# WILDLIFE DETECTION SYSTEM

Applicant»

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# Project Inception

Each year, thousands of collisions with wildlife are reported on British Columbia (BC) highways. Wildlife-Vehicle Collisions (WVCs) often result in serious personal injuries, endanger various wildlife species, and cost millions of dollars annually. The Insurance Corporation of BC's (ICBC) statistics show that between 2011 and 2015 there was a yearly average of 10,000 animal-vehicle incidents in BC. These incidents resulted, on average, in 570 personal injuries, and three fatalities per year. In addition to significant personal loss resulting from WVCs, substantial sums of money are spent, and revenue is lost annually by public agencies. A 2015/2016 Annual Report published by the Wildlife Collision Prevention Program provides estimates that in a typical year, due to WVCs:

- ICBC expends $34 million on animal-vehicle crash incidents
- $700,000 is spent by the BC Ministry of Transportation and Infrastructure for highway clean-up
- $48 million is lost in hunting license revenue and lost value of wildlife to resident and non-resident hunters
- Additional substantial costs are incurred for policing, medical aid, Workers Compensation Board, Employment Insurance, and lost staff productivity

In addition to the significant personal and financial losses resulting from WVCs, thousands of animals are killed each year by collisions in BC alone. MoTI reported that between 1998 and 2007, 93,583 animals were killed on BC highways. This number is estimated to be only 25% to 35% of the total animal deaths, taking into account unreported incidents and the wildlife that eventually die away from the roadway due to collision-related injuries.

Through an analysis of historical collision information, the BC Ministry of Transportation and Infrastructure (the Ministry) identified two corridors along Highway 3 in Southeastern BC as having the highest densities of large WVCs in the province. These two corridors are as follows:

- **Corridor 1: Michel** (approximately 6km section of Highway 3, just east of Sparwood, BC).
- **Corridor 2: Elko** (approximately 5km section of Highway 3, just east of the Highway No. 3 and Highway No. 93 junction).

To protect the surrounding natural wildlife habitat and improve safety for travelers, the Ministry sought to reduce the number of WVCs in the area through the application of an appropriate technology solution. This solution was deemed to be the design, implementation, and commissioning of an effective Wildlife Detection System (WDS) to reduce the number of animal-vehicle incidents. The long term goal is to expand the WDS to other areas of the province. In order to do so, it was necessary to ensure that the system performed correctly and effectively so that additional capital investment could be justified. It was necessary to clearly establish not only what the definition of performance would be, but how that performance would be measured and evaluated. As such, a clear set of performance metrics were established as part of the project specifications and subsequently tracked over the project lifecycle. Many variables had to be taken into consideration for the implementation of the project; a multi-disciplinary team comprised of system and traffic engineers, as well as biologists familiar with the area's fauna, was formed to account for all aspects of the system design.

*System Overview*

The system consists of a suite of ITS components integrated with high-performance security technologies. The typical devices required for the core functionality of the system include Dynamic Message Signs (DMS), WDS sensors, thermal and colour cameras, and various communication devices, some examples of which are shown in **Figure 1**. The system is primarily intended to detect the presence of large animals, namely deer, elk, moose,

and sheep using technologies developed primarily for the security industry. The minimum intended detectable target size is roughly the size of a young deer, although smaller animals have been detected. When a large animal is detected, the control system activates a series of warning signs that advise motorists of the presence of animals to help ensure the safety of the animals and the travelling public. When the wildlife clears the detection zone, the WDS deactivates the warning signs. Additionally, thermal and high-definition video of detected wildlife is recorded and stored for future analysis and review.



**Figure 1 – Warning sign and Detection Devices**

# System Design

## *Functional Requirements*

For any complex ITS system, it is critical to prepare a detailed functional specification to provide a clear set of requirements for both the hardware and software design and development. Each set of criteria needs to be fully testable such that at the time of final acceptance testing, the overall system can be proven to work as intended. A set of functional requirements were prepared to identify the necessary attributes, functionality, and performance requirements of the WDS. PBX's original Functional Requirements document provided a reference point for the Ministry's intended operation and expectations for the project. However, as the detailed design progressed, the Ministry and the design team further enhanced and modified the requirements. Through Field Acceptance Testing (FAT), System Acceptance Testing (SAT), and ongoing User Acceptance Testing (UAT), the performance and behavior of the implemented WDS has been confirmed to meet the system's functional requirements and the accuracy of detection was found to be very high.

## *Wildlife Detection*

A number of potential mitigation options were examined, ranging from civil infrastructure improvements to fencing. However, the most appropriate solution was determined to be the application of an effective technology to detect the presence of wildlife and advise motorists to slow down. Prior to selecting candidate technologies, extensive research was gathered on previously implemented systems, methods of detection, and

prior system test-bed studies to gain a clear understanding of the inherent features and limitations of particular technologies. The following common themes were identified:

**Weather Is Important:** In every single previously implemented, unsuccessful WDS, the inability of sensors to operate in various weather conditions was listed as the prominent deciding factor in the system's discontinuation. Weather-hardened devices needed to be specified as weather across both corridors is inclement and can reach very cold temperatures.

**Test Bed Studies Are No Guarantee:** Detecting wildlife in a test-bed setting is technically simple. Detecting wildlife reliably for decades in a real setting is not. It was important to design a system that would prove to be reliable for years to come, without having to be continuously monitored, tested and re-calibrated to maintain the required level of sensing ability.

**False Positives and System Value:** A high rate of false positives was one of the most common complaints among users; many stated that they had begun to ignore the system completely due to false positives. A WDS may detect all wildlife that passes, but if it has a high rate of false positives, it is essentially an overpriced street sign. The number of false positives for this WDS was monitored over extensive SAT, and the system was optimized to reduce false alarm rates as much as possible.

**Data Validation is Critical:** Previously implemented systems generally did not have the infrastructure necessary to permit rigorous data validation to determine actual achieved detection accuracy.

**All Technologies Are Not Created Equal:** Researching other WDS and, particularly, learning why they were unsuccessful, a general theme with past systems was encountered: people assumed that simple systems are more reliable and more effective. However, PBX found exactly the opposite to be true; one of the critical reasons why past systems failed was because they were insufficiently sophisticated. They lacked the functionality and capability necessary to address this complex problem. The system technology was carefully selected based on the terrain, climate, and the Ministry's functional requirements. Effective detection sensors are critical to proper system operation. Because of the length of the corridors and the limited viewing angles, no one sensor would be able to cover the entire area. Additionally, the system needed to be able to account for and suitably respond to a variety of conditions and exceptions, including:

- Multiple animals.
- Animals that graze on the sides of the road.
- Cars, trucks, motorcycles, cyclists, and pedestrians.
- Inclement weather.

The system was also designed to include a variety of settings and configuration options to allow each corridor to be fine-tuned during the testing phases to suit the specifics of the site. Examples of these settings include:

- Amount of time a target needs to be present before the system is activated.
- Amount of time after the target is no longer detected that the system stays activated for.
- Max amount of time the system should stay activated.
- Target size.
- Min/max target speed.

Sensor performance can be affected by many factors thus it is important to understand the performance criteria associated with detection sensors. These are typically expressed as follows:

- **False Positives:** Invalid events that trigger system operation. They could be caused by sources outside of the desired detection threshold (i.e. the system detects a coyote when it should only

detect large deer and above), weather, temperature, faulty connections, equipment malfunction or damage, etc.

- **False Negatives:** Events that should have triggered system operation, but did not. This could be caused by failed detection of a valid source.
- **False Alarm Rate (FAR):** The total rate of invalid (false positive) events relative to the total quantity of events.
- **Detection Rate (DR):** The total quantity of detection events relative to the total quantity of false negative events.
- **Downtime:** The amount of time where the system is unavailable for normal operation.

The specific functions of the system were identified in detail in the Functional Requirements, and the technology selection and design conformed accordingly. It is the technology selection and integration design that sets this system apart from past WDSs; complexity was chosen over simplicity to produce a high level of integration encompassing all devices of the system from detection to notification. The system utilizes proven sensors designed for sophisticated security applications. This level of integration creates the most effective detection system possible for the location while reducing the number of false alarms caused by non-wildlife detections.

In addition to observed challenges faced by previously implemented systems, infrastructure requirements needed to be assed to meet the specific needs to this systems area of deployment.

| Radar Detection |
| :---: |

Many previous WDS projects have implemented beam-break sensors as the primary or only method of wildlife detection. Beam-break systems generally use active IR, microwave, or laser to detect wildlife as they cross onto the roadway only. For this project, it was identified that beam-break sensors were not suitable as the technology poses too many limitations, due to very limited detection capability (i.e. no tracking, no multi-target detection, etc.). As each sensor site would significantly increase the cost of the project, as well as the implementation complexity, the sensor technology selected had to be capable of area coverage (volumetric) detection as well as a long detection range. Of the sensor technologies that were available, radar was the most appropriate solution. Radar was selected as it provides long range volumetric detection that has been proven to work in similar applications.

The chosen radar units employ Frequency Modulated Continuous Wave (FMCW) detection technology which provides significant advantages over Doppler radar units. FMCW radars operate on the imaging principle; they break up the background into small segments, or resolution cells, and then measure changes in the signal return from each cell to detect small targets, such as walking people, or in this case, wildlife. Typical resolutions for long range FMCW radars are less than 1 meter in range and less than 1 degree in azimuth. The smaller the cell, the easier it is to detect and track a target. FMCW operation is independent of the speed or direction of travel of the target, and relies only on the target's size with respect to the resolution cell in which it is located. Modern FMCW radars can detect objects moving at near zero velocity and in any direction with respect to the radar.



The radar used for this project had the advantage of being designed specifically for perimeter and border surveillance. The benefits of FMCW over other technologies such as Pulse Doppler (PD) are summarized below.

- FMCW is less complex and lower cost than PD.
- FMCW gives low false alarm rates.
- Less likely to trigger alarms due to wind-blown objects such as grass, leaves, and rain.
- FMCW sees a higher percentage of valid targets.
- Will not miss slower targets or tangential ones – no holes in coverage – no one penetrates.

### Thermal Imaging and Video Analytics

The detection beam emitted by the radar detectors is in the shape of a cone. The beam angle can be adjusted through antenna alignment to optimize each installation. However, when the sensor is mounted above grade (for example, at 3m), there is a circular-shaped blind spot centered on the sensor. At a 3m mounting height, the blind spot is approximately 15m in radius. To cover these inherent blind spots, as well as supplement the detection of the radars, thermal cameras paired with a dedicated video analytics platform were installed on adjacent poles. Using the system's video analytics, detections can be made when an animal is present in a radar blind spot. The use of video analytics provides a primary or secondary form of detection in specific areas. The cameras have the ability to determine the shape and size of an object detected, and through filtering and in conjunction with ascertained radar data, make the distinction between wildlife and vehicle. Detections made by the radars along the corridor are cross-referenced with detections made by the video analytics platform, as shown in **Figure 2** ,and are autonomously analyzed in real time to increase the detection range and efficiency of the overall system. Additionally, thermal and high-definition video of detected wildlife is recorded and stored for future analysis and review, which was critical to the SAT process.



**Figure 2 – Thermal Camera Video Analytics**

*Messaging Signs*

There are two types of signs used for the system: Gateway Signs and Warning signs. Gateway Signs are mounted at the extents of each detection corridor on overhead structures, similar to Advance Warning Signs. As motorists approach the detection corridors, they will see these static signs advising them that they are entering the wildlife detection corridor. As motorists leave the extent of the detection corridor, they will see a static sign advising them that they are leaving the wildlife detection corridor.

Motorist advisory of wildlife comes through the deployment of warning signs installed at intermediate locations along the corridor. As shown in **Figure 3**, these signs are a hybrid of both static and dynamic messaging elements. The dynamic portion is a small DMS, which upon system detection of wildlife, is activated, displaying "SLOW DOWN", advising motorists there is wildlife on or along the road, and to drive slowly. The static portion, of which the DMS is mounted to, is an aluminum sign displaying the standardized deer symbol, informing drivers they are in a densely populated wildlife area, and to drive cautiously. Additionally, due to the length of the corridors, the static signs act as frequent reminders to motorists to maintain vigilance while transiting the area.



**Figure 3 – Warning sign Activation**

### Backend Processing

For each of the two corridors, the autonomous detection, identification, and control algorithms are performed on an enterprise-level Windows server installed in an environmentally-controlled communications cabinet at one of the sensor locations. The server amalgamates the radar detection backend application, logging and reporting database, video analytics platform, wireless network management software, and user client interface (as shown in **Figure 4**) in a single operating system instance. The unification of these applications on a single server machine allows for efficient management, configuration, and monitoring of the WDS software components through a single, commonly-used Windows interface. The radar and video management interface can be accessed locally at the communication cabinet, or remotely over a secure cellular connection.
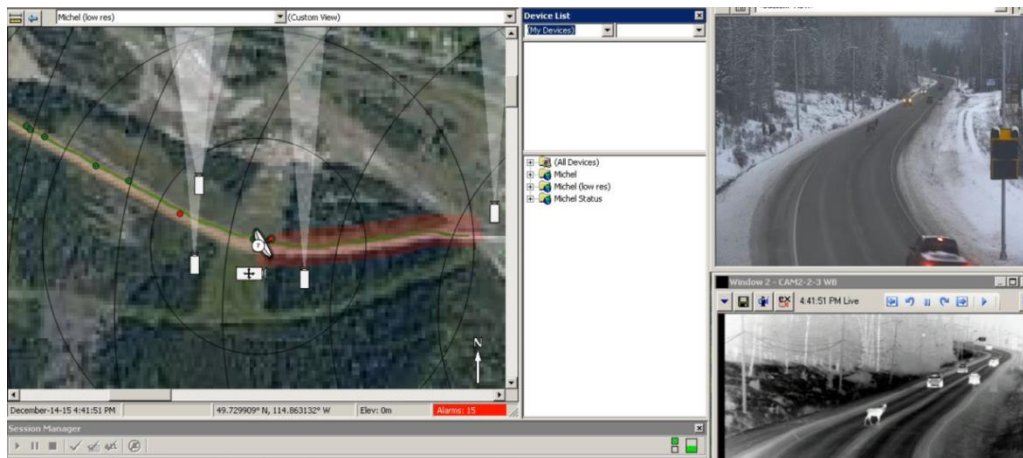


**Figure 4 – User client interface showing radar detection and CCTV coverage**

### Technology Integration

The WDS operates autonomously, without the need for operator intervention. Remote access to the devices is provided by the means of cellular modems at select cabinets so that the system can be monitored, remote alarms can be received, and data can be exported. In addition to the primary detection data used by the system to warn motorists of wildlife, the WDS collects valuable metrics for testing, validation, performance verification, and initial calibration of the system. The additional metrics that are collected and utilized are as follows:

- **WVC incident rates:** Information on these rates is regularly collected by the Ministry.
- **Vehicle Volumes:** Information on the amount of vehicle traffic passing through the corridor.
- **Vehicle speeds through the corridor:** This information will assist in determining how drivers are responding to the system when the signs are activated.
- **Activation Rates:** Information on the number of wildlife detections along the corridor over a given time period.

In the future, this system could interface with on-board vehicle collision avoidance systems to provide detection information directly to a vehicle, including autonomous vehicles. The system may also be deployed on corridors equipped with Variable Speed Limit Systems, allowing the system to connect to and form part of the ITS used to determine and display the appropriate corridor speeds to motorists.

### Network Communication

The system uses point-to-point wireless radio and cellular technologies to interconnect the corridor devices with the remote monitoring station at the Regional Transportation Management Center (RTMC). For the overall WDS there are two types of communication paths, as follows:

- **Site to Site:** This is accomplished using encrypted wireless Ethernet radio links.
- **Corridor to Remote Monitoring Station:** This is accomplished using a cellular data connection.

During the preliminary design, both corridors were noted as having intermittent cellular coverage. Therefore, a master sensor location was selected at each corridor. These sites were chosen on their ability to receive a consistent cellular signal, and would act as a singular cell access point for each corridor. Reliable cell coverage and communication to each corridor was imperative for the ability to remotely access the system for testing and monitoring. Inter-site data transmission is used for communication between the sensor sites along the corridor. This communication is achieved by point-to-point wireless Ethernet radio links. Industry-standard Quality of Service and data encryption is utilized at each link in order to optimize data rates and secure the WDS against unauthorized access, both over the local area network (LAN) and the wide area network (WAN).

### Optimal Equipment Placement

In addition to challenges noted from previously implemented WDSs, extensive consideration and optimization was required for the geographical positioning of infrastructure, due to the project area's difficult topography and remote location. This culminated in multiple comprehensive site investigations at each phase of the project implementation.

Although the corridors are generally flat over their length, with only minor undulations and changes in elevation, careful consideration was put into the placement of each and every device. The physical location and orientation of devices has a significant impact on the ability of the overall system to operate to the level of performance dictated by the system's functional requirements. Both corridors have curves that impact viewing angles, and terrain and sightline variations along roadway shoulders factored heavily into sensor and camera placement as depicted in the figure below. By optimizing sensor and infrastructure placement, it was possible to minimize detection blind spots and obtain complete end-to-end detection coverage of each corridor.
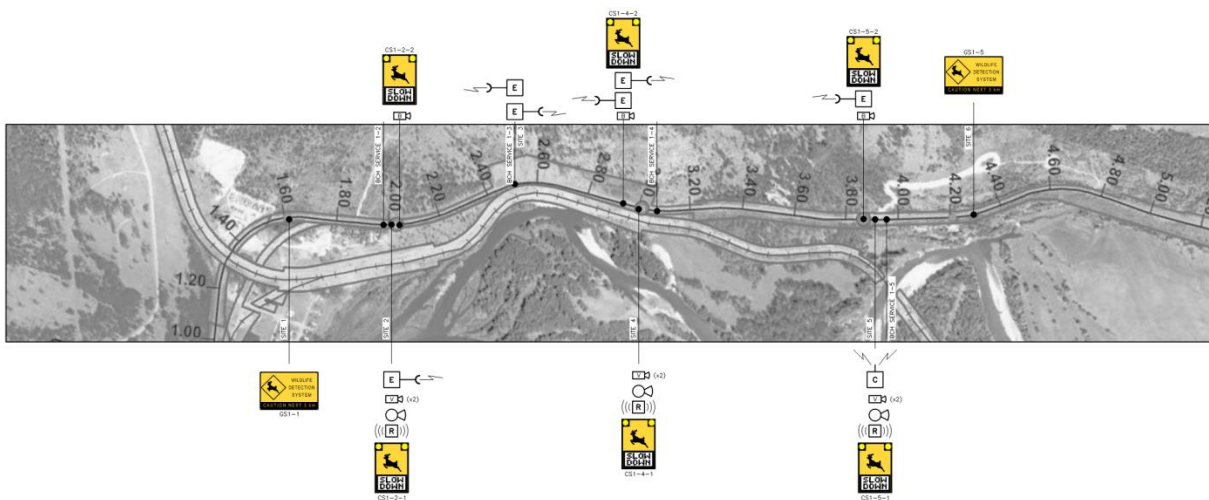


The curve in the corridors also factored into the effectiveness of communication between devices. Poles with wireless Ethernet transceivers were placed in such a manner as to have an open line of site between communicating devices. The placement of the master sensor was critical as to obtain the strongest cell signal possible in a low cellular-coverage, mountainous area.

Due to the rural nature of the project area, a limited number of electrical service connections were available. Placement of poles and the supporting electrical service infrastructure had to be considered to reduce the need for extensive cable and conduit runs for power service, which would greatly increase cost and complexity of installation.

### *Testing and Data Validation*

It was critical to the project's success that the client be able to demonstrate and prove accurate performance of the system. A rigorous and systematic testing methodology was developed and applied. Certain technology elements were installed as part of the system specifically to support the data validation process. This included additional cameras, recording equipment, and interface tools. Data from the cameras and system were used by the team to identify issues, adjust the sensor configurations, and assess and accurately validate the detection capability and overall performance accuracy of the system. The system was found to be approximately 97% accurate, meaning that 97% of the time that the signs are activated, there is in fact wildlife on or near the road.
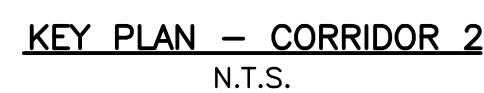
## Benefits of the WDS

The WDS has a demonstrated impact on driver behavior, with vehicles traveling measurably slower through the corridor when warning signs are activated, resulting in a lower wildlife collision rate and increased roadway safety. It is anticipated that the success of this project will set a standard for future systems, and take the place of traditional mitigation strategies. In doing so, this will both reduce human casualties and monetary costs resulting from WVCs, as well as curtail significant construction and maintenance costs associated with less-sophisticated systems, civil infrastructure and fencing.

Prior to the start of design, Highway 3 in Southeastern BC was identified as having the highest densities of WVCs in the province. Within this region alone, there were 516 reported collisions with large animals in 2012, averaging out to more than one a day. As such, MoTI selected this region as the ideal location for the province's first WDS, providing a means to increase safety for motorists and local fauna alike, and with the ultimate goal of implementing this system in other regions of the province.

The substantial size of traditional mitigation options, such as civil infrastructure and fencing, can cause vast disruption to the local habitat. In contrast, the footprint of the WDS infrastructure within the project area is inconsequential. The WDS does not compromise the local habitat, nor does it encumber wildlife, unlike fencing techniques which often run kilometers in length along roadways, preventing wildlife from having free passage across.

## Conclusion

PBX drew on our extensive experience in ITS and security systems to address this complex challenge. The engineered solution was a highly effective fusion of driver notification systems from the transportation field, combined with sophisticated detection and analysis technologies from the security field. The resulting WDS provides the area's wildlife with greater protection and motorists within the corridor a safer commute than ever before. Extensive field testing confirmed the very high degree of accuracy of the system, providing drivers with confidence that when the signs are activated, wildlife is nearby. The system has a demonstrated impact on driver behavior, with vehicles traveling measurably slower through the corridor when the warning signs are activated, resulting in a lower wildlife collision rate and increased roadway safety. This is an industry-leading, made-in-BC solution, applying locally developed technology and engineering expertise to overcome a difficult challenge, positively affecting our natural environment, as well as the people of BC.

**KEY PLAN – CORRIDOR 2**
N.T.S.

**SYSTEM DIAGRAM – CORRIDOR 2**

CS2-2-2
CS2-4-2
CS2-5-2
CS2-6
CS2-1
CS2-2-1
CS2-4-1
CS2-5-1

WILDLIFE DETECTION SYSTEM
CAUTION NEXT 3 km

SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6

SEN2-2
SEN2-5
SEN2-3

CAM2-2-1
CAM2-2-3
CAM2-2-4
CAM2-2-2
ETH2-2-1

CAM2-5-1
CAM2-5-2
CAM2-5-3
CAM2-5-4

CAM2-3-1
CAM2-3-3
CAM2-3-2

CAM2-3-4

CS2-2-1
CS2-2-2
CS2-4-1
CS2-4-2
CS2-5-1
CS2-5-2
CS2-6

SC
NS
C
CEL2-2

ETH2-4-2
ETH2-4-1

WDS SERVER

CC2-2
CC2-4
CC2-5
CC2-3A
(RELAY POLE)
CC2-3B

INTERNET

ETH2-2-1
ETH2-3-1
ETH2-3-2
ETH2-3-4
ETH2-3-3
ETH2-5-1

**MOXA EDS-516A 16-PORT MANAGED ETHERNET SWITCH**
CELLULAR AMPLIFIER
SP2
SP3
IOM2
POE2
POE3
SP1

WIRELESS ETHERNET TRANSCEIVER
CELL MODEM ANTENNA
FIXED THERMAL CAMERA (VERIFICATION)
PTZ CAMERA
WDS SENSOR
RADAR HEATER
SEE NOTE 2
ITS CABINET
CONFIRMATORY SIGN POLE
CONFIRMATORY SIGN
2C No. 18 TWP SH. (SIGN COMM.)

**SIGN OR SERVICE POLE**
WIRELESS ETHERNET TRANSCEIVER
WIRELESS ETHERNET TRANSCEIVER
OUTSIDE AIR TEMP. SENSOR
CONFIRMATORY SIGN
FIXED THERMAL CAMERA HEATER (WITHIN FIXED THERMAL CAMERA)
FIXED THERMAL CAMERA (BLIND SPOT MITIGATION)

**SAMPLE CONFIRMATORY SIGN POLE – COMMUNICATIONS**
N.T.S.

**SITE WIRING DIAGRAM**

CONFIRMATORY SIGN POLE
CONFIRMATORY SIGN
TERMINATIONS IN WIREWAY ENCLOSURE ON REAR OF SIGN (TYP. FOR ALL SIGNS)
2 No. 16 (BEACON PWR.)
2 No. 6 (SIGN PWR.)
FIXED THERMAL CAMERA (VERIFICATION)
FIXED THERMAL CAMERA HEATER (WITHIN FIXED THERMAL CAMERA)
1-2C No. 16
WDS SENSOR
RADAR HEATER
SEE NOTE 2
ITS CABINET
SIGN POWER DISTRIBUTION AND FIELD TERMINALS
GFI
CIRCUIT BREAKER
REFER TO ITS CABINET WIRING DIAGRAMS FOR BREAKER ASSIGNMENTS
TERMINAL BLOCK – DC GROUND
2 No. 6 (BEACON PWR.)(1 SPARE) (2 No. 8 AT SITE 2-4 ONLY)
2 No. 6 (SIGN PWR.) (2 No. 8 AT SITE 2-4 ONLY)
1-2C No. 16
SPLICE WIRE AT BASE OF POLE TO FEED CAMERA HEATER AND CAMERA POWER
2 No. 6

**SAMPLE CONFIRMATORY SIGN POLE – POWER**
N.T.S.

CLIENT
BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
ELECTRICAL ENGINEERING CENTRE

TITLE
WILDLIFE DETECTION SYSTEM
ACEC – CANADA AWARDS

PROJECT
WILDLIFE DETECTION SYSTEM

| Rev. | DATE | ISSUE / REVISION DESCRIPTION | DESN | QC | QA |
|---|---|---|---|---|---|
| 1 | 170407 | SUBMITTED FOR ACEC CANADA AWARDS | RV | IS | PBX |

| SCALE | PROJECT NUMBER | DRAWING NUMBER | REV. |
|---|---|---|---|
| AS SHOWN | 15016 | | 1 |