MEMORANDUM

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DATE: December 30, 2010

SUBJECT: **ODOT Region 4 10-Year Phased ITS and Communications Plan**

P06287-010

The Oregon Department of Transportation (ODOT) recently installed a central traffic signal system server in the Bend and Redmond urban areas. Communications between the central server and the field traffic signals is required to take full advantage of the traffic signal system capabilities. This intelligent transportation system (ITS) and communications plan discusses the communications infrastructure and field devices needed that will be necessary to support active transportation system management and operations on the Bend and Redmond urban area roadways. The plan also emphasizes interconnecting traffic signals with the new regional central traffic signal system.

The projects included in this plan will be phased over a 10-year period that is based ODOT's current annual allocation of ITS funds in Region 4. The phased plan can also be used to guide future funding applications, identify opportunities to install communications in conjunction with other capital improvement projects or private development, and identify opportunities to share communications infrastructure with other public agencies representing Deschutes County, City of Bend, and City of Redmond.

This memorandum includes an overview of the existing ITS and communications infrastructure, the recommended communications media, and the planned ITS and communications infrastructure with a phased deployment plan that includes maps and project descriptions. A wireless path analysis that confirms the feasibility of wireless links proposed in the plan is discussed and details are attached in **Appendix C**.

EXISTING ITS AND COMMUNICATIONS INFRASTRUCTURE

This section describes the existing ITS and communications infrastructure for the Bend and Redmond urban areas, which forms the baseline for future project expansion and build-out of the ITS and communications infrastructure.

As seen in **Figure 1**, the communications network in Bend is limited and disconnected. Twisted pair copper interconnect is used at many locations between traffic signals; however, communications to the central server is typically provided by leased dial-up phone connections. One corridor includes a segment of very high bit-rate digital subscriber line (VDSL) over twisted pair copper. There are only a few cameras and road weather information system (RWIS) stations in Bend. Communications to these cameras are provided by Bend Broadband through an informal agreement and future reliability is uncertain. There is no physical communications plant into the ODOT Region 4 Headquarters building, which houses the Region 4 Traffic Operations Center (TOC) and provides the central interface to the ODOT wide area network.

Redmond has recently installed an adaptive traffic signal system with communications to nearly all traffic signals. **Figure 2** depicts the major communications infrastructure upgrades. This network includes fiber optic cable, VDSL over twisted pair copper, wireless connections, and a leased cellular backhaul. The cellular backhaul is used to connect the Redmond communications hub to the ODOT wide area network.

ODOT operates and maintains all of the traffic signals in both urban areas, but the cities own traffic signals located on local facilities. Most of the traffic signals in Redmond and a few of the traffic signals in Bend were recently brought online to either ODOT's TransSuite central traffic signal system or its SCATS (Sydney Coordinated Adaptive Traffic System) adaptive traffic signal system. The traffic signals in Bend are available through frame relay or dial-up telephone communications and ODOT ultimately plans to connect all of these traffic signals to one of its central systems.

ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 1 - BEND
EXISTING ITS AND COMMUNICATIONS INFRASTRUCTURE

Legend

Communications Type

- Wireless
- VDSL over Twisted Pair Copper
- Twisted Pair Interconnect (Aerial)
- Twisted Pair Interconnect (Conduit)

Devices

- Existing Camera
- Existing RWIS
- Existing Traffic Signal

Backhaul Type

- Bend Broadband
- Frame Relay

- ODOT Region 4 Headquarters
- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

DKS Associates
TRANSPORTATION SOLUTIONS

HIGHWAY 20
HIGHWAY 97
DESCHUTES MKT RD
COOLEY RD
O B RILEY RD
ROBAL LN
Bend Fire Department
Deschutes County 911
Oregon State Police
Deschutes County Sheriff
YEOMAN RD
HAMEHOOK RD
E BRIGGS RD
Region 4 Headquarters
EMPIRE AVE
BUTLER MKT RD
BRINSON BLVD
BOYD ACRES RD
MT WASHINGTON DR
SUMMIT DR
WELLS ACRES RD
27TH ST
HAMBY RD
12TH ST
REVERE AVE
8TH ST
PURCELL BLVD
NEFF RD
9TH ST
Deschutes County Administration
OLNEY AVE
-Bend Police
-Bend Area Transit
-City of Bend Public Works
NEWPORT AVE
GREENWOOD AVE
GALVESTON AVE
Bend City Hall
FRANKLIN AVE
SKYLINERS RD
14TH ST
COLORADO AVE
ARIZONA AVE
HIGHWAY 20
4TH ST
BEAR CREEK RD
SIMPSON AVE
3RD ST
9TH ST
15TH ST
PETTIGREW RD
WARD RD
REED MARKET RD
STEVENS RD
CENTURY DR
BROOKSWOOD BLVD
POWERS RD
CHASE RD
AMERICAN LN
27TH ST
Deschutes County Road Department
HIGHWAY 97
MURPHY RD
BROSTERHOUS RD
KNOTT RD

0 0.5 1 Miles

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ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 2 - REDMOND
EXISTING ITS AND COMMUNICATIONS INFRASTRUCTURE

Legend

Communications Type

- Fiber Optic
- Wireless
- VDSL over Twisted Pair Copper

Devices

- Existing Traffic Signal

Backhaul Type

- Cellular

- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

DKS Associates
TRANSPORTATION SOLUTIONS

PERSHALL W...
NORTHWEST WAY
10TH ST
HWY 97
CANAL BLVD
KING WAY
NEGUS WAY
MAPLE AVE
NEGUS WAY
KINGWOOD AVE
19TH ST
35TH ST
HEMLOCK AVE
CANYON DR
DOGWOOD AVE
9TH ST
6TH ST
5TH ST
ANTLER AVE
BLACK BUTTE BLVD
2ND ST
JACKSON ST
EVERGREEN AVE
27TH ST
HWY 126
RIMROCK WAY
HIGHLAND AVE
HELMHOLTZ WAY
15TH ST
11TH ST
LAKE RD
3RD ST
OBSIDIAN AVE
23RD ST
QUARTZ AVE
SISTERS AVE
HWY 1
SALMON AVE
ODEM MEDO WAY
S CANAL BLVD
AIRPORT WAY
RESERVOIR RD
WICKIUP AVE
YEW AVE
51ST ST
SOUTH CANAL BLVD

0 0.5 1 Miles

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COMMUNICATIONS OPTIONS

The ultimate plan for communications technology and medium in the Bend and Redmond urban areas assumes the following options will be used:

- Ethernet will be used as the common communications protocol for all center to field communications.
- Fiber optic cable is the preferred medium for communications to field devices and between centers.
- Wireless will be used for communications to isolated locations and may be used as an interim method to connect more field devices.
- VDSL over twisted pair copper cable may be used for locations with low bandwidth requirements or to expand the communications network more cost effectively.
- Leased services may be used in the interim where available or for remote locations where feasible.

The following sections explain the communications options.

Ethernet

ODOT has chosen Ethernet as the common communications protocol for Bend and Redmond because:

- Ethernet is not proprietary.
- Well-defined standards are in use.
- Numerous manufacturers and vendors supply equipment to support Ethernet.
- Training is widely available.

Fiber Optic Cable

Fiber optic cable, which will be the backbone of the ultimate network, has become the preferred physical medium for transportation communications networks because:

- A single fiber can carry very large bandwidth.
- There is low signal loss, which means signals may be carried long distances without repeaters.
- Fiber optic cable is not subject to electromagnetic interference (EMI) like copper cable.
- The costs for fiber optic cable are comparable to twisted pair copper cable but fiber optic cable supports much higher bandwidth capability.
- Transmission systems for video signals are cost effective.

There are a few downsides to installing fiber optic cable. Existing conduit available for use is limited so fiber optic cable will need to be installed either underground in new conduit or aerially on utility poles. New conduit is the most expensive option, particularly in the Bend and Redmond areas because of the rocky native soil. Aerial installations may be more cost effective but there can be ongoing maintenance fees for pole attachments and additional installation costs where utility lines must be moved to meet National Electric Safety code clearance requirements. Further costs for fiber optic cable may be incurred from exposure to severe weather, falling trees or debris, or damage when utility poles are hit by vehicles.

To reduce costs, ODOT plans to work with Deschutes County and the City of Bend's Public Works and IT/Facilities groups to share fiber optic cable infrastructure where feasible. The City of Bend has very limited fiber optic cable plant today but has a number of facilities along key corridors where ODOT plans to install communications.

Wireless

ODOT plans to use wireless solutions to extend communications from the end of a hardwire link (fiber optic cable or twisted pair copper cable) to a remote traffic signal or field device as a last mile connection. Properly designed wireless systems are a viable option where a clear line of sight is available and bandwidth requirements are low. A wireless path analysis, described later in this memorandum, was conducted to identify feasible locations for its use.

Wireless systems use Ethernet 802.11 on the 4.9 GHz Public Safety Band with a throughput of at least 5.5 Mbps. ODOT holds a statewide license for 4.9 GHz and coordinates wireless deployments internally through the Wireless Regional Planning Committee (RPC 35) to avoid interference. ODOT has a price agreement with ENCOM for the purchase of wireless equipment.

VDSL over Twisted Pair Copper Cable

ODOT will use VDSL over twisted pair copper cable for locations with low bandwidth requirements where twisted pair copper interconnect is already in place or as an interim lower cost alternative until fiber optic cable can be installed. A significant drawback of twisted pair copper cable is its narrow bandwidth. It is also more sensitive to grounding and interference than analog signals.

Leased Services

Leased services, which require an ongoing monthly fee, will be used to reach remote locations or as an interim solution until fiber optic cable can be installed. They are flexible and can provide large bandwidth between field devices and the Region 4 TOC. Leased services work well for locations where commercial providers have already installed cellular networks or

broadband cable and the installation of other communications is cost-prohibitive. Leased services are available in the area from Bend Broadband and BendTel.

PLANNED ITS AND COMMUNICATIONS INFRASTRUCTURE

Figure 3 and **Figure 4** illustrate the planned ITS and communications infrastructure for the Bend and Redmond areas, respectively. The planned ITS device locations are based on the *Regional ITS Operations and Implementation Plan for Deschutes County* and input from ODOT staff. The communications network is planned to support all ITS devices and most traffic signals in Bend and Redmond.

Figure 3 shows two main fiber optic cable rings in Bend. Rings provide redundancy and high bandwidth, which is required to support the many cameras planned for traffic management and incident management. VDSL is planned to extend from the fiber rings on existing twisted pair copper cable interconnect between traffic signals and no cameras are planned. Wireless is planned to a few remote locations where line of sight is feasible and fiber optic cable installation is cost-prohibitive. Leased services are planned at two locations as interim communications links until adequate portions of the fiber optic cable network are in place. The communications network connects to all but a few traffic signals that operate in remote locations.

Figure 4 shows the planned communications network for Redmond. Much of the network has already been built out. The main change is to replace the wireless currently used at the south end of Redmond with leased fiber optic cable, which will improve reliability and support planned cameras.

ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 3 - BEND
FUTURE ITS AND COMMUNICATIONS INFRASTRUCTURE

Legend

Communications Type

- Fiber Optic
- Wireless
- VDSL over Twisted Pair Copper
- Twisted Pair Interconnect (Aerial)
- Twisted Pair Interconnect (Conduit)

Devices

- Existing Camera
- Future Camera
- Existing RWIS
- Existing Traffic Signal
- Future Traffic Signal

Future Communications

- Future Fiber Optic
- Future VDSL over Twisted Pair Copper
- Future Wireless
- Future Leased Service (Fiber) to Region 4 TOC

Backhaul Type

- Bend Broadband
- Cellular
- Frame Relay

- ODOT Region 4 Headquarters
- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

DKS Associates
TRANSPORTATION SOLUTIONS

HIGHWAY 97
HIGHWAY 20
DESCHUTES MKT RD
COOLEY RD
O B RILEY RD
ROBAL LN
Bend Fire Department
Oregon State Police
Deschutes County 911
Deschutes County Sherriff
YEOMAN RD
HAMEHOOK RD
E BRIGGS RD
Region 4 Headquarters
EMPIRE AVE
BUTLER MKT RD
MT WASHINGTON DR
BOYD ACRES RD
BRINSON BLVD
WELLS ACRES RD
27TH ST
HAMBY RD
12TH ST
9TH ST
REVERE AVE
8TH ST
PURCELL BLVD
NEFF RD
Deschutes County Administration
OLNEY AVE
NEWPORT AVE
GREENWOOD AVE
- Police
- Bend Area Transit
- Public Works
GALVESTON AVE
Bend City Hall
FRANKLIN AVE
SKYLINERS RD
14TH ST
4TH ST
HIGHWAY 20
COLORADO AVE
ARIZONA AVE
BEAR CREEK RD
SIMPSON AVE
3RD ST
9TH ST
15TH ST
PETTIGREW RD
WARD RD
REED MARKET RD
STEVENS RD
BROOKSWOOD BLVD
AMERICAN LN
POWERS RD
CHASE RD
27TH ST
Deschutes County Road Department
BROSTERHOUS RD
HIGHWAY 97
MURPHY RD
CENTURY DR
BROOKSWOOD BLVD
KNOTT RD
15TH ST
KNOTT RD

0 0.5 1 Miles

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ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 4 - REDMOND
FUTURE ITS AND COMMUNICATIONS INFRASTRUCTURE

Legend

Communications Type

- Fiber Optic
- Wireless
- VDSL over Twisted Pair Copper

Devices

- Existing Camera
- Future Camera
- Existing RWIS
- Existing Traffic Signal
- Future Traffic Signal

Future Communications

- Future Fiber Optic
- Future VDSL over Twisted Pair Copper
- Future Wireless
- Future Leased Service (Fiber) to Region 4 TOC
- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

DKS *Associates*
TRANSPORTATION SOLUTIONS

O'NEIL HWY
PERSHALL WAY
NORTHWEST WAY
10TH ST
HWY 97
CANAL BLVD
KING WAY
NEGUS WAY
MAPLE AVE
19TH ST
KINGWOOD AVE
HEMLOCK AVE
CANYON DR
DOGWOOD AVE
9TH ST
6TH ST
5TH ST
ANTLER AVE
BLACK BUTTE BLVD
2ND ST
JACKSON ST
EVERGREEN AVE
27TH ST
RIMROCK WAY
HWY 126
35TH ST
HIGHLAND AVE
HELMHOLTZ WAY
15TH ST
11TH ST
LAKE RD
3RD ST
OBSIDIAN AVE
23RD ST
QUARTZ AVE
SISTERS AVE
HWY 1
SALMON AVE
RESERVOIR RD
WICKIUP AVE
S CANAL BLVD
MEDO WAY
ODEM
AIRPORT WAY
YEW AVE
51ST ST
SOUTH CANAL BLVD

0 0.5 1 Miles

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Phased Deployment Plan

This section includes an ITS and communications deployment plan for several phases: currently funded projects, planned projects for 2014 through 2023, future projects after 2023, and possible projects by other agencies. The phasing is based on input from ODOT and supports the following important goals:

- Support remote access to traffic signals and incident management on the Bend Parkway.
- Build out from the existing communications infrastructure.
- Build redundancy into the network.

A table for each category includes a project number, name, description, and cost estimate. The cost estimate range accounts for the many unknowns that may occur during construction. For example, the low cost for a fiber optic cable project assumes aerial plant whereas the high cost assumes installing conduit by trenching in difficult rocky soils. All costs for wireless assume that radios and antennas will be mounted on existing traffic signal mast arms, luminaire arms, or camera poles.

Currently Funded Projects

Table 1 lists projects in the Bend-Redmond area for which funding has already been allocated. The table includes the deployment status and description for each project.

Planned Projects for Years 2014 – 2023

This subsection includes the planned projects for years 2014 through 2023. ODOT Region 4 typically funds ITS and communications projects through the Statewide Transportation Improvement Program (STIP). The next funding cycle that Region 4 can apply for is the 2014 through 2017 STIP, which is why this 10-year phased plan starts with year 2014. Although rural ITS projects are not included in this plan, ODOT Region 4 will also request STIP funding allocations for rural ITS projects throughout the.

The 10-year build out of the Bend communications network is shown in **Figure 5**. The project phasing for the Redmond area is shown in **Figure 6**. Projects for each annual phase are described in **Table 2**, including the portion of the anticipated ITS and communications infrastructure that can be built based on predicted funding allocations. The remaining projects slated for the future are described in the next subsection.

The top priority is to lease services to connect the Region 4 TOC to groups of interconnected signals and ITS equipment. The first three years of the plan emphasizes establishing communications links and adding to the Redmond communications hub, the south and east

sides of Bend, and Highway 20 near the Region 4 TOC. The next steps will be to add surveillance cameras and extend the communications infrastructure.

An alternate build-out plan for the same timeframe is presented in **Appendix B**: **Figure 7** and **Table 7**. This alternate plan relies less on commercial leased services and concentrates more on constructing a fiber optic backbone in Bend. While operating costs for fiber optic are lower, the additional expense associated with its installation limits the extent of the communications network and reduces the number of camera installations. Leveraging leased services allows for connections to six more traffic signals and six additional camera installations.

Future Projects After 2023

Based on predicted funding allocations, a portion of the full ITS and communications network cannot be constructed during the 2014 to 2023 timeframe. These lower priority projects are listed in **Table 3**. These projects may be constructed earlier if funding becomes available, priorities change, or resource sharing opportunities arise.

Possible Projects by Other Agencies

A list of possible projects by other agencies is included in **Table 4**. Most of these projects are intended for implementation by the City of Bend except for one Deschutes County project. These projects provide great opportunities for creating physical fiber optic cable rings as well as inter-agency communications network sharing. ODOT Region 1 has done well by sharing fiber optic infrastructure with other public agencies, which has supported the expansion of its network to a much greater degree than it could have funded on its own.

Table 1. Funded Projects

Deployment Year	Project Name	Project Description
2011	US 20 Signal Upgrades (Key #13853)	● 2008 - 2011 STIP Project ● Design completed and construction scheduled for 2011 ● Upgrade traffic signal controllers and loops at NE 3rd Street/NE Revere Avenue and NE 3rd Street/NE Greenwood Avenue
2011 or 2012	Traffic Signal Efficiency Improvements (3rd and 27th Corridors)	● Planned City of Bend project through the Energy Efficiency and Conservation Block Grant (EECBG) Program ● NE/SE 3rd Street: Upgrade 8 traffic signal controllers between NE Greenwood Avenue and Murphy Road, connect to TransSuite by dial-up, and update signal timings, add communications to NE 3rd Street/NE Franklin Avenue and NE 3rd Street/SE Wilson Avenue ● NE 27th Street: Upgrade 7 traffic signal controllers from NE Neff Rd to Bear Creek Road and 1 traffic signal controller at NE Neff Road/NE Medical Center Drive, connect to TransSuite by dial-up, and update signal timings ● Replace existing non-functioning or poorly functioning video detection throughout Bend
Pending	Reed Market Rd: 9th St to 27th St (Key #14210)	● Pending 2008 - 2011 STIP Project ● Widen SE Reed Market Road from SE 9th Street to SE 27th Street ● Replace traffic signals at SE Reed Market Road/SE 15th Street and SE Reed Market Road/SE 27th Street

ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 5 - BEND PROJECT PHASING

Legend

Communications Type

- Fiber Optic
- Wireless
- VDSL over Twisted Pair Copper
- Twisted Pair Interconnect (Aerial)
- Twisted Pair Interconnect (Conduit)

Backhaul Type

- Bend Broadband
- Cellular
- Frame Relay

- ODOT Region 4 Headquarters
- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

Future Infrastucture

- 2000 Project Phase
- Future Projects (by color)
- Future Leased Service (Fiber) to Region 4 TOC
- Existing Camera
- Future Camera
- Existing RWIS
- Existing Traffic Signal
- Future Traffic Signal

DKS Associates TRANSPORTATION SOLUTIONS

HIGHWAY 20
HIGHWAY 97
DESCHUTES MKT RD
COOLEY RD
O B RILEY RD
ROBAL LN
Bend Fire Department
Oregon State Police
Deschutes County 911
Deschutes County Sherriff
Region 4 Headquarters
2014
PUTNAM RD
ARCHIE BRIGGS RD
MT WASHINGTON DR
SUMMIT DR
12TH ST
9TH ST
BOYD ACRES RD
EMPIRE AVE
YEOMAN RD
BUTLER MKT RD
BRINSON BLVD
WELLS ACRES RD
27TH ST
HAMBY RD
HAMEHOOK RD
PURCELL BLVD
NEFF RD
REVERE AVE
8TH ST
OLNEY AVE
Deschutes County Administration
2015
NEWPORT AVE
GREENWOOD AVE
2021
-Bend Police
-Bend Area Transit
-City of Bend Public Works
2023
GALVESTON AVE
Bend City Hall
FRANKLIN AVE
HIGHWAY 20
2017
SKYLINERS RD
14TH ST
2023
COLORADO AVE
ARIZONA AVE
4TH ST
BEAR CREEK RD
SIMPSON AVE
3RD ST
9TH ST
15TH ST
PETTIGREW RD
WARD RD
2019
2018
REED MARKET RD
STEVENS RD
CENTURY DR
BROOKSWOOD BLVD
3RD ST
AMERICAN LN
POWERS RD
CHASE RD
2022
2014
27TH ST
Deschutes County Road Department
HIGHWAY 97
MURPHY RD
BROSTERHOUS RD
15TH ST
KNOTT RD
BROOKSWOOD BLVD
97
KNOTT RD

0 0.5 1 Miles

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ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 6 - REDMOND PROJECT PHASING

Legend

Communications Type

- Fiber Optic
- Wireless
- VDSL over Twisted Pair Copper

- Existing Traffic Signal
- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

DKS Associates
TRANSPORTATION SOLUTIONS

Future Infrastucture

- 2000 Project Phase
- Future Projects
- Future Leased Service (Fiber) to Region 4 TOC
- Future Camera
- Future Traffic Signal

2014

O'NEIL HWY
PERSHALL WAY
NORTHWEST WAY
10TH ST
HWY 97
CANAL BLVD
KING WAY
NEGUS WAY
MAPLE AVE
KINGWOOD AVE
19TH ST
35TH ST
HEMLOCK AVE
CANYON DR
DOGWOOD AVE
9TH ST
6TH ST
5TH ST
ANTLER AVE
BLACK BUTTE BLVD
2ND ST
JACKSON ST
27TH ST
EVERGREEN AVE
RIMROCK WAY
HWY 126
HIGHLAND AVE
15TH ST
11TH ST
LAKE RD
3RD ST
HELMHOLTZ WAY
OBSIDIAN AVE
23RD ST
QUARTZ AVE
SISTERS AVE
HWY 1
SALMON AVE
ODEM MEDO WAY
S CANAL BLVD
AIRPORT WAY
RESERVOIR RD
WICKIUP AVE
YEW AVE
51ST ST
SOUTH CANAL BLVD

0 0.5 1 Miles

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Table 2. Planned Projects for Years 2014 - 2023

Deployment Year	Project Name	Project Description	Cost			
			Budget	Low	High	Recurring
2014	Region 4 TOC to Redmond	● Subscribe to leased services between ODOT Region 4 TOC and Redmond communications hub at SW 6th Street/SW Glacier Avenue	$817,000	$12,000	$29,000	$10,000
	Region 4 TOC to 3rd St RWIS	● Install fiber optic cable along 3rd Street/The Dalles-California Highway between Region 4 TOC and Division Street, use existing conduit between OB Riley Road and the RWIS near the Bend Parkway ● Upgrade traffic signal controllers at: 1. 3rd Street/The Dalles-California Highway/NE Bed River Mall Drive 2. 3rd Street/The Dalles-California Highway/OB Riley Road 3. 3rd Street/The Dalles-California Highway/Mt Washington Drive/Butler Market Road 4. 3rd Street/The Dalles-California Highway/Division Street ● Connect to existing cameras as 3rd Street/The Dalles-California Highway/Mt Washington Drive/Butler Market Road		$325,000	$711,000	$10,000
	Bend Pkwy and 3rd St: Reed Market Rd to Murphy Rd (Stage 1)	● Subscribe to leased services between ODOT Region 4 TOC and communications hub TBD between Reed Market Road and Murphy Road ● Install VDSL in existing conduit and existing aerial route along 3rd Street/The Dalles-California Highway between Reed Market Road and Power Road ● Install fiber optic cable in existing conduit along Powers Road between 3rd Street/The Dalles-California Highway Bend Parkway ● Install fiber optic cable in existing conduit along Bend Parkway between Powers Road and Murphy Road ● Upgrade traffic signal controllers at: 1. Bend Parkway/Powers Road 2. Bend Parkway/Pinebrook Boulevard 3. Bend Parkway/3rd Street/The Dalles-California Highway ● Install PTZ cameras at 1. Bend Parkway/Powers Road 2. Bend Parkway/3rd Street/The Dalles-California Highway		$138,000	$157,000	$10,000
2015-16	Revere Ave and Wall St to 3rd St and Greenwood Ave (Hwy 20)	● Subscribe to leased services between ODOT Region 4 TOC and new communications hub at NW Revere Avenue/NW Wall Street ● Install fiber optic cable: 1. Use existing conduit along Revere Avenue between NE Wall Street and 3rd Street/The Dalles-California Highway 2. On existing aerial route along 3rd Street/The Dalles-California Highway between Revere Avenue and Greenwood Avenue ● Connect to existing interconnect to: 1. NE Wall Street/NW Portland Avenue/NW Olney Avenue 2. 3rd Street/The Dalles-California Highway/Franklin Avenue ● Upgrade traffic signal controllers at: 1. NW Revere Avenue/NW Wall Street/Bend Parkway southbound ramps 2. NW Revere Avenue/NE Division Street/Bend Parkway northbound ramps 3. 3rd Street/The Dalles-California Highway/Olney Avenue ● Install PTZ cameras at: 1. 3rd Street/The Dalles-California Highway/Olney Avenue 2. 3rd Street/The Dalles-California Highway/Greenwood Avenue	$500,000	$366,000	$547,000	-
	Ongoing Leased Services (2 years)	● Two years of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road		-	-	$40,000
2017	Hwy 20/Greenwood from 15th St to Purcell Blvd	● Subscribe to leased services between ODOT Region 4 TOC and new communications hub at Greenwood Avenue/SE 15th Street ● Install fiber optic cable along Greenwood Avenue between 15th Street and Purcell Boulevard ● Upgrade traffic signal controller at Greenwood Avenue/15th Street ● Possible inter-agency communications with Bend Area Transit, Bend Police, and City of Bend Public Works	$250,000	$185,000	$315,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road 3. Communications hub at NW Revere Avenue/NW Wall Street		-	-	$30,000
2018	Reed Market Road from Bend Pkwy to 3rd St	● Install fiber optic cable along Reed Market Road between Bend Parkway southbound ramps traffic signal and 3rd Street/The Dalles-California Highway ● Upgrade traffic signal controller at Reed Market Road/Bend Parkway southbound ramps ● Connect to existing interconnect along 3rd Street/The Dalles-California Highway to Wilson Avenue ● Install PTZ camera on Bend Parkway south of Reed Market Road ● Install wireless communications to PTZ camera	$250,000	$188,000	$442,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road 3. Communications hub at NW Revere Avenue/NW Wall Street 4. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$40,000
2019-20	Bend Pkwy from Hwy 372/Colorado Ave to Reed Market Rd	● Install fiber optic cable along Bend Parkway between Colorado Avenue/State Highway 372 and Reed Market Road ● Install PTZ camera on Bend Parkway north of Reed Market Road ● Connect to existing PTZ camera near Colorado Avenue/State Highway 372	$500,000	$383,000	$576,000	-
	Ongoing Leased Services (2 years)	● Two years of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road 3. Communications hub at NW Revere Avenue/NW Wall Street 4. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$80,000
2021	Hwy 20/Greenwood Ave from 3rd St to 8th St	● Install wireless along NE Greenwood Avenue between 3rd Street/The Dalles-California Highway and 8th Street ● Upgrade traffic signal controller at NE Greenwood Avenue/8th Street ● Install PTZ camera at NE Greenwood Avenue/8th Street	$250,000	$51,000	$445,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road 3. Communications hub at NW Revere Avenue/NW Wall Street 4. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$40,000
2022	Bend Pkwy and 3rd St: Reed Market Rd to Murphy Rd (Stage 2)	● Install fiber optic cable in existing conduit and existing aerial route along 3rd Street/The Dalles-California Highway between Reed Market Road and Powers Road ● Install fiber optic cable in existing conduit along Powers Road between 3rd Street/The Dalles-California Highway Bend Parkway ● Install fiber optic cable in existing conduit along Bend Parkway between Powers Road and Murphy Road ● Salvage removed VDSL equipment from 3rd Street/The Dalles-California Highway, Powers Road, and Bend Parkway for use on State Highway 372/Colorado-Arizona Couplet	$250,000	$237,000	$361,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road 3. Communications hub at NW Revere Avenue/NW Wall Street 4. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$40,000
2023	State Highway 372/Colorado-Arizona Couplet	● Install fiber optic cable between Bend Parkway and traffic signal at Colorado Avenue/State Highway 372/Bend Parkway southbound ramps ● Install VDSL on existing twisted pair to traffic signals along Colorado-Arizona Couplet ● Upgrade traffic signal controllers at: 1. NW Colorado Avenue/State Highway 372/Bend Parkway southbound ramps 2. NW Colorado Avenue/State Highway 372/NW Bond Street 3. NW Colorado Avenue/State Highway 372/NW Wall Street 4. NW Colorado Avenue/State Highway 372/SW Industrial Way 5. NW Arizona Avenue/State Highway 372/NW Wall Street 6. NW Arizona Avenue/State Highway 372/NW Bond Street	$250,000	$47,000	$173,000	-
	Hwy 20/Greenwood from Purcell to 27th Ave	● Install fiber optic cable in existing conduit along Greenwood Avenue between Purcell Boulevard and 27th Street ● Connect to existing interconnect along 27th Street ● Install PTZ cameras at: 1. Greenwood Avenue/15th Street 2. Greenwood Avenue/Purcell Blvd 3. Greenwood Avenue/27th Street		$97,000	$147,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Powers Road-Murphy Road 3. Communications hub at NW Revere Avenue/NW Wall Street 4. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$40,000

Table 3. Future Projects for After Year 2023 (or as funding becomes available)

Project Name	Project Description	Cost	
		Low	High
VMS: Bend Parkway northbound at Empire	● Install variable message sign on Bend Parkway northbound at Empire Boulevard	$250,000	$350,000
VMS: The Dalles-California Highway northbound at Cooley	● Install variable message sign on The Dalles-California-Highway northbound at Cooley Road ● On hold pending US 97 Bend North Corridor EIS	$250,000	$350,000
VMS: McKenzie-Bend Highway westbound at Cooley	● Install variable message sign on McKenzie-Bend Highway westbound at Cooley ● On hold pending US 97 Bend North Corridor EIS	$250,000	$350,000
Bend Parkway: Revere Avenue to Franklin Avenue	● Install fiber optic cable along Bend Parkway between hub at Revere Avenue/Wall Street and Franklin Avenue	$286,000	$589,000
Bend Parkway: Empire Avenue to Cooley Road	● Install fiber optic cable along Bend Parkway between Empire Ave and Cooley Ave ● Connect to existing interconnect along Robal Road ● Upgrade traffic signal controller at Robal Road/Berg Lane	$394,000	$1,485,000
The Dalles-California Highway: Glacier to Yew/Airport	● Install fiber optic cable in Redmond along The Dalles-California Highway between hub at SW 6th Street/SW Glacier Avenue and SW Yew Avenue/SW Airport Way	$440,000	$1,952,000
Northeast Ring: 27th to Empire	● Install fiber optic cable along NE 27th Street between NE Neff Road and NE Butler Market Road ● Install fiber optic cable along Empire Avenue between Region 4 TOC and NE Purcell Boulevard ● Install fiber optic cable along future Empire Avenue extension between NE Purcell Boulevard and NE 27th Street ● Install fiber optic cable along NE Purcell Boulevard between Empire Avenue and NE Butler Market Road traffic signal ● Project provides a redundant path back to the ODOT Region 4 TOC and communications for future traffic signals	$854,000	$3,297,000

Table 4. Possible Projects by Other Agencies

Agency	Project Name	Project Description	Cost	
			Low	High
City of Bend	Reed Market Road: 3rd Street to 27th Street	● Install fiber optic cable along Reed Market Road between 3rd Street and 27th Street ● Consider combining with Reed Market Road project Key #14210 ● Project provides a redundant path and communications to traffic signals at: 1. Reed Market Road/SE 9th Street 2. Reed Market Road/SE 27th Street	$588,000	$1,058,000
City of Bend	Communications to Remote Traffic Signals	● Install communications to: 1. Existing traffic signal at NE Butler Market Road/NE Boyd Acres Road 2. Existing traffic signal at NE 8th Street/NE Penn Avenue 3. Possible future traffic signal at NE Butler Market Road/NE 4th Street 4. Possible future traffic signal at SE Wilson Avenue/SE 9th Street	$71,000	$194,000
City of Bend	Wall Street and Bond Street Wireless	● Install wireless on NW Wall Street and NW Bond Street between Greenwood Avenue and Franklin Avenue ● Upgrade traffic signal controllers at: 1. NW Wall Street/Greenwood Avenue 2. NW Wall Street/NW Oregon Avenue 3. NW Wall Street/Franklin Avenue 4. NW Bond Street/Greenwood Avenue 5. NW Bond Street/NW Oregon Avenue 6. NW Bond Street/Franklin Avenue ● Possible inter-agency communications with Bend City Hall	$133,000	$666,000
City of Bend	Franklin Avenue: 3rd Street to Bond Street	● Install fiber optic cable on Franklin Avenue between 3rd Street and NW Bond Street ● Possible inter-agency communications with Bend City Hall	$102,000	$798,000
City of Bend	27th Street Corridor Upgrade	● Install fiber optic cable in existing conduit along 27th Street between Bear Creek Road and Neff Road ● Install fiber optic cable in existing conduit along Neff Road between 27th Street and Purcell Boulevard	$167,000	$269,000
City of Bend	Wall Street: Greenwood Avenue to Portland Ave/Olney Ave	● Install fiber optic cable along NW Wall Street between NW Portland Ave/NW Olney Ave and Greenwood Ave	$132,000	$400,000
City of Bend	Remaining 170 to 2070 upgrades	● Upgrade traffic signal controllers at: 1. NE Butler Market Road/NE Boyd Acres Road 2. NE 8th Street/NE Penn Avenue	$28,000	$68,000
City of Bend	Wall Street: Revere Avenue to Portland Ave/Olney Ave	● Install fiber optic cable in existing conduit along NW Wall Street between NW Revere Avenue and NW Portland Avenue/NW Olney Avenue ● Upgrade traffic signal controller at NW Wall Street/NW Portland Avenue/NW Olney Avenue	$44,000	$52,000
Deschutes County	Deschutes County 911 Communications	● Install fiber optic cable along 3rd Street/The Dalles-California Highway and Jamison Road or McKenzie-Bend Highway between Empire Avenue and Deschutes County 911 facility ● Connect to Deschutes County 911 ● Connect to existing PTZ camera near Bend Parkway/Highway 20 interchange ● Possible inter-agency communications with Bend Fire Department, Deschutes County Sherriff, and Oregon State Police	$243,000	$870,000

WIRELESS PATH ANALYSIS

This section presents the results of a wireless path analysis at a few select locations where ODOT staff who know the area thought wireless communications might be feasible. The site analysis is followed by recommendations of the proposed wireless equipment and locations.

Site Analysis

GHz Communications conducted a site analysis for five proposed wireless paths in Bend (see **Appendix B** for details). **Table 5** includes the results of this analysis. All path analyses, with the exclusion of Purcell Boulevard to City of Bend facilities (Path D, nodes C1 – C3), evidenced robust propagation characteristics and will provide the required quality of service.

The table includes the path distance, path loss, and fade margin. Path loss is the expected reduction in signal due to propagation and absorption of the radio waves. Fading when the strength of the received signal varies due to anomalies such as interference, absorption, reflection, scattering, refraction, heavy rain fall, and the like. The fade margin is the difference between the received signal and the required level for the desired data transfer rate at the receiver. Fade-margin is defined as the amount by which a received signal lever may be further reduced without causing system performance to fall below a specified threshold value. Generally, a fade margin of at least 35 dB is considered sufficient.

There are no signs of other 4.9 GHz operators in the areas of the proposed wireless networks. However, the process will require coordinating with the Region 35 Regional Planning Committees (RPC 35).

Proposed Wireless Equipment

Table 6 lists the specific equipment recommended to support two wireless paths at four locations in Bend. Typically, integrated directional antennas are used for end-point installations, radio with multiple directional antennas for intermediary or repeater sites, and radio with omni-directional antennas for multipoint or mesh networks.

Only two of the analyzed paths are planned to be constructed in the 10-year phasing. Path A along the Bend Parkway uses two directional antennas at A-1 and A-2 to reach a camera installation at a curve on the Parkway. Path B along Greenwood Avenue/Highway 20 uses a directional antenna at B-1 and an omni-directional antenna at B-2. The omni-directional antenna allows for future expansion of the wireless network to the 3rd Street/Franklin Avenue signal.

Path C on Greenwood Avenue/Highway 20 between 15th Street and Purcell Boulevard is feasible but is not planned for construction. The limited bandwidth available over this wireless

link would not sufficient to support the proposed downstream equipment: 10 traffic signals and two cameras.

Table 5. Wireless Path Analysis Feasibility

Bend Parkway *(Path A)*	Reed Market Road (*A-1*) to near Garfield Avenue (*A-2*)	▪ Distance: 1,733 feet ▪ Path Loss: -98.2 dB ▪ Fade Margin: 70 dB	Feasible
Greenwood Ave/ Highway 20 *(Path B)*	8th Street (*B-1*) to 3rd Street (*B-2*)	▪ Distance: 2,349 feet ▪ Path Loss: -103.2 dB ▪ Fade Margin: 48.5 dB	Feasible
3rd Street *(Path B)*	Greenwood Avenue (*B-2*) to Franklin Avenue (*E-1)*	▪ Distance: 1,385 feet ▪ Path Loss: -94.4 dB ▪ Fade Margin: 57.6 dB	Feasible
Greenwood Ave/ Highway 20 *(Path C)*	Purcell Blvd (*C-1*) to 15th Street (*C-2*)	▪ Distance: 4,016 feet ▪ Path Loss: -112 dB ▪ Fade Margin: 57 dB	Feasible
Greenwood Ave/ Highway 20 *(Path D)*	Purcell Blvd (*C-1*) to City of Bend facilities (*C-3*)	▪ Distance: 4,174 feet	Not Feasible: Significant Obstructions in Path

Table 6. Proposed Wireless Equipment

Bend Parkway at Reed Market Rd (*A-1*)	▪ Integrated 4.9 GHz Radio and 23 dBi Directional Antenna ENCOM COMMPAK BB49 INT
Bend Parkway near Garfield Ave (*A-2*)	▪ Integrated 4.9 GHz Radio and 23 dBi Directional Antenna ENCOM COMMPAK BB49 INT
Greenwood Ave at 8th Street (*B-1*)	▪ Integrated 4.9 GHz Radio and 23 dBi Directional Antenna ENCOM COMMPAK BB49 INT
Greenwood Ave at 3rd Street (*B-2*)	▪ 4.9 GHz Radio ENCOM COMMPAK BB49 ▪ 4.9 GHz 6 dBi Omni-Directional Antenna ENCOM AN-199

APPENDIX A
ACKNOWLEDGMENTS

ACKNOWLEDGMENTS

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Tyler Deke

DKS Associates:

Jim Peters
Joshua Crain
Renee Hurtado

In Association with:

Justin Healy, Real Urban Geographics
Lynn McLean, GHz Communications

APPENDIX B
ALTERNATE PHASING

ODOT REGION 4 10-YEAR PHASED ITS AND COMMUNICATIONS PROJECT PLAN

FIGURE 7 - BEND
ALTERNATE PROJECT PHASING

Legend

Communications Type

- Fiber Optic
- Wireless
- VDSL over Twisted Pair Copper
- Twisted Pair Interconnect (Aerial)
- Twisted Pair Interconnect (Conduit)

Backhaul Type

- Bend Broadband
- Cellular
- Frame Relay

- ODOT Region 4 Headquarters
- Other Key Public Facilities
- Railroad
- MPO Boundary
- City Limits
- Streams
- River
- City Limits
- Urban Growth Boundary
- Highway/Major Arterial
- Other Roads

Future Infrastucture

- 2000 Project Phase
- Future Projects (by color)
- Future Leased Service (Fiber) to Region 4 TOC
- Existing Camera
- Future Camera
- Existing RWIS
- Existing Traffic Signal
- Future Traffic Signal

DKS Associates TRANSPORTATION SOLUTIONS

Region 4 Headquarters
Deschutes County Sherriff
Bend Fire Department
Oregon State Police
Deschutes County 911
Deschutes County Administration
Bend City Hall
-Bend Police
-Bend Area Transit
-City of Bend Public Works
Deschutes County Road Department

2014
2015
2022
2014
2016
2023
2015
2017
2018
2020
2021

HIGHWAY 20
HIGHWAY 97
20
97
COOLEY RD
O B RILEY RD
ROBAL LN
DESCHUTES MKT RD
YEOMAN RD
EMPIRE AVE
BUTLER MKT RD
BRINSON BLVD
WELLS ACRES RD
BOYD ACRES RD
ARCHIE BRIGGS RD
PUTNAM RD
MT WASHINGTON DR
SUMMIT DR
12TH ST
9TH ST
27TH ST
HAMBY RD
REVERE AVE
OLNEY AVE
8TH ST
PURCELL BLVD
NEFF RD
NEWPORT AVE
GREENWOOD AVE
FRANKLIN AVE
GALVESTON AVE
SKYLINERS RD
14TH ST
COLORADO AVE
ARIZONA AVE
4TH ST
BEAR CREEK RD
SIMPSON AVE
3RD ST
9TH ST
15TH ST
PETTIGREW RD
WARD RD
REED MARKET RD
STEVENS RD
BROOKSWOOD BLVD
CENTURY DR
POWERS RD
CHASE RD
AMERICAN LN
MURPHY RD
BROSTERHOUS RD
KNOTT RD

0 0.5 1 Miles

December 28, 2010 Real Urban Geographics

Table 7. Alternate Planned Projects for Years 2014 – 2023

Deployment Year	Project Name	Project Description	Cost			
			Budget	Low	High	Recurring
2014	Region 4 TOC to Redmond	● Subscribe to leased services between ODOT Region 4 TOC and Redmond communications hub at SW 6th Street/SW Glacier Avenue	$817,000	$12,000	$29,000	$10,000
	Region 4 TOC to 3rd St/Division St/Bend Pkwy	● Install fiber optic cable along 3rd Street/The Dalles-California Highway between Region 4 TOC and Division Street, use existing conduit between OB Riley Road and Division Street ● Upgrade traffic signal controllers at: 1. 3rd Street/The Dalles-California Highway/NE Bed River Mall Drive 2. 3rd Street/The Dalles-California Highway/OB Riley Road 3. 3rd Street/The Dalles-California Highway/Mt Washington Drive/Butler Market Road 4. 3rd Street/The Dalles-California Highway/Division Street ● Connect to existing cameras as 3rd Street/The Dalles-California Highway/Mt Washington Drive/Butler Market Road		$297,000	$696,000	-
	Revere Ave and Wall St to 3rd St and Greenwood Ave (Hwy 20)	● Subscribe to leased services between ODOT Region 4 TOC and new communications hub at NW Revere Avenue/NW Wall Street ● Install fiber optic cable: 1. Use existing conduit along Revere Avenue between NE Wall Street and 3rd Street/The Dalles-California Highway 2. On existing aerial route along 3rd Street/The Dalles-California Highway between Revere Avenue and Greenwood Avenue ● Connect to existing interconnect to: 1. NE Wall Street/NW Portland Avenue/NW Olney Avenue 2. 3rd Street/The Dalles-California Highway/Franklin Avenue ● Upgrade traffic signal controllers at: 1. NW Revere Avenue/NW Wall Street/Bend Parkway southbound ramps 2. NW Revere Avenue/NE Division Street/Bend Parkway northbound ramps 3. 3rd Street/The Dalles-California Highway/Olney Avenue ● Install PTZ cameras at: 1. 3rd Street/The Dalles-California Highway/Olney Avenue 2. 3rd Street/The Dalles-California Highway/Greenwood Avenue		$366,000	$547,000	$10,000
2015	Hwy 20/3rd St from Division St to RWIS	● Install fiber optic cable in existing conduit along 3rd Street/The Dalles-California Highway between Division Street and the RWIS near the Bend Parkway	$250,000	$25,000	$33,000	-
	Hwy 20/Greenwood Ave from 15th St to Purcell Blvd	● Subscribe to leased services between ODOT Region 4 TOC and new communications hub at Greenwood Avenue/SE 15th Street ● Install fiber optic cable along Greenwood Avenue between 15th Street and Purcell Boulevard ● Upgrade traffic signal controller at Greenwood Avenue/15th Street ● Possible inter-agency communications with Bend Area Transit, Bend Police, and City of Bend Public Works		$185,000	$315,000	$10,000
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at NW Revere Avenue/NW Wall Street		-	-	$20,000
2016	3rd St from Greenwood Ave to Franklin Ave	● Install fiber optic cable along 3rd Street/The Dalles-California Highway between Greenwood Avenue and Franklin Avenue	$250,000	$81,000	$379,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at NW Revere Avenue/NW Wall Street 3. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$30,000
2017	3rd Street at Franklin Ave to Bend parkway at Hwy 372/Colorado-Arizona Couplet	● Install fiber optic cable: 1. Along Franklin Avenue between 3rd Street/The Dalles-California Highway and Bend Parkway 2. On Bend Parkway between NW Franklin Avenue and State Hwy 372/Colorado Avenue ● Connect to existing PTZ camera near State Highway 372/Colorado Avenue	$250,000	$192,000	$509,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at NW Revere Avenue/NW Wall Street 3. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$30,000
2018-19	Bend Pkwy from Hwy 372/Colorado Ave to Reed Market Rd	● Install fiber optic cable along Bend Parkway between Colorado Avenue/State Highway 372 and Reed Market Road	$500,000	$345,000	$517,000	-
	Ongoing Leased Services (2 years)	● Two years of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at NW Revere Avenue/NW Wall Street 3. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$60,000
2020	Reed Market Rd from Bend Pkwy to 3rd St	● Install fiber optic cable along Reed Market Road between Bend Parkway southbound ramps traffic signal and 3rd Street/The Dalles-California Highway ● Upgrade traffic signal controller at Reed Market Road/Bend Parkway southbound ramps ● Connect to existing interconnect along 3rd Street/The Dalles-California Highway to Wilson Avenue	$250,000	$136,000	$369,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at NW Revere Avenue/NW Wall Street 3. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$30,000
2021	Bend Pkwy and 3rd St: Reed Market Rd to Murphy Rd	● Install VDSL on existing twisted pair interconnect along 3rd Street/The Dalles-California Highway between Reed Market Road and Murphy Road ● Install VDSL on existing twisted pair interconnect along Powers Road between 3rd Street/The Dalles-California Highway Bend Parkway ● Install VDSL on existing twisted pair interconnect along Bend Parkway between Powers Road and Murphy Road ● Upgrade traffic signal controllers at: 1. Bend Parkway/Powers Road 2. Bend Parkway/Pinebrook Boulevard 3. Bend Parkway/3rd Street/The Dalles-California Highway ● Install PTZ cameras at 1. Bend Parkway/Powers Road 2. Bend Parkway/3rd Street/The Dalles-California Highway	$250,000	$126,000	$128,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at NW Revere Avenue/NW Wall Street 3. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$30,000
2022	Bend Pkwy from Division St to Revere Ave	● Install fiber optic cable along Bend Parkway between Division Street and NW Revere Avenue ● Connect to future hub at NW Revere Avenue/NW Wall Street, remove leased service at hub	$250,000	$201,000	$508,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and: 1. Redmond communications hub at SW 6th Street/SW Glacier Avenue 2. Communications hub at Greenwood Avenue/SE 15th Street		-	-	$20,000
2023	Hwy 20/Greenwood Ave from 3rd Street to 15th Street	● Install fiber optic cable along NE Greenwood Avenue between 3rd Street/The Dalles-California Highway and 15th Street ● Upgrade traffic signal controller at NE Greenwood Avenue/8th Street ● Connect to future hub at Greenwood Avenue/15th Street, removed leased service at hub ● Possible inter-agency communications with Bend Area Transit, Bend Police, and City of Bend Public Works	$250,000	$217,000	$637,000	-
	Ongoing Leased Services	● Year of leased service between ODOT Region 4 TOC and Redmond communications hub at SW 6th Street/SW Glacier Avenue		-	-	$10,000

APPENDIX C
WIRELESS PATH ANALYSIS

GHz COMMUNICATIONS, INC.

ODOT Bend, OR

4.9 GHz

Wireless Path Analysis

Final Report

Lynn Dennis McLean, GHz Communications, Inc.

Jim Peters, P.E., DKS Associates, Inc.

11/27/2010

GHz Communications, Inc.

DKS Associates
TRANSPORTATION SOLUTIONS

Statement of Microwave Path Sufficiencies

This report presents results from the RF propagation and path analysis for the proposed implementation of 4.9 GHz mesh type network for linking sites as shown in the schedule, below. The following proposed 4.9 GHz radio paths in the City of Bend, Oregon, on the paths shown below, have been evaluated at the request of the Oregon Department of Transportation. The analysis considered path availability, acceptable elevation profiles and calculated the path losses to assess the capability of the proposed paths to support the proposed signalization. The paths shown below are deemed to be acceptable when used as described within this document package.

- Reed-Market Road Overpass, Southward to N. Bank of Central Oregon Canal via US 97
- NE 8th St. to NE 3rd St. via NE Greenwood Ave. (US 20)
- NE. Greenwood Ave (US 20) to NE Franklin Ave. via NE 3rd St.
- Purcell Blvd. to NE 15th St. via NE Greenwood Ave. (US 20)

Sincerely,
***DKS** Associates*
A Corporation

Jim Peters, P.E., P.T.O.E.
Principal

Lynn Dennis McLean
GHz Communications, Inc.

Bend, OR/ ODOT Wireless Path Analysis

Client: Oregon Department of Transportation

Contact: Mr. Dennis Mitchell and Mr. Nathan Potter

Date: November 27, 2010

Project: Preliminary Study of proposed radio paths associated with various locations in Bend, OR.

Location: Bend, OR

FCC: ***47cfr90.1201 to §90.1217 et al***
Regulations Governing Licensing and Use of Frequencies in the 4940-4990 MHz Band.

General:

1. Planned systems will utilize *Ethernet 802.11a*, data link layer protocol and frame format on the *4.9 GHz Public Safety Band* and will support a data transfer rate of at least 5.5 mbps (megabits-per-second).
2. Radio mountings will be collocated with traffic control signals. (For Paths B, C, and E, above)
3. Mounting details for Path A (Reed Market Road to Central Oregon Canal via Hwy 97 to be determined – e.g., Reed Market/97 Bridge S. face/center to 32' pole N. of the canal.
4. For purpose of this project and effort, the ***Encom COMMPAK BB49 wireless Access Radio*** was used to drive project planning and calculations. There are multiple manufacturers that satisfy the form, fit, and function requirements of this planned system.
5. Directional gain antennas (Integral with radio) are planned with the exception of the Greenwood/NE 3rd St. Location where an omnidirectional is appropriate.

Project Objectives:

- Conduct a wireless path analysis of proposed paths to link locations enumerated in this document.
- Wireless path analysis to include elevation profiles, antenna tilt and azimuths, propagation analysis and link budgets.

Survey details:

Survey work elements consist of the following:

- Mark up topographic maps to show the locations of the proposed sites.
- Construct worksheets showing location information of the sites.
- Description of Paths: 'Walk-the-path' precisely determining and recording precise location of sites. Note all critical obstructions. All measurements will be relative to

Mean Sea Level. (MSL) Also – measure and record all key site attributes such as proposed antenna height elevations, etc. Photograph where necessary

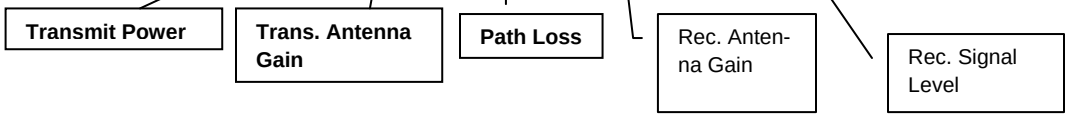
- Perform link budget calculations to project path performance throughout the extent of lengths. A link budget is a tool wherein all system gains and losses are taken in the aggregate to project system performance(s). The mathematical model for free-space loss is the ***Hata line-of-sight (Modified for 4.9 GHz)*** – a common tool for this purpose. It should be noted that in this service (4.9 GHz), transmitter power is limited to 28 dBm for a 5.5 MHz bandwidth as stated in **FCC Rules and Regulations.**[1]
- Prepare Report showing all maps, tables and calculated results along with photographs
- Prepare Summary Document.

Terminology: The meanings of most terms used throughout this report are self-explanatory however, 'fade-margin' would benefit from clarification:

- **Fade-margin** is defined as the amount by which a received signal lever may be reduced without causing system performance to fall below a specified threshold value:
- Fading, of course, is any time of varying level of a received signal due to anomalies such as absorption, reflection, scattering, refraction, heavy rain fall, and the like.
- The Encom BB49 access point requires a received signal level of -95 dBm for a data transfer rate of 5.5 megabits-per-second. (mbps)
- Signal levels less than -95 dBm will cause a link to operate at a lesser data rate and, in the limit, will constitute link failure.

The **Link Budget** a tool, used throughout the worksheets, allows a comparison of anticipated receive signal level to the required signal level at the receiver for the needed data transfer rate (5.5 mbps). Below, is shown a sample calculation:

LINK BUDGET: 28 dBm+ 23 dBi – 108 dB + 23 dB = -34 dBm



The **fade margin** is the difference between the received signal **(-34 dBm)** and the required level for the desired data transfer rate at the receiver **(-95 dBm)** or:
(-34 dBm) – (-95 dBm) = **61 dB.** This is an example of an unusually robust path/circuit that would tolerate extreme amounts of degradation.

Summary:
All path analyses with the exclusion of Purcell Blvd to Police Dept. (Path D, nodes C1 – C3) evidenced robust propagation characteristics and will provide the required quality-of-service.

[1] ***47cfr90.1215 Power Limits***

There are no signs of other 4.9 GHz operators in the areas of the proposed networks. However – the process requires going public with the Regional Planning Committee (RPC 35.) to afford mutual protection from interference for all licensees.

LDM

The following paths and sites are described and evaluated on the subsequent sheets:

Path A – A1 to A2:
Reed-Market Road Overpass, Southward to N. Bank of Central Oregon Canal via US 97

Path B – B1 to B2: US 20
NE 8th St. to NE 3rd St. via NE Greenwood Ave. (US 20)

Path E – B2 to E1:
NE. Greenwood Ave (US 20) to NE Franklin Ave. via NE 3rd St.

Path C - C1 to C2:
Purcell Blvd. to NE 15th St. via NE Greenwood Ave.(US 20)

Path D - C1 to C3:
~~US 20 (NE Greenwood Ave.) from Purcell Blvd. to Bend Police Dept.~~
Path found to be unsuitable

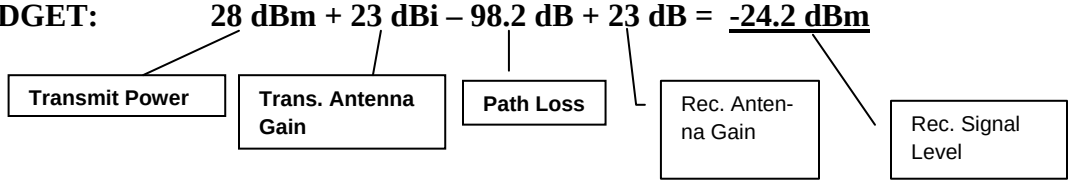
Logical groupings of nodes and the paths in which they reside.

Node:	Site:	Function:	Gnd. Elev:	Ant. Ht: haat	Latitude (N)°	Longitude (W)°	Ant. Type:	Equip. Model
A-1	Reed-Market Road	**Path A** Video Relay	3720	32	44.038577	121.308123 AZ 220.5° L=1733'	23 dBi Dir. Tilt +1.7°	Encomm BB49 INT.
A-2	Central Oregon Canal	" " "	3739	32	44.035156	121.312449 AZ 40.5°	23 dBi Dir. Tilt -1.7°	Encomm BB49 INT.
B-1	NE 8th on Greenwood	**Path B, E** Traffic Sig-nalization	3626	23	44.060027	121.293621 AZ 203.9° L=2349'	23 dBi Dir.	Encomm BB49 INT.
B-2	NE 3rd & Greenwood	" " "	3631	32	44.059869	121.303626	6 dBi Omni.	Encomm BB49
E-1	NE 3rd and Franklin	" " "	3642	32	44.056071	121.302388 AZ 3° L=1385'	23 dBi Dir.	Encomm BB49 INT.
C-1	Purcell & Greenwood	**Path C** Traffic Sig-nalization	3640	42	44.054859	121.268459 AZ 278.5° L=4016'	23 dBi Dir.	Encomm BB49 INT.
C-2	NE 15th & Greenwood	" " "	3680	42	44.056451	121.283584 AZ 98.5°	23 dBi Dir.	Encomm BB49 INT.
C-3	Police Dept.	**Path D***** (C-1 to C-3) **Unworkable**	3663	32	44.055977	121.284522	23 dBi Dir.	Encomm BB49 INT.

4.9 GHz Site and Path Data Information Sheet

PATH DESIGNATION: **Path A – A1 to A2:**
US 97 from Reed-Market Road Overpass, Southward, to N. Bank of Central Oregon Canal

PATH LENGTH: **1,733 feet**
PATH LOSS: **-98.2 dB**
LINK BUDGET: **28 dBm + 23 dBi – 98.2 dB + 23 dB = -24.2 dBm**



FADE MARGIN: 70 dB
No significant path obstructions noted.

SITE NAME: Reed-Market Road Overpass (A1)
Latitude: (dd.dddddd) 44.038577°
Longitude: -121.308123°
North American Datum: NAD-83
Elevation: 3720 feet amsl

ANTENNA:
TYPE: Directional
BEAMWIDTH: 10°
UPTILT: +1.7°
Manufacturer: Encom wireless
Azimuth: 220.5°T
Antenna Gain: 23 dBi
Height above ground: 32 feet

ACCESS POINT:
Manufacturer: Encom wireless
Model: COMMPAK BB49 INT
Transmitter Power: 28 dBm
Effective Radiated Power: 51 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

PATH DESIGNATION: **Path A – A2 to A1:**
US 97 From Bank of Central Oregon Canal, Northward to Reed-Market Road Overpass

SITE NAME: A-2 Central Oregon Canal
Latitude: (dd.dddddd) 44.035156º
Longitude: -121.312449º
North American Datum: NAD-83
Elevation: 3739 feet amsl

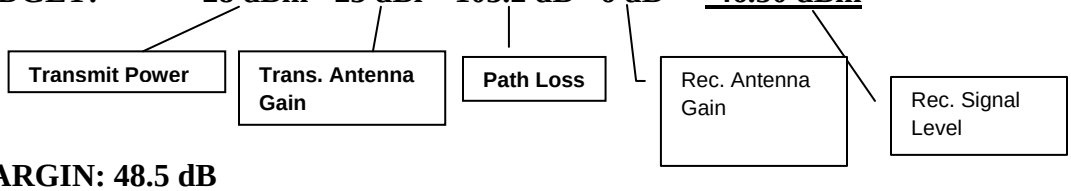
ANTENNA:
TYPE: Directional
BEAMWIDTH: 10º
DOWNTILT: -1.7º
Manufacturer: Encom wireless
Azimuth: 40.5ºT
Antenna Gain: 23 dBi
Height above ground: 32 feet

ACCESS POINT:
Manufacturer: Encom
Model: COMMPAK BB49 INT
Transmitter Power: 28 dBm
Effective Radiated Power: 51 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

4.9 GHz Site and Path Data Information Sheet

PATH DESIGNATION: **Path B – B1 to B2**
US 20 (NE Greenwood) from NE 8th St. to NE 3rd St.

PATH LENGTH: **2349 feet**
PATH LOSS: **-103.2 dB**
LINK BUDGET: **28 dBm+ 23 dBi – 103.2 dB+ 6 dB = -46.50 dBm**



FADE MARGIN: 48.5 dB
No significant path obstructions noted.

SITE NAME: **B-1 NE 8th & Greenwood(US 20)**
Latitude: (dd.dddddd) **44.060027°**
Longitude: **-121.293621°**
North American Datum: **NAD-83**
Elevation: 3626 feet amsl

ANTENNA:
TYPE: Directional
BEAMWIDTH: 10°
DOWNTILT:
Manufacturer: Encom wireless
Azimuth: 203.9°T
Antenna Gain: 23 dBi
Height above ground: 23 feet

ACCESS POINT:
Manufacturer: **Encom**
Model: **COMMPAK BB49 INT**
Transmitter Power: 28 dBm
Effective Radiated Power: 51 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

PATH DESIGNATION: **Path B – B2 to B1**
SITE NAME: **B2 – NE 3rd & NE Greenwood**
Latitude: (dd.dddddd) **44.059869º**
Longitude: **-121.303626º**
North American Datum: NAD-83
Elevation: 3631 feet amsl

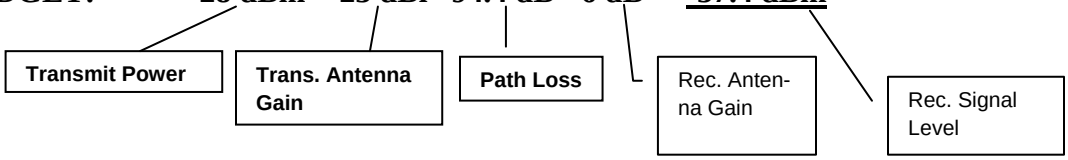
ANTENNA:
TYPE: Omni-Directional
VERTICAL BEAMWIDTH: 25º
UPTILT:
Manufacturer: Mobile Mark
Model: ECO6-4900
Azimuth:
Antenna Gain: 6 dBi
Height above ground: 32 feet

ACCESS POINT:
Manufacturer: **Encom**
Model: **COMMPAK BB49 INT**
Transmitter Power: 28 dBm
Effective Radiated Power: 34 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

4.9 GHz Site and Path Data Information Sheet

PATH DESIGNATION: **Path E - E1 to B2**
NE Franklin to NE 3rd St. & Greenwood via NE 3rd St. (Bus. 97)

PATH LENGTH: **1385 feet**
PATH LOSS: **-94.4 dB**
LINK BUDGET: **28 dBm + 23 dBi– 94.4 dB+ 6 dB = -37.4 dBm**



FADE MARGIN: 57.6 dB
No significant path obstructions noted.

SITE NAME: **E1 – NE Franklin & NE 3rd St.**
Latitude: (dd.dddddd) **44.056071°**
Longitude: **-121.302388°**
North American Datum: **NAD-83**
Elevation: 3642 feet amsl

ANTENNA:
TYPE: Directional
BEAMWIDTH: 10°
DOWNTILT: 0°
Manufacturer: Encom wireless
Azimuth: 3°T
Antenna Gain: 23 dBi
Height above ground: 32 feet

ACCESS POINT:
Manufacturer: **Encom**
Model: **COMMPAK BB49 INT**
Transmitter Power: 28 dBm
Effective Radiated Power: 51 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

PATH DESIGNATION: **Path B – B2 to B1**
SITE NAME: **B2 – NE 3rd & NE Greenwood**
Latitude: (dd.dddddd) **44.059869º**
Longitude: **-121.303626º**
North American Datum: NAD-83
Elevation: 3631 feet amsl

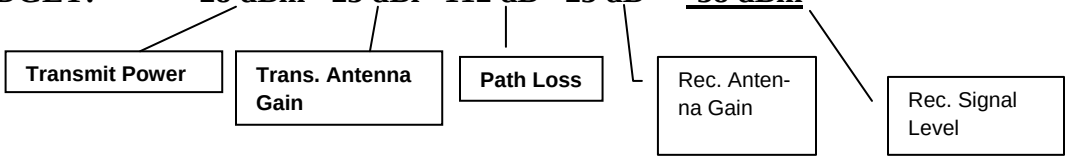
ANTENNA:
TYPE: Omni-directional
VERTICAL BEAMWIDTH: 25º
DOWNTILT: -
Manufacturer: Mobile Mark
Model: ECO6-4900
Azimuth:
Antenna Gain: 6 dBi
Height above ground: 32 feet

ACCESS POINT:
Manufacturer: **Encom**
Model: **COMMPAK BB49 INT**
Transmitter Power: 28 dBm
Effective Radiated Power: 34 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

4.9 GHz Site and Path Data Information Sheet

PATH DESIGNATION: **Path C - C1 to C2**
Purcell Blvd. to NE 15th St. Via NE Greenwood (US 20)

PATH LENGTH: **4016 feet**
PATH LOSS: **-112 dB**
LINK BUDGET: **28 dBm+ 23 dBi– 112 dB+ 23 dB = -38 dBm**



FADE MARGIN: 57 dB
No significant path obstructions noted.

SITE NAME: **C1 – Purcell Blvd and NE Greenwood (US 20)**
Latitude: (dd.dddddd) **44.054859°**
Longitude: **-122.268459°**
North American Datum: NAD-83
Elevation: 3640 feet amsl

ANTENNA:
TYPE: Directional
BEAMWIDTH: 10°
UPTILT: + .56°
Manufacturer: Encom wireless
Azimuth: 278.5°T
Antenna Gain: 23 dBi
Height above ground: 42feet

ACCESS POINT:
Manufacturer: **Encom**
Model: **COMMPAK BB49 INT**
Transmitter Power: 28 dBm
Effective Radiated Power: 51 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

PATH DESIGNATION: **Path C – C2 to C1**
SITE NAME: **C2 – NE 15th St. & NE Greenwood**
Latitude: (dd.dddddd) **44.056451°**
Longitude: **-121.283584°**
North American Datum: NAD-83
Elevation: 3680 feet amsl

ANTENNA:
TYPE: Directional
BEAMWIDTH: 10°
DOWNTILT: -.56°
Manufacturer: Encom wireless
Azimuth: 98.5°T
Antenna Gain: 23 dBi
Height above ground: 42 feet

ACCESS POINT:
Manufacturer: **Encom**
Model: **COMMPAK BB49 INT**
Transmitter Power: 28 dBm
Effective Radiated Power: 51 dBeirp
Data Transfer Rate: 5.5 mbps
Receiver Sensitivity: 5.5 mbps -95 dBm

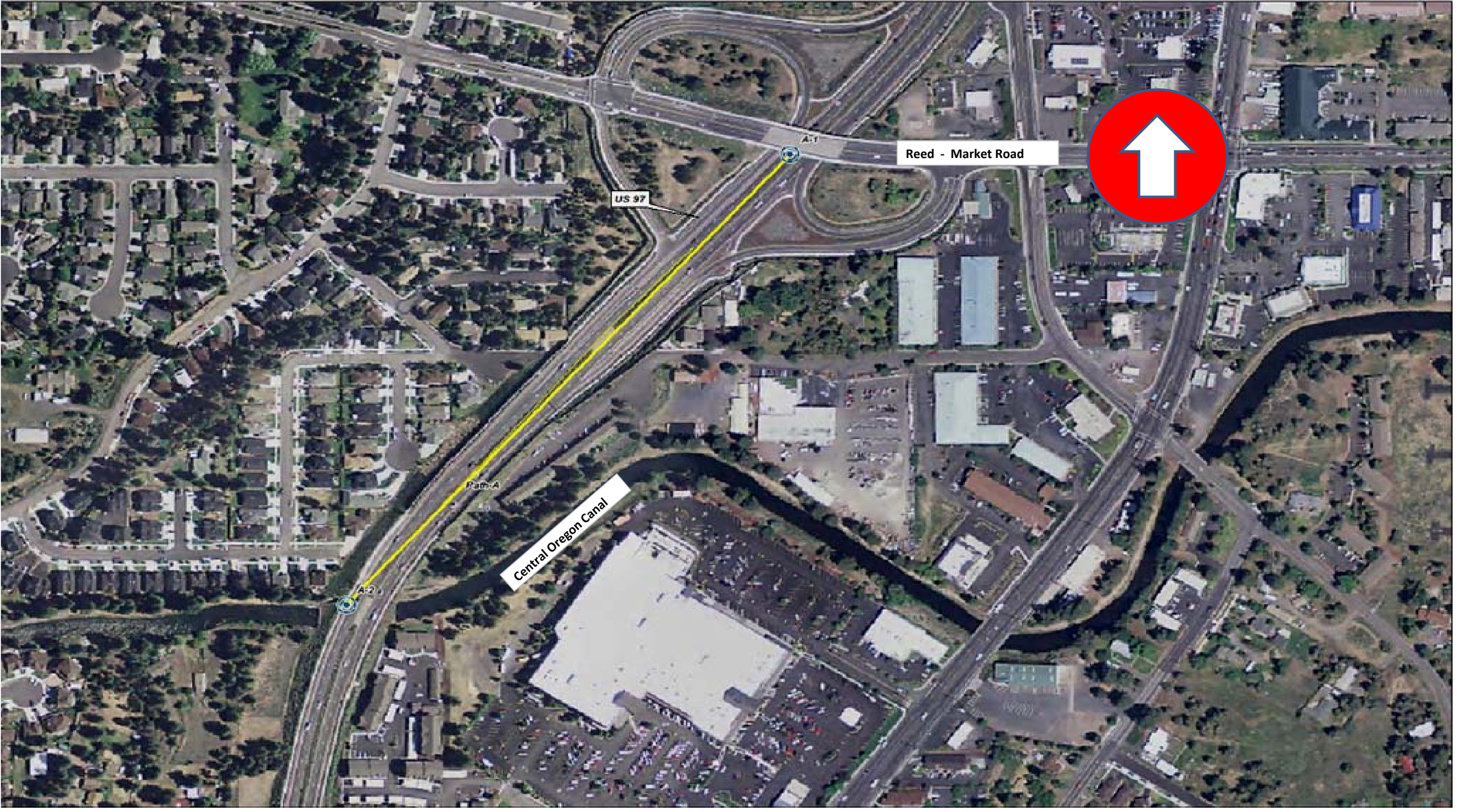
Appendix

Project Aerial Photographs/Maps, Elevation Contour Plots and Site Photographs

1. **Path A – Aerial Photo/Map (Reed-Market to Central Oregon Canal Via US97)**
2. **Path A – Elevation Profile**
3. **Path B – Aerial Photo/Map (NE 8th St. to NE 3rd Via Greenwood to Franklin Via NE 3rd**
4. **Path B1 – B2 Elevation Profile**
5. **Path B2 – E1 Elevation Profile**
6. **Path C – Aerial Photo/Map (Purcell Blvd. to NE 15th St. Via NE Greenwood**
7. **Path C – Elevation Profile**

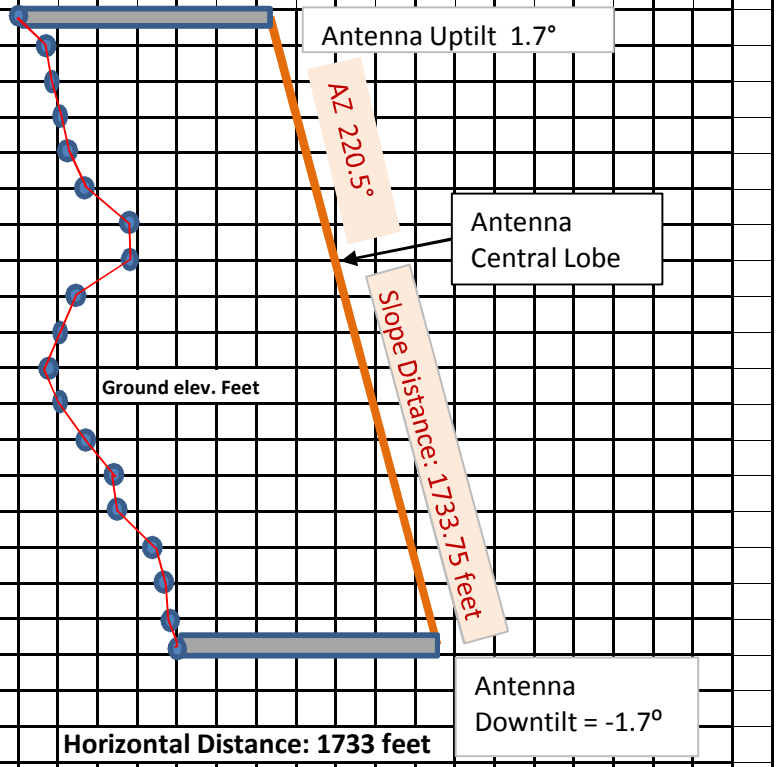
Site Photographs - Figures 1 – 16

Encom Wireless Cut Sheets



Path A - Reed Market Rd. to Central Oregon Canal via US 97

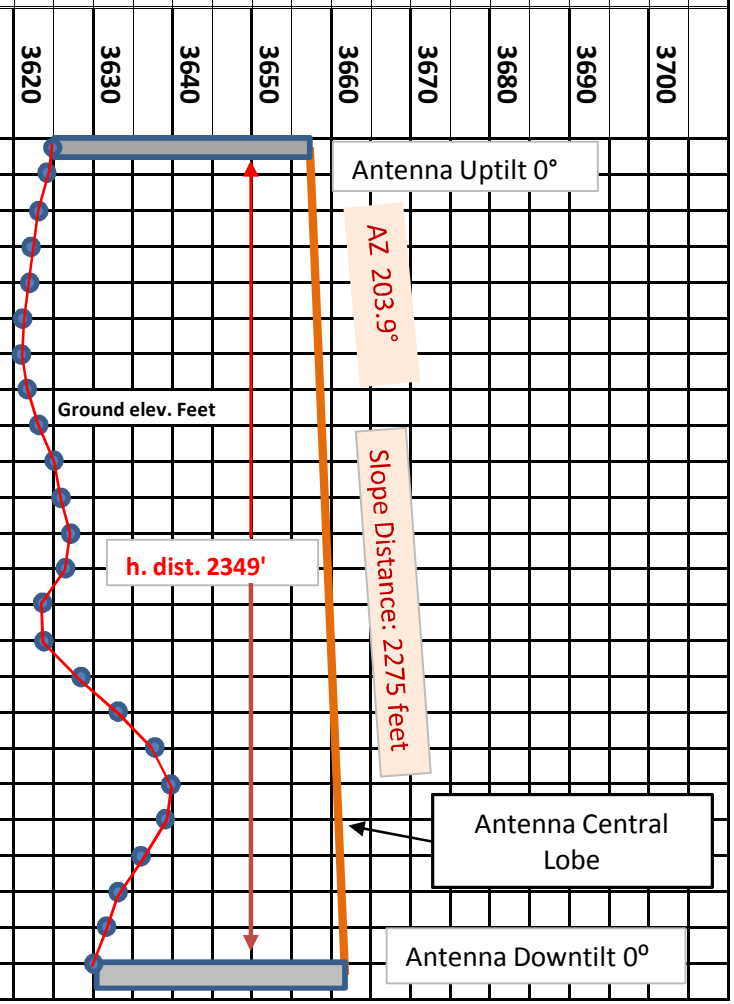
Seq:		Ground Elev.	Antenna	Lat(N):	Long(W):	.60 Fresnel Radius in feet	Dist. Ft
23	Reed-Market Road Overpass	3720	3752	44.038682	121.308094	0	000
22	(A1)	3723		44.038475	121.308352	2	100
21		3724		44.038268	121.308610	4	200
20		3725		44.038061	121.308868	4	300
19		3626		44.037854	121.309126	4	400
18		3728		44.037647	121.309384	6	500
17		3733		44.037440	121.309642	6	600
16		3733		44.037233	121.309900	6	700
15		3727		44.037026	121.310158	6	800
14		3724		44.036819	121.310416	6	900
13		3723		44.036612	121.310674	6	1000
12		3725		44.036405	121.310932	6	1100
11		3728		44.036199	121.311189	6	1200
10		3732		44.035992	121.311447	4	1300
9		3733		44.035785	121.311705	4	1400
8		3736		44.035578	121.311963	4	1500
7		3738		44.035371	121.312221	2	1600
6	Central Oregon Canal	3739	3771	44.035164	121.312479	0	1700
5	N. Bank - W. Side of US97	3740		44.034957	121.312737		1800
4	(A2)			44.034750	121.312995		1900
3				44.034543	121.313253		2000
2				44.034336	121.313511		2100
1				44.034129	121.313769		2200
0				44.033922	121.314027		2300



Ground Elevation Contour Plot - Reed-Market to Central Oregon Canal Via US 97

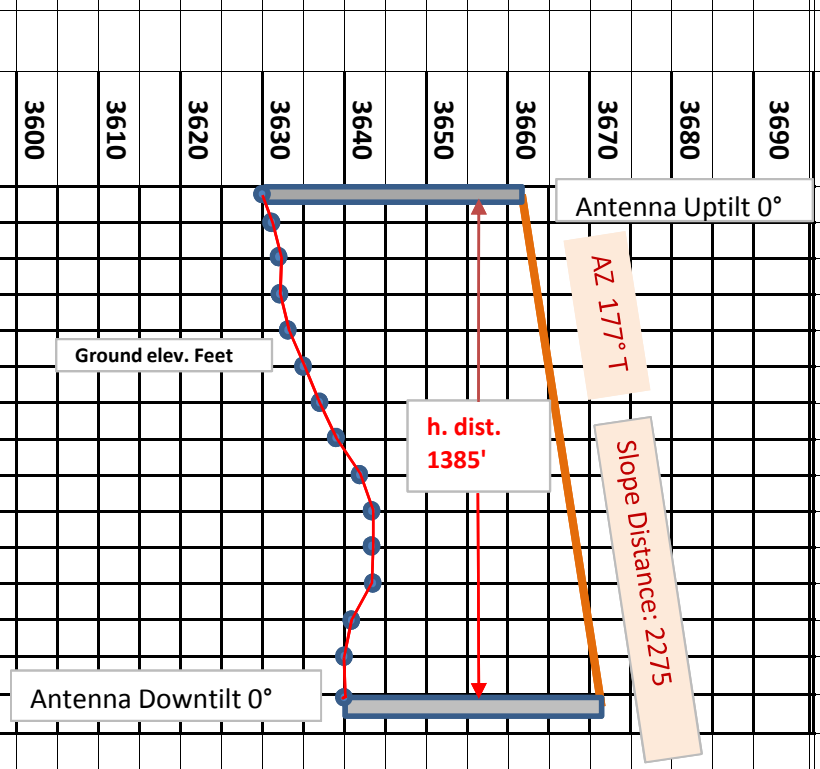
Path B1 - B2 - E1 NE 8th to NE 3rd to Franklin St. via Greenwood/NE 3rd

Seq:		Ground Elev.	Antennaa	Lat(N):	Long(W):	.60 Fresnel Radius in feet	Dist. Ft:
23	Greenwood(20) @ NE 8th St.	3626	3658	44.060030	121.293624	0	000
22	(B1)	3624		44.060023	121.294061	2	100
21		3623		44.060015	121.294497	4	200
20		3622		44.060008	121.294934	6	300
19		3622		44.060001	121.295371	6	400
18		3621		44.059993	121.295807	6	500
17		3621		44.059986	121.296244	6	600
16		3622		44.059979	121.296681	6	700
15		3623		44.059971	121.297118	6	800
14		3625		44.059964	121.297554	6	900
13		3626		44.059957	121.297991	6	1000
12		3627		44.059949	121.298428	6	1100
11		3626		44.059942	121.298864	6	1200
10		3624		44.059934	121.299301	6	1300
9		3624		44.059927	121.299738	6	1400
8		3628		44.059920	121.300174	6	1500
7		3633		44.059912	121.300611	6	1600
6		3639		44.059905	121.301048	6	1700
5		3640		44.059898	121.301485	6	1800
4		3639		44.059890	121.301921	6	1900
3		3636		44.059883	121.302358	6	2000
2		3633		44.059876	121.302795	4	2100
1	(B2)	3632		44.059868	121.303231	2	2200
0	Greenwood(20) @ NE 3rd St.	3630	3662	44.059861	121.303668	0	2300

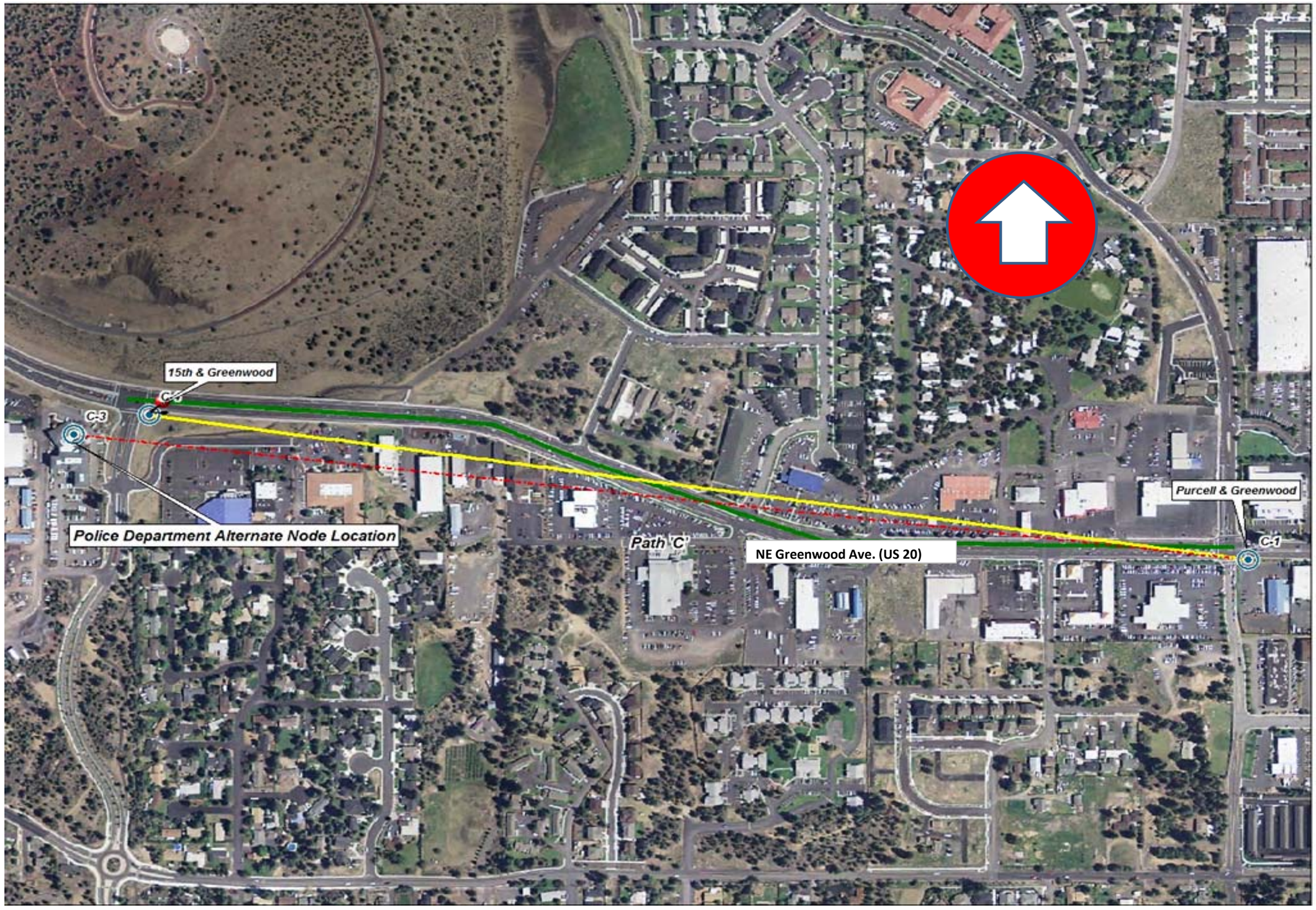


Ground Elevation Contour Plot - NE 8th St. to NE 3rd St. Via Greenwood (US 20) - Path B1 - B2

Seq:		Ground Elev.	Antenna amsl	Lat(N):	Long(W):	.60 Fresnel Radius in	Dist. Ft:
14	Greenwood(20) @ NE 3rd St.	3630	3662	44.059861	121.303668	0	000
13	(B2)	3631		44.059587	121.303597	2	100
12		3632		44.059312	121.303525	4	200
11		3632		44.059038	121.303454	4	300
10		3633		44.058763	121.303382	4	400
9		3635		44.058489	121.303311	4	500
8		3637		44.058214	121.303239	4	600
7		3639		44.057940	121.303168	4	700
6		3642		44.057666	121.303097	4	800
5		3643		44.057391	121.303025	4	900
4		3643		44.057117	121.302954	4	1000
3		3643		44.056842	121.302882	4	1100
2		3641		44.056568	121.302811	4	1200
1		3640		44.056293	121.302739	2	1300
0	NE 3rd St. @ Franklin	3640	3672	44.056019	121.302668	0	1400
	(E1)						

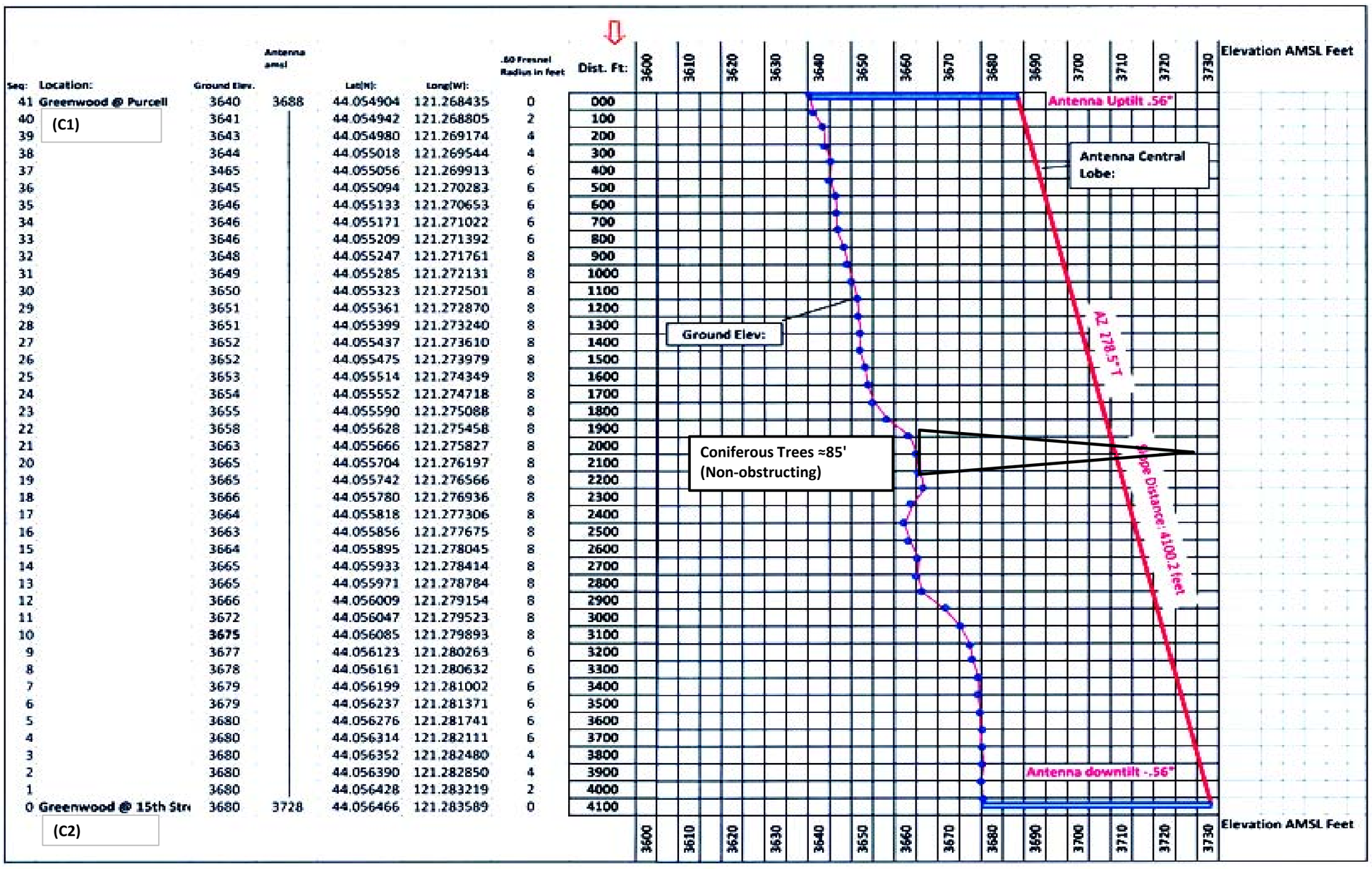


 Ground Elevation Contour Plot - Greenwood (US 20) to Franklin Ave. Via Business US 97 - Path B2-E1


15th & Greenwood
C-2
C-3
Police Department Alternate Node Location
Path 'C'
NE Greenwood Ave. (US 20)
Purcell & Greenwood
C-1

Seq:	Location:	Ground Elev.	Antenna amsl	Lat(N):	Long(W):	.60 Fresnel Radius in feet	Dist. Ft:
41	Greenwood @ Purcell	3640	3688	44.054904	121.268435	0	000
40	(C1)	3641		44.054942	121.268805	2	100
39		3643		44.054980	121.269174	4	200
38		3644		44.055018	121.269544	4	300
37		3465		44.055056	121.269913	6	400
36		3645		44.055094	121.270283	6	500
35		3646		44.055133	121.270653	6	600
34		3646		44.055171	121.271022	6	700
33		3646		44.055209	121.271392	6	800
32		3648		44.055247	121.271761	8	900
31		3649		44.055285	121.272131	8	1000
30		3650		44.055323	121.272501	8	1100
29		3651		44.055361	121.272870	8	1200
28		3651		44.055399	121.273240	8	1300
27		3652		44.055437	121.273610	8	1400
26		3652		44.055475	121.273979	8	1500
25		3653		44.055514	121.274349	8	1600
24		3654		44.055552	121.274718	8	1700
23		3655		44.055590	121.275088	8	1800
22		3658		44.055628	121.275458	8	1900
21		3663		44.055666	121.275827	8	2000
20		3665		44.055704	121.276197	8	2100
19		3665		44.055742	121.276566	8	2200
18		3666		44.055780	121.276936	8	2300
17		3664		44.055818	121.277306	8	2400
16		3663		44.055856	121.277675	8	2500
15		3664		44.055895	121.278045	8	2600
14		3665		44.055933	121.278414	8	2700
13		3665		44.055971	121.278784	8	2800
12		3666		44.056009	121.279154	8	2900
11		3672		44.056047	121.279523	8	3000
10		3675		44.056085	121.279893	8	3100
9		3677		44.056123	121.280263	6	3200
8		3678		44.056161	121.280632	6	3300
7		3679		44.056199	121.281002	6	3400
6		3679		44.056237	121.281371	6	3500
5		3680		44.056276	121.281741	6	3600
4		3680		44.056314	121.282111	6	3700
3		3680		44.056352	121.282480	4	3800
2		3680		44.056390	121.282850	4	3900
1		3680		44.056428	121.283219	2	4000
0	Greenwood @ 15th Str	3680	3728	44.056466	121.283589	0	4100

(C2)



Ground Elevation Contour Plot - Purcell to 15th Street Via Greenwood (Path C)

fig. 1 **Proposed location for node C-1. Luminaire ht is approximately 42 feet.**

fig. 2 **Proposed location for node C-2. Luminaire ht is approximately 42 feet.**

fig. 3 **Proposed location for node C-2.**

fig, 4 **Node C-2**

fig. 5 Parapet at antenna field (L) is approximately 30 feet. Site C-3

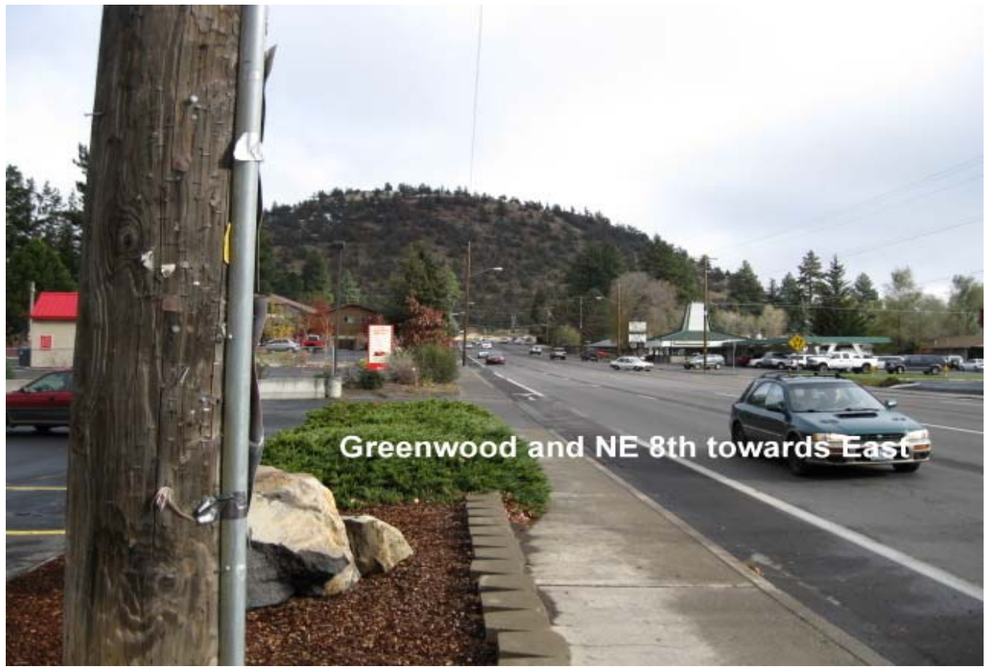


fig. 6 Site B1

fig. 7 Site B--1. Luminaire ht ≈ 32 feet.

fig. 8 Site B-1 towards B-2.

fig. 9 Proposed location for site B-2. Luminaire ht ≈ 32 feet.

fig. 10 Site E-1. Luminaire ht ≈ 32 feet.

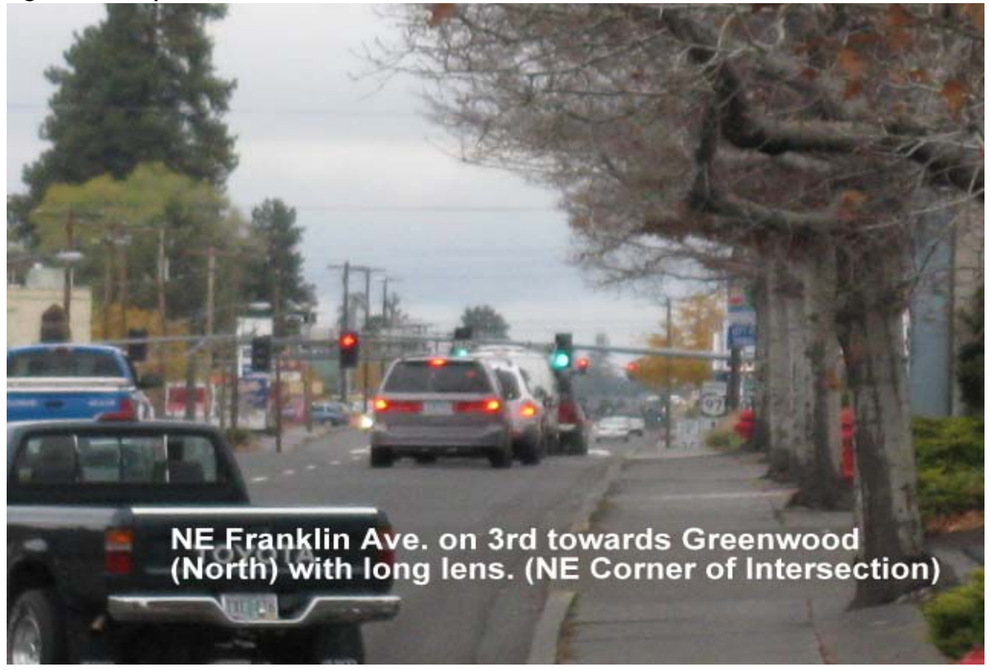


fig. 11 Site E-1 to the North.

fig. 12 From Site A-2 toward the NE

fig. 13

fig. 14

fig. 15 Across US97 towards proposed site of A-2. 32-foot mounting structure nominal, appropriate.

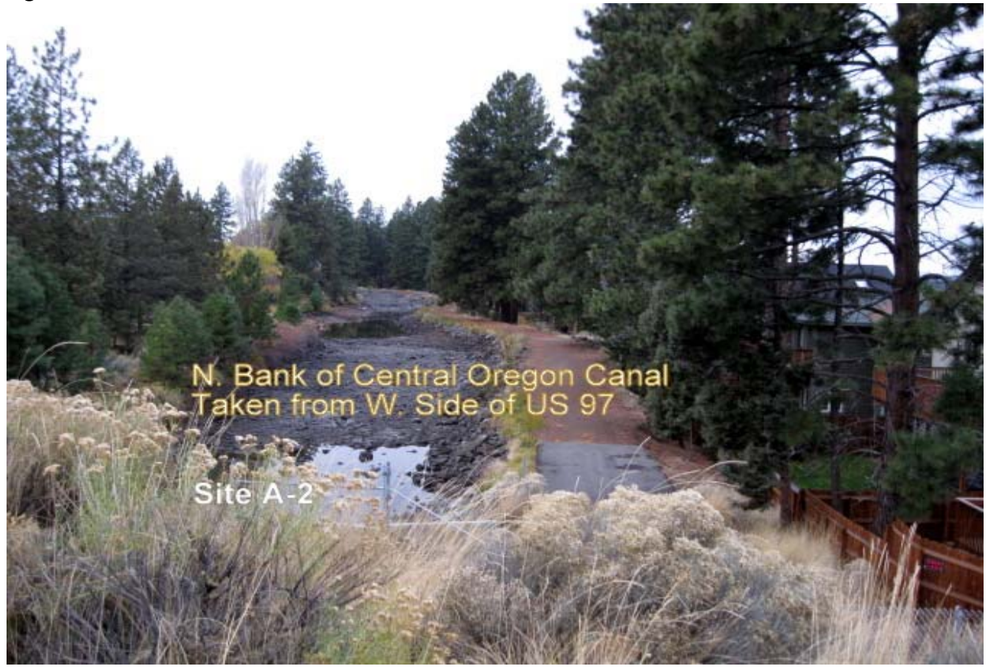


fig. 16 Site A-2

encom
WIRELESS

COMMPAK Broadband

2.4 GHz, 4.9 GHz, 5.2/5.8 GHz, 802.11 a/b/g/n

Experience the most powerful, reliable and cost-effective wireless solution on the market.

Municipalities across North America trust wireless networks built with ENCOM COMMPAK products to enable agile, intelligent communications systems that deliver bullet-proof dependability. More economical to implement, expand and maintain than costly wired networks, ENCOM wireless solutions provide maximum functionality at minimal expense, and without compromising quality.

Proven dependability

ENCOM's 20-plus years of field experience, personal level of service and extensive track record in government and industry ensure the success of your network. With uptimes of 99.999%, built-in diagnostic tools, top-performing products that meet NEMA operating standards, and three-year warranties, COMMPAK products are the reliable choice for municipal governments.

Cost savings that don't compromise quality

Wireless networks are 1/10th the cost of wired solutions* and are far easier—and faster—to install, reconfigure, upgrade and expand, than wired networks, and eliminate the need for leased telephone lines. Field-proven, environmentally hardened ENCOM COMMPAK units also reduce maintenance costs while ensuring highest-quality operations.

Industrial-grade performance (802.11 a/b/g/n up to 300 Mbps)

COMMPAK units are built to perform in challenging environments. With weather-proof and environmentally hardened enclosures, powerful 600 watt transmitters and operation ranges of up to 60 miles, COMMAK products have performance features that enable them to excel in harsh outdoor conditions, busy urban settings and remote locations. Our powerful point-to-point units have a total available bandwidth up to 300 Mbps, while our point-to-multipoint systems offer 70 Mbps.

Rock-solid security

Wireless security is critical to network reliability. All ENCOM broadband systems are equipped with the most advanced and comprehensive suite of security features available, including WPA2, WPA, WEP, MAC authentication and radius server authentication.

Future-proof and flexible

With COMMPAK broadband, you can grow, modify and upgrade your network with minimal time and cost, even in difficult terrain. You can select the best licensed or non-licensed frequencies for your needs, including 2.4, 4.9, 5.2, 5.3 and 5.8 GHz. Each unit can function as a master, remote, repeater or mesh node, making it easy to create networks optimized for your enterprise.

*According to recent U.S. Department of Transport data

Choose ENCOM COMMPAK for

- WiFi and WiMAX (fixed and mobile)
- Wide-area networks (WAN)
- Video surveillance (CCTV)
- Wireless MESH networks (WMN)
- Point-to-point and point-to-multipoint

Who relies on ENCOM?

- Municipal governments
- Corporate IT departments
- Department of Homeland Security
- Departments of Transportation
- Emergency first responders
- Mobile workforces
- Heavy industry (oil and gas manufacturing)
- Electrical utilities (Smart Grid)
- Water and waste water management

Dedicated to your enterprise

ENCOM's COMMPAK Broadband product family provides carrier-class functionality in an environmentally hardened, robust package. The product line operates on your choice of 2.4, 4.9, 5.2, 5.3 and 5.8GHz frequencies and comes either with an integrated flat-panel antenna or connector for an external antenna.

Integrated Unit (Point-to-Multipoint)

Integrated units are equipped with a flat-panel antenna with directional 23dBi gain. These all-in-one units enable rapid and simplified deployment, and are perfect components of high-capacity point-to-point and point-to-multipoint networks. A 2.4 GHz hot spot can be added to any integrated unit for dedicated broadband mobility applications.

- Up to 54 Mbps data range
- 60-mile range, use for all remote locations
- 10-degree beamwidth on antenna
- Low wind loading
- Three-year warranty

Non-Integrated Unit

Non-integrated units feature an N female connector to plug in to your choice of external antenna. These units are an excellent choice for master locations and repeater sites and are available in single and dual radio configurations. An ENCOM dual radio configuration causes no reduction in bandwidth when used as a repeater.

- Master sites with sectoral antennas
- Repeater sites
- Simple configuration with ControlPAK software
- Three-year warranty

Point to Point Backhaul

- +300 Mbps data rates
- 802.11n 3x3 Mimo technology
- Non line-of-sight performance
- 2.4 GHz and 5.8 Ghz
- +20 Mile range

Backhaul Applications:

- ITS wireless video
- Security
- Public safety

Single and Dual Mesh routers

- 802.11 a/b/g/n
- Self Forming/Self Healing network
- Eliminated need for line of sight
- Mobility networking
- Single network for multiple applications

Mesh Applications:

- Mobile networking
- Video-surveillance

About ENCOM:

ENCOM, based in Calgary, Canada, provides field proven, cost-effective wireless data solutions for municipal and industrial clients, with applications in the areas of:

- Intelligent transportation systems
- Public safety communications
- Municipal corporate security and IT networks
- Water and waste water management
- Electrical utilities
- Oil and gas

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WIRELESS PERFORMANCE

Receive signal	1 Mbps -97 dBm 2 Mbps -96 dBm 5.5 Mbps -95 dBm 6 Mbps -94 dBm 9 Mbps -93 dBm 11 Mbps -92 dBm	12 Mbps -91 dBm 18 Mbps -90 dBm 24 Mbps -86 dBm 36 Mbps -83 dBm 48 Mbps -77 dBm 54 Mbps -74 dBm
Transmit power	23 dB, 600 mW	
Range	60 miles	
Modulation	OFDM and DSS	
Wireless interface	802.11 a/b/g/n or EN-Stream propriety protocol (enhanced security), dynamic frequency selection, 5MHz, 10 MHz and 20 MHz channels, antenna alignment tool	
NETWORK FEATURES	Spanning tree protocol (STP), Network Time Protocol (NTP), DHCP server or client, firewall and NAT, bandwidth test tool, routing, QOS, VPN, VLAN, SNMP	
SYSTEM MANAGEMENT	IP discovery tool (managed remotely), remote SSH, SNMP, FTP	
SECURITY	AES-CCM, WEP Encryption (64 bit, 128bit), WPA, WPA2, TKIP, Mac/ RADIUS Server authentication, EAP-TLS / EAP pass-through	

PHYSICAL SPECIFICATIONS

Enclosure	**Pole/wall mount unit** • Die-cast aluminum • Dimensions: 8.5" x 7"x2" • Weight: 3 lbs • IP67 Weatherproof rating	**Integrated antenna unit** • UV stabilized plastic and die-cast aluminum • Dimensions: 13"x13"x3" • Weight: 5 lbs • IP67 Weatherproof rating
Environmental	Operating temperature range -30°C to +60°C (storage temperature -40°C to +80°C) Humidity (non-condensing): 5% to 95%	
Antenna	Units come with either an integrated, flat-panel antenna with 23dBi gain, or an N-female connector to connect to an external antenna	
ACCESSORIES INCLUDED	Pole mounting hardware, PoE Injector, 150' Cat5e or better industrial outdoor rated cable with weatherproof connector, 6' ethernet crossover cable	
WARRANTY	Three-year warranty	

SPECIFICATIONS

Security (Encryption)	• AES-CCM Encryption • 64 bit, 128 bit WEP Encryption • WPA • WPA2 • TKIP • MAC / RADIUS Server authentication • EAP-tls / EAP-passthrough
Networking Features	• STP (Spanning Tree Protocol) • DHCP Server or Client • NTP Network Time Protocol • Firewall and NAT • Routing • QOS • VPN • VLAN • SNMP • Bandwidth test tool
Interface	• Industrial Weatherproof 10/100 Base-T Ethernet (RJ45) • 150' Cat5e or better Industrial Outdoor rated cable included
Wireless Interface	• Dynamic Frequency Selection • Antenna alignment tool **2.4** 802.11 b/g/n or eMax Proprietary protocol **4.9** 802.11 a/b/g or eMax Proprietary protocol **5.8** 802.11 a/n or eMax Proprietary protocol
Management	• IP discovery tool with remote management • Remote SSH • SNMP • FTP
Radio Transmit Power	600 mW
Antennas	• Omni, Yagi and Panel Antennas available
Power	• Power over Ethernet injector with lightning and surge protection included • POE input voltage: 100 to 240 VAC • POE output voltage: 1 A @ 18 VDC • Power Consumption: 0.5A transmit 0.2A standby (9W max 8W typical 3W standby) @ 18 VDC

802.11N SPECIFICATIONS

Data Rates	Up to 300Mbps (Legacy 802.11a/b/g (1-54Mbps), 802.11n (up to 300Mbps))	
Data Rate	MCS 0 to 15 for High Throughput mode (6.5 – 300 Mbps) BPSK, QPSK, 16-QAM and 64-QAM for legacy mode (6Mbps - 54Mbps)	
RX Sensivity (BER=10^{-6})	**Channel Size**	**40Mhz**
	MCS 0 / MCS 8	-95dBm
	MCS 7	-74dBm
	MCS 15	-75dBm

Order Information

PART NUMBERS

Frequency	Wireless unit	With integrated antenna	Panel Antenna	Sectoral Antenna	Omni Antenna
2.4 GHz	COMMPAK BB24	COMMPAKBB24 INT	AN-215K (10°, 20 dBd gain)	Not applicable	AN-199 (360°, 7.5 dBd gain)
4.9 GHz	COMMPAK BB49	COMMPAK BB49 INT	AN-196 (10°, 23 dBd gain)	AN-206 (90°, 13 dB gain)	Not applicable
5.8 GHz	COMMPAK BB58	COMMPAK BB58 INT	AN-196 (10°, 23 dBd gain)	AN-206 (90°, 13 dB gain)	AN-199 (360°, 7.5 dBd gain)
2.4 / 5.8 GHz	COMMPAK BB24/58	COMMPAK BB24/58 INT	See above	See above	See above
5.8 / 5.8 GHz	COMMPAK BB58/58	COMMPAK BB58/58 INT	See above	See above	See above
4.9 / 5.8 GHz	COMMPAK BB49/58	COMMPAK BB49/58 INT	See above	See above	See above

Please call for other frequency options.

***300 Mbps: call ENCOM**

***Mesh: call ENCOM**