DKS Associates
TRANSPORTATION SOLUTIONS

Memorandum

DATE: January 9, 2012

TO: Stephanie Serpico, HDR Engineering

FROM: Chris Maciejewski, P.E., P.T.O.E.

SUBJECT: **Mt. Washington Drive at Simpson Avenue**
Intersection Traffic Control Determination and Design Recommendation

P11181-007

Introduction

The purpose of this memorandum is to document the transportation analysis conducted at the intersection of Mt. Washington Drive at Simpson Avenue (shown in Figure 1) to determine the recommended intersection design. The analysis performed and documented in this memorandum follows the City's *Roundabout Evaluation and Design Guidelines*[1] in order to determine the most appropriate intersection control at this intersection through the year 2030. The intersection traffic control evaluation includes a summary of prior traffic studies conducted at the intersection, system context, intersection use, baseline performance, alternatives evaluation, additional considerations, and recommendations.

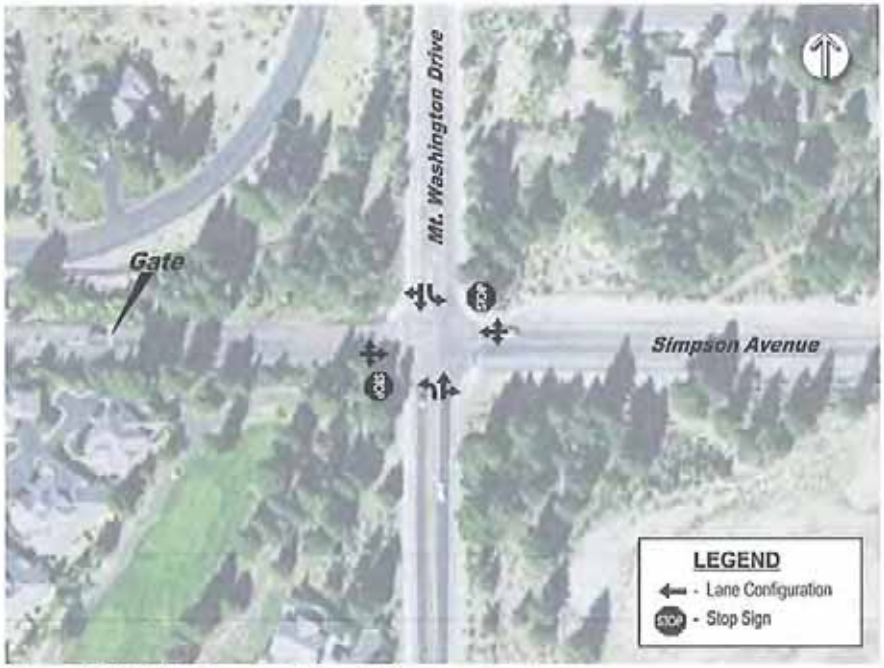

Figure 1: Mt. Washington Drive at Simpson Avenue

[1] City of Bend Roundabout Evaluation and Design Guidelines, Kittelson & Associates, Inc., April 2010.

The evaluation uses the *Tier 1 Intersection Form Selection Criteria* outlined in the *Roundabout Evaluation and Design Guidelines* to determine the best solution for traffic control, while also keeping in mind that Bend maintains a "roundabouts first" approach to intersection treatments.[2]

Summary of Prior Traffic Studies

A previous intersection control study was completed in September 2010 by Kittelson & Associates at the intersection of Mt. Washington Drive and Simpson Avenue[3]. In addition, WHPacific, Inc. prepared a conceptual design report in February 2011 for a recommended single lane roundabout located at the identified intersection[4]. The studies implemented portions of the City's new Roundabout Evaluation and Design Guidelines in an effort to get feedback on the process. The studies also identified potential property acquisition requirements, used AASHTO guidelines to provide sight line improvements, and completed a safety analysis based on data from 2001-2009.

Data collected and assumptions that were used as part of the September 2010 and February 2011 studies are listed below:

- Existing AM Traffic Counts (February 11, 2011) with a peak hour from 7:15-8:15am
- Existing PM Traffic Counts (February 11, 2011) with a peak hour from 2:45-3:45pm
- Single lane roundabout conceptual design

System Context

Identifying the system in which an intersection operates is important to determine the factors that will contribute to its overall function. The existing and future context of the intersection of Mt. Washington Drive and Simpson Avenue is discussed below. Factors including the motor vehicle system, pedestrian system, bicycle system, transit system, and emergency response system are outlined.

Motor Vehicle System

A field inventory was conducted on December 5, 2011 to determine characteristics of the study intersection. Data collected included posted speed limits, travel lanes, lane configurations, and intersection control. The summary of the study area roadways are listed in Table 1.

[2] City of Bend Roundabout Evaluation and Design Guidelines, Kittelson & Associates, Inc., April 2010.
[3] Mt. Washington Drive/Simpson Avenue Roundabout Concept Design, Kittelson & Associates, September 6, 2010.
[4] Mt. Washington Drive and Simpson Avenue Roundabout Conceptual Design Report, WHPacific, Inc., February 2011.

Table 1: Existing Study Area Roadway Characteristics

Roadway (Intersection Leg)	Agency	Functional Classification[5]	Posted Speed Limit (mph)	Traffic Control	Number of Travel Lanes	Turn Lane Storage Length (ft)	Shoulder (ft)	Additional Notes
Mt. Washington Dr (North Leg)	City of Bend	Minor Arterial	35	Uncontrolled	3 (including turn lane)	Left Turn Lane (50)	6.0	Two sets of traverse mid-lane pavement markings are located with Speed Limit sign and Intersection Ahead warning sign.
Simpson Ave (East Leg)	City of Bend	Minor Arterial	40	Stop-Controlled	2	None	1.0-2.0 Varies	Rumble Strips on approach to intersection.
Mt. Washington Dr (South Leg)	City of Bend	Minor Arterial	35	Uncontrolled	3 (including turn lane)	Left Turn Lane (100)	6.0	Two sets of traverse mid-lane pavement markings are located with Speed Limit sign and Intersection Ahead warning sign.
Simpson Ave (West Leg)	Private Ownership	Private/Local	25	Stop-Controlled	2	None	N/A	Gated entrance to Broken Top Homeowners Association. Gate is approximately 275 feet from study intersection.

Nearby Traffic Control

The adjacent intersections located near Mt. Washington Drive and Simpson Avenue are stop-controlled along the side streets. On the north leg of Mt. Washington Drive, the adjacent intersection of SW Troon Avenue is a local street that intersects Mt. Washington Drive from the east approximately 900 feet north of Simpson Avenue. On the east leg of Simpson Avenue, SW 18th Street abuts Simpson Avenue approximately 1,000 feet east of the intersection. On the south leg, Broken Top Drive intersects Mt. Washington Drive approximately 1,600 feet south of the intersection. The west leg of the intersection serves as the primary access to the Broken Top Home Owners Association. The gate to the access controlled community is located approximately 275 feet from the study intersection.

[5]Bend Urban Area Transportation System Plan. Updated 2006-06-21. https://scholarsbank.uoregon.edu/xmlui/handle/1794/3223. Accessed December 13, 2011.

Pedestrian System

Field review of the study intersection revealed that concrete sidewalks are present on both sides of Mt. Washington Drive. On the north leg of the intersection, the sidewalks are adjacent to the travel lane. On the south leg of the intersection, sidewalks are present on the west side of Mt. Washington Drive, but are not provided along the east side of the roadway (gap of approximately 3,600 feet). The missing sidewalk on the east side of Mt. Washington was identified in the Bend TSP as an infill sidewalk, but not a priority need infill.[6] At the intersection itself, standard crosswalks are provided for the east and west legs. Curb ramps are provided at all four corners of the intersection. Along the west leg of Simpson Avenue, no sidewalks are present. On the east leg of Simpson Avenue a concrete sidewalk is located on the north side of the roadway and is set back from the travel lane. On the south side of the east leg of Simpson Avenue, a setback asphalt sidewalk is present for approximately 1,700 feet (extending to the Park & Recreation District office, short of SW Century Drive).

Bicycle System

Along Mt. Washington Drive, a six foot paved bike lane is present on both approaches adjacent to the travel lane. Near the study intersection along Simpson Avenue, a one to two foot wide paved shoulder is available on the east leg. Bike lanes do exist on Simpson Avenue further east, but only for small segments. No bike facilities are provided on the west leg of Simpson Avenue.

Transit System

Transit services in the City of Bend are provided by Cascade East Transit. The Galveston 11 Route travels through the study intersection. The one-way route heads west along Simpson Avenue and then turns south on Mt. Washington Drive. Buses operate Monday through Friday and have approximately 40 minute headways during the AM and PM peaks.[7] A bus stop is located east of the intersection near SW 18th Street (approximately 1,000 feet from Mt. Washington Drive).

Emergency Response System

The fire station responsible for the area surrounding the study intersection is Station 301 (West Station), which is located at 1212 SW Simpson Avenue approximately three quarters of a mile east of the study intersection. This station also serves as the Fire Administration Building for Deschutes County.

The main hospital in town is the St. Charles Medical Center. The medical center is located near the corner of NE Neff Rd and NE 27th Street, which is approximately five miles northeast of the study intersection.

The Bend Police Department is located on 555 NE 15th Street, which is east of US 97 and just off of US 20. The Deschutes County Sheriff's office and the Oregon State Police Patrol office are located near the north end of town where US 20 and US 97 converge.

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[6] Bend Urban Area Transportation System Plan. Bend Urban Area Sidewalk Inventory Map. Updated 2006-06-21. https://scholarsbank.uoregon.edu/xmlui/handle/1794/3223. Accessed December 13, 2011.

[7] Cascade East Transit, Bend Bus Service. *Galveston 11*. http://www.cascadeseasttransit.com/bend-schedule.html. Accessed December 9, 2011.

Land Use

The existing zoning near the Simpson Avenue/Mt. Washington Drive intersection is Residential Urban Standard Density and Surface Mining District, as illustrated in Figure 2. The land parcels in the northeast and southeast quadrants of the intersection are designated as surface mining along with the east side of the south leg of Mt. Washington Drive. The remaining land parcels are Residential Urban Standard Density, which provides opportunity for a wide variety of residential housing types at the most common residential densities in places where community sewer and water services are available. The residential density rate in this district is 2.0 to 7.3 dwelling units per acre.[8] Surface mining districts are to allow the extraction of surface mining materials needed by the community while protecting the health and safety of adjoining residents and uses.[9]

Three public schools are also located near the study area. Nearby schools include Summit High School to the northwest, Cascade Middle School to the southeast and Miller Elementary School to the northwest.

[8] *Bend Code – Chapter 10-10 Development Code*, Section 2.1.100, http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006. Accessed December 12, 2011.
[9] *Bend Code – Chapter 10-10 Development Code*, Section 2.5.100, http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006. Accessed December 12, 2011.

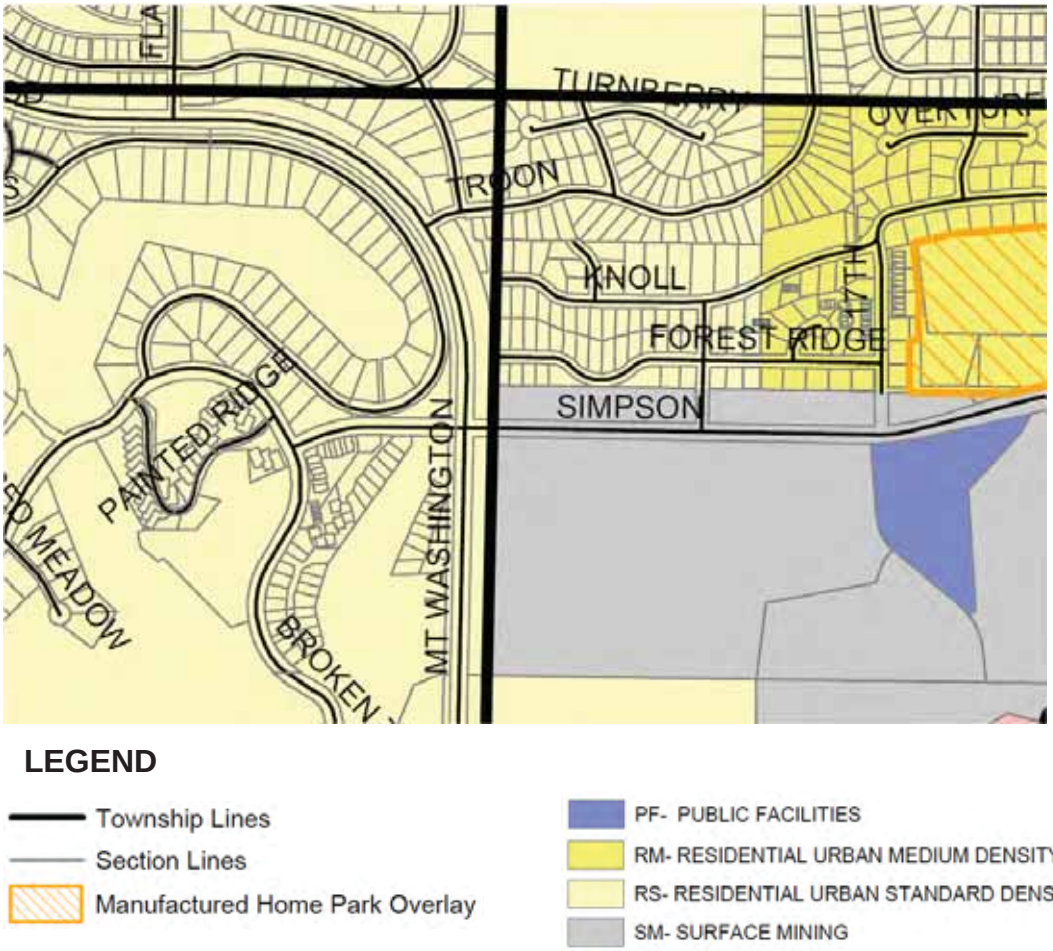


Figure 2: Existing Land Use Zoning

Intersection Use

This section identities the users of the study intersection and quantifies the existing motor vehicle, pedestrian, and bicycle use at the study intersection during the AM and PM peak periods. In addition, motor vehicle volumes for the future year of 2030 are provided.

Existing Volumes

Intersection turn movements counted at the study intersection during the morning (7:00-9:00) and afternoon (2:30-4:30) peak periods are shown in Figure 3.[10] The peak hour traffic volumes are consistent with those used in previous analysis and are attached in Appendix A. The location of this intersection is in close proximately to several schools; therefore the afternoon peak period is considered the evening peak since this time period captures the let-out of school when volumes at this intersection are highest.

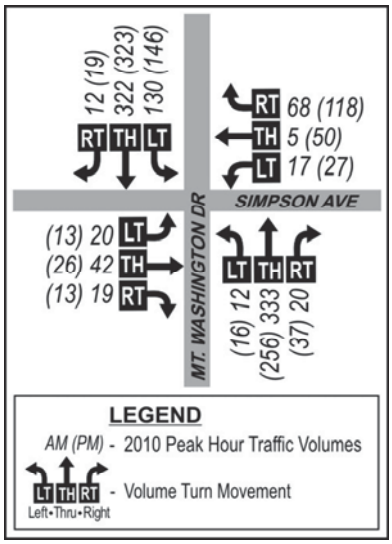


Figure 3: Existing Peak Hour Volumes

Because the study intersection is located near three schools, it is subject to passing school children. However, traffic counts indicate a total of two pedestrians at the intersection during the AM peak hour and four pedestrians during the PM peak hour. No bicyclists were observed during these times, but are anticipated to pass through the intersection.

Future Volumes

Future traffic demand for the intersection was forecasted to the year 2030 to analyze future traffic operations. The future 2030 peak period turn movement volumes were developed using the Bend MPO's regional travel demand model "Financially Committed" scenario. Traffic forecasts were "post processed" following a methodology consistent with NCHRP Report 255[11].

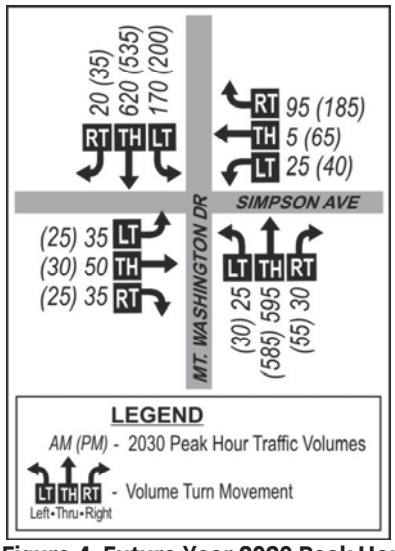


Figure 4: Future Year 2030 Peak Hour Volumes

AM and midday peak hour volumes were forecasted by applying the existing ratio of AM and afternoon volumes to PM volumes to the post-processed future year PM peak hour volumes. In addition, traffic forecasts considered the unique impact of local traffic demand peaks related to area schools by not factoring growth for the school related

[10] Intersection turn movement counts, Quality Counts, February 11, 2010.
[11] *Highway Traffic Data for Urbanized Area Project Planning and Design - National Cooperative Highway Research Program Report 255*, Transportation Research Board, Washington D.C., 1982.

spikes in traffic. The resulting future 2030 morning and afternoon peak hour turn movement volumes for the intersection are shown in Figure 4.

Design Vehicle

Both Mt. Washington Drive and Simpson Avenue are classified as minor arterials. Therefore, they are subject to varying modes of traffic and vehicles. Although the intersection is not located along a designated truck route, the intersection is located within a residential area and near schools. It is subject to large vehicles such as emergency vehicles, garbage trucks, construction vehicles, and school buses. The City's base design vehicle is a WB-50; however, larger trucks such as a WB-67 should be accommodated[12] based on the nearby industrial activities. The existing traffic volumes indicate the heavy vehicle percentages[13] at the intersection to be approximately 3-4% on Mt. Washington Drive and approximately 2-3% on Simpson Avenue. The previous study and design concept accommodated a WB-50 and WB-67 for all movements on all approaches. Additionally, at roundabout controlled intersections, the City's design guidelines require that emergency vehicles be accommodated at the intersection without the use of truck aprons or mountable curbs.

Baseline Performance

This section summarizes intersection safety and existing and future intersection operations. The purpose is to form a baseline for which future conditions can be compared to.

Safety

To evaluate the safety of the existing intersection, the most recent three years of collision data at the intersection of Mt. Washington Drive/Simpson Avenue was obtained from the Oregon Department of Transportation (ODOT) and are attached in Appendix B[14]. Due to the proportionality of the number of vehicles entering an intersection and the total number of collisions experienced, a collision rate describing frequency of collisions per million entering vehicles (MEV) is used to determine if the number of collisions is significant enough to indicate that there may be a safety issue. A collision rate of 1.0 MEV or greater typically warrants further investigation. As listed in Table 2, the collision rate at the study intersection is 0.75, which is below the 1.0 threshold typically warranting additional evaluation.

Table 2: Intersection Collision Summary (2008-2010)

Intersection	Collisions by Year			Total	Collision Severity			Collision Rate[b]
	2008	2009	2010		Fatal	Injury	PDO[a]	
Mt. Washington Drive/Simpson Avenue	2	4	2	8	0	4	4	0.75

[12] A WB-50 is the design vehicle (i.e., the vehicle can stay in lane but the trailer can track onto the truck apron), but a WB-67 will be able to use the roundabout utilizing the truck apron (i.e., both the vehicle and the trailer can track onto the truck apron).
[13] Based on traffic volume counts collected, heavy vehicle percentages included vehicles where classified as Class 4 and above.
[14] ODOT Collision Data for January 1, 2008 through December 31, 2010.

[a]PDO = Property damage only.
[b]Average annual collisions per million entering vehicles (MEV); MEV based on PM Peak Hour Volumes.

Of the eight collisions reported in the collision records, six resulted from vehicles failing to stop or running a stop sign. A total of 6 collisions involved southbound approaching vehicles where the horizontal sight distance is restricted due to the alignment of the roadway and vegetation. Currently, rumble strips exist along the east approaches of the intersection to provide advanced warning of an approaching intersection. Along the north and south approaches, two sets of transverse mid-lane pavement markings are associated with the speed limit sign and the intersection ahead warning sign.

In addition to the ODOT 2008 to 2010 collision data, the City of Bend has provided a 2011 year to date set of collision data. The 2011 data set provided by the City of Bend accounts for collisions occurring in the City of Bend from January 2011 through November 2011. Based on this information, no additional crashes have occurred at the intersection of Mt. Washington Drive/Simpson Avenue between January and November 2011.

Operations

The following sections outline the City of Bend's intersection performance measures and intersection operation standards for various intersection control types.

Measures of Effectiveness

The City of Bend uses four measures of effectiveness (MOEs) to evaluate the operation of an intersection. These measures include the volumes-to-capacity ratio, vehicle queuing, level of service, and delay. A combination of these four measures are used to evaluate two-way stop controlled intersections, all-way stop controlled intersections, and a signalized intersection. A summary of each of the MOEs is given below.

Volume to Capacity Ratio

The volume-to-capacity ratio is a measure used to represent the level of saturation (i.e., the portion of capacity that is being used). It is given as a decimal typically between 0.00 and 1.00 and is determined by dividing the peak hour traffic volume by the hourly capacity of a given intersection or movement. A lower ratio indicates smoother operations and lower delays. As the ratio approaches 1.00, congestion increases and performance is reduced. If the forecasted ratio is greater than 1.00, the intersection, lane, or movement is oversaturated and usually results in excessive queues and long delays.

Queuing

Queuing reports typically show the 95th percentile queue, defined to be the length of queue which is exceeded five percent of the time during the analysis time period. The 95th percentile is useful in determining the appropriate length of turn pockets, but is not representative of what an average driver would experience during their commute.

Level of Service

The level of service (LOS) is a measure of effectiveness that is similar to a "report card" rating and is based on average vehicle delay. Level of service A, B, and C indicate

conditions where traffic moves without significant delays over periods of peak hour travel demand. Level of service D and E are progressively worse operating conditions. Level of service F represents conditions where average vehicle delay has become excessive and demand is near capacity. The average delay value (in seconds) corresponds to each level of service designations.

The unsignalized level of service calculation evaluates each movement separately to identify problems (typically left turns from side streets). The calculation is based on the average total delay per vehicle for stop-controlled movements (typically on the minor side street or left turn movements). Level of service F indicates that there are insufficient gaps of suitable size to allow minor street traffic to safely enter or cross the major street. This is generally evident by long delays and queuing on the minor street.

Delay

The City's operational performance standard for roundabouts is measured against a volume to capacity ratio, but delay is used to compare alternative intersection forms to a roundabout. Typically under the same traffic conditions, a roundabout will result in lower overall delay than traffic signals and all-way stop control, but may result in higher overall delay than a two-way stop controlled intersection.

Agency Operational Standards

The City of Bend has established operation standards for two-way stop control intersections, all-way stop control intersections, roundabouts, and signalized intersections under the jurisdiction of the City of Bend. Below are the operational standards from the Bend Code – Chapter 10-10 Development Code.[15]

- Two-Way Stop Control – Approaches with greater than 100 peak hour trips; average delay for the critical lane group is less than or equal to 50 seconds during the Peak Hour;
- All-Way Stop Control – Average delay for the intersection as a whole is less than or equal to 80 seconds during the Peak Hour;
- Roundabout – Volume to capacity ratio for the intersection as a whole is less than or equal to 1.0 during the Peak Hour;
- Signalized Intersection under the jurisdiction of the City of Bend:
    - For intersections that are not constructed to the widths and infrastructure elements of the Bend Urban Transportation System Plan or other approved master plan and not located within or directly adjoining a historic district of Central Business Zone, the volume to capacity ratio for the intersection as a whole is less than or equal to 1.0 during the Peak Hour.
    - For intersections that are not constructed to the widths and infrastructure elements of the Bend Urban Area Transportation System Plan or other approved master plan and are located within or directly adjoining a historic district or Central Business Zone, the volume to capacity ratio for the intersection as a whole is less

[15] Bend Code – Chapter 10-10 Development Code. Section 4.7.400 Part B. http://www.ci.bend.or.us/modules/showdocument.aspx?documentid=4006 Accessed on December 12, 2011.

than or equal to 1.0 during the hour directly preceding and following the Peak Hour.

- For intersections that are already constructed to the widths and infrastructure elements of the Bend Urban Area Transportation System Plan or other approved master plan, the operation standard shall be a volume-to-capacity ratio less than or equal to the 1.0 for the intersection as a whole during the hour directly preceding and following the Peak Hour.

Existing Intersection Operations

Intersection traffic operations were analyzed at the study intersection using Synchro 7™ software, which employs the *2000 Highway Capacity Manual*[16] methodology for signalized and unsignalized intersections. The following sections summarize existing and future peak period intersection operations at the study intersection.

Table 3 summarizes the morning (AM) and afternoon peak hour intersection operations at the Mt. Washington Drive/Simpson Avenue intersection. Due to the relatively high volumes along Mt. Washington Drive the side street stop controlled approaches experience significant delay. The delays experienced along the side streets are at LOS F conditions. This intersection currently does not meet the City's unsignalized operational standard during the AM and afternoon peak hours. Existing intersection operation calculation sheets are attached in Appendix D.

[16] *2000 Highway Capacity Manual*, Transportation Research Board, Washington DC, 2000.

Table 3: Existing 2010 Intersection Operating Conditions (AM/Afternoon Peak Hour)

	Existing 2010					
	AM Peak Hour			Afternoon Peak Hour*		
	Delay	LOS	V/C	Delay	LOS	V/C
Unsignalized Intersections						
Mt Washington Dr/Simpson Ave	**154.6**	**F/A**	**1.00**	**71.8**	**F/A**	**0.90**

Unsignalized Intersections
Delay = Individual lane group stopped delay per vehicle (seconds) for the worst case approach
LOS = Minor Street/Major Street level-of-service
V/C = Individual lane group volume-to-capacity ratio
*Afternoon Peak Hour is from 2:30 p.m. to 4:30p.m.

Future 2030 Intersection Operations

Table 4 summarizes the future 2030 AM and Afternoon peak hour intersection operations at the Mt. Washington Drive/Simpson Avenue intersection. With the additional traffic volumes associated with future background traffic growth, this intersection would continue failing to meet the City's unsignalized operational standard during the AM and afternoon peak hours. Future year intersection operation calculation sheets are attached in Appendix E.

Table 4: Future 2030 Intersection Operating Conditions (AM/Afternoon Peak Hour)

	Future 2030					
	AM Peak Hour			Afternoon Peak Hour		
	Delay	LOS	V/C	Delay	LOS	V/C
Unsignalized Intersections						
Mt Washington Dr/Simpson Ave	**>200.0**	**F/B**	**>2.00**	**>200.0**	**F/B**	**>2.00**

Unsignalized Intersections
Delay = Individual lane group stopped delay per vehicle (seconds) for the worst case approach
LOS = Minor Street/Major Street level-of-service
V/C = Individual lane group volume-to-capacity ratio

Potential Solutions

In order to reduce delays along the side streets at the study intersection, a preliminary alternative anaysis was conducted in order to determine the most appropriate intersection configuration to accommodate future growth to the year 2030. The alternatives analysis focused on intersection improvements such as all-way stop control, traffic signalization, and a roundabout.

Roundabout

The City currently implements a roundabout first policy[17]; therefore a roundabout will be considered as a viable intersection control alternative and carried forward with the alternatives

[17] City of Bend Roundabout Evaluation and Design Guidelines, Kittelson & Associates, Inc., April 2010.

analysis. The alternatives analysis will determine the required number of circulating lanes within the roundabout.

All-Way Stop

All-way stop warrants were reviewed for the study intersection to determine the merit based on the requirements outlined in the Manual of Uniform Traffic Control Devices (MUTCD)[18].

An all-way stop would likely be warranted (approximating eight hour volumes from peak hour volumes) at this intersection based on future 2030 traffic volumes; however this intersection would fail to meet the City's intersection operational standards for all way stop control (average delay greater than 80 seconds during the AM and afternoon peak hour). Therefore, this intersection control was not considered for further analysis.

Traffic Signal

The peak hour traffic signal warrant as outlined in the MUTCD[19] would be met based on the future 2030 afternoon peak hour volumes at this intersection. The warrant computation is attached in Appendix C. Preliminary analysis indicates that a traffic signal would operate within the City's operational requirements. Therefore, it was carried forward with the alternatives analysis.

Alternatives Evaluation

Based on the potential solutions identified in the previous section, both a roundabout and traffic signal were analyzed in more detail. Each alternative was evaluated using the future 2030 AM and afternoon peak hour traffic volumes previously identified. The following sections provide a comparison of the traffic operations and queuing analysis for both intersection alternatives.

Alternative 1 – Roundabout

The first alternative included a single-lane roundabout, which was evaluated per City of Bend guidelines.[20] A summary of the traffic operations and queuing analysis is listed in Table 5 and calculation sheets are attached in Appendix F. A concept design for the single-lane roundabout was completed as part of the previous study, and is included in Appendix H.

[18] 2009 Manual on Uniform Traffic Control Devices, Section 2B-07 Multi-Way Stop Applications, U.S. Department of Transportation and Federal Highway Administration.
[19] 2009 Manual on Uniform Traffic Control Devices, Warrant 3 Peak Hour, U.S. Department of Transportation and Federal Highway Administration.
[20] *Roundabout Operational Analysis Guidelines*, City of Bend, April 2010.

Table 5: Alternative 1 - Future 2030 Single-Lane Roundabout Operations and Queuing Results

Traffic Operations	Future 2030							
	AM Peak				Afternoon Peak			
	North Leg	East Leg	South Leg	West Leg	North Leg	East Leg	South Leg	West Leg
Volume/Capacity	0.90	0.27	0.90	0.31	0.80	0.48	0.78	0.15
Critical Lane Average Delay (sec)	26.2	9.4	30.5	11.4	18.3	12.3	18.7	7.6
Intersection Control Delay (sec)	25.6				17.0			
Intersection Level of Service	D				C			
Queuing Results (95th Percentile Queues)								
Peak 15 min. volume (ft)*	375	50	350	50	250	75	225	25
Peak Hour volume (ft)	150	25	125	25	175	50	150	25

* 95th-percentile queue likely to occur with the peak fifteen minute flow rates, which is the most comparable to the queuing analysis of the signalized control scenario evaluated with Synchro/SimTraffic™

The single-lane roundabout alternative would meet the City's operational standards without any additional circulating lanes or right-turn by-pass lanes. Additionally, excessive queuing would not be an issue at the intersection.

Alternative 2 – Traffic Signal

The second alternative included a traffic signal, assuming the existing intersection lane configuration. Traffic signal operations were evaluated using Synchro 7™ and queuing estimates were made using SimTraffic™. Estimates of 95th percentile queue lengths were determined using an average of five simulation runs of the SimTraffic™ model.

It was assumed that the traffic signal would operate with protected-permissive left-turn phasing on the Mt. Washington Drive northbound and southbound approaches and permissive left-turn phasing on the Simpson Avenue approaches. The results of the traffic operations and queuing analysis is summarized in Table 6. Intersection operation calculation sheets for Alternative 2 are attached in Appendix G.

Table 6: Alternative 2 - Future 2030 Traffic Signal Operations and Queuing Results

Traffic Operations		Future 2030	
		AM Peak	Afternoon Peak
Volume/Capacity		0.82	0.85
Intersection Control Delay (sec)		20.9	24.1
Intersection Level of Service		C	C
Queuing Results (95th Percentile Queues)			
Southbound	L	150 ft	200 ft
	T/R	300 ft	275 ft
Westbound	L/T/R	175 ft	400 ft
Northbound	L	75 ft	100 ft
	T/R	400 ft	450 ft
Eastbound	L/T/R	175 ft	100 ft

L = Left; T = Through; R = Right

The traffic signal would operate within City standards with the existing intersection lane configuration. However, additional storage length would be needed for the southbound left-turn pocket on Mt. Washington Drive. A concept sketch showing the proposed traffic signal layout and additional left-turn storage is included in the Appendix I. The traffic signal layout would require widening of the north leg of Mt. Washington Drive to accommodate a longer left turn pocket.

Alternatives Evaluation

Per the City's Tier 1 Table from the *Intersection Form Evaluation Framework*, a comparison between Alternative 1 (Roundabout) and Alternative 2 (Traffic Signal) was performed to determine the preferred alternative. The comparison is summarized in Table 7.

Table 7: Tier 1 Intersection Form Selection Criteria

Category	Criteria	Evaluation Comments	Conclusion
Safety			
Motor Vehicle Safety	Conflict points (exposure) Severity (speed)	Conflict Points: Traffic signal w/four approaches = 32 Roundabout w/four approaches = 8 Posted Speed: Mt. Washington Drive = 35mph Simpson Avenue = 40 mph A roundabout has fewer motor vehicle conflict points therefore reducing the exposure to potential accidents. A roundabout would have less severe collisions than a traffic signal due to the geometry and lower entry/circulating speeds.	Roundabout
Non-Motorized Vehicle Safety	Conflict points (exposure) Severity (speed)	Conflict Points: Traffic signal w/four approaches = 24 Roundabout w/four approaches = 8 Posted Speed: Mt. Washington Drive = 35mph Simpson Avenue = 40 mph A roundabout has fewer pedestrian conflict points therefore reducing the exposure to potential accidents. A roundabout would provide a shorter pedestrian crossing distance than a traffic signal. A traffic signal, however, would provide a protected pedestrian movement.	Roundabout
Traffic Operations			
Peak-Hour Traffic Operations	Volume-to-capacity ratio Average delay LOS Queue lengths	Both a roundabout and traffic signal would operate similarly during the AM and afternoon peak hours in terms of delays and volume-to-capacity ratios. A roundabout would result in shorter queues along all approaches during the AM and afternoon peak hours.	Roundabout
Anticipated Users			
Design Vehicle	Appropriate heavy vehicle Buses Emergency vehicles	Both a traffic signal and roundabout would be designed using the same design/accommodated vehicle(s).	Neutral
Special User Needs	School children Elderly Visually impaired ADA compliance	Both a traffic signal and roundabout would be designed to accommodate special user needs at the intersection.	Neutral

System Context			
System Effects	Adjacent traffic control Railroad crossing	There are no existing traffic signals within the near proximity of the intersection. There are existing roundabouts located to the north (approximately 4,200 feet), south (approximately 4,200 feet, and east of the intersection (approximately 3,200 feet). Due to the large spacing to surrounding intersection neither a traffic signal nor roundabout would impact the existing roadway system operations.	Neutral
Environmental Impacts	Land use context	The land use zoning surrounding the intersection is mostly residential with the southeast quadrant currently zoned as surface mining. Neither a traffic signal nor roundabout is anticipated to have significant environmental impacts.	Neutral
Emergency Response	Response time/control delay	A traffic signal would be equipped with emergency vehicle preemption and emergency vehicles would be able to use left turn lanes and opposing traffic lanes to maneuver through the intersection. The City's roundabout standards require a 20 foot wide entrance and exit lane in or allow emergency vehicles to pass vehicles stopped within the roundabout.	Neutral
Context at Intersection			
Intersection Footprint	Intersection proper (physical & operational influence area)	A traffic signal would require widening within existing ROW along Mt. Washington Drive to the north in order to accommodate a 200 foot southbound left turn lane. All traffic signal equipment is anticipated to fit within existing ROW. A roundabout would require ROW acquisition on all four corners of the intersection and would require right-of-way (ROW) entry to the private drive on the west leg of the intersection.	Traffic Signal
Intersection Influence Area	Driveway closures or impacts	There are currently no accesses along Mt. Washington Drive or Simpson Avenue near the study intersection that would be impacted by a traffic signal or roundabout.	Neutral

Additional Considerations

Additional factors that could influence the design of the recommended roundabout were evaluated, including year of opening operation and multimodal system considerations. The following subsections discuss each of these factors.

Year of Opening Operations

A single lane roundabout would operate well within the City's operational standards under existing year (2010) traffic conditions. A single lane roundabout would be the full build out at this intersection and no additional work would be required. Table 8 shows the expected day of opening single-lane roundabout traffic operations and queuing.

Table 8: Alternative 1 – Existing 2010 Single-Lane Roundabout Operations and Queuing Results

	Existing 2010							
	AM Peak				Afternoon Peak			
	North Leg	East Leg	South Leg	West Leg	North Leg	East Leg	South Leg	West Leg
Volume/Capacity	0.54	0.16	0.51	0.16	0.52	0.25	0.36	0.08
Critical Lane Average Delay (sec)	9.0	5.9	9.7	6.5	9.1	6.3	7.2	5.4
Intersection Control Delay (sec)	8.8				7.8			
Intersection Level of Service	A				A			
Queuing Results (95th Percentile Queues)								
Peak 15 min. (ft)*	100	25	100	25	100	50	50	25
Peak Hour (ft)	50	25	50	25	75	25	50	25

* 95th-percentile queue likely to occur with the peak fifteen minute flow rates, which is the most comparable to the queuing analysis of the signalized control scenario evaluated with Synchro/SimTraffic™

Multimodal System Connectivity

As described in the system context section, a few multi-modal system connections are missing near the study intersection (sidewalks to the south and east, as well as bike lanes to the east).

On the east side of the south leg of Mt. Washington Drive, there is a sidewalk gap of approximately 3,600 feet (sidewalks are complete on the west side of the street). There is vacant land along this sidewalk gap that could develop and construct sidewalks. Due to the distance of the gap, the likelihood for future fronting development improvements, and the provision of sidewalks on the west side of the street, expanding this roundabout project to include a sidewalk extension may not be warranted at this time. However, the roundabout design should include sidewalks along the roundabout and ramps as necessary to connect to this future facility.

Along south side of the east leg of Simpson Avenue, the sidewalk ends approximately 1,700 feet east of the intersection (prior to SW Century Drive). Because the missing link in the sidewalk is

so far away from the study intersection, completing the link is likely outside of the scope for this project. Currently the sidewalk on the north side of Simpson Avenue should be used by pedestrians accessing SW Century Drive.

In addition to the missing sidewalk link along Simpson Avenue, bike lanes are also absent for the entire segment from Mt. Washington Drive to SW Century Drive. Providing this facility would require significant road widening and is likely outside the scope of this roundabout project. Future paving or improvement projects along Simpson Avenue should consider constructing bike lanes.

Recommendations Summary

The alternatives analysis reveals that a single lane roundabout is the preferred intersection control at the intersection of Mt. Washington Drive/Simpson Avenue based. Using the City's intersection form evaluation framework outlined in Table 7, a roundabout would provide safer motor vehicle and pedestrian operations and result in shorter queues during the AM and afternoon peak hours than a traffic signal. The design of the single-lane roundabout should consider:

- Design vehicles of a WB-50, as well as a WB-50 with "pup" trailer (allowing the truck cab to stay in-lane with the trailer potentially tracking onto the truck apron)
- Design for allowing emergency response vehicles (ambulance and a hook/ladder fire truck) to stay in-lane.
- Accommodate a WB-67 for all movements (with use of an apron if necessary).
- Improve sight distance, as needed, to the north of the intersection to provide adequate stopping sight distance for vehicles approaching the roundabout.

Appendix A

Existing Intersection Turn Movement Counts (AM/Afternoon)

Type of peak hour being reported: Intersection Peak

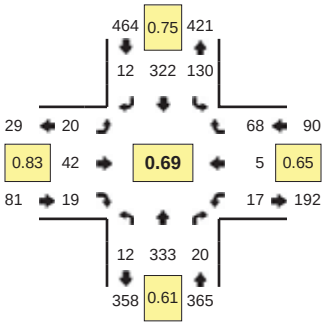
Method for determining peak hour: Total Entering Volume

LOCATION: Mt Washington Dr -- Simpson Ave

QC JOB #: 10474601

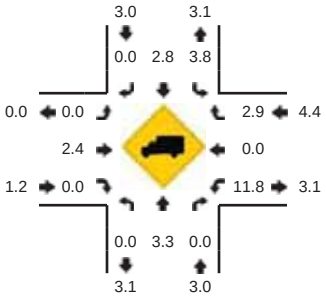
CITY/STATE: Bend, OR

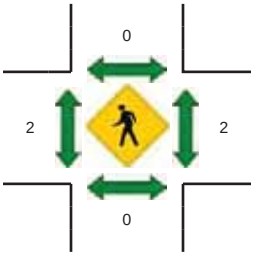
DATE: 2/11/2010

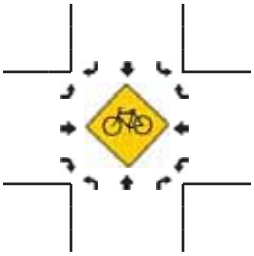


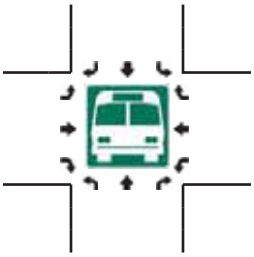
Peak-Hour: 7:15 AM -- 8:15 AM

Peak 15-Min: 7:25 AM -- 7:40 AM









5-Min Count Period Beginning At	Mt Washington Dr (Northbound)				Mt Washington Dr (Southbound)				Simpson Ave (Eastbound)				Simpson Ave (Westbound)				Total	Hourly Totals
	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U		
7:00 AM	0	8	2	0	5	4	1	0	0	4	0	0	1	0	3	0	28	
7:05 AM	1	4	1	0	4	9	1	0	0	2	0	0	0	0	3	0	25	
7:10 AM	0	26	0	0	2	15	0	0	0	1	0	0	0	0	4	0	48	
7:15 AM	0	34	3	0	5	21	0	0	3	4	0	0	2	0	1	0	73	
7:20 AM	0	33	1	0	9	32	1	0	2	1	3	0	3	0	9	0	94	
7:25 AM	1	55	2	0	3	44	0	0	4	7	1	0	1	0	14	0	132	
7:30 AM	4	48	2	0	12	33	3	0	4	1	2	0	2	1	9	0	121	
7:35 AM	1	38	2	0	24	30	3	0	3	3	0	0	1	0	4	0	109	
7:40 AM	2	29	3	0	20	27	2	0	1	7	0	0	1	0	7	0	99	
7:45 AM	0	14	4	0	11	19	2	0	2	6	1	0	0	0	3	0	62	
7:50 AM	0	15	1	0	10	28	1	0	1	0	2	0	2	0	2	0	62	
7:55 AM	1	15	1	0	4	26	0	0	0	2	5	0	2	0	5	0	61	914
8:00 AM	1	15	1	0	14	25	0	0	0	4	1	0	0	1	6	0	68	954
8:05 AM	1	19	0	0	10	20	0	0	0	3	3	0	1	0	2	0	59	988
8:10 AM	1	18	0	0	8	17	0	0	0	4	1	0	2	3	6	0	60	1000
8:15 AM	1	11	1	0	6	14	0	0	0	3	1	0	3	0	6	0	46	973
8:20 AM	1	10	7	0	7	15	0	0	1	4	0	0	0	0	6	0	51	930
8:25 AM	0	16	2	0	9	13	0	0	0	5	2	0	2	0	7	0	56	854
8:30 AM	0	12	4	0	7	20	0	0	3	4	2	0	2	0	5	0	59	792
8:35 AM	0	17	3	0	5	17	2	0	1	5	2	0	1	0	2	0	55	738
8:40 AM	0	16	2	0	11	16	0	0	2	4	1	0	1	3	12	0	68	707
8:45 AM	0	22	3	0	12	21	0	0	4	3	3	0	1	0	13	0	82	727
8:50 AM	0	19	2	0	12	23	3	0	1	2	1	0	2	2	10	0	77	742
8:55 AM	0	15	2	0	15	29	1	0	2	7	2	0	3	0	4	0	80	761

Peak 15-Min Flowrates	Northbound				Southbound				Eastbound				Westbound				Total
	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U	
All Vehicles	24	564	24	0	156	428	24	0	44	44	12	0	16	4	108	0	1448
Heavy Trucks	0	0	0		16	12	0		0	0	0		4	0	0		32
Pedestrians		0				0				0				4			4
Bicycles																	
Railroad																	
Stopped Buses																	

Comments:

Report generated on 3/23/2010 4:47 PM

SOURCE: Quality Counts, LLC (http://www.qualitycounts.net)

Type of peak hour being reported: Intersection Peak

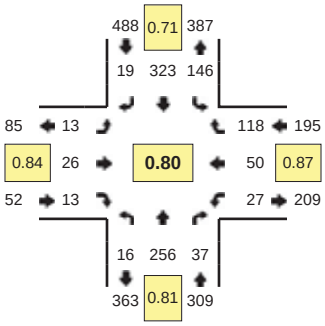
Method for determining peak hour: Total Entering Volume

LOCATION: Mt Washington Dr -- Simpson Ave

QC JOB #: 10474602

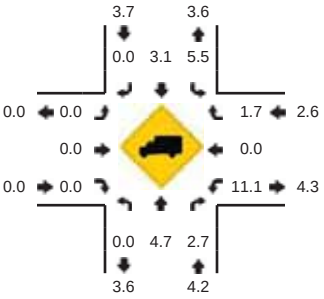
CITY/STATE: Bend, OR

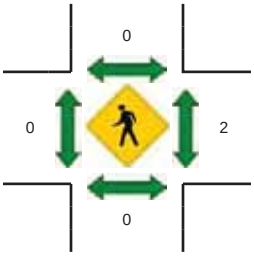
DATE: 2/11/2010

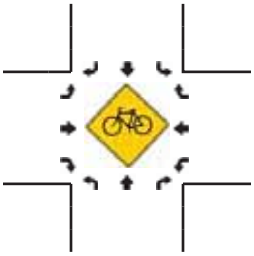


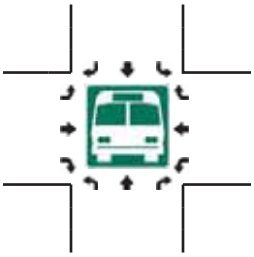
Peak-Hour: 2:45 PM -- 3:45 PM

Peak 15-Min: 2:55 PM -- 3:10 PM









5-Min Count Period Beginning At	Mt Washington Dr (Northbound)				Mt Washington Dr (Southbound)				Simpson Ave (Eastbound)				Simpson Ave (Westbound)				Total	Hourly Totals
	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U		
2:30 PM	1	11	7	0	3	9	1	0	1	3	1	0	4	0	10	0	51	
2:35 PM	1	15	3	0	5	10	2	0	4	2	1	0	1	4	5	0	53	
2:40 PM	1	18	4	0	5	15	2	0	0	4	1	0	3	2	13	0	68	
2:45 PM	1	25	7	0	6	17	0	0	1	3	1	0	1	4	3	0	69	
2:50 PM	0	32	5	0	13	35	1	0	1	1	2	0	1	1	6	0	98	
2:55 PM	2	23	2	0	13	47	2	0	2	1	0	0	4	2	17	0	115	
3:00 PM	1	19	2	0	11	49	3	0	0	4	3	0	4	4	11	0	111	
3:05 PM	4	22	3	0	12	31	5	0	2	1	1	0	2	5	12	0	100	
3:10 PM	1	17	3	0	12	23	1	0	1	2	0	0	4	7	7	0	78	
3:15 PM	0	20	2	0	12	16	0	0	2	2	2	0	2	5	7	0	70	
3:20 PM	0	24	4	0	12	15	0	0	1	3	1	0	0	1	16	0	77	
3:25 PM	3	28	2	0	11	13	2	0	0	2	1	0	1	2	12	0	77	967
3:30 PM	1	16	3	0	10	15	1	0	1	1	2	0	2	7	11	0	70	986
3:35 PM	1	15	2	0	13	34	2	0	1	3	0	0	3	7	7	0	88	1021
3:40 PM	2	15	2	0	21	28	2	0	1	3	0	0	3	5	9	0	91	1044
3:45 PM	1	16	1	0	4	23	2	0	1	2	4	0	2	3	8	0	67	1042
3:50 PM	1	23	3	0	11	17	1	0	0	3	1	0	1	4	8	0	73	1017
3:55 PM	3	14	4	0	8	16	1	0	0	1	1	0	0	3	12	0	63	965
4:00 PM	0	11	2	0	7	22	1	0	0	3	0	0	5	4	6	0	61	915
4:05 PM	0	8	2	0	16	20	1	0	0	5	0	0	1	3	10	0	66	881
4:10 PM	2	14	3	0	7	16	2	0	1	1	1	0	5	4	10	0	66	869
4:15 PM	0	8	2	0	4	12	0	0	0	0	0	0	5	0	6	0	37	836
4:20 PM	0	23	6	0	5	19	1	0	0	2	0	0	1	4	12	0	73	832
4:25 PM	2	19	0	0	3	14	1	0	1	0	0	0	2	1	12	0	55	810

Peak 15-Min Flowrates	Northbound				Southbound				Eastbound				Westbound				Total
	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U	Left	Thru	Right	U	
All Vehicles	28	256	28	0	144	508	40	0	16	24	16	0	40	44	160	0	1304
Heavy Trucks	0	12	0		20	32	0		0	0	0		4	0	4		72
Pedestrians		0				0				0				4			4
Bicycles																	
Railroad																	
Stopped Buses																	

Comments:

Report generated on 3/23/2010 4:47 PM

SOURCE: Quality Counts, LLC (http://www.qualitycounts.net)

Appendix B

Intersection Collision Records (2008-2010)

OREGON.. DEPARTMENT OF TRANSPORTATION - TRANSPORTATION DEVELOPMENT DIVISION
TRANSPORTATION DATA SECTION - CRASH ANAYLYSIS AND REPORTING UNIT
URBAN NON-SYSTEM CRASH LISTING

CITY OF BEND, DESCHUTES COUNTY

SIMPSON AVE at MT WASHINGTON DR, City of Bend, Deschutes County, 01/01/2007 to 04/30/2011

Total crash records: 8

SER# / INVEST	SPEED	ALCHL	DRUGS	SCHL	WORK	DATE / DAY / TIME	CLASS / DIST FROM	CITY STREET / FIRST STREET / SECOND STREET	RD CHAR / DIRECT / LOCTN	INT-TYPE (MEDIAN) / LEGS (#LANES)	INT-REL / TRAF-CONTL	OFFRD / RNDBT / DRVWY	WTHR / SURF / LIGHT	CRASH / COLL / SVRTY	V#	SPCL USE / TRLR QTY / OWNER	MOVE / FROM / TO	P#	PRTC TYPE	INJ SVRTY	AGE	SEX	LICNS RES / OR-Y / OR<25	PED LOC	ERROR	ACT	EVENT	CAUSE
00331	N	N	N	N	N	02/18/2008	16	MT WASHINGTON DR	INTER	CROSS	N	N	CLR	ANGL-OTH	01	NONE 0	STRGHT											03
CITY						MO	0	SIMPSON AVE	CN		STOP SIGN	N	DRY	ANGL		PRVTE	S -N									000		00
						8A			02	0		N	DAY	INJ		PSNGR CAR		01	DRVR	NONE	63	M	OR-Y		000	000		00
																							OR<25					
															02	NONE 0	STRGHT											
																PRVTE	E -W									000	013	00
																PSNGR CAR		01	DRVR	INJB	62	F	OTH-Y		021	000		03
																							OR<25					
															03	NONE 0	STRGHT											
																PRVTE	N -S									000		00
																PSNGR CAR		01	DRVR	INJB	45	M	OR-Y		000	000		00
																							OR<25					
01776	N	N	N	N	N	11/06/2008	19	MT WASHINGTON DR	INTER	CROSS	N	N	CLD	ANGL-OTH	01	NONE 0	STRGHT											03
CITY						TH	0	SIMPSON AVE	CN		STOP SIGN	N	WET	ANGL		PRVTE	W -E									000		00
						9A			02	0		N	DAY	INJ		PSNGR CAR		01	DRVR	INJC	33	F	OTH-Y		003	000		03
																							OR<25					
															02	NONE 0	STRGHT											
																PRVTE	S -N									000		00
																PSNGR CAR		01	DRVR	NONE	52	M	OR-Y		000	000		00
																							OR<25					
00421	N	N	N	N	N	03/27/2009	16	MT WASHINGTON DR	INTER	CROSS	N	Y	CLR	ANGL-OTH	01	NONE 0	STRGHT										058	03
CITY						FR	0	SIMPSON AVE	CN		STOP SIGN	N	DRY	ANGL		PRVTE	E -W									000		00
						6P			01	0		N	DAY	INJ		PSNGR CAR		01	DRVR	INJB	63	F	OR-Y		021	000		03
																							OR<25					
															02	NONE 0	STRGHT											
																PRVTE	N -S									000	058	00
																PSNGR CAR		01	DRVR	INJC	23	F	OR-Y		000	000		00
																							OR<25					
00836	N	N	N			06/22/2009	16	MT WASHINGTON DR	INTER	CROSS	N	N	CLR	ANGL-OTH	01	NONE 0	STRGHT											03
NO RPT						MO	0	SIMPSON AVE	CN		STOP SIGN	N	DRY	ANGL		PRVTE	E -W									000		00
						10A			01	0		N	DAY	INJ		PSNGR CAR		01	DRVR	INJC	66	F	OR-Y		021	000		03
																							OR<25					
															02	NONE 0	STRGHT											
																PRVTE	N -S									000		00
																PSNGR CAR		01	DRVR	NONE	00	M	UNK		000	000		00
																							UNK					
01119	N	N	N			08/26/2009	16	MT WASHINGTON DR	INTER	CROSS	N	N	CLR	ANGL-OTH	01	NONE 0	STRGHT											27,03
NONE						WE	0	SIMPSON AVE	CN		STOP SIGN	N	DRY	ANGL		PRVTE	E -W									000		00
						8A			01	0		N	DAY	PDO		PSNGR CAR		01	DRVR	NONE	34	M	OR-Y		021,016	000		03,27
																							OR<25					
															02	NONE 0	STRGHT											
																PRVTE	N -S									000		00
																PSNGR CAR		01	DRVR	NONE	72	M	OR-Y		000	000		00
																							OR<25					
01034	N	N	N			08/03/2009	19	MT WASHINGTON DR	INTER	CROSS	N	N	CLR	S-OTHER	01	NONE 0	TURN-R											06
CITY						MO	0	SIMPSON AVE	CN		NONE	N	DRY	TURN		PRVTE	S -E									000		00
						5P			04	0		N	DAY	PDO		PSNGR CAR		01	DRVR	NONE	46	F	OTH-Y		031	000		06
																							N-RES					
															02	NONE 0	TURN-R											
																PRVTE	S -E									000		00
																PSNGR CAR		01	DRVR	NONE	18	M	OR-Y		000	000		00

CITY OF BEND, DESCHUTES COUNTY

SIMPSON AVE at MT WASHINGTON DR, City of Bend, Deschutes County, 01/01/2007 to 04/30/2011

Total crash records: 8

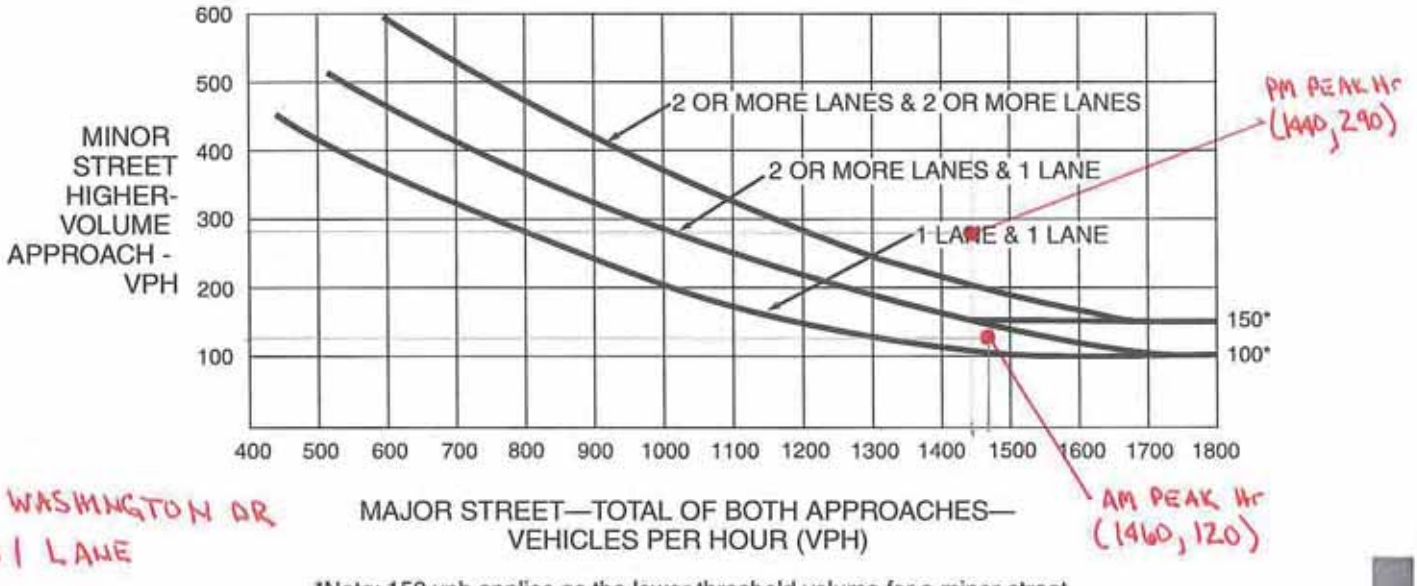
SER# / INVEST	S P E D	A L C	R U G S	S C H L	W O R K	DATE / DAY / TIME	CLASS / DIST / FROM	CITY STREET / FIRST STREET / SECOND STREET	RD CHAR / DIRECT / LOCTN	INT-TYPE (MEDIAN) / LEGS (#LANES)	INT-REL / TRAF- / CONTL	OFFRD / RNDBT / DRVWY	WTHR / SURF / LIGHT	CRASH / COLL / SVRTY	V#	SPCL USE / TRLR QTY / OWNER	MOVE / FROM / TO	P#	PRTC TYPE	INJ SVRTY	A G E	S E X	LICNS RES OR<25	PED LOC	ERROR	ACT EVENT	CAUSE
00083	N	N	N			01/01/2010	16	MT WASHINGTON DR	INTER	CROSS	N	N	RAIN	ANGL-OTH	01	NONE 0	STRGHT										03
NO RPT						FR	0	SIMPSON AVE	CN		STOP SIGN	N	ICE	ANGL		PRVTE	E -W									000	00
						11A			01	0		N	DAY	PDO		PSNGR CAR		01	DRVR	NONE	63	F	OR-Y		021	000	03
																							OR<25				
															02	NONE 0	STRGHT										
																PRVTE	N -S									000	00
																PSNGR CAR		01	DRVR	NONE	22	M	OR-Y		000	000	00
																							OR<25				
															02	NONE 0	STRGHT										
																PRVTE	N -S									000	00
																PSNGR CAR		02	PSNG	NO<5	01	M			000	000	00
00849	N	N	N			07/25/2010	16	MT WASHINGTON DR	INTER	CROSS	N	N	CLR	O-1TURN	01	NONE	TURN-L										08
NO RPT						SU	0	SIMPSON AVE	CN		UNKNOWN	N	DRY	TURN		PRVTE	N -E									000	00
						9A			02	0		N	DAY	PDO		PSNGR CAR		01	DRVR	NONE	51	M	OR-Y		004	000	08
																							OR<25				
															02	NONE 0	STRGHT										
																PRVTE	N -S									000	00
																PSNGR CAR		01	DRVR	NONE	74	F	OR-Y		000	000	00
																							OR<25				

Appendix C

Future Year 2030 Traffic Signal Warrant

MT. WASHINGTON DR. AT SIMPSON AVE.
FUTURE 2030 PEAK HOUR TRAFFIC SIGNAL WARRANT

Figure 4C-3. Warrant 3, Peak Hour



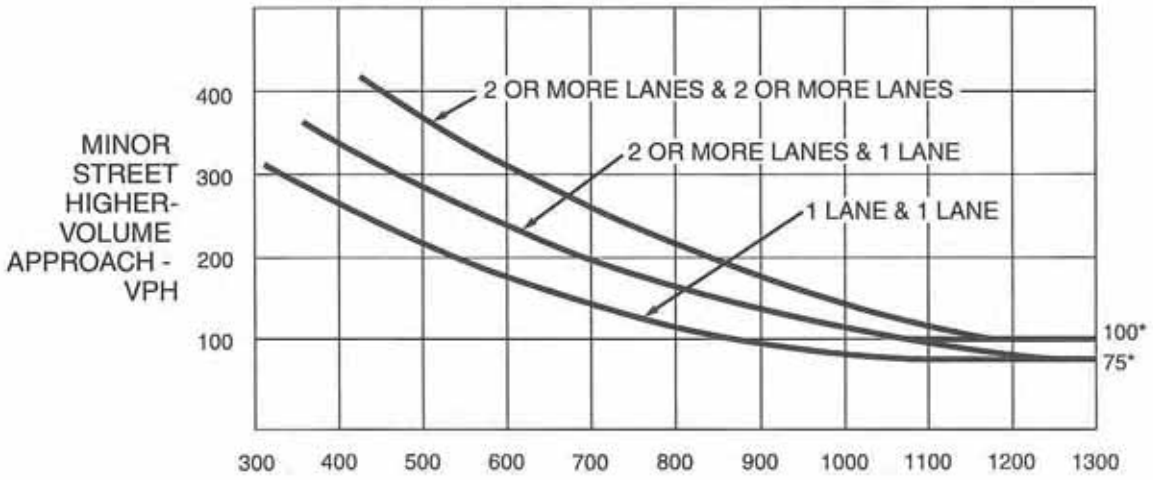
MT. WASHINGTON DR
↳ 1 LANE

SIMPSON AVE
↳ 1 LANE

*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

Appendix D

Existing Intersection Operations (AM/Afternoon Peak Hour)

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	20	42	19	17	5	68	12	333	20	130	322	12
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Hourly flow rate (vph)	29	61	28	25	7	99	17	483	29	188	467	17
Pedestrians		2			2							
Lane Width (ft)		12.0			12.0							
Walking Speed (ft/s)		4.0			4.0							
Percent Blockage		0			0							
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	1474	1403	477	1435	1397	499	486			514		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	1474	1403	477	1435	1397	499	486			514		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	58	46	95	52	94	83	98			82		
cM capacity (veh/h)	70	112	587	52	112	567	1070			1045		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1	SB 2
Volume Total	117	130	17	512	188	484
Volume Left	29	25	17	0	188	0
Volume Right	28	99	0	29	0	17
cSH	117	183	1070	1700	1045	1700
Volume to Capacity	1.00	0.71	0.02	0.30	0.18	0.28
Queue Length 95th (ft)	167	111	1	0	16	0
Control Delay (s)	154.6	62.7	8.4	0.0	9.2	0.0
Lane LOS	F	F	A		A	
Approach Delay (s)	154.6	62.7	0.3		2.6	
Approach LOS	F	F				

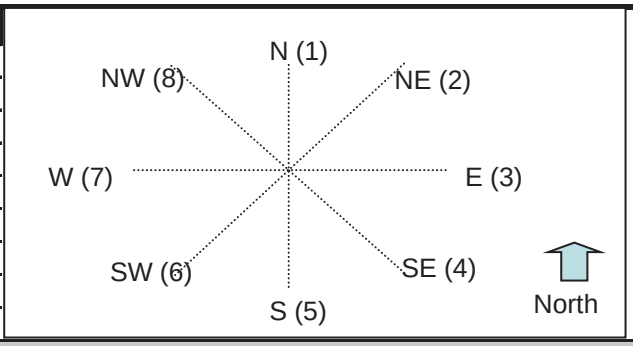
Intersection Summary				
Average Delay	19.5			
Intersection Capacity Utilization	45.4%	ICU Level of Service		A
Analysis Period (min)	15			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	13	26	13	27	50	118	16	256	37	146	323	19
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Hourly flow rate (vph)	16	32	16	34	62	148	20	320	46	182	404	24
Pedestrians					2							
Lane Width (ft)					12.0							
Walking Speed (ft/s)					4.0							
Percent Blockage					0							
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	1319	1189	416	1186	1178	345	428			368		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	1319	1189	416	1186	1178	345	428			368		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	75	79	97	71	60	79	98			84		
cM capacity (veh/h)	64	156	637	117	157	694	1121			1177		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1	SB 2
Volume Total	65	244	20	366	182	428
Volume Left	16	34	20	0	182	0
Volume Right	16	148	0	46	0	24
cSH	133	272	1121	1700	1177	1700
Volume to Capacity	0.49	0.90	0.02	0.22	0.16	0.25
Queue Length 95th (ft)	57	199	1	0	14	0
Control Delay (s)	55.5	71.8	8.3	0.0	8.6	0.0
Lane LOS	F	F	A		A	
Approach Delay (s)	55.5	71.8	0.4		2.6	
Approach LOS	F	F				

Intersection Summary				
Average Delay	17.5			
Intersection Capacity Utilization	50.1%	ICU Level of Service		A
Analysis Period (min)	15			

General & Site Information	
Analyst:	N. Schroeder
Agency/Company:	DKS Associates, Inc.
Date:	12/16/2011
Project Name:	Bend G.O. Bond Projects
Intersection:	Simpson/Mt. Washington
Analysis Time Period:	AM Peak
Jurisdiction:	City of Bend
Year:	2010



Volumes		Roundabout Approach/Entry Legs							
		N (1)	NE (2)	E (3)	SE (4)	S (5)	SW (6)	W (7)	NW (8)
Input	N (1), vph			68		333		20	
Volumes	NE (2), vph								
to Leg #	E (3), vph	130				20		42	
	SE (4), vph								
	S (5), vph	322		17				19	
	SW (6), vph								
	W (7), vph	12		5		12			
	NW (8), vph								
Output	Total Vehicles	464	0	90	0	365	0	81	0

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	3.0	0.0	4.0	0.0	3.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
F_{HV}	0.971	1.000	0.962	1.000	0.971	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	102	0	497	0	30	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	194	0	0	0	30	0	62	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	481	0	26	0	0	0	28	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	18	0	8	0	18	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	693	0	136	0	545	0	120	0
Conflicting flow, pce/h	51	680	545	831	286	820	700	744
Entry capacity, pce/h	1280	NA	862	NA	1061	NA	761	NA

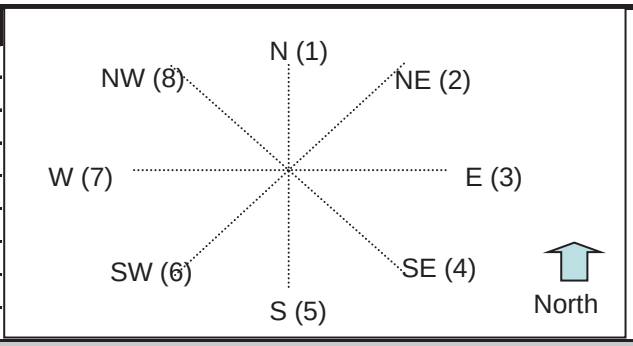
Results	N	NE	E	SE	S	SW	W	NW
Entry Volume, vph	672	0	130	0	529	0	117	0
Entry Capacity, vph	1242	#VALUE!	829	#VALUE!	1030	#VALUE!	746	#VALUE!
Leg v/c ratio	0.54	#VALUE!	0.16	#VALUE!	0.51	#VALUE!	0.16	#VALUE!
Control Delay, s/veh	9.0	#VALUE!	5.9	#VALUE!	9.7	#VALUE!	6.5	#VALUE!
LOS	A	#VALUE!	A	#VALUE!	A	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	89	0	15	0	79	0	14	0

For Hourly Queuing Calc (PHF = 1.0)

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	3.0	0.0	4.0	0.0	3.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F_{HV}	0.971	1.000	0.962	1.000	0.971	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	71	0	343	0	20	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	134	0	0	0	21	0	43	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	332	0	18	0	0	0	19	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	12	0	5	0	12	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	478	0	94	0	376	0	83	0
Conflicting flow, pce/h	35	469	376	573	197	566	483	513
Entry capacity, pce/h	1296	NA	987	NA	1139	NA	906	NA
Results	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
Entry Volume, vph	464	0	90	0	365	0	81	0
Entry Capacity, vph	1258	#VALUE!	949	#VALUE!	1105	#VALUE!	888	#VALUE!
Leg v/c ratio	0.37	#VALUE!	0.09	#VALUE!	0.33	#VALUE!	0.09	#VALUE!
Control Delay, s/veh	6.4	#VALUE!	4.7	#VALUE!	6.5	#VALUE!	4.9	#VALUE!
LOS	A	#VALUE!	A	#VALUE!	A	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	46	0	8	0	39	0	8	0

General & Site Information	
Analyst:	N. Schroeder
Agency/Company:	DKS Associates, Inc.
Date:	12/16/2011
Project Name:	Bend G.O. Bond Projects
Intersection:	Simpson/Mt. Washington
Analysis Time Period:	PM Peak
Jurisdiction:	City of Bend
Year:	2011



Volumes		Roundabout Approach/Entry Legs							
		N (1)	NE (2)	E (3)	SE (4)	S (5)	SW (6)	W (7)	NW (8)
Input	N (1), vph			118		256		13	
Volumes	NE (2), vph								
to Leg #	E (3), vph	146				37		26	
	SE (4), vph								
	S (5), vph	323		27				13	
	SW (6), vph								
	W (7), vph	19		50		16			
	NW (8), vph								
Output	Total Vehicles	488	0	195	0	309	0	52	0

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	4.0	0.0	3.0	0.0	4.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
F_{HV}	0.962	1.000	0.971	1.000	0.962	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	152	0	333	0	17	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	190	0	0	0	48	0	33	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	420	0	35	0	0	0	17	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	25	0	64	0	21	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	634	0	251	0	402	0	66	0
Conflicting flow, pce/h	120	621	370	641	240	711	644	754
Entry capacity, pce/h	1211	NA	991	NA	1101	NA	796	NA

Results	N	NE	E	SE	S	SW	W	NW
Entry Volume, vph	610	0	244	0	386	0	65	0
Entry Capacity, vph	1164	#VALUE!	962	#VALUE!	1058	#VALUE!	780	#VALUE!
Leg v/c ratio	0.52	#VALUE!	0.25	#VALUE!	0.36	#VALUE!	0.08	#VALUE!
Control Delay, s/veh	9.1	#VALUE!	6.3	#VALUE!	7.2	#VALUE!	5.4	#VALUE!
LOS	A	#VALUE!	A	#VALUE!	A	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	84	0	26	0	45	0	7	0

For Hourly Queuing Calc (PHF = 1.0)

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	4.0	0.0	3.0	0.0	4.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F_{HV}	0.962	1.000	0.971	1.000	0.962	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	122	0	266	0	13	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	152	0	0	0	38	0	27	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	336	0	28	0	0	0	13	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	20	0	52	0	17	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	508	0	201	0	321	0	53	0
Conflicting flow, pce/h	96	497	296	513	192	569	516	603
Entry capacity, pce/h	1235	NA	1052	NA	1144	NA	882	NA
Results	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
Entry Volume, vph	488	0	195	0	309	0	52	0
Entry Capacity, vph	1187	#VALUE!	1021	#VALUE!	1100	#VALUE!	865	#VALUE!
Leg v/c ratio	0.41	#VALUE!	0.19	#VALUE!	0.28	#VALUE!	0.06	#VALUE!
Control Delay, s/veh	7.2	#VALUE!	5.3	#VALUE!	6.0	#VALUE!	4.7	#VALUE!
LOS	A	#VALUE!	A	#VALUE!	A	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	55	0	19	0	31	0	5	0

Appendix E

Future Year 2030 Intersection Operations (AM/Afternoon Peak Hour)

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	35	50	35	25	5	95	25	595	30	170	620	20
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Hourly flow rate (vph)	47	68	47	34	7	128	34	804	41	230	838	27
Pedestrians					2							
Lane Width (ft)					12.0							
Walking Speed (ft/s)					4.0							
Percent Blockage					0							
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	2314	2225	851	2272	2218	826	865			847		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2314	2225	851	2272	2218	826	865			847		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	0	87	0	77	65	96			71		
cM capacity (veh/h)	11	29	360	0	29	368	774			785		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1	SB 2
Volume Total	162	169	34	845	230	865
Volume Left	47	34	34	0	230	0
Volume Right	47	128	0	41	0	27
cSH	24	0	774	1700	785	1700
Volume to Capacity	6.85	Err	0.04	0.50	0.29	0.51
Queue Length 95th (ft)	Err	Err	3	0	30	0
Control Delay (s)	Err	Err	9.9	0.0	11.5	0.0
Lane LOS	F	F	A		B	
Approach Delay (s)	Err	Err	0.4		2.4	
Approach LOS	F	F				

Intersection Summary				
Average Delay	Err			
Intersection Capacity Utilization	67.5%	ICU Level of Service	C	
Analysis Period (min)	15			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	25	30	25	40	65	185	30	585	55	200	535	35
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Hourly flow rate (vph)	29	35	29	47	76	215	35	680	64	233	622	41
Pedestrians					2							
Lane Width (ft)					12.0							
Walking Speed (ft/s)					4.0							
Percent Blockage					0							
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	2110	1924	642	1918	1912	714	663			746		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2110	1924	642	1918	1912	714	663			746		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	25	94	0	0	50	96			73		
cM capacity (veh/h)	0	47	474	15	47	429	917			852		

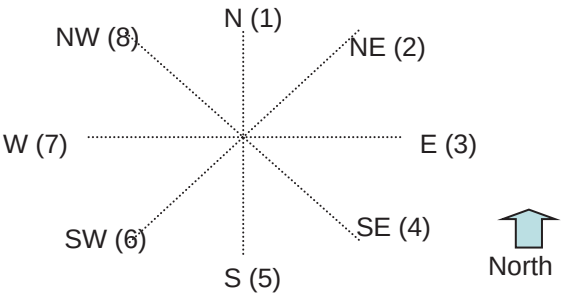
Direction, Lane #	EB 1	WB 1	NB 1	NB 2	SB 1	SB 2
Volume Total	93	337	35	744	233	663
Volume Left	29	47	35	0	233	0
Volume Right	29	215	0	64	0	41
cSH	0	64	917	1700	852	1700
Volume to Capacity	Err	5.25	0.04	0.44	0.27	0.39
Queue Length 95th (ft)	Err	Err	3	0	28	0
Control Delay (s)	Err	Err	9.1	0.0	10.8	0.0
Lane LOS	F	F	A		B	
Approach Delay (s)	Err	Err	0.4		2.8	
Approach LOS	F	F				

Intersection Summary				
Average Delay	Err			
Intersection Capacity Utilization	79.4%	ICU Level of Service	D	
Analysis Period (min)	15			

Appendix F

Alternative 1 – Future Year 2030 Roundabout Operations (AM/Afternoon Peak Hour)

General & Site Information	
Analyst:	N. Schroeder
Agency/Company:	DKS Associates, Inc.
Date:	12/15/2011
Project Name:	Bend G.O. Bond Projects
Intersection:	Simpson/Mt. Washington
Analysis Time Period:	AM Peak
Jurisdiction:	City of Bend
Year:	2030



Volumes		Roundabout Approach/Entry Legs							
		N (1)	NE (2)	E (3)	SE (4)	S (5)	SW (6)	W (7)	NW (8)
Input Volumes to Leg #	N (1), vph			95		595		35	
	NE (2), vph								
	E (3), vph	170				30		50	
	SE (4), vph								
	S (5), vph	620		25				35	
	SW (6), vph								
	W (7), vph	20		5		25			
	NW (8), vph								
Output	Total Vehicles	810	0	125	0	650	0	120	0

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	3.0	0.0	4.0	0.0	3.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
F_{HV}	0.971	1.000	0.962	1.000	0.971	1.000	0.980	1.000

Entry/Conflicting Flows		N	NE	E	SE	S	SW	W	NW
Flow to Leg #	N (1), pce/h	0	0	134	0	828	0	48	0
	NE (2), pce/h	0	0	0	0	0	0	0	0
	E (3), pce/h	237	0	0	0	42	0	69	0
	SE (4), pce/h	0	0	0	0	0	0	0	0
	S (5), pce/h	863	0	35	0	0	0	48	0
	SW (6), pce/h	0	0	0	0	0	0	0	0
	W (7), pce/h	28	0	7	0	35	0	0	0
	NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h		1127	0	176	0	905	0	165	0
Conflicting flow, pce/h		77	1087	911	1259	354	1300	1135	1204
Entry capacity, pce/h		1253	NA	643	NA	1004	NA	538	NA

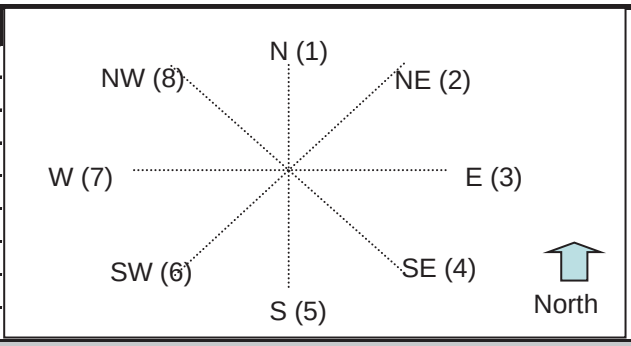
Results	N	NE	E	SE	S	SW	W	NW
Entry Volume, vph	1095	0	169	0	878	0	162	0
Entry Capacity, vph	1217	#VALUE!	618	#VALUE!	975	#VALUE!	527	#VALUE!
Leg v/c ratio	0.90	#VALUE!	0.27	#VALUE!	0.90	#VALUE!	0.31	#VALUE!
Control Delay, s/veh	26.2	#VALUE!	9.4	#VALUE!	30.5	#VALUE!	11.4	#VALUE!
LOS	D	#VALUE!	A	#VALUE!	D	#VALUE!	B	#VALUE!
95th Percentile Queue (ft)	367	0	29	0	343	0	33	0

For Hourly Queuing Calc (PHF = 1.0)

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	3.0	0.0	4.0	0.0	3.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F_{HV}	0.971	1.000	0.962	1.000	0.971	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	99	0	613	0	36	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	175	0	0	0	31	0	51	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	639	0	26	0	0	0	36	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	21	0	5	0	26	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	834	0	130	0	670	0	122	0
Conflicting flow, pce/h	57	804	674	931	262	962	840	891
Entry capacity, pce/h	1274	NA	777	NA	1081	NA	681	NA
Results	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
Entry Volume, vph	810	0	125	0	650	0	120	0
Entry Capacity, vph	1237	#VALUE!	747	#VALUE!	1050	#VALUE!	668	#VALUE!
Leg v/c ratio	0.66	#VALUE!	0.17	#VALUE!	0.62	#VALUE!	0.18	#VALUE!
Control Delay, s/veh	11.5	#VALUE!	6.6	#VALUE!	11.9	#VALUE!	7.5	#VALUE!
LOS	B	#VALUE!	A	#VALUE!	B	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	145	0	16	0	125	0	17	0

General & Site Information	
Analyst:	N. Schroeder
Agency/Company:	DKS Associates, Inc.
Date:	12/15/2011
Project Name:	Bend G.O. Bond Projects
Intersection:	Simpson/Mt. Washington
Analysis Time Period:	PM Peak
Jurisdiction:	City of Bend
Year:	2030



Volumes		Roundabout Approach/Entry Legs							
		N (1)	NE (2)	E (3)	SE (4)	S (5)	SW (6)	W (7)	NW (8)
Input	N (1), vph			185		585		25	
Volumes	NE (2), vph								
to Leg #	E (3), vph	200				55		30	
	SE (4), vph								
	S (5), vph	535		40				25	
	SW (6), vph								
	W (7), vph	35		65		30			
	NW (8), vph								
Output	Total Vehicles	770	0	290	0	670	0	80	0

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	4.0	0.0	3.0	0.0	4.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
F_{HV}	0.962	1.000	0.971	1.000	0.962	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	222	0	707	0	30	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	242	0	0	0	67	0	36	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	647	0	48	0	0	0	30	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	42	0	78	0	36	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	931	0	347	0	810	0	95	0
Conflicting flow, pce/h	162	1121	773	1117	307	1032	937	1093
Entry capacity, pce/h	1171	NA	718	NA	1043	NA	630	NA

Results	N	NE	E	SE	S	SW	W	NW
Entry Volume, vph	895	0	337	0	779	0	93	0
Entry Capacity, vph	1126	#VALUE!	697	#VALUE!	1003	#VALUE!	618	#VALUE!
Leg v/c ratio	0.80	#VALUE!	0.48	#VALUE!	0.78	#VALUE!	0.15	#VALUE!
Control Delay, s/veh	18.3	#VALUE!	12.3	#VALUE!	18.7	#VALUE!	7.6	#VALUE!
LOS	C	#VALUE!	B	#VALUE!	C	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	237	0	70	0	216	0	14	0

For Hourly Queuing Calc (PHF = 1.0)

Volume Characteristics	N	NE	E	SE	S	SW	W	NW
% Trucks	4.0	0.0	3.0	0.0	4.0	0.0	2.0	0.0
E_t	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F_{HV}	0.962	1.000	0.971	1.000	0.962	1.000	0.980	1.000

Entry/Conflicting Flows	N	NE	E	SE	S	SW	W	NW
Flow to Leg # N (1), pce/h	0	0	191	0	608	0	26	0
NE (2), pce/h	0	0	0	0	0	0	0	0
E (3), pce/h	208	0	0	0	57	0	31	0
SE (4), pce/h	0	0	0	0	0	0	0	0
S (5), pce/h	556	0	41	0	0	0	26	0
SW (6), pce/h	0	0	0	0	0	0	0	0
W (7), pce/h	36	0	67	0	31	0	0	0
NW (8), pce/h	0	0	0	0	0	0	0	0
Entry flow, pce/h	801	0	299	0	697	0	82	0
Conflicting flow, pce/h	139	964	665	961	264	887	806	940
Entry capacity, pce/h	1192	NA	783	NA	1079	NA	700	NA
Results	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
Entry Volume, vph	770	0	290	0	670	0	80	0
Entry Capacity, vph	1147	#VALUE!	760	#VALUE!	1038	#VALUE!	686	#VALUE!
Leg v/c ratio	0.67	#VALUE!	0.38	#VALUE!	0.65	#VALUE!	0.12	#VALUE!
Control Delay, s/veh	12.7	#VALUE!	9.5	#VALUE!	12.8	#VALUE!	6.5	#VALUE!
LOS	B	#VALUE!	A	#VALUE!	B	#VALUE!	A	#VALUE!
95th Percentile Queue (ft)	158	0	48	0	141	0	10	0

Appendix G

Alternative 2 – Future Year 2030 Traffic Signal Operations (AM/Afternoon Peak Hour)

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	35	50	35	25	5	95	25	595	30	170	620	20
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)		4.0			4.0		4.0	4.0		4.0	4.0	
Lane Util. Factor		1.00			1.00		1.00	1.00		1.00	1.00	
Frpb, ped/bikes		1.00			1.00		1.00	1.00		1.00	1.00	
Flpb, ped/bikes		1.00			1.00		1.00	1.00		1.00	1.00	
Frt		0.96			0.90		1.00	0.99		1.00	1.00	
Flt Protected		0.99			0.99		0.95	1.00		0.95	1.00	
Satd. Flow (prot)		1625			1496		1614	1685		1614	1691	
Flt Permitted		0.80			0.90		0.22	1.00		0.13	1.00	
Satd. Flow (perm)		1322			1353		369	1685		227	1691	
Peak-hour factor, PHF	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Adj. Flow (vph)	47	68	47	34	7	128	34	804	41	230	838	27
RTOR Reduction (vph)	0	16	0	0	107	0	0	2	0	0	1	0
Lane Group Flow (vph)	0	146	0	0	62	0	34	843	0	230	864	0
Confl. Peds. (#/hr)									2	2		
Heavy Vehicles (%)	2%	2%	2%	4%	4%	4%	3%	3%	3%	3%	3%	3%
Turn Type	Perm			Perm			pm+pt			pm+pt		
Protected Phases		4			8		5	2		1	6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		12.4			12.4		46.9	43.7		56.5	49.3	
Effective Green, g (s)		12.4			12.4		46.9	43.7		56.5	49.3	
Actuated g/C Ratio		0.16			0.16		0.61	0.57		0.73	0.64	
Clearance Time (s)		4.0			4.0		4.0	4.0		4.0	4.0	
Vehicle Extension (s)		3.0			3.0		3.0	3.0		3.0	3.0	
Lane Grp Cap (vph)		213			218		277	958		326	1084	
v/s Ratio Prot							0.01	c0.50		c0.08	0.51	
v/s Ratio Perm		c0.11			0.05		0.07			0.44		
v/c Ratio		0.69			0.28		0.12	0.88		0.71	0.80	
Uniform Delay, d1		30.4			28.3		7.7	14.3		12.5	10.1	
Progression Factor		1.00			1.00		1.00	1.00		1.00	1.00	
Incremental Delay, d2		8.8			0.7		0.2	9.3		6.8	4.1	
Delay (s)		39.2			29.1		7.9	23.6		19.3	14.3	
Level of Service		D			C		A	C		B	B	
Approach Delay (s)		39.2			29.1			23.0			15.3	
Approach LOS		D			C			C			B	

Intersection Summary			
HCM Average Control Delay	20.9	HCM Level of Service	C
HCM Volume to Capacity ratio	0.82		
Actuated Cycle Length (s)	76.9	Sum of lost time (s)	12.0
Intersection Capacity Utilization	67.5%	ICU Level of Service	C
Analysis Period (min)	15		
c Critical Lane Group			

Intersection: 11: Simpson Ave & Mt Washington Dr

Movement	EB	WB	NB	NB	SB	SB	B13
Directions Served	LTR	LTR	L	TR	L	TR	T
Maximum Queue (ft)	224	251	83	515	236	457	41
Average Queue (ft)	77	74	21	172	71	122	1
95th Queue (ft)	170	168	58	384	149	294	17
Link Distance (ft)	468	1108		976		428	708
Upstream Blk Time (%)						0	
Queuing Penalty (veh)						0	
Storage Bay Dist (ft)			300		300		
Storage Blk Time (%)				2		1	
Queuing Penalty (veh)				1		2	

Network Summary

Network wide Queuing Penalty: 2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	25	30	25	40	65	185	30	585	55	200	535	35
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Total Lost time (s)		4.0			4.0		4.0	4.0		4.0	4.0	
Lane Util. Factor		1.00			1.00		1.00	1.00		1.00	1.00	
Frpb, ped/bikes		1.00			1.00		1.00	1.00		1.00	1.00	
Flpb, ped/bikes		1.00			1.00		1.00	1.00		1.00	1.00	
Frt		0.96			0.91		1.00	0.99		1.00	0.99	
Flt Protected		0.98			0.99		0.95	1.00		0.95	1.00	
Satd. Flow (prot)		1618			1542		1599	1658		1599	1667	
Flt Permitted		0.72			0.94		0.34	1.00		0.14	1.00	
Satd. Flow (perm)		1188			1467		577	1658		242	1667	
Peak-hour factor, PHF	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Adj. Flow (vph)	29	35	29	47	76	215	35	680	64	233	622	41
RTOR Reduction (vph)	0	20	0	0	78	0	0	4	0	0	3	0
Lane Group Flow (vph)	0	73	0	0	260	0	35	740	0	233	660	0
Confl. Peds. (#/hr)									2	2		
Heavy Vehicles (%)	2%	2%	2%	3%	3%	3%	4%	4%	4%	4%	4%	4%
Turn Type	Perm			Perm			pm+pt			pm+pt		
Protected Phases		4			8		5	2		1	6	
Permitted Phases	4			8			2			6		
Actuated Green, G (s)		15.3			15.3		39.3	37.1		50.2	44.0	
Effective Green, g (s)		15.3			15.3		39.3	37.1		50.2	44.0	
Actuated g/C Ratio		0.21			0.21		0.53	0.50		0.68	0.60	
Clearance Time (s)		4.0			4.0		4.0	4.0		4.0	4.0	
Vehicle Extension (s)		3.0			3.0		3.0	3.0		3.0	3.0	
Lane Grp Cap (vph)		247			305		339	837		333	998	
v/s Ratio Prot							0.00	c0.45		c0.09	0.40	
v/s Ratio Perm		0.06			c0.18		0.05			0.39		
v/c Ratio		0.30			0.85		0.10	0.88		0.70	0.66	
Uniform Delay, d1		24.6			28.0		8.4	16.3		11.3	9.8	
Progression Factor		1.00			1.00		1.00	1.00		1.00	1.00	
Incremental Delay, d2		0.7			20.1		0.1	10.9		6.3	1.7	
Delay (s)		25.2			48.1		8.6	27.2		17.6	11.5	
Level of Service		C			D		A	C		B	B	
Approach Delay (s)		25.2			48.1			26.3			13.1	
Approach LOS		C			D			C			B	

Intersection Summary			
HCM Average Control Delay	24.1	HCM Level of Service	C
HCM Volume to Capacity ratio	0.85		
Actuated Cycle Length (s)	73.5	Sum of lost time (s)	12.0
Intersection Capacity Utilization	79.4%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

Intersection: 11: Simpson Ave & Mt Washington Dr

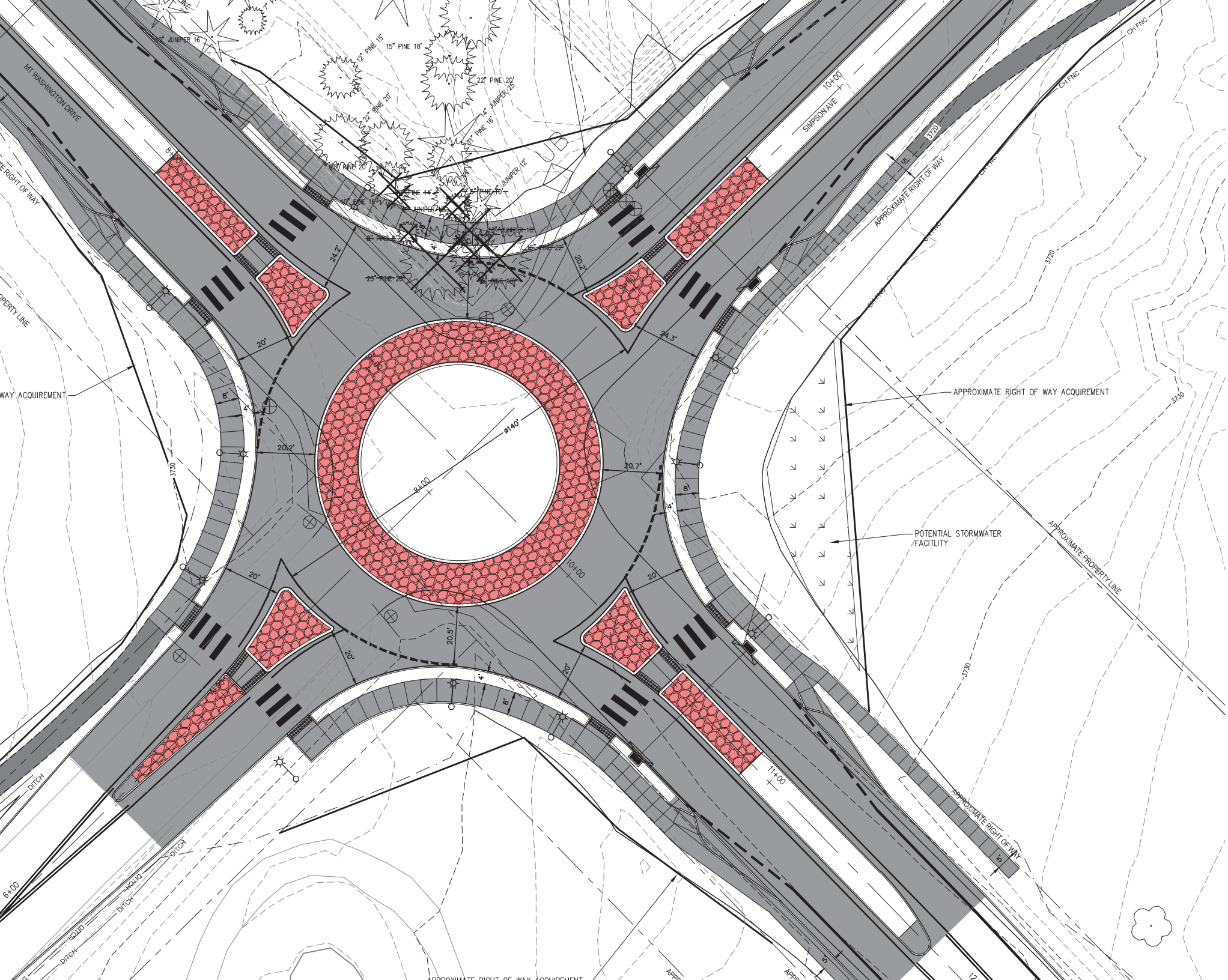
Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	L	TR	L	TR
Maximum Queue (ft)	118	486	218	586	238	356
Average Queue (ft)	51	177	27	238	97	127
95th Queue (ft)	96	388	94	447	181	262
Link Distance (ft)	468	1108		976		428
Upstream Blk Time (%)						0
Queuing Penalty (veh)						0
Storage Bay Dist (ft)			300		300	
Storage Blk Time (%)			0	3	0	0
Queuing Penalty (veh)			0	1	0	1

Network Summary

Network wide Queuing Penalty: 2

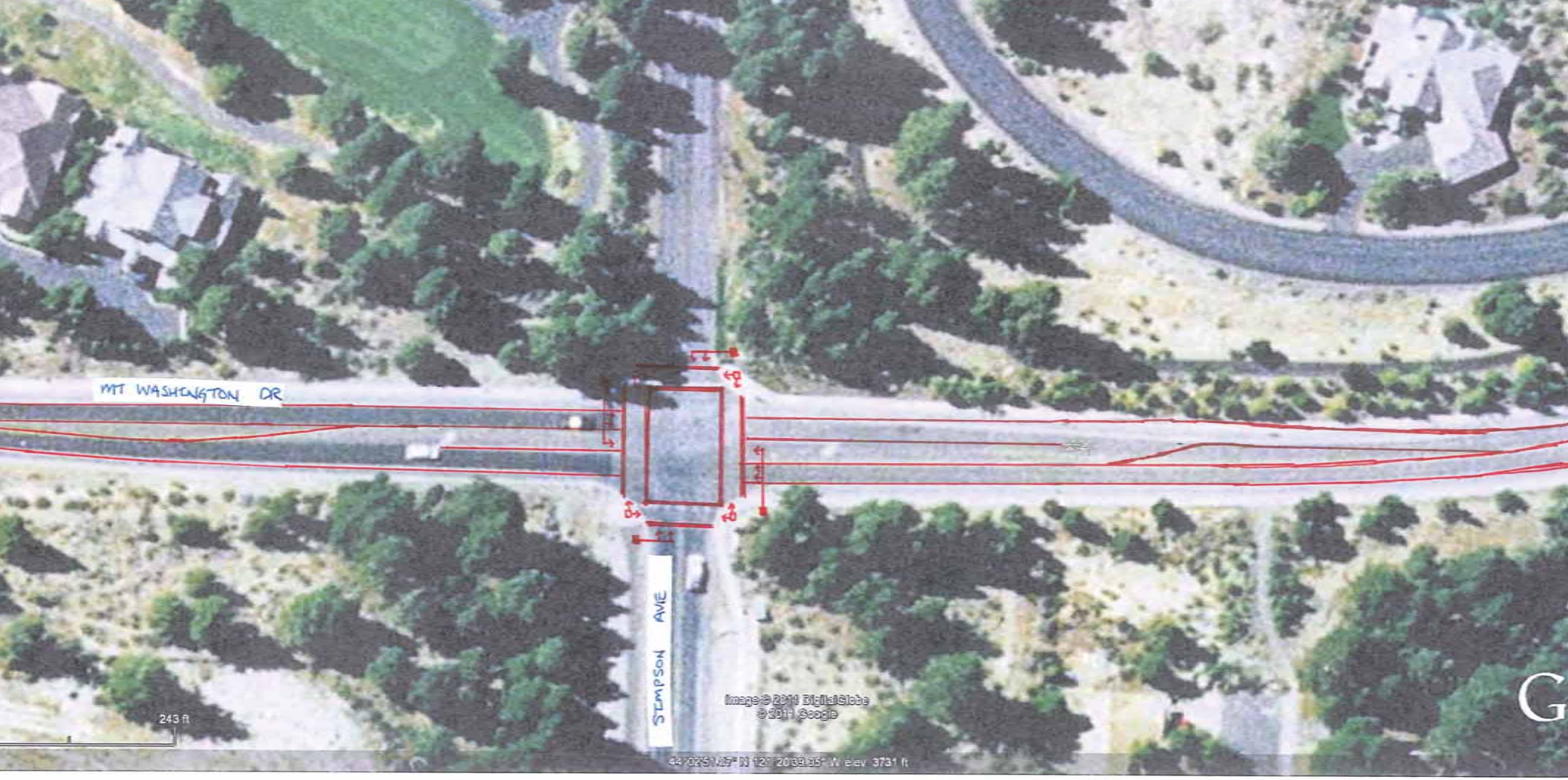
Appendix H

Roundabout Concept Design


MT WASHINGTON DRIVE
SIMPSON AVE
APPROXIMATE RIGHT OF WAY ACQUIREMENT
APPROXIMATE RIGHT OF WAY
APPROXIMATE PROPERTY LINE
POTENTIAL STORMWATER FACILITY
DITCH
EDGE
HDWG
CH FNC
Ø140'
8+00
10+00
11+00
6+00
3720
3730
3740
24.2'
24.3'
20.2'
20.7'
20.5'
20'
8'
4'

Appendix I

Traffic Signal Concept Design


MT WASHINGTON DR
STEMPSON AVE
243 ft
Image © 2014 DigitalGlobe
© 2014 Google
44°02'51.65" N 121° 20'39.35" W elev 3731 ft

TRAFFI

DKS