MEMORANDUM

To:	Multnomah County
From:	Mike Sellinger, Bianca Popescu, Kelly Dunn, Rohan Oprisko, and David Wasserman, Alta Planning + Design
Date:	October 2024
Re:	East Multnomah County Systemic Safety Analysis Technical Memo DRAFT

Introduction

This systemic safety analysis examined the locations where there are crashes and the severity of the crashes, as well as contributing factors and crash types by relevant road users. The analysis investigated the traits of the parties involved, crash types (e.g., rear-end, broadside), preceding movements, unsafe behaviors, and other contributing factors like time of day, weather, or alcohol influence. In addition, the analysis investigated trends in contextual characteristics such as roadway speeds and volumes, intersection traffic controls, the presence of pedestrian and bicycle facilities, and the types of nearby land uses.

Focusing on severe injury and fatal crashes, these variables tell the story of the safety of roadway users and help to identify locations, contextual characteristics, and contributing factors that will influence project prioritization and countermeasure recommendations. The systemic safety analysis deliverables are summarized in the following sections:

1. Summary of Key Crash Trends
2. Crash Locations and the High Injury Network (HIN)
3. Equity Analysis
4. Spatial-Temporal Analysis
5. Crash Profiles and Crash Trees

Data Inputs

This analysis pulled data from the following sources:

- Crash data and reporting (including from ODOT and Multnomah County, 2013-2022),
- Roadway data (e.g., traffic volumes, posted speeds, number of lanes, bicycle and pedestrian facilities, etc.)
- Socioeconomic data
- Transit routes and ridership
- High Injury Corridors provided by Metro
- Breakdown of crashes and fatalities by severity, mode, time of day, and other factors
- Regional and jurisdictional trends

Executive Summary

All Mode Crashes

- The most severe crashes in East Multnomah County occur on the arterial network.
- For all crashes in the study area, vulnerable road users (people walking, biking, and using a motorcycle) were more likely to be involved in a serious injury or fatal crash.
- Serious injuries and fatalities spike in the winter months for all modes, with a larger spike in November possibly attributed to Daylight Savings Time change. This trend is especially stark for pedestrians and bicyclists at dusk and dawn.
- The majority of fatalities happen after dark, and of those after-dark fatalities, drug or alcohol impairment is involved in 83% of crashes. Alcohol and drug involved crashes appear disproportionately among fatal and severe injury crashes.
- Fixed object crashes on 35 MPH roads were found to occur disproportionately among fatal and severe injury crashes.
- Fatal and severe injury motorcycle crashes were found to occur disproportionately at intersections with a turning vehicle.
- For vehicle crashes, there is a significant number of crashes on every thoroughfare in the study area, particularly in central and western portions.
- Fatalities are distributed throughout the County but concentrated on Burnside Road and 181st Avenue, and are largely at intersections.
- Crashes have increased over time in the communities of Wood Village and Fairview.
- Crashes have increased over time at the intersections of NE Burnside Road & NE Division Street and SE 181st Ave & SE Stark Street. They are also located in equity priority areas.
- Crashes have decreased over time in the community of Troutdale and along Division Street.

Pedestrian Crashes

- In pedestrian-involved injury crashes, the most common cause is failure to yield the right of way and the second-most common cause is a pedestrian being illegally in the roadway.
- Darkness on roads with or without streetlights, with a full or partial sidewalk, was found to be a risk factor for pedestrian fatal and severe injury crashes.
- Fatal and severe injury pedestrian crashes were found to occur disproportionately at intersections with an improper maneuver by the driver.
- The highest concentrations of all pedestrian crashes are surrounding the intersections at NE Division & NE Cane Drive, NE Burnside Rd & NE Division, SE 182nd Avenue & W Powell Boulevard, and E. Burnside Street and SE 181st Avenue.
- High pedestrian crash corridors include SE Stark Street, Burnside Road, 181st, 182nd, and NE 162nd Avenues.

Bicycle Crashes

- Fatal and severe injury bicycle crashes were found to occur disproportionately at intersections with a turning vehicle, on roads with a dedicated bicycle facility.

- Bike crashes are concentrated in a few corridors particularly along 181st Avenue, Burnside Road, Powell Boulevard, NE Glisan Street, and segments of Powell Blvd, Kane Drive, and NE Halsey Street.

Summary of Key Crash Trends

Alta examined cross-tabulations of crash data prepared by Metro and observed the following trends:

Crashes by Mode

There were 8,474 crashes that occurred in the study area from 2013 to 2022. Compared to vehicle crashes, vulnerable road users (people walking, biking, and using a motorcycle) were more likely to be involved in a serious injury or fatal crash, as shown in **Figure 1**. Of the 417 pedestrian crashes, 22% were fatal or serious injury crashes, with 39 fatalities during this period. Of the 248 bicycle crashes, 10% were fatal or serious injury crashes, with 4 fatalities during this period. Of the 229 motorcycle crashes, 27% were fatal or serious injury crashes, with 1 fatality during this period. Of the 7,580 vehicle crashes, only 5% were fatal or serious injury crashes.

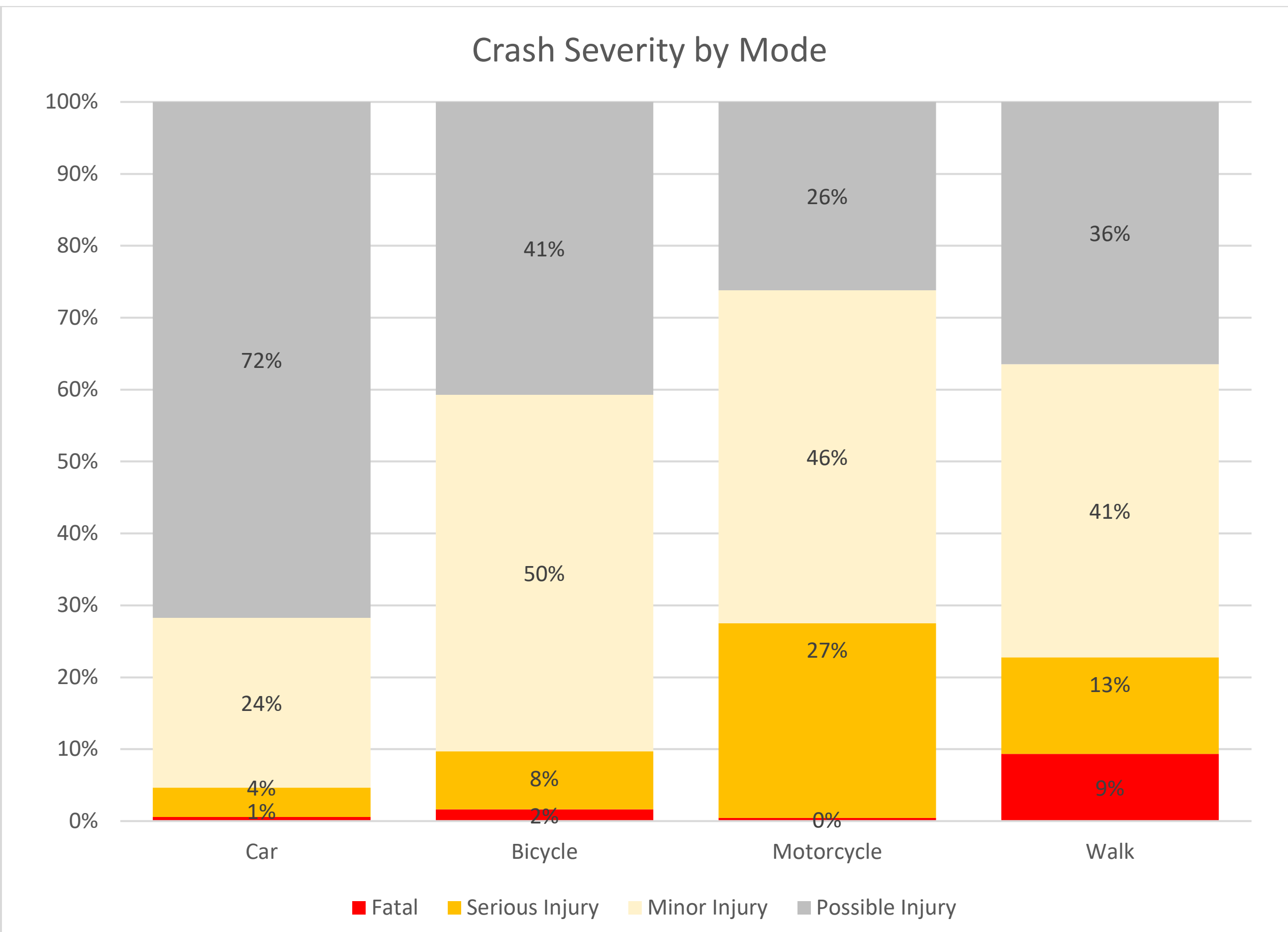

Figure 1: Crash Severity by Mode

Crash Trends by Month

Serious injuries and deaths spike in November and the winter months for both vulnerable road users and motorist-involved crashes, as shown in **Figure 2.**

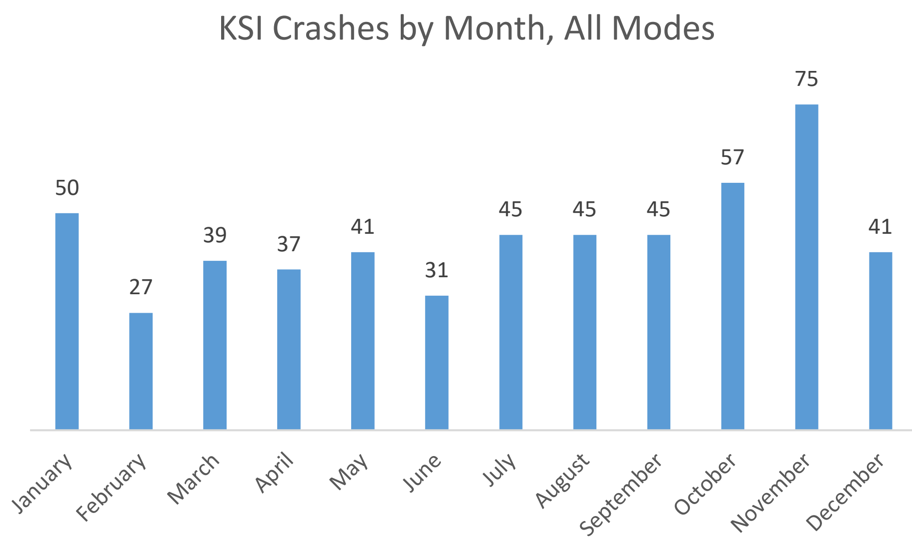

Figure 2: Severe and fatal injury crashes by month for all modes

This trend cannot be explained by longer dark hours alone, since darkness peaks in December. In fact, the trend toward November is accentuated when examining all injury crashes occurring at dusk and dawn, as shown in **Figure 3,** despite the fact that all months have approximately the same number of hours of twilight.

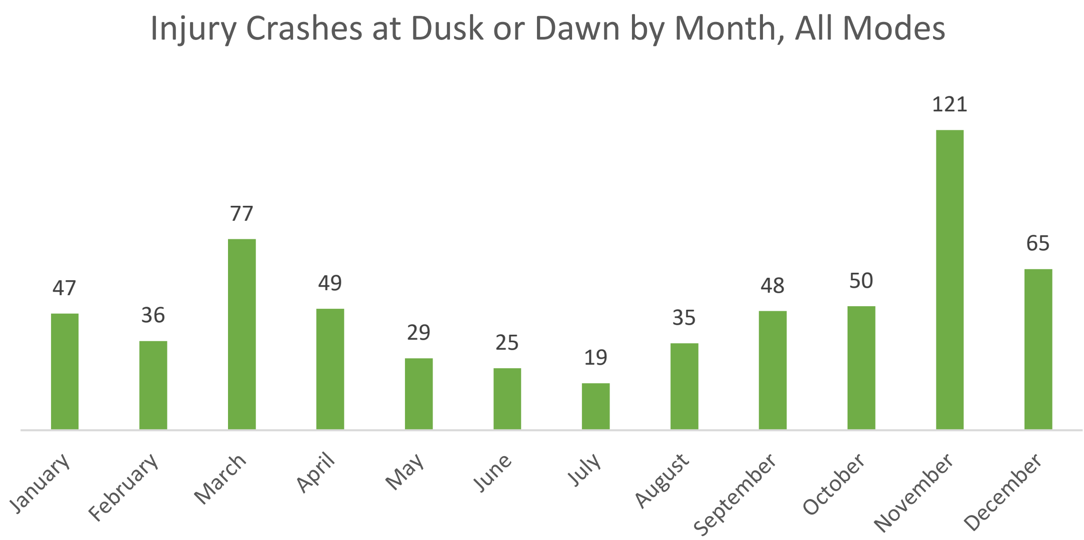

Figure 2: Crashes at dusk and dawn for all modes

Notably, there is another small spike in March. The trend coincides with the months of Daylight Savings Time beginning and ending, when the dusk and dawn hours suddenly shift into peak commuting times: In November, sunset shifts earlier from about 6pm to 5pm, whereas in March, sunrise shifts later from about 6:30 am to 7:30 am. The trend is particularly stark for bicyclists and pedestrians, as shown in **Figure 4.**

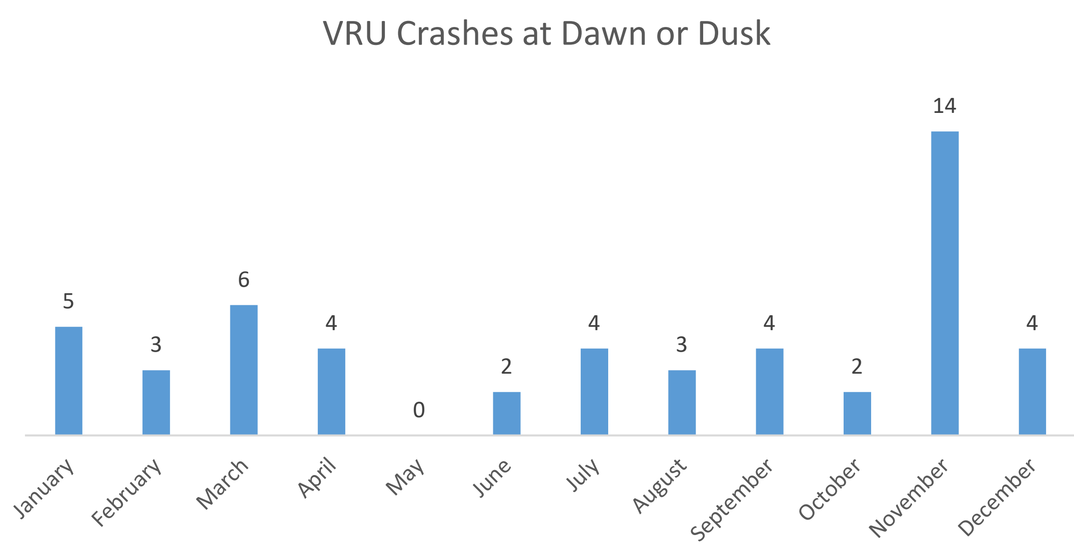

Figure 4: Vulnerable Road Users (VRUs) - bicycle or pedestrian crashes at dusk or dawn

Pedestrian Crash Trends

In pedestrian-involved injury crashes, the most common cause is failure to yield the right of way and the second-most common cause is a pedestrian being illegally in the roadway, such as crossing outside of a marked crosswalk.

Lighting

While most injury crashes overall happen during daylight hours, the majority of fatalities happen after dark. In 84% of after-dark fatalities, drug or alcohol impairment is involved (see **Figure 5**). This is much higher than severe or minor injury crashes after-dark with drug or alcohol impairment. In contrast, in 29% of after-dark severe injury crashes and 14% of after-dark minor injury crashes, drug or alcohol impairment is involved. Drug and alcohol impairment is significantly increasing crash severity in the study area, especially after dark.

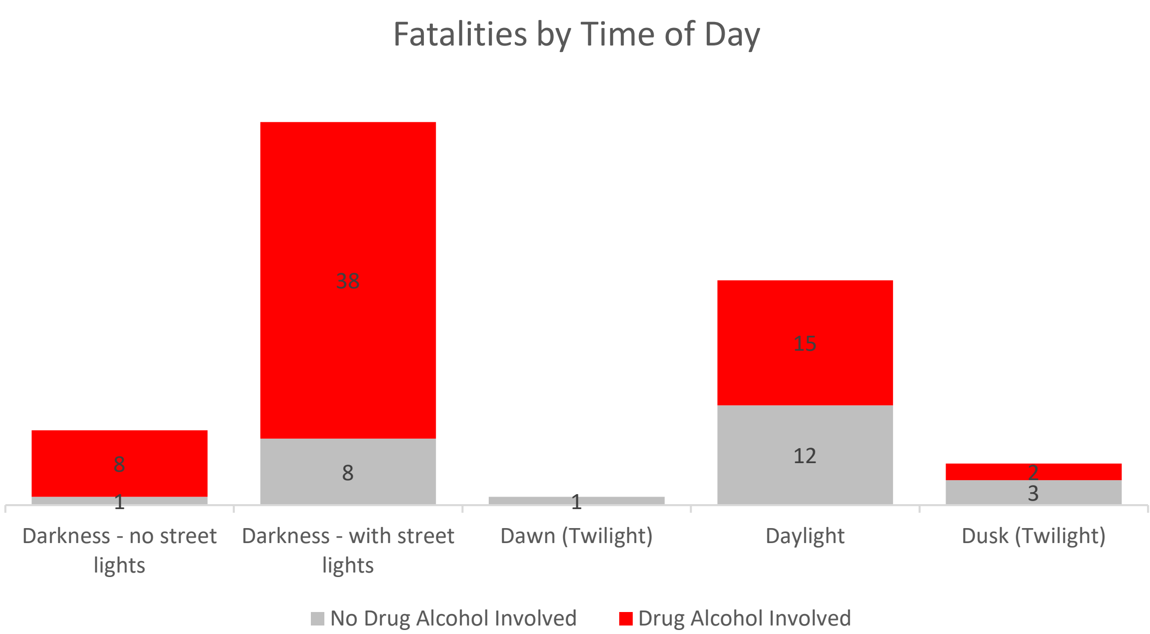

Figure 3: Fatalities by Time of Day

Crash Locations and the High Injury Network

The following section summarized the key findings from the initial data review (Task 3.3) and includes a crash analysis by mode and the regional High Injury Network (HIN) developed by Metro. This analysis used 10-year crash data and did not consider time-specific trends.

Crash Locations

The crashes in the study area were mapped by mode of travel and symbolized by injury and crash type. Additionally, a crash concentration index was developed for each mode that summarizes crash frequency and severity within a 0.2-

mile-wide hexagon grid[1]. Each hexagon's score is the sum of crash scores weighted by severity. Crashes were weighted on a simple downwards scale from five to one according to the KABCO crash classification[2]:

- Fatal Injury (K) = 5
- Suspected Serious Injury (A) = 4
- Suspected Minor injury Crash (B) = 3
- Possibly Injury Crash (C) = 2
- No Apparent injury/Property Damage Only (PDO) Crash (O) = 1

The key trends were summarized for each map.

Pedestrian Crash Analysis

Pedestrian crash points are mapped in **Figure 6** and pedestrian crash concentrations are shown in **Figure 7**. The highest concentrations of pedestrian crashes are at intersections distributed across the study area including NE Division & NE Cane Drive, NE Burnside Rd & NE Division, SE 182nd Avenue & W Powell Boulevard, and E. Burnside Street and SE 181st Avenue.

High pedestrian crash corridors include Stark Street, Burnside Road, 181st, 182nd, and NE 162nd Avenues, whereas pedestrian fatalities are concentrated on major thoroughfares, especially along the SE 181st and 182nd Avenues.

Some pedestrian fatalities are also identified directly along Highway 84 or on highway ramps, with the crash cause due to improper driving or pedestrian being illegally in roadway.

In the study area, the northwest portions have particularly high concentrations of severe crashes. This includes segments of E Burnside Street, SE 181st Avenue, and NE Glisan Street.

[1] Hexagons were chosen for this analysis, as they reduce sampling bias, better represent curved data outputs, and are better suited for analyzing connectivity or movement paths, among other aspects. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-whyhexagons.htm

[2] KABCO Injury Classification Scale and Definitions, FHWA. https://highways.dot.gov/media/20141

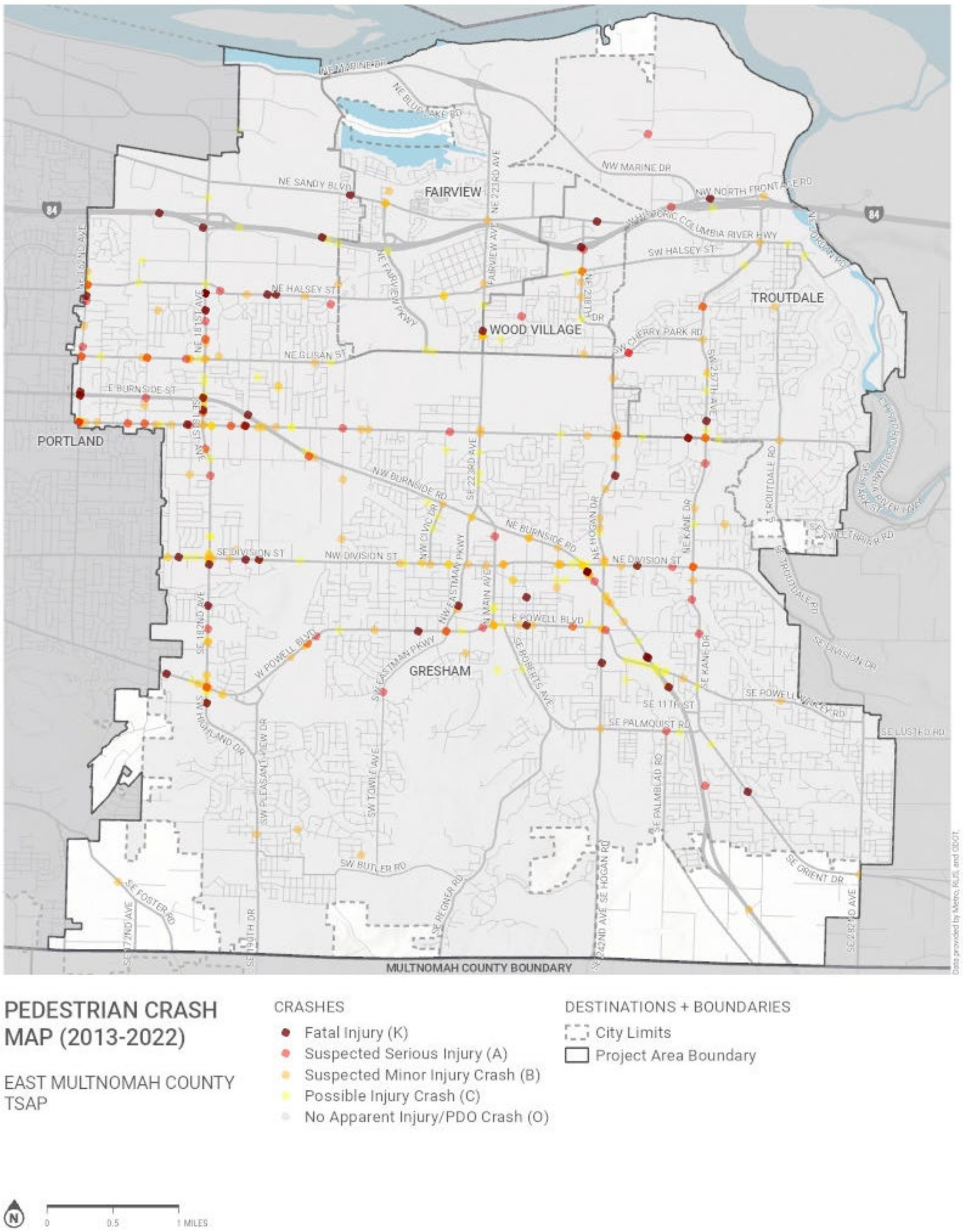

Figure 4: Pedestrian-involved Crash Points by Severity

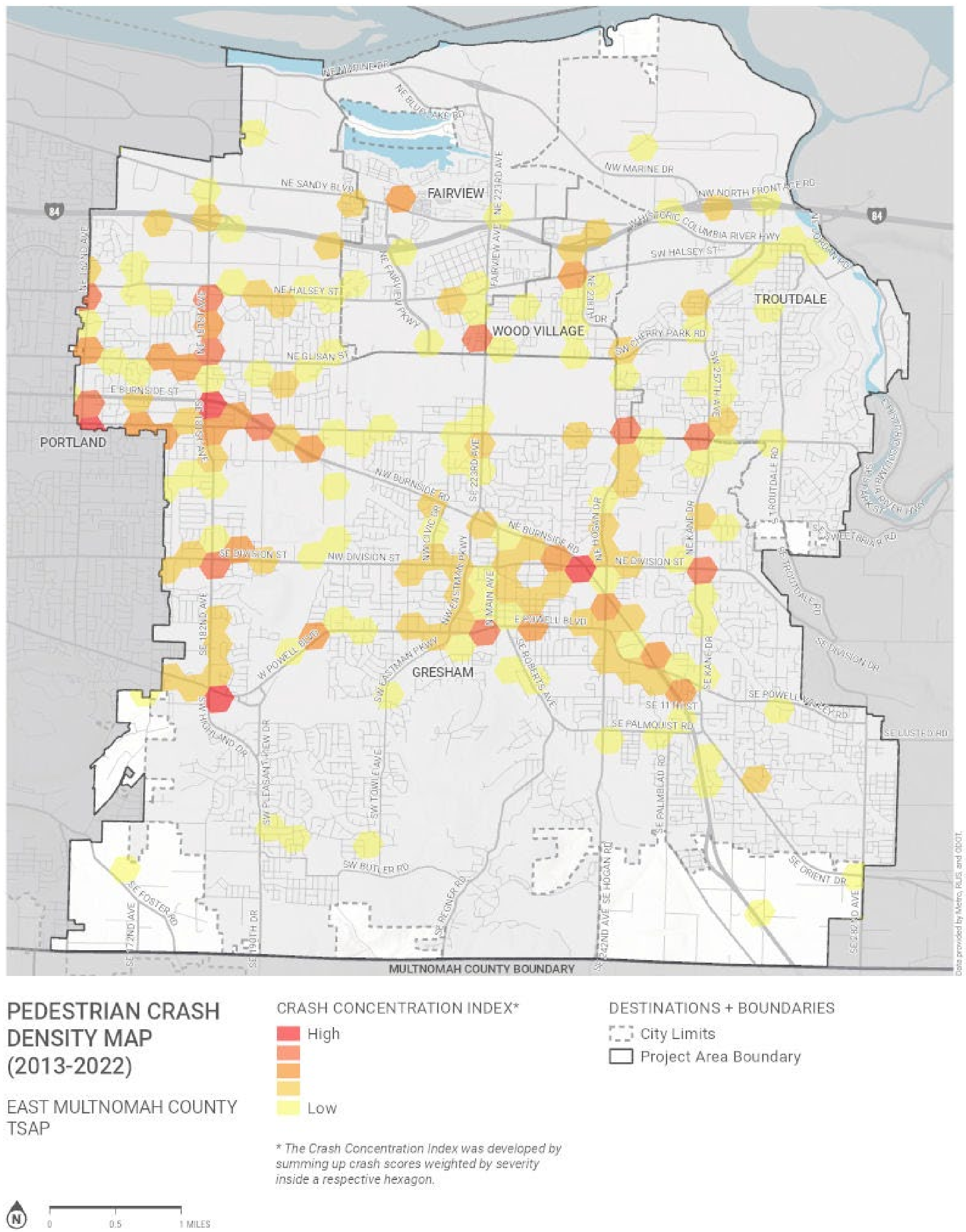

Figure 5: Pedestrian Crash Density, Weighted by Severity

Bicycle Crash Analysis

Figure 8 shows bicycle-involved crash points, while **Figure 9** shows weighted crash concentrations by hexagon. Bike crashes are concentrated in a few corridors particularly along 181st Avenue, Burnside Road, Powell Boulevard, and NE Glisan Street. The intersection of Burnside Road and Division Street has a particularly high concentration. Some other corridors of concern based on crash agglomerations include segments on Powell Blvd, Kane Drive, NE Glisan Street and NE Halsey Street.

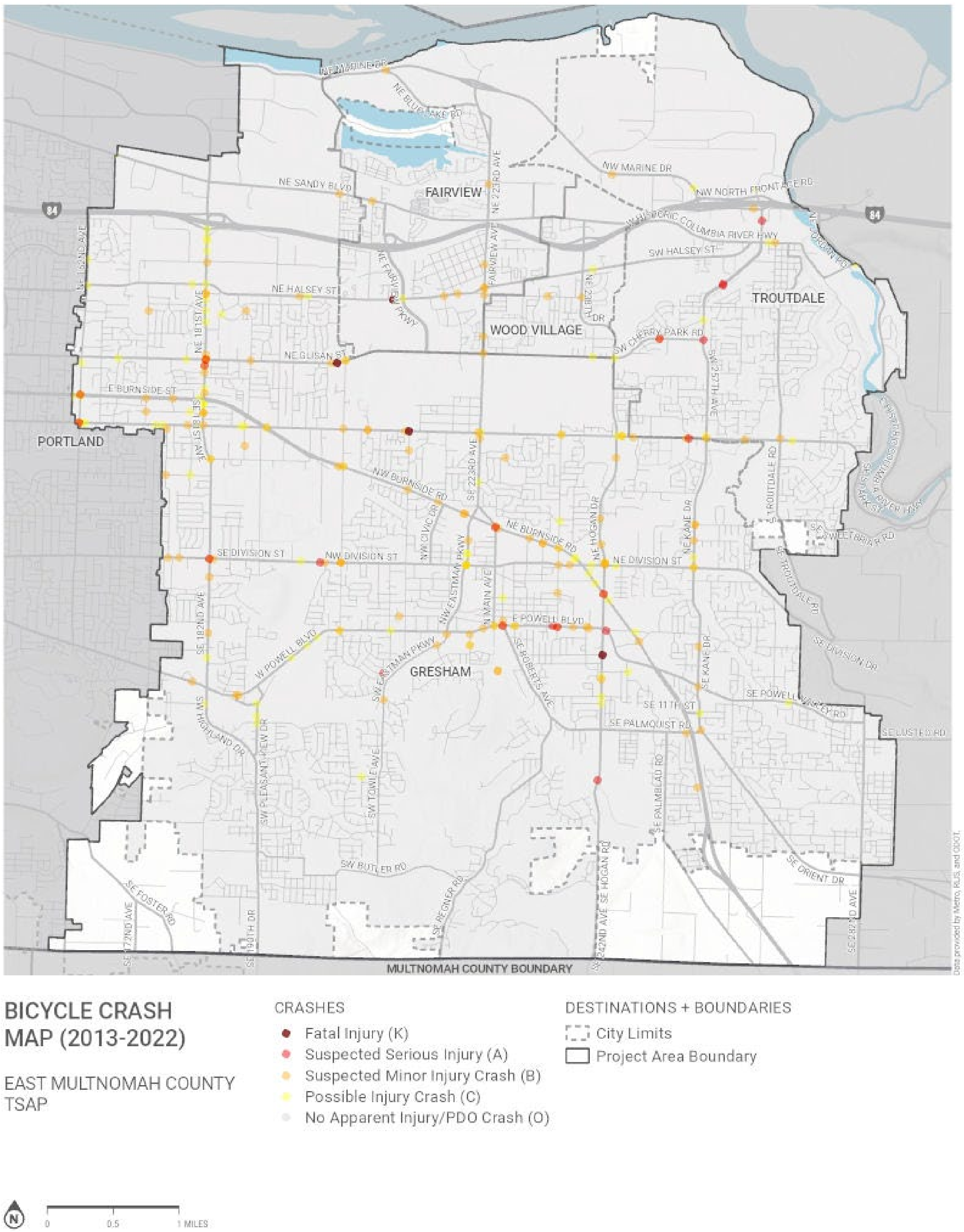

Figure 6: Bicycle-Involved Crash Points by Severity

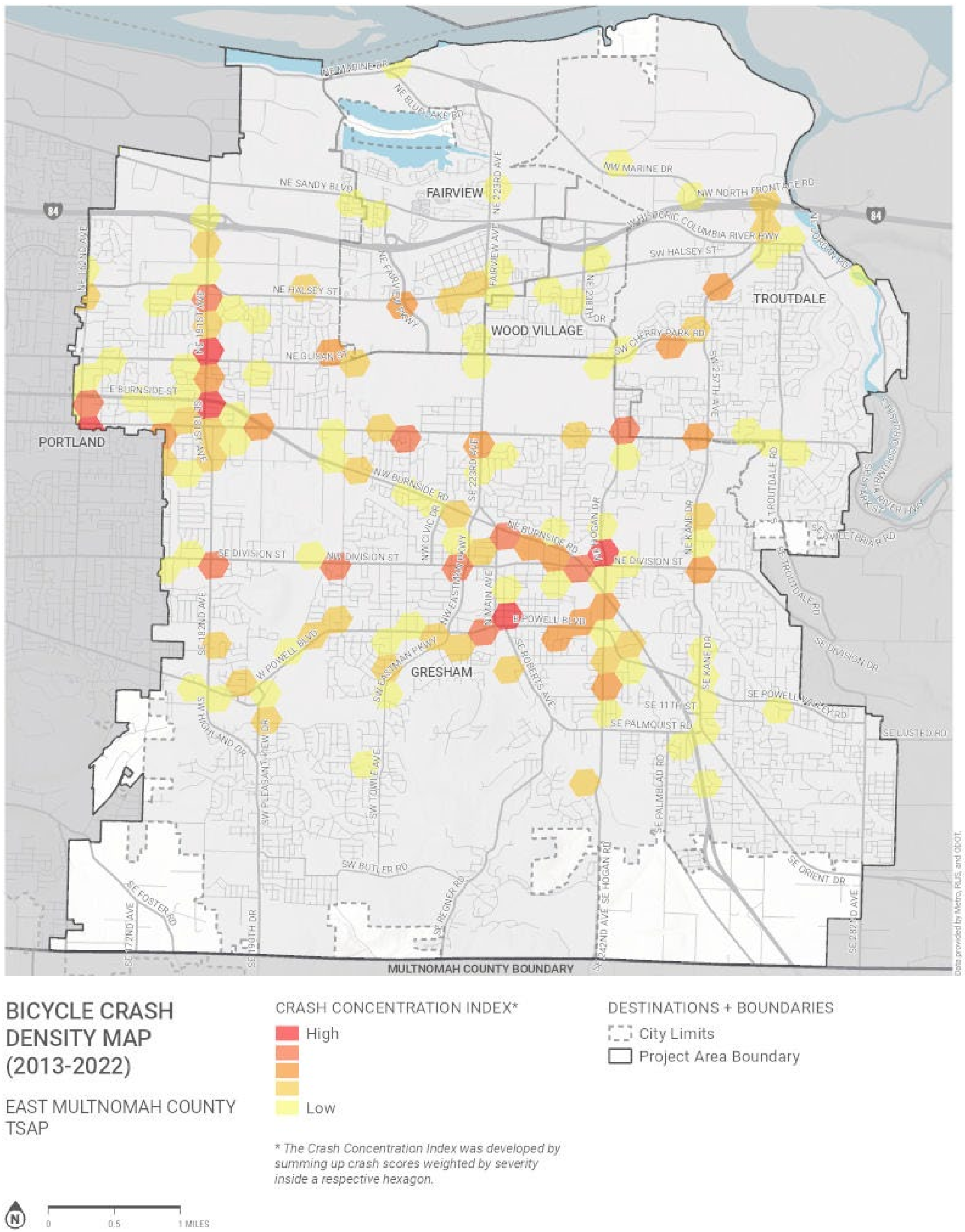

Figure 7: Bicycle Crash Density, Weighted by Severity

Vehicle Crash Analysis

Figure 10 shows vehicle crash points, while **Figure 11** shows weighted crash concentrations by hexagon.

There are a significant number of crashes on every thoroughfare in the study area, particularly in central and western portions. Fatalities are distributed throughout the study area but concentrated on Burnside Road and 181st Avenue. Fatalities throughout the county are largely at intersections. Minor injury crashes are distributed throughout the urban East Multnomah County.

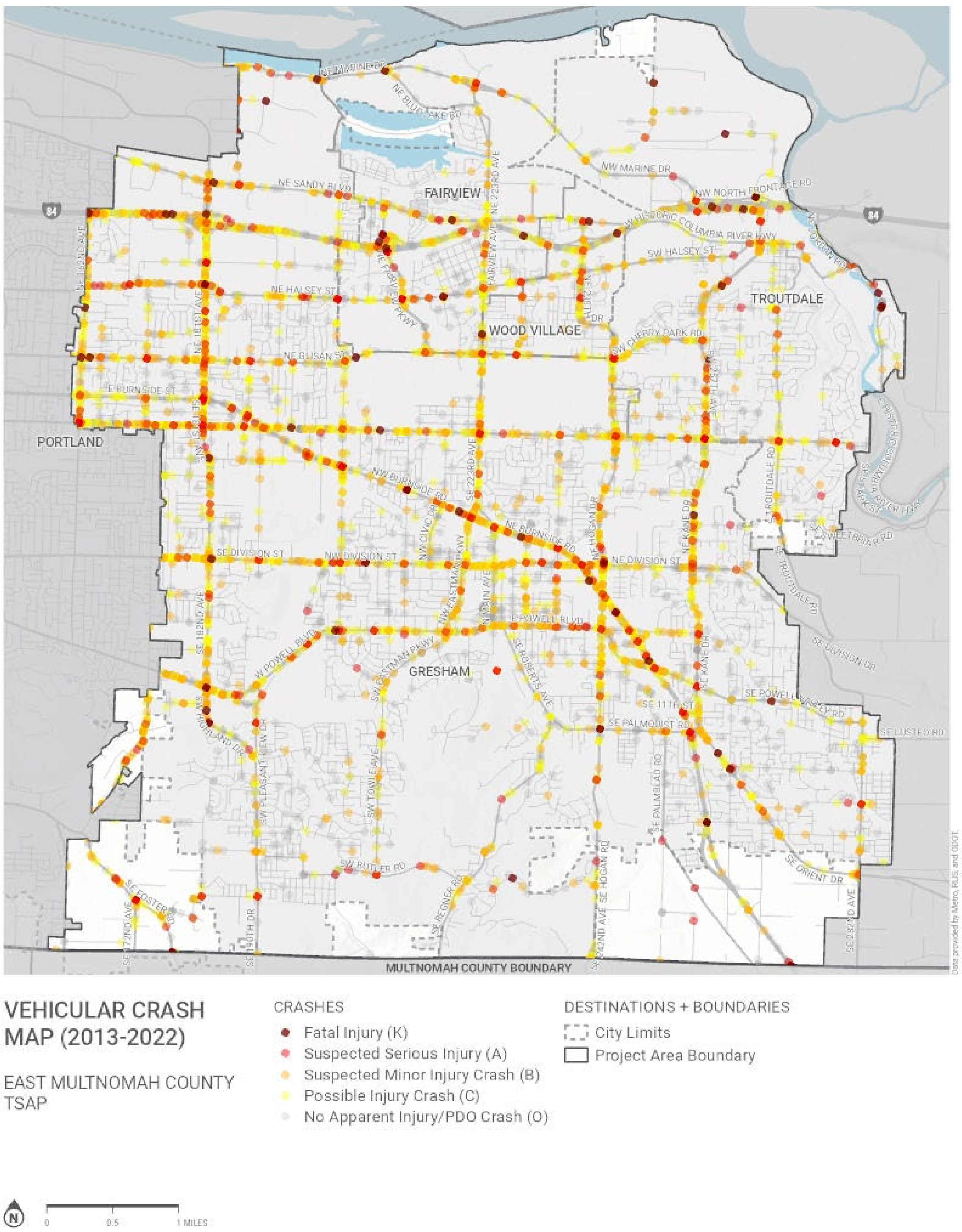

Figure 8: Vehicle Crash Points by Severity

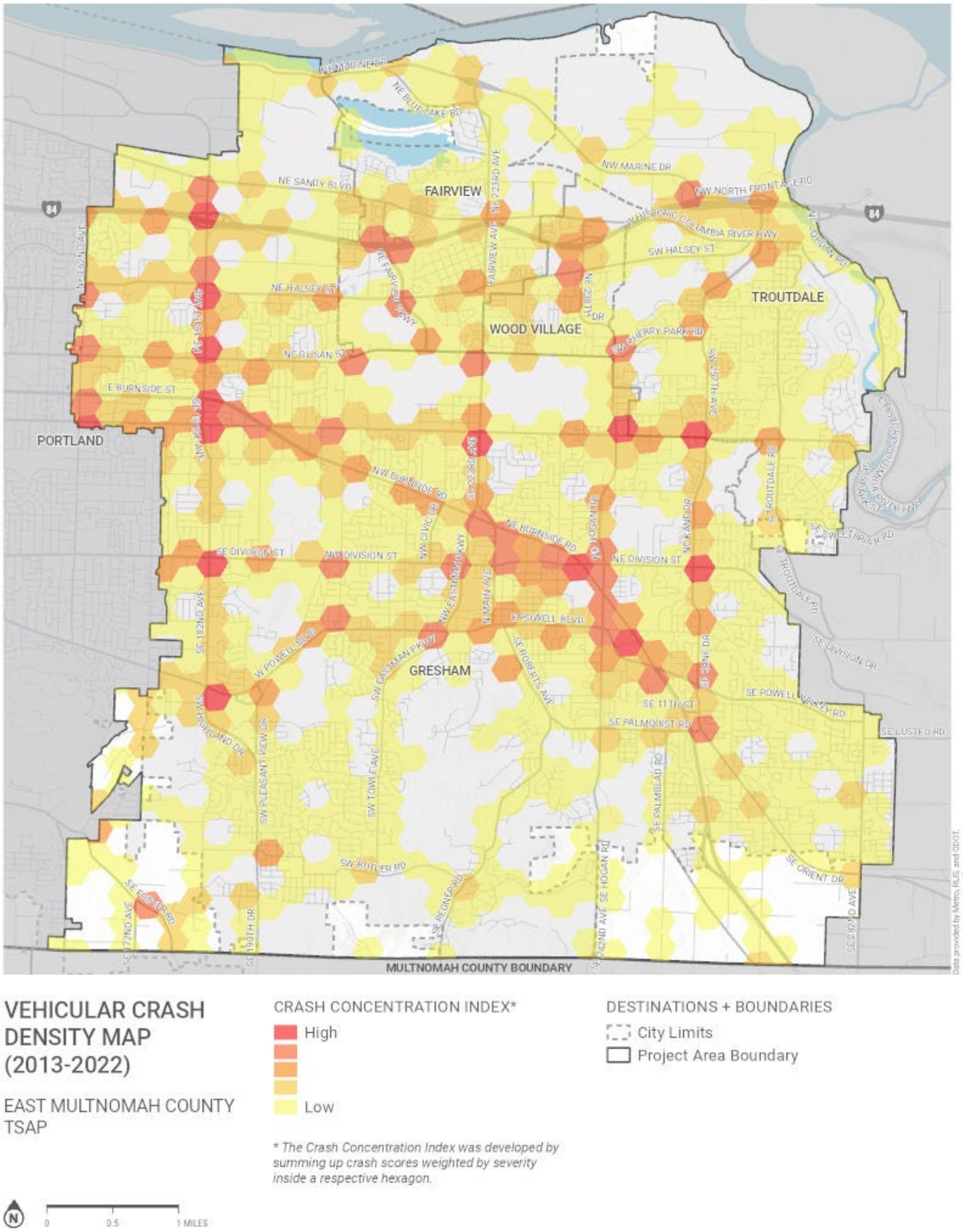

Figure 9: Vehicle Crash Density

All Modes Crash Concentration Analysis

The map featuring crashes of all modes together, shown in **Figure 12**, largely mirrors the motor vehicle crash map because they represent 89% of all crashes. Again, the highest concentration of any type of injury crash is found near Burnside Road and 181st Avenue. This is an intersection of two five- to six-lane arterials and a MAX station.

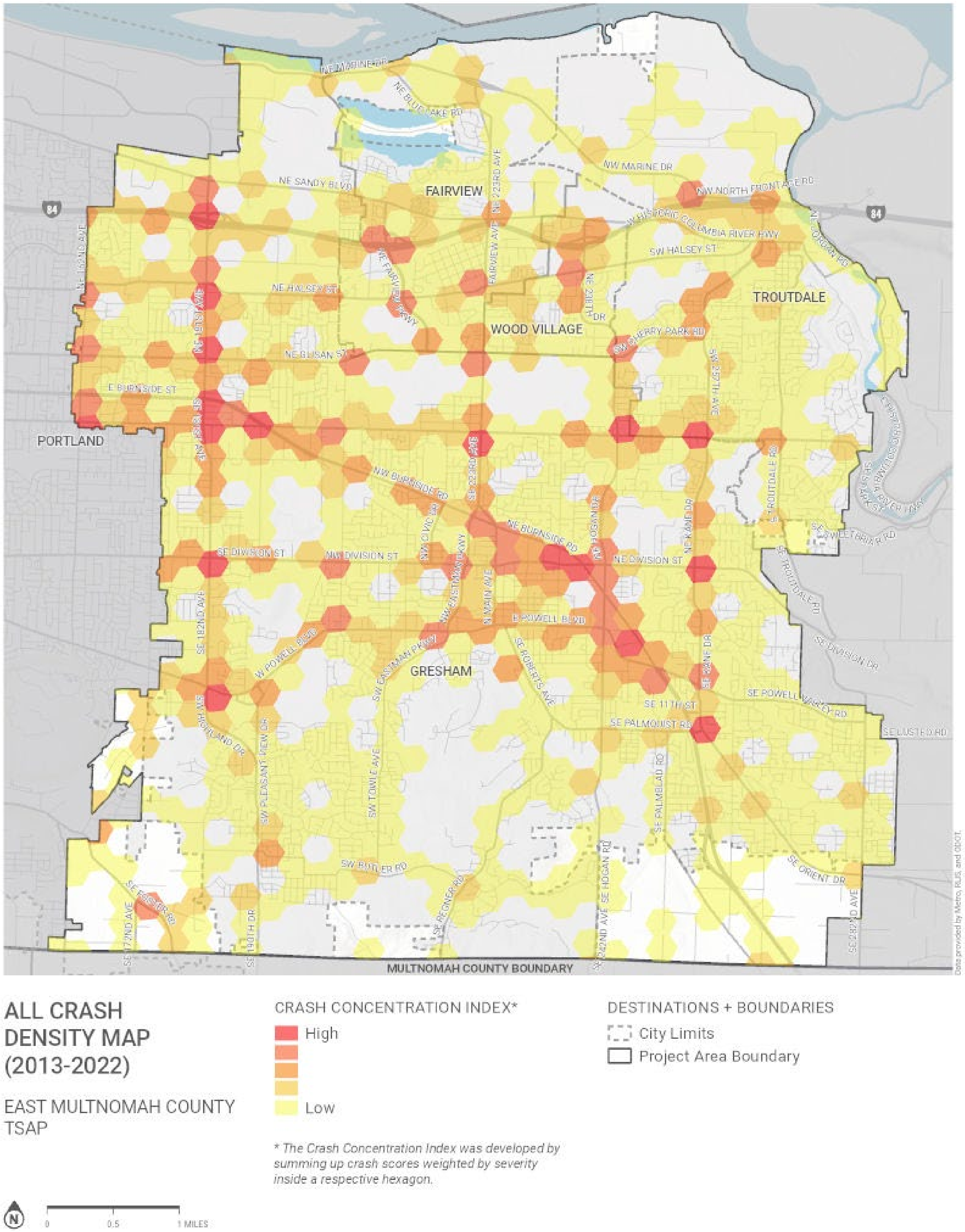

Figure 10: Crash Density, Severity-Weighted, All Modes

High Injury Networks (HIN)

Regional High Injury Networks

Figure 13 displays three mode-specific High Injury Network analyses completed at the regional scale by Metro: Bicycle, Pedestrian, and All Modes. The analyses identify the corridors with the most injury crashes throughout the greater Portland area. Roadways are scored based on the number of fatal and serious injury crashes per mile (or all injury crashes for bike and pedestrian high injury corridors). A roadway qualifies as a high injury corridor if the number of serious crashes per mile places it within the top 20 percent worst scores.[3] This map highlights only the portion of the analysis in urban East Multnomah County.

As shown, the regional HIN corridors are largely in the northern portions of the study area. Burnside Road, highlighted as an area of crash concentrations, appears on the HIN for each of the three modes.

The HIN highlights some different patterns than the crash analyses that are specific to East Multnomah County. Roads that do not rise to the top of crash rates for East Multnomah are still, when compared to the region, relatively high-risk.

[3] Metro High Injury Corridor Metadata

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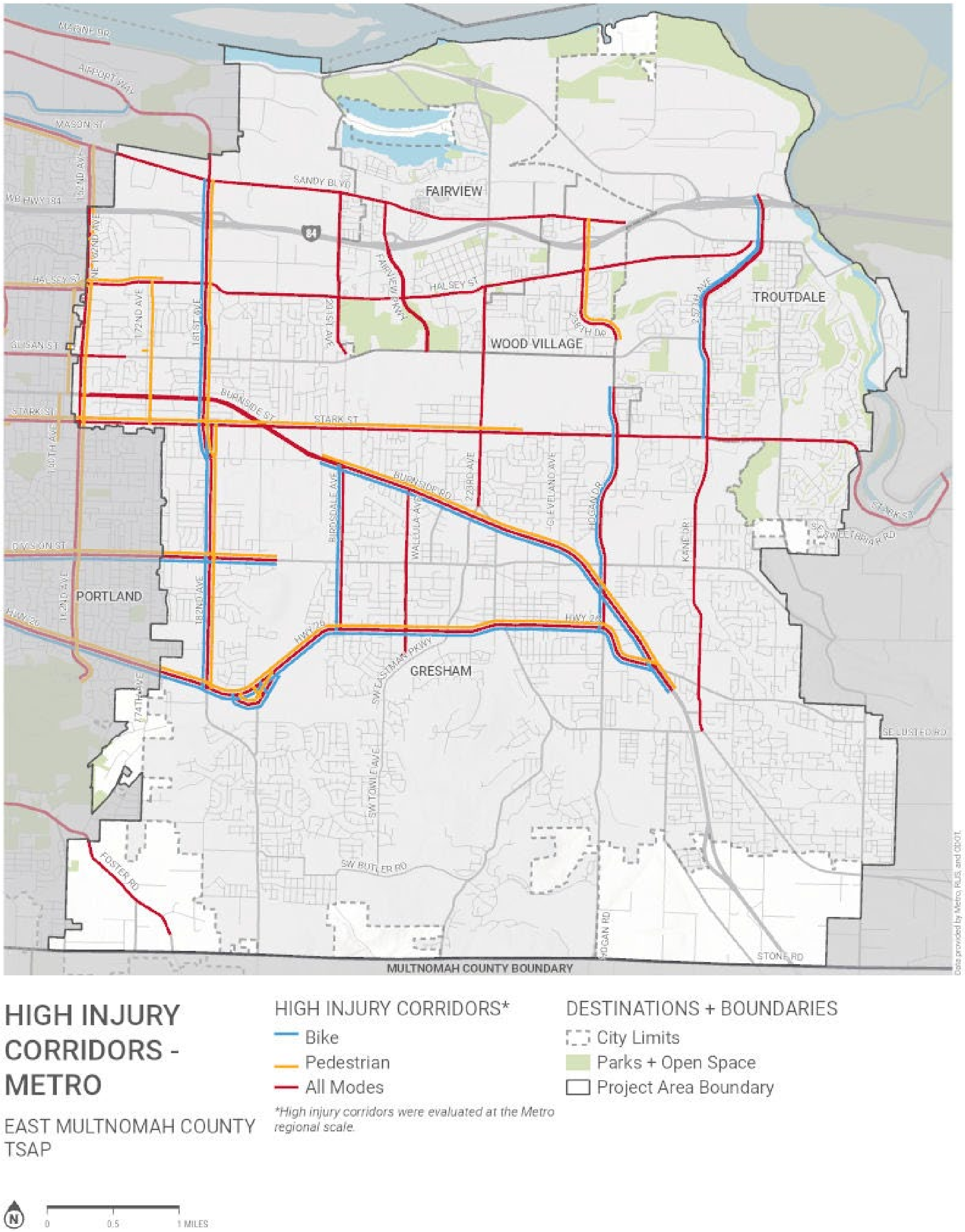

Figure 11: HIN analysis. Source: Metro

Equity Analysis

Justice 40 and Metro Equity Focus Areas

At the census tract level, Alta identified equity areas present in the U.S. Council on Environmental Quality Justice 40 and Metro datasets. This is shown in **Figure 14**.

Most of the census tracts in the East Multnomah County study area were identified as equity focus areas in either the Metro or Justice 40 datasets, with several being identified in both. Due to this, Alta developed a composite equity score to better prioritize census tracts, as described in the next section.

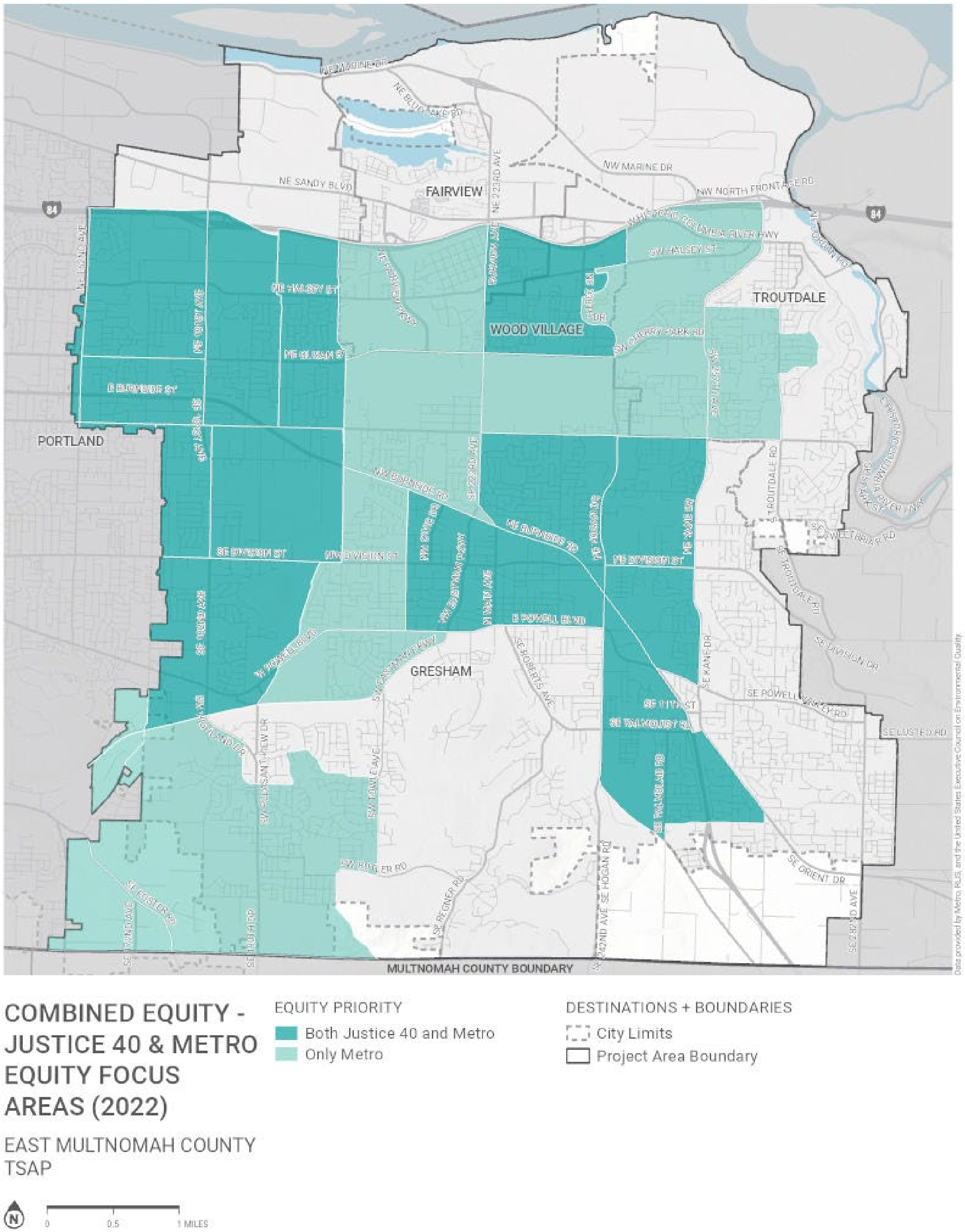

Figure 12: Combined Equity Focus Areas

Composite Equity Priority Map

Alta completed an equity analysis to identify areas of high equity priority in East Multnomah County. A composite equity score was generated using ten weighted variables as shown in **Table 1.**

Table 1: Equity analysis variables

Variable	Weight	Data Source
Percent low-income households	25%	American Community Survey, 2022
Percent people of color or Hispanic	20%	American Community Survey, 2022
Percent youth or senior (Under 19 or over 65)	5%	American Community Survey, 2022
Percent of households with no vehicle	10%	American Community Survey, 2022
Housing Cost Burden	5%	American Community Survey, 2022
Percent with no High School Diploma or GED	10%	American Community Survey, 2022
PM 2.5 levels of air pollution	5%	EJScreen
Lack of Tree canopy	5%	Tree Equity Score
Economic Opportunity	10%	Opportunity Atlas
Coronary Heart Disease	5%	CDC Places

Higher equity priority areas are in the western portions of the study area with pockets alongside Burnside Road in southeast portions of the study area, as shown in **Figure 15**. Equity priority areas align somewhat with the areas with higher crashes, highlighting a need for focused safety measures in these areas. Central portions of the study area are areas of median equity priority. The tracts with the top 20% of equity scores in the study area were extracted and used for comparison in the safety analysis.

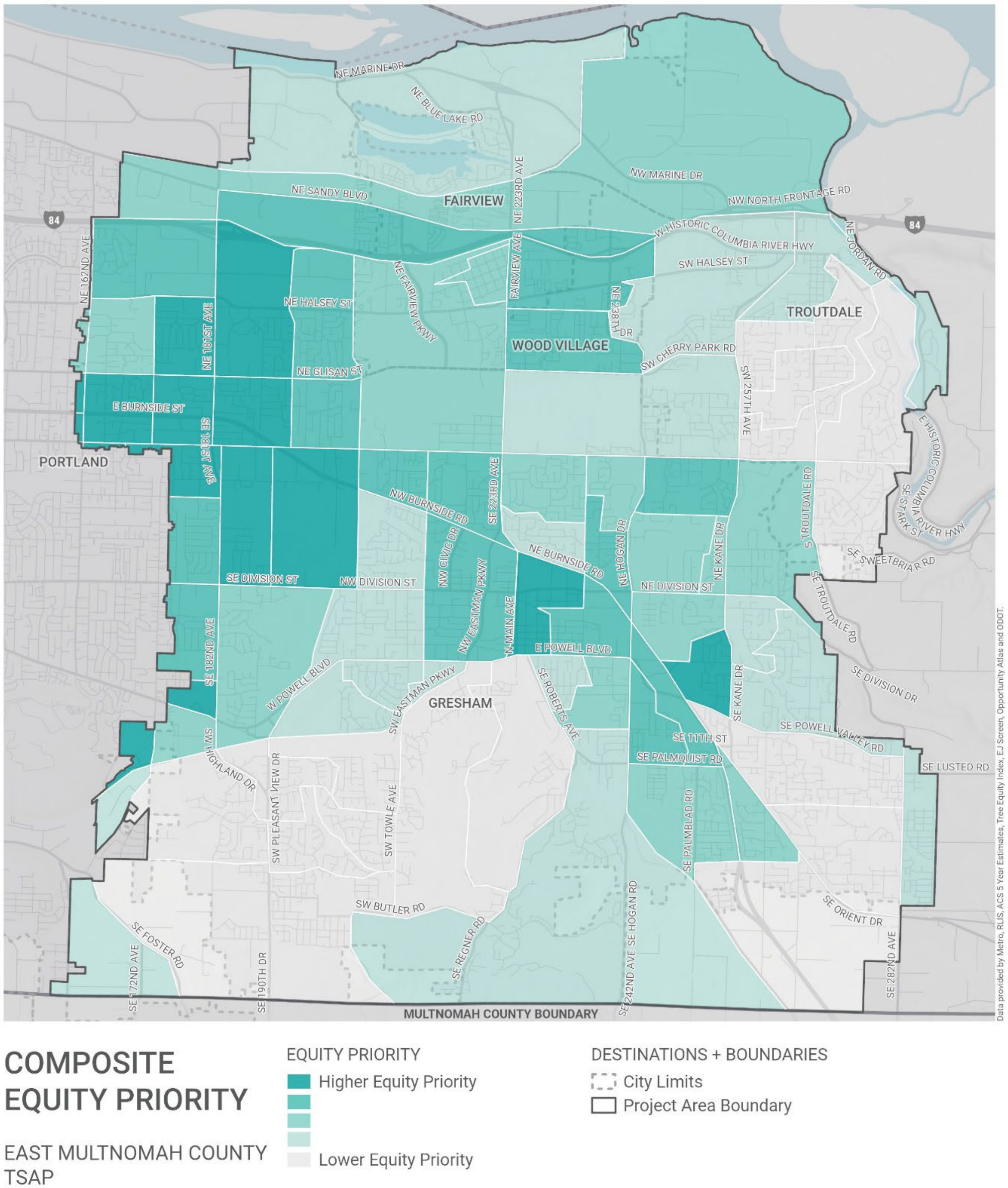

Figure 13: Equity Priority Scores

Spatial-Temporal Analysis

The Alta team conducted a spatial-temporal analysis of crashes (2013-2022) in the study area, identifying specific crash hotspot locations, and trends of crashes in hexagon areas. These results were then compared with hexagons from the crash concentration analysis and top 20% equity areas. This section is divided into the following parts:

1. Introduction to Spatial-Temporal Analyses and Space Time Cubes.
2. Maps resulting from the Spatial Temporal Analysis and discussion.
3. Maps and relation of Equity Analysis to Spatial-Temporal Analysis.

Introduction to Spatial-Temporal Analyses and Space Time Cubes

Typically, crash analyses focus on the spatial nature of crashes that occurred over a set window of time, such as five or ten years. These analyses consider *where* a crash occurred, but do not specifically consider *when* in the window it occurred. By considering the role of time in addition to location, trends can emerge that help distinguish between areas with short-term or seasonal crash spikes and areas with consistent crash patterns. Using crash data from 2013 – 2022, Alta performed a spatial-temporal analysis to analyze injury-causing crashes over time.

The concept of temporal analysis can be best illustrated with an example. Consider two hypothetical intersections over a period of five years. Location A has five injury-causing crashes and location B has three injury-causing crashes in that five-year window.

Location A	Location B
5 crashes	3 crashes

A traditional crash analysis would identify Location A as a higher priority for safety investments based solely from crash count. However, by considering time, it might become apparent that all the crashes at Location A occurred in year one, while Location B's crashes were distributed evenly across the five-year window.

Year	Location A	Location B
1	5 crashes	1 crash
2		
3		1 crash
4		
5		1 crash

This addition of the time component paints a different picture than a spatial analysis alone. Year one may have been an anomaly that caused five crashes in an intersection that usually has no crashes: perhaps an ice storm or major event that brought many visitors to the city, for example. It could also indicate where safety improvements during the study period have been effective in reducing crashes, so the area does not need to be flagged for further improvements. On the other hand, data at Location B suggests a steady pattern of crashes that may require attention.

The Alta team conducted the spatial-temporal analysis of crashes (2013-2022), through employing a geospatial space time cube. The space time cube agglomerated crash points in hexagons with a radius of 200 feet, at a timeframe of two-month periods. A visual depiction of the process is displayed in **Figure 16** and **Figure 17**.

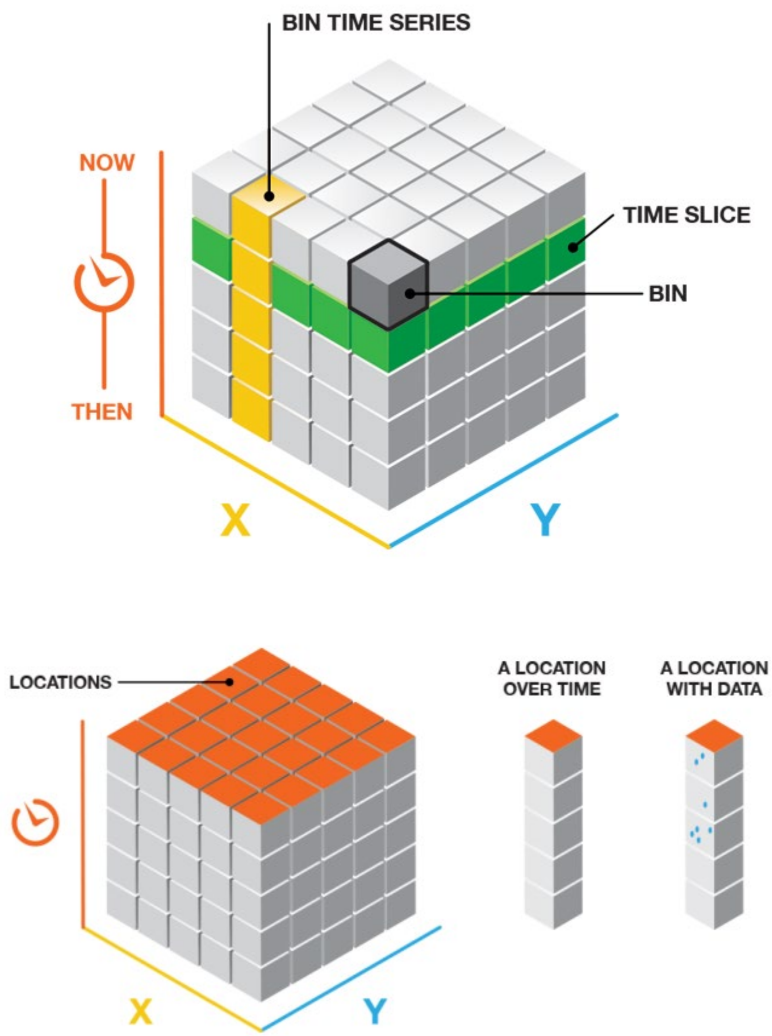

Figure 14: Space-time cubes show trends in data over time rather than analyzing only one slice of time (such as 10 years). Source: ESRI

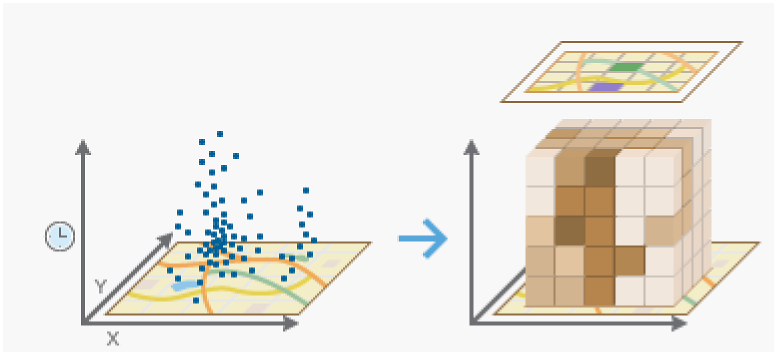

Figure 15: Space-time cubes can be thought of as adding a third dimension, time, to two-dimensional spatial data. Source: ESRI

The Alta team ran an emerging hot spot analysis on the newly created space time cube. This analysis functions by identifying trends in the spatial clustering of crash points, comparing these clusters to a global density value in a defined time period[4]. Temporal patterns are then identified to create a joint conceptualization of clusters across space and time by comparing local neighborhood pattens being statistically different from global patterns.

For this analysis, the Alta team analyzed data in two-month periods. Crashes were clustered within 800-foot-wide neighborhoods, which allows for the identification of relatively small hotspots and generates different outputs than when larger neighborhood sizes are used. The Alta team ran a sensitivity analysis of the results, determining the following parameters, including the impacts of fluctuations of the neighborhood time step, neighborhood extent and defined global window. A detailed definition of parameters used in the analysis is provided in **Appendix A**. Through this sensitivity analysis, the Alta team determined that these parameters were the most suitable for the analysis.

Results

As there still exist difficulties in communicating the results of a space time cube in a three-dimensional format, the Alta team concluded the best way to visualize the results would be in a two-dimensional format. The list below outlines the maps included in this section. Furthermore, descriptions of results are included under each map.

1. Crash Trend Analysis: All Modes
2. Temporal Crash Hotspot & Concentrations
3. Temporal Crash Hotspot & Trend Bin Analysis

Crash Hotspot Analysis: All Modes

Figure 18 displays the hotspots of crashes (2013-2022), comparing each hexagon repeatedly over yearly periods to a global hexagon average in terms of crash count. The hot spots show the locations with a continuous trend of a high number of crashes. A takeaway from this map is that hotspot locations are distributed throughout urban East Multnomah County. Concentrations are found in the communities of Wood Village and Fairview, along Burnside Road

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[4] Esri. (2023). Emerging Hot Spot Analysis (Space Time Pattern Mining)—ArcGIS Pro. https://pro.arcgis.com/en/pro-app/latest/tool-reference/space-time-pattern-mining/emerginghotspots.htm

and Division Street and the 181st Ave/182nd Ave/Highland Drive corridor. Furthermore, there are smaller concentrations found in the Northwest and the Southeast of the maps. It is important to note however, that the relative distribution of the hotspots is highly dependent on the specific parameters used in the emerging hot spot analysis, described above and in **Appendix A**. With a neighborhood search distance of 800 feet, the focus of this analysis was primarily on identifying small geographic areas of crash clusters that providing a similar neighborhood search scale to our larger hexagons used for our previous summaries.

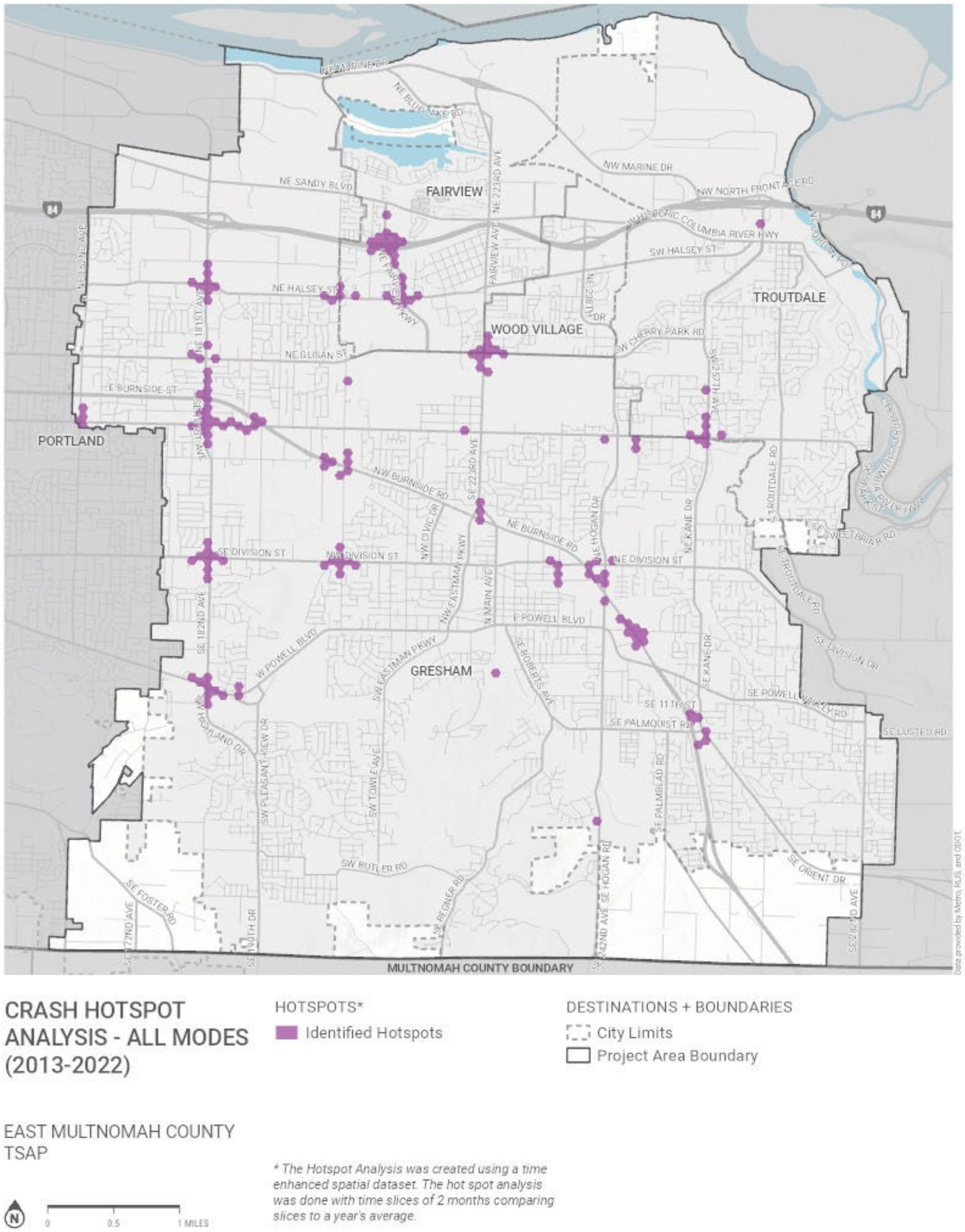

Figure 16: Crash Hotspots, All Modes

Crash Trend Analysis: All Modes

Figure 19 demonstrates the results of a crash trend analysis at the hexagon level. This analysis evaluates a location and deduces whether there is statistically significant[5] upward or downward trend in the number of crashes at that location over time. Trend analysis complements the crash concentration analysis by highlighting how crash numbers are changing in an area, rather than the absolute number of crashes there. The lack of an upward trend does not mean the location does not have a high number of crashes; rather it may indicate persistent crashes. Similarly, a downward trend indicates an area where crash rates have improved, but this does not say how many crashes are still occurring there.

The map shows that the communities of Wood Village and Fairview have high concentrations of hexagons which are trending upwards, while having a lower number of hexagons trending downwards. This could potentially be correlated with an increase in activity in the area. Furthermore, 181st Street and NE Burnside Road have a mix of upward and downward trend bins. As this analysis was done on a micro scale, this could potentially be attributed to treatments that have had an effect over time. However, it should be noted that NE Burnside Road appears to have an upward trend throughout East Multnomah County, and is a major thoroughfare through the region.

This map also demonstrates a substantial number of areas where there are downward trends in crashes. These concentrations are primarily located in Troutdale and along Kane Drive and Division Street.

[5] Statistical significance, shown in terms of confidence levels on the map, states how confidently we can say that the apparent trend is due to an actual change in crash rates rather than random chance.

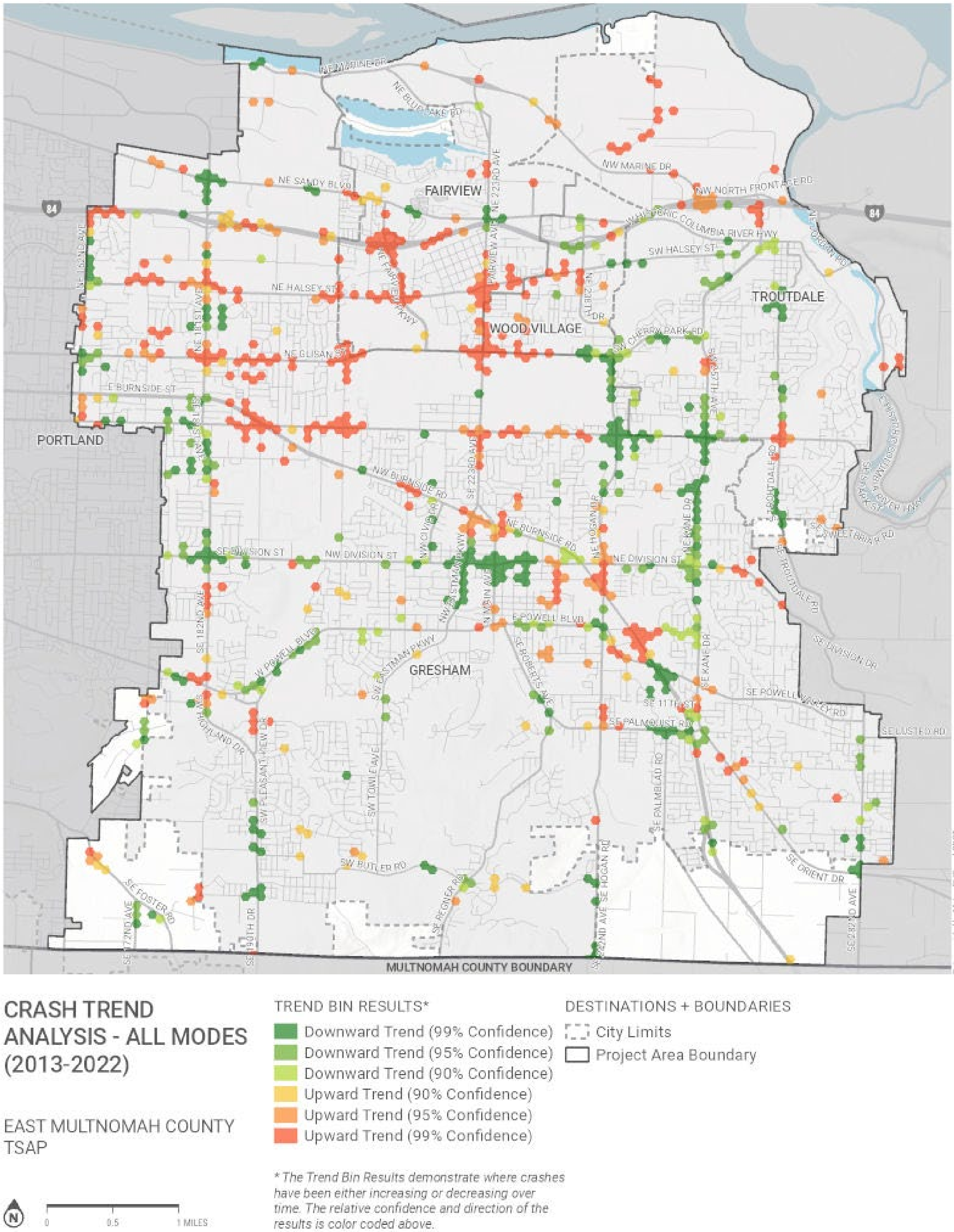

Figure 17: Crash Trend Analysis - All Modes

Temporal Crash Hotspot & Concentrations

Figure 20 overlays the hotspots from **Figure 19** on top of the crash concentrations from **Figure 12**. The resulting map compares the crash concentration areas with the temporal crash hotspots that have a constantly high number of crashes over time. As is to be expected, there is high overlap, but there are locations that have high crash concentration values, but no hotspots. This could indicate that in these areas, total crash numbers were influenced by a specific year or otherwise isolated events and not evenly distributed throughout the ten year time period. It is important to note that the emerging hot spot analysis does not give weight by severity, so it could also indicate that the location had fewer total crashes but they were more severe.

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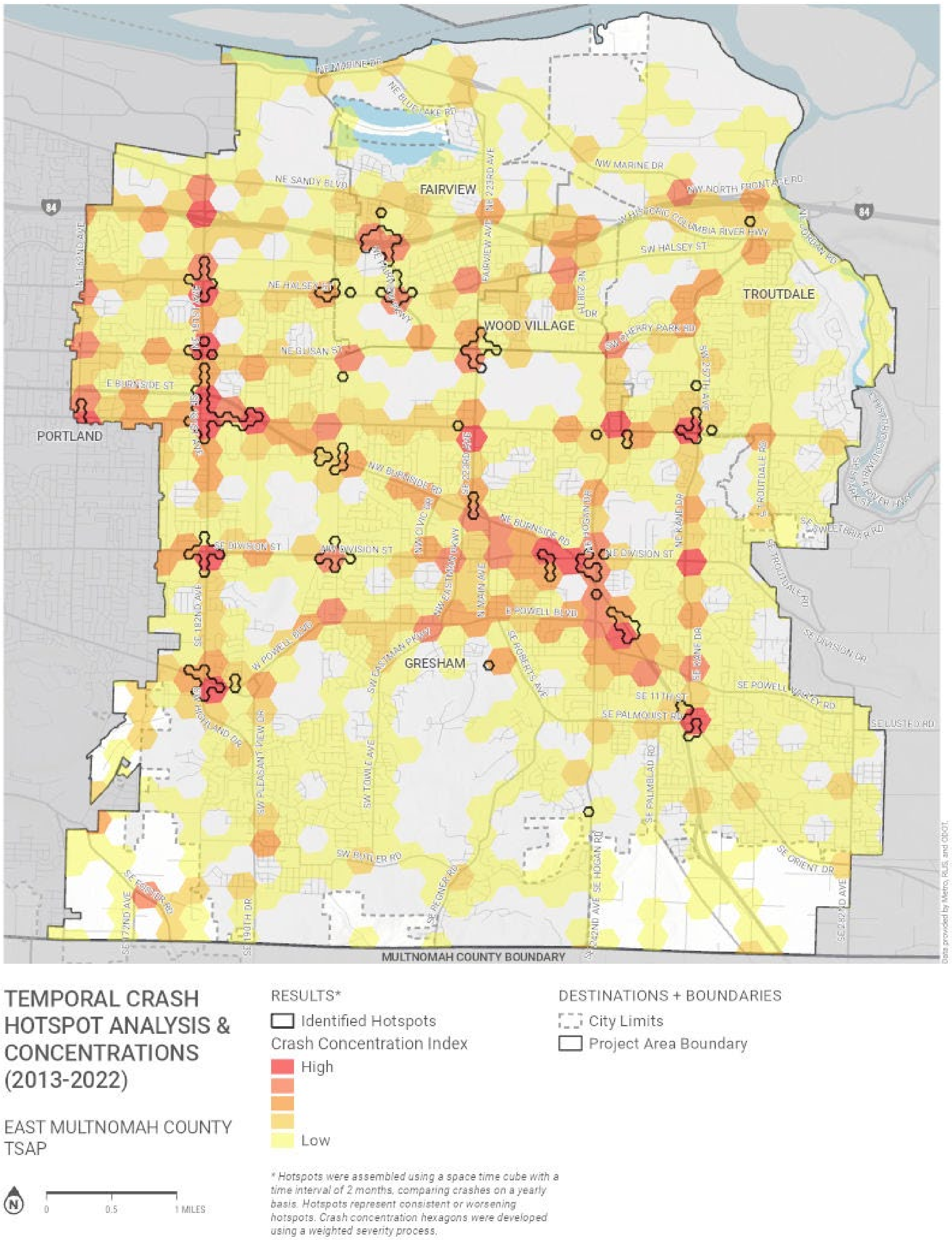

Figure 18: Crash Hotspots and Crash Concentrations

Temporal Crash Hotspot & Trend Bin Analysis

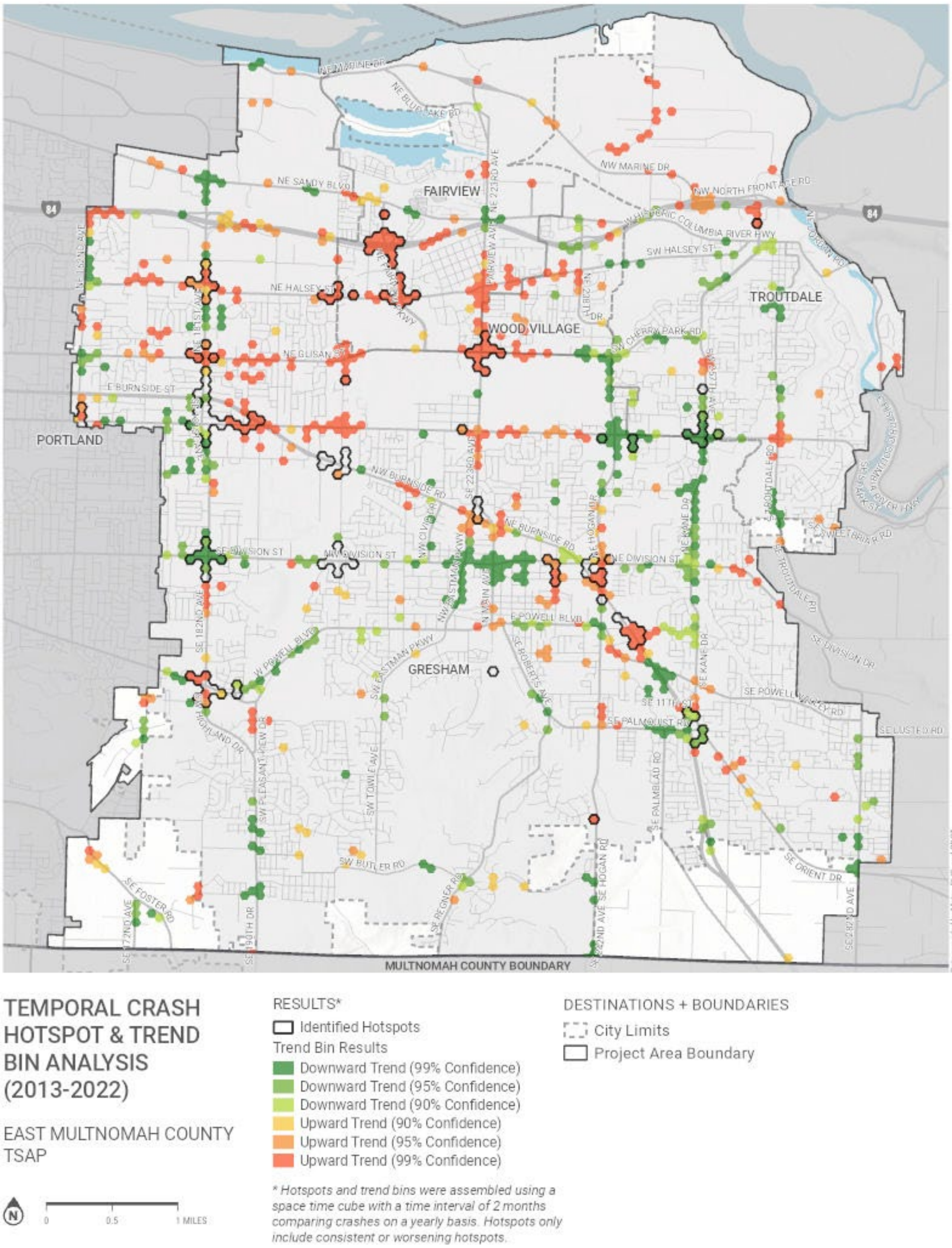

Figure 19: Crash Hot Spots and Trends

Figure 21 compares the trend bin analysis and the hotspot analysis, presenting a complete picture of how trends are interacting with hotspot locations.

The most important locations highlighted on this map are those with both hotspots and an upward trend. These locations should be studied individually in more detail and prioritized in terms of safety features, because they have high crash rates that are getting worse. However, this should not detract from the hotspot locations where there is no detected trend. No trend locations indicate that the frequency of crashes in that location is consistently high. If that location is a hotspot, that is also a cause for concern. A specific example of this occurrence is on the 181st corridor. This location has a fair amount of no trend hexagons. However, all analyses point to this area being high-risk.

When reviewing this map, it is also critical to understand why a hotspot location could have a decreasing trend. This generally indicates that in early years of the time period under study (2013-2022), this location was a source of more crashes, but the crash rate has decreased since then. This could be due to safety treatments or loss of an activity center leading to lower volumes, for example. However, the magnitude of crashes occurring are still high compared to the rest of E Multnomah County such that the area still is regarded as a hotspot.

It should be noted that hotspot locations with decreasing trends should be continued to be analyzed into the future, but they perhaps do not need to be prioritized as heavily as other locations. While saying this, it is crucial to recognize that the emerging hot spot analysis does not take crash severity into consideration, so while total crashes may be decreasing in an area, the analysis does not weigh crashes based on severity.

Temporal Analysis Summary

These analyses demonstrate that the highest crash concentrations overall are along NE 181st Ave and NE Burnside Street. Since our analysis is at a small scale, it also points to many smaller clusters of crashes, some of which are not visible on a large scale. Depending on the time period or size of hexagon used, different areas may be highlighted.

Comparing Spatial-Temporal Analysis with Equity Results

Disadvantaged and disenfranchised communities have historically faced the brunt of unsafe roadways, lack of transportation options, and crashes concentration areas. As such, the Alta team explicitly looked at equity in the context of the results of the spatial-temporal analyses. The two maps in this section overlay the top 20% of equity communities, identified through the equity analysis conducted by this study, to evaluate if there is in fact a relationship. Although these communities represent 20% of census tracts in the study area, they had more than 20% of the share of hot spots, increasing crash trends, and high-crash areas. In particular, equity priority tracts account for:

- 47% of all hotspots
- 30% of all increasing trend bins (hexagons)
- 33% of the top crash concentration hexagons.

Top 20% Equity Priority Areas Crash Maps

Figure 22 demonstrates the top 20% of equity areas overlaid on top of the combined crash concentration and hotspot analyses. This map visualizes the overrepresentation of both the crashes concentration corridors and hotspot locations in equity areas. This furthers the call for prioritization of the 181st and NE Burnside Road corridors in terms of safety treatments, as they are the most prominent locations in the equity areas.

Figure 23 shows the top equity areas overlaid on top of the hot spot and trend analyses. This map visualizes how equity areas are again overrepresented among locations with increasing trends in crash numbers. The most notable takeaway is that while there are some downward trends along the 181st corridor, hexagon locations in equity areas typically see upward trends in crashes. This is primarily seen in the hotspot location areas.

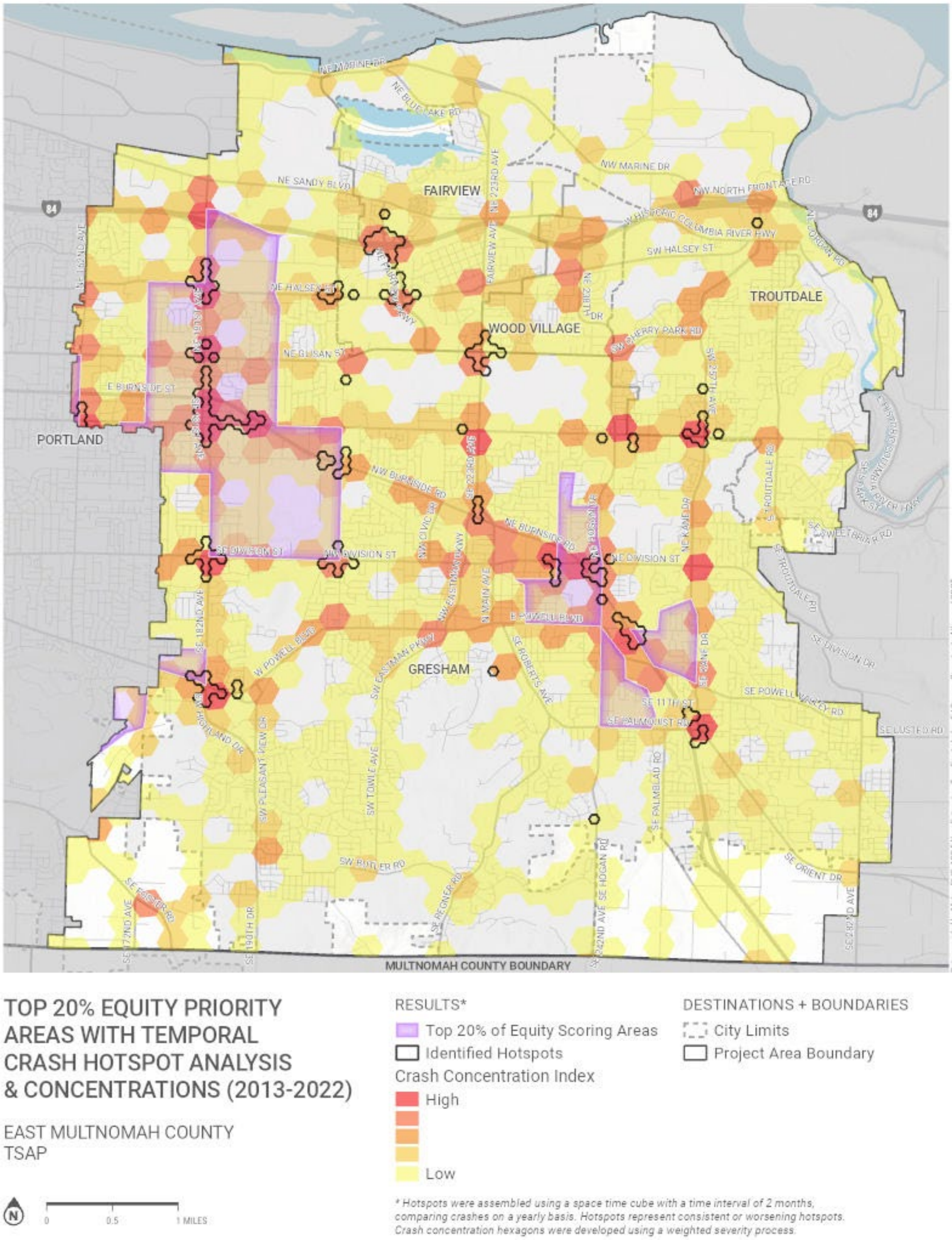

Figure 20: Equity areas, crash hot spots, and crash concentrations (all modes)

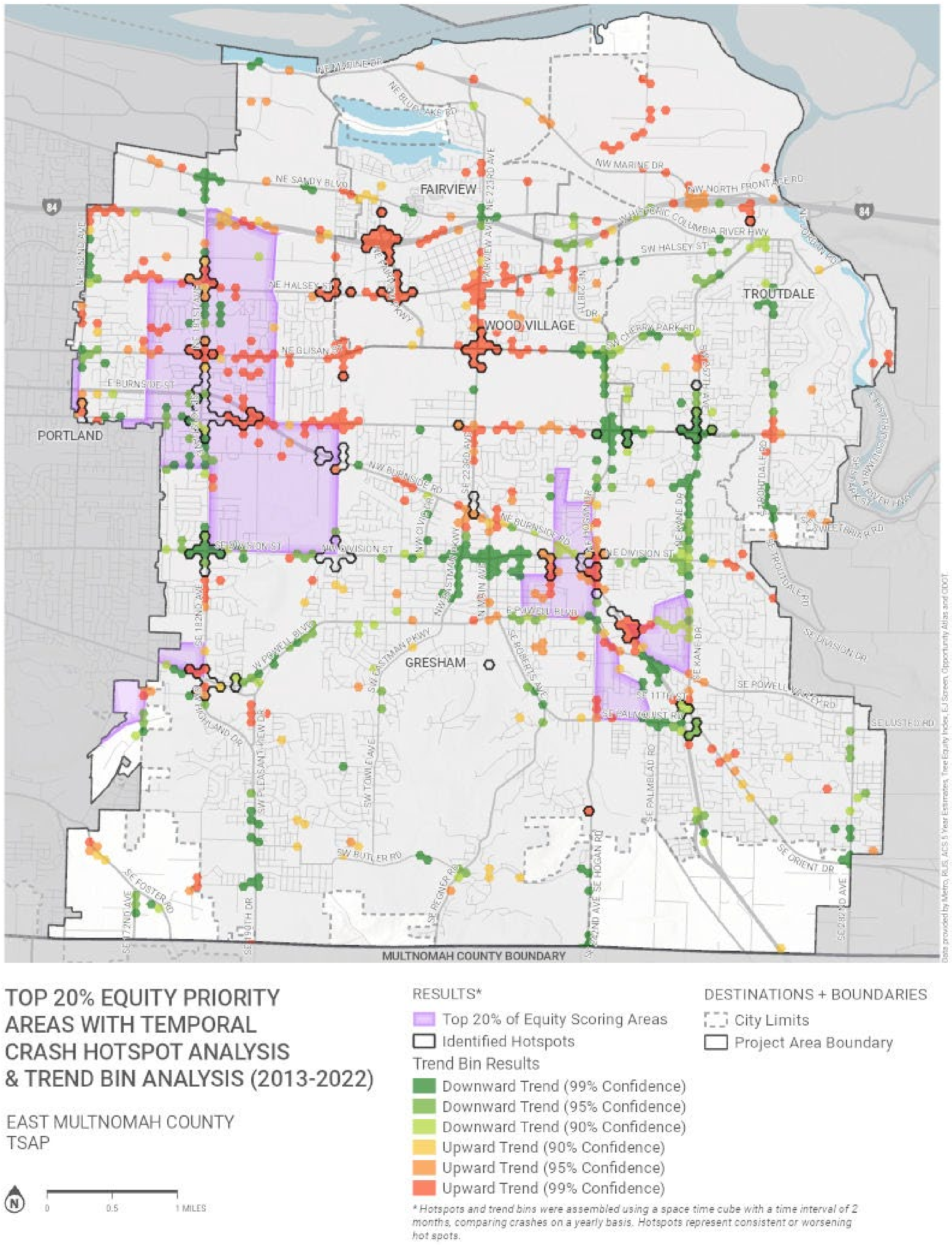

Figure 21: Equity areas, crash hot spots, and trends (all modes)

Crash Profiles and Crash Trees

Methodology

Alta performed an exploratory crash pattern analysis of crash factors using crosstabulations. This analysis identified characteristics that many crashes tended to have in common, and in particular those that were disproportionately with fatal and severe injury crashes. Using this exploratory analysis as a starting point, Alta further developed these crash profiles by looking for additional variables that would describe crashes more specifically. Crash trees, as shown in **Figure 24,** helped to identify combinations of variables that accounted for large shares of crashes.

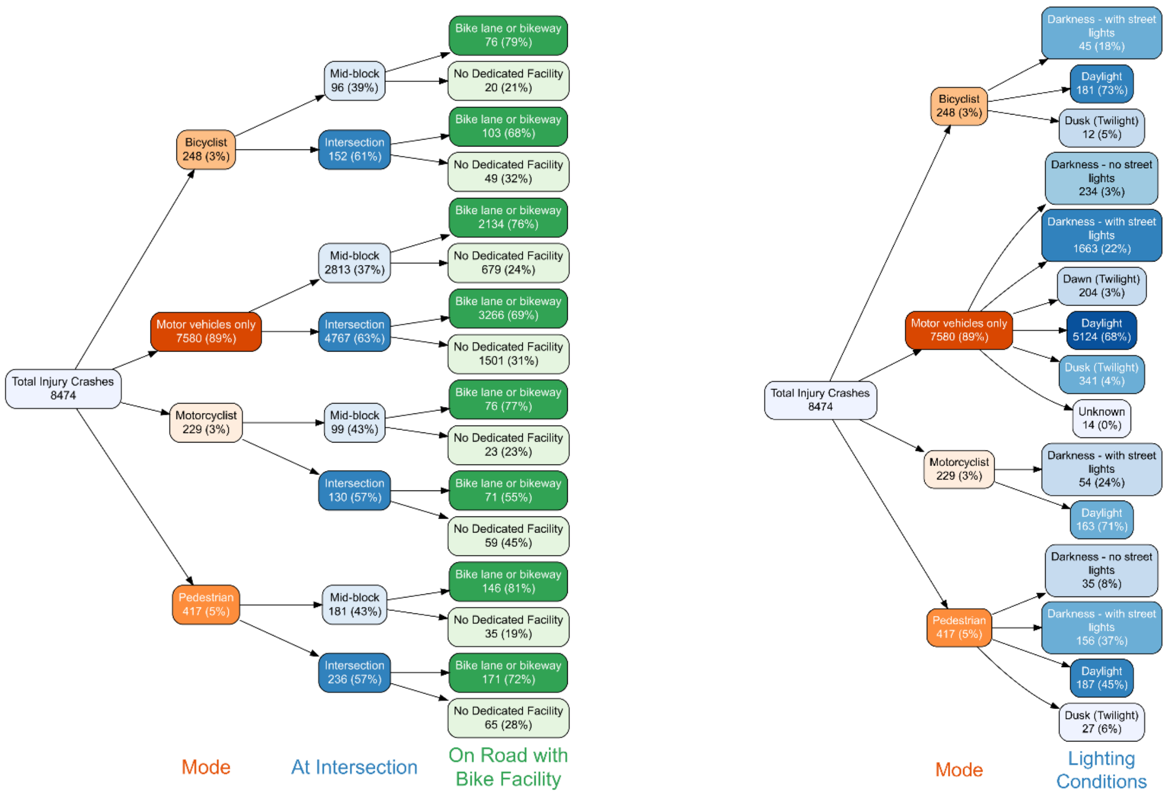

Figure 22 Crash Trees were used as an exploratory data analysis tool to identify and visualize the trends highlighted in crash profiles. The crash trees can be viewed in and in an HTML, file provided alongside this memo.

Crash Profiles Summary

Alta has identified six crash profiles, groups of crashes with similar characteristics. Profiles were chosen based on the number of crashes represented and the factors that appeared disproportionately among fatal and severe injury crashes. Profiles are summarized in **Table 2** and described in more detail below. Maps of the crashes in each profile follow.

Table 2: Crash Profile Summary

Profile Number	Mode	Crash Factor	Contextual Factor	Share of injury crashes for this mode	Share of fatal and severe injury crashes for this mode
1	All	Alcohol or drugs involved		7%	24.0%
2	All	Fixed object	35 mph road	3%	8.6%
3	Pedestrian	Dark	Road with full or partial sidewalk	38%	46.3%
4	Pedestrian	Improper maneuver by driver	At intersection	38%	25.3%
5	Bicyclist	Vehicle turning movement	At intersection, on road with dedicated bike lane or trail	29%	33.3%
6	Motorcyclist	Vehicle turning movement	At intersection	30%	31.7%

Note: Profiles are not mutually exclusive. Some crashes may belong to more than one profile while others do not belong to any.

Profile 1: Crashes with Alcohol or Drugs Involved

Alcohol- or drug-involved crashes can involve impairment on the part of a driver, a vulnerable road user, or both. These crashes were four times as likely as injury crashes overall to result in a fatal and severe injury crash. When the crash results in a fatality, about half the time the crash is with a pedestrian. When the crash results in a serious injury, it is usually because an impaired driver collides with a fixed object.

The highest number of injury crashes in this profile occurred between 7 pm and midnight, with 38% of crashes. In comparison, only 17% of non-substance involved crashes occurred between those hours. These trends are highlighted in the crash trees.

This profile is mapped in **Figure 25**. As with crashes overall, high concentrations are found along Burnside Road and NE 181st Avenue, with significant numbers along SE Stark St as well.

Profile 2: Fixed Object Crashes on 35 MPH roads

This profile accounts for 9% of all fatal and severe injury crashes, regardless of mode, and 3% of all injury crashes. Roads with a 35 MPH speed limit are disproportionately involved in injury crashes. Though they account for 11% of centerline miles overall, they account for 66% of fatal and severe injury crashes. This is a reflection both of higher traffic volumes on these streets and of the role of high speeds in commercial areas.

In equity areas, these roads account for an even higher share of fatal and severe injury crashes, at 89%. This is partly because a higher share of centerline miles in these areas are also 35 mph roads. Equity areas, for this analysis, included the top 20% of census tracts by the Alta-derived equity score, which is derived from demographic variables associated with marginalized populations and described in more detail in the Equity analysis section.

This profile is mapped in **Figure 26,** which shows particularly high numbers along NE 181st Ave.

Profile 3: Pedestrian Crash, After Dark, On Road with Full or Partial Sidewalk

Crashes in this profile account for 46% of pedestrian fatal and severe injury crashes and 38% of all pedestrian injury crashes.

The crash trees show that of all modes, crashes involving pedestrians were the most likely to occur after dark. This suggests that pedestrians are particularly vulnerable to poor visibility. Interestingly, crashes occurred in spite of street lights; 85% of crashes in this profile were on lit streets. Furthermore, about half of the crashes in this profile were at an intersection. Lighting at intersections may not be sufficient to make pedestrians visible to drivers, and the risk could be exacerbated when speeds are high and vehicles are large.

This profile is mapped in **Figure 27.** These crashes are more concentrated than crashes overall, with clusters near the intersection of Burnside St and Division St and along 181st Ave NE between NE Halsey St and SE Stark St. In particular, there are six crashes just south of the intersection of Burnside & Division. Of these, the majority were noted as having a pedestrian illegally in the roadway. This location is in a busy commercial corridor, with a Motel 6 on one side of the street and McDonald's on another, and there is nearly a quarter-mile in between crosswalks. It appears that pedestrians are attempting to save time by crossing where no crosswalk exists.

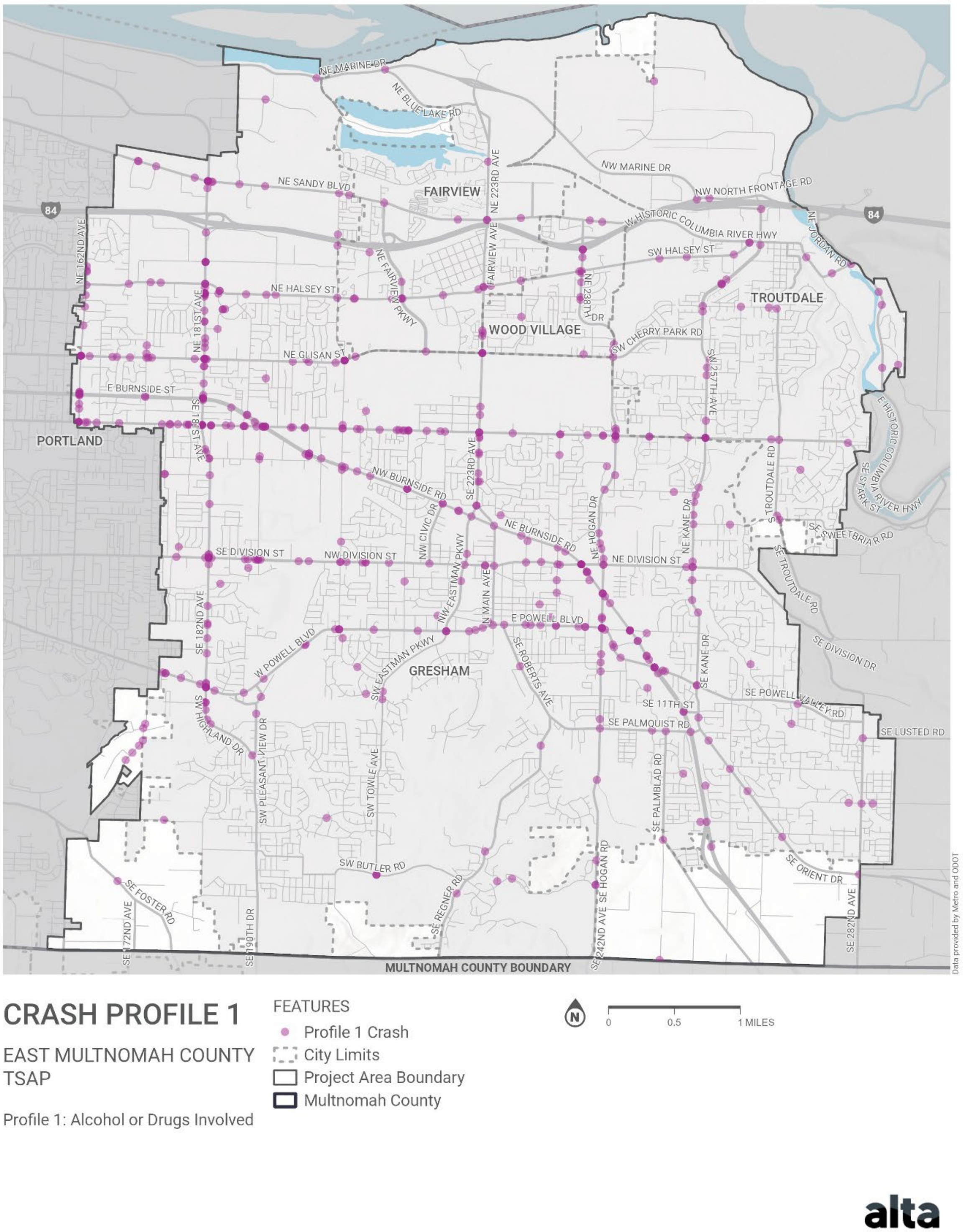

Figure 23: Crash Profile 1: Crashes with Alcohol or Drugs Involved

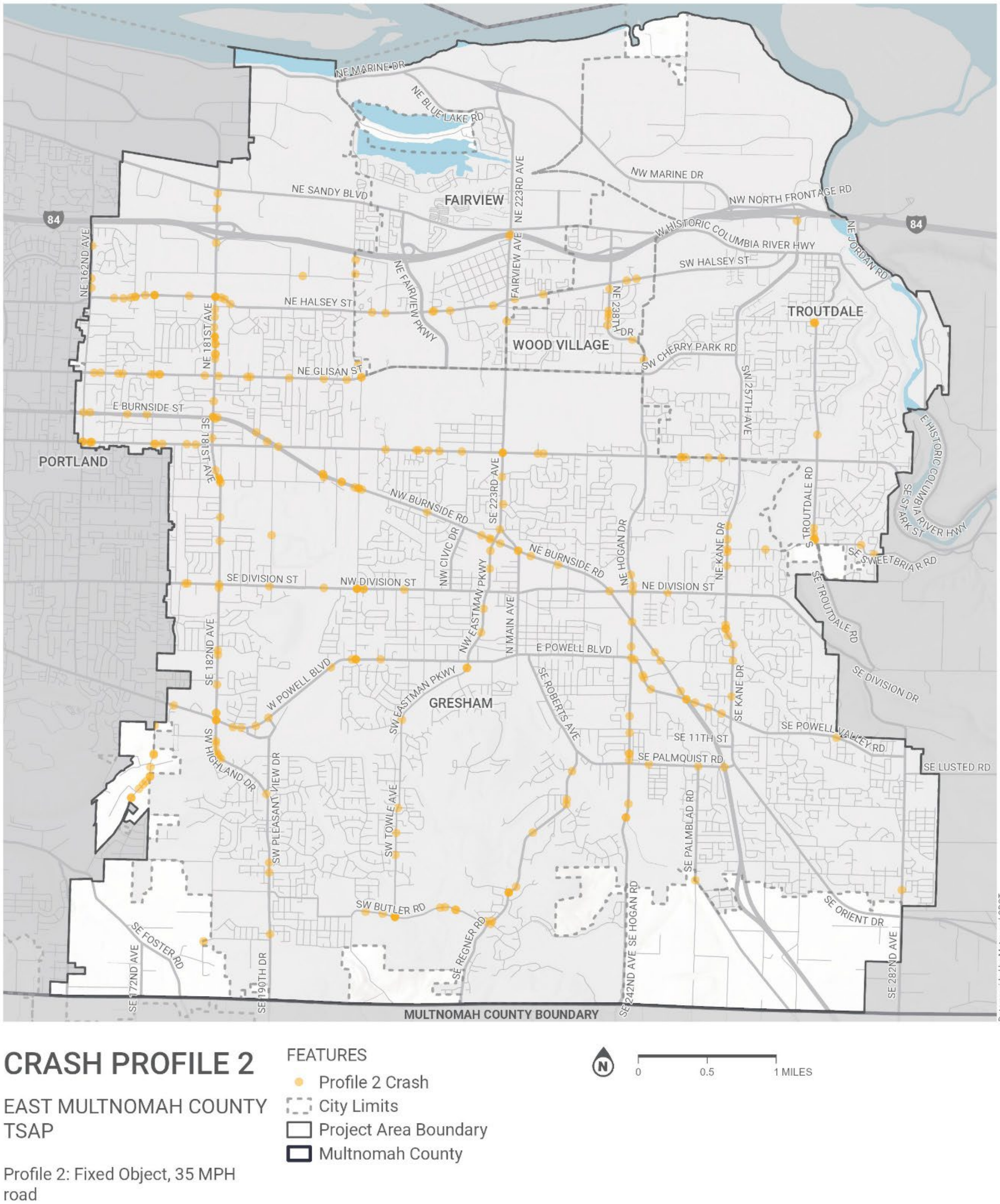

Figure 24: Crash Profile 2: Fixed Object Crashes on 35 MPH roads

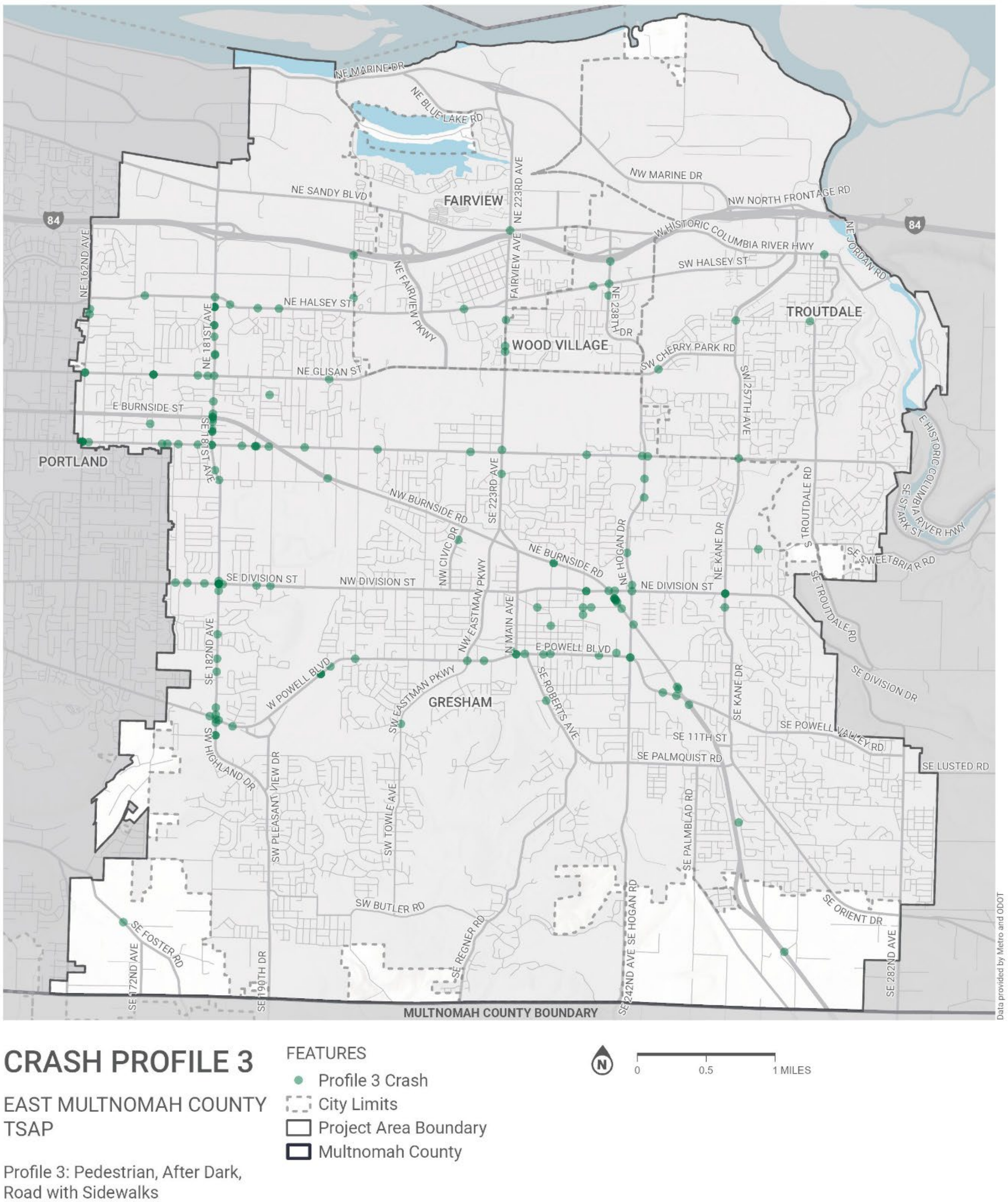

Figure 25: Crash Profile 3: Pedestrian Crash, After Dark, On Road with Full or Partial Sidewalk

Profile 4: Pedestrian Crash, At intersection, with Improper Maneuver by Driver

Crashes in this profile account for 25% of pedestrian fatal and severe injury crashes and 38% of pedestrian injury crashes. About half occurred at signalized intersections, and half at unsignalized. The highest cause was failure to yield the right-of way.

This profile is mapped in **Figure 28** and crashes are fairly distributed throughout the study area.

Profile 5: Bicycle Crash, At Intersection, with a Turning Vehicle, On Road with Dedicated Bike Facility

This profile accounts for 33% of bicycle-involved fatal and severe injury crashes and 29% of bicycle injury crashes. For this analysis, bike facilities are bike lanes (protected or unprotected) or shared-use paths. Crashes on roads with sharrows or signage but no dedicated infrastructure are not included. These numbers indicate that even on a facility with some level of separation or protection from traffic, cyclists are still vulnerable to turning vehicles at intersections.

In 70% of these crashes, the cause was failure to yield right-of-way. Half of crashes in this profile were at unsignalized intersections, where right-of-way may be ambiguous.

This profile is mapped in **Figure 29.** As with the pedestrian crashes in profile 3, these crashes are concentrated on a segment of 181st Ave NE. This corridor is a major connecting street in the area with a bike lane, but it lacks physical separation or protection. There are also many commercial uses and driveways along this corridor, presenting safety risks to cyclists.

Profile 6: Motorcyclist Crash, At Intersection, with a Turning Vehicle

This profile accounts for 32% of motorcyclist fatal and severe injury crashes and 30% of motorcyclist injury crashes. As with many other profiles, the leading cause was a failure to yield right-of-way. The majority (59%) of these crashes were at unsignalized intersections. In half of the fatal and severe injury crashes in this profile, one vehicle was making a left turn. This profile is mapped in **Figure 30** and shows that these crashes are fairly distributed through the region.

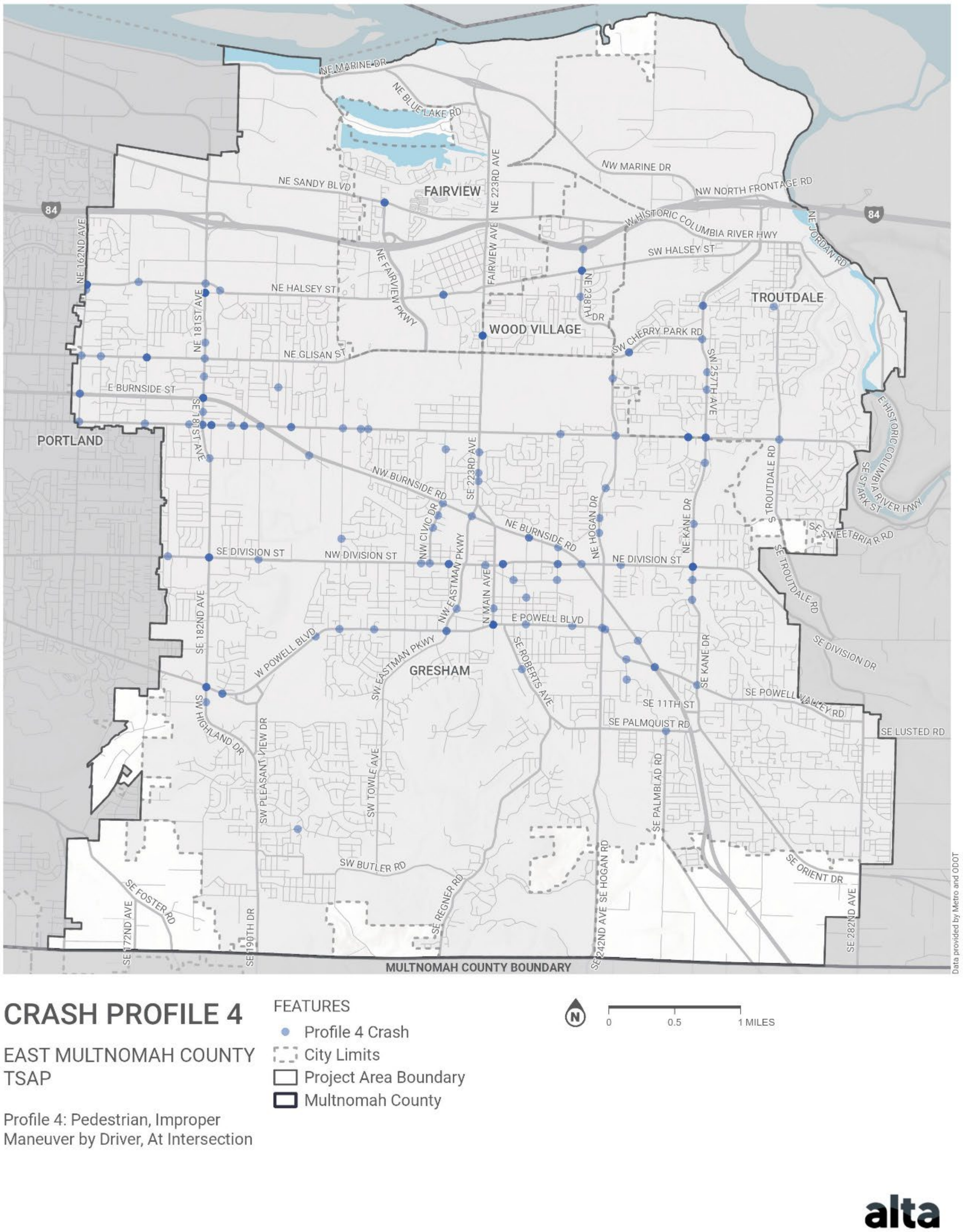

Figure 26: Crash Profile 4: Pedestrian Crash, At intersection, with Improper Maneuver by Driver

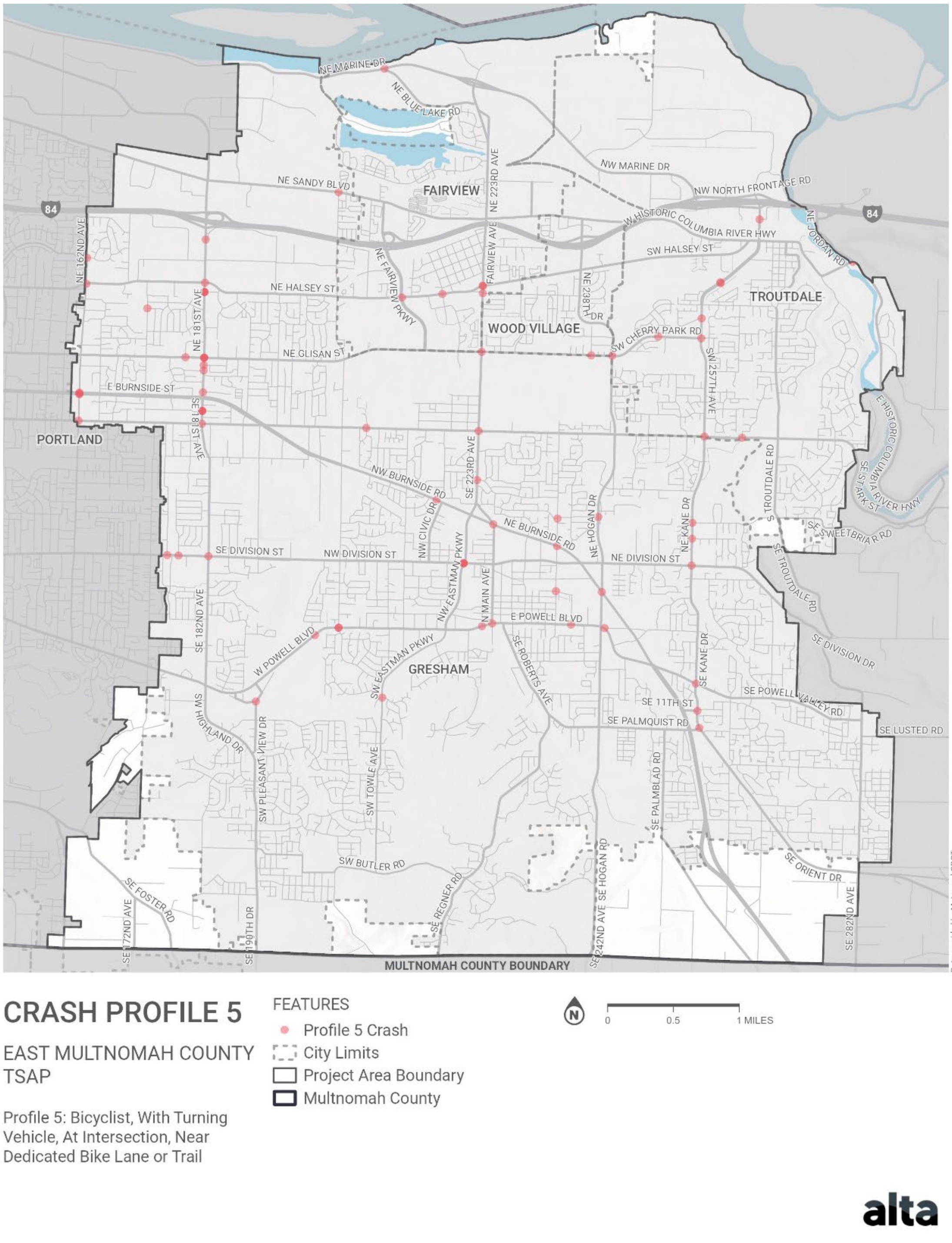

Figure 27: Crash Profile 5: Bicycle Crash, At Intersection, with a Turning Vehicle, On Road with Dedicated Bike Facility

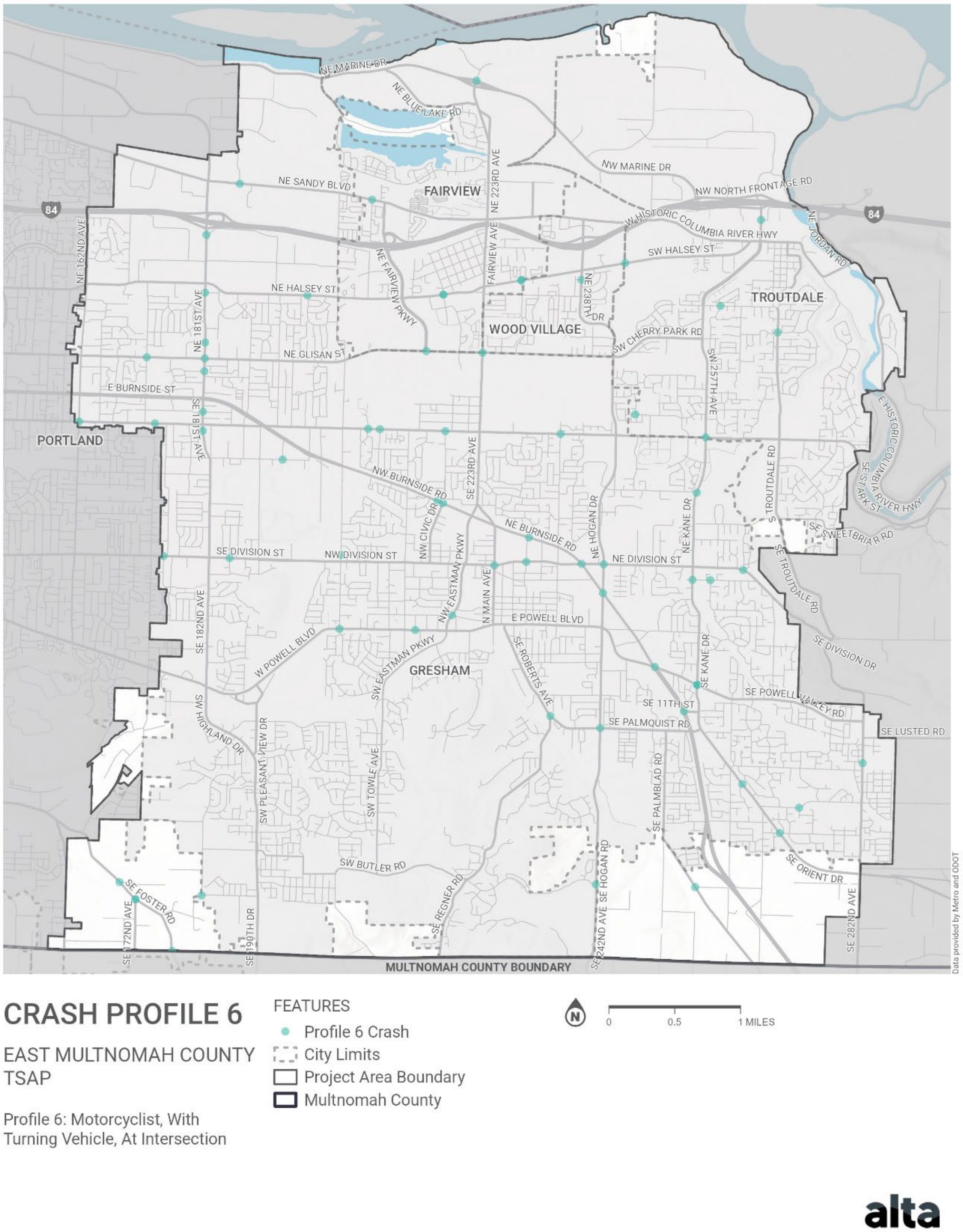

Figure 28: Crash Profile 6: Motorcyclist Crash, At Intersection, with a Turning Vehicle

Appendix A

Parameters used for Space-Time Cube Tool

The Alta team ran an emerging hot spot analysis on the newly created space time cube. This analysis functions by identifying trends in the clustering of values, comparing these clusters to a global value in a defined time period[6]. These values are clustered based off specific factors. For this analysis, the Alta team specified the following factors:

- **Spatially determined neighborhood extents:** The determining factor of what values are analyzed together to assess local space-time clustering. A neighborhood extent of **800 feet** was used for the analysis. This was chosen to replicate the crash concentration hexagons.
- **Neighborhood time steps:** The number of time-step intervals to include in the analysis neighborhood. A neighborhood time step of six was used for this analysis. As points were agglomerated in **two-month** intervals, this would in turn represent a comparison time step of a year.
- **Conceptualization of spatial relationships:** The specification on how spatial relationships among bins are defined. A **fixed distance approach** was selected. This approach specifies that bins inside the defined neighborhood extent distance of 800 feet receive a weight of one and exert influence on computations from the target bin. Those that fall outside of the 800 feet do not influence a target bin's computations.
- **A defined global window:** The parameter by which bins are used to calculate the global value. The neighborhood time step was selected.

[6] ESRI definition of ArcGIS Tool: https://pro.arcgis.com/en/pro-app/latest/tool-reference/space-time-pattern-mining/emerginghotspots.html

Appendix B

Crash Trees Developed for Profiles

Below are crash trees developed to help identify and visualize trends in the crash profiles developed as part of Alta's systemic safety analysis. The trees can be further inspected in an HTML file provided alongside this memo.

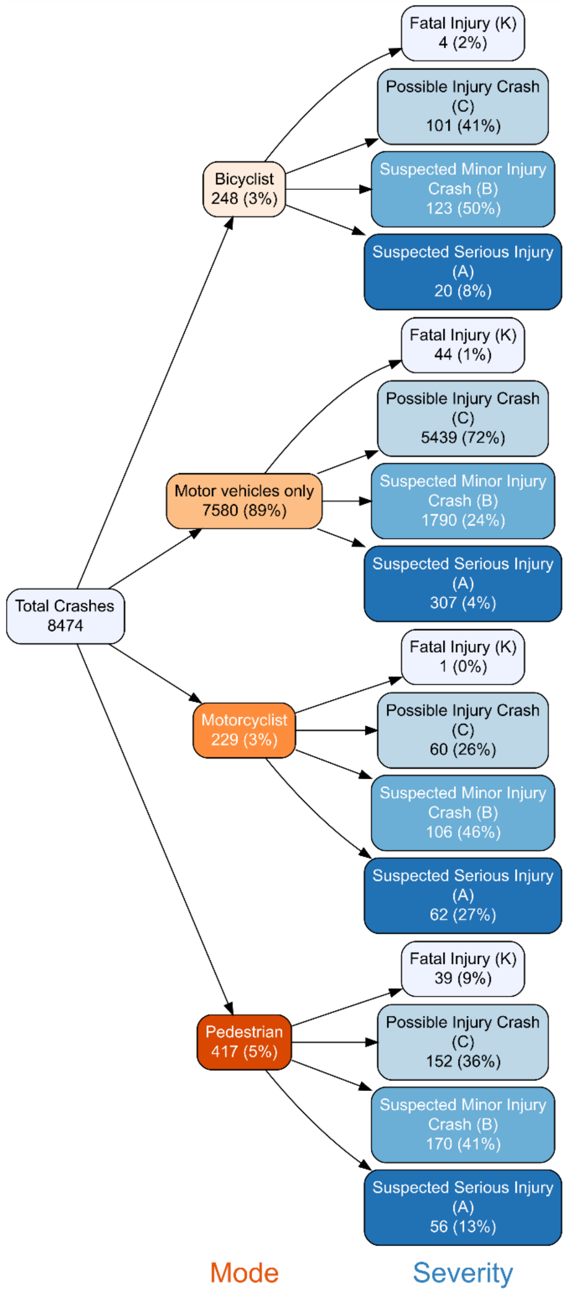

Figure 29: All Injury-Causing Crashes by Mode and Severity

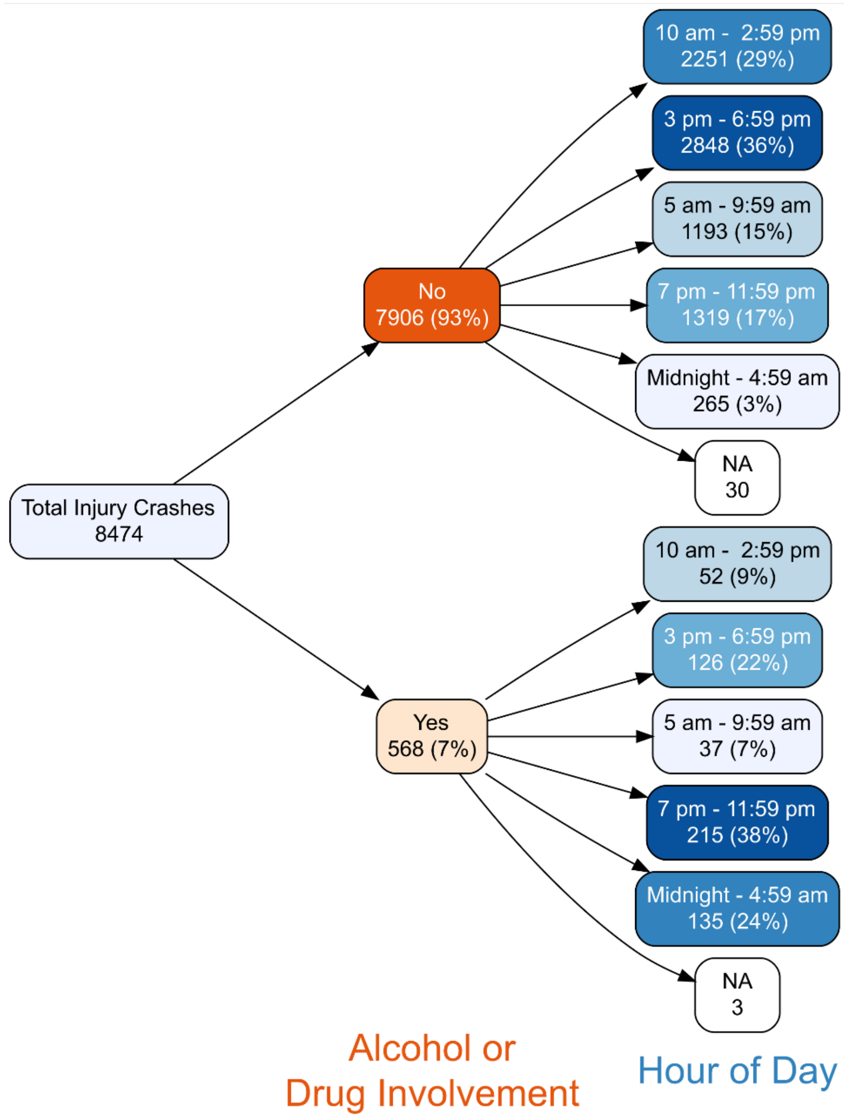

Figure 30: Profile 1 - Alcohol or Drug Involvement, with Time of Day

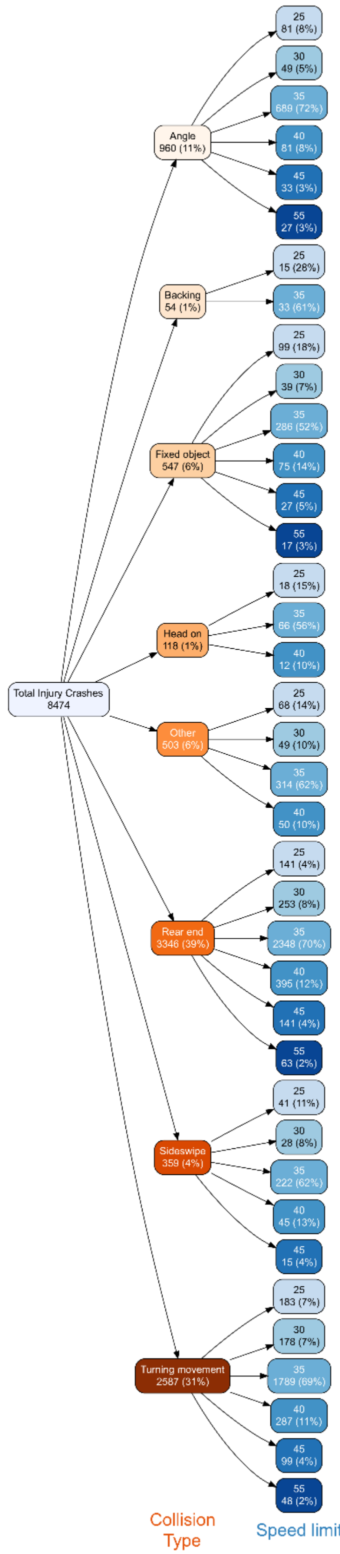

Figure 31: Profile 2 – Crash Type and Speed Limit

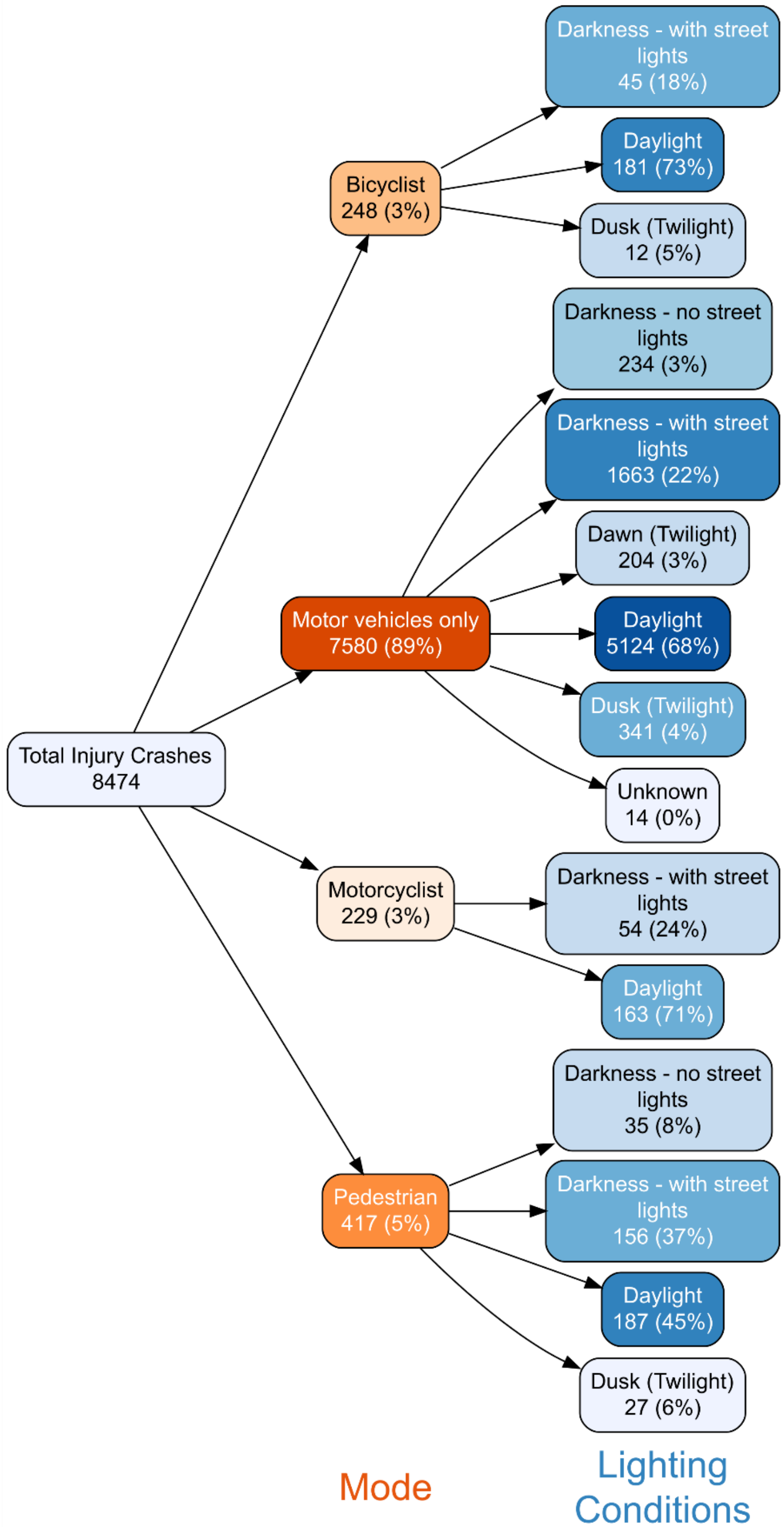

Figure 32: Profile 3 – Mode and Lighting Conditions

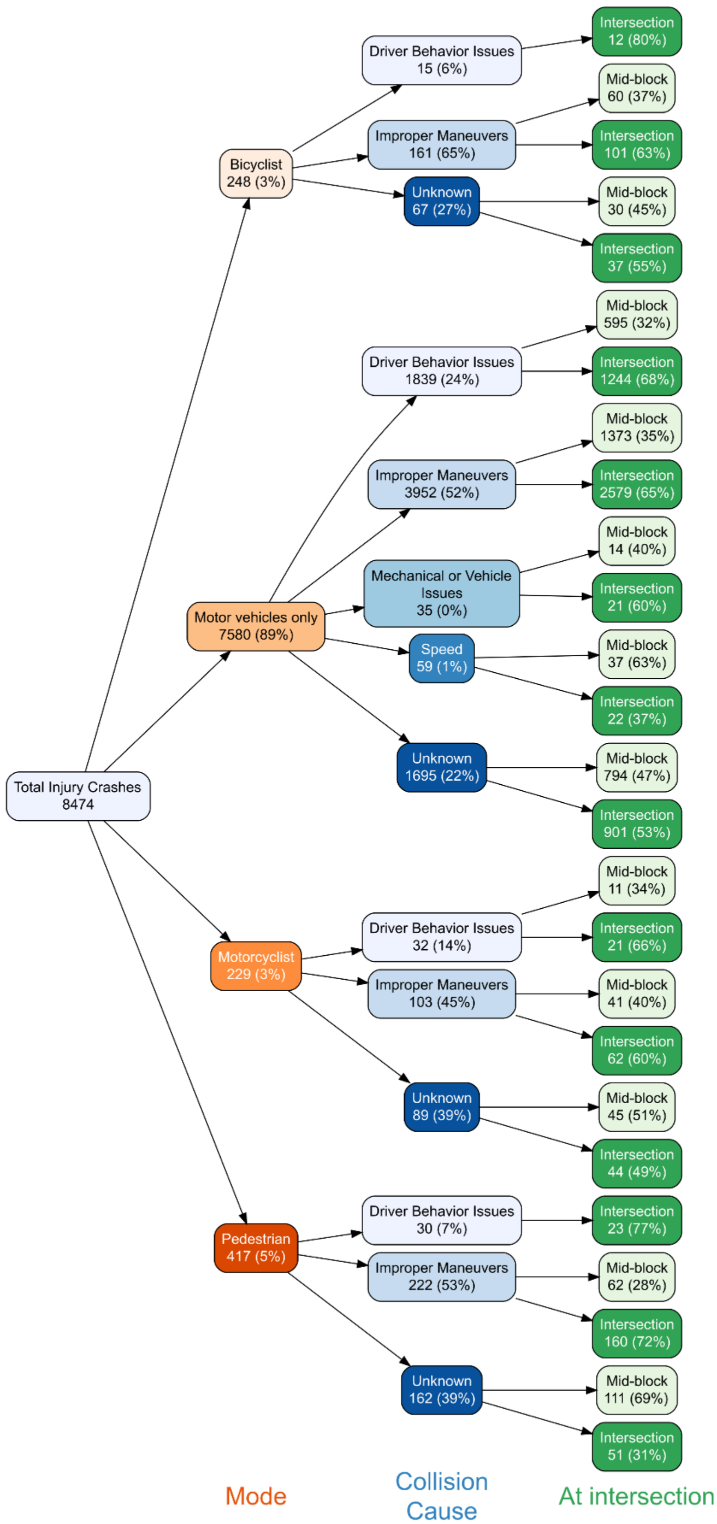

Figure 33: Profile 4 - Mode, Crash Cause, and Intersection Status

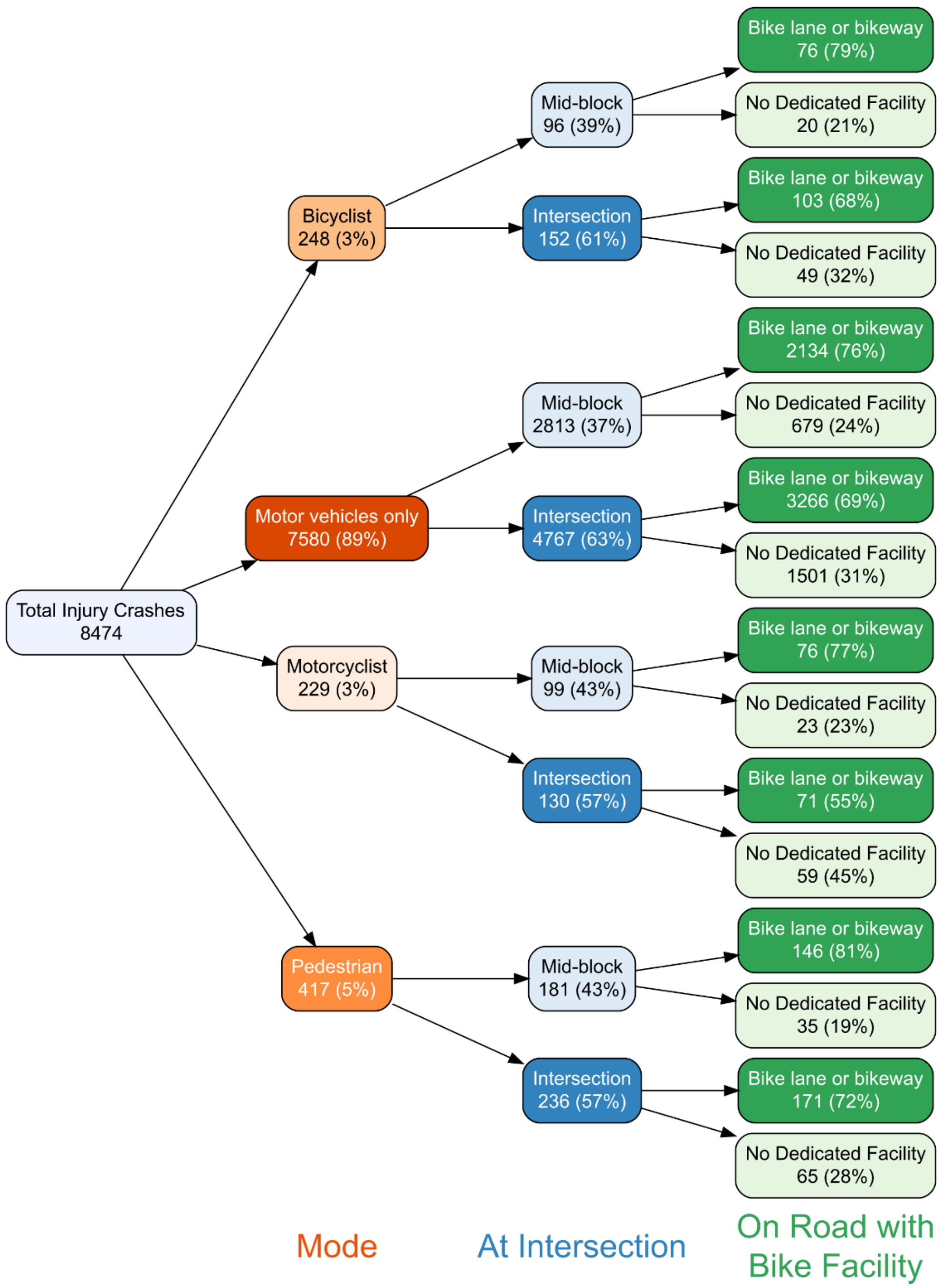

Figure 34: Profile 5 - Mode, Intersection Status, Bike Facility Presence

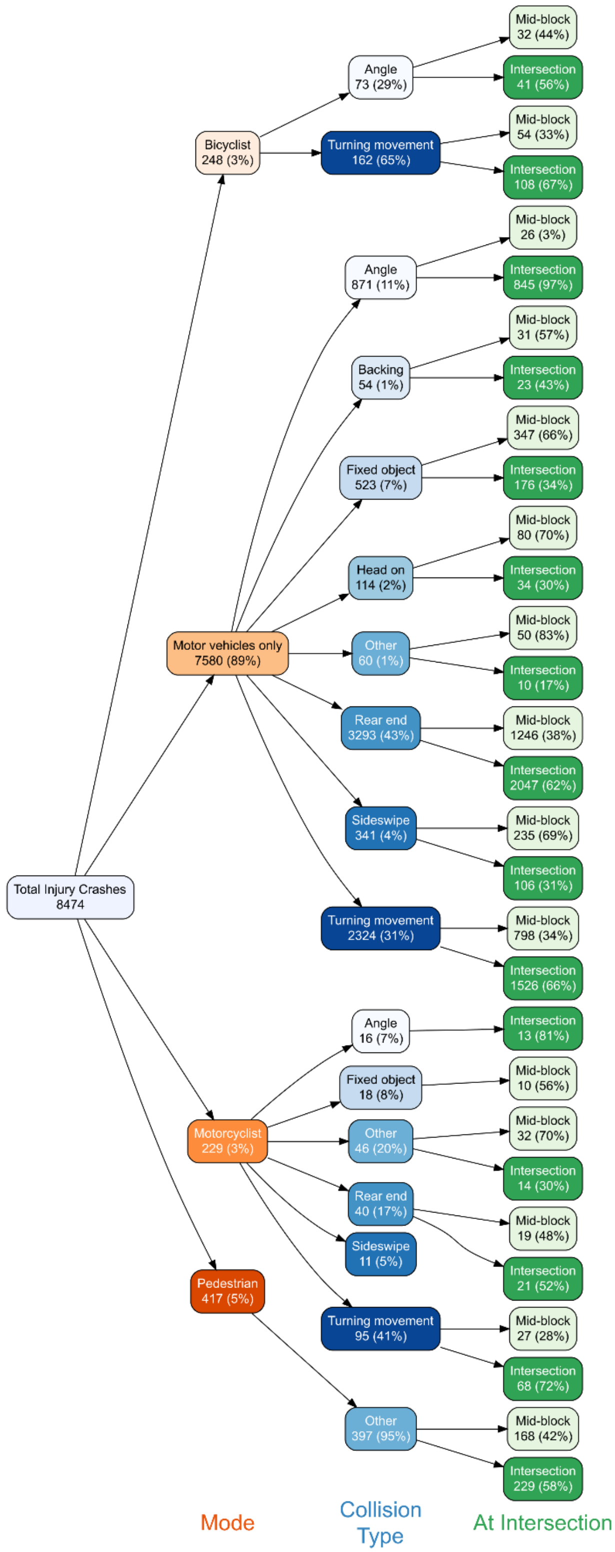

Figure 35: Profile 6 - Mode, Crash Type, and Intersection Status