WSDOT Field Tests of Wireless and Microwave Vehicle Detection Systems

2008 Western States Rural Transportation Technology Implementers Forum

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Washington State Department of Transportation

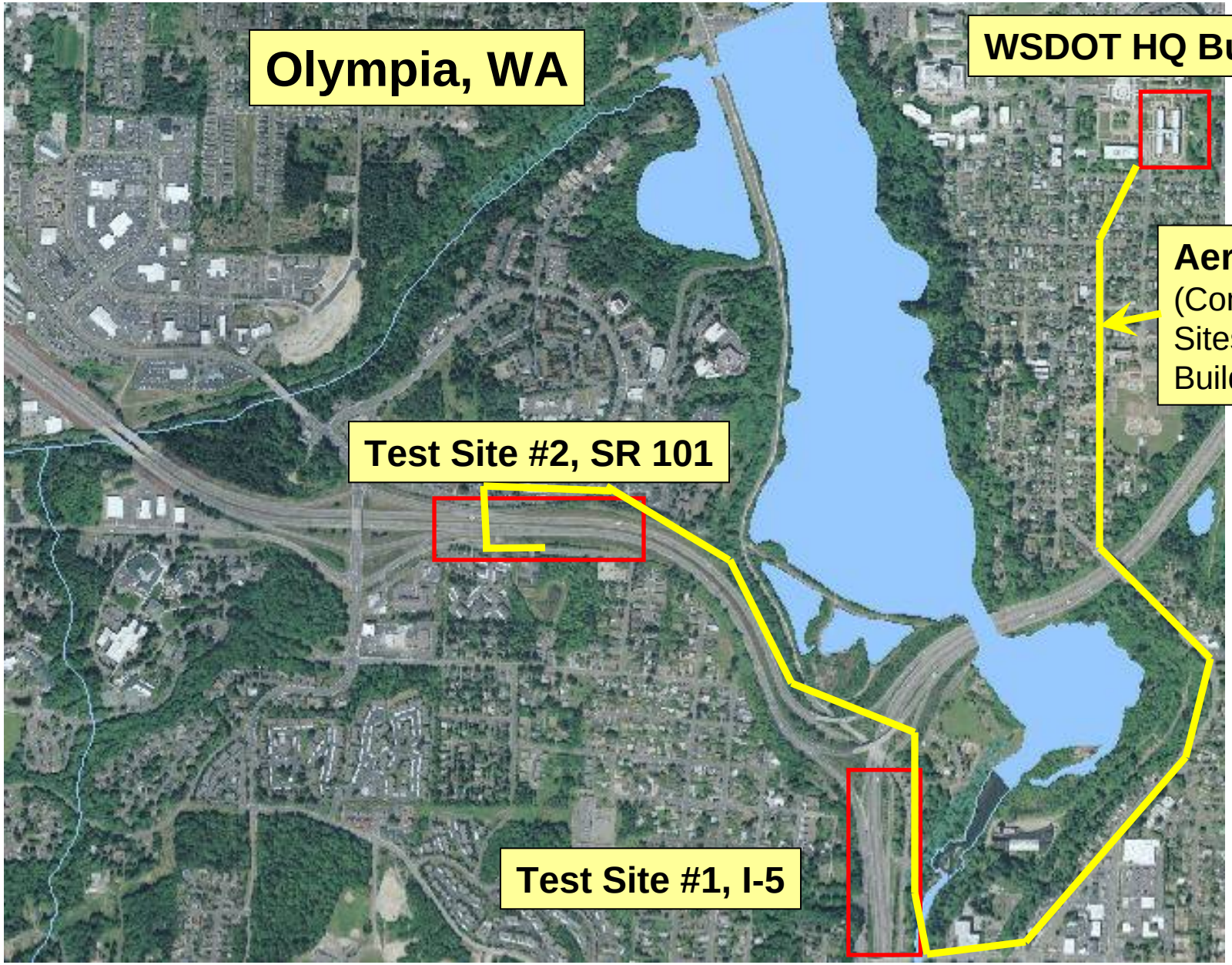
Abstract

- The Washington State Department of Transportation (WSDOT) has implemented two field test sites in Olympia, WA for the sole purpose of testing various kinds of ITS equipment. One of the field test sites is equipped with a video surveillance system for monitoring site operations while both sites have a control cabinet, with a 50ft special design pole for hanging multiple devices, and a direct fiber connection back to our headquarters office for remote operation and data collection.

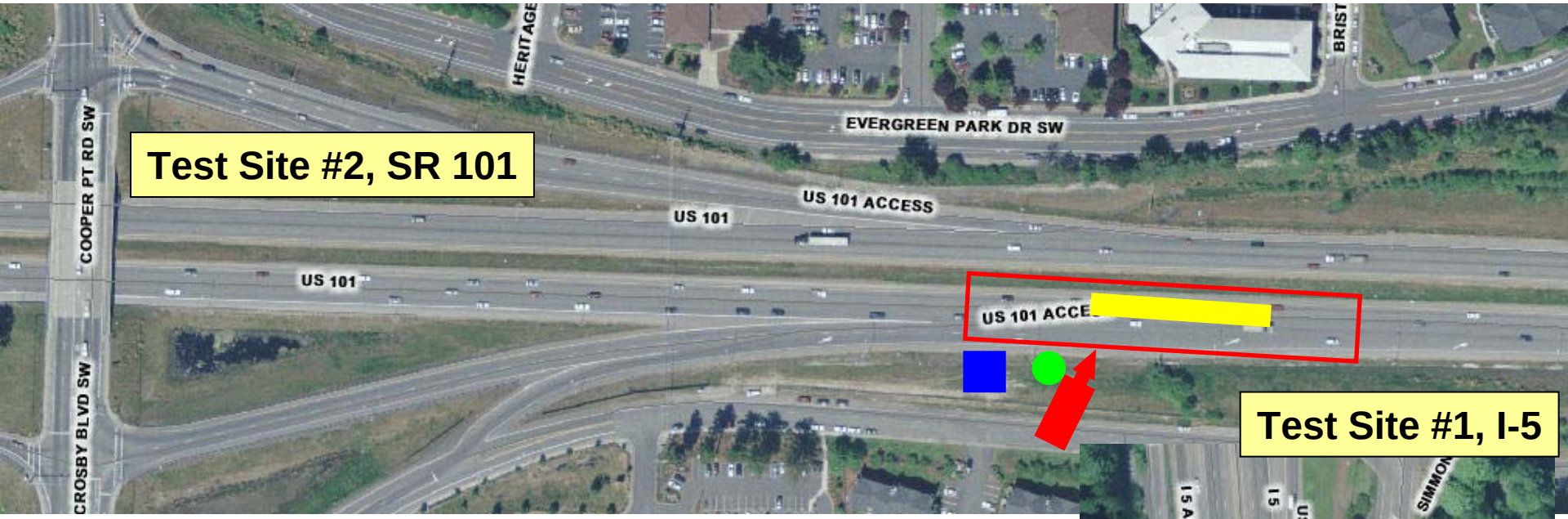
- As part of WSDOTs field research, tests have been completed at these two locations for Wavetronix, Speedinfo and Sensys Wireless Vehicle Detection Systems. Vehicle speeds and count data were collected side-by-side with data gathered from traditional loops or manual counts.

- The installation process, lessons learned along with the data comparison will be shared. The results of these tests have led to the deployment of Speedinfo and Sensys Network detection systems along the I-5 corridor and a planned deployments of a traffic signal systems with some or all Sensys Networks detection systems during the summer of 2008.

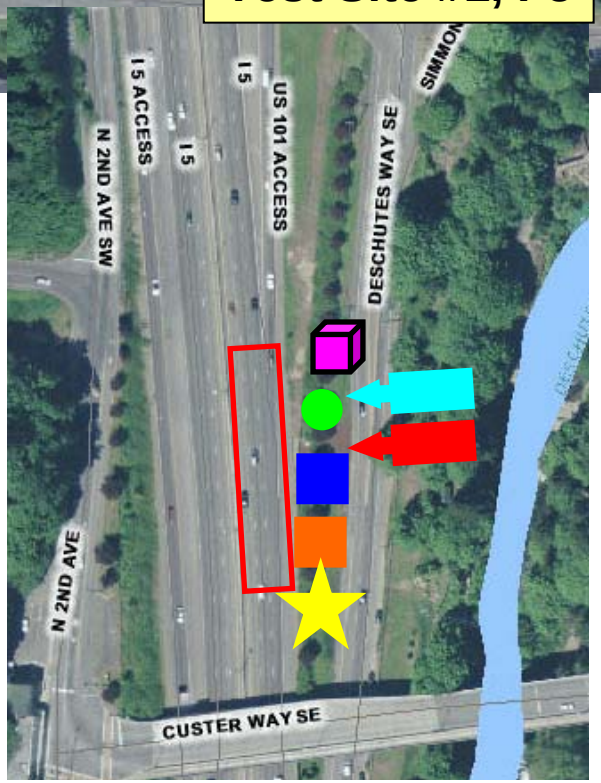
Location of WSDOT Field Test Sites



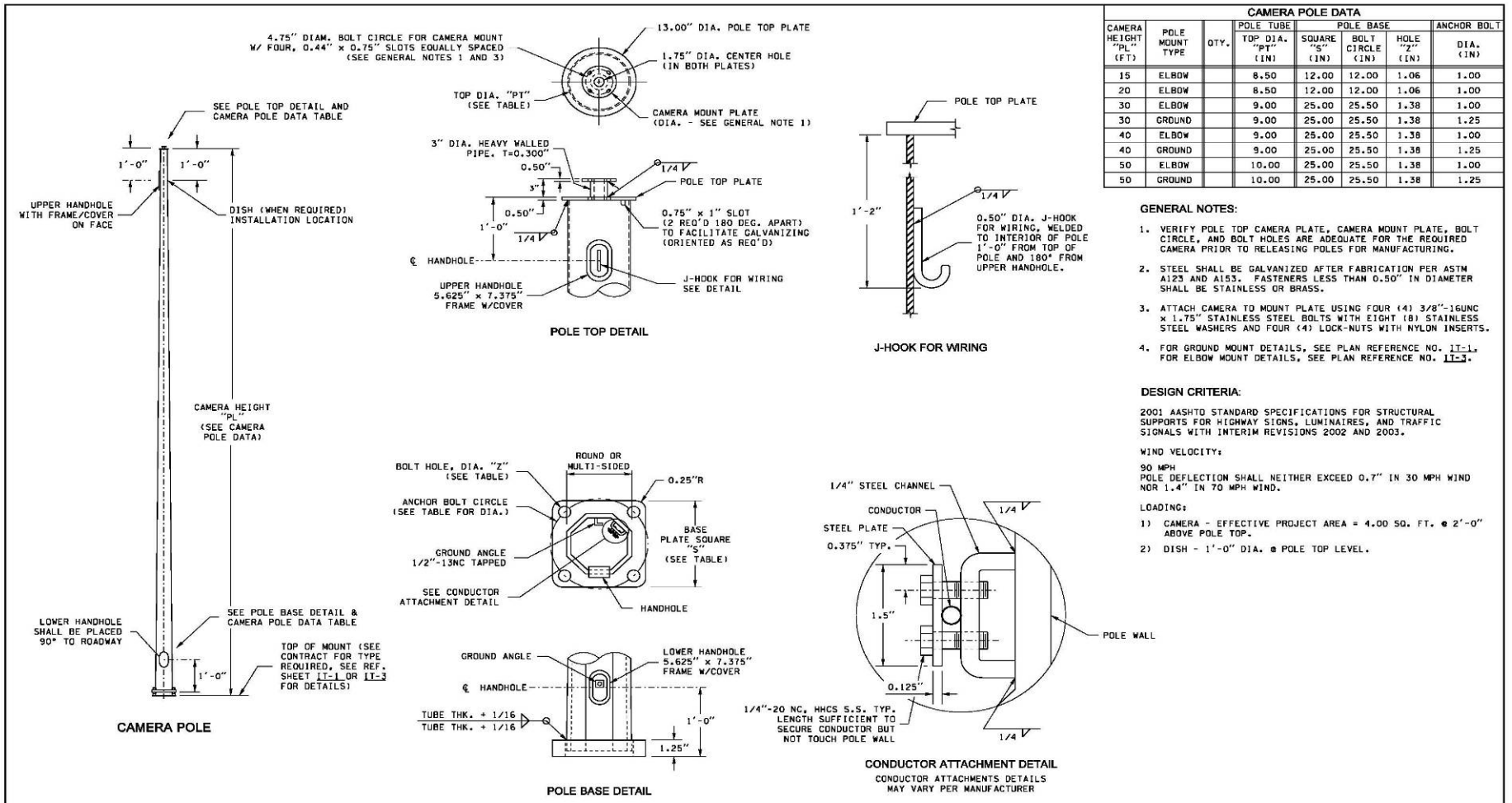
WSDOT Field Test Site Equipment



- Controller and Service Cabinets
- 50ft Camera Pole
- Generator with automatic transfer switch
- Fiber / Communication Hub
- Loop Locations
- Sensys Network “Sensor” Locations
- Wavetronix Sensor Location
- Cohu CCTV Camera Location
- Pelco CCTV Camera Location



WSDOTs New Standard ITS Pole Design



CAMERA POLE DATA

CAMERA HEIGHT "PL" (FT)	POLE MOUNT TYPE	QTY.	POLE TUBE	POLE BASE			ANCHOR BOLT
			TOP DIA. "PT" (IN)	SQUARE "S" (IN)	BOLT CIRCLE (IN)	HOLE "Z" (IN)	DIA. (IN)
15	ELBOW		8.50	12.00	12.00	1.06	1.00
20	ELBOW		8.50	12.00	12.00	1.06	1.00
30	ELBOW		9.00	25.00	25.50	1.38	1.00
30	GROUND		9.00	25.00	25.50	1.38	1.25
40	ELBOW		9.00	25.00	25.50	1.38	1.00
40	GROUND		9.00	25.00	25.50	1.38	1.25
50	ELBOW		10.00	25.00	25.50	1.38	1.00
50	GROUND		10.00	25.00	25.50	1.38	1.25

GENERAL NOTES:

1. VERIFY POLE TOP CAMERA PLATE, CAMERA MOUNT PLATE, BOLT CIRCLE, AND BOLT HOLES ARE ADEQUATE FOR THE REQUIRED CAMERA PRIOR TO RELEASING POLES FOR MANUFACTURING.
2. STEEL SHALL BE GALVANIZED AFTER FABRICATION PER ASTM A123 AND A153. FASTENERS LESS THAN 0.50" IN DIAMETER SHALL BE STAINLESS OR BRASS.
3. ATTACH CAMERA TO MOUNT PLATE USING FOUR (4) 3/8"-16UNC x 1.75" STAINLESS STEEL BOLTS WITH EIGHT (8) STAINLESS STEEL WASHERS AND FOUR (4) LOCK-NUTS WITH NYLON INSERTS.
4. FOR GROUND MOUNT DETAILS, SEE PLAN REFERENCE NO. IT-1, FOR ELBOW MOUNT DETAILS, SEE PLAN REFERENCE NO. IT-3.

DESIGN CRITERIA:

2001 AASHTO STANDARD SPECIFICATIONS FOR STRUCTURAL SUPPORTS FOR HIGHWAY SIGNS, LUMINAIRES, AND TRAFFIC SIGNALS WITH INTERIM REVISIONS 2002 AND 2003.

WIND VELOCITY:

90 MPH
POLE DEFLECTION SHALL NEITHER EXCEED 0.7" IN 30 MPH WIND NOR 1.4" IN 70 MPH WIND.

LOADING:

1) CAMERA - EFFECTIVE PROJECT AREA = 4.00 SQ. FT. @ 2'-0" ABOVE POLE TOP.
2) DISH - 1'-0" DIA. @ POLE TOP LEVEL.

FILE NAME	h:\PSL\IT-1\IT-1.dgn
TIME	1:36:47 PM
DATE	1/9/2007
PLOTTED BY	sujkom
DESIGNED BY	
ENTERED BY	M. Sujka
CHECKED BY	
PROJ. ENGR.	
REGIONAL ADM.	

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.
JOB NUMBER
CONTRACT NO. | LOCATION NO.

P.E. STAMP BOX | DATE

P.E. STAMP BOX | DATE

Washington State Department of Transportation

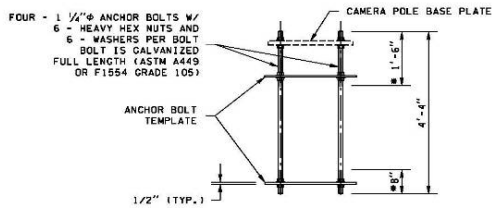
CAMERA POLE DETAILS

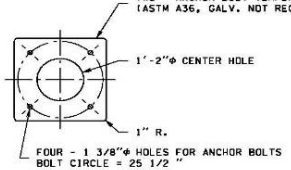
IT-2

SHEET OF SHEETS

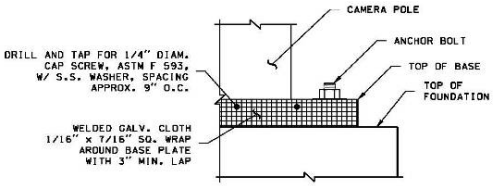
WSDOTs New Standard ITS Pole Foundation Design

CAMERA POLE HEIGHT	DEPTH OF FOUNDATION "D"		ANCHOR BOLT ASTM A449 OR F1554 GR. 105		
	3H:1V OR FLATTER	2H:1V	DIAMETER	LENGTH	BOLT CIRCLE
50'	7'-0"	9'-0"	1 1/4"	4'-4"	25 1/2"
40'	5'-6"	7'-6"	1 1/4"	4'-4"	25 1/2"
30'	4'-6"	6'-6"	1 1/4"	4'-4"	25 1/2"

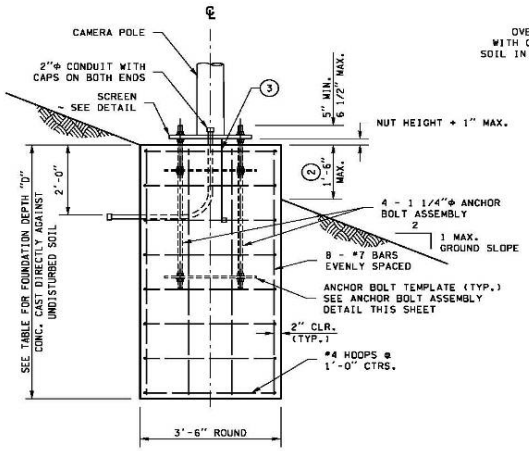




ANCHOR BOLT ASSEMBLY
* THREADED LENGTH

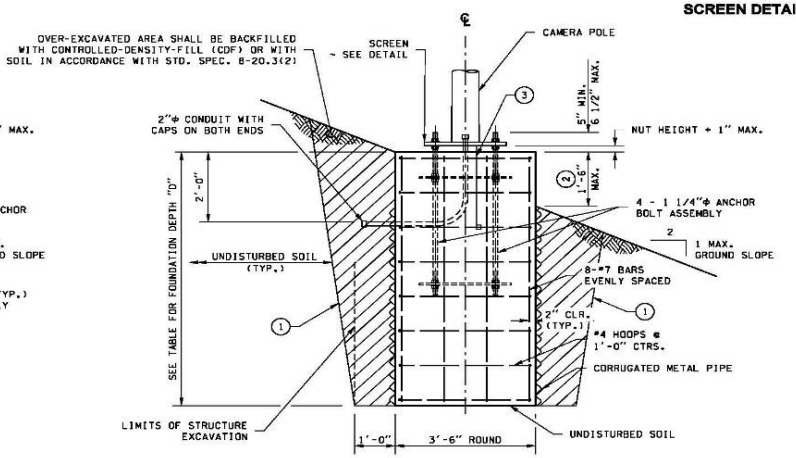


SCREEN DETAIL



FOUNDATION REINFORCEMENT DETAIL
CONCRETE CAST DIRECTLY AGAINST UNDISTURBED EARTH.

ALTERNATE # 1
N.T.S.



FOUNDATION REINFORCEMENT AND BACKFILL DETAIL
CONCRETE CAST INSIDE CORRUGATED METAL PIPE STAY-IN-PLACE FORM. PAPER OR CARBOARD FORM SHALL NOT BE USED BENEATH THE GROUND SURFACE. (2)

ALTERNATE # 2
N.T.S.

GENERAL NOTES:

1. THESE FOUNDATIONS ARE DESIGNED FOR A MINIMUM OF 1,500 PSF ALLOWABLE LATERAL BEARING PRESSURE FOR THE SOIL. A SPECIAL FOUNDATION SHALL BE REQUIRED FOR SOIL WITH LOWER ALLOWABLE LATERAL BEARING PRESSURE THAN 1,500 PSF.
2. THESE FOUNDATIONS ARE DESIGNED FOR INSTALLATION ON LEVEL GROUND, OR ON SLOPING GROUND NOT TO EXCEED 2:1 SLOPES. STEEPER THAN 2:1 REQUIRE A SPECIAL DESIGN.
3. FOUNDATION CONSTRUCTED WITHIN ECOLOGY EMBANKMENTS SHALL BE INCREASED IN DEPTH BY THE DEPTH OF THE ECOLOGY EMBANKMENT.

DESIGN CRITERIA:
2001 AASHTO STANDARD SPECIFICATIONS FOR STRUCTURAL SUPPORTS FOR HIGHWAY SIGNS, LUMINAIRES AND TRAFFIC SIGNALS WITH INTERIM REVISIONS 2002 AND 2003.
WIND VELOCITY:
90 MPH
MAXIMUM POLE DEFLECTION SHALL NOT EXCEED 0.7" IN 30 MPH AND 1.4" IN 70 MPH WIND.
LOADING:
1.) CAMERA - EFFECTIVE PROJECT AREA = 4.00 SQ. FT. @ 2'-0" ABOVE POLE TOP.
2.) DISH - 1'-0"Φ @ POLE TOP LEVEL.

(1) SHORING OR EXTRA EXCAVATION AS REQUIRED.

(2) FOUNDATION TOP (1'-6") SHALL BE FORMED TO CREATE A SMOOTH CONCRETE SURFACE. ALL EXPOSED FORMING SHALL BE REMOVED UPON COMPLETION OF FOUNDATION CONSTRUCTION.

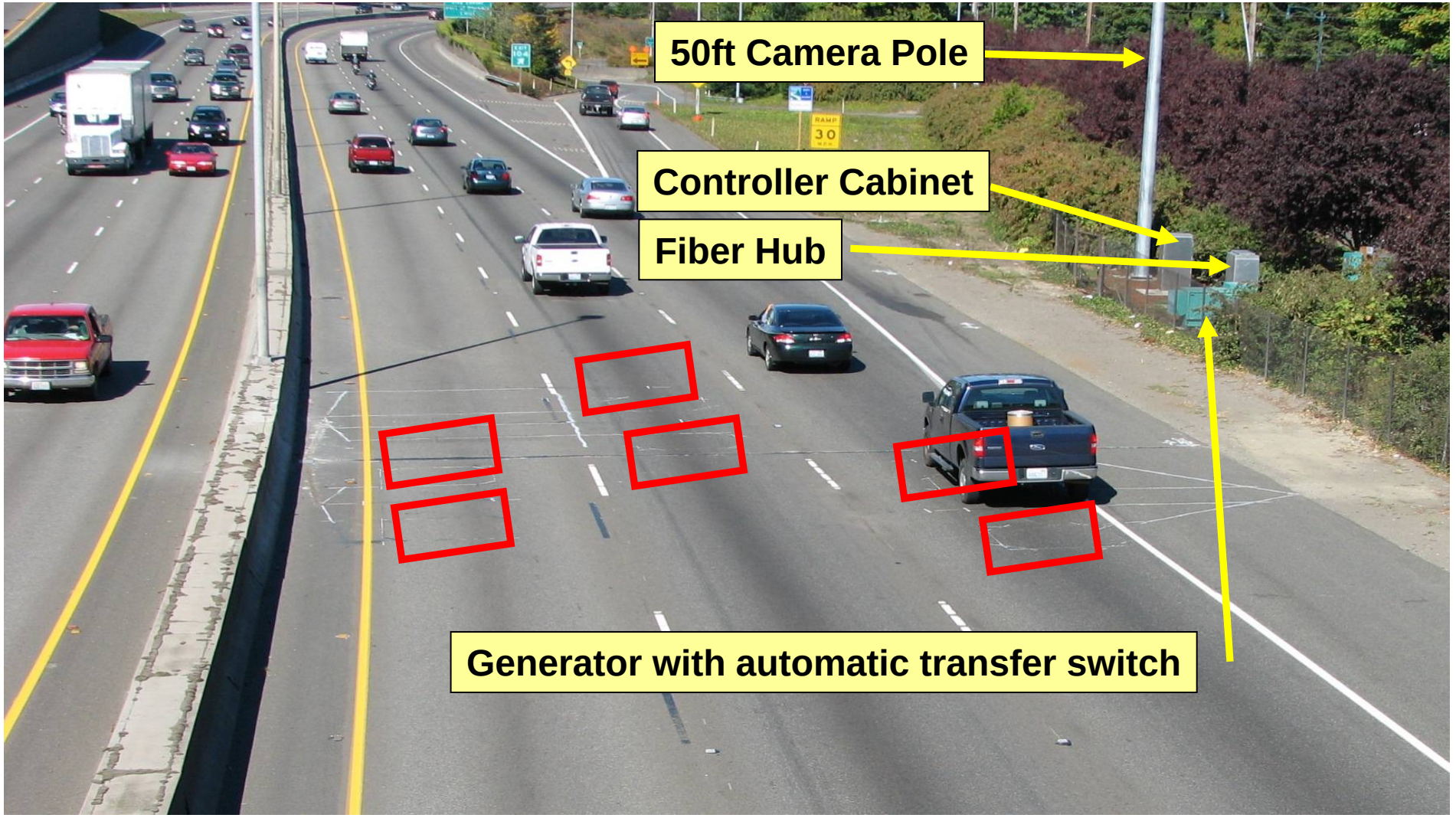
(3) GROUNDING CONDUCTOR #4 AWG STRANDED COPPER WITH 3'-0" MIN. SLACK. CLAMP CONDUCTOR TO REBAR WITH LISTED CONDUCTOR SUITABLE FOR USE EMBEDED IN CONCRETE. ROUTE CONDUCTOR TO CAMERA POLE GROUNDING STUD.

FILE NAME	CAMERA POLE FOUNDATION PLAN			REGION NO.	STATE	FED.AID PROJ.NO.		Washington State Department of Transportation	PLOT1
TIME	7:37:21 AM			10	WASH				IT-1
DATE	9/27/2006			JOB NUMBER					
PLOTTED BY	sujkam			CONTRACT NO.	LOCATION NO.			CAMERA POLE FOUNDATION DETAILS	SHEET OF SHEETS
DESIGNED BY	BEDI, G.						DATE	DATE	
ENTERED BY	BERENS, B								
CHECKED BY									
PROJ. ENGR.									
REGIONAL ADM.		REVISION	DATE	BY					

ITS Field Test Site
Operations / Maintenance / Lessons Learned

1. $65 / Month Power Bill for 2 Controller Cabinets
2. Annual Budget for materials and installation $50k
3. Equipment Tested – Typically Donated or Loan
4. Installation - State forces ($200/hr for 2 people, bucket truck and traffic control)
5. Installation – Manufactures and vendors are typically present for installation
6. Issues with Partnering with IT and Contractors

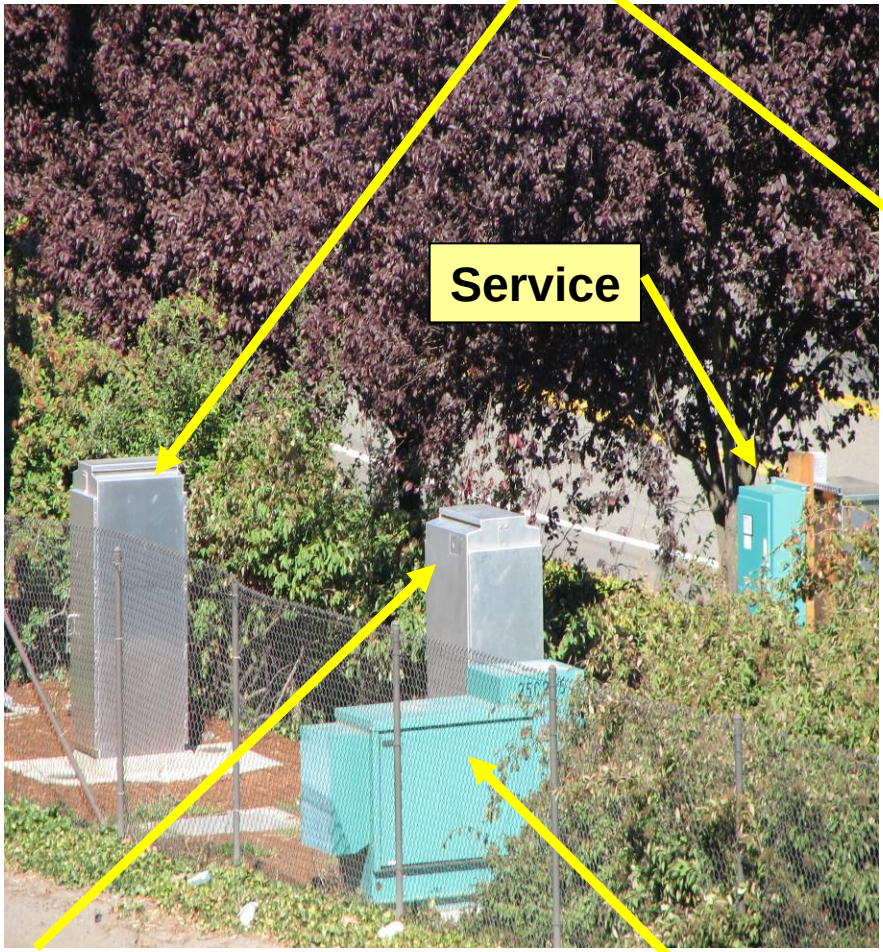
WSDOT Field Test Site #1 – Interstate 5



Loops

WSDOT Field Test Site #1 – Interstate 5

Controller Cabinet (6 Strands)

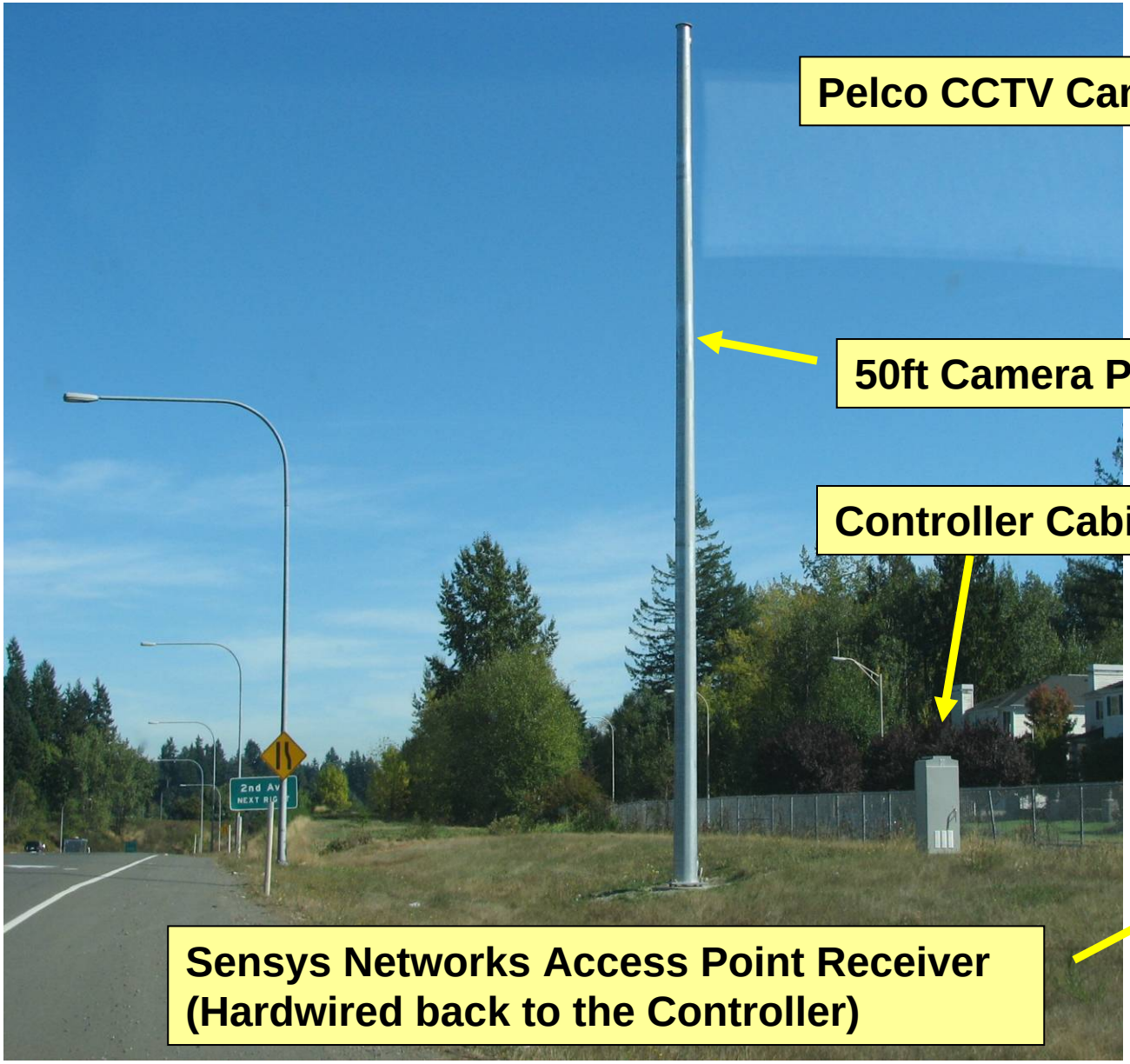


Fiber Hub (288 Strands)

Generator with automatic transfer switch

WSDOT Field Test Site #1 – Interstate 5

WSDOT Field Test Site #2 – SR 101



Speedinfo Evaluation

- **Cost**
  - Option 1, Purchase with 3yr Maintenance, $4,200 per sensor
  - Option 2, Lease for $110 per month per sensor
- **Procurement**
  - Direct Buy IT Purchasing Authority

DVSS-100 SENSOR SPECIFICATIONS

- **Sensor**
  - License free – 24.125GHz
  - Range 1800 ft, bi-directional
    - Single device measures both sides of roadway
  - Accuracy: 0.1mph, avg. +/- 3mph
  - Installs on existing infrastructure
    - Install time 30-45 minutes
  - Solar: 5W or 10W
    - Sealed lead acid batteries
    - 21 days of operation without photons
  - Weight: 16 lbs
    - Small profile, negligible wind loading
  - Programmable sampling rates
    - Default 2 measurements/minute
    - Adaptive reporting rates
  - Data Backhaul – ATT Wireless GPRS
    - Full Duplex
  - External Power and Communication port

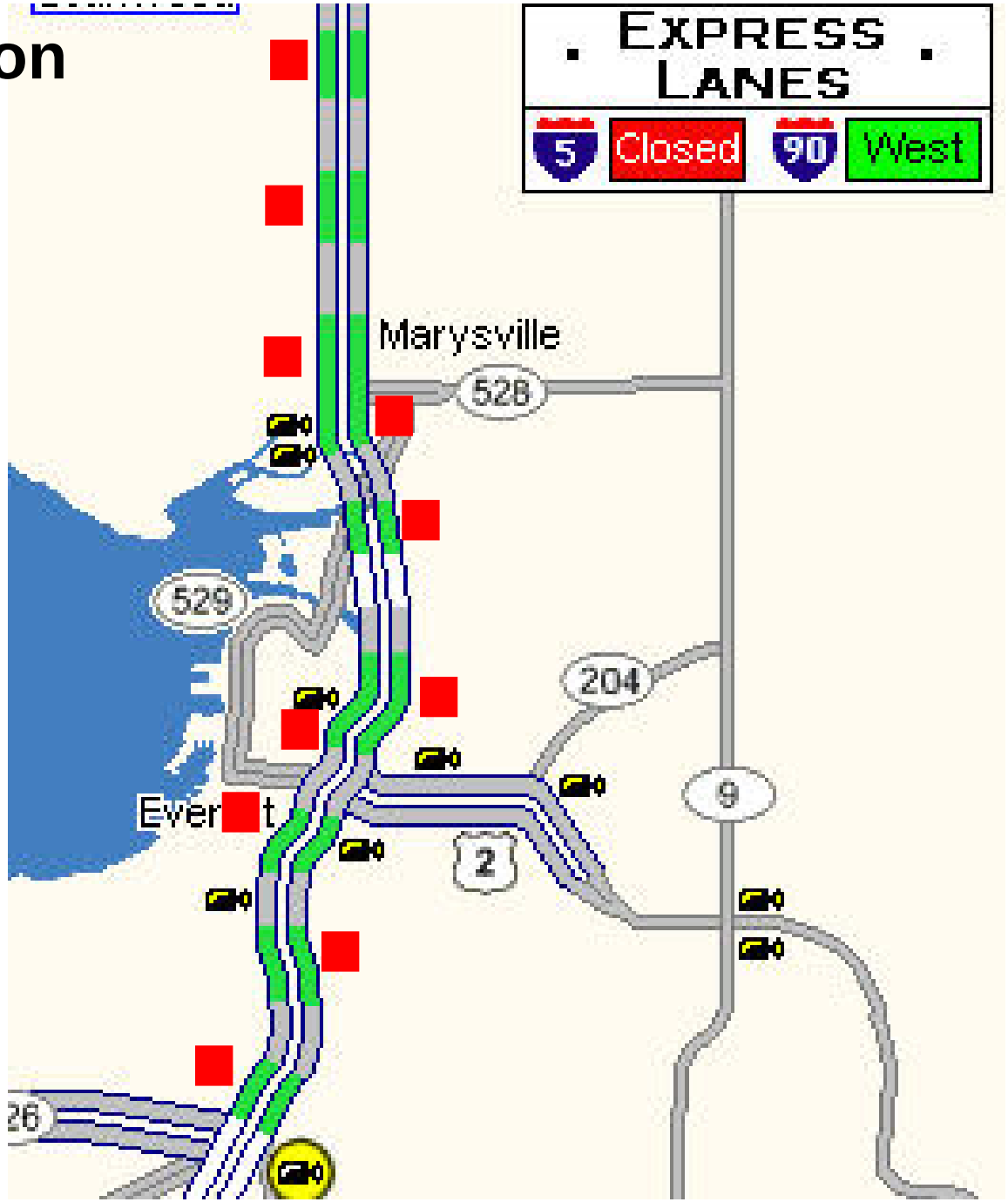
Speedinfo Installation Everett

Everett to Marysville, Speed Info Sensor Locations

Sensor Number	Road Name	Mile Post	Location Name	Equipment Location	Latitude	Longitude	Aim
1	I-5 SB	189.89	I-5 S @ North of SR526/SR527 off ramp	In the Median on sign bridge	47.926662°	-122.203137°	North
2	I-5 SB	191.51	I-5 S @ Lowell Road overpass - Median	In the Median on Sign Bridge	47.946990°	-122.198282°	North
3	I-5 NB	193.45	I-5 N @ Pacific Avenue off ramp	On the Cantiliver Sign	47.973894°	-122.191152°	South
4	I-5 SB	194.78	I-5 S @ East Marine View Drive on ramp	On the Camera Pole	47.990669°	-122.183017°	South
5	I-5 NB	196.41	I-5 N @ North of 12th Street NE	Right on the Wood Pole	48.013611°	-122.174167°	South
6	I-5 NB	197.67	I-5 N @ South of 40th Place NE	Right on the Wood Pole	48.031759°	-122.176864°	South
7	I-5 SB	198.50	I-5 S @ SR529 off ramp	In the gore area On Luminaire Pole	48.043102°	-122.180861°	South
8	I-5 SB	199.35	I-5 S @ Marine Drive Northeast off ramp	In the Median on Sign Bridge	48.054944°	-122.184175°	North
9	I-5 NB	200.73	I-5 @ 88th Avenue on 88th Avenue Bridge	On the Luminaire Pole at the Bridge	48.075651°	-122.184463°	South
10	I-5 NB	202.17	I-5 N @ 116th Street NE	Right On the Luminaire Pole	48.096361°	-122.184199°	South

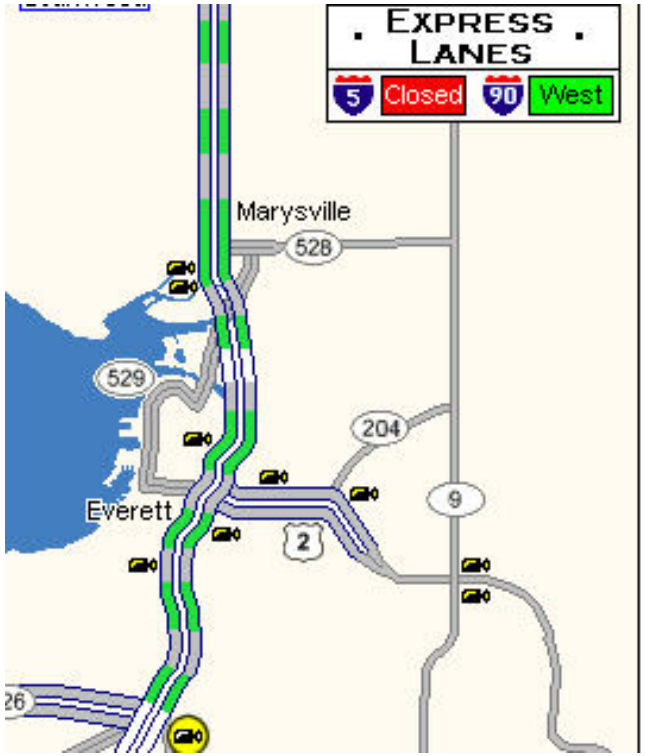
Speedinfo Installation
Everett - Map

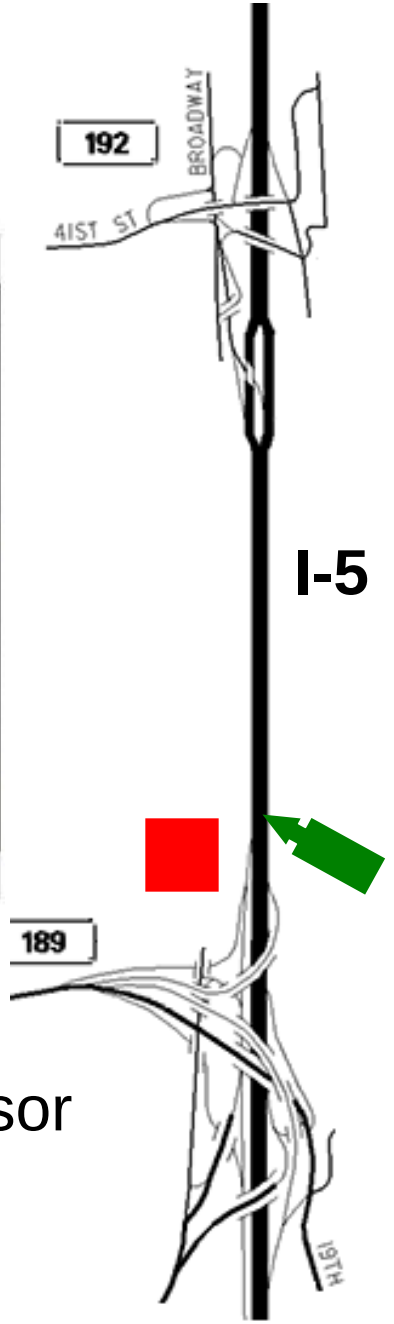
- 10 sensor network
- 10 miles of coverage
  at 1 mile separation on I-5



Speedinfo Sensor

Speedinfo Evaluation - Everett



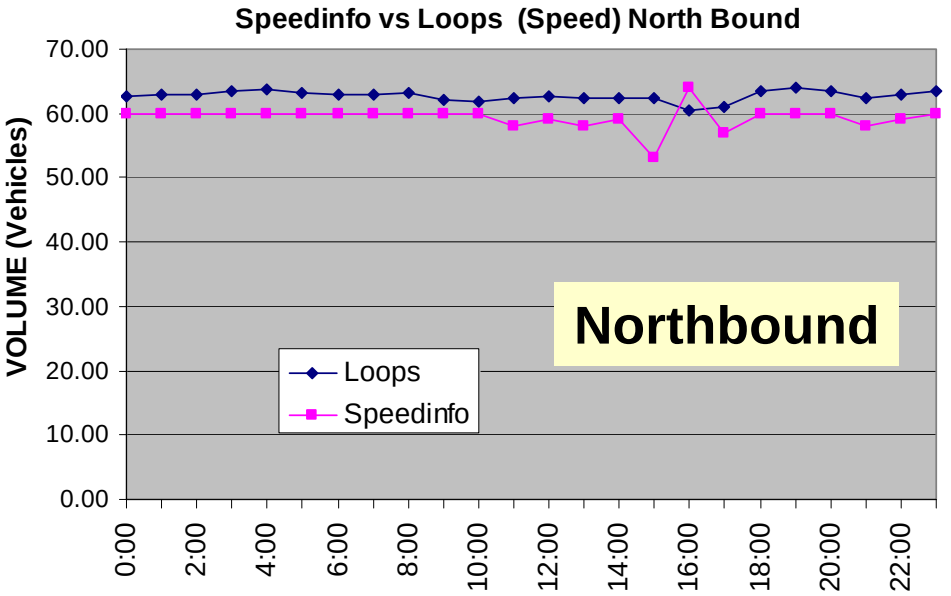


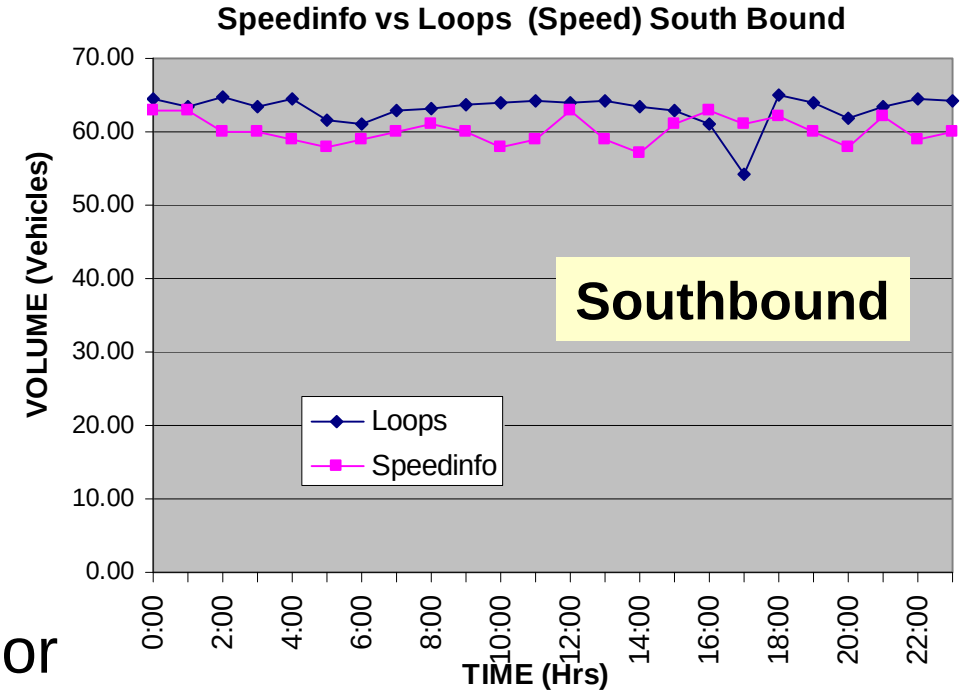
CCTV Camera

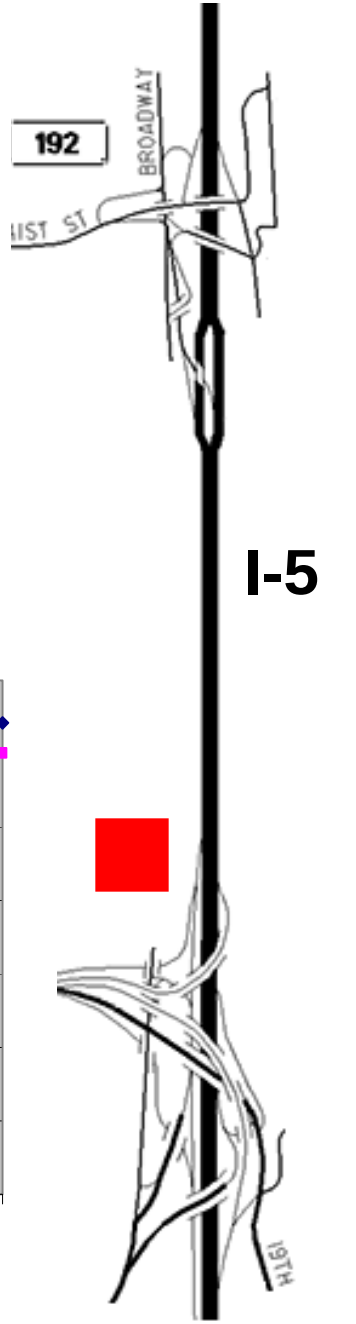
Speedinfo Sensor

Speedinfo Evaluation - Everett

Speed Variance of **5.5% on average over a 24hr period** in comparison to loops (2.9% to 15.1% range)



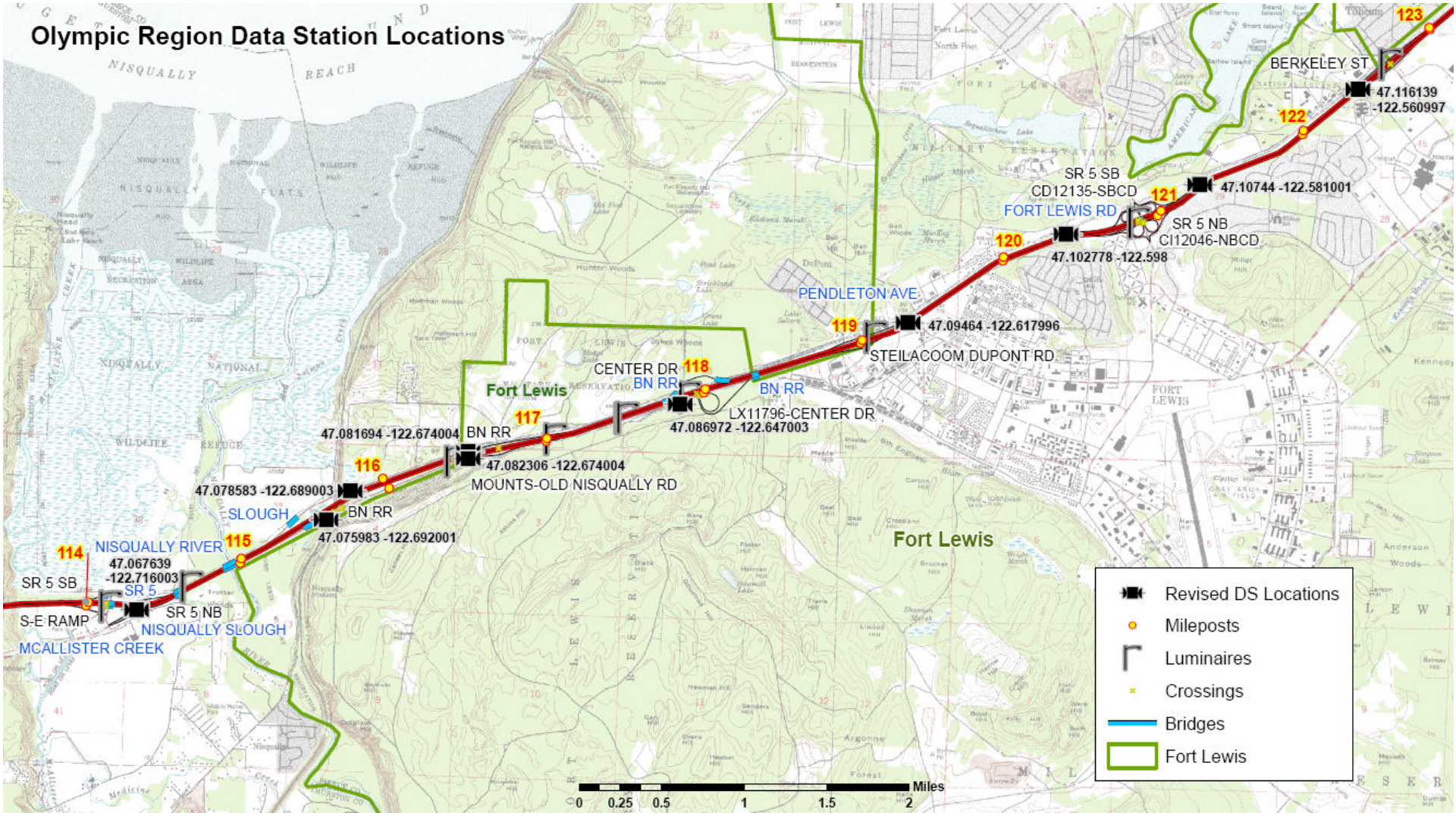




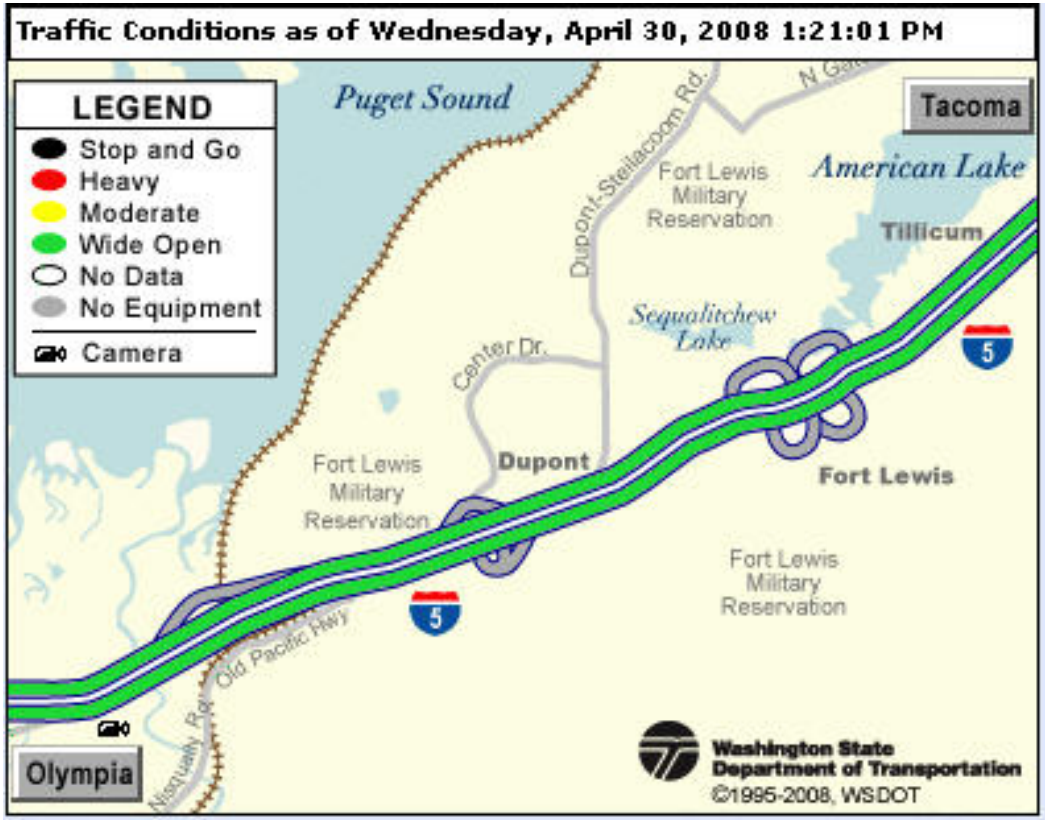
Speedinfo Sensor

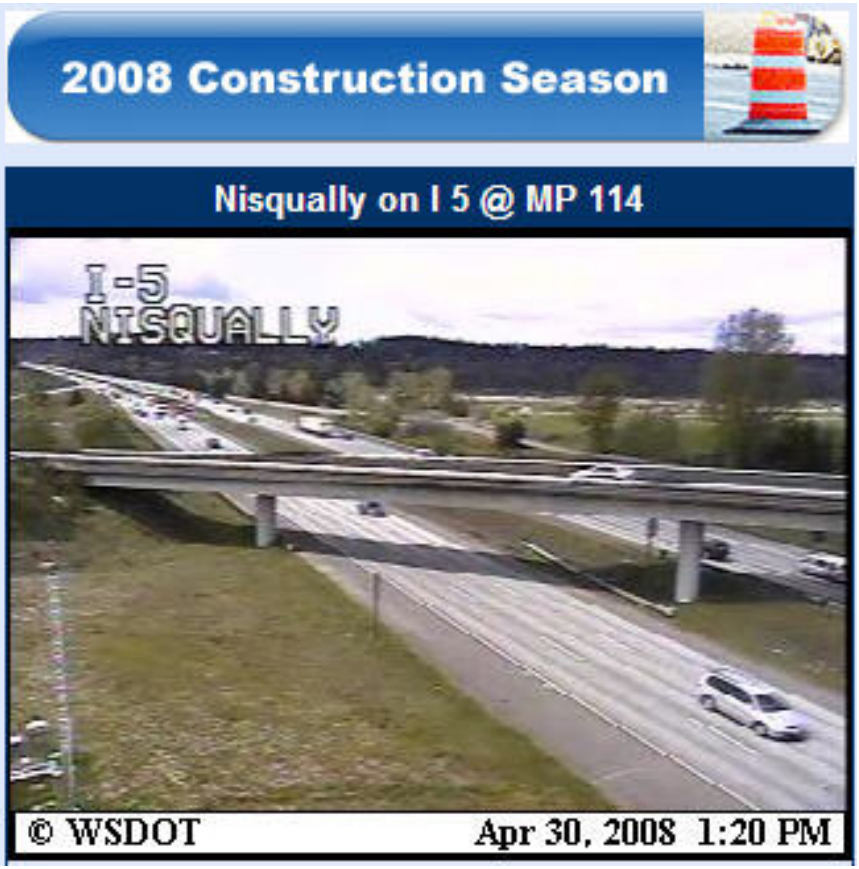
Speedinfo Installation Nisqually Valley

- 10 sensor network
- 10 miles of coverage at 1 mile separation on I-5



Speedinfo Nisqually Valley – Flow Map

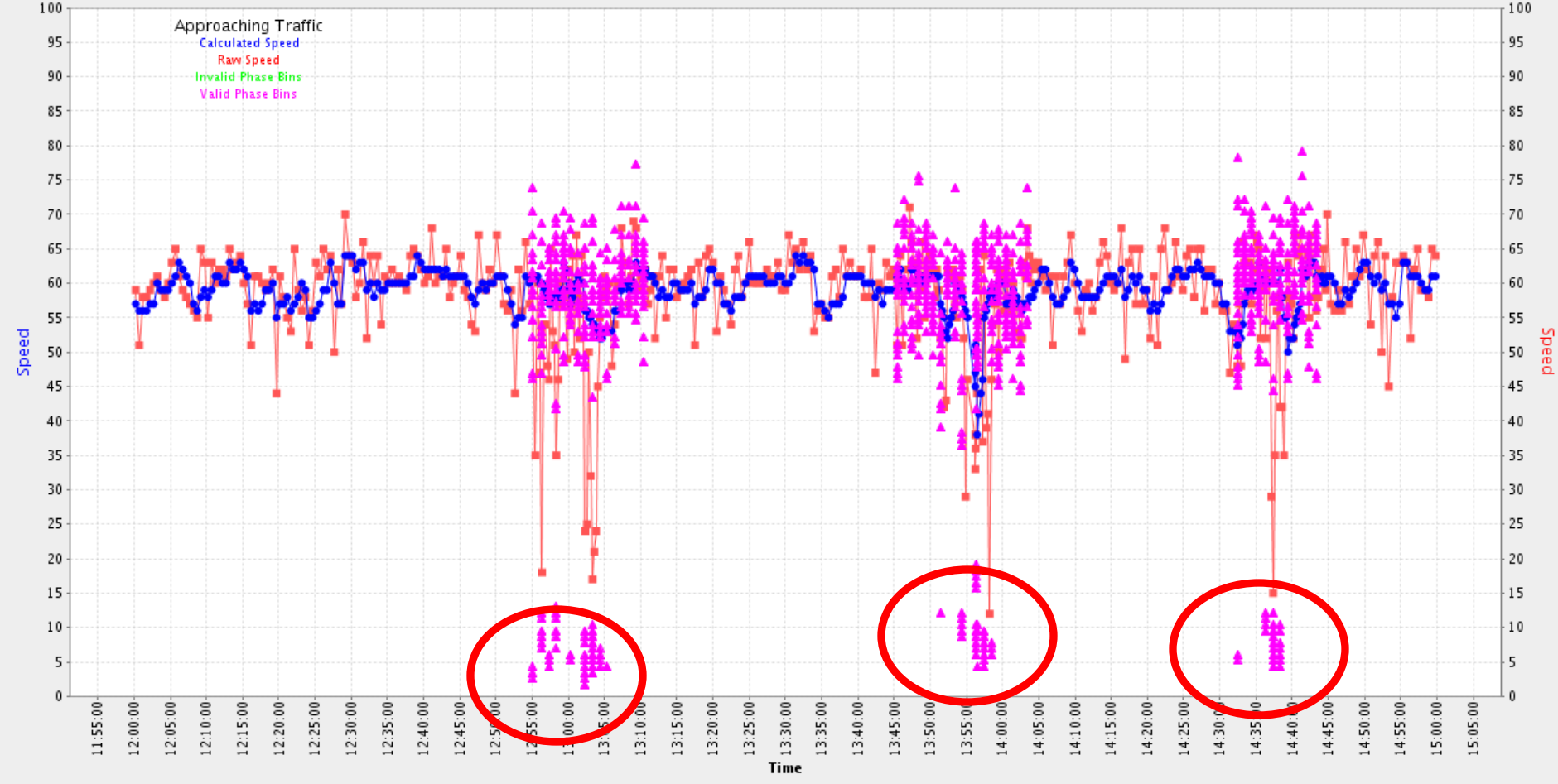




www.wsdot.wa.gov/Traffic/DuPont/

Speedinfo Evaluation – Lessons Learned

- Effects of Rain



- Location Limitations
  - Overpasses
  - Railroad tracks
  - Frontage Roads
  - Locations where Slower speeds can be detected

Speedinfo Data Processing

- XML Datafeed Example 1

```
<?xml version="1.0" encoding="UTF-8" ?>
- <speedInfo xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:type="speedInfo">
- <Speeds xsi:type="speedInfo-speeds">
  <System>SpeedInfo</System>
  <Version>1.0</Version>
- <DateTimeStamp xsi:type="date-timestamp">
  <Date>2008-04-30</Date>
  <Time>10:12:10</Time>
  </DateTimeStamp>
  <Units>US</Units>
- <DeviceData xsi:type="device-data">
- <DateTimeStamp xsi:type="date-timestamp">
  <Date>2008-04-30</Date>
  <Time>10:11:40</Time>
  </DateTimeStamp>
  <Id>10213</Id>
  <Status>OK</Status>
  <Confidence>100</Confidence>
- <Lane xsi:type="lane-data">
  <Id>ALL</Id>
  <Speed>61</Speed>
  </Lane>
  </DeviceData>
```

Speedinfo Data Processing

- XML Datafeed Example 2

```
<?xml version="1.0" encoding="UTF-8" ?>
- <speedInfo xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:type="speedInfo">
- <Setup xsi:type="speedInfo-setup">
  <System>SpeedInfo</System>
  <Version>1.0</Version>
- <DateTimeStamp xsi:type="date-timestamp">
  <Date>2008-04-29</Date>
  <Time>23:13:27</Time>
  </DateTimeStamp>
- <DeviceDescription xsi:type="device-description">
  <Id>10213</Id>
  <RoadName>I-5</RoadName>
  <RoadDir>N</RoadDir>
  <Latitude>48.075651</Latitude>
  <Longitude>-122.184463</Longitude>
  </DeviceDescription>
```

Speedinfo Recommendations / Conclusions

1. Affordable ($110/month)
2. Simple Installation (30 min)
3. Installed by State Forces
4. Flow map Expansion
5. Use for determining travel time, can be used for posting travel times however correction factors will be required
6. Sensor can be moved and relocated as permanent Data Stations are built.

Speedinfo Recommendations / Conclusions

7. Sensor detects rain and averages rain with vehicle speeds, sensor is equipped with an algorithm that filters out the rain however, it takes two minutes for the sensor to correct itself and start reporting vehicle speeds only.

Sensys Networks

- Sensys magnetometers have been installed at two locations in place of loop detection for collecting speed, volume, occupancy and classification data.

Flush-Mount Wireless Sensor

Access Point

Repeater

Controller interface

Sensys Networks

Flush-Mount Wireless Sensors

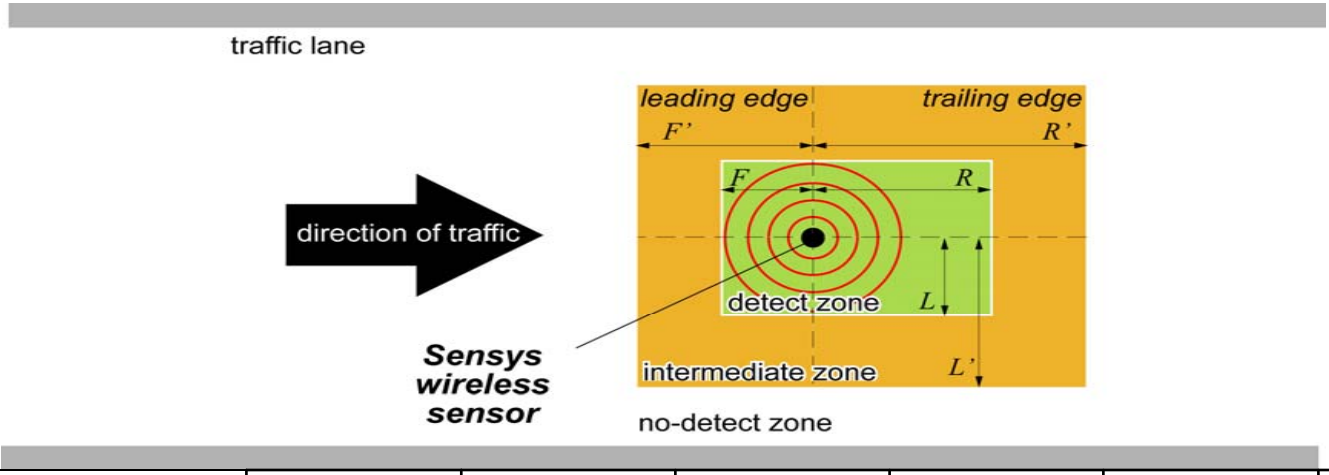
- Magnetometer based detection
- Install using hammer or core drill
- 10 years of battery life
- Auto-calibration

- 2-way radio comms to access point – *uniquely addressable*

Sensys Networks

Sensor Vehicle Detection Zones

Sensys vehicle detection zones are configurable, depending on the application



	F	*F'*	*R*	*R'*	*L*	*L'*
freeway & arterial applications	**~0**	**~0**	**~4 feet / ~1.2 meters**	**~6 feet / ~1.8 meters**	**~2 feet / ~0.6 meters**	**~4 feet / ~1.2 meters**
stop bar detection@ stop bar #7	**~6 feet / ~1.8 meters**	**~8 feet / ~2.4 meters**	**~6 feet / ~1.8 meters**	**~8 feet / ~2.4 meters**	**~3 feet / ~0.9 meters**	**~6 feet / ~1.8 meters**

Sensys Networks

Sensys Access Point

Access point relays sensor data to traffic controller or central servers

- Simple Installation
- Processes, stores, and/or relays sensor data (Linux OS)
  - RS-485 to traffic controller
  - IP (fiber or cellular) to central servers
- Supports as many sensors as necessary
- Can serve as IP router for peripherals (video cams, etc.)

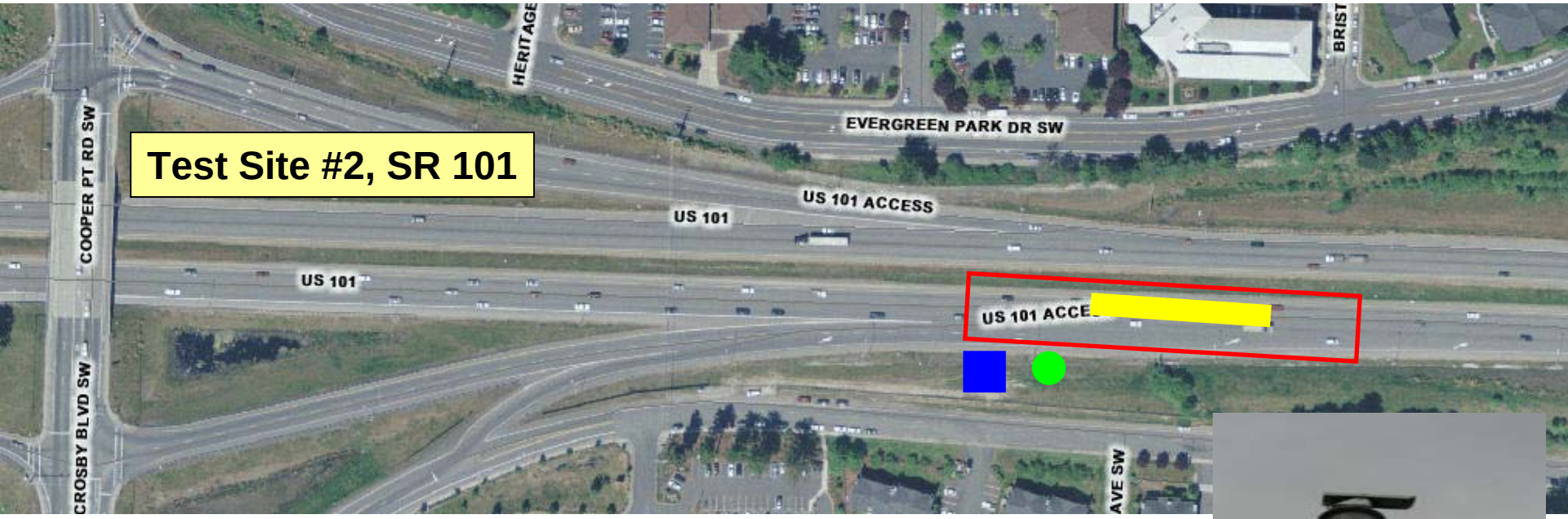
Sensys Networks

Sensys Repeater

Repeater relays sensor data to access point

- Battery-powered unit
- Supports up to 10 wireless sensors
- Relays detection data back to access point, extending range
- Supports mid-block detection – *no trenching required*
- Supports “geometrically complicated” installations

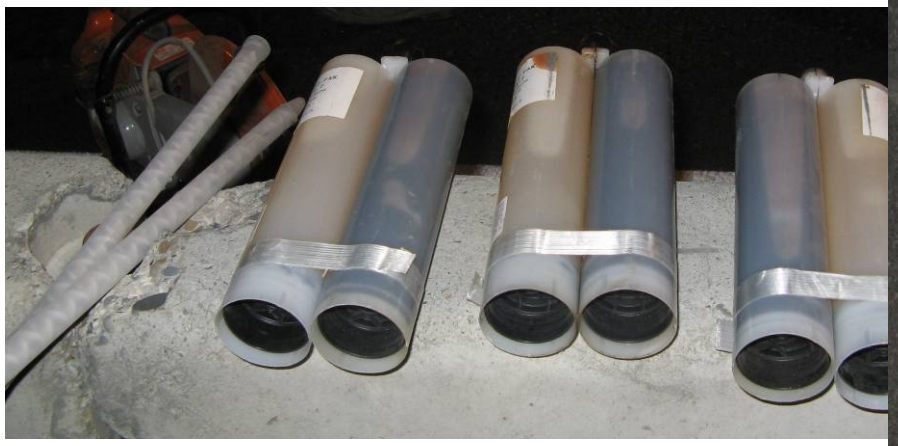
WSDOT Field Test of Sensys Networks

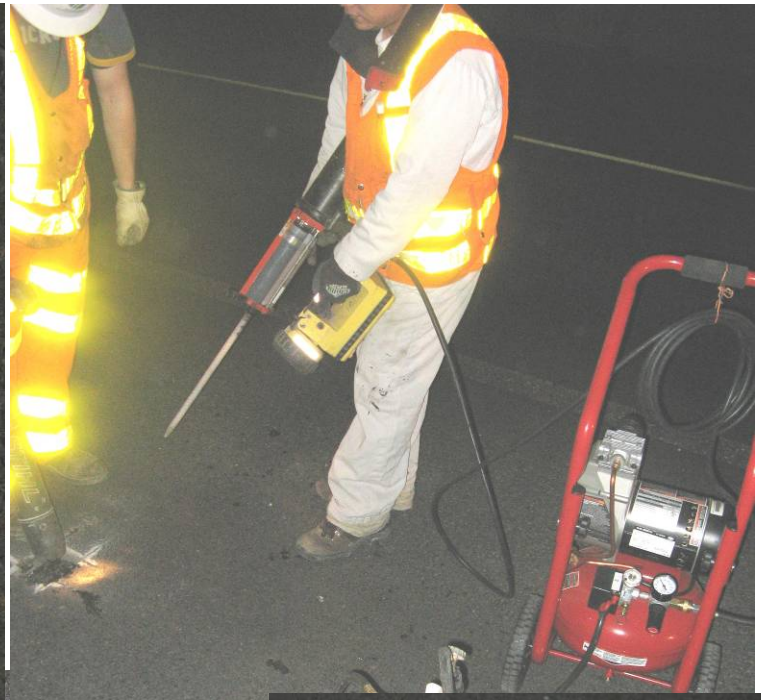


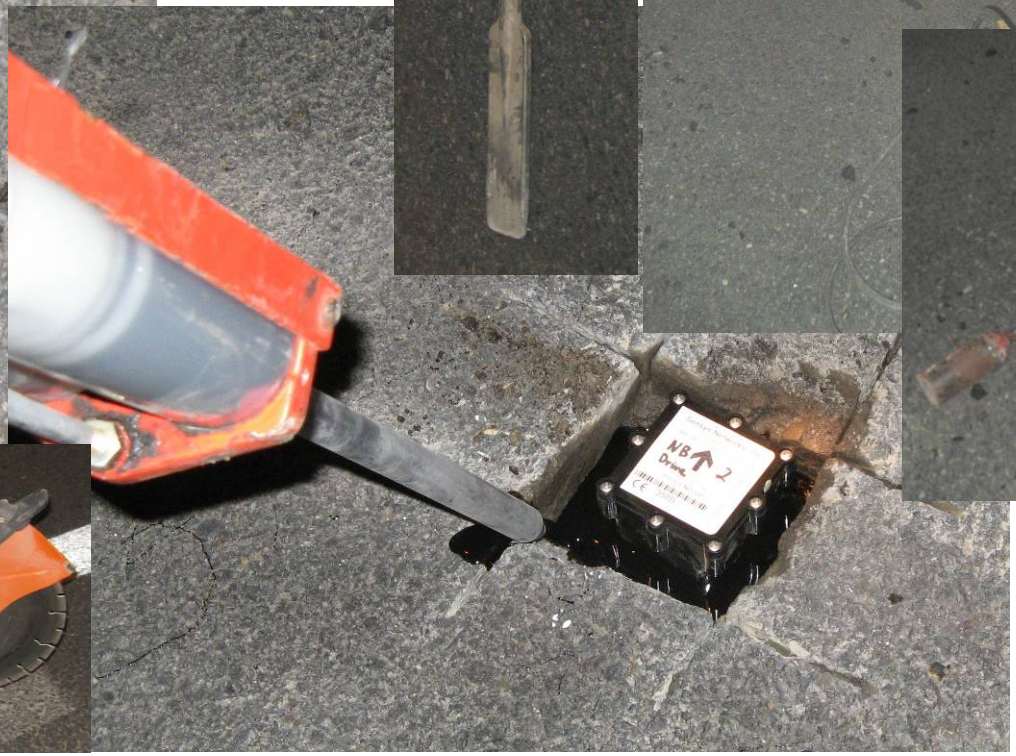
- Controller and Service Cabinets
- 50ft Camera Pole
- Loop Locations
- Sensys Network “Sensor” Locations

Access Point

Sensys Networks
Installation







Sensys Networks
Installation

Sensys Networks
Installation

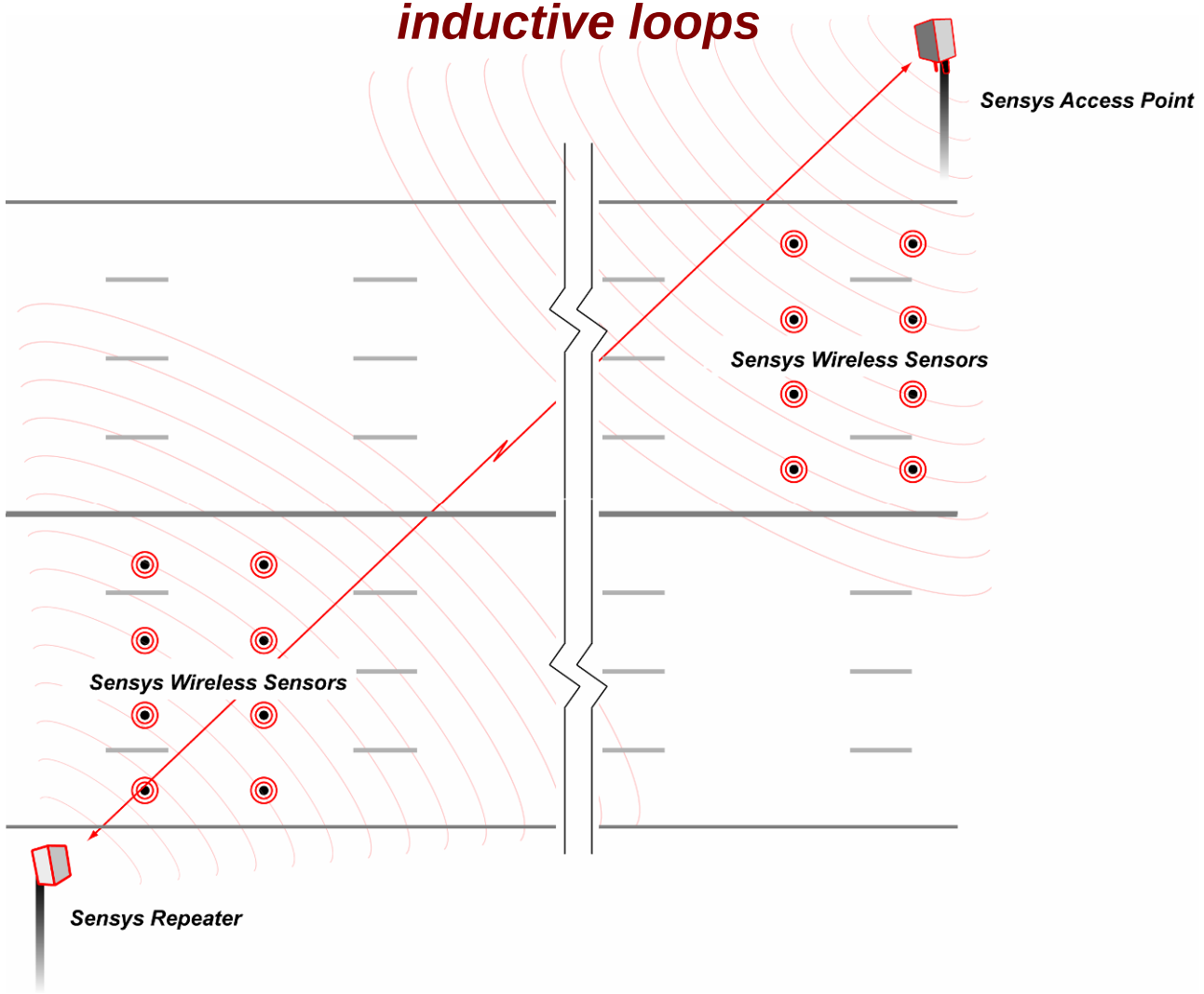
Video Clips

Sensys Networks Installation Video

WSDOT Field Test of Sensys Networks

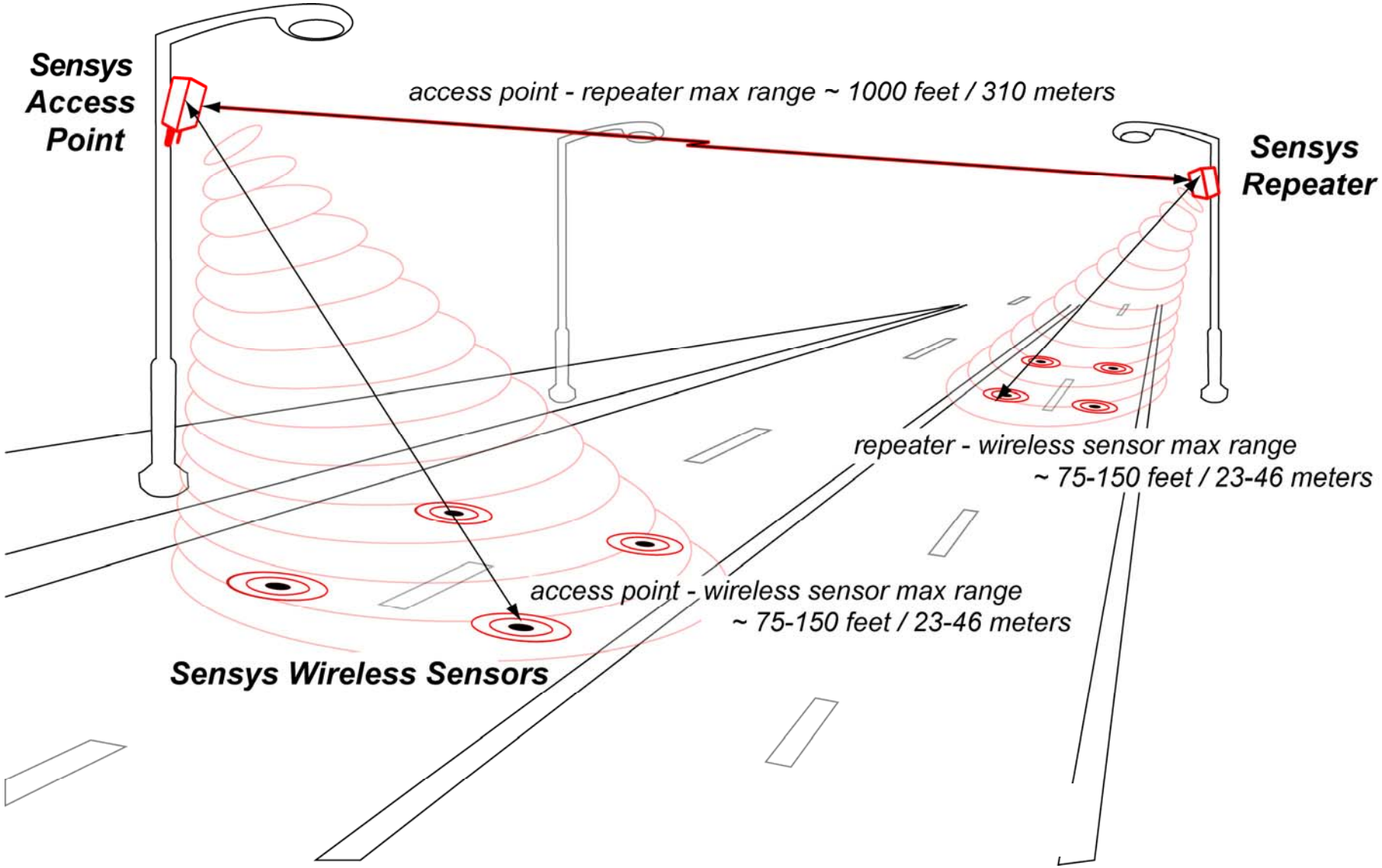
Permanent Count Station (Freeways/Arterials)

Vehicle count, speed, occupancy and classification – just like inductive loops



WSDOT Field Test of Sensys Networks

Radio Ranges

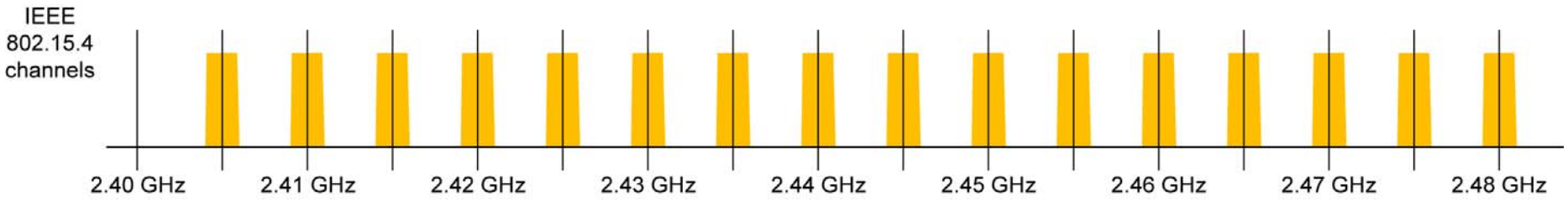


Sensys Networks

Standards-Based Radio Communications

Sensys has adopted standard radio technology

- IEEE 802.15.4 PHY ***– used by ZigBee and other wireless systems***
  - Data rate of 250 kbps used by Sensys
  - 16 frequency channels in the 2.4 GHz ISM band



- Power efficiency is achieved by shutting down the radio entirely outside its assigned time slot (more than 99% of the time).
- Sensys NanoPower (SNP) protocol
  - Operates on top of 802.15.4 PHY as Media Access Protocol (MAC)
  - TDMA scheme allocates time slots for each sensor's transmission
  - Access point acknowledges reception; each sensor re-transmits data is unacknowledged

Sensys Networks

RF Considerations

- AP, RP and sensors have directional antennas – propagation not uniform in all directions.
- AP to Repeater must be in line of sight.
- Up to 1000’ when directly facing each other.
- If they are off axis, distance will be shorter. Make sure of adequate signal strength.

Sensys Networks

SNAPS Manager

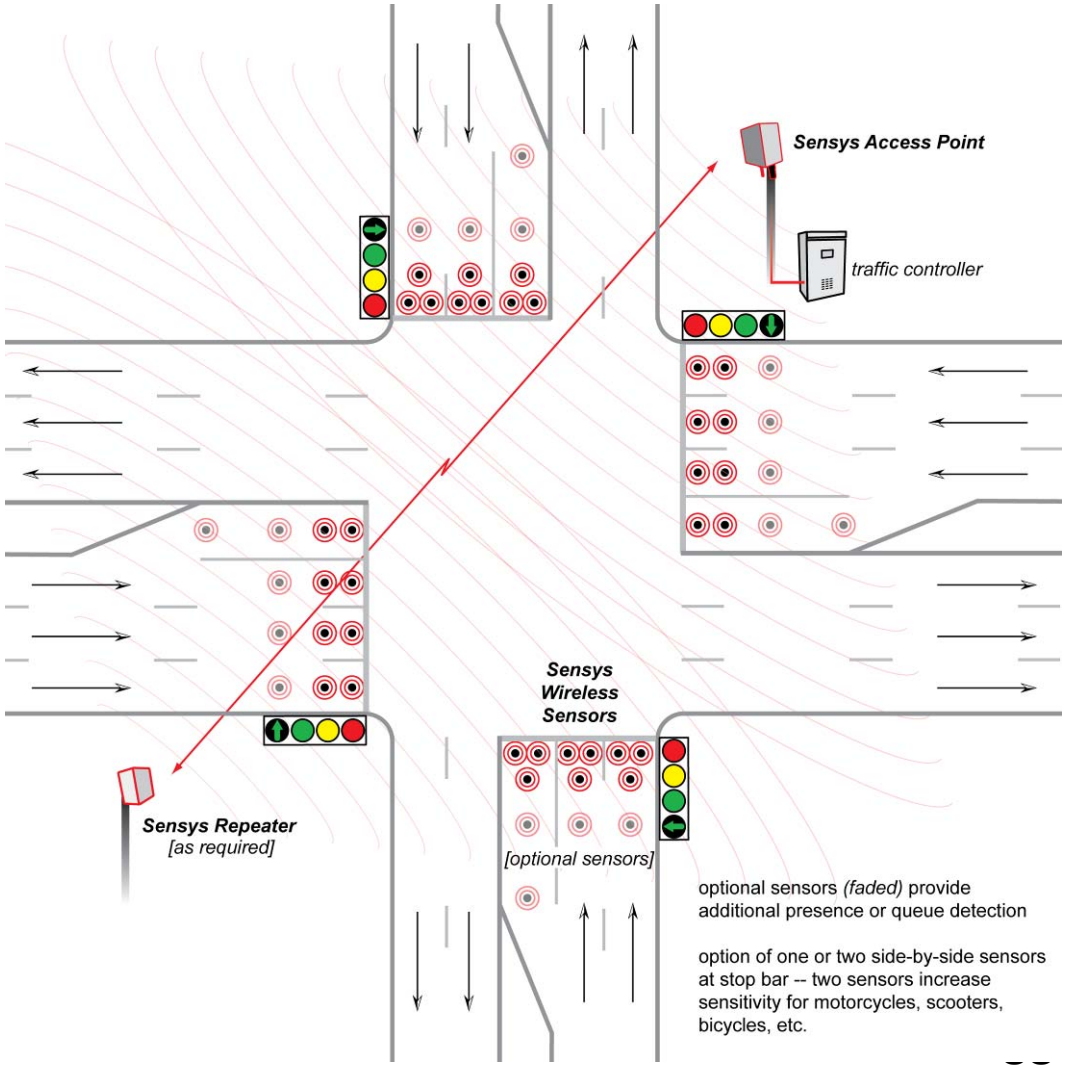
Communications, data analysis & archiving, and network management

- SNAPS Server =
  Sensys Networks Application, Proxy, and Statistics Server
  - Software for server platforms operating under Linux
  - Supported by standard Pentium class PC
- Supports IP connectivity to network of Sensys access points
  - VPN
  - Proxy
  - Facilitates use of cellular data services to provide IP connectivity to APs
- Data archiving
- Supports Internet user access to data
- Push/Poll capability to other applications
- Hosts application-level analysis software

Sensys Networks – Traffic Signal

Stop Bar Detection

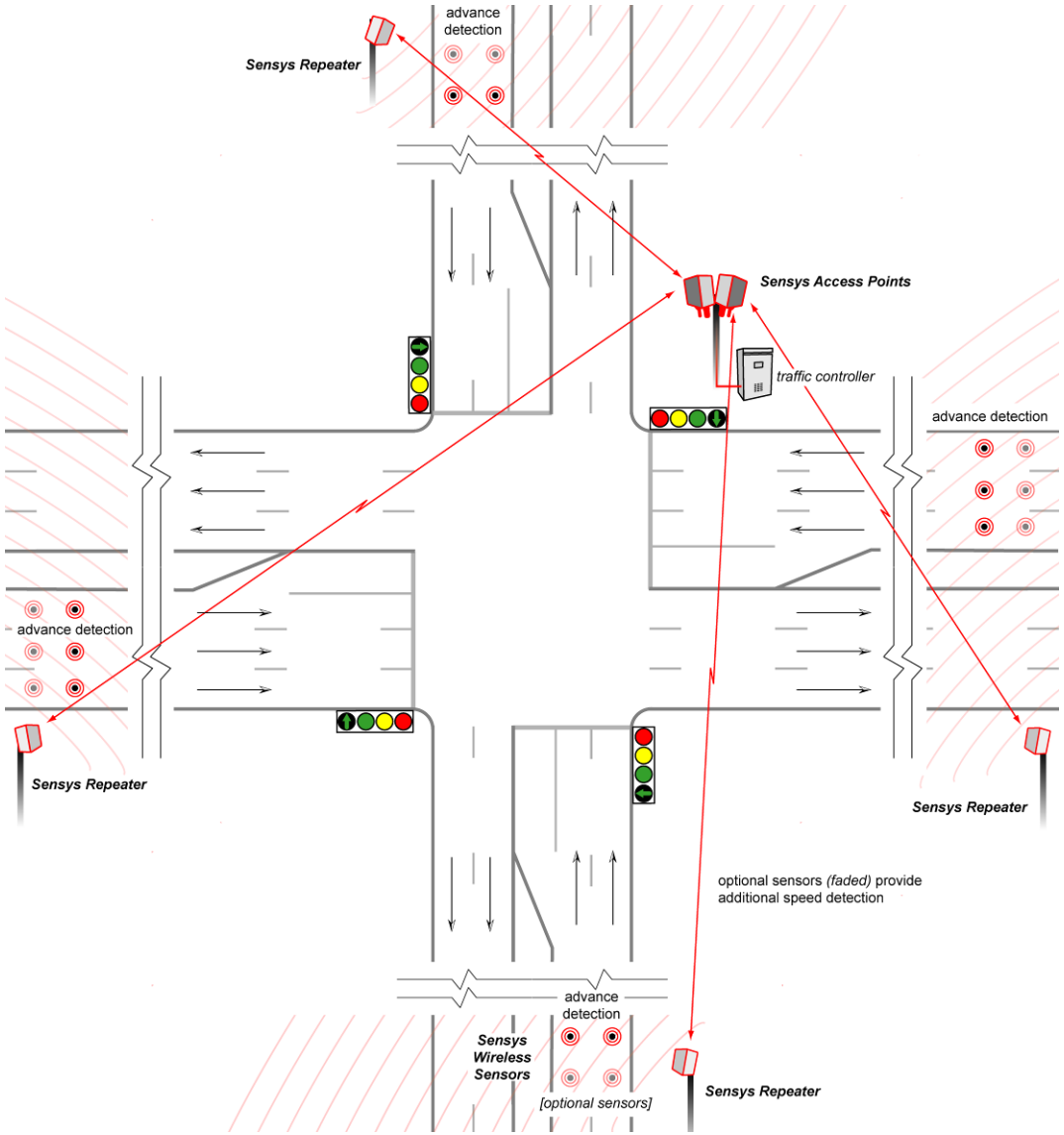
- Wireless sensors can be deployed just like inductive loops
  - Presence detection at/near stop bar
  - Queue detection in turn lanes
- Access point interfaces directly to traffic controller using contact closure cards
  - Presence or pulse modes
  - Sensors in same lane can be OR'ed together



Sensys Networks – Traffic Signal

Advance Detection

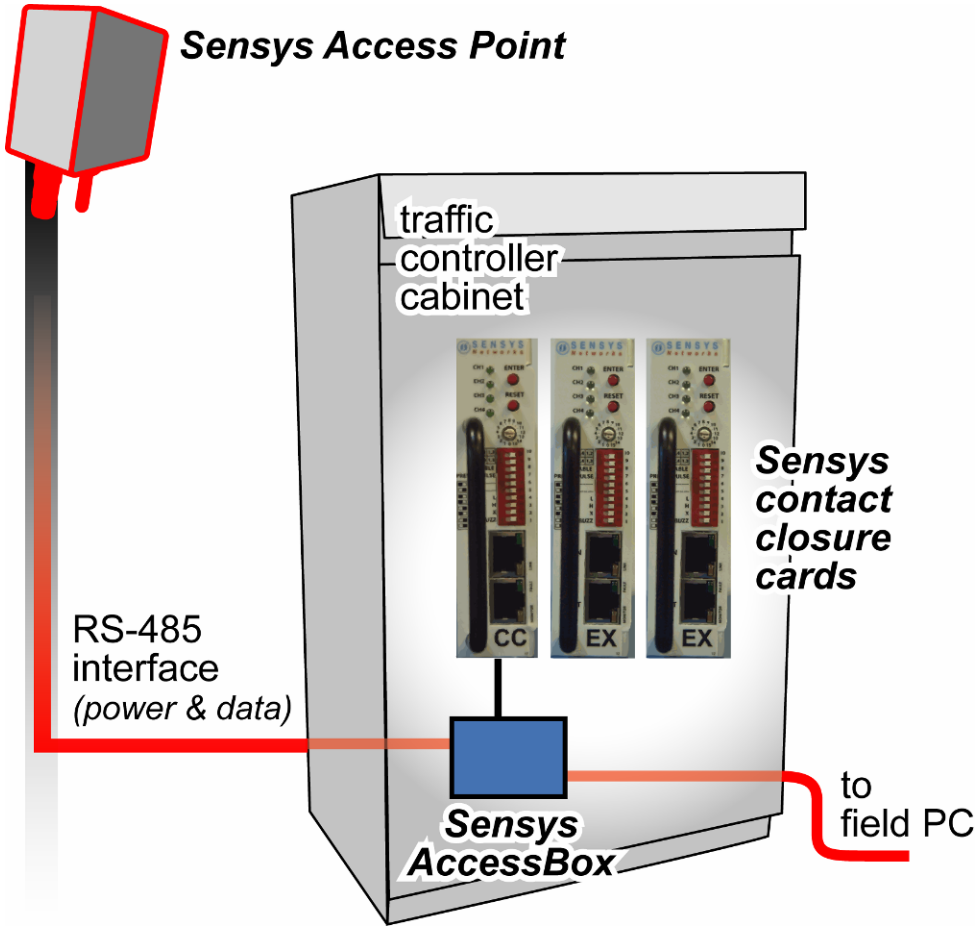
- Wireless sensors located mid-block
  - Traffic calming
  - Dilemma zone protection
- Access point interfaces directly to traffic controller
- Repeaters extend access point range from traffic controller to mid-block locations



Sensys Networks – Traffic Signal

Serial Interface to Traffic Controllers

Interoperable with current roadside infrastructure



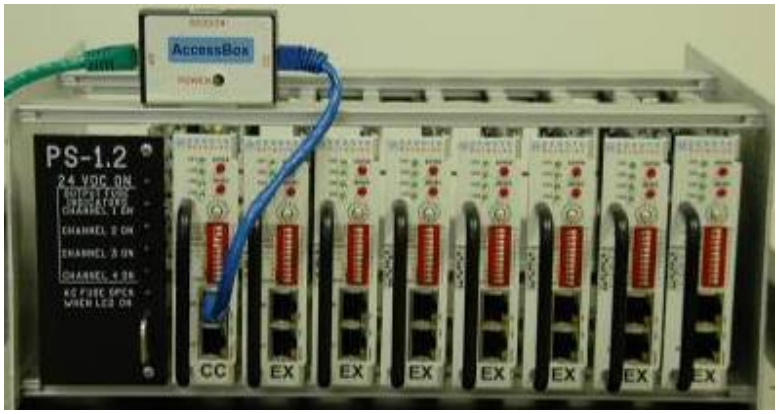
- Type 170
- Type 2070
- NEMA TS1
- NEMA TS2

Sensys Networks – Traffic Signal

Contact Closure (CC) & Expansion (EX) Cards

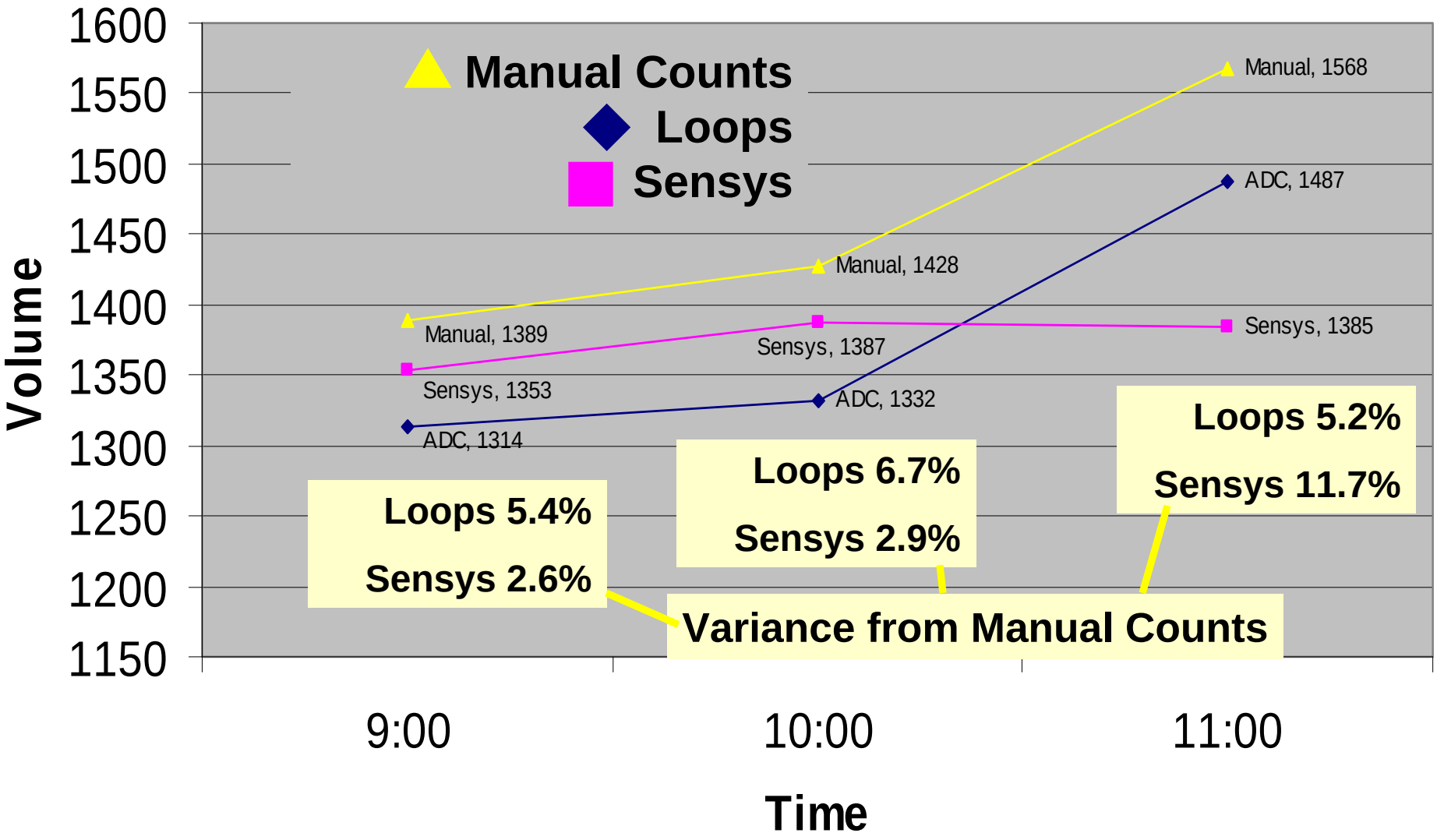
Allow use of Sensys wireless sensors exactly like inductive loops

- One CC card per Access Point
  - Up to 4 channels (i.e., 4 contact closures) per card
  - Provides power and electrical isolation to Sensys access point.
- Additional EX cards as required (4 channels per card)

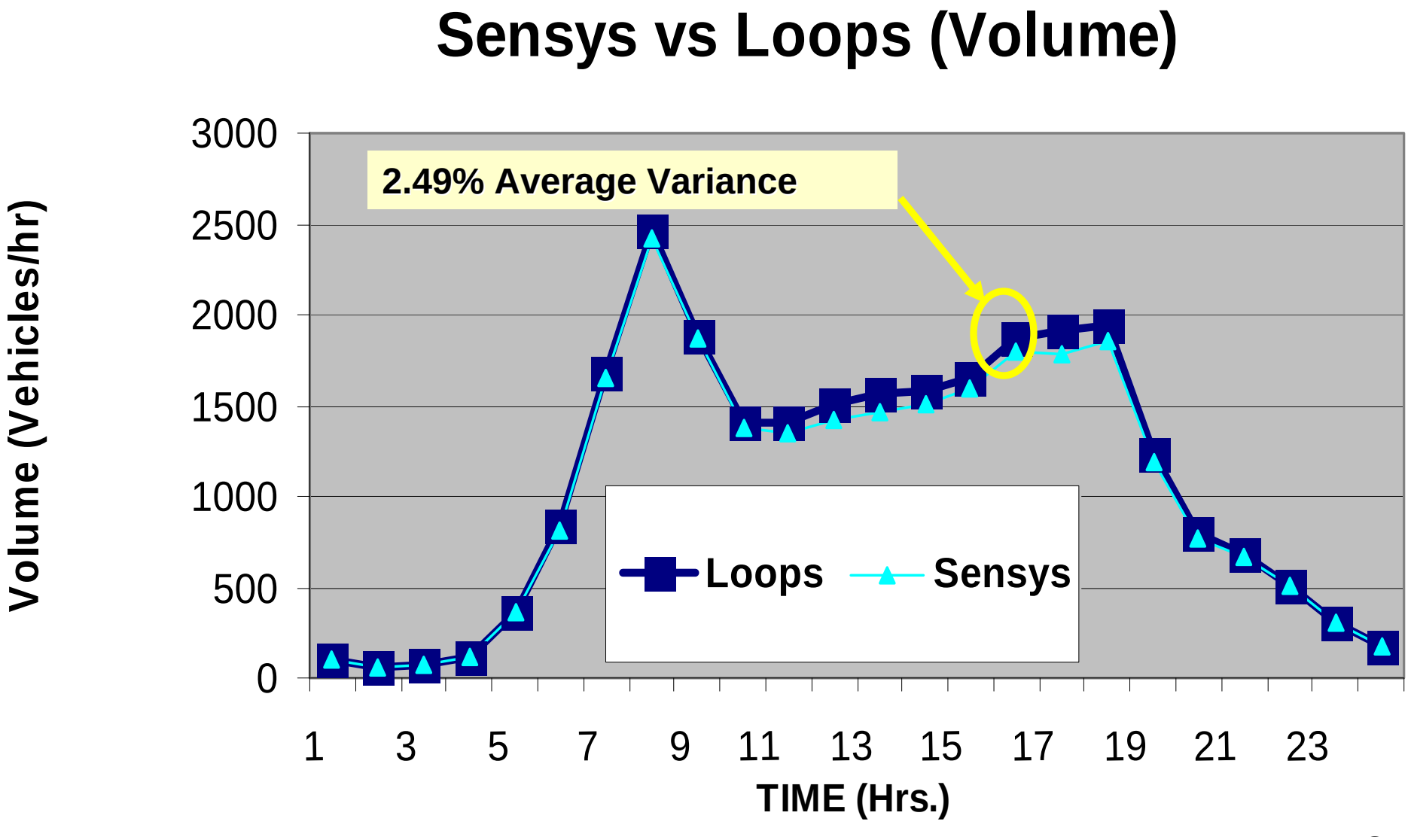


Sensys Networks – Evaluation

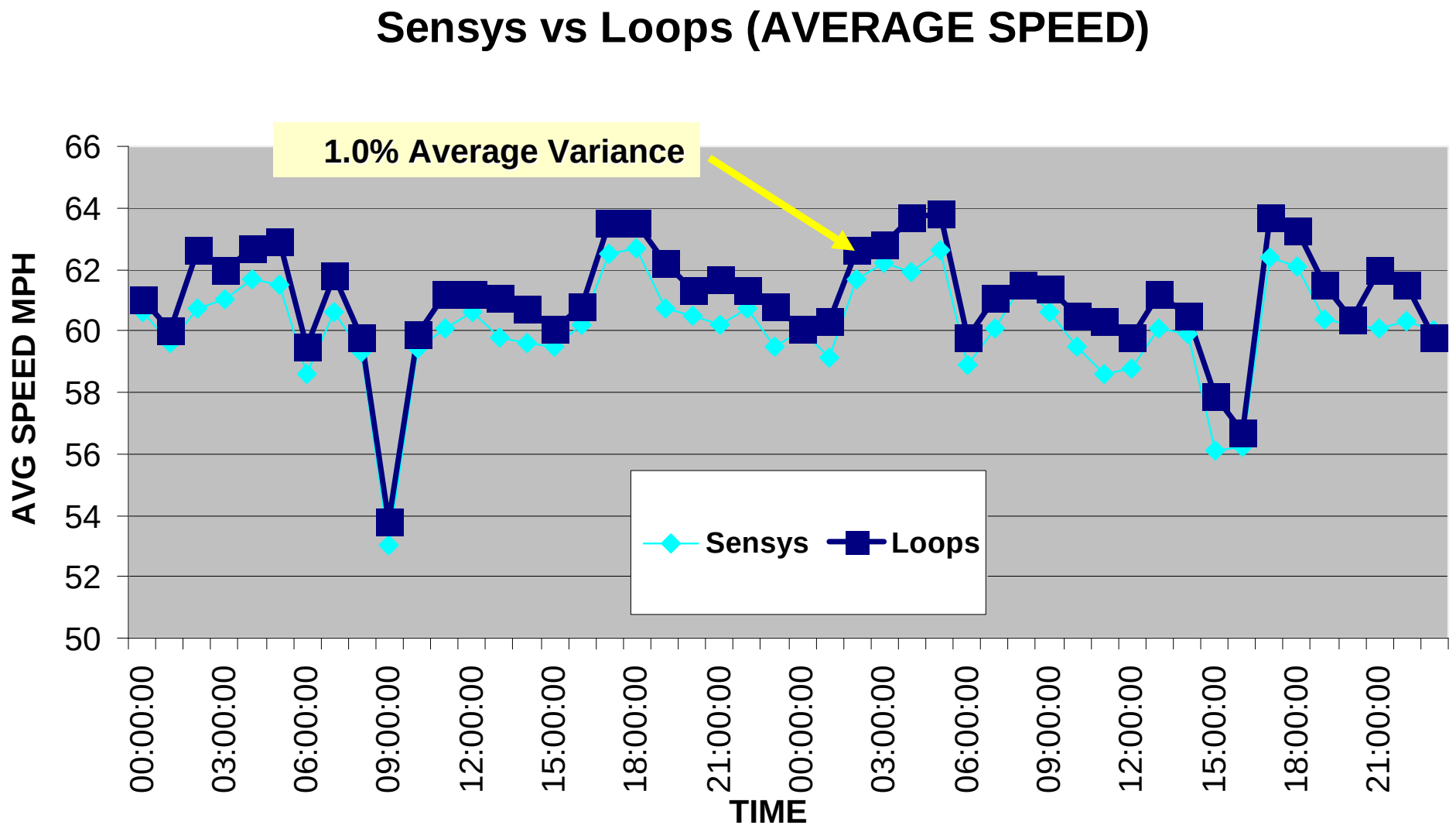
Volume



Sensys Networks – Evaluation



Sensys Networks – Evaluation



Sensys Networks

- **Cost**

Flush-Mount Wireless Sensor

- $460 each

Install - $2,000 for 8 sensors
In 4 lanes / 4hrs

Access Point (GRPS Model)

- $3,600 each

Repeater

- $625 each

Controller interface

- $296 each (each card simulates 4 contact closures

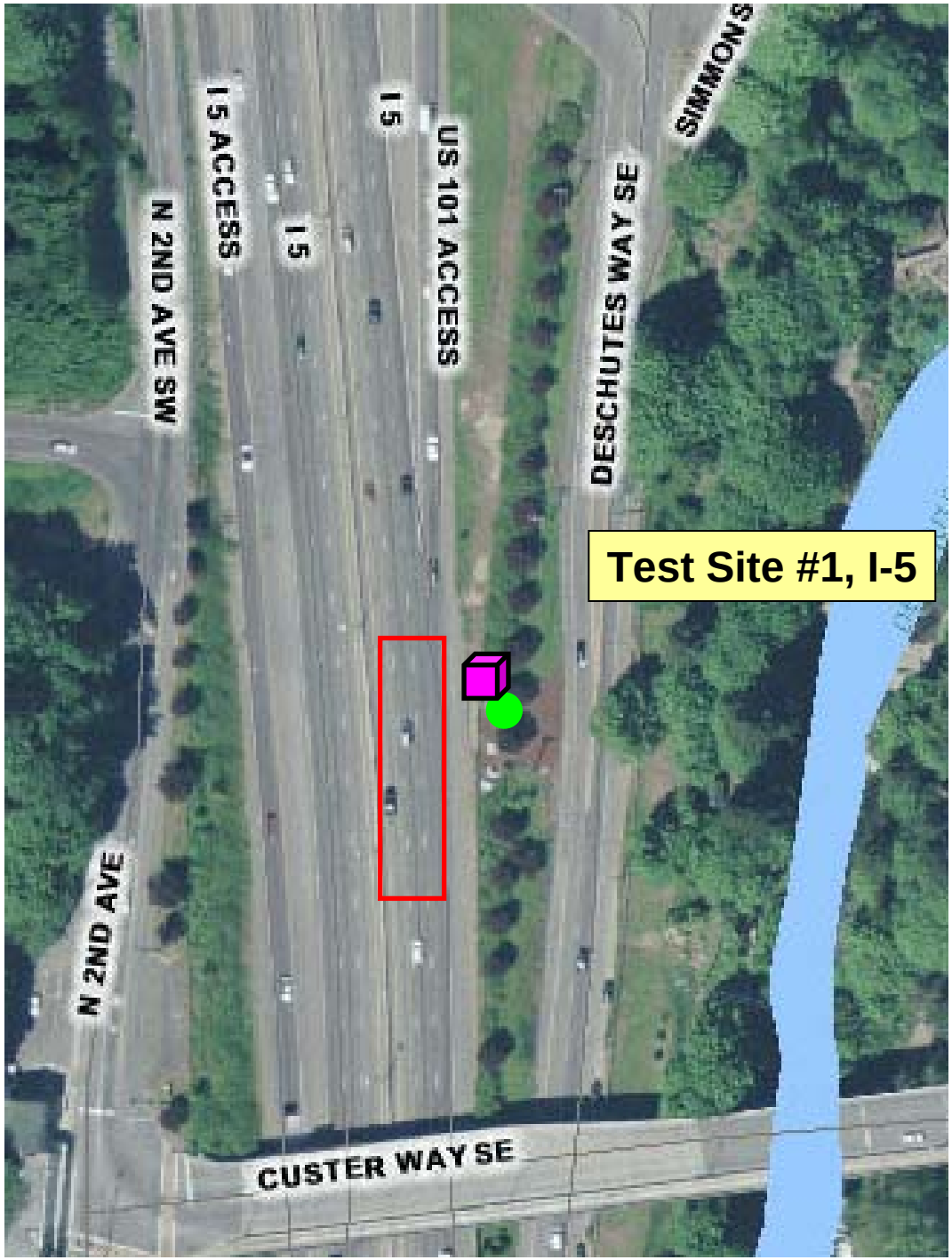
- **Procurement**
  - **State General Administration Contact – Direct buy from McCain**

Sensys Networks Recommendations / Conclusions

1. Equipment set up is strait forward with online manuals and phone support. 1st time set up took 31/2 hrs to configure the A/P and Sensors.
2. Installation took 20 min per lane not including traffic control set up, our State force crew averaged 1 hour per lane including traffic control.
3. Quality of data when pulled from the SNAPS server was better than 97% for speed and Volume
4. SNAP Server Limitations
5. Quality of Data when run through a Diamond Counter and Sensys Contact Closure Cards was not measurable as the Diamond Counter is not compatible with this system.
6. The Sensys system will be tested against loops for intersection control, (i.e. Stop Bar Detection and Queue Detection).

Wavetronix Evaluation

- 50ft Camera Pole
- Loop Locations
- Wavetronix Sensor Location



Wavetronix Evaluation

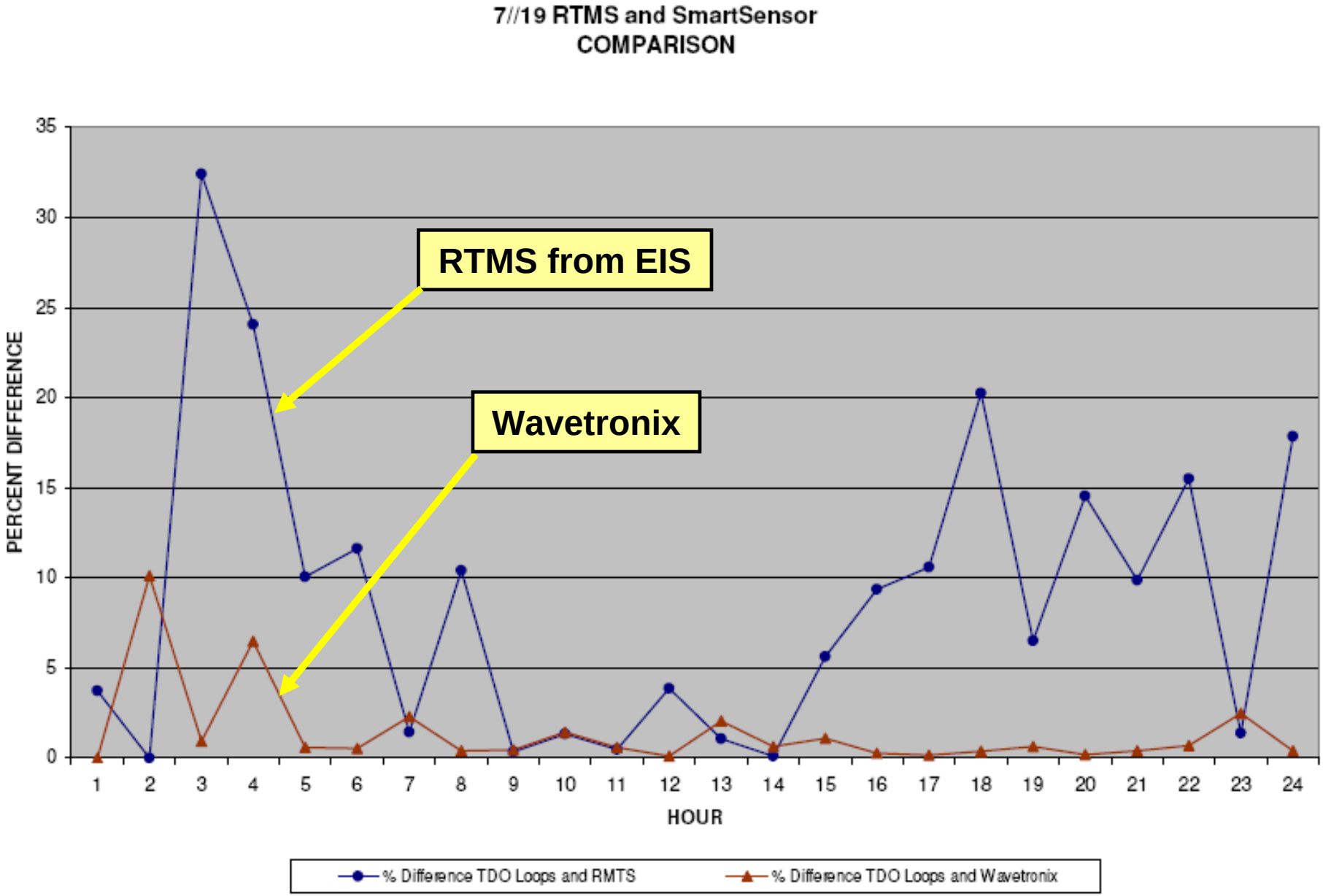
- Cost, $10,00-$20,000 depending on utilities (power & com)
- Simple Installation and calibration
- Concrete barrier caused challenges in environment for the sensor (Splash)
- Occlusion is a major factor in volume error's in area with higher truck volumes

Wavetronix Evaluation

Click 100

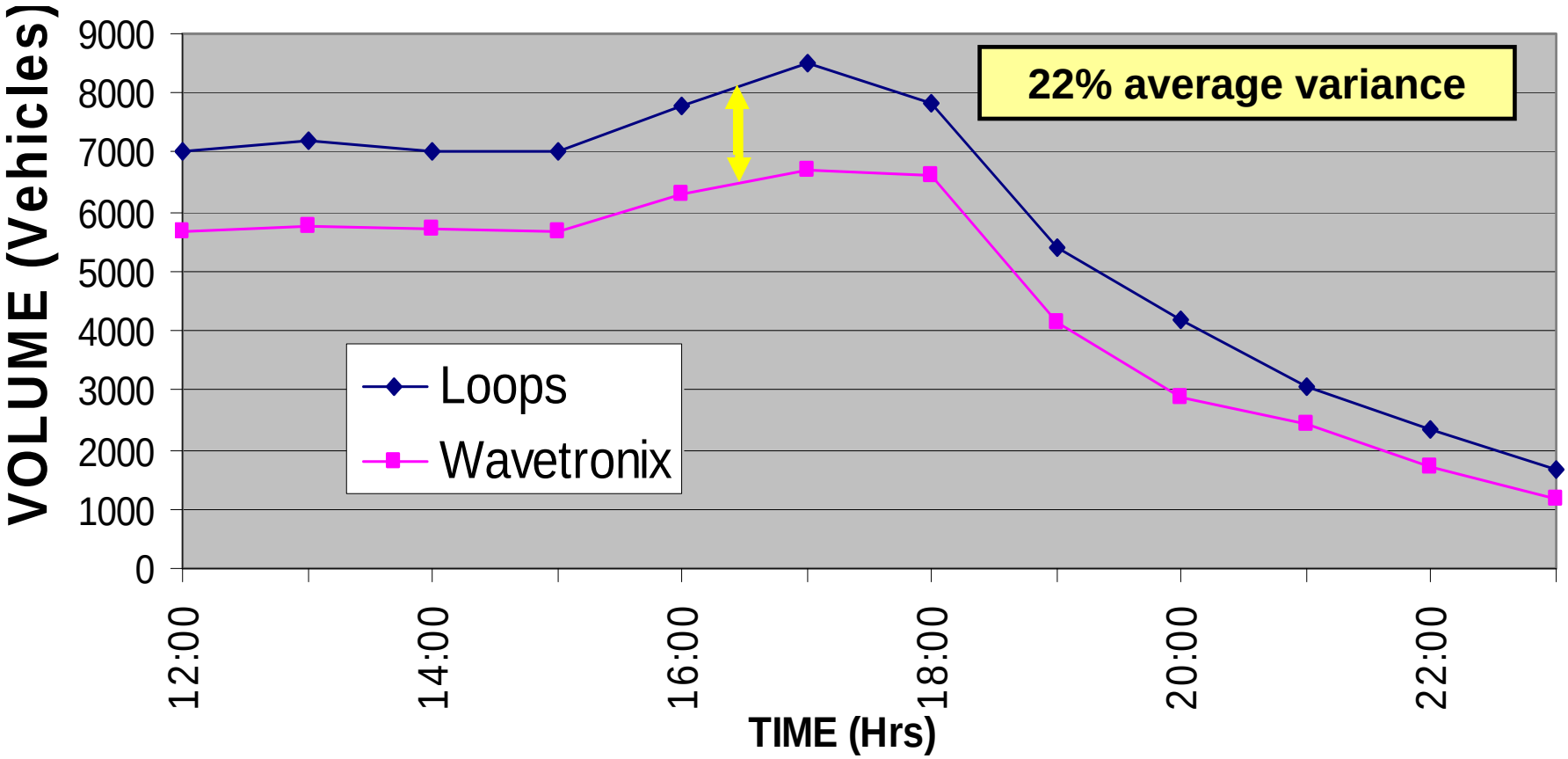
- Collects real time traffic data
- Has 16 outputs to emulate up to 8 lanes of two-loop data
- Auto-detection of baud rates and sensor configuration
- Pluggable screw terminals
- DIN rail mounted
- Hot-swappable power and communication buses
- Multiple modes of operation
- Front panel LEDs provide visual confirmation of vehicle detections
- Low power device

Wavetronix Evaluation
Loops vs Wavetronix and RTMS



Wavetronix Evaluation

Wavetronix vs Loops (Volume)



Wavetronix Conclusions / Recommendations

1. 95% accuracy for speed and volume (at right locations)
2. Initial set up was done with manufacture and was done in less than 2 hour
3. Not recommended for locations with divided concrete barrier, concrete walls or structures.
4. Wavetronix was set up on a 8 lane highway separated with a concrete barrier and a concrete retaining wall 200ft from the sensor and the sensor operated at 75-80%
5. Wavetronix works well in the right location for providing Speed and Volume data, however requires monthly power and communication service

Cohu idome Demonstration

Sensys Networks Archive, Proxy, and Statistics (SNAPS) Server Demonstration