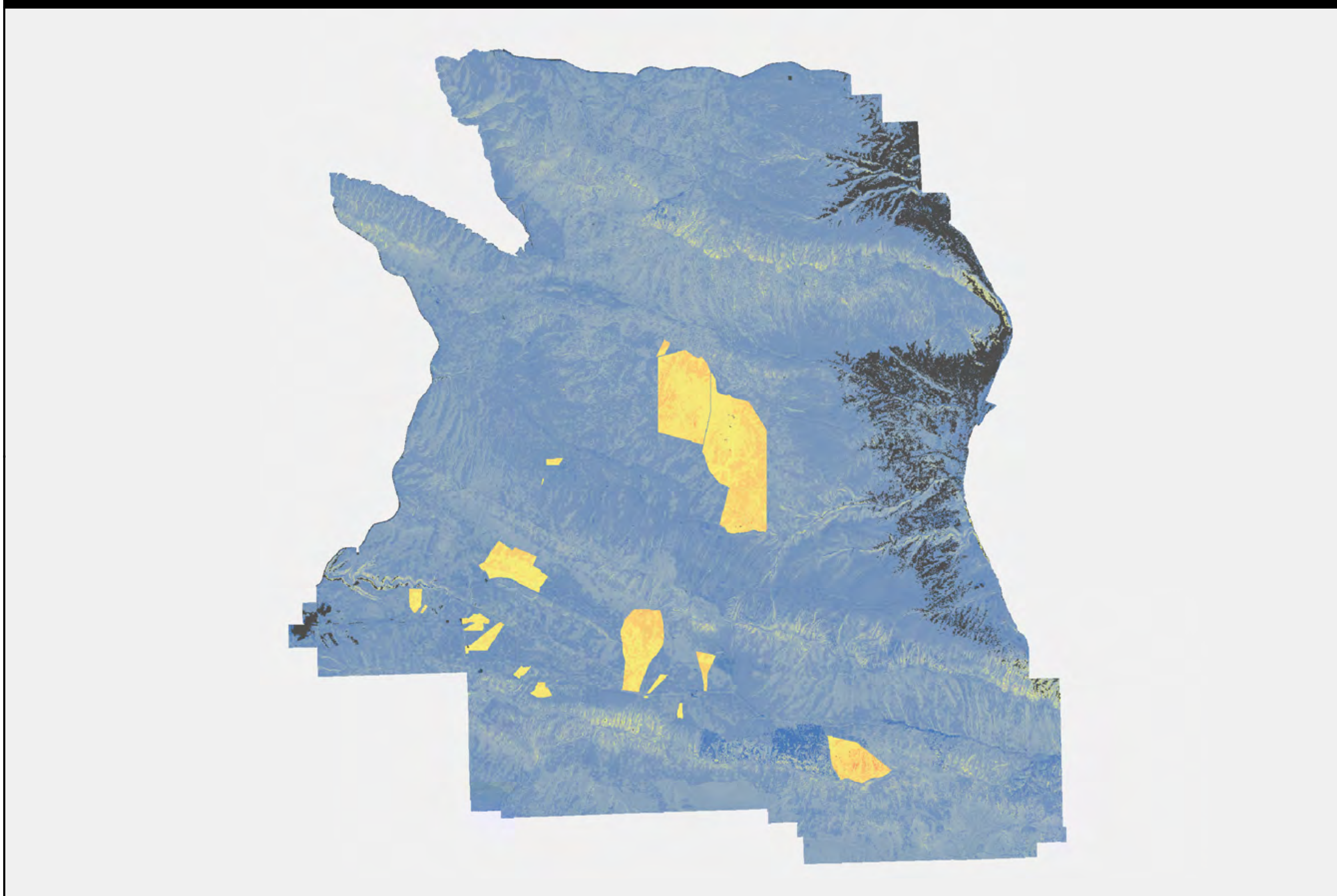
Scaled Cell Values

0
1
250
500
750
1000

Yakima Training Center — High

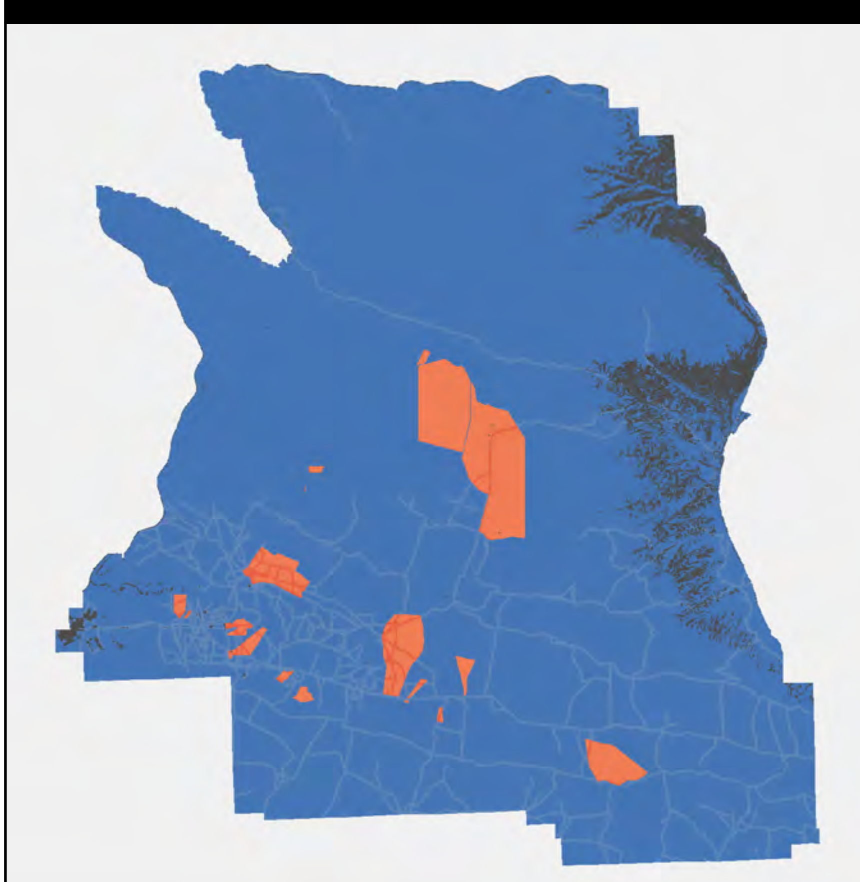
Type 2 Wildfire Risk Assessment

Hazard



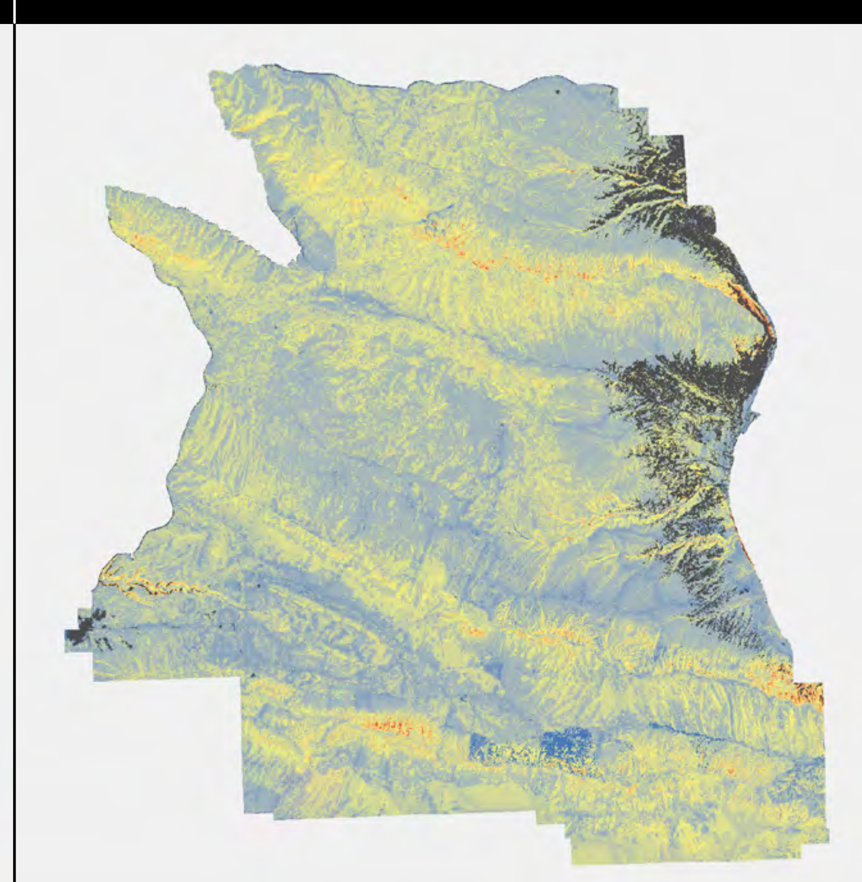
0 5 10 Miles

Ignition Likelihood



0 4 8 Miles

Fire Behavior Magnitude



0 4 8 Miles

Scaled Cell Values

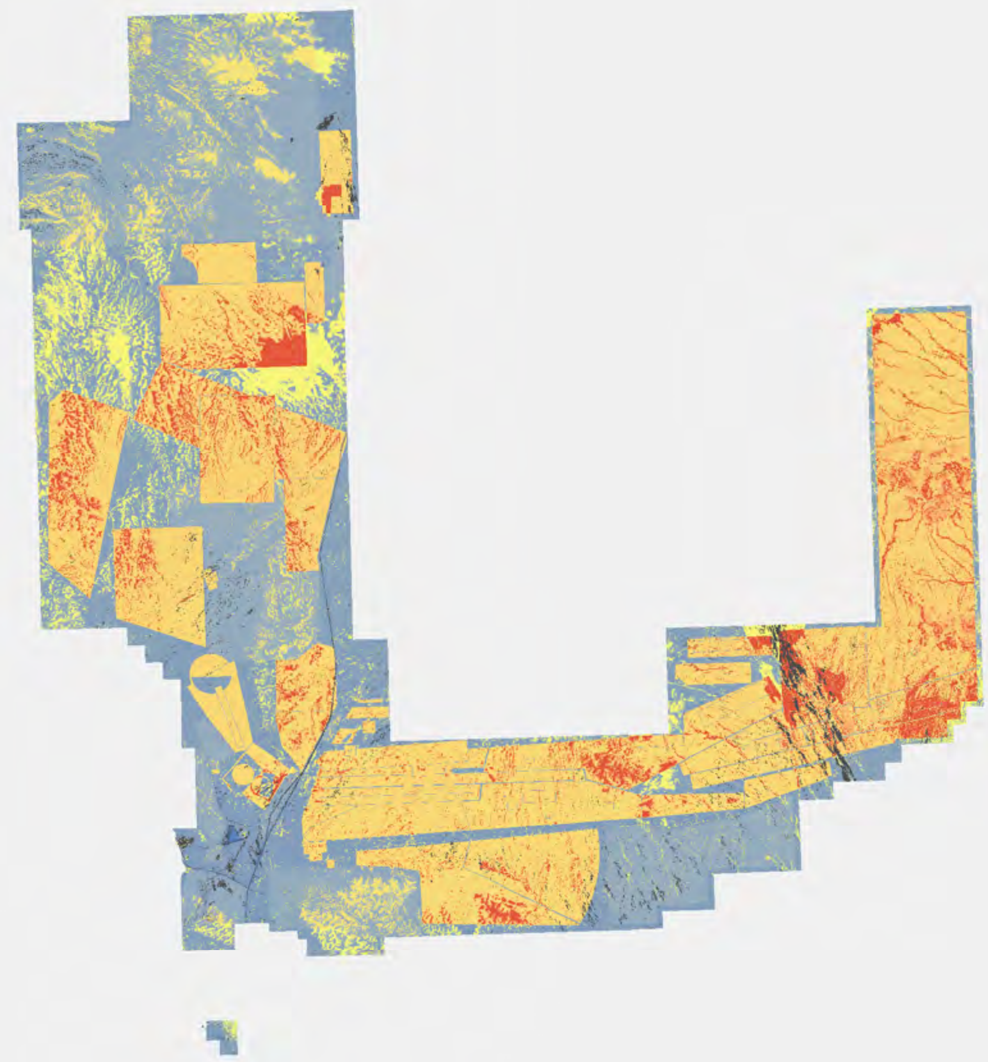
0	250	750
1	500	1000

Yuma Proving Ground

Low

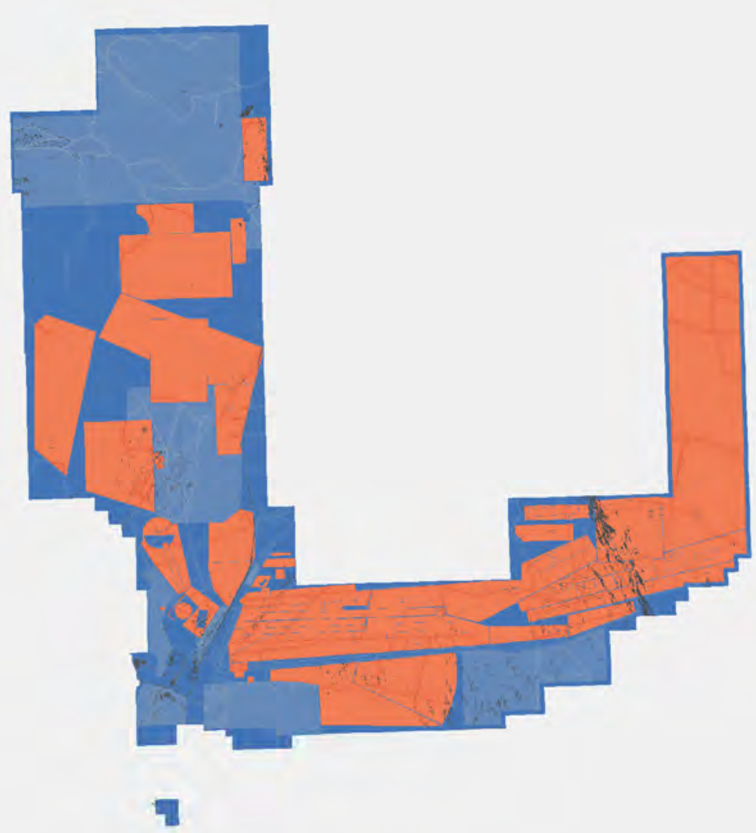
Type 2 Wildfire Risk Assessment

Hazard



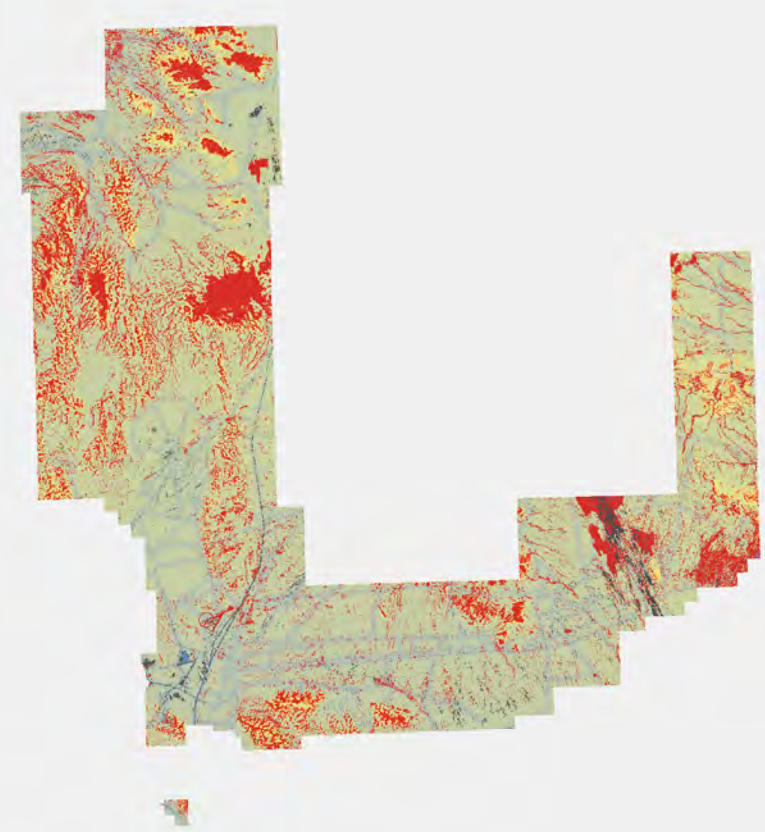
0 10 20 Miles

Ignition Likelihood



0 9 18 Miles

Fire Behavior Magnitude



0 9 18 Miles

Scaled Cell Values

0 | 250 | 750
1 | 500 | 1000