US 97 Parkway Plan Phase 2

Technical Memorandum #4 - Future Conditions

November 9, 2018

Final

Prepared for:

Oregon Department of Transportation

Prepared by:

WSP DKS

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The purpose of this memorandum is to describe "No Build" transportation conditions in the year 2040 for US 97 and the adjacent city street network through Bend. This builds off previous tasks by applying many of the same analysis methods and performance measures used to describe existing conditions (see Technical Memorandum #2) to the forecasted traffic volumes for the year 2040 (see Technical Memorandum #3).

A summary of the key findings from this memorandum is provided below, with further information included in the subsequent sections.

1.0 Summary of Key Findings

1.1 Future Transportation Network

- The regional travel demand model indicates high growth throughout the project limits, with especially high growth at the north and south ends of the analysis area.
- High level travel demand model analysis indicates that the 2040 travel demand on US 97 will exceed the peak hour capacity, while all major east-west connections within the project limits will also operate near or over capacity.
- Daily demand to peak hour capacity analysis indicates likely trip diversion due to congestion on US 97, Empire Boulevard, and Reed Market Road.
- Travel pattern analysis using the Bend-Redmond travel demand model shows that on average 43% of trips on US 97 in Bend in 2040 are local trips (begin and end in Bend) within the city and another 47% of trips using US 97 have either an origin or destination in Bend. This is generally consistent with findings for existing conditions, except for the segment south of Badger Road where the percent of local trips on US 97 increases dramatically (21% to 41%) due to future growth in the southeast UGB expansion area. On average, only 10% of trips on US 97 are through trips, meaning they start and end outside of Bend.

1.2 Multimodal Analysis

- In the future 2040 No Build scenario, the only planned improvement that would significantly change the Bicycle LTS findings from existing conditions is the new traffic signal on Empire Boulevard at the US 97 Southbound Ramp Terminal. Signalization of this intersection would improve the estimated level of traffic stress from Low (LTS 2) to Lowest (LTS 1).
- There are no physically separate bicycle facilities planned for the US 97 mainline and travel speeds are assumed to remain high. Therefore, the Bicycle LTS on the mainline will continue to be high.
- The only planned improvement by 2040 that would significantly change the Pedestrian LTS findings from existing conditions is the new traffic signal on Empire Boulevard at the US 97 Southbound Ramp Terminal. This crossing was rated as having a High (LTS 4) level of traffic stress under existing conditions but improves to a Low (LTS 2) level of traffic stress with signalized control.

- The other three intersections found to have a High Pedestrian level of traffic stress under existing conditions will continue to have high levels of traffic stress under the 2040 No Build condition. These include: 3rd Street/ US 97 Northbound Ramp, Baker Road/ US 97 Southbound Ramps, and Knott Road/ US 97 Northbound Ramps.
- In addition to these, the Pedestrian LTS worsens from Medium (LTS 3) to High (LTS 4) at the intersection of Colorado Avenue/ US 97 Northbound Ramps due to an increase in traffic volumes at this unsignalized crossing.
- The 2040 No Build assessment of Pedestrian LTS on the US 97 mainline is unchanged from existing conditions, with levels of stress ranging from Medium to High.
- An analysis of US 97 crossing needs for people walking and biking that included factors such as the current quality of crossings (e.g., level of traffic stress), distance between crossing opportunities, potential demand resulting from adjacent land uses, crash history, and alignment with the City's low-stress network has identified a number of strategic locations for improvements that would provide low-stress crossings in the corridor at an average spacing of less than ½-mile.

1.3 Safety Analysis

- A predictive crash analysis was performed using Highway Safety Manual Part C procedures to determine a baseline crash frequency for comparison with future safety improvement alternatives.
- A comparison of expected crashes under 2040 No Build conditions and existing conditions indicated a growth in crash frequencies by 20% for locations where the only change between existing and future conditions is traffic volumes.

1.4 Corridor Operations Analysis

- Nearly all Parkway and non-Parkway study intersections fail to meet mobility targets in 2040. Most of the intersections not only fail to meet mobility targets, but also fail to provide sufficient capacity to serve the forecasted volume.
- The Cooley Road Interim Improvements at US 97 identified in the 2014 MTP Update meet mobility targets through 2025 and provide sufficient capacity to serve the forecasted demand through 2035. A southbound right turn lane at the northern Cooley Road and US 97 intersection would likely allow the Interim Improvements to serve the future 2040 demand.
- The US 97 and Robal Road intersection provides less than 70% of the capacity needed to serve the 2040 demand.
- The US 97/Empire Boulevard/US 20/3rd Street area experiences large volume growth, and the improvements for this area included in the 2014 MTP update do not provide nearly enough capacity for the forecasted demand.

- The portions of the Parkway south of Empire Boulevard are only able to serve approximately 83% of the forecasted seasonal demand, based on simulation results.
- The capacity failures at the Reed Market interchange ramp terminals appear to cause the largest bottleneck in the system, generating long queues for both northbound and southbound US 97. The capacity failures at the ramp terminals are accelerated by capacity constraints at the 3rd Street and Reed Market intersection.
- The Powers Road intersection fails to provide sufficient capacity for the northbound and southbound movements on US 97.
- All right-in/right-out intersections queue extensively on the minor street approaches.
- Congestion at all interchange ramp merging, diverging, and weaving areas on the Parkway will worsen by 2040. In fact, 10 of the 15 mainline/ramp junctions analyzed are projected to have insufficient capacity to serve the traffic demand. This could result in more bottleneck locations on the Parkway mainline, diversion of traffic to adjacent city streets, and an increased duration of congestion.
- In the northbound direction, the stretch of interchange ramp merging and diverging areas on the Parkway mainline failing to meet the adopted mobility target will extend from the Colorado Avenue on-ramp to the Empire Boulevard off-ramp.
- In the southbound direction, all analyzed interchange ramp merging and diverging areas on the Parkway mainline from Division Street to Colorado Avenue will fail to meet the adopted mobility target.

1.5 Travel Time Reliability Analysis

- In general, travel time reliability will get worse for most segments on the US 97 corridor when comparing existing to future no build conditions. Key locations that showed significant deterioration in the future include Clausen Road to Cooley Road, Robal Road to the US 20 interchange, and Hawthorne Avenue to the Colorado Avenue interchange.
- Corridor travel times on US 97 are projected to increase by as much as 25 minutes throughout the PM peak period by the year 2040.

2.0 FUTURE TRANSPORTATION FACILITIES

The 2040 No Build transportation network includes several planned improvement projects within and surrounding the study area. These projects were taken from recent planning studies and combined to create a "Financially Constrained" transportation network, which will be the baseline from which to compare improvement alternatives. A summary of planned improvements included in the 2040 No Build network that could significantly impact travel within the US 97 study corridor is provided below.[1]

Source: Bend MTP (2014 Update)

- Empire Boulevard Widening (MTP Project #7): Widen Empire Boulevard to 5 lanes between 3rd Street and US 97 Northbound Ramps. Also install a signal at the US 97 Southbound Ramps.

  Impacts to Study Area: This project will impact the traffic patterns for the US 20 southbound to US 97 southbound movement.

- Empire Boulevard Extension (MTP Project #8): Extend Empire Boulevard from Purcell Boulevard to 27th Street.

  Impacts to Study Area: This project will impact traffic at the Empire Boulevard and US 97 interchange ramp terminals.

- Murphy Road Extension (MTP Project #11): Extend Murphy Road from Brosterhous Road to 15th Avenue.

  Impacts to Study Area: This project will impact the traffic at the Murphy Road and US 97 interchange.

- US 97/Cooley Road Area Improvements (MTP Project #12): Assumed to include grade separation of US 97 at Cooley Road, with signalized connections.

  Impacts to Study Area: This project will impact US 97 at Cooley Road.

- Empire Boulevard/US 97 Northbound Ramp widening (MTP Project #13): Widen US 97 northbound off-ramp at Empire Boulevard to two lanes.

  Impacts to Study Area: This project will impact the traffic on US 97 at Empire Boulevard.

- North Frontage Road (MTP Project #17): New two-lane frontage road from Murphy Road to Powers Road. Assumed to include closure of the Badger Road and Pinebrook Boulevard Right-In/Right-Out.

  Impacts to Study Area: This project will impact traffic operations on US 97.

- South Frontage Road (MTP Project #18): New two-lane frontage road from Murphy Road to Ponderosa Street.

  Impacts to Study Area: This project will impact the traffic at the Murphy Road and US 97 interchange.

- US 97/Murphy Road Interchange Ramps (MTP Project #25): Northbound on-ramp and southbound off-ramp.

[1] Note: This list of improvements was also provided in Tech Memo #3.

Impacts to Study Area: This project will impact traffic operations on US 97.

- US 20 Widening (MTP Project #42): Add second southbound lane between Cooley Road and 3rd Street.

  Impacts to Study Area: This project will impact travel demand on US 97 southbound.

Source: Bend Urban Growth Boundary Expansion (2016)

- China Hat Road Widening (#S-1): Widen China Hat Road from two to three lanes from US 97 to Mountain High Drive.

  Impacts to Study Area: This project will impact demand at the China Hat access to US 97.

Again, note that the "Baseline" model scenario used for the Bend MTP/TSP update currently underway is the same scenario that will be used as the future "No Build" scenario for the US 97 Bend Parkway Project. The projects included in this scenario are also the current Bend MTP Financially Constrained Project List.

3.0 TRAFFIC VOLUME

This section describes motor vehicle traffic volume characteristics along US 97 under future conditions (2040).

3.1 PEAK HOUR TRAFFIC VOLUMES

Future traffic volumes were forecasted for the year 2040 using the Bend-Redmond Travel Demand Model. The future forecasting methodology and intersection turn movement volumes can be found in the Future Traffic Forecast Technical Memorandum.[2] In the Existing Conditions Memorandum, the peak hour of traffic was identified to occur from about 4:30 PM to 5:30 PM.

3.2 DEMAND COMPARISON

A high-level regional demand analysis was performed using the Bend-Redmond Model (BRM). The analysis included the following measures:

- Percent change in PM peak hour demand from 2010 (the model base year) to 2040 (Figures 1-3)
- Peak hour demand to capacity ratios for 2010 and 2040 (Figures 4-9)
- Daily demand to peak hour capacity ratios for 2010 and 2040 (Figures 10-15)

The percent change in PM peak hour demand from 2010 to 2040 shows the roadways in Bend with the highest growth. Note that roadways either constructed between 2010 and 2018 (present day) or added to the model as projects from the MTP Financially Constrained list show as >300% growth. Throughout the area, there is significant growth in travel demand. The north and south study areas see the largest trip growth, in part due to the expected growth in housing and employment in areas brought into the Bend Urban Growth Boundary (UGB) in 2016. The central study area sees a lower level of trip growth, with some links barely changing between 2010 and 2040.

A peak hour demand to capacity ratio above 0.9 indicates likely capacity failures at intersections along a corridor. Under 2010 conditions, most of the system operates below a demand to capacity ratio of 0.7, essentially indicating that the key corridors within the project limits will experience only minor delays during the PM peak hour. During the 2040 PM peak hour, the demand volumes exceed the hourly capacity in numerous areas. Large segments of the Parkway are congested with high demand-to-capacity ratios. This is particularly pronounced in the central study area, with congestion on the Parkway and other key routes in the city. At least some portion of every east-west connection across US 97 within the project limits has a location where the demand either approaches or exceeds the capacity.

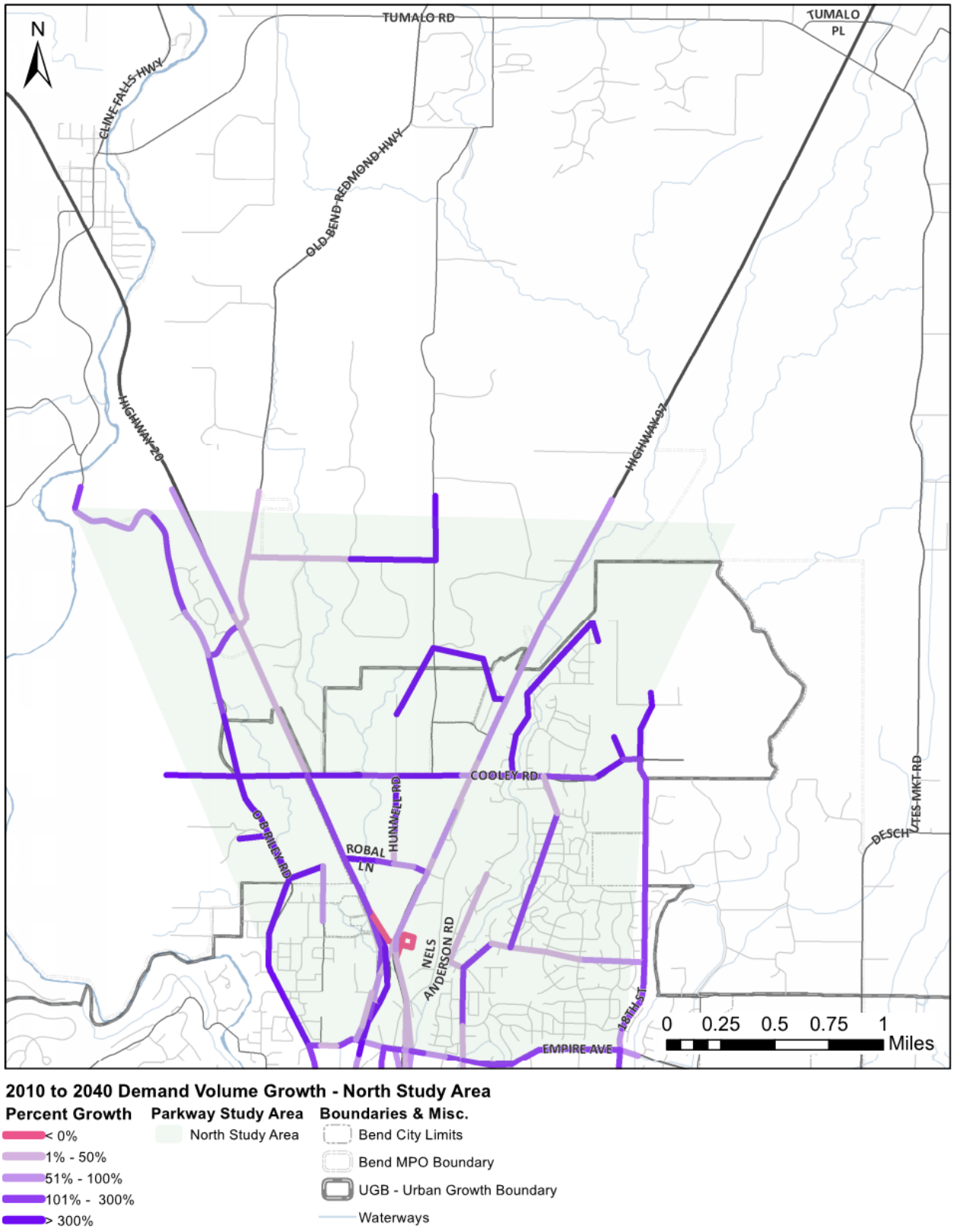
The daily demand to peak hour capacity ratio is a rough measure of the level of congestion. It is a way to estimate peak spreading on a road system and is considered a higher planning level rating of the level of congestion as compared to duration of congestion or queuing.[3] The daily demand to peak hour capacity ratios indicate locations where traffic is likely to shift to an alternate route (if available) to avoid

[2] US 97 Parkway Plan Phase 2 Technical Memorandum #3 – Future Traffic Forecast, September 2018.
[3] Analysis Procedures Manual Version 2 - Chapter 9, July 2018.

congestion or that the duration of the congested period may increase. A typical daily demand to capacity could range to as high as 12. A demand to capacity ratio greater than 12 indicates that the peak hour demand will likely exceed the capacity, and therefore shift to an alternate route, or that the duration of congestion may extend beyond the peak hour into multiple hours.

Figures displaying the daily demand to peak hour capacity ratios for 2010 and 2040 can be seen below. The figures below are based on the Bend-Redmond travel demand model volumes and capacities and therefore, cover an area much larger than the plan study area. Given this approach, the extent of the issues may be understated. Further analysis, as described in the corridor operations analysis section (section 6.0), will describe the extent of the congestion issues in more detail. Under 2010 conditions, only Empire Boulevard between US 20 and US 97 shows an indication of PM peak hour diversion to alternate routes (likely Butler Market Road). Under 2040 conditions, numerous locations on US 97 show daily demand to peak hour capacity ratios greater than 12. Empire Boulevard and Reed Market Road are two key east-west corridors most likely to divert PM peak hour demand to other routes.

Figure 1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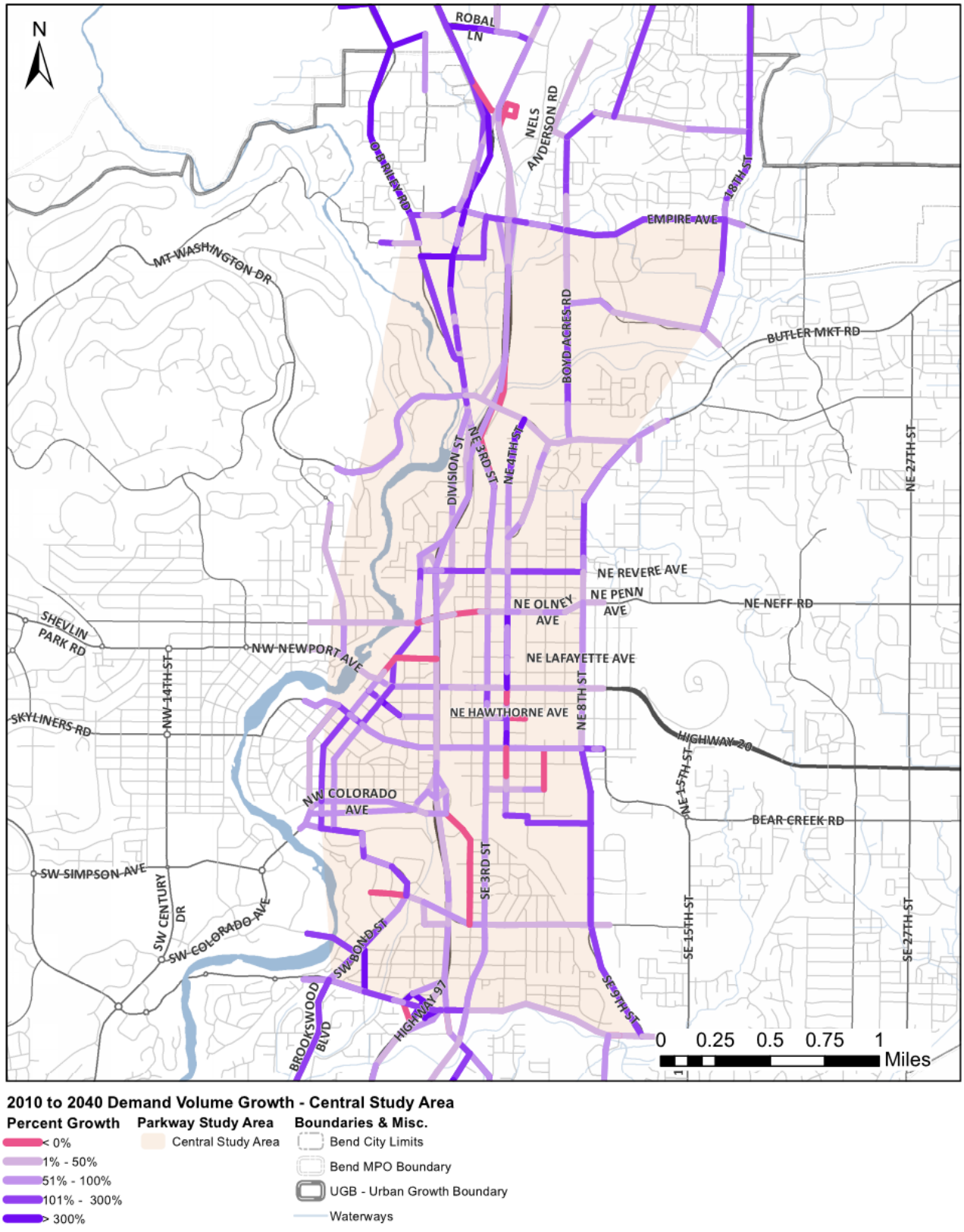
TUMALO RD
TUMALO PL
CLINE FALLS HWY
OLD BEND-REDMOND HWY
HIGHWAY 20
HIGHWAY 97
COOLEY RD
O'BRIEN RD
HUNNELL RD
ROBAL LN
NELS ANDERSON RD
DESCHUTES MKT RD
18TH ST
EMPIRE AVE
0 0.25 0.5 0.75 1 Miles
2010 to 2040 Demand Volume Growth - North Study Area
Percent Growth
< 0%
1% - 50%
51% - 100%
101% - 300%
> 300%
Parkway Study Area
North Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 2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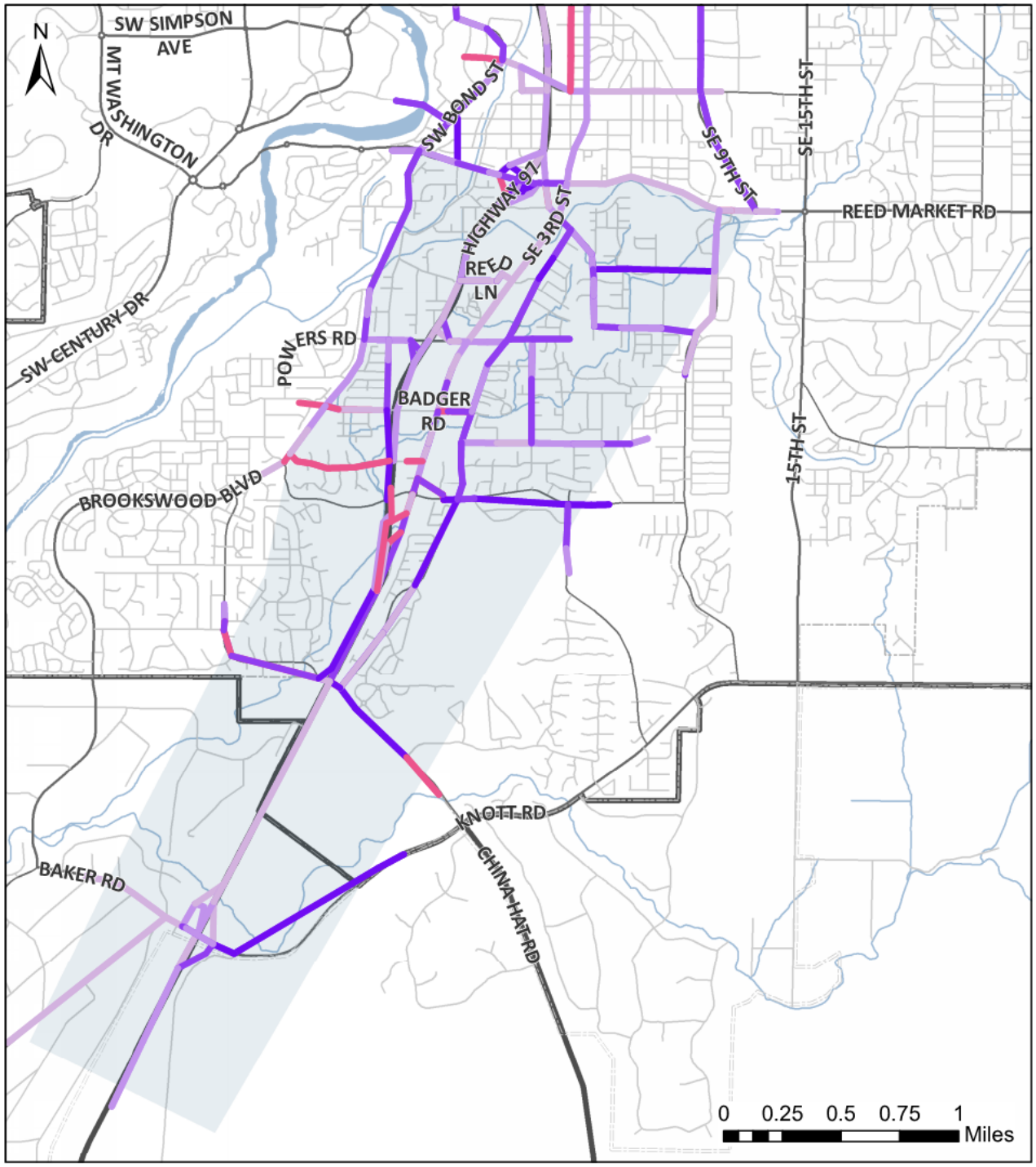
O'BRIEN RD
18TH ST
EMPIRE AVE
MT WASHINGTON DR
BOND ACRES RD
BUTLER MKT RD
DIVISION ST
NE 3RD ST
NE 4TH ST
NE 27TH ST
NE REVERE AVE
NE PENN AVE
NE OLNEY AVE
NE NEFF RD
SHEVLIN PARK RD
NW NEWPORT AVE
NE LAFAYETTE AVE
NW 14TH ST
NE 8TH ST
SKYLINERS RD
NE HAWTHORNE AVE
HIGHWAY 20
NE 15TH ST
NW COLORADO AVE
BEAR CREEK RD
SW SIMPSON AVE
SE 3RD ST
SW CENTURY DR
SW COLORADO AVE
SW BOND ST
SE 15TH ST
SE 27TH ST
SE 9TH ST
BROOKSWOOD BLVD
HIGHWAY 97
0 0.25 0.5 0.75 1 Miles
2010 to 2040 Demand Volume Growth - Central Study Area
Percent Growth
< 0%
1% - 50%
51% - 100%
101% - 300%
> 300%
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 3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MT WASHINGTON DR
SW BOND ST
HIGHWAY 97
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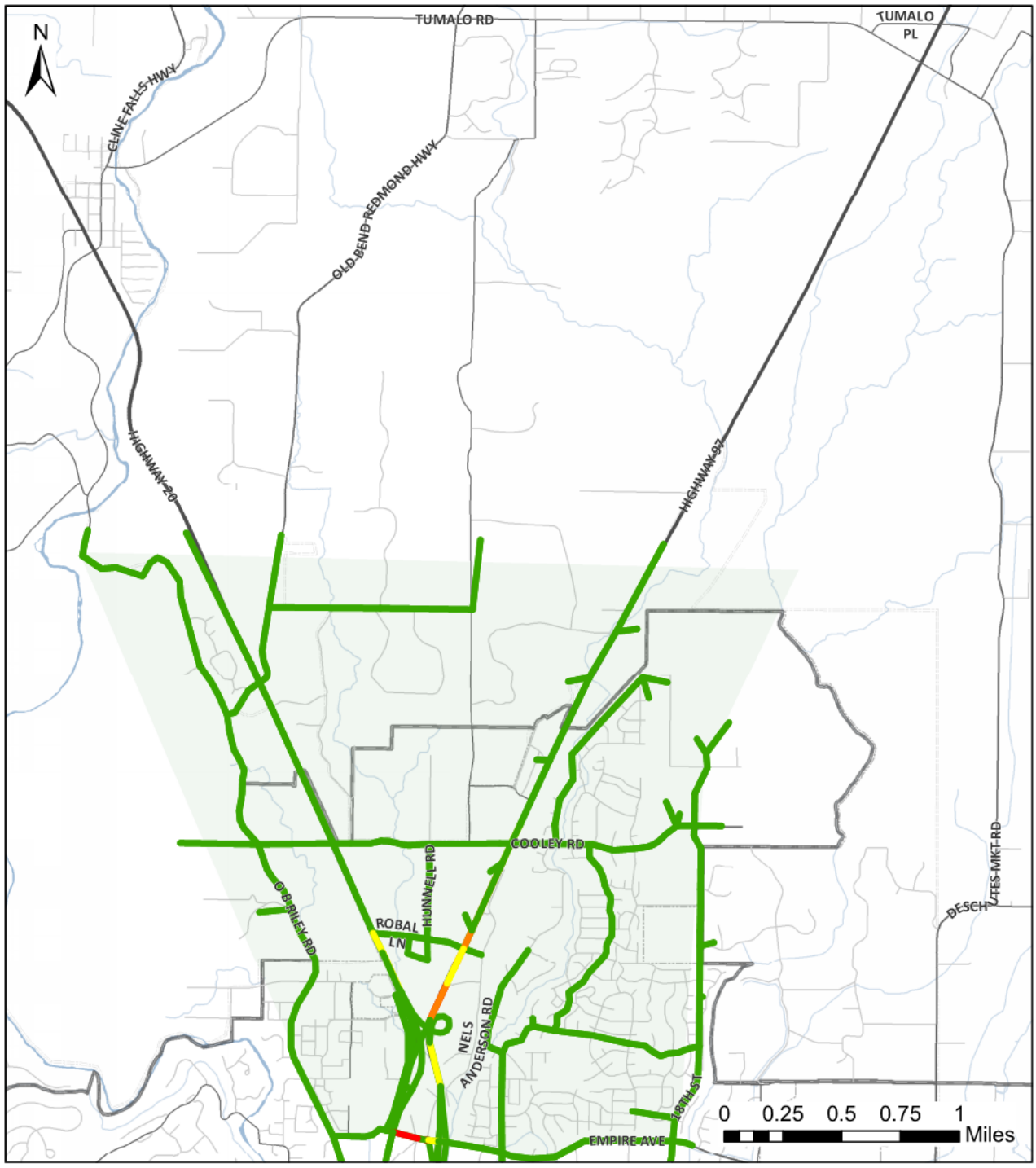
SE 15TH ST
REED MARKET RD
REED LN
SE 3RD ST
SW CENTURY DR
POWERS RD
BADGER RD
15TH ST
BROOKSWOOD BLVD
KNOTT RD
CHINA HAT RD
BAKER RD
0 0.25 0.5 0.75 1
Miles
2010 to 2040 Demand Volume Growth - South Study Area
Percent Growth
< 0%
1% - 50%
51% - 100%
101% - 300%
> 300%
Parkway Study Area
South Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 4



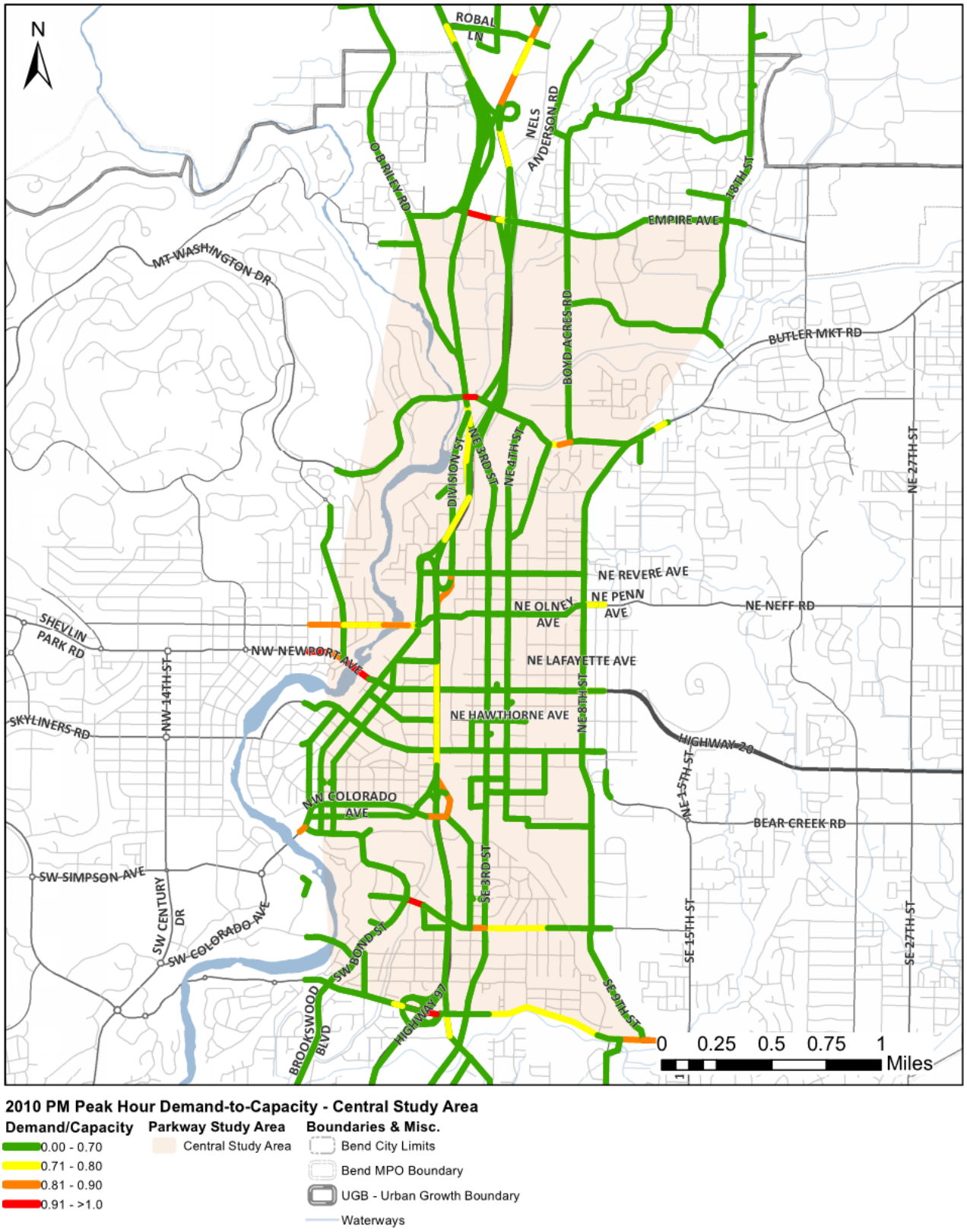
2010 PM Peak Hour Demand-to-Capacity - North Study Area

Demand/Capacity
- 0.00 - 0.70
- 0.71 - 0.80
- 0.81 - 0.90
- 0.91 - >1.0

Parkway Study Area
- North Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Boundary
- Waterways

Figure 5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BEAR CREEK RD
SW SIMPSON AVE
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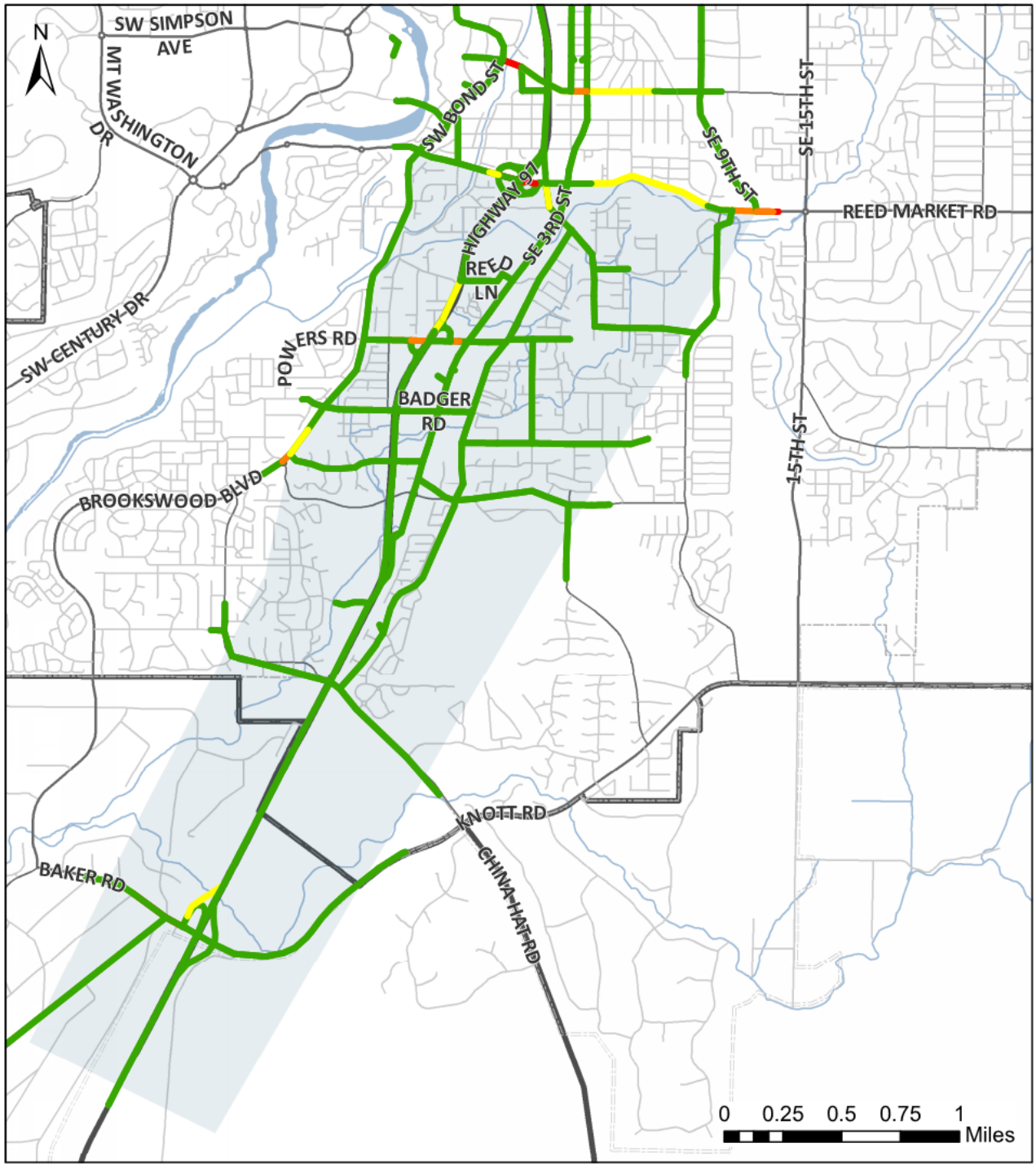
SE 15TH ST
SE 27TH ST
BROOKSWOOD BLVD
HIGHWAY 97
SE 9TH ST
0 0.25 0.5 0.75 1
Miles
2010 PM Peak Hour Demand-to-Capacity - Central Study Area
Demand/Capacity
0.00 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - >1.0
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

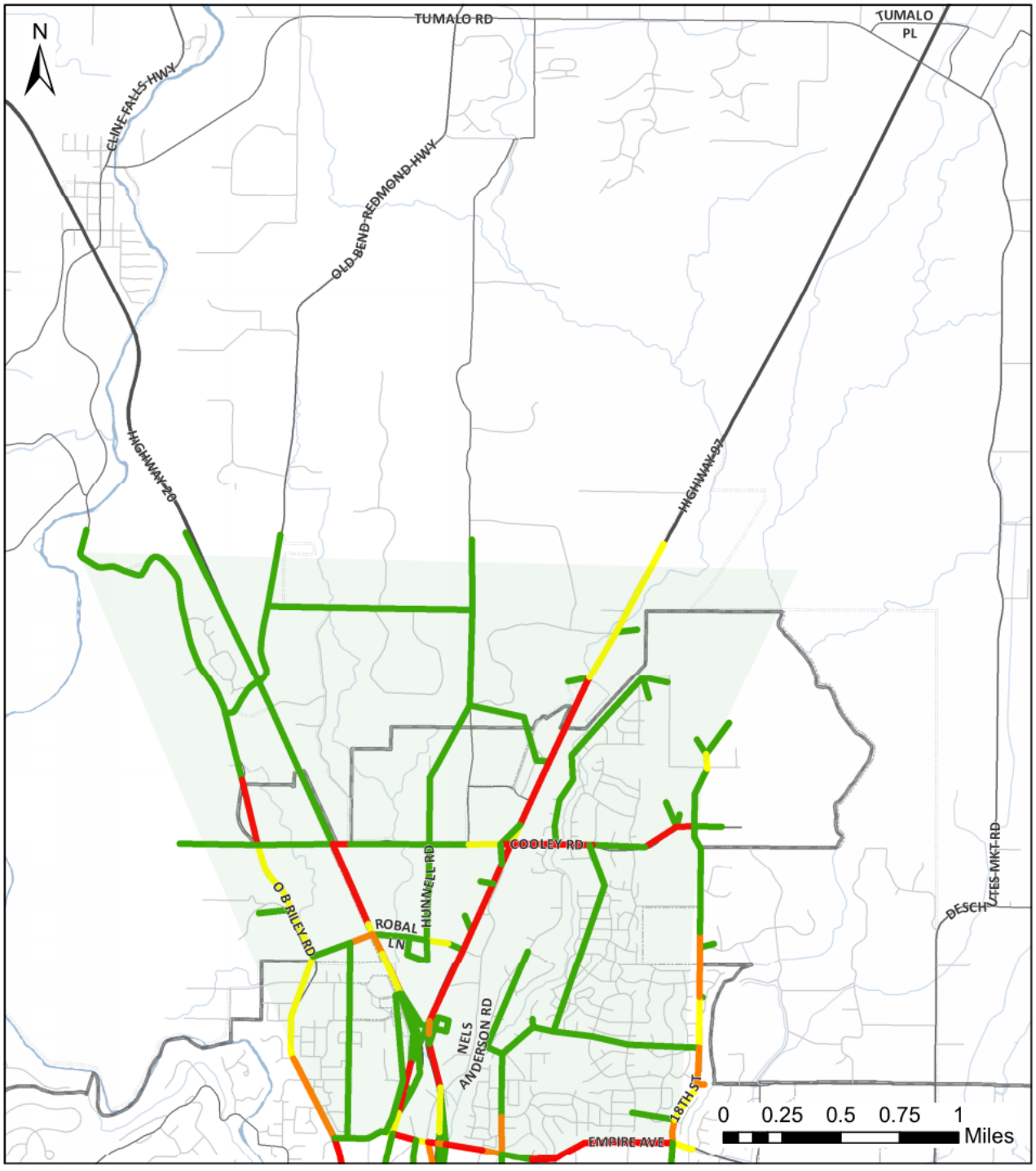
Figure 6



2010 PM Peak Hour Demand to Capacity - South Study Area

Demand/Capacity	Parkway Study Area	Boundaries & Misc.
0.00 - 0.70	South Study Area	Bend City Limits
0.71 - 0.80		Bend MPO Boundary
0.81 - 0.90		UGB - Urban Growth Boundary
0.91 - >1.0		Waterways

Figure 7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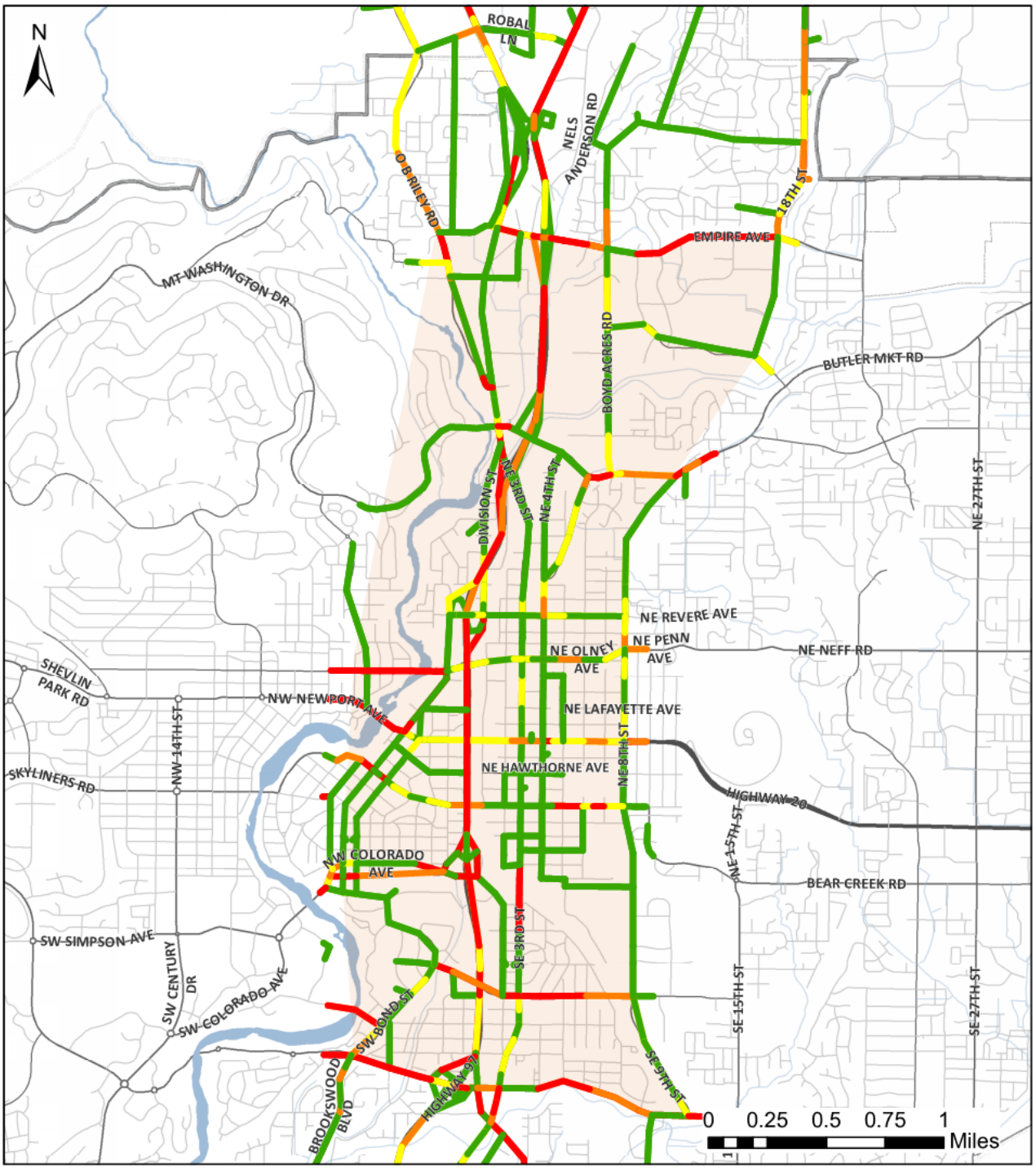
O'BRILEY RD
ROBAL LN
HUNNELL RD
NELS ANDERSON RD
18TH ST
EMPIRE AVE
DESCHUTES MKT RD
0 0.25 0.5 0.75 1
Miles
2040 PM Peak Hour Demand-to-Capacity - North Study Area
Demand/Capacity
0.00 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - >1.0
Parkway Study Area
North Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 8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SE 9TH ST
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HIGHWAY 97
0 0.25 0.5 0.75 1
Miles
2040 PM Peak Hour Demand-to-Capacity - Central Study Area
Demand/Capacity
0.00 - 0.70
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0.91 - >1.0
Parkway Study Area
Central Study Area
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Bend MPO Boundary
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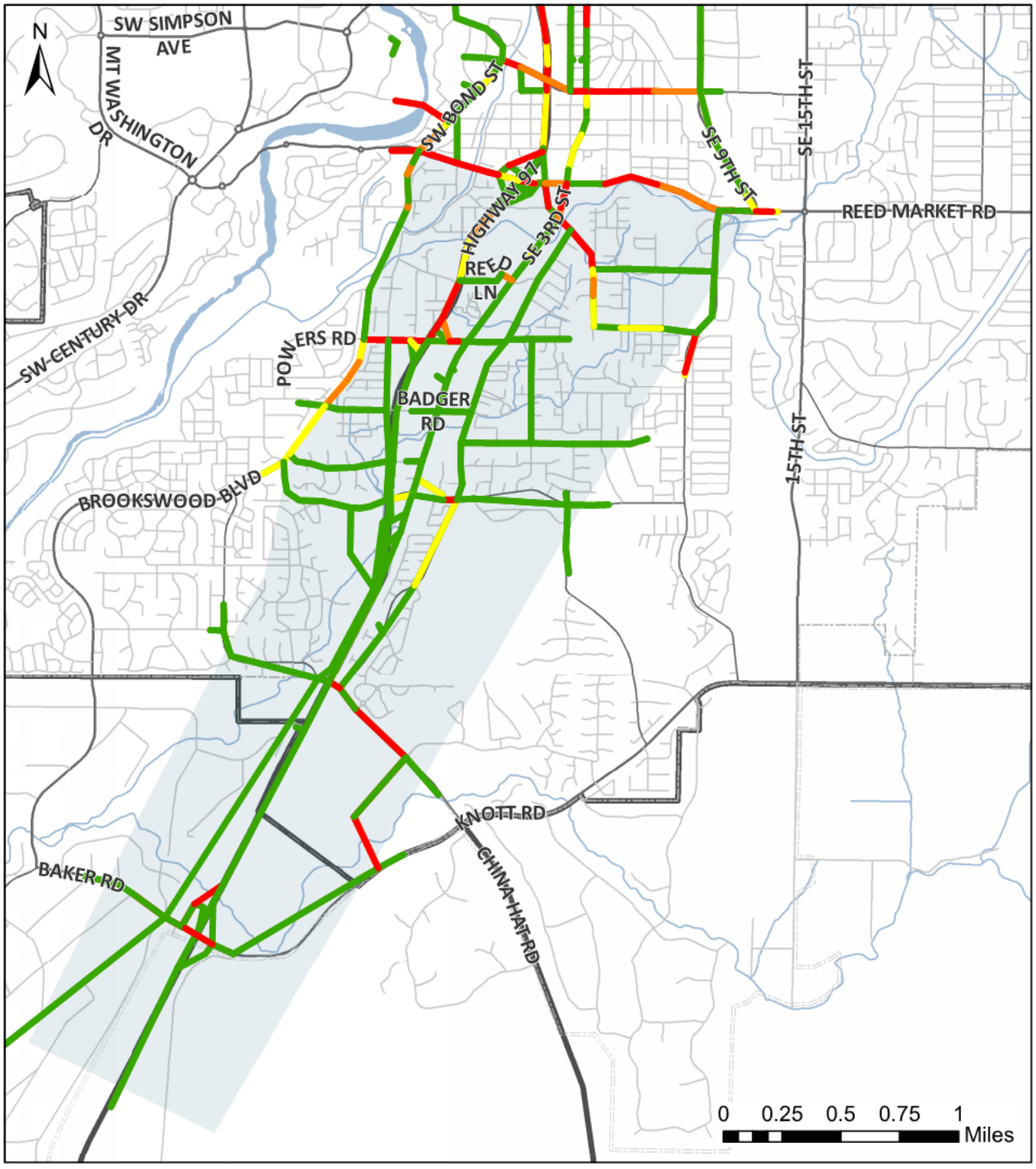
Waterways

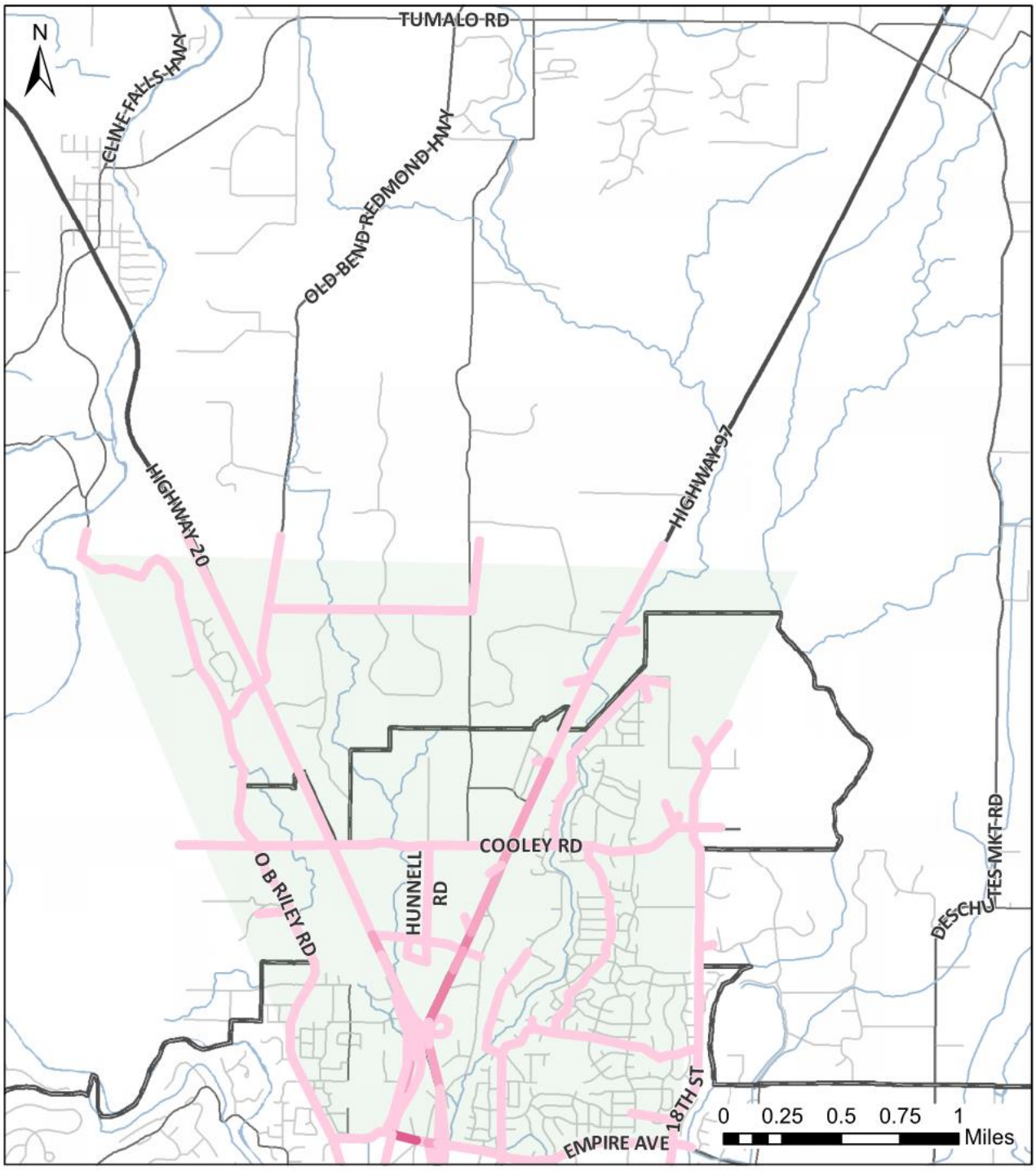
Figure 9



2040 PM Peak Hour Demand to Capacity - South Study Area

Demand/Capacity	Parkway Study Area	Boundaries & Misc.
0.00 - 0.70	South Study Area	Bend City Limits
0.71 - 0.80		Bend MPO Boundary
0.81 - 0.90		UGB - Urban Growth Boundary
0.91 - >1.0		Waterways

Figure 10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OLD BEND REDMOND HWY
HIGHWAY 20
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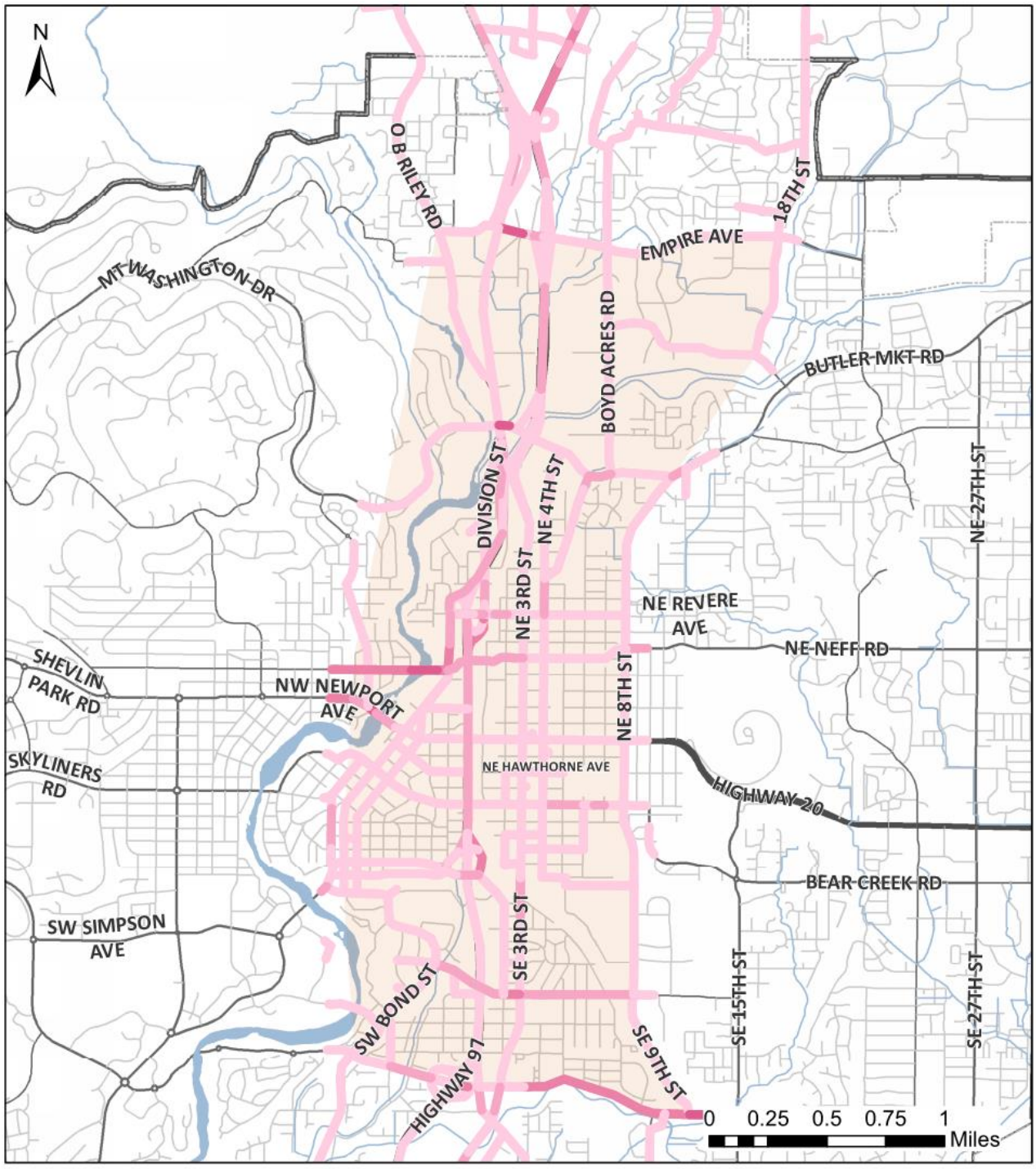
O B RILEY RD
HUNNELL RD
DESCHUTES MKT RD
18TH ST
EMPIRE AVE
0 0.25 0.5 0.75 1
Miles
2010 Daily Demand-to-Capacity - North Study Area
Demand/Capacity
0.00 - 6.75
6.75 - 9.25
9.25 - 10.75
10.75 - 13.75
13.75 - 15.25
> 15.25
Parkway Study Area
North Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

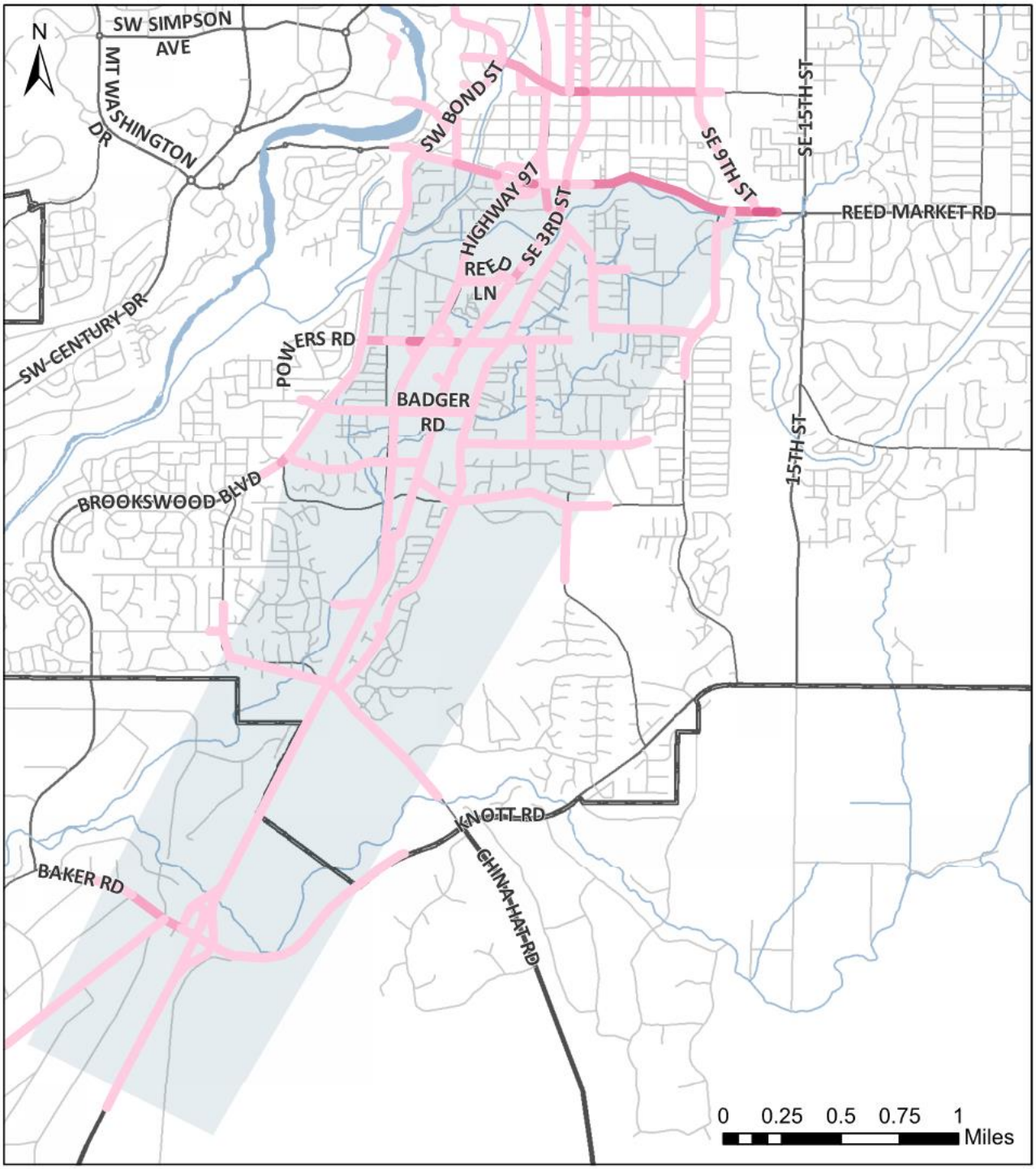
Figure 11



2010 Daily Demand-to-Capacity - Central Study Area

Demand/Capacity	Parkway Study Area	Boundaries & Misc.
0.00 - 6.75	Central Study Area	Bend City Limits
6.75 - 9.25		Bend MPO Boundary
9.25 - 10.75		UGB - Urban Growth Boundary
10.75 - 13.75		Waterways
13.75 - 15.25		
> 15.25		

Figure 12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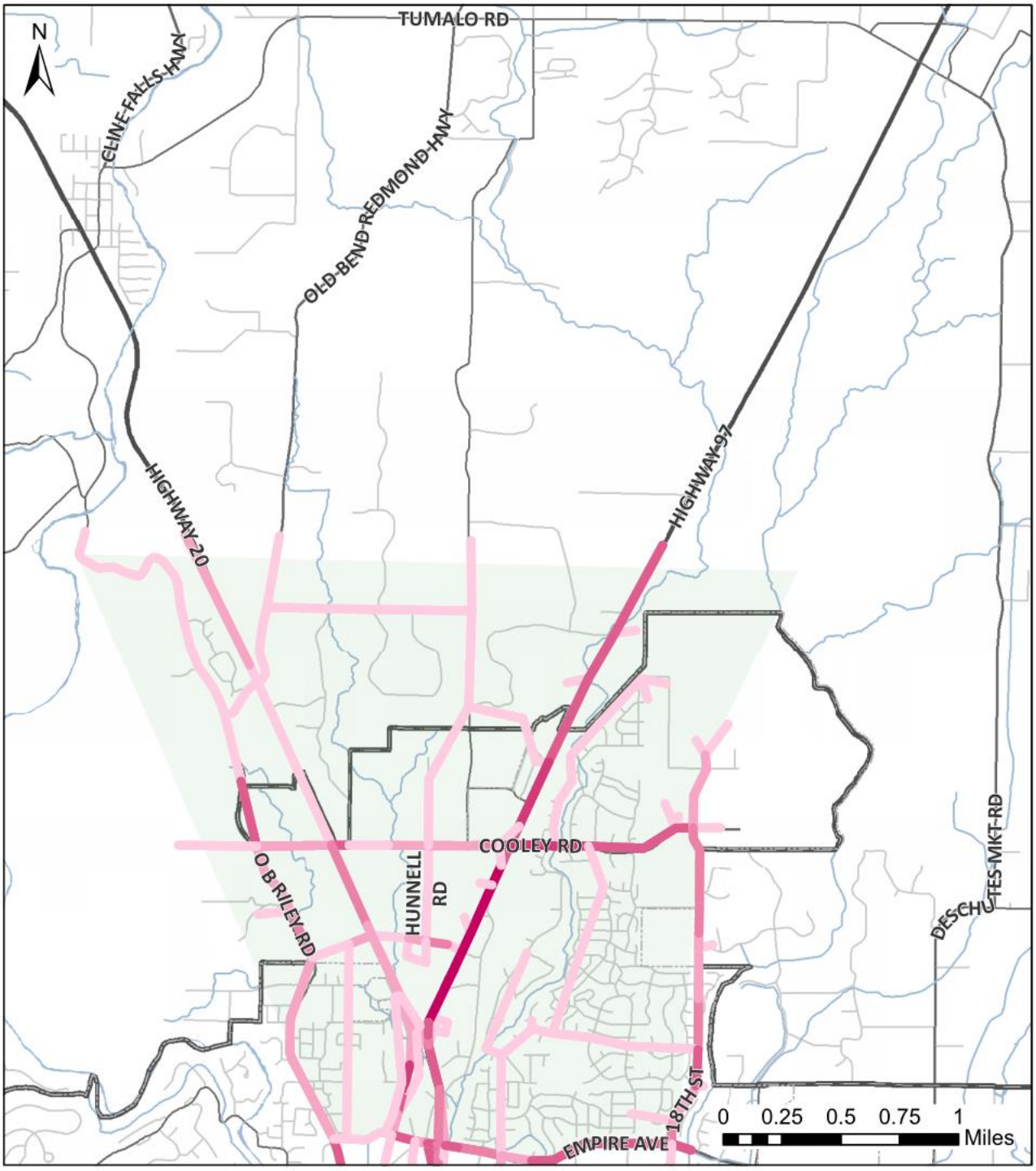
SE 15TH ST
REED MARKET RD
HIGHWAY 97
REED LN
SE 3RD ST
SW CENTURY DR
POWERS RD
BADGER RD
15TH ST
BROOKSWOOD BLVD
KNOTT RD
BAKER RD
CHINA HAT RD
0 0.25 0.5 0.75 1
Miles
2010 Daily Demand to Capacity - South Study Area
Demand/Capacity
0.00 - 6.75
6.75 - 9.25
9.25 - 10.75
10.75 - 13.75
13.75 - 15.25
> 15.25
Parkway Study Area
South Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 13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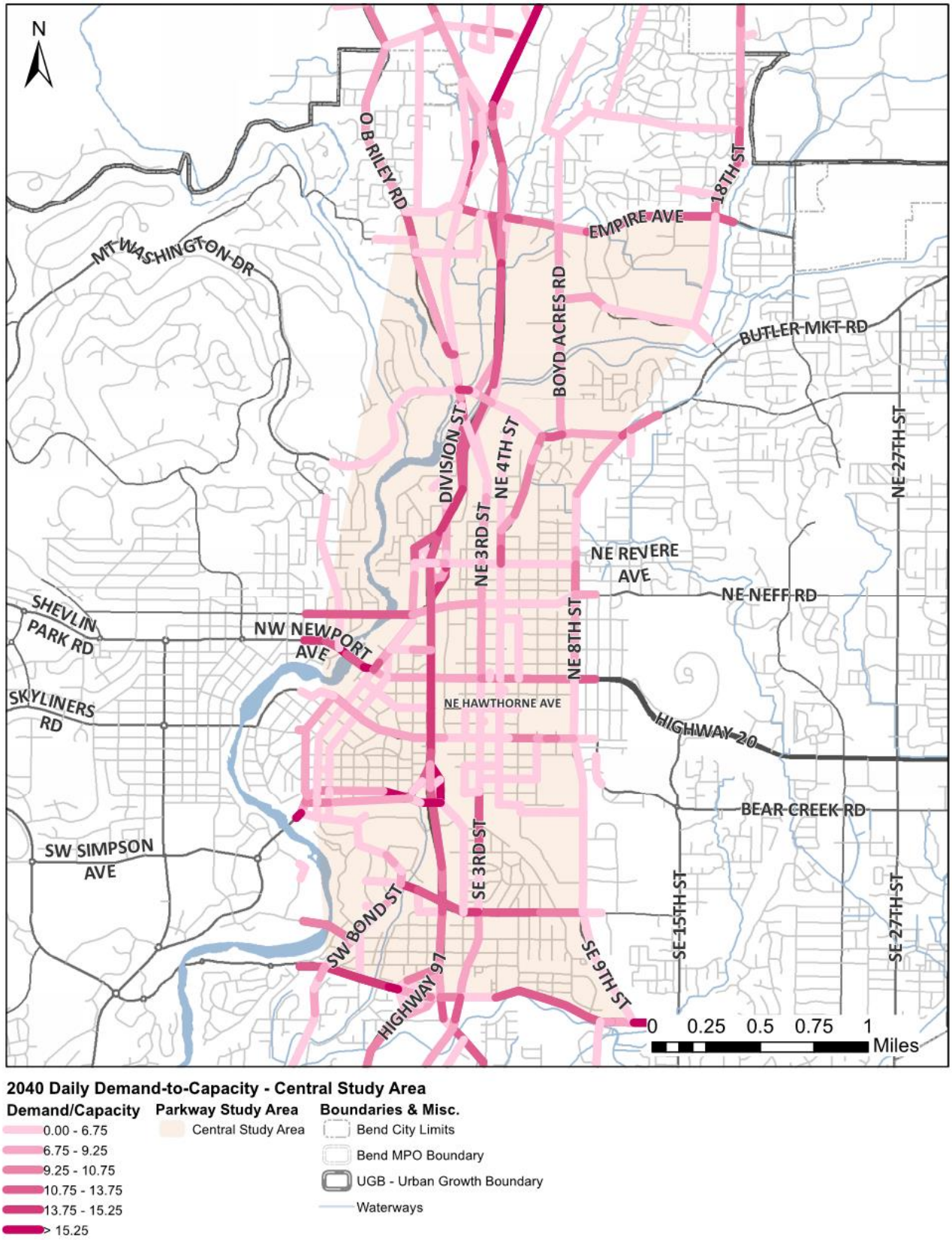
CLINE FALLS HWY
OLD BEND-REDMOND HWY
HIGHWAY 20
HIGHWAY 97
COOLEY RD
O'BRIEN RD
HUNNELL RD
DESCHUTES MKT RD
18TH ST
EMPIRE AVE
0 0.25 0.5 0.75 1
Miles
2040 Daily Demand-to-Capacity - North Study Area
Demand/Capacity
0.00 - 6.75
6.75 - 9.25
9.25 - 10.75
10.75 - 13.75
13.75 - 15.25
> 15.25
Parkway Study Area
North Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 14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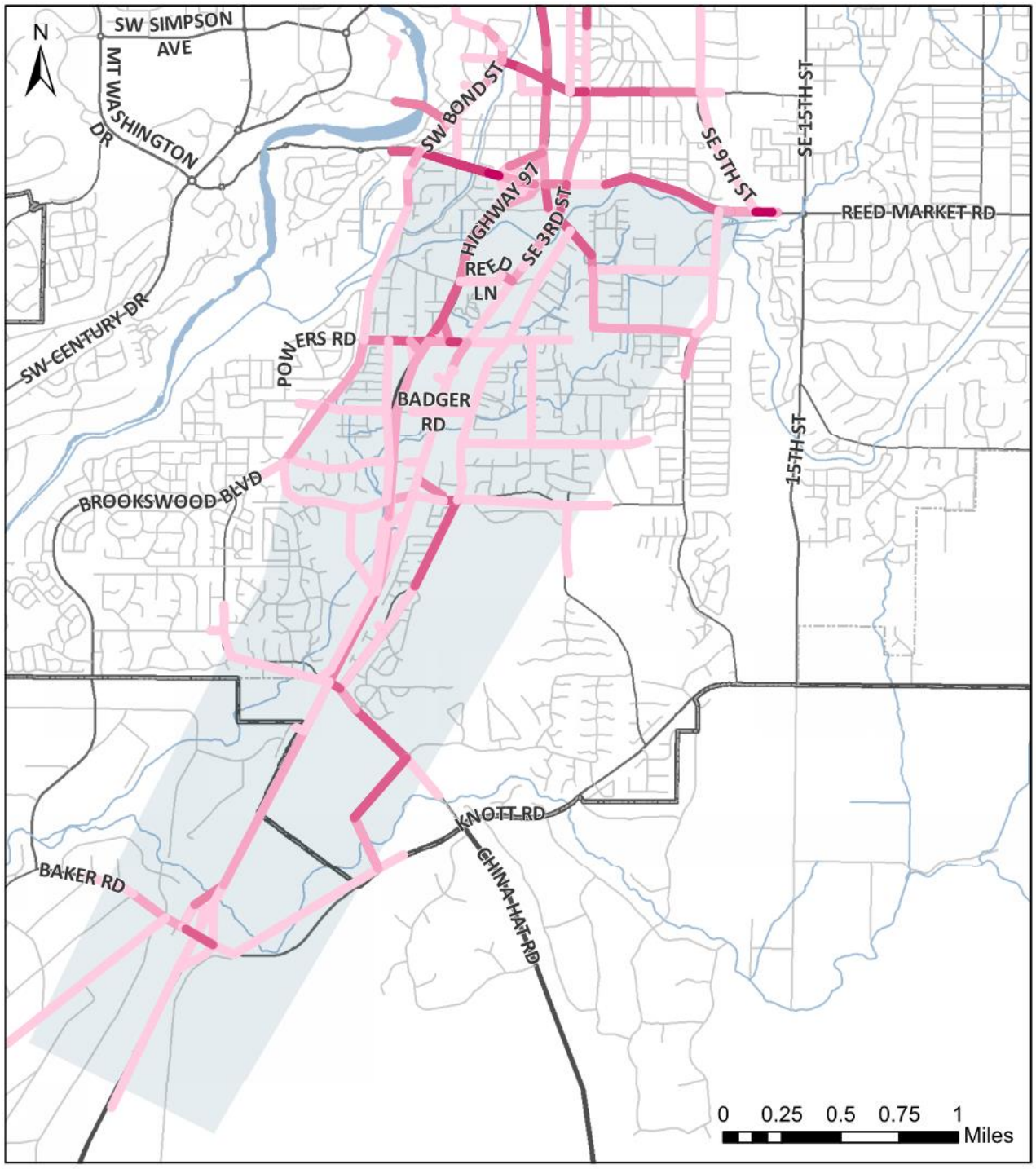
O B RILEY RD
MT WASHINGTON DR
EMPIRE AVE
18TH ST
BOYD ACRES RD
BUTLER MKT RD
DIVISION ST
NE 4TH ST
NE 3RD ST
NE 27TH ST
NE REVERE AVE
NE NEFF RD
SHEVLIN PARK RD
NW NEWPORT AVE
NE 8TH ST
SKYLINERS RD
NE HAWTHORNE AVE
HIGHWAY 20
BEAR CREEK RD
SW SIMPSON AVE
SE 3RD ST
SW BOND ST
SE 15TH ST
SE 27TH ST
SE 9TH ST
HIGHWAY 97
0 0.25 0.5 0.75 1
Miles
2040 Daily Demand-to-Capacity - Central Study Area
Demand/Capacity
0.00 - 6.75
6.75 - 9.25
9.25 - 10.75
10.75 - 13.75
13.75 - 15.25
> 15.25
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 15



2040 Daily Demand to Capacity - South Study Area

Demand/Capacity
daily_vc_c
- 0.00 - 6.75
- 6.75 - 9.25
- 9.25 - 10.75
- 10.75 - 13.75
- 13.75 - 15.25
- > 15.25

Parkway Study Area
- South Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Boundary
- Waterways

3.3 Regional Travel Patterns

An analysis was performed to determine what percentage of trips using US 97 originate or terminate in a local destination in Bend or a regional destination. The 2040 Bend-Redmond travel demand model was used to estimate the distribution of trips using US 97 at four locations along the corridor. Table 1 breaks down the corridor usage by trips that begin and end in Bend, trips that either originate or terminate in Bend, and trips that begin and end outside of Bend[4].

Table 1: US 97 Corridor Travel Patterns Comparing Existing Conditions to 2040 No Build Conditions

Location	Begin and End in Bend 2040 / (2010)	Begin or End in Bend 2040 / (2010)	Begin and End Outside Bend 2040 / (2010)
US 97/Bend Parkway Southbound			
South of US 20 interchange	41% / (40%)	48% / (50%)	11% / (10%)
South of Revere Ave interchange	56% / (53%)	35% / (38%)	9% / (9%)
South of Truman Ave	58% / (54%)	33% / (37%)	9% / (9%)
South of Badger Rd	42% / (21%)	41% / (60%)	17% / (19%)
US 97/Bend Parkway Northbound			
South of US 20 interchange	34% / (27%)	59% / (65%)	7% / (8%)
South of Revere Ave interchange	54% / (55%)	38% / (36%)	8% / (9%)
South of Truman Ave	57% / (52%)	32% / (36%)	11% / (12%)
South of Badger Rd	41% / (21%)	41% / (59%)	18% / (20%)

The travel pattern analysis shows that on average 43% of trips on US 97 in Bend in 2040 are local trips within the city and 47% of trips using US 97 have either an origin or destination in Bend. Of particular note, the percent of local trips (begin and end in Bend) on US 97 south of Badger Road increases dramatically (21% to 41%) due to future growth in the southeast UGB expansion area. On average, only 10% of trips on US 97 are through trips, meaning they start and end outside of Bend.

[4] The 2040 Bend urban growth boundary was used for the purpose of identifying trips that begin and/or end in Bend.

4.0 MULTIMODAL ANALYSIS

This section includes an overview of the future state of the bicycle and pedestrian facilities along the study corridor. The multimodal analysis focuses on the Level of Traffic Stress (LTS) experienced by people walking and biking, as was done under existing conditions. Again, the LTS analysis was applied only to the mainline of the US 97 corridor and key crossing locations.

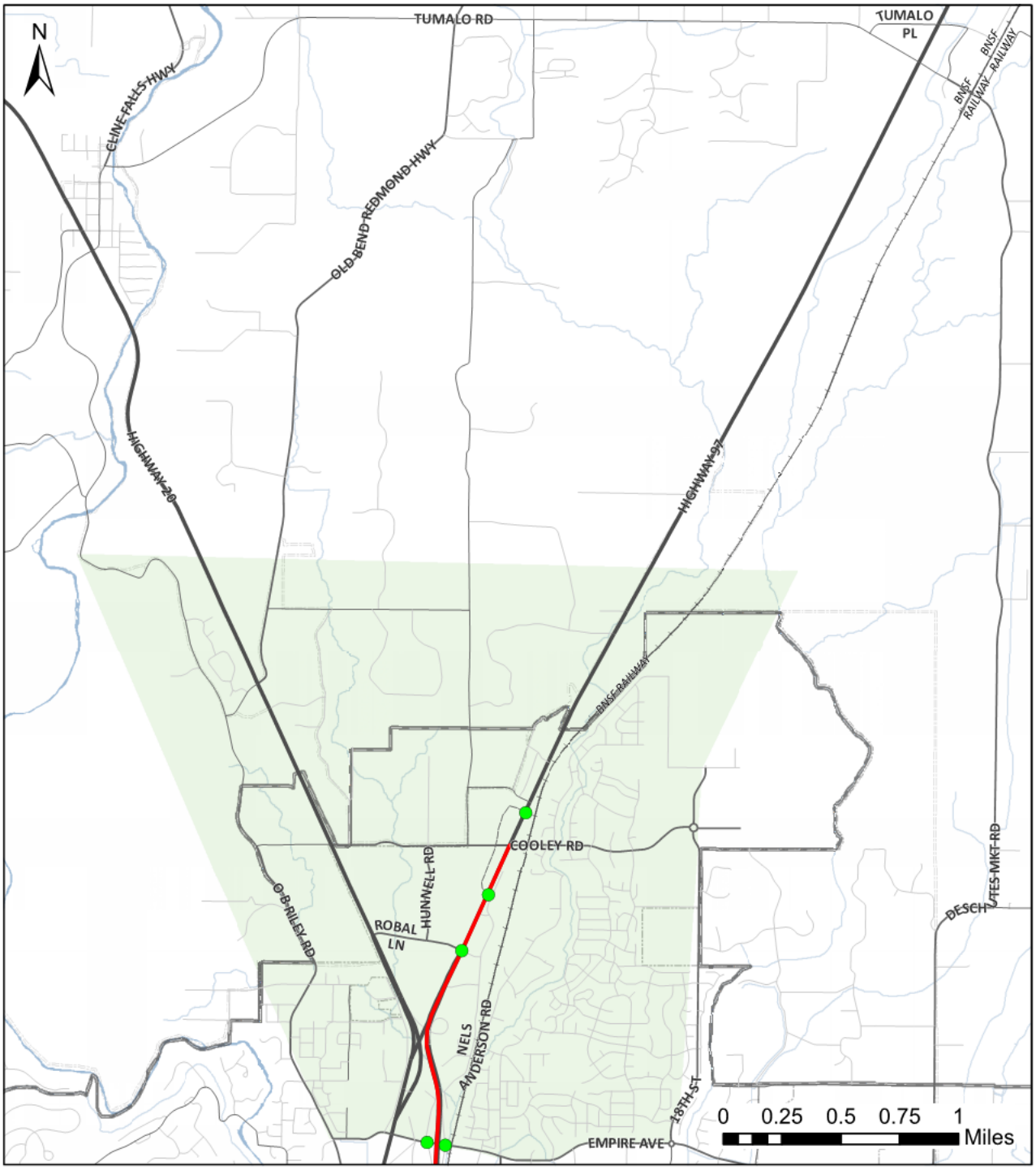
4.1 BICYCLE LEVEL OF TRAFFIC STRESS ASSESSMENT

In the future 2040 No Build scenario, the only planned improvement that would significantly change the Bicycle LTS findings from existing conditions is the new traffic signal on Empire Boulevard at the US 97 Southbound Ramp Terminal. Under existing conditions, it was found that the unsignalized crossings generally experienced higher levels of traffic stress. Signalization of Empire Boulevard at the US 97 Southbound Ramp Terminal would improve the estimated level of traffic stress at this location from Low (LTS 2) to Lowest (LTS 1).

There are no physically separate bicycle facilities planned for the US 97 mainline and travel speeds are assumed to remain high. Therefore, the Bicycle LTS on the mainline will continue to be high.

Figures 16-18 show the Bicycle LTS projected for the US 97 mainline and key crossing locations under 2040 No Build conditions.

Figure 16



2040 No-Build Bicycle Level of Traffic Stress - North Study Area

Roads
- Highway
- Arterial
- Collector
- Local
- Future Roadway

Infrastructure
- Railroads

Bicycle Level of Traffic Stress

Segment Stress
- High

Intersection Stress
- Lowest

Parkway Study Area
- North Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Boundary
- Waterways

Figure 17

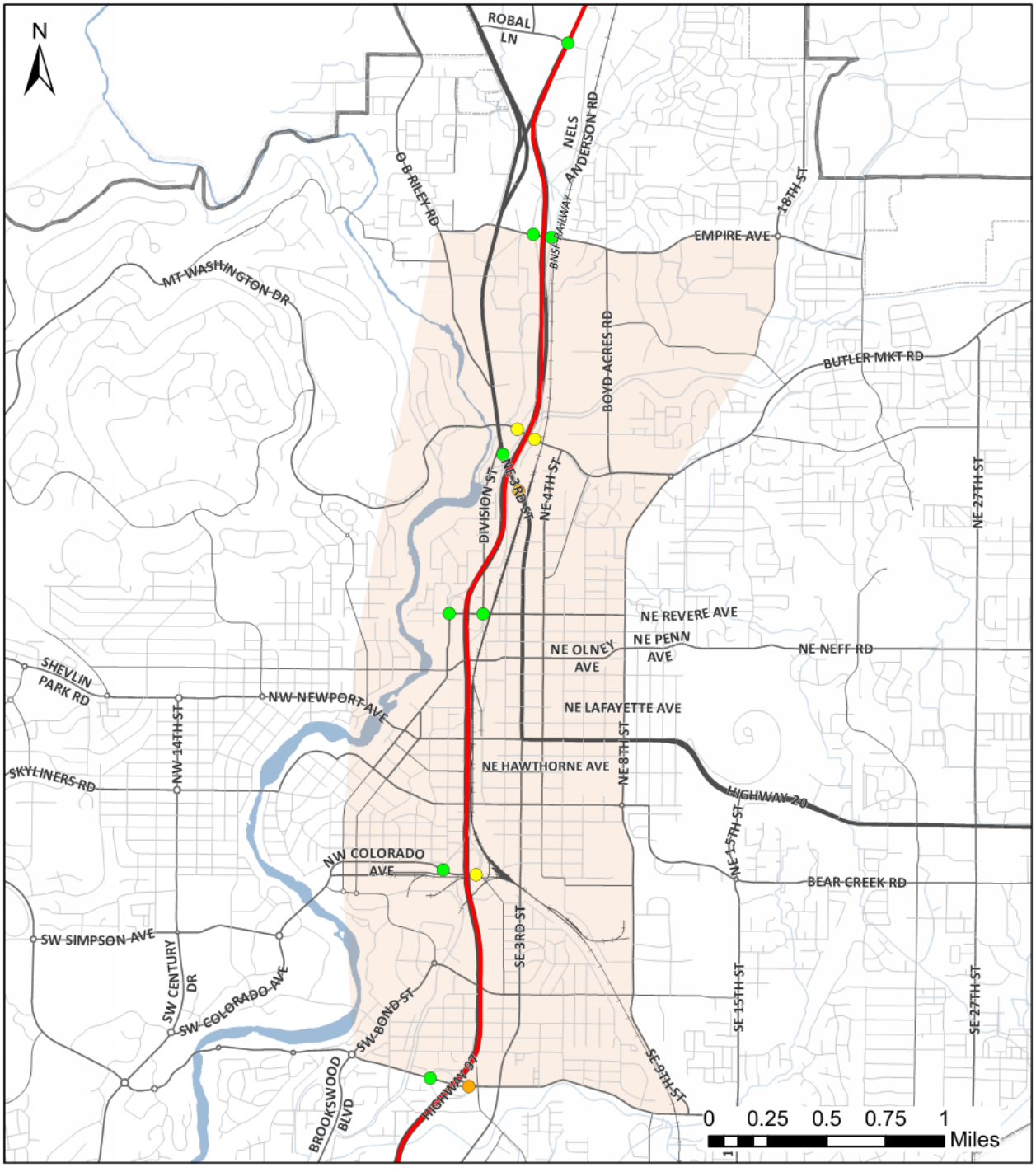
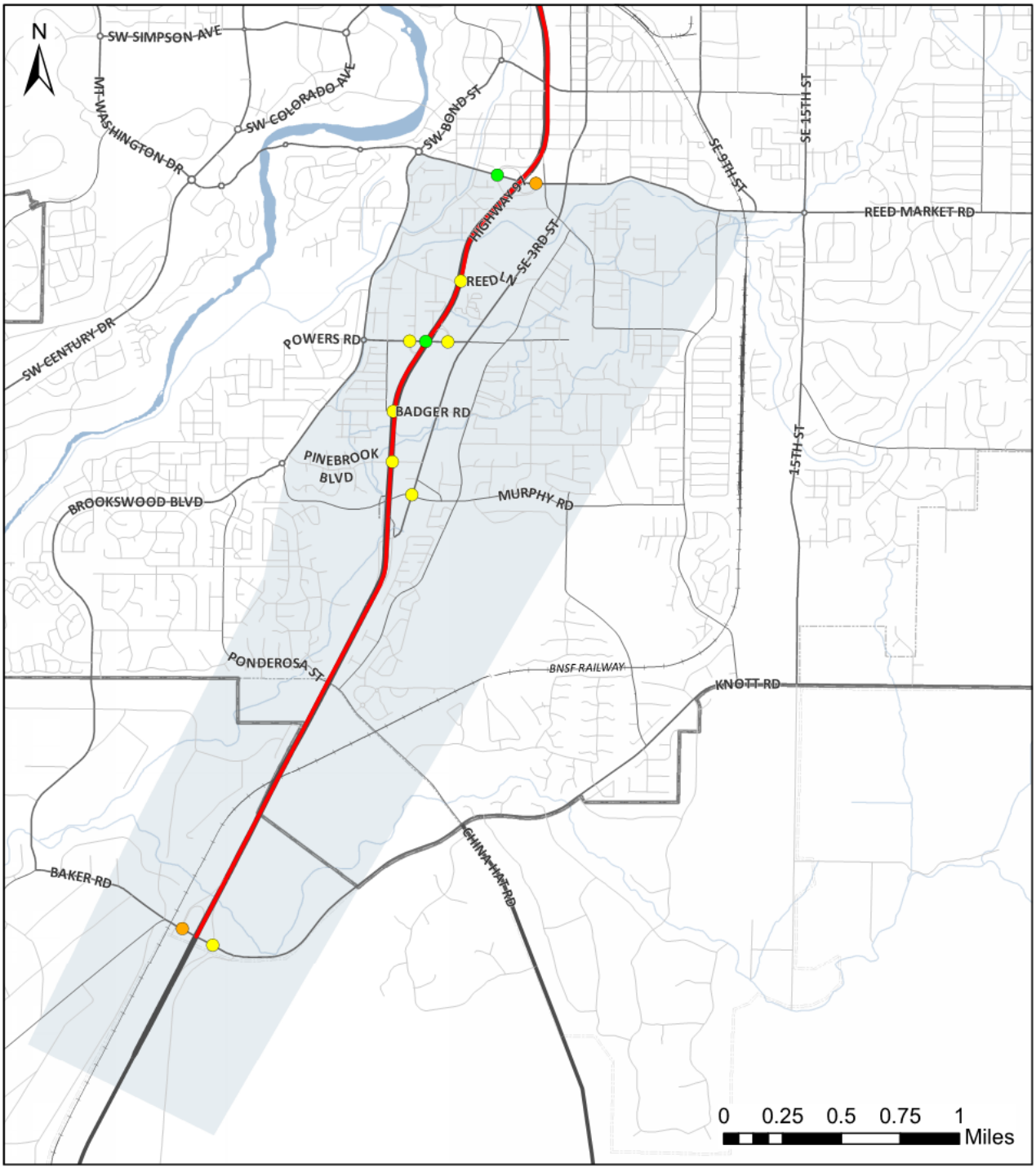

N
ROBAL LN
NELS ANDERSON RD
O B RILEY RD
BUSINESS HWY
18TH ST
EMPIRE AVE
MT WASHINGTON DR
BOYD ACRES RD
BUTLER MKT RD
DIVISION ST
NE 3RD ST
NE 4TH ST
NE 27TH ST
NE REVERE AVE
NE PENN AVE
NE OLNEY AVE
NE NEFF RD
SHEVLIN PARK RD
NW NEWPORT AVE
NE LAFAYETTE AVE
NW 14TH ST
NE 8TH ST
SKYLINERS RD
NE HAWTHORNE AVE
HIGHWAY 20
NE 15TH ST
NW COLORADO AVE
BEAR CREEK RD
SW SIMPSON AVE
SE 3RD ST
SW CENTURY DR
SW COLORADO AVE
SW BOND ST
SE 15TH ST
SE 27TH ST
SE 9TH ST
BROOKSWOOD BLVD
HIGHWAY 97
0 0.25 0.5 0.75 1
Miles
2040 No-Build Bicycle Level of Traffic Stress - Central Study Area
Roads
Highway
Arterial
Collector
Local
Infrastructure
Railroads
Bicycle Level of Traffic Stress
Segment Stress
High
Intersection Stress
Lowest
Low
Medium
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 18



2040 No-Build Bicycle Level of Traffic Stress - South Study Area

Roads
- Highway
- Arterial
- Collector
- Local
- Future Roadway

Infrastructure
- Railroads

Bicycle Level of Traffic Stress

Segment Stress
- High

Intersection Stress
- Lowest
- Low
- Medium

Parkway Study Area
- South Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Bounda
- Waterways

4.2 Pedestrian Level of Traffic Stress Assessment

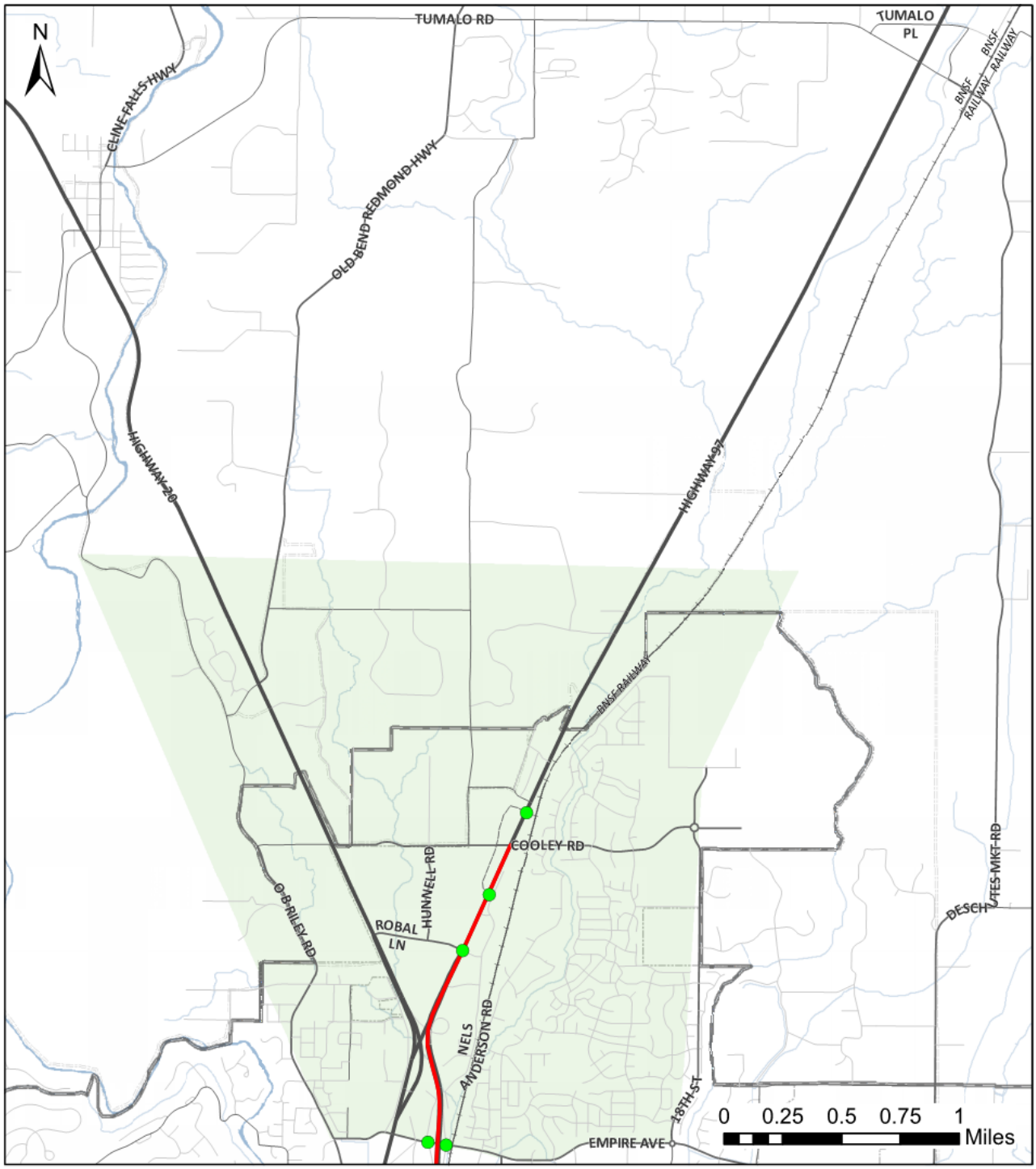
As with the Bicycle LTS analysis, the only planned improvement by 2040 is the new traffic signal on Empire Boulevard at the US 97 Southbound Ramp Terminal. This crossing was rated as having a High (LTS 4) level of traffic stress under existing conditions but improves to a Low level of traffic stress with signalized control. The other three intersections found to have a high level of traffic stress under existing conditions will continue to have high levels of traffic stress under the 2040 No Build condition. These include: 3rd Street/ US 97 Northbound Ramp, Baker Road/ US 97 Southbound Ramps, and Knott Road/ US 97 Northbound Ramps.

In addition to these, the Pedestrian LTS worsens from Medium (LTS 3) to High at the intersection of Colorado Avenue/ US 97 Northbound Ramps due to an increase in traffic volumes at this unsignalized crossing.

Under existing conditions, the US 97 mainline was noted being a Medium to High stress pedestrian environment. There are no planned improvements along the US 97 mainline that would lessen levels of traffic stress experienced by people walking and the Pedestrian LTS analysis methodology for street segments is unaffected by traffic volume. Therefore, the 2040 No Build assessment of Pedestrian LTS on the US 97 mainline is unchanged from existing conditions.

Figures 19-21 show the Pedestrian LTS projected for the US 97 mainline and key crossing locations under 2040 No Build conditions.

Figure 19



2040 No-Build Bicycle Level of Traffic Stress - North Study Area

Roads
- Highway
- Arterial
- Collector
- Local
- Future Roadway

Infrastructure
- Railroads

Bicycle Level of Traffic Stress

Segment Stress
- High

Intersection Stress
- Lowest

Parkway Study Area
- North Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Boundary
- Waterways

Figure 20

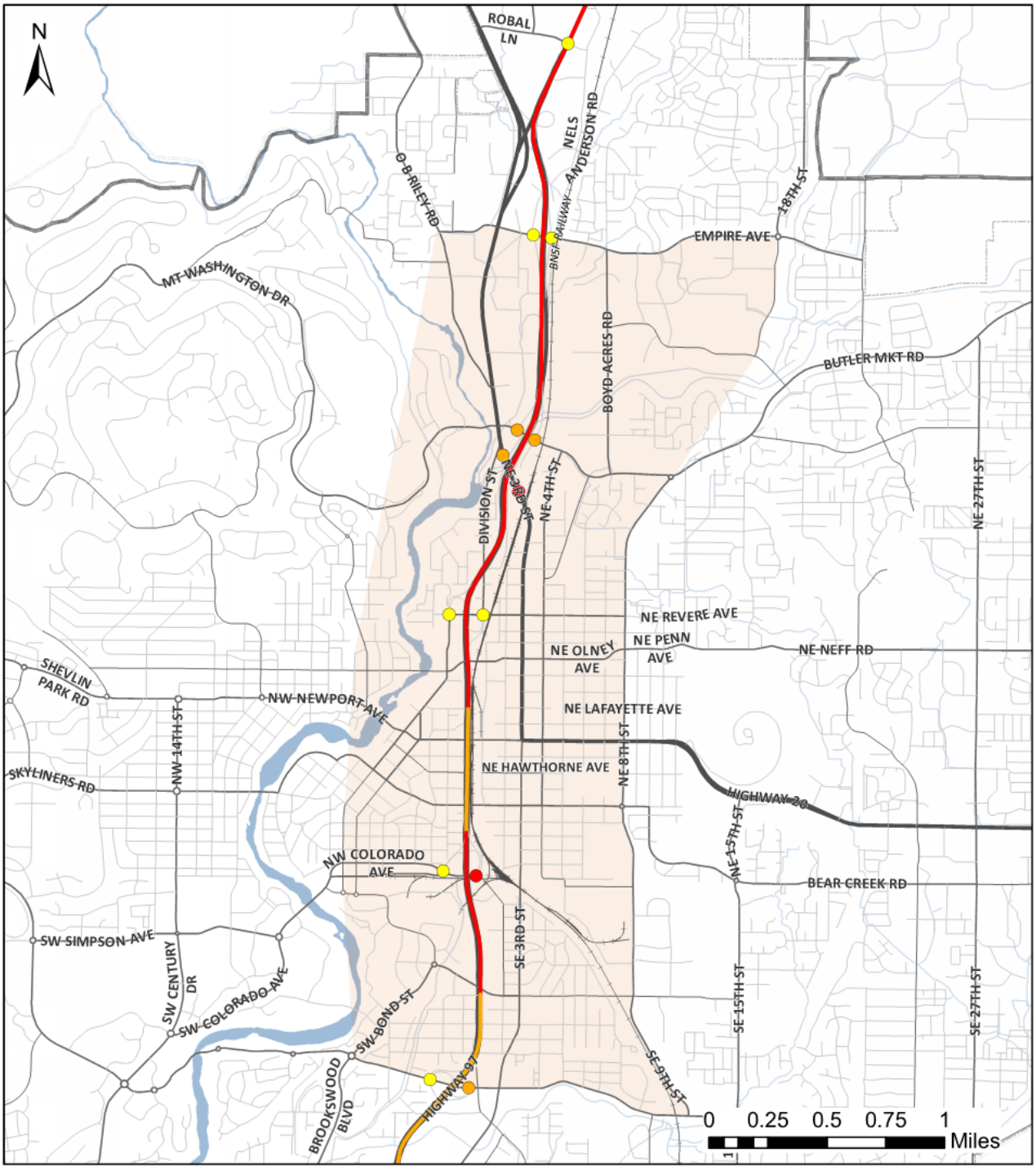
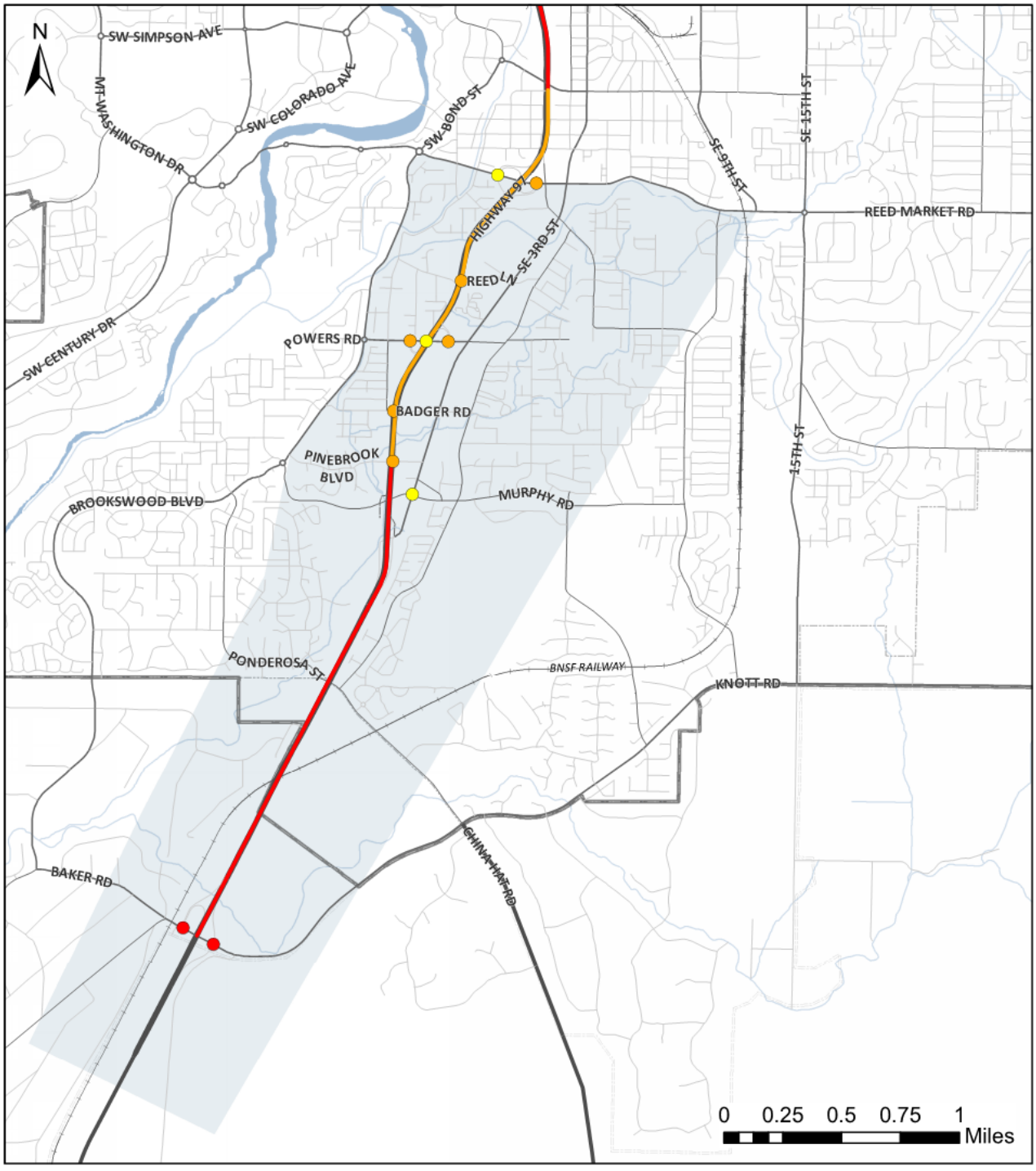

N
ROBAL LN
NELS ANDERSON RD
O B RILEY RD
BNSF RAILWAY
EMPIRE AVE
18TH ST
MT WASHINGTON DR
BOYD ACRES RD
BUTLER MKT RD
DIVISION ST
NE 3RD ST
NE 4TH ST
NE 27TH ST
NE REVERE AVE
NE OLNEY AVE
NE PENN AVE
NE NEFF RD
SHEVLIN PARK RD
NW NEWPORT AVE
NE LAFAYETTE AVE
NW 14TH ST
NE 8TH ST
SKYLINERS RD
NE HAWTHORNE AVE
HIGHWAY 20
NE 15TH ST
NW COLORADO AVE
BEAR CREEK RD
SW SIMPSON AVE
SE 3RD ST
SW CENTURY DR
SW COLORADO AVE
SW BOND ST
SE 15TH ST
SE 27TH ST
SE 9TH ST
BROOKSWOOD BLVD
HIGHWAY 97
0 0.25 0.5 0.75 1 Miles
2040 No-Build Pedestrian Level of Traffic Stress - Central Study Area
Roads
Highway
Arterial
Collector
Local
Infrastructure
Railroads
Pedestrian Level of Traffic Stress
Segment Stress
Medium
High
Intersection Stress
Low
Medium
High
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 21



2040 No-Build Pedestrian Level of Traffic Stress - South Study Area

Roads
- Highway
- Arterial
- Collector
- Local
- Future Roadway

Infrastructure
- Railroads

Pedestrian Level of Traffic Stress

Segment Stress
- Medium
- High

Intersection Stress
- Low
- Medium
- High

Parkway Study Area
- South Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Boundary
- Waterways

4.3 Pedestrian and Bicycle Crossing Improvement Priorities

A separate Bicycle and Pedestrian Working Group comprised of ODOT and City of Bend staff has provided supplemental analysis focused on the need for more high-quality crossing opportunities along US 97 for people walking and biking. This analysis included factors such as the current quality of crossings (e.g., level of traffic stress), distance between crossing opportunities, potential demand resulting from adjacent land uses, crash history, and alignment with the City's low-stress network.

Tables 2 and 3 show the results of this analysis, documenting locations for crossing enhancements related to existing crossing locations and new crossing locations, respectively. The crossing enhancements locations were broken down into two tier levels: Tier 1 locations are considered higher priority and Tier 2 projects, while still important, are considered lower priority. All new crossings are assumed to be grade-separated (i.e., they would cross over or under US 97).

Table 2: Tier 1 and 2 Locations for Improving Existing US 97 Pedestrian & Bicycle Crossings

Study Area	Tier 1 Investment Locations	Tier 2 Investment Locations
North	Empire Blvd	Robal Rd
	Cooley Rd	
Central	Butler Market Rd	Revere Ave
	Olney Ave	Greenwood Ave
	Wilson Ave	Franklin Ave
		Reed Market Rd
South	Canal/Garfield Ave	Powers Rd
	Baker Rd/Knott Rd	Murphy Rd

Table 3: Tier 1 and 2 Locations for Creating New US 97 Pedestrian & Bicycle Crossings

Study Area	Tier 1 Investment Locations	Tier 2 Investment Locations
North	(none)	
Central	Hawthorne Ave	
South	Badger Rd/Pinebrook Blvd	
	China Hat Rd	

The proposed investments in existing and new pedestrian and bicycle crossing improvements would result in the low-stress crossing spacing detailed in Table 4.

Table 4: Pedestrian & Bicycle Low-Stress Crossing Spacing on US 97 Resulting from Investments in Existing and New Crossing Improvements

Study Area	Cross Street 1	Cross Street 2	Distance (ft)	Distance (mi)
North	Cooley Rd	Robal Rd	2,620	0.50
	Robal Rd	Empire Blvd	4,545	0.86
Central	Empire Blvd	Butler Market Rd	4,510	0.85
	Butler Market Rd	Underwood Ave	3,170	0.60
	Underwood Ave	Revere Ave	1,170	0.22
	Revere Ave	Olney Ave	1,045	0.20
	Olney Ave	Greenwood Ave	1,775	0.34
	Greenwood Ave	Hawthorne Ave	735	0.14
	Hawthorne Ave	Franklin Ave	730	0.14
	Franklin Ave	Colorado Ave	1,610	0.30
	Colorado Ave	Aune Rd	590	0.11
	Aune Rd	Wilson Ave	1,980	0.38
	Wilson Ave	Reed Market Rd	2,380	0.45
South	Reed Market Rd	Canal/ Garfield Ave	1,630	0.31
	Canal/Garfield Ave	Powers Rd	2,820	0.53
	Powers Rd	Badger Rd/Pinebrook Blvd	2,275	0.43
	Badger Rd/Pinebrook Blvd	Murphy Rd	1,480	0.28
	Murphy Rd	China Hat Rd	4,380	0.83
	China Hat Rd	Baker Rd/Knott Rd	6,410	1.21

Figures 22-24 illustrate the resulting low-stress pedestrian and bicycle crossing spacing assuming all investments in existing and new facilities are made (consistent with Table 4).

Figure 22

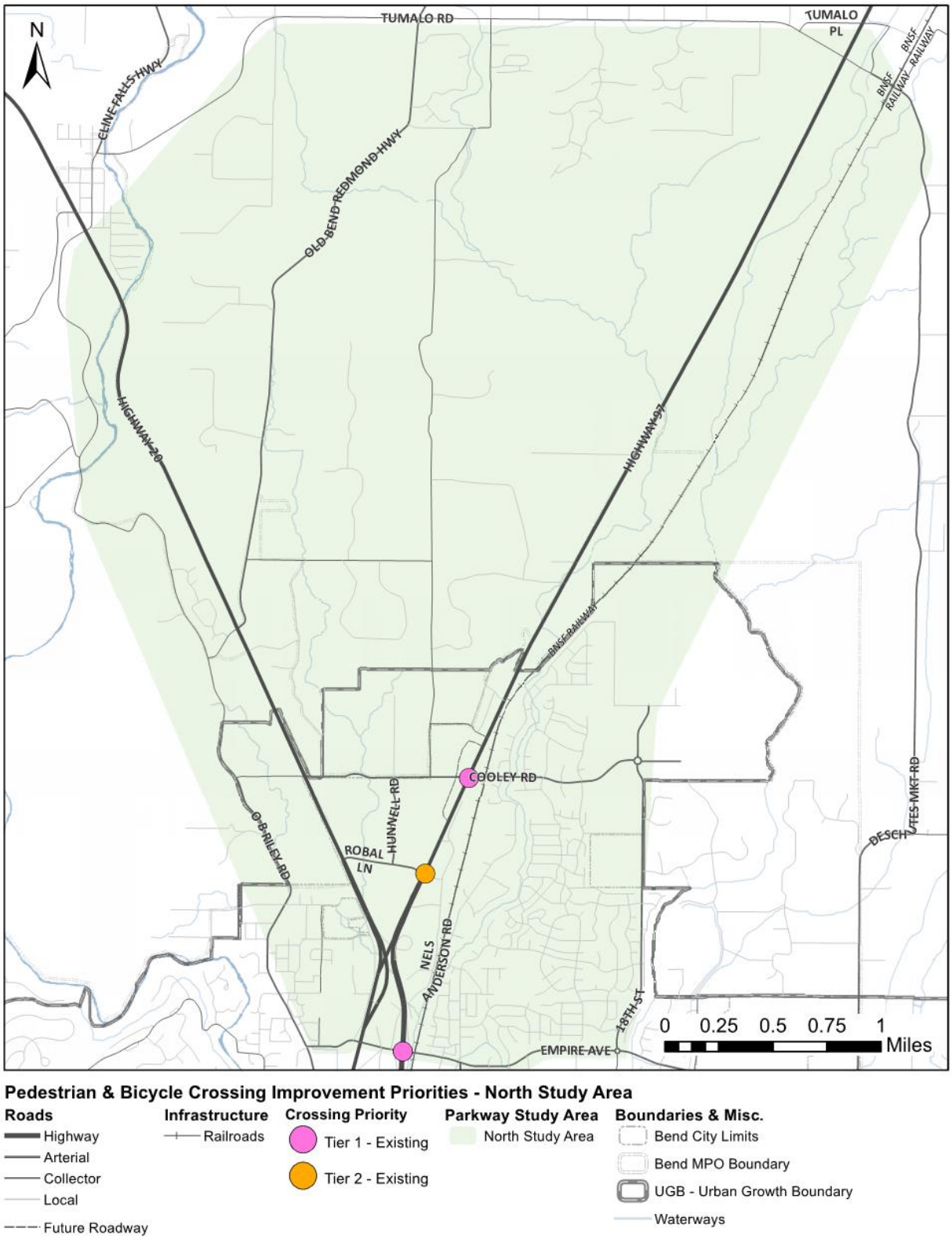

N
TUMALO RD
TUMALO PL
BNSF RAILWAY - RAILWAY
CLINE FALLS HWY
OLD BEND-REDMOND HWY
HIGHWAY 20
HIGHWAY 97
BNSF RAILWAY
COOLEY RD
O'BRILEY RD
HUNNELL RD
ROBAL LN
NELS ANDERSON RD
DESCHUTES MKT RD
18TH ST
EMPIRE AVE
0 0.25 0.5 0.75 1
Miles
Pedestrian & Bicycle Crossing Improvement Priorities - North Study Area
Roads
Highway
Arterial
Collector
Local
Future Roadway
Infrastructure
Railroads
Crossing Priority
Tier 1 - Existing
Tier 2 - Existing
Parkway Study Area
North Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 23

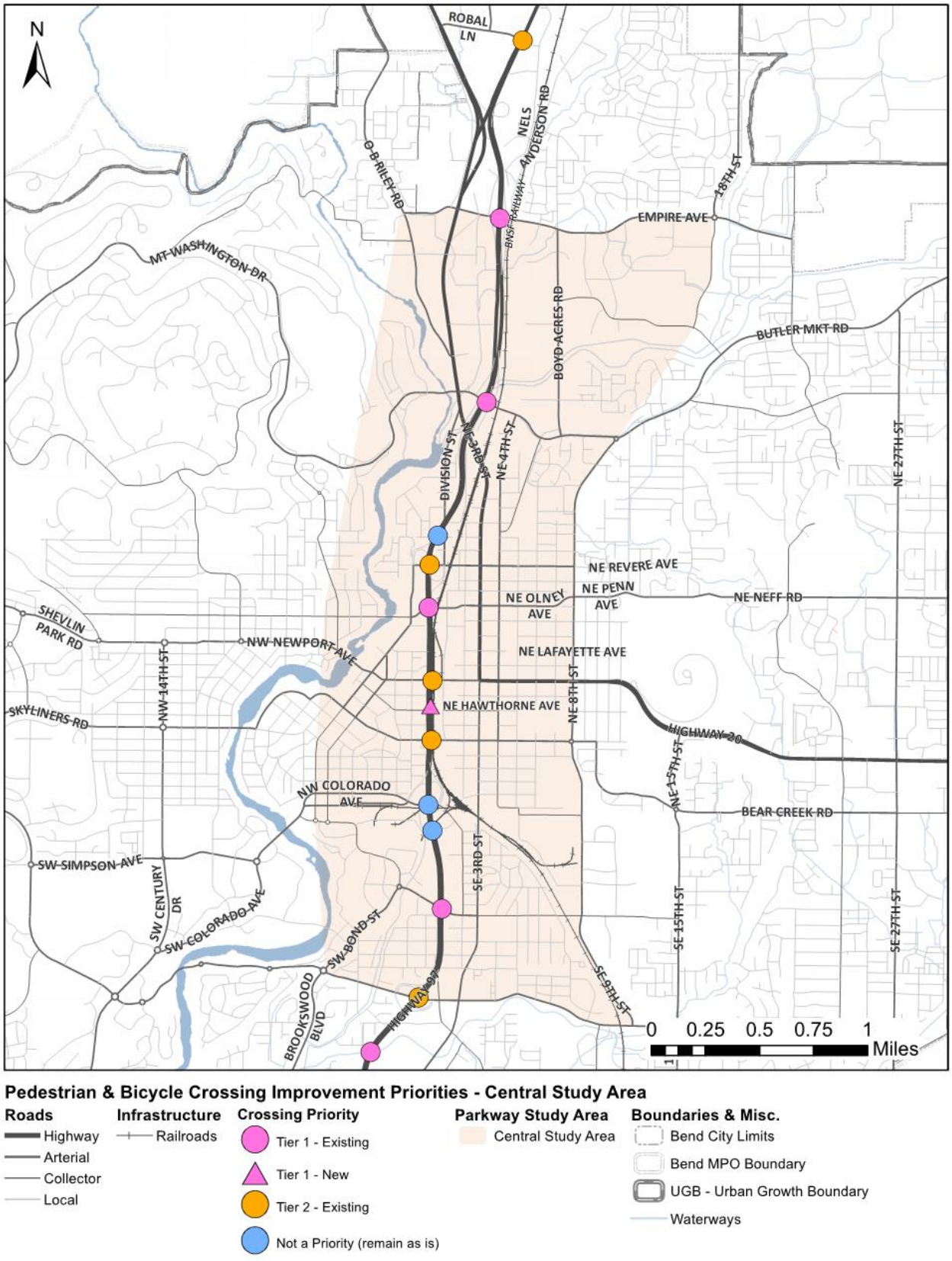
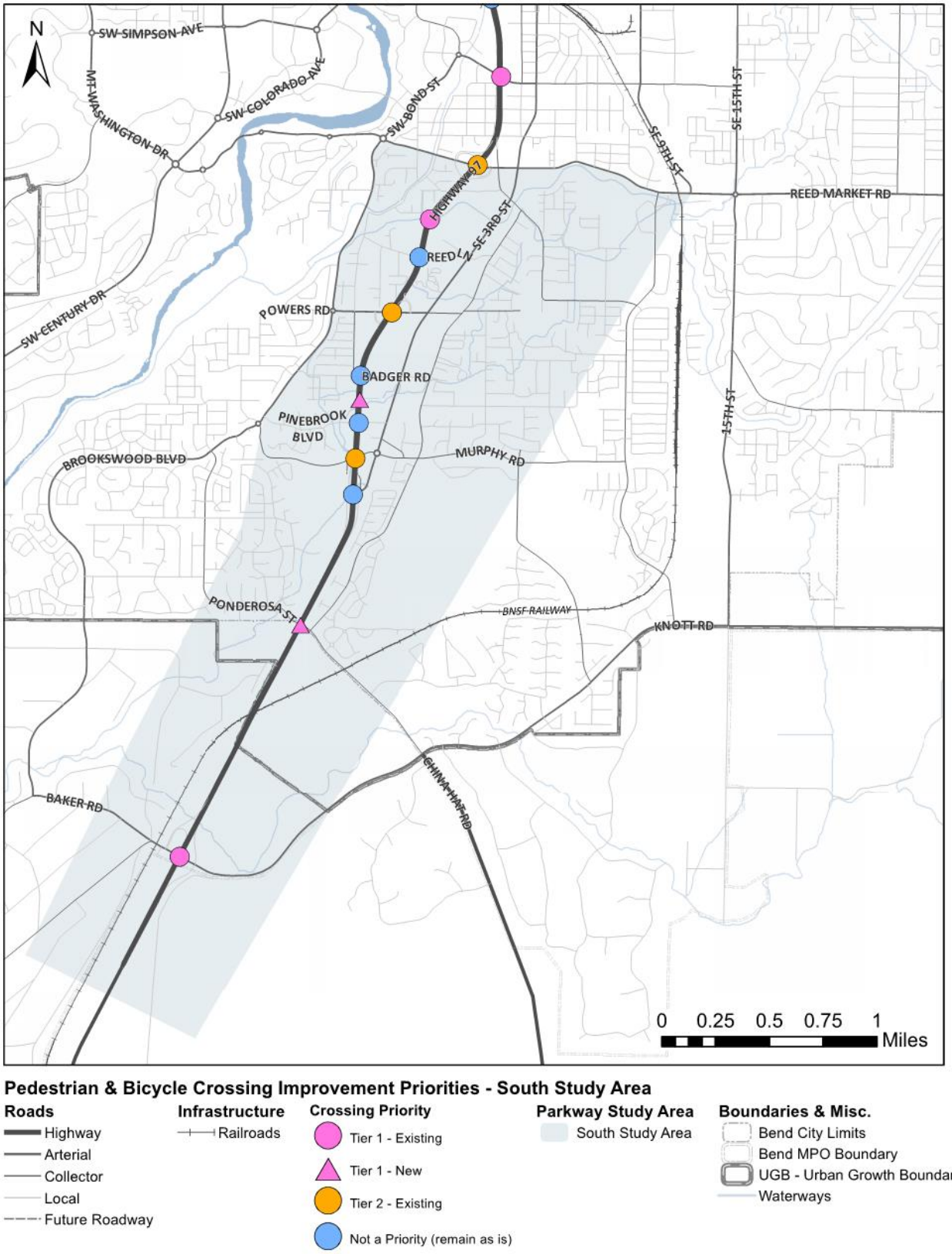

N
ROBAL LN
NELS ANDERSON RD
O-BRILEY-RD
BNSF RAILWAY
18TH ST
EMPIRE AVE
MT WASHINGTON DR
BOYD ACRES RD
BUTLER MKT RD
DIVISION ST
NE 3RD ST
NE 4TH ST
NE 27TH ST
NE REVERE AVE
NE PENN AVE
NE OLNEY AVE
NE NEFF RD
SHEVLIN PARK RD
NW NEWPORT AVE
NE LAFAYETTE AVE
NW 14TH ST
NE 8TH ST
SKYLINERS RD
NE HAWTHORNE AVE
HIGHWAY 20
NE 15TH ST
NW COLORADO AVE
BEAR CREEK RD
SW SIMPSON AVE
SE 3RD ST
SW CENTURY DR
SW COLORADO AVE
SW BOND ST
SE 15TH ST
SE 27TH ST
SE 9TH ST
BROOKSWOOD BLVD
HIGHWAY 97
0 0.25 0.5 0.75 1 Miles
Pedestrian & Bicycle Crossing Improvement Priorities - Central Study Area
Roads
Highway
Arterial
Collector
Local
Infrastructure
Railroads
Crossing Priority
Tier 1 - Existing
Tier 1 - New
Tier 2 - Existing
Not a Priority (remain as is)
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 24


N
SW SIMPSON AVE
MT WASHINGTON DR
SW COLORADO AVE
SW BOND ST
SE 9TH ST
SE 15TH ST
REED MARKET RD
HIGHWAY 97
REED LN
SE 3RD ST
SW CENTURY DR
POWERS RD
BADGER RD
PINEBROOK BLVD
BROOKSWOOD BLVD
MURPHY RD
15TH ST
PONDEROSA ST
BNSF RAILWAY
KNOTT RD
BAKER RD
CHINA HAT RD
0 0.25 0.5 0.75 1 Miles
Pedestrian & Bicycle Crossing Improvement Priorities - South Study Area
Roads
Highway
Arterial
Collector
Local
Future Roadway
Infrastructure
Railroads
Crossing Priority
Tier 1 - Existing
Tier 1 - New
Tier 2 - Existing
Not a Priority (remain as is)
Parkway Study Area
South Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundar
Waterways

5.0 SAFETY ANALYSIS

To establish a future 2040 baseline from which to compare the effectiveness of alternatives, the same predictive crash analysis (Highway Safety Manual Part C) performed under existing conditions was performed for the 2040 No Build condition. Predictive methods are used to assess safety performance at the intersection, segment, or interchange level and are effective for a comparison of future alternatives. "Predicted" crash frequency was calculated for all locations, including those where additional geometry changes were assumed under the 2040 No Build conditions. "Expected" crash frequency was calculated at locations where the only change under 2040 No Build conditions is traffic volumes[5]. The difference between these two methods is that the expected crash frequency utilizes historical crash data, whereas the predictive crash frequency does not.

5.1 ANALYSIS RESULTS

Since the predicted crash frequencies will be used for comparison of future alternatives, predicted crash frequency by crash severity (fatal and injury, property damage only, and total crashes) is presented in the tables below for the 2040 No Build condition. These values have little meaning on their own and will be most useful for comparison with future alternative conditions for evaluation of potential safety improvements. Note that intersections US 97/Pinebrook Boulevard and US 97/Badger Road are not included in the 2040 No Build analysis because they are assumed to be closed in the future.

[5] At locations where the AADT volume exceeds the maximum value in the HSM Calculation spreadsheet for urban arterials the maximum AADT value was used instead. The locations where this occurred and the actual AADT are noted in the appendix.

Table 5: 2040 No Build Predicted Crashes on US 97 – Segments

Study Site	Segment MP	Predicted Crashes per Year		
		Fatal and Injury	Property Damage Only	Total
Clausen Rd to South Cooley Rd Intersection	133.9-134.35	0.7	2.1	2.8
South Cooley Rd Intersection to Robal Rd	134.35-134.6	0.6	1.8	2.4
Robal Rd to Nels Anderson Pl	134.6-134.75	0.4	1.3	1.7
Nels Anderson Pl to US 20 off ramp	134.75-134.92	0.4	1.3	1.7
Empire Blvd ramp to Butler Market Rd ramp	35.77-135.92	0.4	1.2	1.6
Butler Market Rd ramp to Revere Blvd ramp	136.81-136.96	0.4	1.2	1.6
Revere Ave ramp to Lafayette Ave	137.32-137.53	0.6	1.8	2.4
Lafayette Ave to Hawthorne Ave	137.53-137.8	0.8	2.2	3
Hawthorne Ave to Colorado Ave ramp	137.8-137.97	0.5	1.4	1.9
Colorado Ave ramp to Truman Ave	138.4-138.75	0.9	2.8	3.7
Truman Ave to Reed Market Rd ramp	138.75-138.85	0.4	1.1	1.5
Reed Market Rd ramp to Reed Ln	139.43-139.68	0.5	1.3	1.8
Reed Ln to Powers Rd	139.68-139.97	0.6	1.7	2.3
Powers Rd to Badger Rd	139.97-140.3	0.5	1.3	1.8
Badger Rd to Pinebrook Blvd	140.3-140.52	0.3	0.9	1.2
Pinebrook Blvd to Murphy Rd ramp	140.52-140.72	0.6	1.6	2.2
Murphy Rd ramp to Ponderosa St/China Hat Rd	142.02-142.24	0.6	1.4	2
Ponderosa St/China Hat Rd to MP 142.52	142.24-142.52	0.5	1.3	1.8
MP 142.52 to Baker Rd/Knott Rd ramp	142.52-143.1	1.1	2.9	4
	Totals	**10.8**	**30.6**	**41.4**

Table 6: 2040 No Build Predicted Crashes on US 97 – Intersections

Study Site	Location	Predicted Crashes per Year		
		Fatal and Injury	Property Damage Only	Total
US 97/North Cooley Rd Intersection	MP 133.95	2.2	5.2	7.4
US 97/South Cooley Rd Intersection	MP 134.35	1.8	3.8	5.6
US 97/Robal Rd	MP 134.6	3.4	6.1	9.5
US 97/Nels Anderson Pl	MP 134.75	1	1.4	2.4
US 97/Lafayette Ave	MP 137.53	0.4	0.8	1.2
US 97/Hawthorne Ave	MP 137.8	0.7	1.8	2.5
US 97/Truman Ave	MP 138.75	0.8	1.8	2.6
US 97/Reed Ln	MP 139.68	0.7	1.4	2.1
US 97/Powers Rd	MP 139.97	5.6	10.5	16.1
US 97/Ponderosa St/China Hat Rd	MP 142.24	1.2	1.6	2.8
	Totals	**17.8**	**34.4**	**52.2**

Table 7: 2040 No Build Predicted Crashes on US 97 – Interchanges

Study Site	Segment MP	Predicted Crashes per Year		
		Fatal and Injury	Property Damage Only	Total
US 20 Interchange	134.92-135.13	4.1	6.4	10.5
Empire Blvd Interchange	135.13-135.77	11.5	16.4	27.9
Butler Market Rd/US 20 Interchange	135.92-136.81	7.5	14.1	21.6
Revere Ave Interchange	136.96-137.32	13.5	19	32.5
Colorado Ave Interchange	137.97-138.4	9.3	14.4	23.7
Reed Market Rd Interchange	138.85-139.43	7.6	12.7	20.3
Murphy Rd Interchange	140.72-142.02	2	3.1	5.1
Baker Rd/Knott Rd Interchange	143.1-143.7	4.1	7.3	11.4
Totals		**59.6**	**93.4**	**153**

Overall, about 246 crashes per year were predicted for US 97 through Bend (88 fatal or injury, 158 property damage only). This finding, along with the above tables, will be used to evaluate future alternatives to improve safety on the entire US 97 corridor in Bend. Note that the expected crash frequencies for existing conditions presented in the Existing Conditions memorandum should not be compared to the 2040 No Build predicted crashes, as they are based on different methodologies.

2040 No Build conditions can be compared back to existing conditions for some locations where only traffic volumes are assumed to change (i.e., no infrastructure improvements are made) using the "excess expected crash frequency" measure. This metric compares the difference between expected (uses historic crash data) and predicted (uses predictive model only) crash frequency for a study site under specific conditions. A positive excess expected crash frequency indicates that a site's crash frequency is greater than comparable sites and safety countermeasures may be needed. If the measure is negative, this indicates the crash frequency at the site is less than comparable sites. The following tables show the expected crashes per year and excess expected crash frequency for each site where traffic volumes are the only characteristic that changes under 2040 No Build conditions. It should be noted that the only locations to have a higher (positive) excess expected crash frequency are US 97 at Hawthorne Avenue and Lafayette Avenue. In addition, the change between excess expected crash frequency for 2040 No Build and existing conditions is provided.

Table 8: 2040 No Build Expected Crashes on US 97 – Segments

Study Site	Segment MP	Expected Crashes per Year (2040)			Excess Expected Crash Frequency (2040) *	Change in Excess Expected Crash Frequency (2040-2010)
		Fatal and Injury	Property Damage Only	Total		
Robal Rd to Nels Anderson Pl	134.6-134.75	0.3	0.9	1.2	-0.5	-0.4
Nels Anderson Pl to US 20 off ramp	134.75-134.92	0.2	0.6	0.8	-0.9	-0.5
Empire Blvd ramp to Butler Market Rd ramp	35.77-135.92	0.4	1.1	1.5	-0.1	-0.2
Butler Market Rd ramp to Revere Blvd ramp	136.81-136.96	0.2	0.6	0.8	-0.8	-0.4
Revere Ave ramp to Lafayette Ave	137.32-137.53	0.3	0.9	1.2	-1.2	-0.2
Lafayette Ave to Hawthorne Ave	137.53-137.8	0.2	0.6	0.8	-2.2	-0.2
Hawthorne Ave to Colorado Ave ramp	137.8-137.97	0.3	0.9	1.2	-0.7	-0.1
Colorado Ave ramp to Truman Ave	138.4-138.75	0.3	0.6	0.9	-2.8	-1
Truman Ave to Reed Market Rd ramp	138.75-138.85	0.2	0.6	0.8	-0.7	-0.4
Reed Market Rd ramp to Reed Ln	139.43-139.68	0.2	0.6	0.8	-1	-0.5
Reed Ln to Powers Rd	139.68-139.97	0.3	0.8	1.1	-1.2	-0.6
Powers Rd to Badger Rd	139.97-140.3	0.2	0.6	0.8	-1	-0.5
Badger Rd to Pinebrook Blvd	140.3-140.52	0.2	0.5	0.7	-0.5	-0.3
Murphy Rd ramp to Ponderosa St/China Hat Rd	142.02-142.24	0.4	0.9	1.3	-0.7	-0.3
Ponderosa St/China Hat Rd to MP 142.52	142.24-142.52	0.3	0.8	1.1	-0.7	-0.3
MP 142.52 to Baker Rd/Knott Rd ramp	142.52-143.1	0.5	1.2	1.7	-2.3	-1
Totals		**4.5**	**12.2**	**16.7**	**-17.3**	**-6.9**

*negative values indicate site has a lower crash frequency than other comparable sites

Table 9: 2040 No Build Expected Crashes on US 97 – Intersections

Study Site	Location	Expected Crashes per Year (2040)			Excess Expected Crash Frequency (2040) *	Change in Excess Expected Crash Frequency (2040-2010)
		Fatal and Injury	Property Damage Only	Total		
US 97/Robal Rd	MP 134.6	3.2	5.3	8.5	-1	-2.7
US 97/Nels Anderson Pl	MP 134.75	0.7	0.9	1.6	-0.8	0.2
US 97/Lafayette Ave	MP 137.53	0.7	1.2	1.9	0.7	0.1
US 97/Hawthorne Ave	MP 137.8	1.3	3.3	4.6	2.1	-0.1
US 97/Truman Ave	MP 138.75	0.5	1	1.5	-1.1	-0.7
US 97/Reed Ln	MP 139.68	0.6	1.2	1.8	-0.3	-0.3
US 97/Powers Rd	MP 139.97	3.9	6.8	10.7	-5.4	-4.3
US 97/Ponderosa St/China Hat Rd	MP 142.24	1	1.3	2.3	-0.5	-0.5
Totals		**11.9**	**21**	**32.9**	**-6.3**	**-8.3**

*negative values indicate site has a lower crash frequency than other comparable sites

Table 10: 2040 No Build Expected Crashes on US 97 – Interchanges

Study Site	Segment MP	Expected Crashes per Year (2040)			Excess Expected Crash Frequency (2040) *	Change in Excess Expected Crash Frequency (2040-2010)
		Fatal and Injury	Property Damage Only	Total		
US 20 Interchange	134.92-135.13	1.8	2.5	4.3	-6.2	-2.4
Butler Market Rd/US 20 Interchange	135.92-136.81	4.9	6.6	11.5	-10.1	-16
Revere Ave Interchange	136.96-137.32	6.3	10	16.3	-16.2	-18.6
Colorado Ave Interchange	137.97-138.4	3.2	5.5	8.7	-15	-19.6
Reed Market Rd Interchange	138.85-139.43	4.9	6.9	11.8	-8.5	-11.5
Baker Rd/Knott Rd Interchange	143.1-143.7	3.5	5.8	9.3	-2.1	-3.7
Totals		**24.6**	**37.3**	**61.9**	**-58.1**	**-71.8**

*negative values indicate site has a lower crash frequency than other comparable sites

The overall expected crashes for the portion of US 97 in Bend where no geometric changes occur under 2040 No Build conditions are 112 crashes (41 fatal or injury, 71 property damage only). The same portion of US 97 had 95 expected crashes (34 fatal or injury, 61 property damage only) under existing conditions. As volumes increase, crash frequencies will also increase; in this case the growth in crashes is about 18%. The excess expected crash frequency for 2040 No Build conditions is mostly negative, which means that the crash frequency at the study sites generally have a lower crash frequency than comparable sites.

Even though both expected and predicted crash frequencies increased under future conditions due to an increase in traffic volumes, the excess expected crash frequency (difference between expected and predicted) decreased. This indicates that the sites will continue to have a lower crash frequency than comparable sites under 2040 No Build conditions. At locations with larger changes in excess expected crash frequency between 2040 No Build and existing conditions, this is likely due to a larger increase in traffic volumes when compared to the historic crash frequency.

6.0 CORRIDOR OPERATIONS ANALYSIS

The corridor operations analysis examines the efficiency of travel under future 2040 No Build conditions by identifying locations of congestion and using crowdsourced speed data to describe the variability in travel times.

Existing conditions operations analysis demonstrated capacity issues mainly at the Cooley Road and Robal Road intersections. Furthermore, most of the unsignalized intersections also had some queueing issues, and aggressive driver behavior (short gap acceptance of around 5 seconds compared to Highway Capacity Manual default value of 6.9 seconds) during the peak hour. With aggressive gap selection, a driver is accepting a greater crash risk resulting in a potential increase in crashes at these intersections.

Existing capacity issues were confirmed in the future 2040 operations analysis. Furthermore, the forecasted demand exceeds the capacity at majority of the study intersections.

6.1 INTERSECTION OPERATIONS ANALYSIS

The 2040 No Build analysis assumes that all projects included in the Bend MTP 2014 Update Financially Constrained project list are constructed, as well as the projects identified for construction by the year 2028 in the Bend 2016 UGB Expansion. The Financially Constrained projects that impact the US 97 Parkway Study intersections are listed as follows:

- US 97/Cooley Road Area Improvements (MTP Project #12)
    - Description: Assumed to include grade separation of US 97 at Cooley Road, with signalized connections.
    - Intersection Geometry Impacts: This project grade separates the northbound and southbound through movements at US 97 and Cooley Road (Study Intersection #2), replacing the existing signalized intersection with the following three signalized intersections:
        - Study Intersection 2A: Three-leg intersection, serves the southbound through, southbound right/southbound left (combined into a southbound right), northbound through, eastbound left/westbound right (combined into eastbound left). Assumes dual eastbound left turn lanes, and northbound through and southbound through lanes (no southbound right turn lane).
        - Study Intersection 2B: Four-leg intersection, serves all movements except the northbound through and southbound through. Assumes dual eastbound through and westbound through lanes, single westbound left, dual eastbound lefts, and exclusive northbound right, northbound left, southbound right, and southbound left turn lanes.
        - Study Intersection 2C: Three-leg intersection, serves the southbound through, northbound through, northbound right/northbound left (combined into a northbound left), eastbound right/westbound left (combined into eastbound right). Assumes dual northbound left turn lanes, dual eastbound right turn lanes, and dual northbound through and southbound through lanes.

- Empire Boulevard Widening (MTP Project #7)
    - Description: Widen Empire Boulevard to 5 lanes between 3rd Street and US 97 Northbound Ramps. Also install a signal at the US 97 Southbound Ramps.
    - Intersection Geometry Impacts: This project was assumed to add a second through lane in each direction on Empire Boulevard at US 20 (Study Intersection #7), as well as a second southbound left turn lane. This project was also assumed to drop the second eastbound through lane on Empire at the US 97 Southbound On-Ramp (Study Intersection #5) as a right turn trap lane and add a signal with a protected westbound left turn phase as this study intersection. While these assumptions do not include the full FEIS build out at the US 20 and Empire Boulevard intersections, the assumed improvements are in line with the estimated construction cost included in the Bend MTP 2014 Update.
- Empire Boulevard/US 97 Northbound Ramp widening (MTP Project #13)
    - Description: Widen US 97 northbound off-ramp at Empire Boulevard to two lanes.
    - Intersection Geometry Impacts: The short de-facto northbound right turn lane coded in the analysis model for the US 97 northbound ramps and Empire Boulevard intersection (Study Intersection #6) was updated to include 500' of storage.
- North Frontage Road (MTP Project #17)
    - Description: New two-lane frontage road from Murphy Road to Powers Road.
    - Intersection Geometry Impacts: Assumed to include closure of the Badger Road (Study Intersection #25) and Pinebrook Boulevard (Study Intersection #26) right-in/right-out minor street west leg connections.
- US 97/Murphy Road Interchange Ramps (MTP Project #25)
    - Description: Northbound on-ramp and southbound off-ramp.
    - Intersection Geometry Impacts: Assumed to include closure of the Badger Road (Study Intersection #25) and Pinebrook Boulevard (Study Intersection #26) right-in/right-out minor street east leg connections.

Intersection traffic operations were analyzed using the same tools and methodology applied for existing conditions. The analysis was conducted at all study intersections using the forecasted seasonally factored 30 HV traffic volumes for the year 2040. The 2040 No Build turn movement forecasts are included in the "Future Traffic Forecast Technical Memorandum" for this project.

Given the high growth forecasted for the project study area and the capacity limitations of many of the studied intersections, some of the lower intersection peak hour factors (PHF) were modified using guidance from the Analysis Procedures Manual.[6] The modified peak hour factors are listed below:

- 3rd Street and Butler Market Road – PHF increased from 0.88 to 0.92
- US 97 Northbound Ramps and Revere Avenue – PHF increased from 0.89 to 0.90

[6] Increasing peak hour factors applies an assumption that the peak flow of traffic arriving during the peak hour will be spread out over a longer period (i.e., the duration of the peak flow will be longer in the future).

- US 97 Northbound Ramps and Revere Avenue – PHF increased from 0.87 to 0.90
- US 97 Northbound Ramps and Knott Road – PHF increased from 0.89 to 0.90
- 4th Street and Revere Avenue – PHF increased from 0.89 to 0.90
- Parrell Road and China Hat Road – PHF increased from 0.75 to 0.90

Table 11 summarizes the operations analysis results of the 2040 No Build analysis for the Parkway intersections (including ramp terminals) and for intersections on parallel routes near the Parkway, comparing each intersection's performance against the adopted mobility target.[7] Locations where a performance measure exceeds the mobility target are bolded for ease of reference. The intersection operations analysis results are included in the "Synchro HCM reports (Future No Build)" (signalized and stop-controlled intersections) and the "Vistro HCM reports (Future No Build)" Appendices.

Table 11: 2040 No Build Design Hour[8] Traffic Operations at Study Intersections

US 97/Bend Parkway Study Intersections							
Int. No.	**Intersection**	**Jurisdiction**	**Control D**	**Mobility Target**	**Performance**		
				V/C	**V/C [A]**	**LOS [B]**	**Delay (sec) [C]**
1	US 97 & Tumalo Pl	*(removed from study area after existing conditions analysis was completed)*					
2A	US 97 & Cooley Rd (north)	ODOT/ City	Signalized	< 0.85	**1.07**	D	41.3
2B	US 97 & Cooley Rd	ODOT/ City	Signalized	< 0.85	0.61	D	39.9
2C	US 97 & Cooley Rd (south)	ODOT/ City	Signalized	< 0.85	**0.90**	B	15.3
3	US 97 & Robal Rd	ODOT/ City	Signalized	< 0.85	**1.41**	F	>100
4	US 97 & Nels Anderson Pl/Cascade Village	ODOT/ City	TWSC	< 0.85 (major) < 0.95 (minor)	**>2.00/** **>2.00**	F/F	>100/ >100
5	Bend Pkwy SB On-Ramp & Empire Blvd	ODOT/ City	Signalized E	< 0.85	**1.28**	F	>100
6	Bend Pkwy NB Ramps & Empire Blvd	ODOT/ City	Signalized	< 0.85	**1.33**	F	91.2
7	US 20 & Empire Blvd	ODOT/ City	Signalized	< 0.85	**1.32**	F	>100
8	US 20 & Butler Market Rd	ODOT/ City	Signalized	< 0.85	**1.27**	F	>100
9	Bend Pkwy SB Off-Ramp & Butler Market Rd	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Butler Market Rd)	NA/**1.30**	NA/F	NA/>100
10	Bend Pkwy NB On-Ramp & Butler Market Rd	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Butler Market Rd)	0.11/0.04	B/B	9.5/14.9
11	Bend Pkwy SB On-Ramp/Division St & 3rd St	ODOT/ City	Signalized	< 0.85	**1.37**	F	>100
12	Bend Pkwy SB Ramps & Revere Ave	ODOT/ City	Signalized	< 0.85	**0.99**	D	51.7
13	Bend Pkwy NB Ramps & Revere Ave	ODOT/ City	Signalized	< 0.85	**0.94**	C	25.5

[7] Mobility targets for ODOT facilities obtained from the 1999 Oregon Highway Plan.
[8] The "design hour" is the future equivalent of the 30th highest annual hour (30 HV), which was used for existing conditions analysis.

US 97/Bend Parkway Study Intersections							
Int. No.	Intersection	Jurisdiction	Control D	Mobility Target	Performance		
				V/C	V/C [A]	LOS [B]	Delay (sec) [C]
14	Bend Pkwy & Lafayette Ave	ODOT/ City	TWSC	< 0.85 (major) < 0.95 (minor)	NA/**>2.00**	NA/F	NA/>100
15	Bend Pkwy & Hawthorne Ave	ODOT/ City	TWSC	< 0.85 (major) < 0.95 (minor)	NA/**>2.00**	NA/F	NA/>100
16	Bend Pkwy SB Ramps & Colorado Ave	ODOT/ City	Signalized	< 0.85	**1.17**	E	73.3
17	Bend Pkwy NB Ramps & Colorado Ave	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Colorado Ave)	0.52/**1.29**	C/F	16.6/>100
18	Bend Pkwy & Truman Ave	ODOT/ City	TWSC	< 0.85 (major) < 0.95 (minor)	NA/**>2.00**	NA/F	NA/>100
19	Bend Pkwy SB Ramps & Reed Market Rd	ODOT/ City	Signalized	< 0.85	**1.29**	F	93.2
20	Bend Pkwy NB Ramps & Reed Market Rd	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Reed Market Rd)	NA/**>2.00**	NA/F	NA/>100
21	Bend Pkwy & Reed Ln	ODOT/ City	TWSC	< 0.85 (major) < 0.95 (minor)	NA/**1.05**	NA/F	NA/>100
22	Bend Pkwy SB Ramps & Powers Rd	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Powers Rd)	0.08/**1.24**	A/F	9.5/>100
23	Bend Pkwy & Powers Rd	ODOT/ City	Signalized	< 0.85	**1.45**	F	>100
24	Bend Pkwy NB Ramps & Powers Rd	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Powers Rd)	0.28/0.09	A/B	10/11.4
25	Bend Pkwy & Badger Rd	ODOT/ City	Free F	NA	NA	NA	NA
26	Bend Pkwy & Pinebrook Blvd	ODOT/ City	Free F	NA	NA	NA	NA
27	US 97 & Ponderosa St	ODOT/ City	TWSC	< 0.85 (major) < 0.95 (minor)	NA/**>2.00**	NA/F	NA/>100
28	US 97 SB Ramps & Baker Rd	ODOT/ City	TWSC	< 0.85 (ramp) < 0.95 (Knott Rd)	0.02/**1.26**	A/F	8.6/>100
29	US 97 NB Ramps & Knott Rd	ODOT/ County	TWSC	< 0.85 (ramp) < 0.95 (Knott Rd)	0.41/**>2.00**	B/F	12.5/>100
Study Intersections Paralleling US 97							
40	US 20 & O.B. Riley Rd	ODOT	Signalized	< 0.85	**0.91**	D	35.5
42	Butler Market Rd & 4th St	City	AWSC	(< 50 s)	1.72	F	**>100**
46	Revere Ave & 3rd St	ODOT	Signalized	< 0.85	**1.17**	F	>100
47	Revere Ave & 4th St	City	AWSC	(< 50 s)	>2.00	F	**>100**
49	Reed Market Rd & Brookswood Blvd	City	Roundabout	< 1.00	**>2.00**	F	>100
50	Reed Market Rd & Silver Lake Blvd	City	TWSC	(< 50 s)	0.25/>2.00	B/F	13.3/**>100**

US 97/Bend Parkway Study Intersections							
Int. No.	Intersection	Jurisdiction	Control D	Mobility Target	Performance		
				V/C	V/C [A]	LOS [B]	Delay (sec) [C]
51	Reed Market Rd & Division St	City	TWSC	< 1.00	0.23/0.17	C/D	15.6/25.4
52	Reed Market Rd & 3rd St	City	Signalized	< 1.00	**1.52**	F	>100
53	Powers Rd & Brookswood Blvd	City	Roundabout	< 1.00	**1.30**	F	90.7
54	Powers Rd & 3rd St	City	Signalized	< 1.00	0.98	D	46.2
55	Powers Rd & Parrell Rd	City	TWSC	(< 50 s)	0.03/0.43	A/C	8.6/21.7
57	Badger Rd & 3rd St	City	Signalized	< 1.00	0.55	B	`12.0
58	Pinebrook Blvd & 3rd St	City	TWSC	(< 50 s)	0.17/0.40	B/E	11.6/44.2
59	Murphy Rd & 3rd St	City	Roundabout	< 1.00	**1.48**	F	88.2
60	China Hat Rd and Parrell Rd	City	TWSC	(< 50 s)	0.08/1.42	B/F	10.5/**>100**
62	Powers Rd & Blakely Rd	City	TWSC	(< 50 s)	0.20/1.31	B/F	10.7/**>100**

A Overall intersection V/C ratio at signalized intersections, worst case approach V/C at roundabouts and all-way stop-controlled intersections, and V/C ratio for Major Street/Minor Street at two-way stop-controlled. Major Street NB(SB)/Minor Street at two-way stop-controlled intersections where HCS Multilane Highway Analysis was used.

B Major street LOS/minor street LOS for two-way stop-controlled intersections. Worst case approach LOS at roundabout and all-way stop-controlled intersections. Overall intersection LOS for signalized intersections.

C Control delay for Major Street/Minor Street for two-way stop-controlled intersections. Worst case approach delay at roundabout and all-way stop-controlled intersections. Overall intersection delay for signalized intersections.

D TWSC stands for Two-Way Stop-Controlled. AWSC stands for All-Way Stop-Controlled.

E The delay mobility target for the City of Bend only applies to critical lane groups with 100+ vehicles per hour.

F Control change due to Financially Constrained Project

G Minor street access removed

Bold values indicate performance measures failing to meet adopted mobility targets.

As shown in Table 11, only one of the study intersections (Study Intersection# 2B, US 97 turn movements and Cooley Road) meets mobility targets under future conditions. The only unsignalized intersections meeting mobility targets are both northbound ramp terminals; at Powers Road and Butler Market Road. Off the Parkway, several key local intersections also fail to meet mobility targets. These intersections will be discussed in more detail in context with the microsimulation results. Figures 25-27 summarize intersection performance for the North, Central, and South study areas.

Figure 25

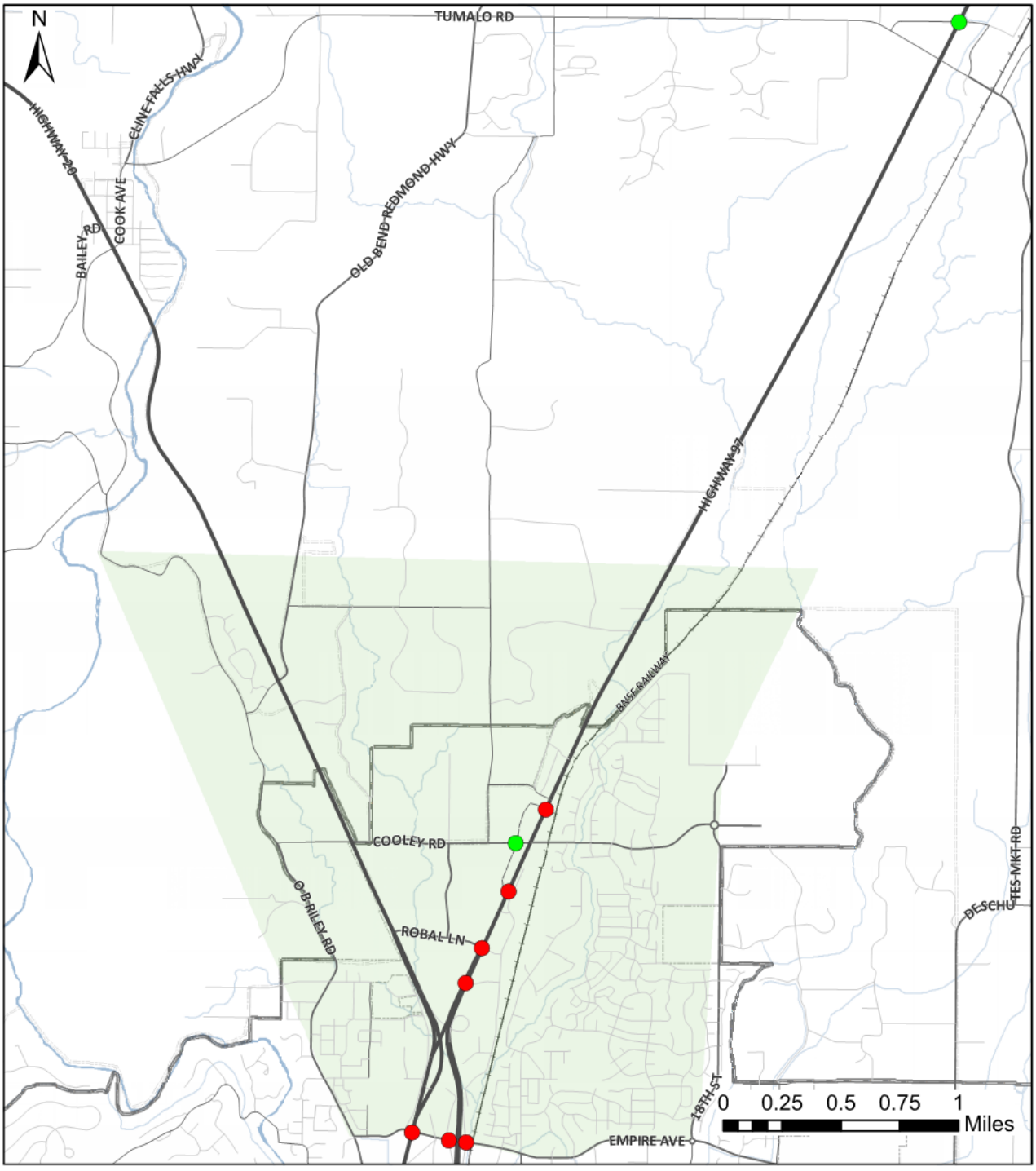

N
TUMALO RD
CLINE FALLS HWY
HIGHWAY 20
COOK AVE
BAILEY RD
OLD BEND REDMOND HWY
HIGHWAY 97
BNSF RAILWAY
COOLEY RD
O'BRILEY RD
ROBAL LN
18TH ST
EMPIRE AVE
DESCHU
TES MKT RD
0 0.25 0.5 0.75 1
Miles
2040 No-Build Intersection Operations Analysis - North Study Area
Intersection Operations
V/C Meets Target
V/C Fails to Meet Target
Roads
Highway
Arterial
Collector
Local
Future Roadway
Infrastructure
Railroads
Parkway Study Area
North Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 26

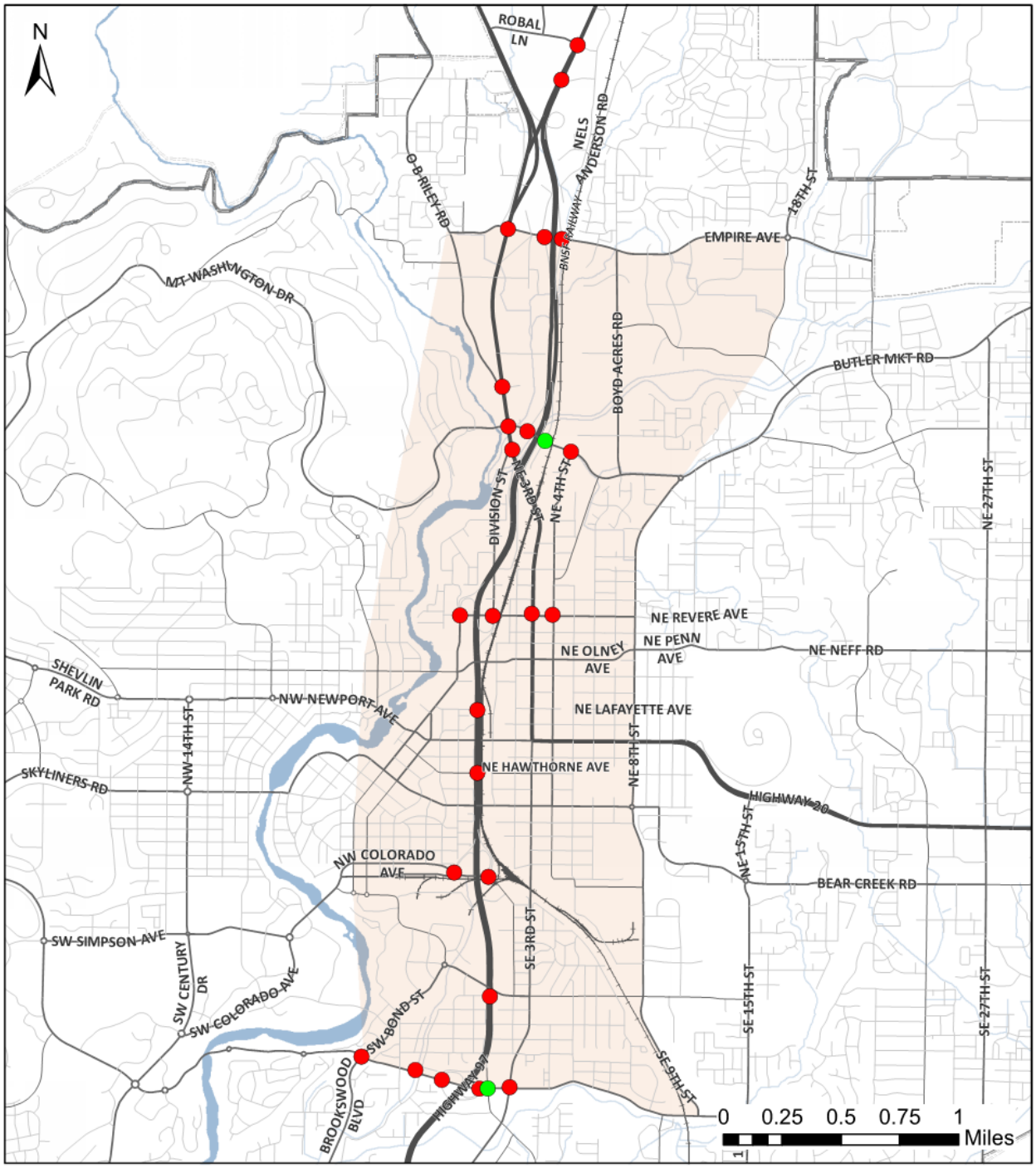
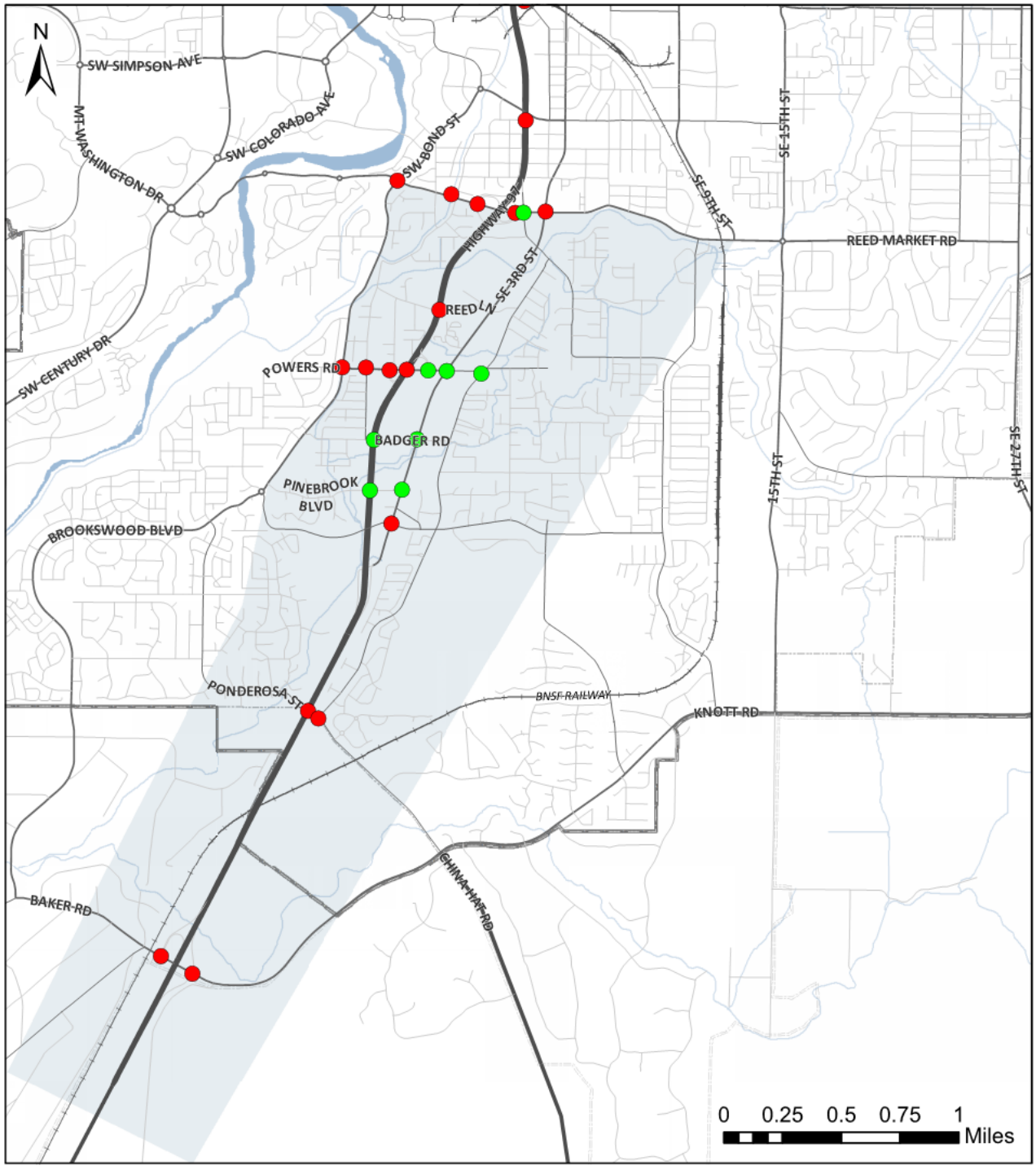

N
ROBAL LN
O B RILEY RD
NELS ANDERSON RD
BNSF RAILWAY
18TH ST
EMPIRE AVE
MT WASHINGTON DR
BOYD ACRES RD
BUTLER MKT RD
DIVISION ST
NE 3RD ST
NE 4TH ST
NE 27TH ST
NE REVERE AVE
NE PENN AVE
NE OLNEY AVE
NE NEFF RD
SHEVLIN PARK RD
NW NEWPORT AVE
NW 14TH ST
NE LAFAYETTE AVE
NE 8TH ST
SKYLINERS RD
NE HAWTHORNE AVE
HIGHWAY 20
NE 15TH ST
NW COLORADO AVE
BEAR CREEK RD
SW SIMPSON AVE
SW CENTURY DR
SE 3RD ST
SW COLORADO AVE
SW BOND ST
SE 15TH ST
SE 27TH ST
SE 9TH ST
BROOKSWOOD BLVD
HIGHWAY 97
0 0.25 0.5 0.75 1
Miles
2040 No-Build Intersection Operations Analysis - Central Study Area
Intersection Operations
V/C Meets Target
V/C Fails to Meet Target
Roads
Highway
Arterial
Collector
Local
Infrastructure
Railroads
Parkway Study Area
Central Study Area
Boundaries & Misc.
Bend City Limits
Bend MPO Boundary
UGB - Urban Growth Boundary
Waterways

Figure 27



2040 No-Build Intersection Operations Analysis - South Study Area

Intersection Operations
- V/C Meets Target
- V/C Fails to Meet Target

Roads
- Highway
- Arterial
- Collector
- Local

Infrastructure
- Railroads

Parkway Study Area
- South Study Area

Boundaries & Misc.
- Bend City Limits
- Bend MPO Boundary
- UGB - Urban Growth Boundary
- Waterways

A vehicle queuing analysis, following the ODOT APM methodology (with SimTraffic 10 and Vissim 10), was used to estimate 95th percentile queues for each dedicated turn lane at the designated study intersections in both the Vissim and SimTraffic analyses. The 95th percentile queues, rounded to the nearest 25 feet, for future forecast are summarized in the Appendices and are discussed with the traffic findings as follows.

The full queuing analysis tables are included in the appendices. Note that as for existing conditions analysis results, both the Vissim and SimTraffic queue tables use the same methodology for estimating storage distance, as follows:

1. For auxiliary turn lanes, the storage length is simply the length of the auxiliary lane (taper not included).
2. For through movements at intersections, the storage length is the distance to the nearest major intersection, which could be either the nearest signal, nearest ramp terminal, nearest roundabout, or nearest major two-way stop-controlled intersection.
3. For non-auxiliary lanes on off-ramps, the available storage is the length of the off-ramp, measured from the beginning of the striped gore to the terminus intersection, minus the safe stopping distance based on the ramp exit design speed.

6.2 Northern Subarea Refined Operations Analysis

The analysis for the northern subarea focused on testing the "Interim Improvements" to the US 97 and Cooley Road intersection (discussed in geometric detail previously), to determine how long the improvements 1) meet mobility targets and 2) provide sufficient capacity to serve design hour volumes. Straight-line traffic growth was estimated between the present day (2017) counts and the future forecast volumes. The three signalized intersections that replace the US 97 and Cooley Road intersection were all tested with the assumption that if one intersection failed to meet mobility targets, the interim improvement project would fail to meet mobility targets. As shown In Table 11, both the north and the south US 97 and Cooley Road intersections (Study Intersections 2A and 2C) failed to meet mobility targets for the forecasted design hour demand in 2040. The northern intersection also failed to provide sufficient capacity to serve the 2040 demand. Iterative testing of interpolated design hour volumes between 2017 and 2040 indicated that all three intersections would meet the ODOT mobility target ($v/c \leq 0.85$) until the year 2025, and the Interim Improvements would provide enough capacity to serve the forecasted demand ($v/c \leq 1.0$) until the year 2035. The SimTraffic model developed during the existing conditions analysis was used to measure the 95th percentile queues for the year 2025. The 95th Percentile queues (rounded to the nearest 25 feet) are summarized in the "SimTraffic (North Area) Queue reports (Future Conditions)" Appendix. These queuing results informed the operations analysis findings presented below:

- US 97 & Cooley Road – operations analysis indicates that under design hour 2040 forecast conditions the north and south intersections fail to meet mobility targets, with the demand at the northern intersection exceeding the capacity. However, the northern intersection does not include a southbound right turn lane, which if constructed would allow southbound right turns (which capture both the southbound right and southbound left turns at Cooley Road) to be removed from the southbound through movement and run as an overlap with eastbound left turn movement. While this improvement would not likely meet the mobility target ($v/c \leq 0.85$), it

would provide sufficient capacity to serve the 2040 demand. Under estimated 2025 conditions, the 95th percentile queues generated by the US 97 and Cooley Road intersections do not cause any major operational issues. However, the queues from the southbound through movement at the US 97 and Robal Road intersection extend north through the Cooley Road intersections and ultimately out of the SimTraffic model.

- US 97 & Robal Road – The Existing Conditions analysis indicated capacity deficiencies at this intersection. The future forecasts indicate increased demand for all movements. The north/south approaches increase 25-35% due to growth in both Bend and Redmond, while the east-west movements increase by more than 100% due to employment growth projected near the intersection and within the Bend North Area. The increased demand leads to increased queuing, with the intersection only providing sufficient capacity to serve a portion of the demand. Under 2040 design hour conditions, queues extend beyond the SimTraffic model extents in all directions and impact the operations at the US 97 and Cooley Road intersections as well.
- US 97 & Nels Anderson Place – This intersection remains over capacity in the future. The forecasted demand for both the northbound left and eastbound right turn movements decreases from existing, due to the increased (>30%) southbound through demand on US 97.

6.3 US 97/Bend Parkway Refined Intersection Operations Analysis

The Vissim model developed as part of the Existing Conditions analysis was updated with origin-destination (O-D) data from the 2040 Bend-Redmond Model (BRM) and volumes from the 2040 design hour forecasts. The “Bend Parkway Study Future No Build Vissim Model Results Report” (see appendix) provides the details on updates to the model associated with the 2040 forecasts and the full model results. As shown in Table 11, most of the study intersections are expected to experience demand well above their capacity under forecasted 2040 design hour conditions. Therefore, the Vissim model generated unserved demand over the two-hour (4-6 PM) analysis interval. Averaged over all the model simulation runs, more than 13,000 vehicles (approximately 17% of the total 4-6 PM demand) were unable to enter the network. Due to the excess levels of demand in the model, it should be noted that the simulation may not be showing all the impacts on a spatial or temporal basis as conditions are worse than shown. Furthermore, it should be noted that when future alternatives are evaluated, capacity issues may not necessarily be resolved due to the latent demand finally being served. The impact of latent demand will be considered when developing and evaluating solutions.

As for existing conditions, the Vissim model provides data relating to speeds on and near US 97 over the entire two-hour (4:00-6:00 PM) evening time period. Delay plots were developed, showing the relative delay throughout the model, giving an indication of the extents of queues throughout the model every 15 minutes from 4:00 PM to 6:00 PM). These delay plots show the time variant traffic patterns throughout the US 97 corridor and are included in the “Vissim Queue plots (Future No Build Conditions)” Appendix. The data from the queue plots shows the capacity breakdown of the throughout the 4-6 PM analysis.

6.4 US 97 Corridor Intersections Operations

Based on the operations analysis from the Synchro model and the analysis results from the Vissim simulations, the following findings were made for the Future No Build analysis at US 97 Corridor intersections.

- US 20 (3rd Street) & Butler Market Road/Division Street – Operations analysis indicates that both the Division Street and Butler Market Road intersections with US 20 (3rd Street) will experience demand well above their capacity under forecasted 2040 No Build design hour volume conditions. The traffic forecasts indicate significant (50% to 80%) east/west growth on Butler Market Road due to housing growth on the West side and in the Northeast Area. The north-south volumes also increase significantly (50% to 90 %) due to growth in Downtown Bend and increased congestion on the Parkway. This finding is supported by the simulation analysis, which shows the following capacity breakdown issues at these two intersections:
    - Southbound and westbound movements at the 3rd Street and Butler Market Road queue up immediately at 4:00 PM. The westbound queues spill back to the US 97 southbound off-ramp onto Butler Market Road, which in turn queues onto southbound US 97 past the Empire Boulevard ramps.
    - The eastbound left turns at the 3rd Street and Division Street intersection queue out of the Vissim model by 4:15 PM.
    - The 3rd Street and O.B. Riley Road intersection acts as a meter for southbound traffic approaching the 3rd Street and Butler Market intersection. By 4:15 PM, the O.B. Riley intersection is over capacity and remains over capacity for the remainder of the analysis time period.
- US 97 Southbound Ramps/Wall Street & Revere Avenue – The northbound approach queues out of the Vissim model by 4:15 PM, due to increased demand (more than 100% increase in northbound right turn volume) which is due to capacity constraints at the other east-west connections across the Bend Parkway.
- US 97 Northbound & Southbound Ramps & Colorado Avenue – The eastbound left turn at the US 97 Northbound Ramps increase by more than 50%, leading to increased queuing back through the Southbound Ramps intersection by 4:00 PM. Both the northbound and southbound off-ramps from US 97 do not experience to full forecasted demand, as queuing elsewhere in the network limits the number of vehicles that can actually reach the ramps.
- US 97 northbound and southbound ramps & Reed Market Road – The volume on the southbound off-ramp only experience a moderate increase (approximately 25%), but large increases in volume (about 100%) for the northbound right turn from the northbound off-ramp, combined with large increases in eastbound volume on Reed Market Road (more than 50%) lead to a bottleneck issue at the 3rd Street and Reed Market Road intersection. The queue spillback from this intersection impacts both the northbound and the southbound off-ramps, leading to queues that extend onto the Parkway mainline by 4:15 PM. This southbound Parkway queue reaches the following cross streets over the analysis time interval:
    - 4:15 PM – Truman Avenue
    - 4:30 PM – Colorado Avenue
    - 4:45 PM – Hawthorne Avenue
    - 5:00 PM – Revere Avenue

    - 5:15 PM to 6:00 PM – Combines with Butler Market Southbound Off-Ramp and Empire southbound on-ramp queues and extends to model extents.
- The northbound Parkway queues caused by the northbound off-ramp to Reed Market Road extends to the following cross streets over the analysis time interval:
    - 4:15 PM – Garfield Avenue
    - 4:30 PM – Reed Lane
    - 4:45 PM – Powers Road
    - 5:00 PM – Badger Road
    - 5:15 PM – Murphy Road
    - 5:30 PM – Romain Village Way
    - 5: 45 to 6:00 Pm – China Hat Road
- US 97 & Powers Road – While the volumes on the Powers Road jug-handle movements do not experience much growth due to the addition of the northbound on-ramp and southbound off-ramp to the Murphy Road interchange, the increase in northbound (70%) and southbound (35%) demand leads to increased queuing. The northbound queue spillback from the northbound off-ramp at Reed Market Road reaches the Powers Road northbound jug handle movement by 4:45 PM, accelerating queues for the other movements.
- US 97 & Baker Road/Knott Road ramp terminals do not experience the full forecasted southbound demand due to the capacity constraints impacting the US 97 southbound traffic to the north.
- Right-in/right-out access to US 97 at China Hat, Reed Lane, Truman, Lafayette, and Hawthorne – all the right-in/right-out approaches queue significantly due to increased northbound and southbound traffic on US 97. The China Hat Road eastbound right turn experiences the largest volume increase due to the projected employment growth in the area surrounded by US 97, China Hat Road, and Knott Road.

6.5 Parallel Route Intersection Operations

Based on the operations analysis from the Synchro model and the analysis results from the Vissim simulations, the following findings were made at study intersections on the parallel State and local system. The full queuing analysis tables are included in the "Vissim (Parkway) Queue reports (No Build Conditions)" Appendix.

- 4th Street & Butler Market Road – The westbound queues at this intersection extend out of the model by 4:15 PM and continue to build unserved demand until the end of the analysis time period.
- 3rd Street and 4th Street & Revere Avenue – increased growth (approximately 60%) for eastbound Revere Avenue due to limited options for east-west travel causes queue spillback from the 4th Street intersection to create northbound and southbound queues on 3rd Street, which also experiences demand beyond the intersection's capacity. Westbound demand on Revere Avenue increases as well. The 3rd Street intersection does not provide sufficient capacity for the increased demand, leading to westbound queues that extend out of the model by 5:00 PM.
- Brookswood Road/Bond Street/Reed Market Road – The roundabout continues to experience demand that exceeds the intersection capacity under Future No Build conditions, with the

northbound and southbound Brookswood Boulevard and Reed Market eastbound approaches queuing out of the model by 4:15 PM.

- 3rd Street & Reed Market Road – This intersection experiences increased east-west demand, with the northbound approach queueing out of the model at 4:00 PM, the eastbound approach queues through the US 97 ramps also by 4:00 PM, and the southbound Reed Market approach queuing out of the model by 5:00 PM.

6.6 Parkway Merging/Diverging Ramp Operations Analysis

Operations analysis was performed for select interchange ramp merging, diverging, and weaving segments on the Parkway using HCM methodologies, [9] consistent with the existing conditions analysis. The select segments included:

- Revere-Butler Market-Empire-Sister's Loop Ramp in northbound direction
- Southbound Division on-ramp & Southbound Revere off-ramp in southbound direction
- Eastbound Reed Market to Northbound US 97 on-ramp and Westbound Reed Market to Northbound US 97 in northbound direction
- Revere to Colorado in both directions

Table 12 summarizes the results of this analysis for the 2040 design hour[10] under No Build conditions compared to those reported under existing conditions. The adopted mobility target for these movements on the Parkway is at a V/C ratio no greater than 0.85. V/C ratios exceeding 0.85 exceed the target. Locations where the V/C mobility target was exceeded are shown in boldface.

Table 12: Existing (2017) and 2040 No Build Merging/Diverging/Weaving Operations

Location	Segment Type	Existing (2017) V/C	2040 No Build V/C
US 97/Bend Parkway Southbound			
SB Division Street Ramp	Merge	**0.94**	**1.24**
SB Revere Avenue Ramp	Diverge	**0.94**	**1.24**
SB Revere Avenue Ramp	Merge	**0.94**	**1.20**
SB Colorado Avenue Ramp	Diverge	**0.94**	**1.21**
SB Colorado Avenue Ramp	Merge	**0.90**	**1.13**
US 97/Bend Parkway Northbound			
NB Reed Market Road Ramp	Merge	0.42	0.66
NB Division Street Ramp (Reed Market)	Merge	0.54	0.82
NB Colorado Avenue Ramp	Diverge	0.54	0.73
NB Colorado Avenue Ramp	Merge	0.84	**1.09**
NB Revere Avenue Ramp	Diverge	0.83	**1.10**
NB Revere Avenue Ramp	Merge	0.72	**0.98**
NB 3rd Street Ramp	Merge	**0.88**	**1.20**
NB Butler Market Road Ramp	Merge	**0.97**	**1.27**
NB Empire Boulevard Ramp	Diverge	**0.95**	**1.27**
NB Empire Boulevard Ramp - Sisters Loop	Weaving	0.61	0.56

[9] Highway Capacity Software (HCS) 7 software and the HCM 6 methodology were used.
[10] The "design hour" is the future equivalent of the 30th highest annual hour (30 HV), which was used for existing conditions analysis.

Bold values indicate performance fails to meet adopted mobility target requiring operation at a V/C ratio no greater than 0.85. Results for Existing (2017) represent the 30th highest annual hour of traffic, while results for 2040 No Build represent the future design hour. Both are generally assumed to be the weekday PM peak hour during the summer.

Under existing conditions, congestion in the southbound direction is more prevalent during the PM peak hour, with all locations analyzed failing to meet the mobility target. Furthermore, congestion in the northbound direction was found to steadily increase from Reed Market Road to Revere Avenue, with performance failing to meet the mobility target from the 3rd Street on-ramp to the Empire Boulevard off-ramp.

A similar trend is projected for the 2040 No Build condition, but the level of congestion at these junctions will be significantly higher and in many cases the traffic demand will exceed the roadway capacity. In the northbound direction, the stretch of merging and diverging ramp connections failing to meet the mobility target expands from the Colorado Avenue on-ramp to the Empire Boulevard off-ramp. However, the findings from the intersection operations and Vissim microsimulation analysis indicate that queues generated from the Parkway off-ramps will cause congestion bottlenecks throughout the system for both northbound and southbound traffic before the merge and diverge locations reach capacity.

7.0 TRAVEL TIME RELIABILITY ANALYSIS

Travel time reliability is a measure of the consistency in travel times over a corridor. Even in a congested corridor, if travel times can be confidently predicted drivers can plan their trips to arrive on time. However, where consistent travel times are less reliable, unexpected delays can make trip planning a frustrating experience.

Travel time reliability analysis was performed using the HERS-ST analysis tool. This is a complex modeling tool that is used by state agencies to analyze highway deficiencies for programming and planning purposes. The tool can capture probabilities and impacts from various delay events or causes, which makes it an effective tool for travel time reliability analysis of future conditions. The HERS-ST tool uses facility characteristics such as geometry, traffic control, and volume components to produce several delay measurements that can be used to calculate travel time reliability measures. These measures are not calibrated to local conditions; thus, only the relative difference is reported for evaluation of alternatives.

Travel time reliability was analyzed by using a planning time index for the study segments along the US 97 corridor. The Federal Highway Administration (FHWA) defines the planning time index as 95th percentile travel time divided by the free-flow travel time, indicating the time a driver should allow to traverse the corridor segment while remaining on schedule 95 percent of the time. The planning time index represents the total travel time that should be planned for, including both typical and unexpected delay. For example, a planning time index of 1.50 means that for a trip that takes 20 minutes in light traffic a traveler should budget a total of 30 minutes to ensure on-time arrival 95 percent of the time. The higher the index, the less reliable the segment.

Table 13 summarizes the results of the travel time reliability analysis as relative change in average daily conditions for the existing year (2015) and 2040 No Build conditions, for each segment of the corridor. The change in planning time index indicates the amount which travel time reliability changes under 2040 No Build conditions as compared to existing conditions.

All the segments except for one showed an increased planning time index, which indicates decreased travel time reliability. This is likely due to an increase in peak hour congestion, which degrades the daily travel time reliability. Key locations that showed significant deterioration in the future include Clausen Road to Cooley Road, Robal Road to the US 20 interchange, and Hawthorne Avenue to the Colorado Avenue interchange. These changes are due to new traffic control (at Cooley Road) and increases in demand along the corridor. Pinebrook Boulevard to Murphy Road was the only segment to improve in reliability, due to the removal of traffic control and closure of the Pinebrook Boulevard intersection under 2040 No Build conditions.

Average daily speed and average travel time support the travel time reliability trends and indicate an increase in congestion where speeds decrease and travel times increase. The entire corridor shows a total travel time increase of just under two minutes.

Table 13: Change in Average Daily Travel Time Reliability

From	To	2040 No Build – 2015 Conditions		
		Change in Average Speed (mph)	Change in Average Travel Time (sec)	Change in Planning Time Index
Clausen Rd	Cooley Rd	-18	38	1.18
Cooley Rd	Robal Rd	-1	2	0.14
Robal Rd	US 20 Interchange	-14	38	2.33
US 20 Interchange	Empire Blvd	-2	1	0.14
Empire Blvd	Butler Market Rd Interchange	-7	6	0.48
Butler Market Rd Interchange	Revere Blvd	-5	9	0.37
Revere Blvd	Lafayette Ave	-3	2	0.21
Lafayette Ave	Hawthorne Ave	-7	3	0.45
Hawthorne Ave	Colorado Ave Interchange	-13	6	0.98
Colorado Ave Interchange	Truman Rd	-6	6	0.40
Truman Rd	Reed Market Rd Interchange	-6	3	0.39
Reed Market Rd Interchange	Reed Ln	-2	1	0.11
Reed Ln	Powers Rd	-2	1	0.11
Powers Rd	Badger Rd	-3	3	0.32
Badger Rd	Pinebrook Blvd	0	0	0.03
Pinebrook Blvd	Murphy Rd	16	-10	-1.17
Murphy Rd	Murphy Interchange	0	0	0.00
Murphy Interchange	Ponderosa St/China Hat Rd	0	0	0.04
Ponderosa St/China Hat Rd	Baker Rd/Knott Rd Interchange	0	0	0.01

In addition to daily travel time reliability, a comparison of simulated travel times from the Vissim microsimulation analysis is provided to give context on 2040 No Build travel conditions. The following figures show how average travel time varies during the PM peak period (using 30th highest hour peak volumes) for the US 97 corridor segment just south of the Empire Boulevard interchange through the Baker Road/Knott Road interchange.

Travel time is fairly consistent throughout the peak period (around nine minutes) under existing conditions, however the 2040 No Build conditions show almost a 25-minute variation throughout the peak period.

Figure 28: Vissim Model Travel Times for the Southbound US 97 Corridor

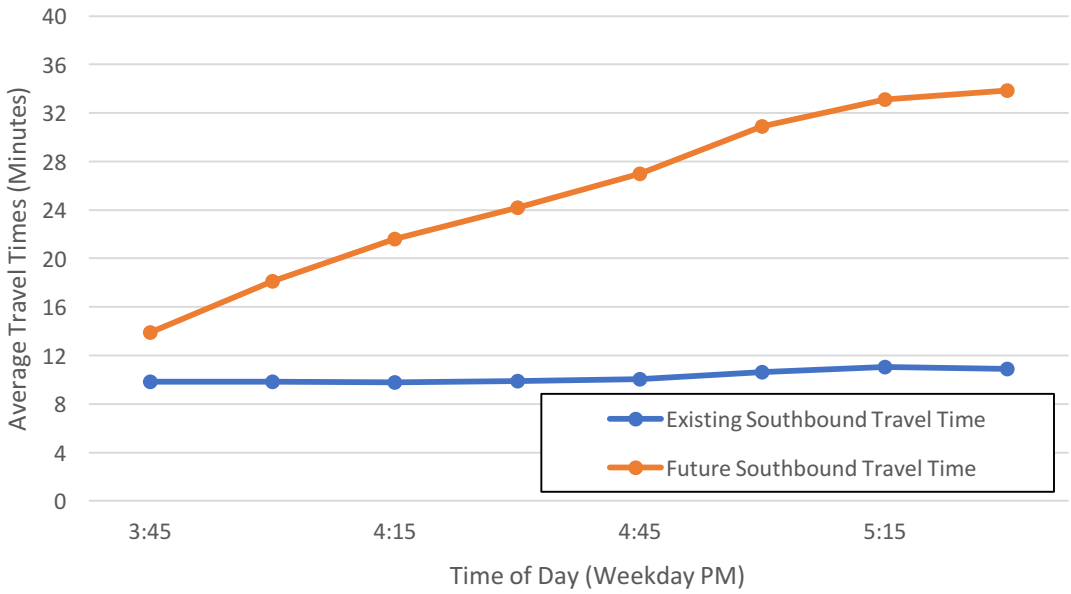


Figure 29: Vissim Model Travel Times for the Northbound US 97 Corridor