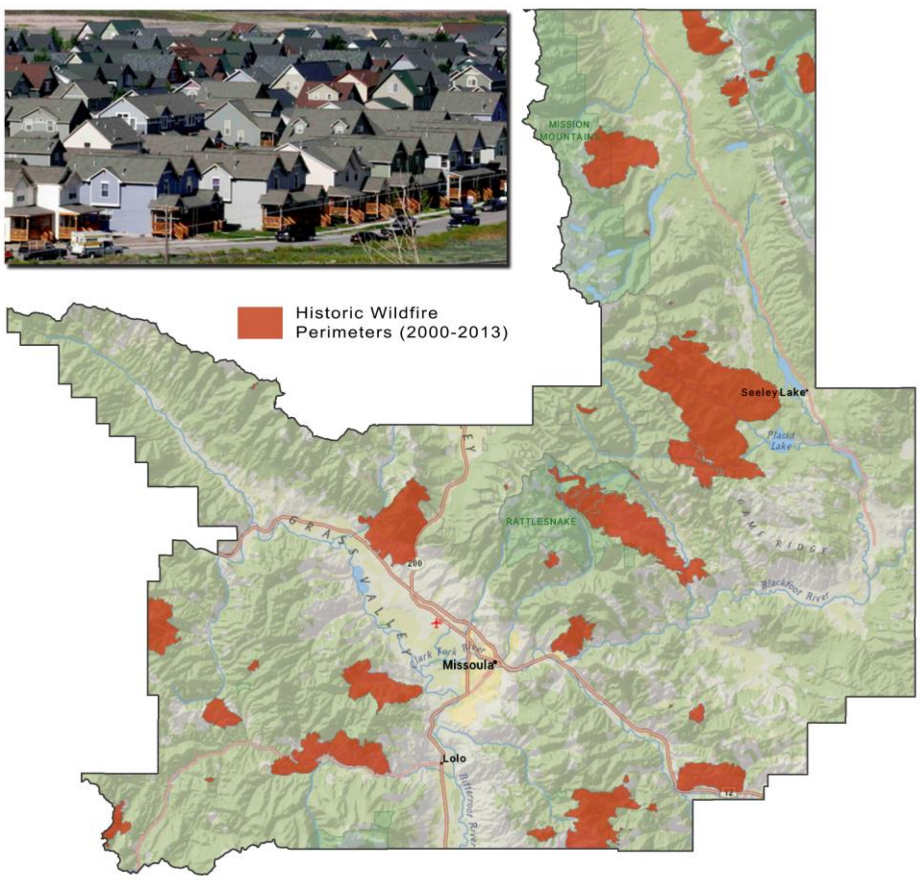
A Reference Document by

HEADWATERS ECONOMICS

Assessing Wildfire Risk and Development Pressures in Missoula County



October 2016

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ABOUT HEADWATERS ECONOMICS

Headwaters Economics is an independent, nonprofit research group whose mission is to improve community development and land management decisions in the West.

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Cover Images: Map of Historic Wildfire Perimeters, Headwaters Economics. Photograph of home subdivision, NewWest.net

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EXECUTIVE SUMMARY

Missoula County is one of the Montana's most populated areas and is likely to experience ongoing growth. As more people move into the region, development within the wildland-urban interface (WUI) will similarly increase. The added presence of homes within the county's WUI is a concern given current and future wildfire risks.

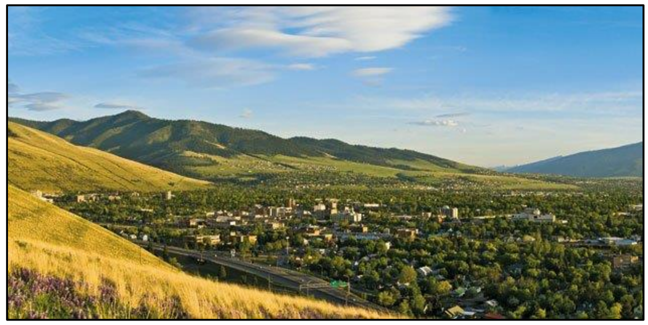
Recognizing the growing threat of wildfires within the WUI, Missoula County collaborated with Headwaters Economics on a countywide wildfire risk assessment. From 2015 to 2016, representatives from Missoula County's Community and Planning Services (CAPS) Department, Department of Natural Resources and Conservation, and U.S. Forest Service convened to discuss the scale and severity of wildfire risk within the county. Additional input was provided by the Rocky Mountain Research Station's Fuels Modeling Institute and University of Montana's College of Forestry and Conservation.

In addition to the wildfire risk assessment, Headwaters Economics developed a predictive residential build-out model for Missoula County. By analyzing historic residential growth patterns from 1900 to 2013, this model identified areas most likely to experience future development pressures over the subsequent decade. The wildfire risk assessment and the predictive residential build-out model are complementary to one another, and together identify wildfire risk within the context of present and future home development in Missoula County.

This reference document assists in the interpretation and application of the wildfire risk assessment and the predictive build-out model. An overview of each model, as well as a description of input variables and analytical assumptions, is provided. This reference document should be used to identify and understand the factors considered in each model and the symbology associated with individual variables. All native files related to the wildfire risk assessment and predictive build-out model are exported from ESRI ArcGIS 10.4 and housed within the Missoula County GIS Department.

INTRODUCTION

Figure 1: The City of Missoula, Montana. (Photo Credit: C. Haney)



Wildfires in Missoula County, Montana, and across the West are presenting communities with complex challenges. Growing in size, frequency, and severity, wildfires increasingly consume agency budgets and place lives and homes at risk. Ongoing development in wildfire-prone areas, coupled with climate change impacts, further exacerbate wildfire risks (Figure 1).

In response to the growing threat of wildfires within Missoula County, Headwaters Economics worked closely with Missoula County land use planners, federal land management agencies, and local fire experts over the course of a year. Initiated in 2015, the collaborative effort was supported through Headwaters Economics' new Community Planning Assistance for Wildfire (CPAW) program. The purpose of CPAW is to assist communities in reducing wildfire risks through improved land use planning.

As a result of the partnership between Headwaters Economics and Missoula County, a detailed countywide mapping assessment of wildfire risks was generated (Figure 2). The purpose of this assessment is to assist county planners, elected officials, and other local departments in the management of the county's wildland-urban interface (WUI). Understanding wildfire risk within the WUI is of particular concern to Missoula County given that a significant portion of the county's wildland-urban interface (WUI), more than 90 percent, has yet to be developed.[1] Unlike many other mapping assessments, such as US Forest Service Wildfire Risk Assessments and other agency modeling efforts, outcomes from this wildfire risk assessment are not intended to inform forest management decisions or improve forest health. This assessment's explicit purpose is to guide decision-making and land use planning processes within the county's WUI and areas within communities at high risk to wildfires.

To complement the wildfire risk assessment, Headwaters Economics also generated a predictive analysis of residential building patterns within Missoula County. This model identifies likely areas of future growth based off historic development trends over the past one hundred years. Together, the wildfire risk assessment and the predictive residential build-out model provides the county with a better understanding of areas most at-risk of wildfires and impending development pressures.

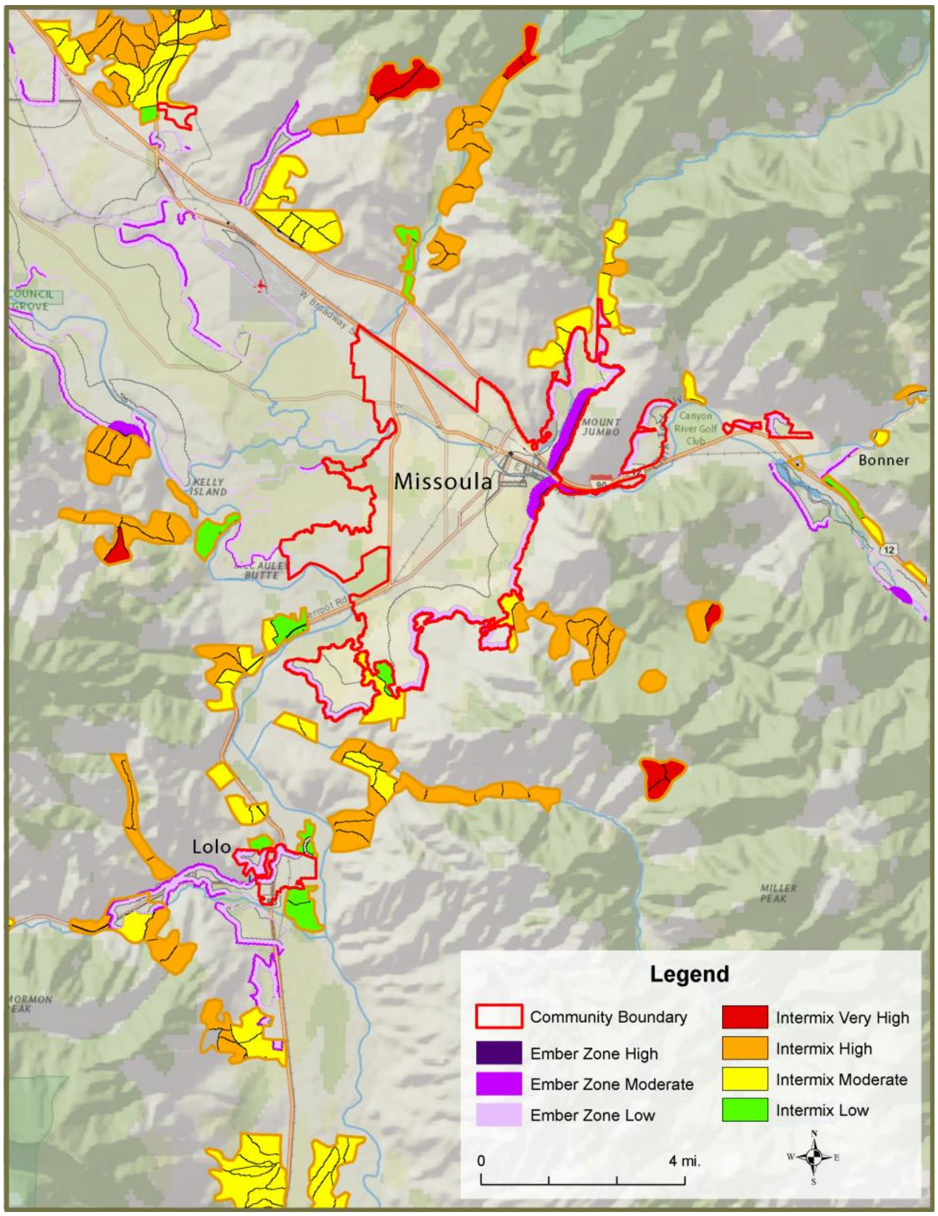
This reference document assists in the interpretation of the wildfire risk assessment and the predictive residential build-out model. Following a brief description of Missoula County's wildfire history and community background, detailed metadata is provided for both modeling efforts. This document should accompany explanation of the modeling results and application of mapping outcomes.

PROJECT OVERVIEW

The Community Planning Assistance for Wildfire (CPAW) program stemmed from an earlier project launched in Summit County, Colorado in 2014. Over the course of a year, Headwaters Economics worked with land use planners, community leaders, and city officials in Summit County to identify wildfire risk reduction measures and integrate them into county land use planning strategies. A suite of recommendations was provided to the county for incorporation into their planning and development processes (read full report here).[2] The success of the Summit County pilot project led to the funding and implementation of similar wildfire risk reduction efforts in five additional communities in the West, including Missoula County, Montana (other communities included Bend, OR, Taos, NM, Wenatchee, WA, and Austin, TX). Collectively known as the Community Planning Assistance for Wildfire (CPAW) program, each community varies in its approach and outcomes are tailored to meet site-specific wildfire risks and needs.

The wildfire risk assessment conducted in Missoula County provided two key datasets, including a Predictive Residential Build-Out Model and the National Hazard and Risk Model (No-HARM). The former model analyzed historic development trends from 1900 to 2013 to estimate future growth patterns between 2013 and 2023. The latter model is a wildfire hazard and risk assessment that analyzed wildfire risk to structures situated within the boundary of the built and natural environment, or the WUI. In combining these two models, county planners can identify where proposed developments are most likely to occur as well as the level of wildfire risk associated with existing and new developments.

Figure 2: Example of wildfire risk map for Missoula County.



COMMUNITY CONTEXT AND BACKGROUND

History of Local Wildfires

According to Missoula County's Community Wildfire Protection Plan (CWPP), one of Montana's most historic fires burned into western Missoula County in 1910 (Figure 3). Burning roughly three million acres, the Great Fires of 1910 killed 78 firefighters and scorched five towns. Some scholars credit the country's early wildland fire policies to the Montana and Idaho fires of 1910.[3]

Figure 3: Historic 1910 wildfires burned through the town of Lolo, Missoula County (source: USDA Forest History)

Since then, wildfires have destroyed homes near the City of Missoula on at least several occasions. In 1977, six homes were lost on the southeastern edge of the city during the Pattee Canyon fire (which burned 1,200 acres total). Later, in 1985, a 2,000-acre fire burned through Pattee Canyon again. In 2003, lightning sparked a fire on Black Mountain, burning 7,316 acres and threatened more than 650 homes. A few years later, in 2006 and again in 2008, Mount Sentinel burned (450 acres total). In 2007, the Black Cat Fire quickly became the fastest growing fire in Missoula's history, burning 12,000 acres over the course of two weeks. The most recent large fire was the West Riverside Fire in 2011, which burned more than 3,800 acres and cost $5.5 million in suppression efforts.[4]

Community Background

With an increasingly diverse economy and employment base, Missoula County continues to attract people and new industries. Since 1970, the county's population has grown 93 percent and is the second-most populated county in the state. Much of this change (62.6 percent) has come from domestic net migration, or people moving into the county from outside the area. With a population of more than 112,000 people as of 2014, Missoula County is projected to grow nearly 30 percent over the next 30 years.[5]

Missoula County's population growth has brought a significant rise in employment, increasing by more than 208 percent since 1970. Much of this growth is attributed to the services sector where there has been a 242 percent rise in jobs related to transportation, retail, finance, and other professional sectors over the past four decades. Comparatively, non-service-related jobs (i.e., forestry, manufacturing, agriculture, and mining) rose 64 percent during the same time period.

Since 1970, income in the county has also risen with employment and as the economy diversifies. For example, labor income grew from $964 million to $2.4 billion, or an increase of 155 percent. Comparatively, non-labor income, or retirement, transfer and hardship payments, and investment returns, rose substantially from $324.5 million to $1.9 billion, or an increase of 475 percent. Per capita income has increased 74 percent since 1970, with government jobs paying the highest wages and service-related jobs paying the lowest. The largest sectors of employment include trade,

Figure 4: The Smurfit-Stone Paper Mill, located in Frenchtown, was permanently closed in 2009, resulting in 417 lost jobs. The mill is now an EPA Superfund Site (Source: Missoulian).

transportation, and utilities, with jobs in the natural resources sector employing the least amount of people (Figure 4).

With respect to land ownership, Missoula County has more than 653,000 (39.7 percent) acres in private land and 991,058 acres in federal, state, and tribal lands. Forest Service lands constitute the largest federal landownership, comprising 42.4 percent of Missoula County.

Vast areas of public land alongside an expanding population base suggest high potential for growth within Missoula County's WUI. As of 2013, approximately 379 square miles of land or 7.7 percent of the county's land base, was considered the WUI. Of that, nearly 30 square miles (8 percent) is developed and contains more than 6,700 homes (13.5 percent of all homes in Missoula County; 1,269 are second residences). By contrast, a large majority of the county's WUI, more than 92 percent, remains undeveloped.

Given Missoula County's projected population trends and continued development patterns, the county's undeveloped WUI is primed for growth. This has important implications in light of wildfire risks. Indeed, when considering homes within the WUI most threatened by wildfire, Missoula County ranks among the top counties in the West. In 2010, for example, Missoula County was in the 89th percentile when assessed for both existing and potential risk of wildfires compared to the other 11 western states. Within the state, Missoula County is in the top 95th percentile for existing risk and 98th percentile for potential wildfire risk.

Local Planning Context

A variety of documents outline strategies for managing and preparing for Missoula County's ongoing growth. For instance, the County Planning Department is in the process of updating its Growth Policy Plan (2005), which is expected to be finalized by the summer of 2016. The Growth Plan seeks to balance the protection of natural resources and landscapes with the county's economic development and long-term sustainability.[6]

Additionally, there are several geographic-specific Land Use Plans for different districts within the county. For instance, the Lolo, Seeley Lake, Missoula Urban Area, and Swan Valley districts all have individual Land Use Plans. For areas not explicitly covered in one of the four district Land Use Plans, a regional land use guide was published in 2002 that outlines specific objectives regarding open space, infrastructure development and construction, land designations, and other land use planning standards.[7]

Several planning documents for emergencies, hazards, and natural disasters, including wildfire, are housed within the county's Department of Emergency Services, including an Emergency Operations Plan (2011), Pre-Disaster Mitigation Plan (2011), and a Community Wildfire Protection Plan (CWPP, 2005), which is slated for an update within the next two years. Outcomes of the wildfire risk assessment described herein will contribute to the next iteration of the CWPP, including new risk maps and the determination of low- to high-risk areas for wildfire.

Project Timeline

The wildfire risk assessment for Missoula County was initially proposed by Headwaters Economics to Missoula County in August 2015. As part of this kick-off, Headwaters Economics convened an initial scoping committee of eight key contacts representing various levels of local, county, and state government, and federal land management agencies. A follow-up meeting took place in September to extend scoping efforts to contacts not included in the first kick-off meeting. Based on the positive reception from both of these meetings, a Memorandum of Understanding was formally signed between Missoula County and Headwaters Economics on October 23, 2015.

The modeling component of the wildfire risk assessment was contracted to Anchor Point Group, a modeling firm based in Boulder, Colorado. It is important to note that Anchor Point Group was requested by Headwaters Economics to generate a mapping product that would assist land use planners and other community leaders in their efforts to reduce wildfire risk within the WUI. In contrast to many existing wildfire risk modeling approaches, Anchor Point Group's wildfire risk assessment focuses explicitly on the county's built environment and is not intended to improve land management activities within the larger National Forest. For example, concurrent with Anchor Point Group's modeling assessment was another wildfire risk modeling effort for the Lolo National Forest. Conducted by the US Forest Service's Fire Modeling Institute, based at the Rocky Mountain Research Station in Missoula, the Lolo National Forest wildfire risk assessment enhances management decision-making within the forest and surrounding public lands. A separate document, entitled *A Comparison of Two Wildfire Risk Modeling Approaches in Missoula County, Montana*, identifies commonalities and differences between the two assessments with respect to audience, purpose, and scale.[8] It was co-authored by Headwaters Economics, Anchor Point Group, and the Rocky Mountain Research Station Fuels Modeling Institute.

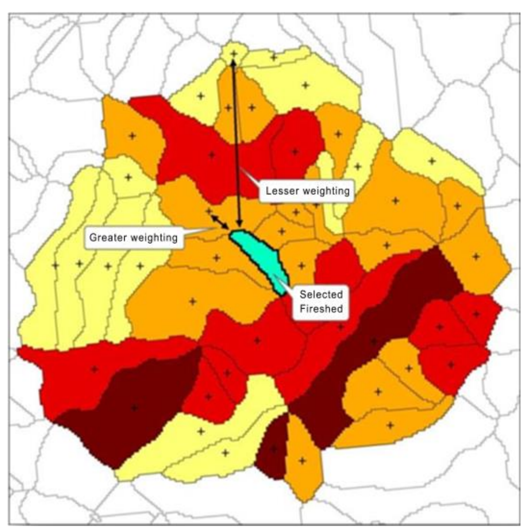
NATIONAL HAZARD AND RISK MODEL (NO-HARM)

Anchor Point Group references their community wildfire risk assessment as the National Hazard and Risk Model (No-HARM). No-HARM is as a nationwide wildfire hazard and risk assessment tool, but it is tailored to the particularities of a community setting and site-specific geographies. Anchor Point Group analysts work with on-the-ground fire experts to procure localized data sets and calibrate the No-HARM analysis to reflect the local wildfire landscape.

The No-HARM model incorporates the predicted severity (hazard) and the predicted frequency (risk) of wildfire in any given location, generating a comprehensive view of wildfire risk within the context of a structure's exposure. Information about individual structures such as construction type or presence of defensible space is not available, however, and only the landscape around a structure is assessed within the No-HARM analysis.

To model wildfire risk at the county scale, No-HARM divides the complete area of analysis into individual polygons known as "FireSheds." Each FireShed exhibits distinct topographical characteristics, such as aspect and slope, and have discrete, non-overlapping boundaries. FireShed delineations are also based on similarities in vegetation, land cover, and the directions wildfires will predominantly burn in the absence of wind. In this way, almost the entire county is disaggregated into separate Fire Sheds with each FireShed ranging in size from around 50- to 250-acres. The areas of exception include concrete parking lots, the inner urban core, and other features on the landscape that are resistant to wildfires due to the lack of continuous fuels.

Figure 5: The No-HARM model analyzes and weights wildfire risk for individual cells, defined as "FireSheds".



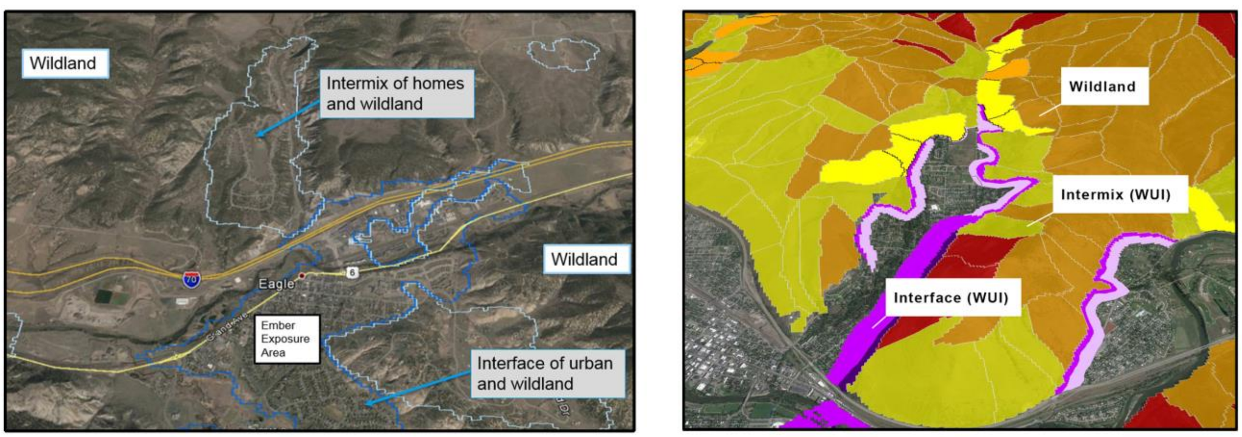
In analyzing wildfire hazard and risk for individual FireSheds, No-HARM also accounts for wildfire behavior in neighboring cells (Figure 5). For instance, a FireShed may contain mostly grass meadow but be surrounded by other FireSheds with dense forest. If a house is built in the meadow, it is not only exposed to the grass fuel within its own FireShed, but is also threatened from the timber fuel in the nearby FireSheds. As a result, No-HARM weights the collective risk from surrounding cells and incorporates it into the individual threat profile for each FireShed.

In addition to analyzing the county as an aggregation of FireSheds, No-HARM identifies three different modeling environments: **Wildland**, **Intermix**, and **Interface** (Figure 6). The modeling environments differ from one another with respect to the presence of the built environment (structures, roads, and other infrastructure) and the availability of wildland fuels.

The Wildland environment refers to a largely unpopulated landscape with minimal structures present, such as the National Forest and other public lands. Alternatively, the Intermix environment is where structures are moderately present with some homes situated directly within or near heavily timbered areas. By comparison, the Interface environment is characterized by areas bordering the community boundary and is heavily populated. Properties and homes within the Interface are most threatened by flame impingement and ember cast.

To distinguish the Intermix from the Interface environment, the former refers to areas where housing and wildland vegetation intermingle while the latter refers to areas where housing is in the vicinity of a large area of dense wildland vegetation.[9] By definition both Interface and Intermix areas contain housing densities of at least one structure per 40 acres. Combined, the Intermix and Interface comprise what is commonly referred to as the WUI. Each of the three No-HARM environments is modeled with its own individual set of inputs and associated methodology.

Figure 6: The No-HARM wildfire risk assessment identifies three different modeling environments: Wildland, Intermix, and Interface (left image). Wildfire risk within these three modeling environments is displayed as individual data layers within ArcGIS and Google Earth (right image).



Wildland Modeling Environment

The Wildland module characterizes areas containing relatively continuous fuels with limited presence of structures, roads, and other human-caused disturbances. Relatively few people live in the Wildland environment, which limits human-caused types of ignition sources. However, any structure located within these areas is surrounded by fuels such as dense timber, brush, and grasses. Depending on weather and topographical conditions, both accounted for in No-HARM, suppressing wildfire can be difficult. Potential mitigation measures typically focus on treatment of the vegetation immediately surrounding a structure and hardening (making wildfire-resistant) the structure itself. Wildfires occurring in the

Wildland will typically burn uninterrupted until conditions are no longer favorable or until the wildfire moves into less volatile fuel.

The relative absence of the built environment in the Wildland module means the risk factors are mostly related to the fuel, topography, typical weather patterns, and historical wildfire occurrences within the area. The one recognition of suppression capabilities in this module is the distance to the nearest fire station.

Factors within the Wildland modeling component include:

- FIRESHEDID – Unique identifying number associated with individual FireShed polygons.
- RISKDESC – This field measures the overall wildfire risk specific to individual FireSheds. There are four descriptive categories of risk: Wildland Low, Wildland Moderate, Wildland High, and Wildland Very High (see below under "RISK50" for numeric equivalent). This is the suggested category to reference when the data is being used for an overview or when demonstrating No-HARM to an audience unfamiliar with wildfire hazard and risk rating systems.
- RISK50 – Referencing the numeric value of risk description (above), this field provides added detail about FireShed risk. As with the other fields, values within this category span a scale from 0 to 49. Risk ranking and risk description are symbolized as follows:
  - 0-9: Low Risk
  - 10-23: Moderate Risk
  - 24-35: High Risk
  - 35-49: Very High Risk
- SEVERITY – This module input estimates the degree of severity that wildfire behavior would exhibit in the event of an ignition. Factored into this estimate is the topography (slope, aspect and elevation), the prevailing weather patterns in the area (based on weather readings at stations located nationwide), and the fuel type present (40 different subsets of timber vegetation, brush, and shrub types). Severity is measured on a scale of 0 to 49, with 0 implying the lowest severity and 49 representing the highest severity.
- FREQUENCY – Together with severity, frequency captures the likelihood of future wildfires based on their occurrence in the area in the past. Frequency uses a simulation-focused approach to determine predictive probability. Similar to the approach used for SEVERITY, a fire can be modeled on the landscape based on topography, weather, and the presence of fuels. Since it is unknown exactly where an ignition will occur, past general patterns of ignitions are used to predict possible future fire occurrence. For instance, if a region has historically had multiple wildfires, many ignitions will be started in random locations within that region. The computer model then allows these simulated wildfires to burn and the corresponding locations of burn areas (within the simulated parameters) is recorded. After a large number of simulated fires, a pattern emerges identifying locations where wildfires are likely and unlikely to burn. This pattern is not based explicitly on previous fires locations, but is a representation of what is likely to happen on the landscape as it exists now (using existing topography, weather, and fuel types). SEVERITY is ranked on a scale of 0 to 49, with 0 representing the least frequent occurrence to 49 as the most likely occurrence of a future wildfire.
- FSTATPROX – This field, measuring the distance to the nearest fire station, is the only human-related variable in the Wildland module. Structures located nearer to a fire station may have a greater probability of successful wildfire suppression or structure protection efforts. A 0 rating implies a fire station is relatively close (within a mile) and a rating of 49 indicates a distant fire station.

- CROWNFIRE – Crown fire activity, whether in isolated trees, isolated groups of trees, or the complete forest canopy, refers to the spreading of wildfire from treetop to treetop. Crown fire represents a worst-case scenario in terms of wildfire behavior. If crown fire activity is high, wildfires are likely to be fast moving, highly intense, and difficult to contain. Crown fires are enabled by strong winds, heavy fuel loading, and steep slopes.
- NONBURNABLE – The amount of non-burnable area (roads, bare ground, and concrete lots) will reduce fuel continuity and therefore the wildfire severity. A greater non-burnable area will increase wildfire risk, while high non-burnable areas mitigates wildfire risk.
- ACRES – The total acreage of individual FireSheds, based on ESRI ArcGIS calculations of polygon size.

In short, the Wildland component models the unbuilt environment where structures and homes are sparse. Calculated fields within the Wildland module provide the "baseline" profile of wildfire risk for all FireSheds. Other characteristics, such as road distribution and water availability, are added to this baseline analysis within the Intermix and Interface module. While the overall intent of the No-HARM assessment is to assist county-level planning around present and proposed developments, thus focusing more explicitly on the Intermix and Interface environment, mapping the Wildland landscapes provides valuable context with respect to where wildfires are likely to occur outside and proximate to the community's WUI.

Intermix Modeling Environment

The Intermix module is characterized by a moderate to high density of structures, roads, and other infrastructure that interrupts the continuity of fuels on the landscape. Threats to values-at-risk in this module focus not only on fuels, but also on the complexity of suppression in this environment. For instance, higher road densities allow better access for suppression resources, but they also introduce an element of potential confusion for ingress and egress. Suppression strategies in Intermix areas must account for groups of houses as opposed to single structures as might be encountered in the Wildland. Along with suppression complexities, the presence of higher population densities within the Intermix implies a higher risk of ignitions due to human-caused sources such as barbecues, fireworks, and matches. The Intermix module accounts for suppression factors and the presence of the built environment by adding more input data appropriate to this task.

Factors in the Intermix modeling component include:

- FIRESHEDID – Unique identifying number associated with individual FireShed polygons.
- RISKDESC – This field measures the overall wildfire risk specific to individual FireSheds. There are four descriptive categories of risk: Intermix Low, Intermix Moderate, Intermix High, and Intermix Very High (see below under "RISK50" for numeric equivalent). This is the suggested category to reference when the data is being used for an overview or when demonstrating No-HARM to an audience unfamiliar with wildfire hazard and risk rating systems.
- RISK50 – Referencing the numeric value of risk description (above), this field provides added detail about FireShed risk. As with the other fields, values within this category span a scale from 0 to 49. Risk ranking and risk description are symbolized as follows:
  - 0-9: Low Risk
  - 10-23: Moderate Risk
  - 24-35: High Risk
  - 35-49: Very High Risk

- SEVERITY – This module input estimates the degree of severity that wildfire behavior would exhibit in the event of an ignition. Factored into this estimate is the topography (slope, aspect and elevation), the prevailing weather patterns in the area (based on weather readings at stations located nationwide) and the fuel type present (40 different subsets of timber vegetation, brush, and shrub types). Severity is measured on a scale of 0 to 49, with 0 implying the lowest severity and 49 representing the highest severity.
- FREQUENCY – Together with severity, frequency captures the likelihood of future wildfires based on their occurrence in the area in the past. Frequency uses a simulation-focused approach to determine predictive probability. Similar to the approach used for SEVERITY, a fire can be modeled on the landscape based on topography, weather, and the presence of fuels. Since it is unknown exactly where an ignition will occur, past general patterns of ignitions are used to predict possible future fire occurrence. For instance, if a region has historically had multiple wildfires, many ignitions will be started in random locations within that region. The computer model then allows these simulated wildfires to burn and the corresponding locations of burn areas (within the simulated parameters) is recorded. After a large number of simulated fires, a pattern emerges identifying locations where wildfires are likely and unlikely to burn. This pattern is not based explicitly on previous fires locations, but is a representation of what is likely to happen on the landscape as it exists now (using existing topography, weather, and fuel types). SEVERITY is ranked on a scale of 0 to 49, with 0 representing the least frequent occurrence to 49 as the most likely occurrence of a future wildfire.
- FSTATPROX – This field, measuring the distance to the nearest fire station, is the only human-related variable in the Wildland module. Structures located nearer to a fire station may have a greater probability of successful wildfire suppression or structure protection efforts. A 0 rating implies a fire station is relatively close, within a mile, and a rating of 49 indicates a distant fire station.
- TOTPTS – This is the total number of points aggregated from all of the fields listed within the Intermix module. The negative or positive value of the aggregated calculation will either add or subtract from the initial baseline risk value (calculated using SEVERITY, FREQUENCY and FSTATPROX). A negative total is associated with low wildfire risk (and the presence of high mitigating factors) and a positive value implies a higher level of wildfire risk (and the minimal presence of mitigating factors).
- ASPECT – The direction and orientation of a slope can influence hydrological conditions (how wet or dry) as well as temperature variations. For instance, in the northern hemisphere, south-facing slopes will typically be drier than north-facing slopes. This can have a large impact on the density of fuels and severity of wildfire behavior in the event of an ignition.
- CONTINUITY – Fuel continuity refers to the degree of continuous or uninterrupted distribution of fuels within an area, which affects a wildfire’s ability to sustain combustion and spread. Low fuel continuity implies a decrease in the ability for the wildfire to distribute across the landscape and is a mitigating factor. Alternatively, high fuel continuity will enable a wildfire to quickly intensify and spread.
- CROWNFIRE – Crown fire activity, whether in isolated trees, isolated groups of trees, or the complete forest canopy, refers to the spreading of wildfire from treetop to treetop. Crown fire represents a worst-case scenario in terms of fire behavior. If crown fire activity is high, wildfires are likely to be fast moving, highly intense, and difficult to contain. Crown fires are enabled by strong winds, heavy fuel loading, and steep slopes.
- GOLFCOURSE – Golf courses are heavily irrigated areas that serve as fuel breaks since they are very unlikely to burn. However, structures located on a golf course can still be threatened by embers and flames from adjacent fuels. Within No-HARM, a “low” golf

course characterization implies the lack of a nearby golf course. By contrast, a "high" categorization suggests there is a golf course within close proximity and thus a potential fuel break and mitigating factor in the overall risk ranking.

- ROADDIST – The distance to the nearest primary road will impact access by suppression resources and ease of evacuation. A "high" road distribution identifies direct access to the FireShed and reduces the overall risk ranking. Alternatively, a "low" road distribution characterizes minimal to non-existent access to the FireShed.
- SLOPE – Higher slopes make suppression operations more complex, less effective, and will increase overall wildfire behavior. Higher slopes also make mitigation operations more costly and difficult to complete. Therefore, high slope categories suggest higher wildfire risk and vice versa with low slope identification.
- WATERDIST – Having a rural water source such as a lake, river, or reservoir near any given area will increase the effectiveness of suppression operations. Having water sources close by will allow suppression equipment and apparatus to be filled more frequently on a quicker turnaround. A high categorization of water distribution therefore suggests high water availability and mitigates wildfire risk. Hydrant systems are not factored into No-HARM.
- VEGCOVER – Vegetation Cover, a measure of the continuity of fuel, is important because wildfire will burn greater areas with continuous fuels than areas that are interrupted by patches of bare ground, all other things being equal. Vegetation cover is closely associated with the Continuity field, thus a high vegetation cover implies wildfire will move across the landscape with greater severity and speed than with low vegetation cover.
- ACRES – The total acreage of individual FireSheds, based on ESRI ArcGIS calculations of polygon size.

The Intermix area references the convergence of the human-built environment and natural unbuilt environment. Within the wider body of literature, this zone in combination with the Interface zone described below is commonly referred to as the WUI. The Intermix is distinguished from the Interface by structure density and vegetation cover. For most land use planners, city officials, and other land management agencies, the Intermix and Interface areas will be of most interest because together they define the area where homes and infrastructure are most vulnerable to wildfires.

Interface Modeling Environment

The Interface module is characterized by densely populated areas and many structures and roads. These human-built disturbances break up the landscape and reduce the presence of vegetation cover and fuel continuity. Unlike Wildland and Intermix areas, homes and buildings within the Interface are primarily threatened by flame impingement (direct contact by flames) on one or two sides, as well as ember cast and smoke from adjacent areas. While No-HARM does not assess individual structures for flammability, the Interface component does identify different zones or "tiers" of ember threat.

Factors in the Intermix modeling component include:

- FIRESHEDID – Unique identifying number associated with individual FireShed polygons.
- RISKDESC – This field measures the overall wildfire risk specific to individual FireSheds. There are four descriptive categories of risk: Interface Low, Interface Moderate, and Interface High. This is the suggested category to use when the data is being used for an overview or when demonstrating No-HARM to an audience unfamiliar with wildfire hazard and risk rating systems.

- RISK – Risk to structures within the Intermix is defined by the proximity of fuels and the likelihood of ignition. Corresponding values for risk are as follows:
  - 0: High
  - 1: Moderate
  - 2: Low
  - 3: Smoke only and thus no identified risk to the structure.
- TIER – This refers to the type of threat present when considering if structures are exposed to direct flame impingement, embers, and/or smoke. Categories and approximate linear distances of each tier from the community's edge (in feet) for this field include:
  - 1: Flame impingement, embers, and smoke (up to 600 feet),
  - 2: Embers and smoke (up to 2000 feet), and;
  - 3: Smoke (up to 1 mile).
- ACRES – The total acreage of individual FireSheds, based on ESRI ArcGIS calculations of polygon size.

The Interface classification is helpful when considering homes, buildings, and critical infrastructure at risk to wildfires despite their location within more urban settings. Indeed, it is estimated that 70 to 90 percent of homes that burn are ignited by embers[10]. Winds quickly transfer embers long distances. Embers can easily ignite a fire when they come into contact with vulnerable rooftops, decking materials, and exposed ventilation systems. The fire can then rapidly spread from one home to the next, consuming entire subdivisions and neighborhoods. The Interface module is thus a useful tool to identify those areas within the community most likely to burn given their proximity to ember zones and flame impingement, and where fire-resistant construction materials should be advised.

The three different modules—Wildland, Intermix, and Interface—are mutually exclusive and together provide a countywide assessment of wildfire risk. Both public and private lands are evaluated within the No-HARM model and no discrimination is made among different types of land ownership. However, for purposes of reducing wildfire risk within the WUI and built environment, the Intermix and Interface components are of most relevance to land use planning departments and other land management agencies concerned with structure location and community vulnerability.

FORECASTING COUNTYWIDE HOUSING PRESSURE

In a separate effort, Headwaters Economics developed a model predicting areas of future home development in Missoula County. The model indicates what lands may experience increasing development pressure in the near-term future. Input variables for the model were based on county tax assessor records, which are used for collecting property taxes and are a reliable data source.

For each county included in the residential forecasting model, Headwaters Economics collected the location and year-built for every single-family home. The tax assessors provided home locations in quarter sections which are 160-acre blocks of land delineated by the Public Land Survey Section (PLSS) System. Headwaters Economics then generated a 10-year forecast based on development patterns from 2003 to 2013. The forecasts show where and how much development might occur by 2023. Given the wide variety of factors impacting the pace of home construction, such as national and global economic markets, it is more reasonable to view the forecast as an indicator of development *potential* rather than a prediction.

Headwaters Economics quantified the relationship between the listed factors and home construction using a statistical model called a negative binomial regression (Table 1). The Statistics Department at Montana

State University was consulted in the modeling selection process and identification of appropriate techniques. Headwaters Economics assessed accuracy by comparing the actual number of homes built per quarter section from 2003 to 2013 to the model estimates for the same period. Outcomes from this model include a map and corresponding geodatabase identifying areas where predicted home development is most likely.

Table 1: Factors Used to Forecast Home Construction in Missoula County	
Existing Housing	Housing already present
	Homes built in past decade
	Homes already present in surrounding 1 sq. mi.
	Homes built in past decade in surrounding 1 sq. mi.
	Homes built in past decade in surrounding 15 sq. mi.
Socioeconomic	Population density
	Per capita income
Access/Infrastructure	Near a large town (population > 10K)
	Distance to major roads
	Presence of roads
	Road density in surrounding 1 sq. mi.
	Travel time to towns
	Travel time to airports
Environment	Distance to water
	Mountainous

Accuracy of Model Results

Despite the fact that rural development occurs over a larger area, the model performs well in rural areas, defined here as *farther* than a 15-minute drive from the nearest population center with greater than 10,000 residents. The model correctly predicted whether or not homes would be built in 99 percent of rural quarter sections where no homes were present in 2003. For rural areas with homes already present, the model correctly predicted whether or not homes would be built in 81 percent of quarter sections. In both of these cases, the model was conservative, sometimes under-predicting growth in rural areas.

Alternatively, accuracy in the more urban areas was lower although still relatively high for locations without existing development (Table 2). For the locations *within* a 15-minute drive of population centers greater than 10,000 residents, the model correctly predicted whether or not homes would be built in 79 percent of rural quarter sections where no homes were present in 2003. For more urban areas with homes already present, the model correctly predicted whether or not homes would be built in 60 percent of quarter sections. In urban areas with existing housing, the model tended to over-predict new home construction.

Table 2. Percentage of model accuracy for rural and urban areas

Type of Area	Accuracy (%)
Rural, No Homes	99.30
Rural, Homes	81.20
Urban, No Homes	78.90
Urban, Homes	60.00

Observed changes in home counts from 2003-2013 were compared to model estimates for the same period.

The model is most useful for investigating what areas may be affected by different levels of development pressure in the near future. For example, in Missoula County, areas around the Rattlesnake, East Missoula, Lolo, and the Bitterroot Valley are likely to experience increasing growth based on historical development trends. Growth directly within city limits is also very likely in the coming decade. The total amount of forecasted growth is consistent with the amount of growth observed from 2003 to 2013. Since national and global economic trends impact the pace of home construction, the model is not useful for predicting specific home counts. It is more useful for examining where no homes, some homes, or many homes are predicted.

The data sets for the future residential development model can be interfaced with the wildfire risk assessment using ArcGIS. Scale compatibility is accurate to the smallest common unit of analysis (quarter-section or 160 acres). By overlaying the two models, it is possible to identify areas of concern where high wildfire risk overlaps high development potential. Alternatively, it is also possible to determine the most suitable areas for future growth based on low wildfire risk and high development potential. Together, the models inform county land use planners, elected officials, and other local leaders where wildfire and development are likely or not likely to coincide.

CONCLUSION

The information produced from the wildfire risk assessment and the predictive housing development model can assist in the planning of safe and responsible land development intended to reduce wildfire risk. County land use planners, local fire departments, and other land management agencies can view the maps to improve growth management and wildfire risk reduction within the WUI. All modeling data and related geodatabases are housed within the Missoula County GIS Department and are available to departments and agencies for planning purposes. Outcomes from both the wildfire risk assessment and the predictive housing development model serve to guide short and long-term decision-making efforts around land use planning within Missoula County’s WUI area.

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