

What Happens When the Freeway is Closed for Repairs?

Results from the Fix-I5 Study

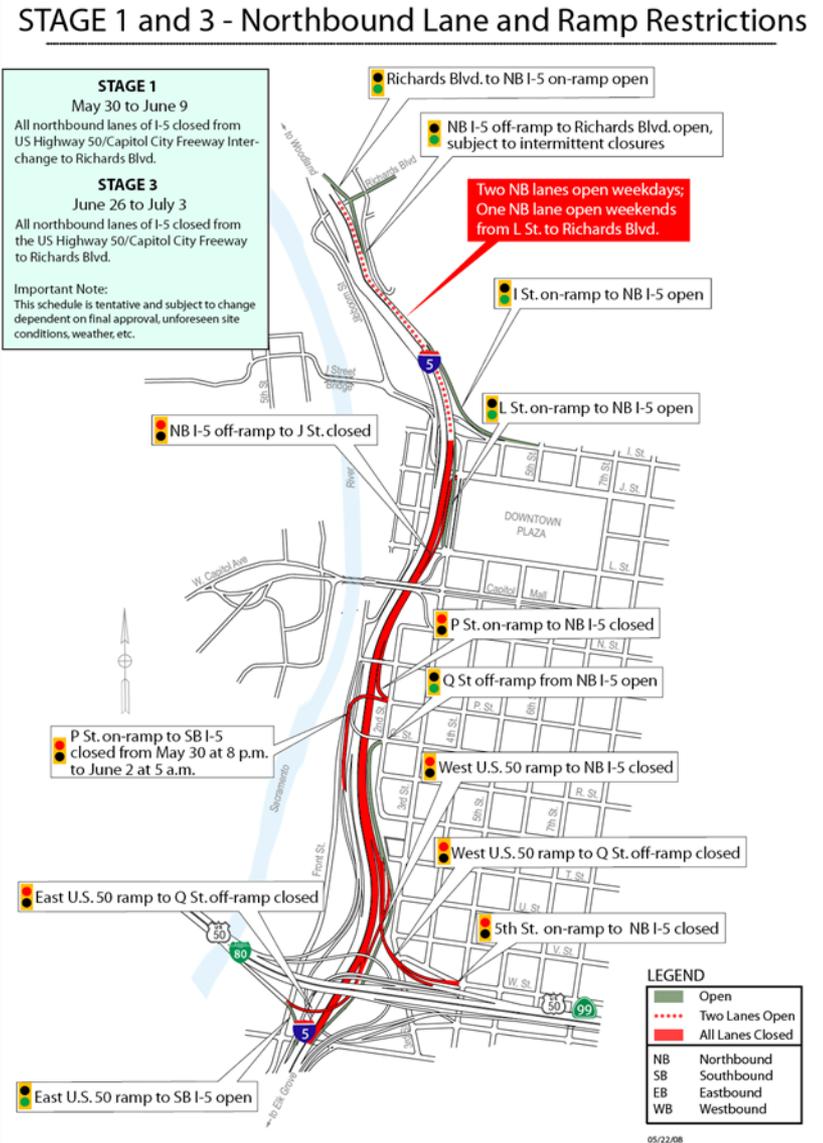
Prof. Michael Zhang
Dept. of Civil and Env. Engineering, and
Institute of Transportation Studies
University of California
Davis, CA 95616

Outline of Presentation

- What is the Fix-I5 project?
- Data Collection
- Summary of Results
 - Changes in transit ridership
 - Changes in traffic flow (passenger cars and trucks, freeway and arterial)
 - Changes in travel times
- Modeling VMT and Emissions
- Conclusions

The Fix-I5 project: Repair of the "Boat" section

- 190,000 vehicles per day
- Full closure of one direction at a time
- 4 stages of closures, 2 for NB
2 for SB
- 35 working days + 3 weekends
May 30, 2008-July 27, 2008



Picture courtesy of Fix-I5 project website

The Fix-15 project: Why?

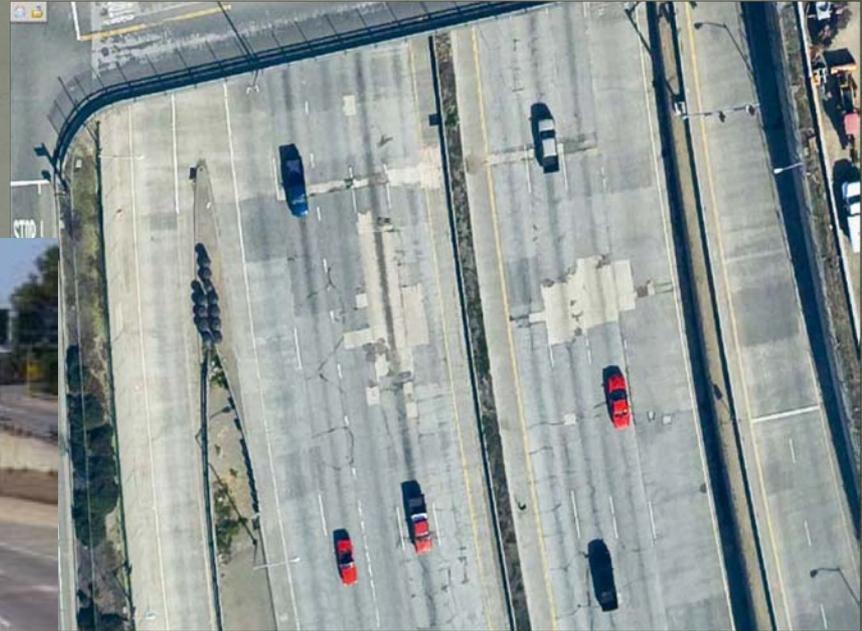


Photo courtesy of Ryan Billeci
City of Sacramento

What the FiX-15 Study Tries to accomplish?

- What is the **actual** traffic impact of the project?

Major traffic impacts were anticipated:

SacBee.com reported on 4/14/2008 that travel times for commuting during the fix-i5 project:

- “Elk Grove and Laguna areas toward downtown/ **Quadruple** (NB C) / **Double** (SB C)”
- “80/50 toward downtown from Davis/Yolo/ **19 times** (SB C)”

EXECUTIVE ORDER S-04-08

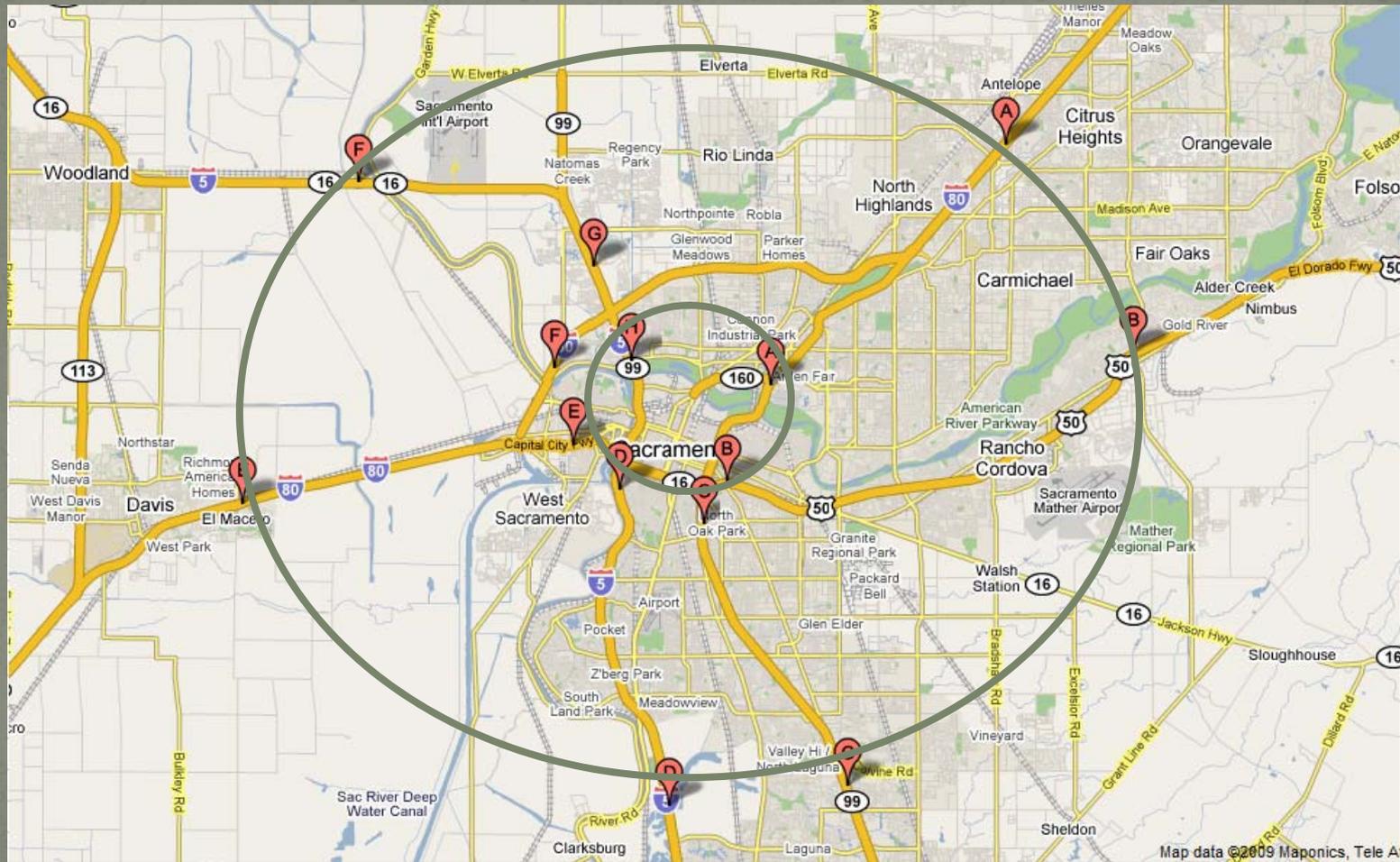
“WHEREAS reports indicate that the closure of portions of Interstate 5 could cause up to **nineteen times** the amount of current traffic congestion during commute hours”

- How do travelers respond?
- What can we learn from this project?
 - Future planned large reconstruction projects
 - Disaster response (earthquake, fire, etc)

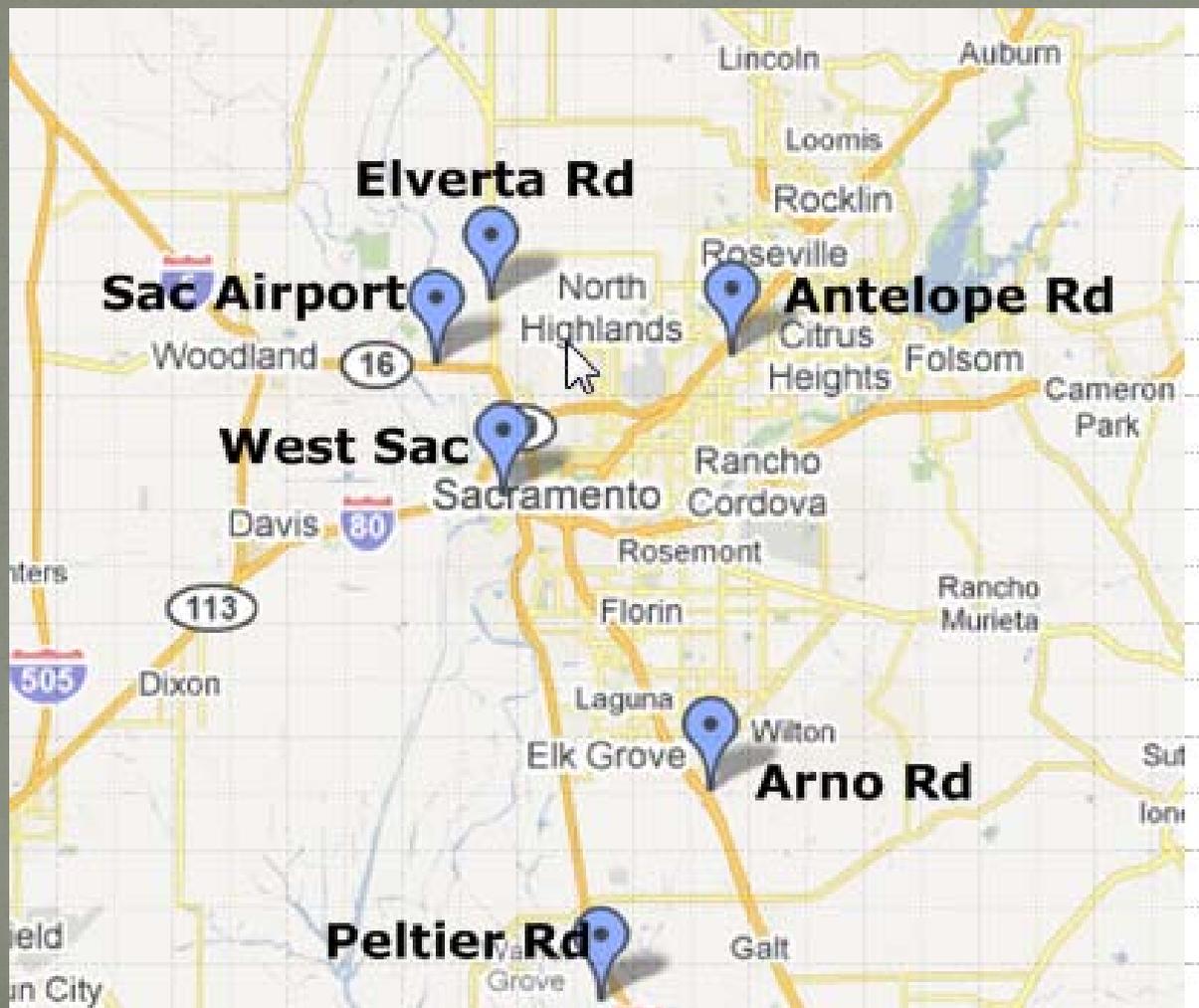
Data Collected

- Ground Truth Data (Prof. Michael Zhang)
 - PeMS Traffic Counts on Freeways
 - 24 hour traffic counts on major arterials on the periphery of downtown Sacramento
 - Weigh-in-motion truck counts
 - Floating car (GPS) travel time measurements on major detour arterial routes
 - Screen line light rail ridership counts
 - Transit ridership from all local transit agencies
- Behavior Data (Prof. Pat Morkhtarian)
 - Three waves of on-line travel survey

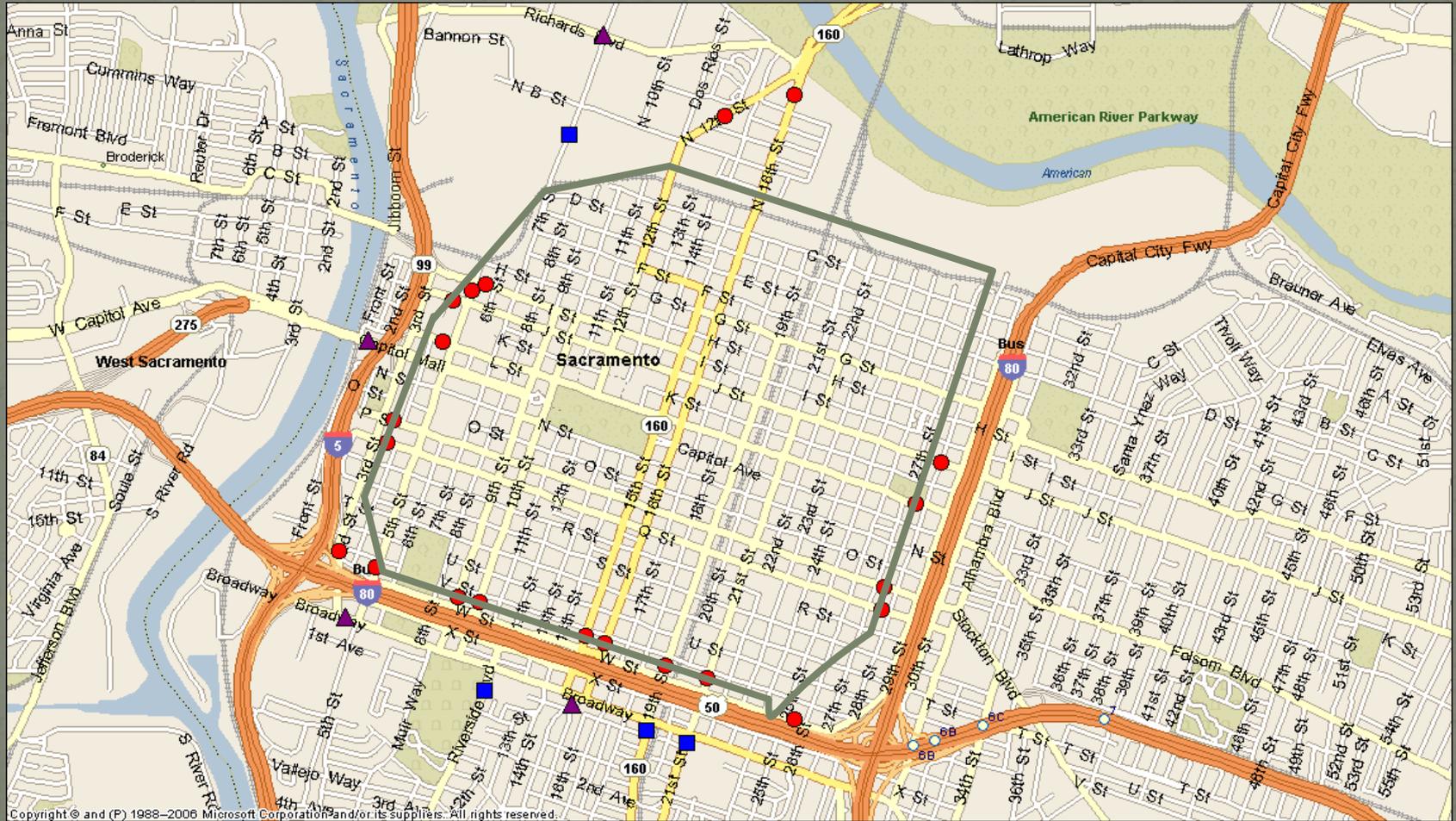
Traffic Counts: Freeway Locations



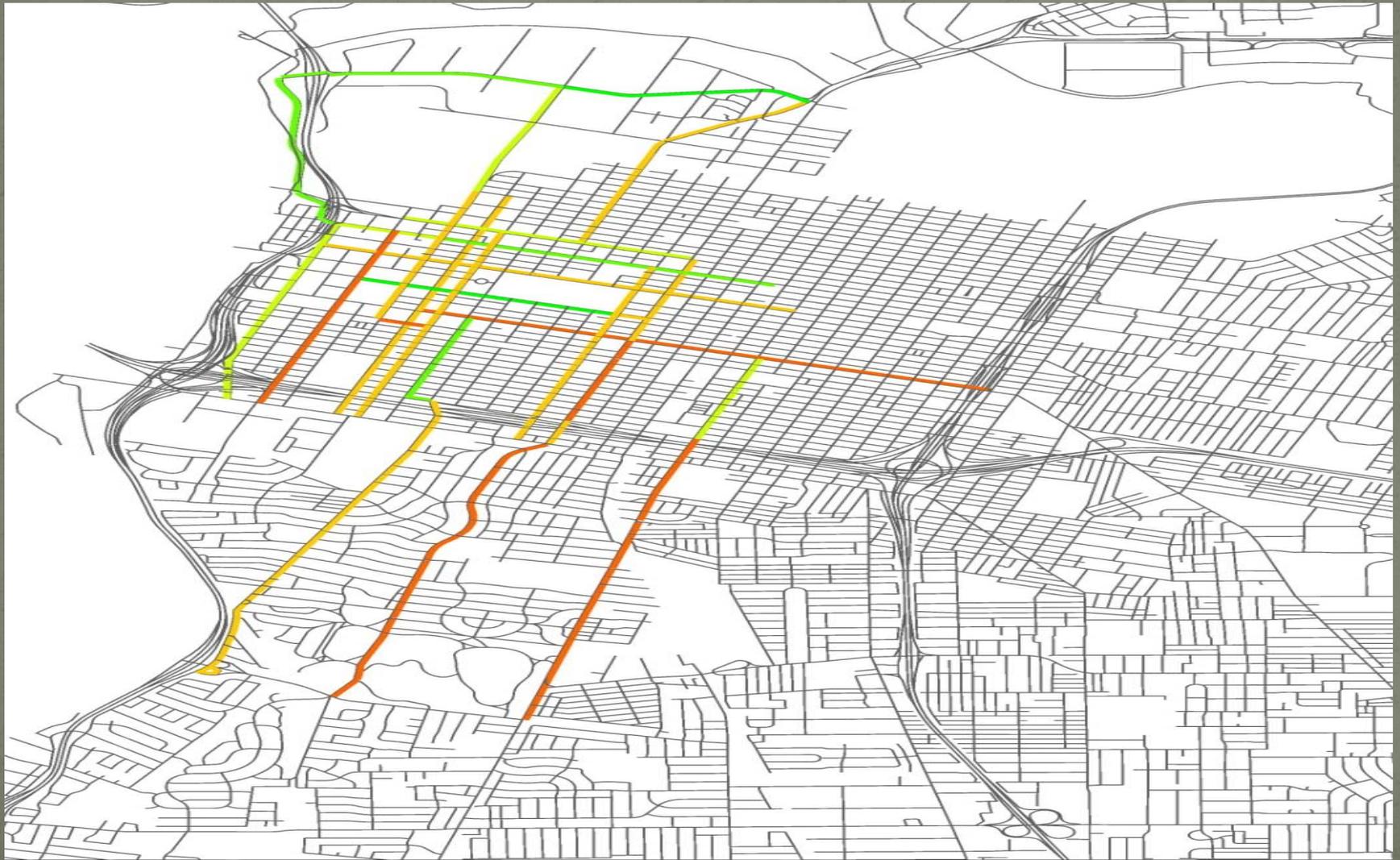
Weigh-in-Motion Truck Volume Count Locations



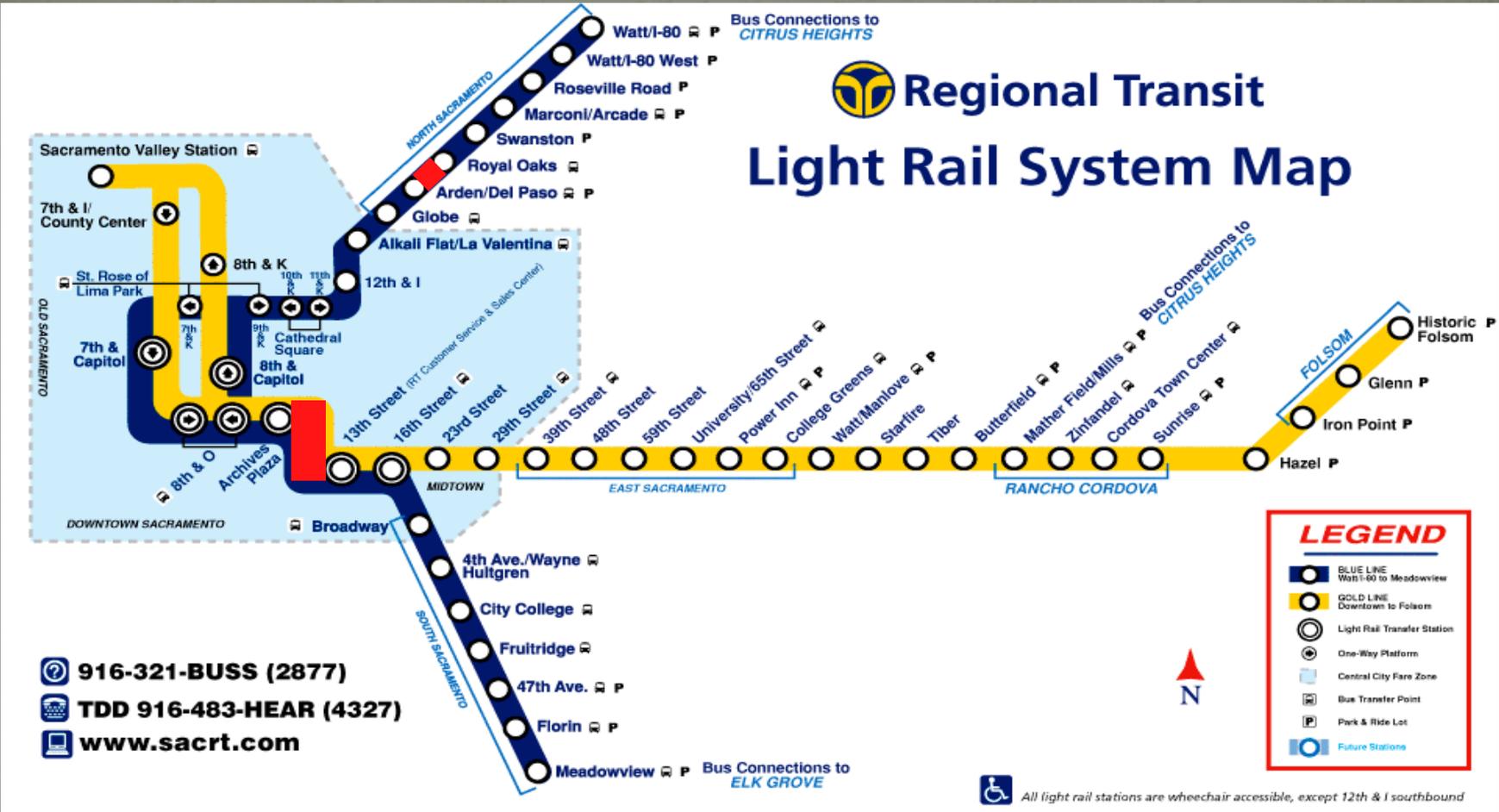
Traffic Counts: Arterial Locations



Arterial Travel Times: GPS measurement routes



Light Rail Ridership Count Locations



The map shows the Sacramento Light Rail system with the following stations and features:

- North Sacramento Line (Blue Line):** Watt/I-80 P, Watt/I-80 West P, Roseville Road P, Marconi/Arcade P, Swanston P, Royal Oaks P, Arden/Del Paso P, Globe P, Alkali Flat/La Valentina P.
- Downtown Sacramento (Central City Fare Zone):** Sacramento Valley Station, 7th & I/County Center, St. Rose of Lima Park, 7th & Capitol, 8th & Capitol, Cathedral Square, 8th & K, 9th & K, 10th & K, 11th & K, Archives Plaza, 8th & O, Broadway.
- Midtown Line (Blue Line):** 12th & I, 13th Street (RT Customer Service & Sales Center), 16th Street, 23rd Street, 29th Street, 39th Street, 48th Street, 59th Street.
- East Sacramento Line (Gold Line):** University/65th Street P, Power Inn P, College Greens P, Watt/Manlove P, Starline P, Tiber P, Butterfield P, Mather Field/Mills P, Zinfandel P, Cordova Town Center P, Sunrise P.
- Rancho Cordova Line (Gold Line):** Hazel P.
- Folsom Line (Gold Line):** Iron Point P, Glenn P, Historic Folsom P.
- South Sacramento Line (Blue Line):** 4th Ave./Wayne Hultgren P, City College P, Fruitridge P, 47th Ave. P, Florin P, Meadowview P.

Transfer points and connections are marked with 'P' and 'Bus Connections to CITRUS HEIGHTS' or 'ELK GROVE'. A legend in the bottom right explains the line colors and symbols.

 **916-321-BUSS (2877)**
 **TDD 916-483-HEAR (4327)**
 **www.sacrt.com**

LEGEND

-  BLUE LINE
Watt/I-80 to Meadowview
-  GOLD LINE
Downtown to Folsom
-  Light Rail Transfer Station
-  One-Way Platform
-  Central City Fare Zone
-  Bus Transfer Point
-  Park & Ride Lot
-  Future Stations

 All light rail stations are wheelchair accessible, except 12th & I southbound

Bus Transit Ridership Data

Transit Agencies providing data:

- Yuba-Sutter Transit
- North Natomas Transportation Management Association (The Flyer)
- Yolo County Transportation District (Yolobus)
- Roseville Transit
- Elk Grove Transit (E-TRAN)
- Sacramento Regional Transit



Methods of Data Collection

- Automatic Passenger Counters (APC)
- Electronic Fareboxes
- Manual Counts by Route Checkers
- Manual Counts by Bus Driver

Transit Agency	Contact	Contact's Official Position Title	Type of Personal Correspondence
Regional Transit	James Drake	Assistant Planner	e-mail, phone, mail, in-person
Yolobus	Erik Reitz	Transit Planner	e-mail, phone, mail, in-person
Roseville Transit	Teri Sheets	Alternative Transportation Analyst	e-mail
	Elizabeth Haydu	Administrative Technician	e-mail, phone, in-person
North Natomas TMA	Sarah Janus	Program Coordinator	e-mail
Yuba-Sutter Transit	Dawna Dutra	Analyst	e-mail, phone

Data Scope

- *Routes*: Origins and Destinations within Sacramento Downtown core
 - North boundary: Richards Blvd
 - South boundary: 50/80 Freeway
 - West boundary: Sacramento River
 - East boundary: Business 80/99 Freeway
- *Time*: Peak Hour Travel (as defined by each transit agency) but approximately:
 - AM Peak (Inbound): 6:30AM-9:30AM
 - PM Peak (Outbound): 3:00PM-6:00PM
- *Days*: Tuesday through Thursday

Data Sample after Filtering

Transit Agency	Downtown-Servicing Lines
Regional Transit	2,3,6,7,11,15,29,30,31,33,34,36,38,50E,51,62,63,67,68,86,88,89,109
Yolobus	39,40,41,42A,42B,43,44,45,230,231,232,240,241
North Natomas	Eastside Route, Westside Route, and Central Route
Roseville Transit	AM Routes 1-8, PM Routes 1-8
Yuba-Sutter Transit	Sacramento Commuter Express

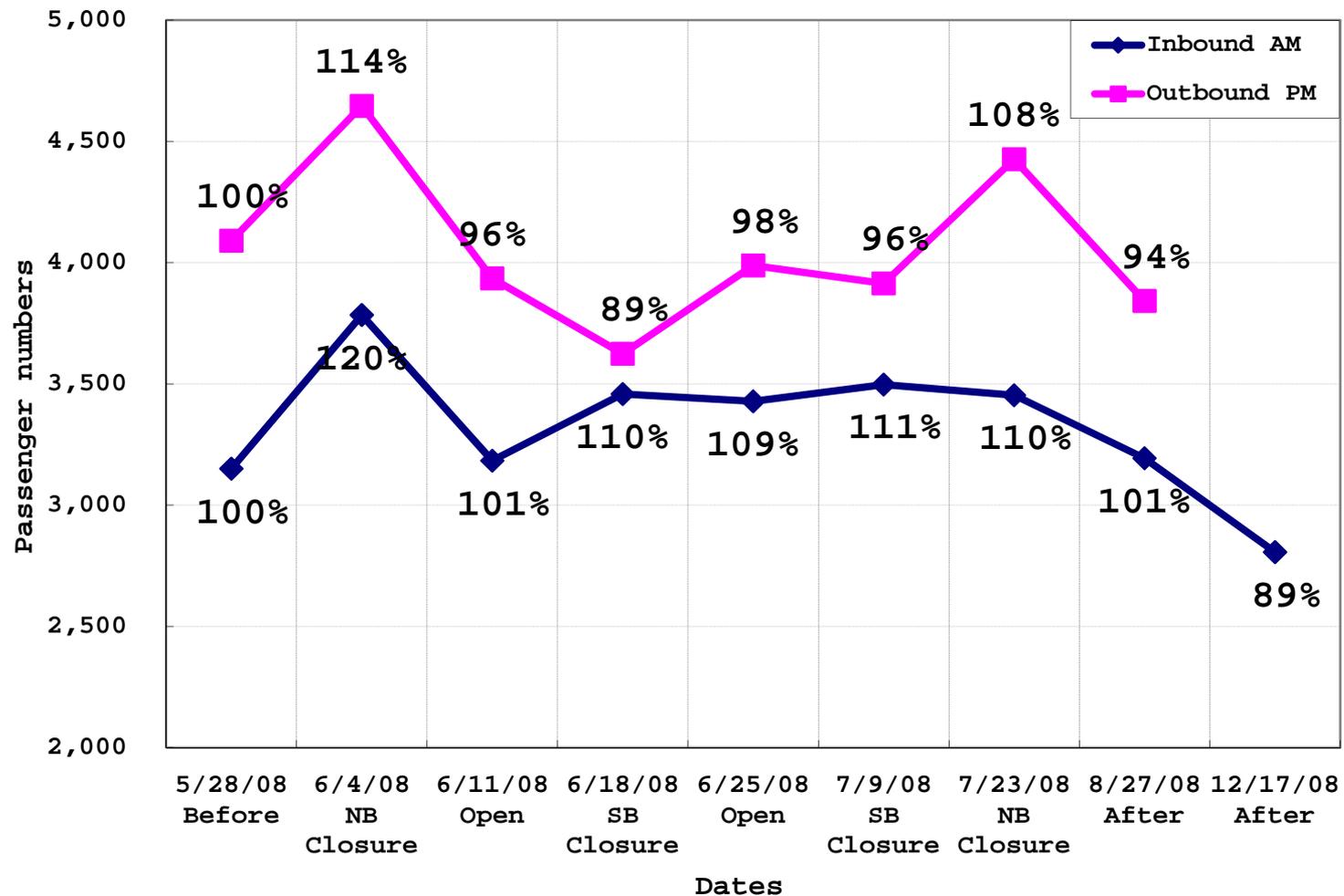
Transit Agency	AM Peak Period Definition	PM Peak Period Definition
Regional Transit	6:30-9:00	3:00-6:00
Yolobus	Daily Data	Daily Data
North Natomas	<i>Route:</i> Eastside: 5:54-9:04, Westside: 6:00-7:44, Central: 6:03-9:04	<i>Route:</i> Eastside: 3:35-6:54, Westside: 4:30-6:30, Central: 4:07-7:06
Roseville Transit	5:00-9:00	3:30-7:30
Yuba-Sutter Transit	5:20-8:00	3:45-6:50

Transit Agency	Time Period	Aggregation	Sample Size
Regional Transit	2008	Weekly, Peak Period	49
Yolobus	2006-2008	Daily	441
North Natomas	2008	Daily, Peak Period	147
Roseville Transit	2006-2008	Daily, Peak Period	441
Yuba-Sutter Transit	2006-2008	Daily, Peak Period	441

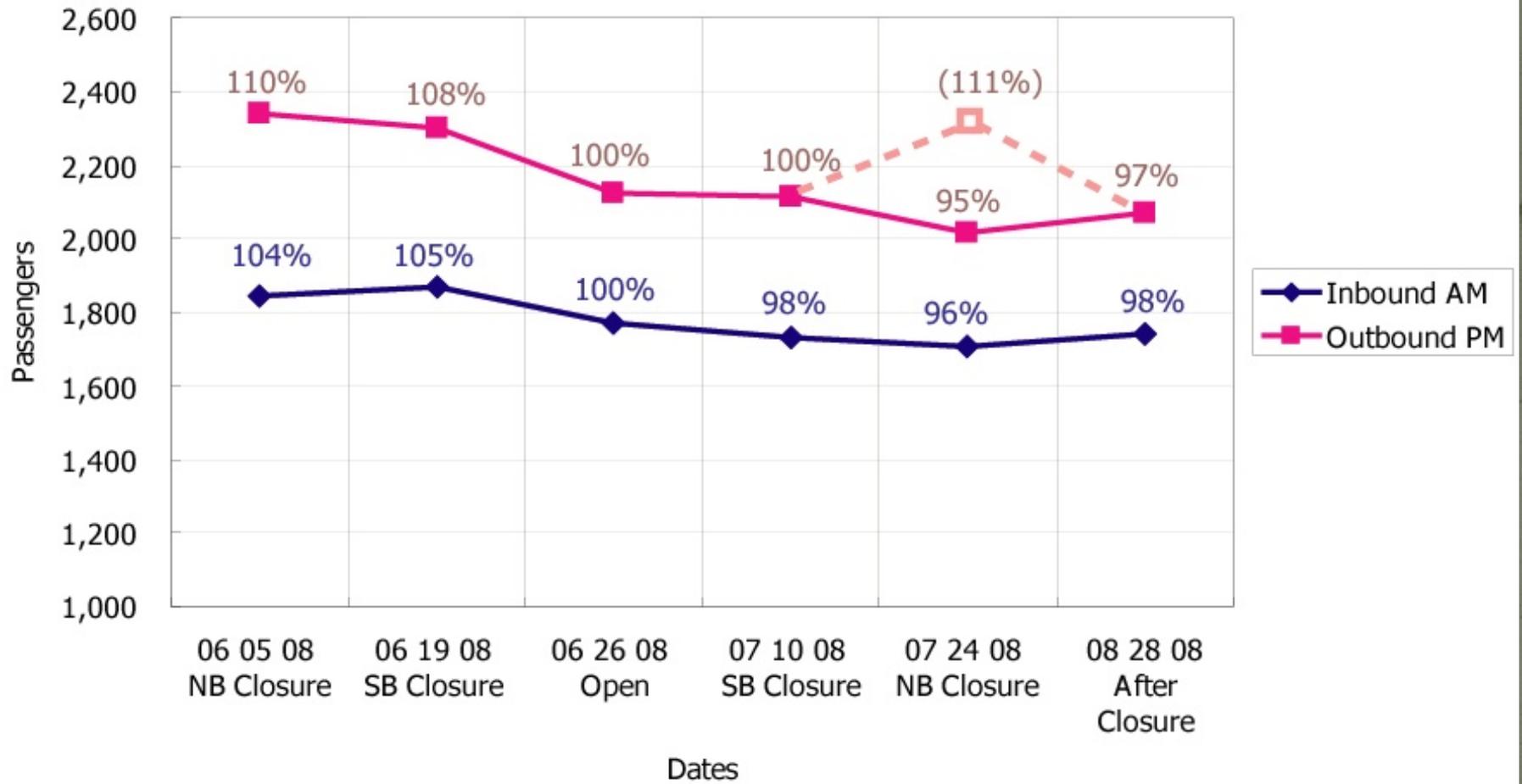
Results

Section I: Transit Ridership

Light-Rail Ridership Changes Crossing 13th Street Station (AM/PM)



Light Rail Ridership Changes Crossing Arden/Del Paso



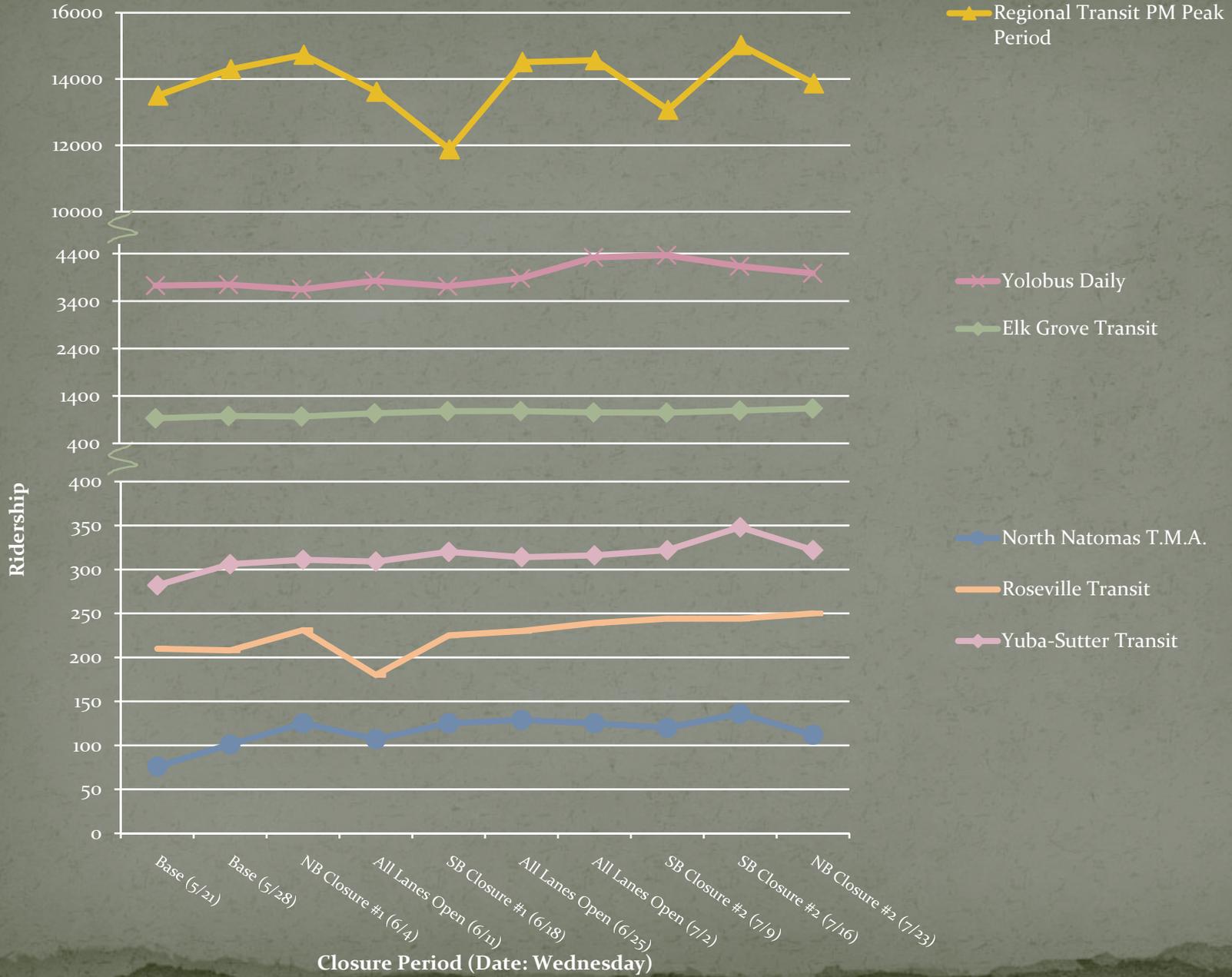
Bus Transit Ridership

			Ridership							
Transit Agency	Data Aggregation	Peak Period	Base (Wednesday: 5/28)	NB* Closure #1 (Wednesday: 6/4)	All Lanes Open (Wednesday: 6/11)	SB** Closure #1 (Wednesday: 6/18)	All Lanes Open (Wednesday: 6/25)	SB** Closure #2 (Wednesday: 7/9)	SB** Closure #2 (Wednesday: 7/16)	NB* Closure #2 (Wednesday: 7/23)
Regional Transit	Weekly	AM	14990	17641	15601	14664	14164	16510	16583	14661
		PM	14294	14729	13615	11879	14510	13069	15023	13867
Yolobus	Daily		3748	3648	3828	3715	3879	4367	4136	3986
North Natomas	Daily	AM	113	134	124	147	150	147	158	149
		PM	101	125	107	125	129	120	136	112
Roseville Transit	Daily	AM	235	272	249	231	245	275	302	263
		PM	208	231	180	225	230	244	244	250
Yuba-Sutter Transit	Daily	AM	313	305	309	310	302	322	326	336
		PM	306	311	309	320	314	322	348	322
Elk Grove Transit	Daily	AM	1019	1101	1106	1133	1114	1099	1162	1138
		PM	977	966	1034	1079	1080	1047	1092	1136

AM Peak Period

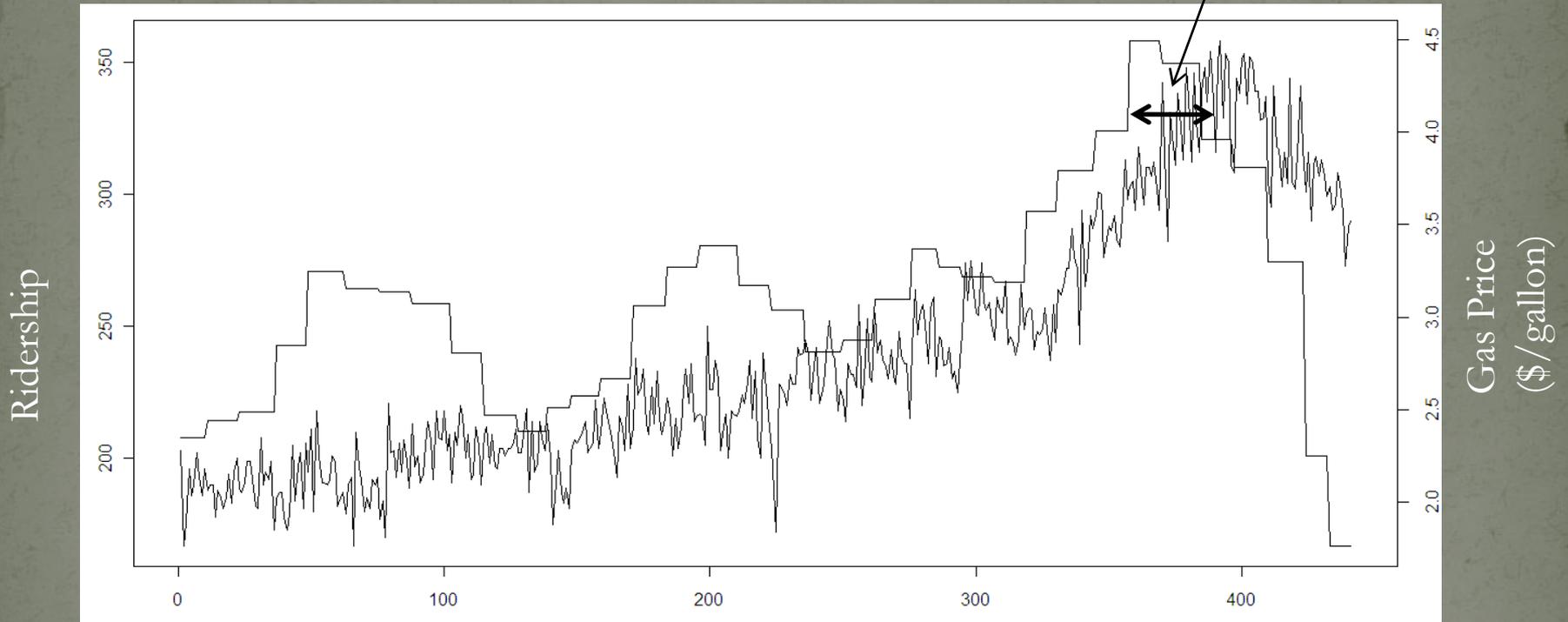


PM Peak Period



Yuba-Sutter Transit AM peak Ridership and Gas Price

Fix-I5 project period



January 2006 – December 2008

Transit Ridership Analysis

- Data show visible increases in ridership in both light rail and commuter bus services during Fix-I5
- Are these changes a result of Fix-I5, or other factors such as the rise of gas prices, or simply random fluctuations?
- Used time series modeling to find an answer
 - Multiple Regression to eliminate fluctuations in bus transit ridership due to changes in area gas prices, employment rates, transit fares, and gross domestic product.
 - Periodogram analysis to remove cyclic behavior in ridership (i.e. from weekly, monthly, and yearly patterns), and
 - Intervention analysis to decide the change in the mean level ridership associated with the Fix I-5 construction project, and establish if this change in ridership was temporary or permanent.

Case Study:

Yuba-Sutter Transit AM Peak Period

Transit Agency	Data Aggregation	Indicator Function	Final Model Estimate (mean change in riders)	Observed Mean Ridership during Fix I-5 Project (w+CFR)	w/(w+CFR) x 100%
Yuba-Sutter Transit	AM	Pulse	-7.4	314	-2.36%

Transit Agency	Data Aggregation	Cumulative Detrended Adjusted R ²	Cumulative Deseasoned Adjusted R ²	Cumulative Intervention Analysis Adjusted R ²	Final Model Adjusted R ²
Yuba-Sutter Transit	AM	0.8762	0.9228 (0.0466)	0.9997 (0.0769)	0.9997

Gas prices and employment rates explain the biggest amount of variance in the Yuba-Sutter Transit AM peak period ridership data, followed by the Fix I-5 project, then seasonal cycles. The final model fits the data near perfectly: adjusted R² = 0.9997.

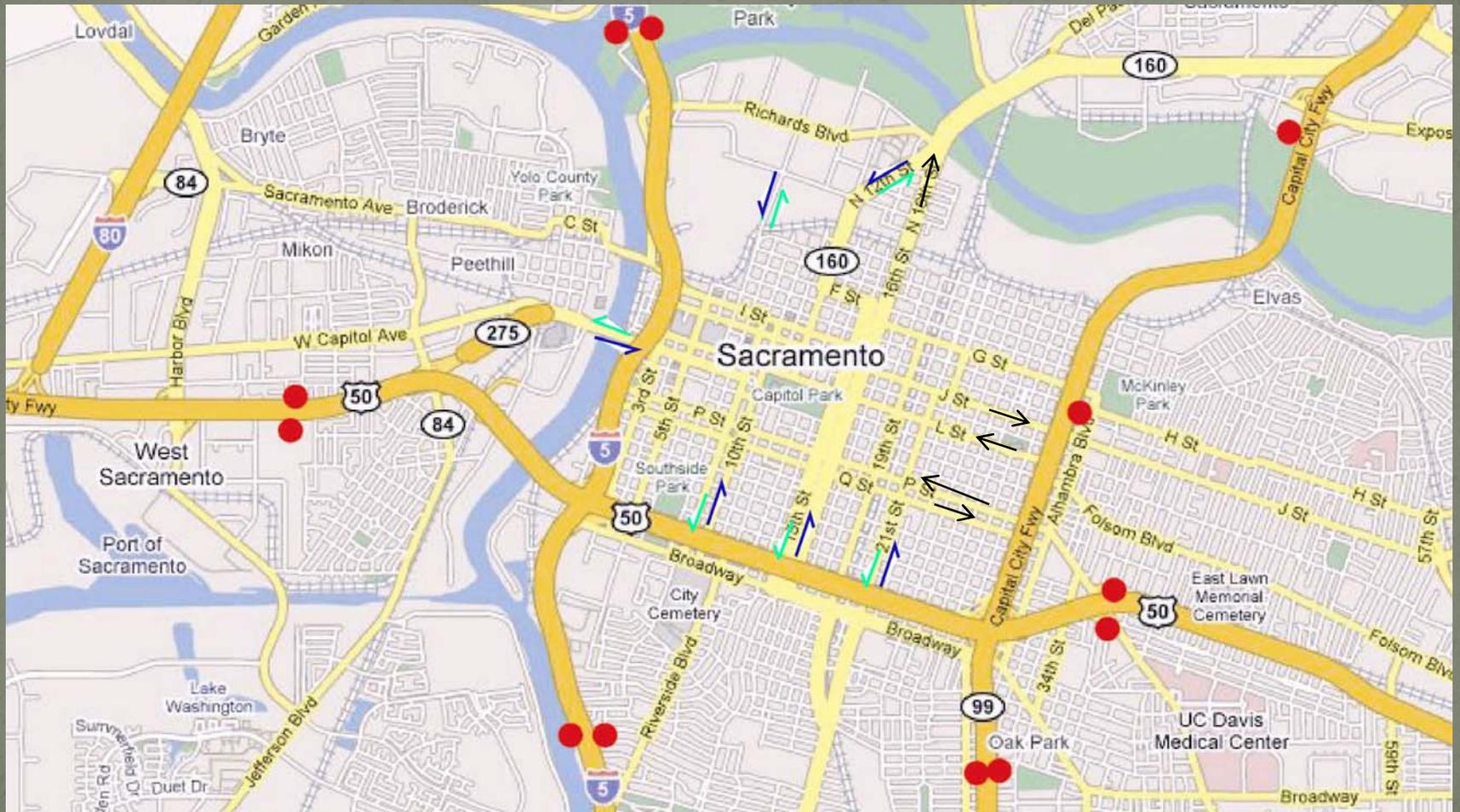
Overall Results for Transit Ridership

Transit Agency	Data Aggregation	Indicator Function	Final Model Estimate (mean change in riders)	Observed Mean Ridership during Fix I-5 Project (w+CFR)	w/(w+CFR) x 100%
Yuba-Sutter Transit	AM	Pulse	-7.4	314	-2.36%
Yuba-Sutter Transit	PM	Pulse	-6.25	317.2	-1.97%
Yolobus	Daily	Pulse	-13.65	4023.5	-0.34%
Roseville Transit	AM	Pulse	-1.15	253.8	-0.45%
Roseville Transit	PM	Pulse	-3.75	226	-1.66%
North Natomas TMA	AM	Step	1.2	146.2	0.82%
North Natomas TMA	PM	Pulse	2.6	124.3	2.09%
Regional Transit	AM	Step	552.6	15525.8	3.56%
Regional Transit	PM	Step	351.1	13907.5	2.52%

Results

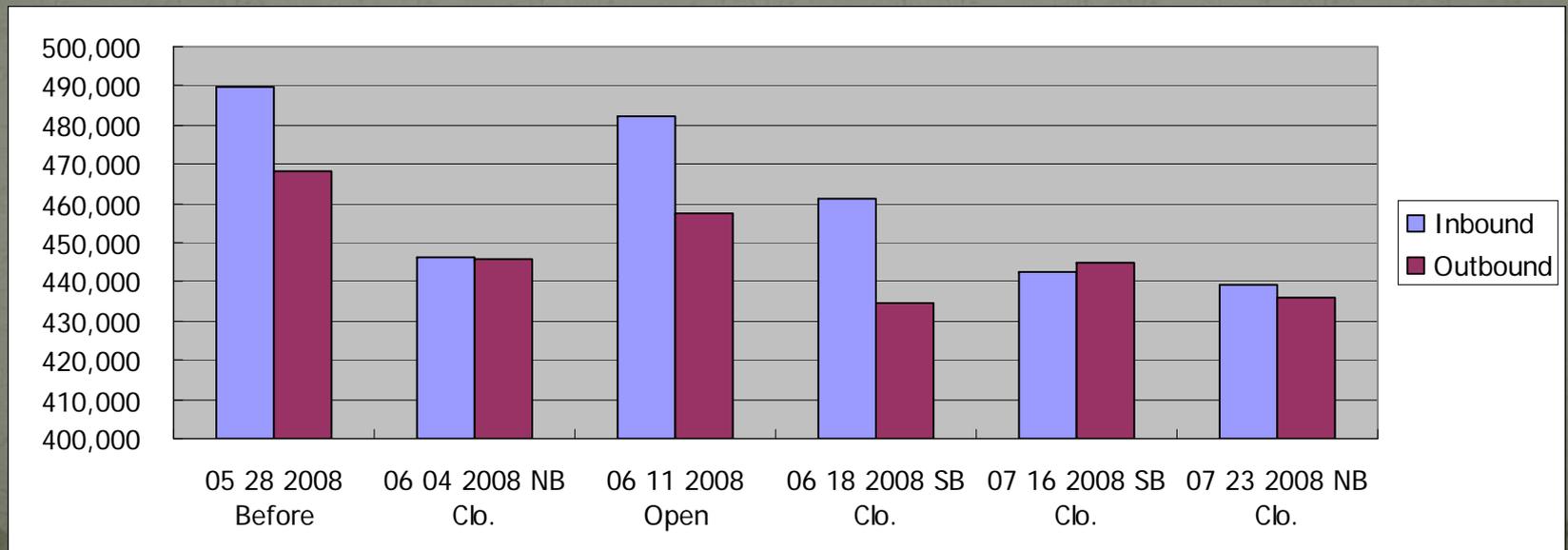
Section II: Traffic Flow

Cordon Flow: In and Out Bounds



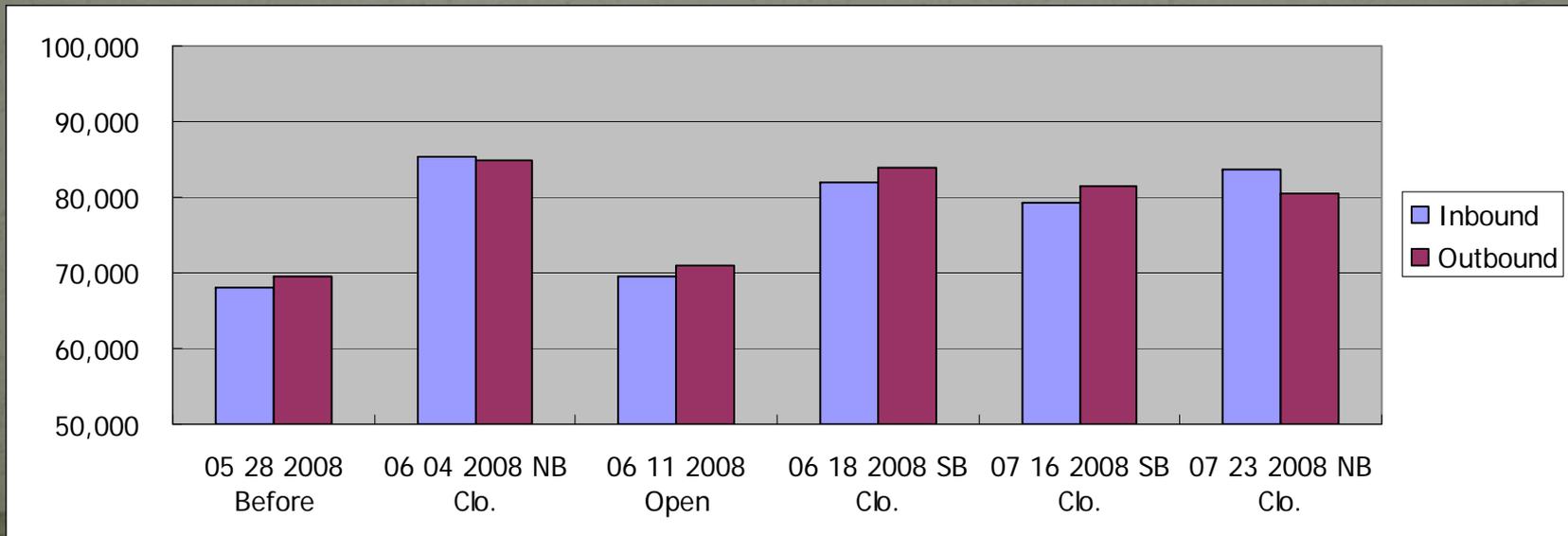
Total Freeway ADT (Wed) Crossing the Cordon

Freeways	Inbound	Outbound
5/28/2008 (Before)	489,877 (100%)	468,137 (100%)
6/4/2008 (NB Clo.)	446,157 (91%)	445,608 (95%)
6/11/2008 (Open)	482,206 (98%)	457,635 (98%)
6/18/2008 (SB Clo.)	461,182 (94%)	434,480 (93%)
7/16/2008 (SB Clo.)	442,483 (90%)	444,662 (95%)
7/23/2008 (NB Clo.)	439,050 (90%)	435,798 (93%)



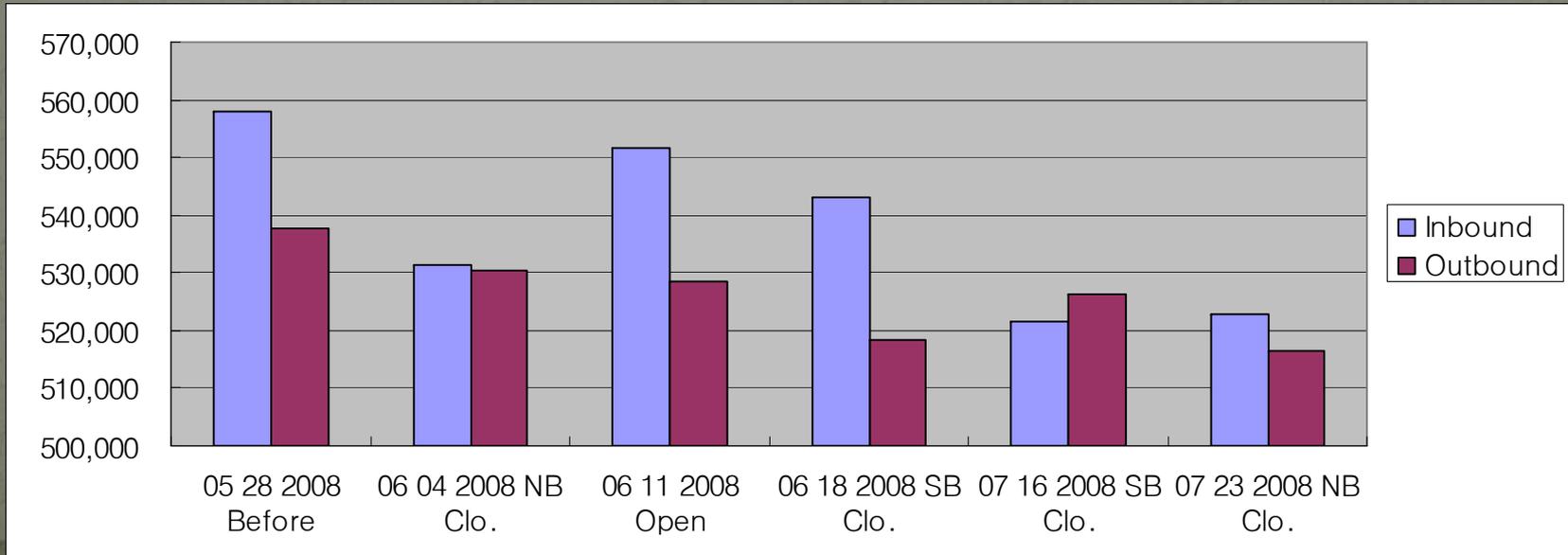
Total Arterial ADT (Wed) Crossing the Cordon

Arterials	Inbound	Outbound
5/28/2008 (Before)	67,998 (100%)	69,525 (100%)
6/4/2008 (NB Clo.)	85,249 (125%)	84,925 (122%)
6/11/2008 (Open)	69,421 (102%)	71,013 (102%)
6/18/2008 (SB Clo.)	81,833 (120%)	83,946 (121%)
7/16/2008 (SB Clo.)	79,164 (116%)	81,570 (117%)
7/23/2008 (NB Clo.)	83,703 (123%)	80,580 (116%)

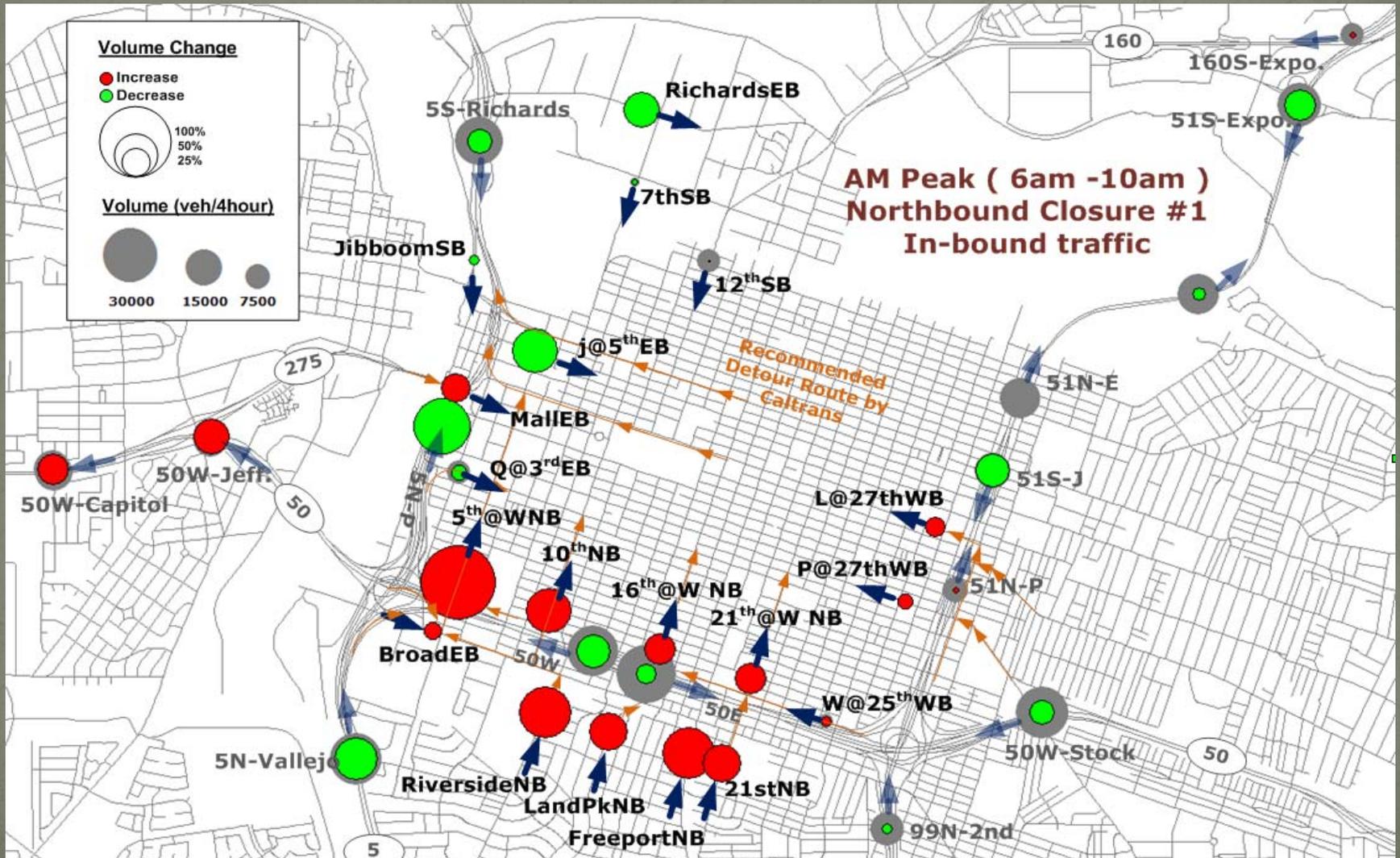


Total ADT (Wed) on Both Freeways and Arterials-Downtown Core

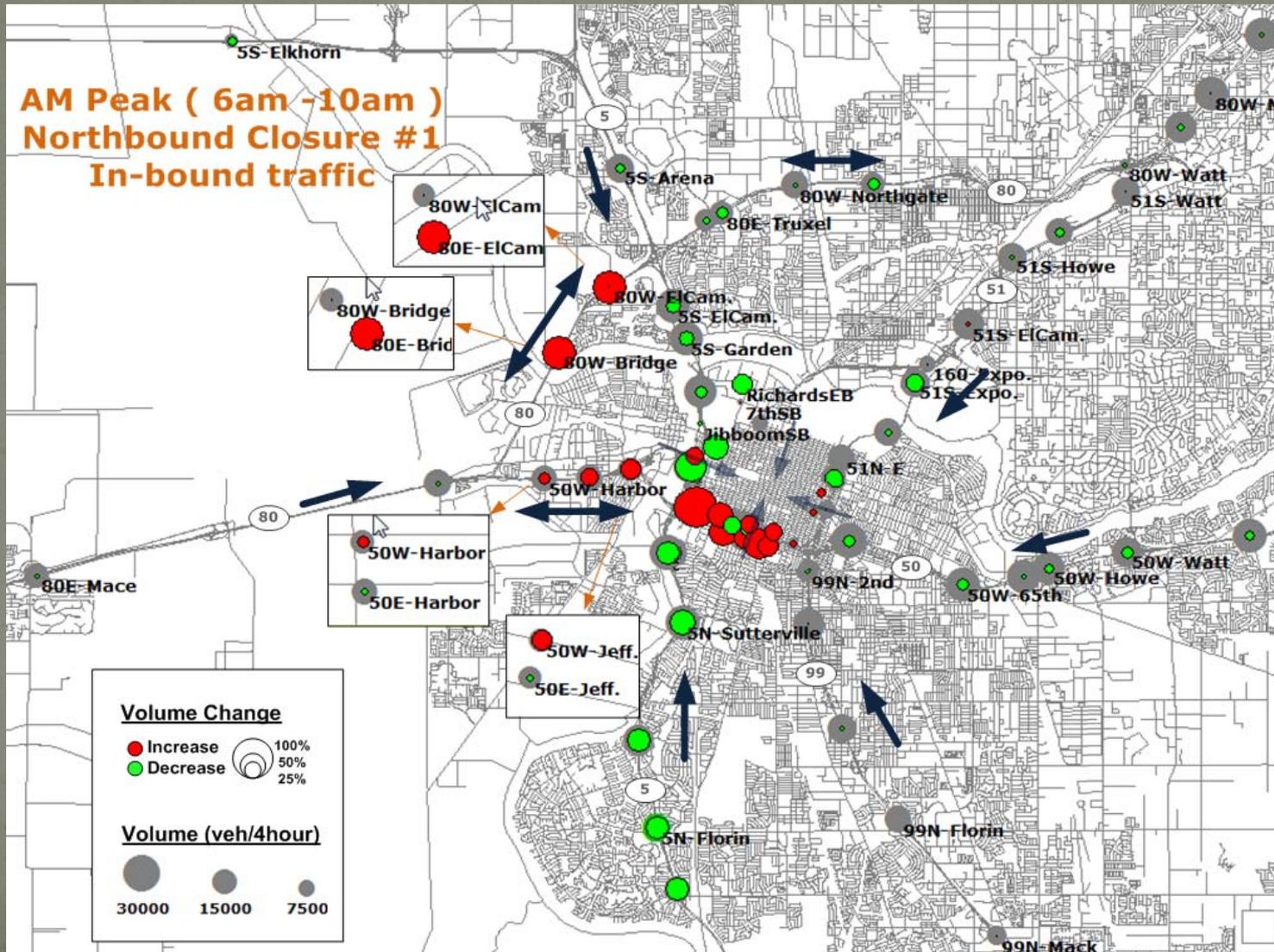
Freeways+Arterials	Inbound	Outbound
5/28/08 (Before)	557,875 (100%)	537,662 (100%)
6/4/08 (NB Clo.)	531,406 (95%)	530,533 (99%)
6/11/08 (Open)	551,627 (99%)	528,648 (98%)
6/18/08 (SB Clo.)	543,015 (97%)	518,426 (96%)
7/16/08 (SB Clo.)	521,647 (94%)	526,232 (98%)
7/23/08 (NB Clo.)	522,753 (94%)	516,378 (96%)



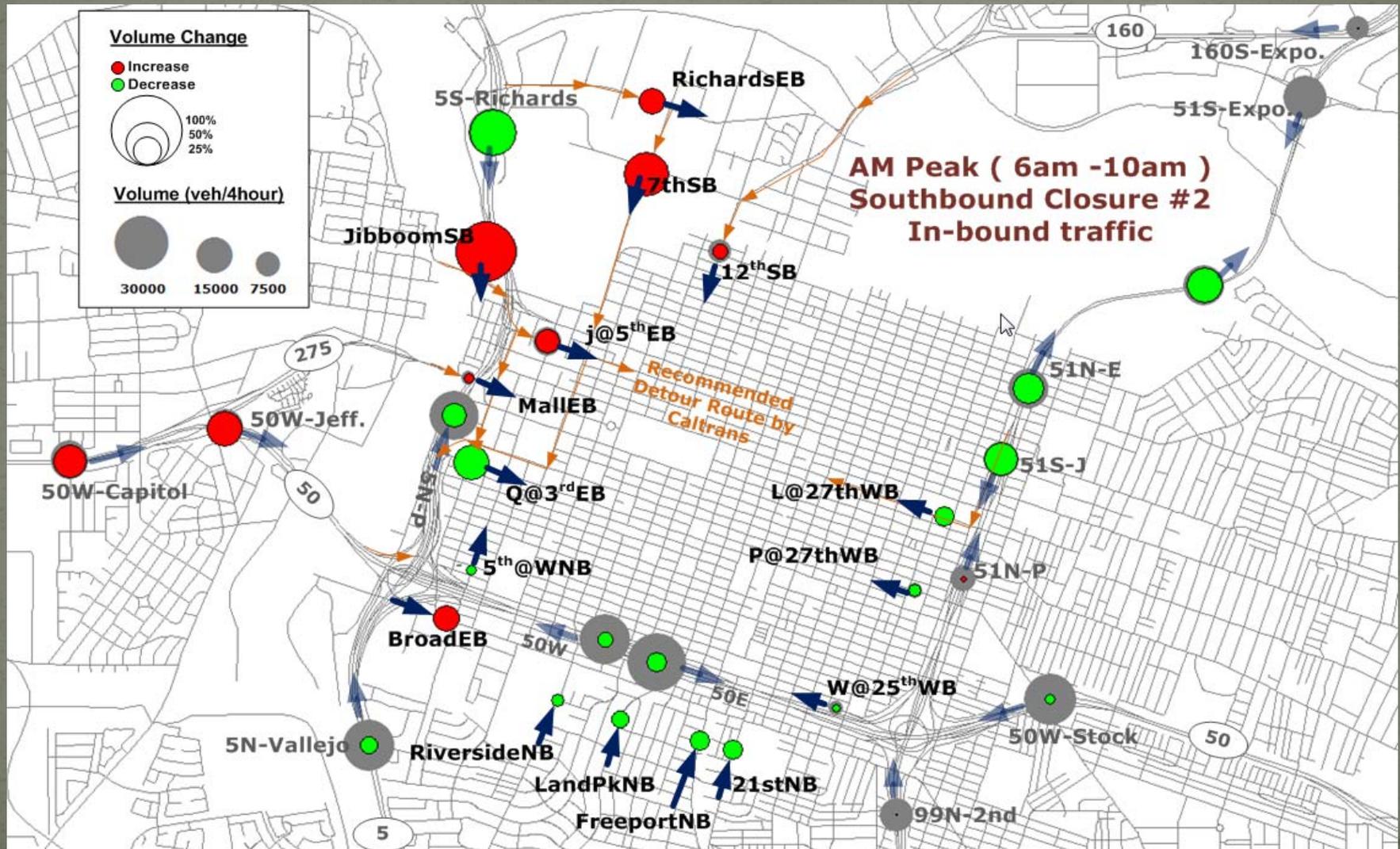
Flow Changes During AM Peak: NBC #1



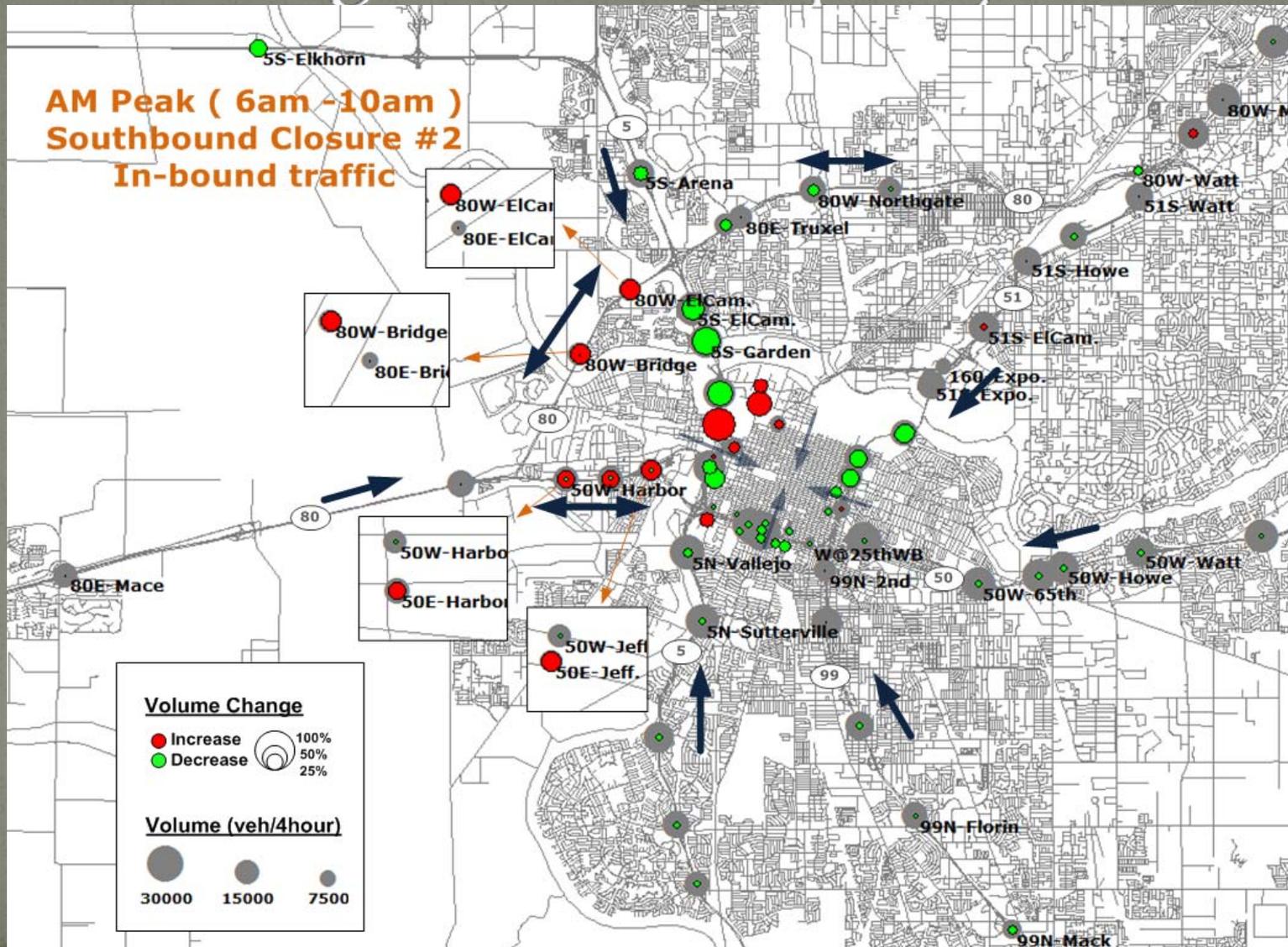
Flow Changes at the Periphery: NBC #1



Flow Changes During AM Peak: SBC #2



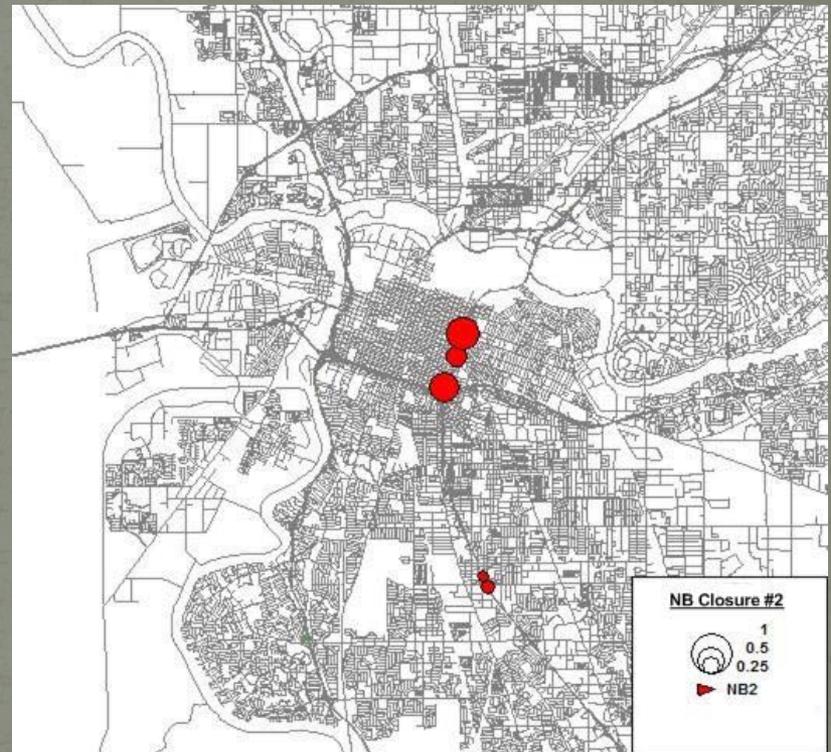
Flow Changes at the Periphery : SBC #2



Changes in HOV traffic



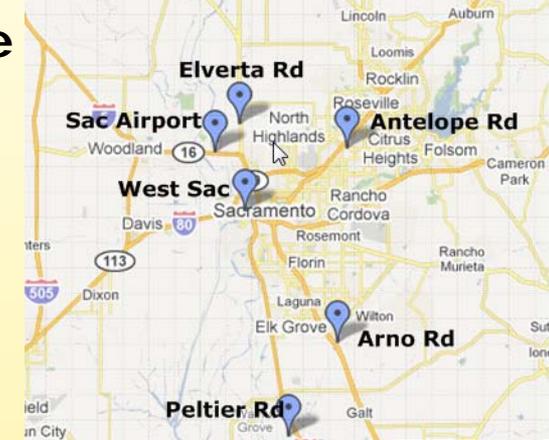
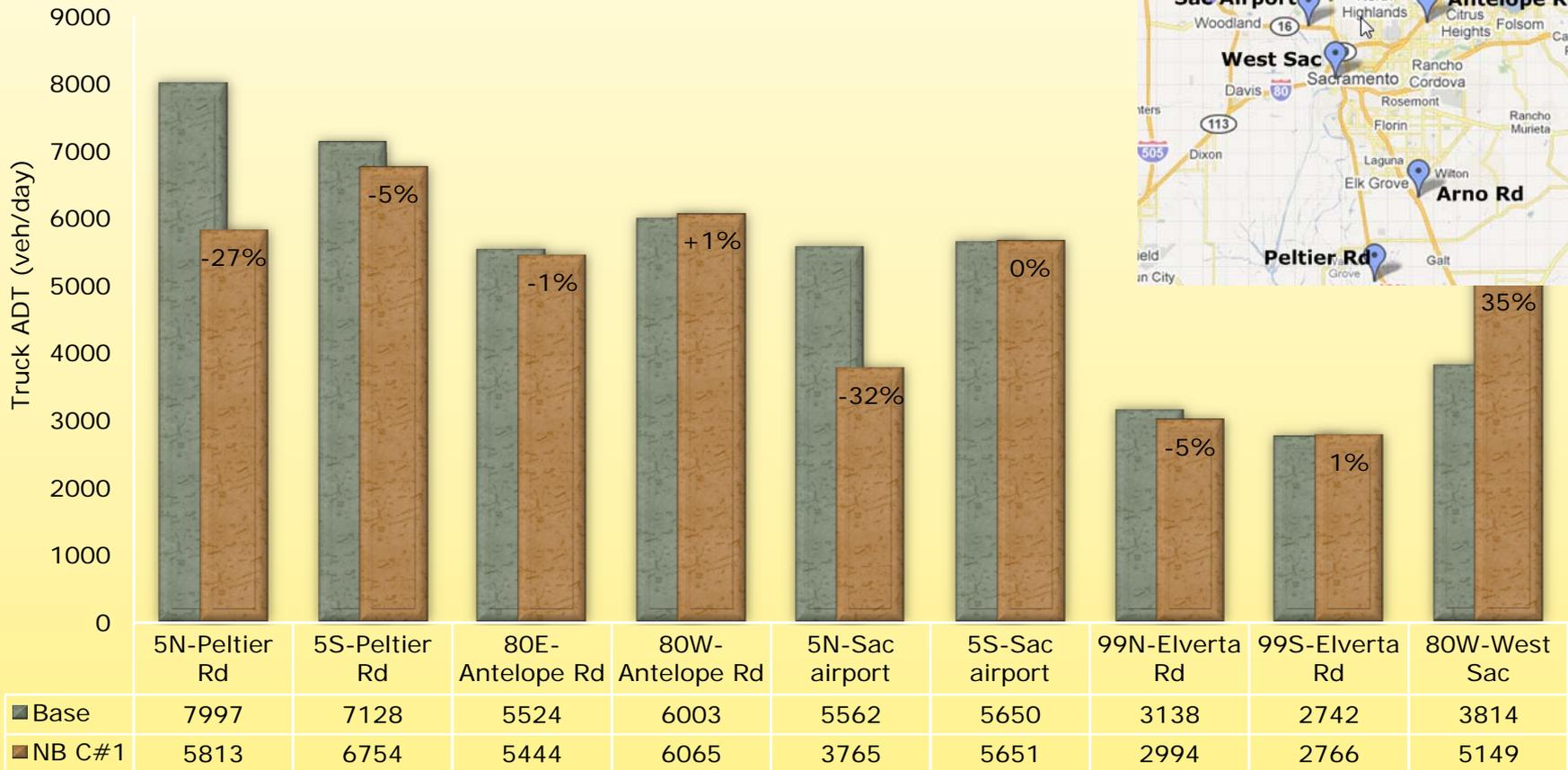
NBC#1



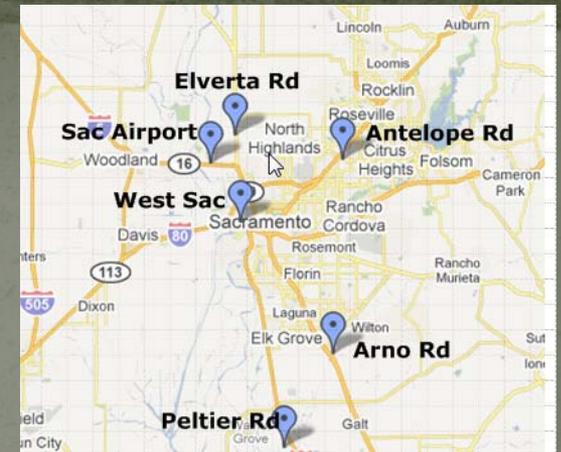
NBC#2

Truck Volume Changes – NB C#1

Truck Volume Change - NB Closure



Truck Volume Changes Overall



Weigh Station	Freeway	Location	Base	NBC#1	Open#1	SBC#1	Open#2	SBC#2	NBC#2	After
24	I-5 NB	Peltier Rd	100%	66%	89%	92%	101%	96%	80%	102%
24	I-5 SB	Peltier Rd	100%	92%	93%	86%	100%	90%	98%	107%
299	I-80 EB	Antelope	100%	92%	99%	93%	104%	104%	105%	103%
300	I-80 WB	Antelope	100%	101%	99%	102%	102%	102%	101%	105%
409	I-80 WB	West Sac	100%	135%	101%	101%	103%	100%	135%	109%
543	I-5 NB	Sac Airport	100%	65%	97%	100%	100%	98%	71%	101%
543	I-5 SB	Sac Airport	100%	99%	101%	64%	101%	70%	101%	104%
544	SR-99	Elverta Rd	100%	96%	96%	103%	104%	53%	-	108%
544	SR-99	Elverta Rd	100%	101%	94%	96%	98%	50%	-	107%

Results

Section III: Travel Times

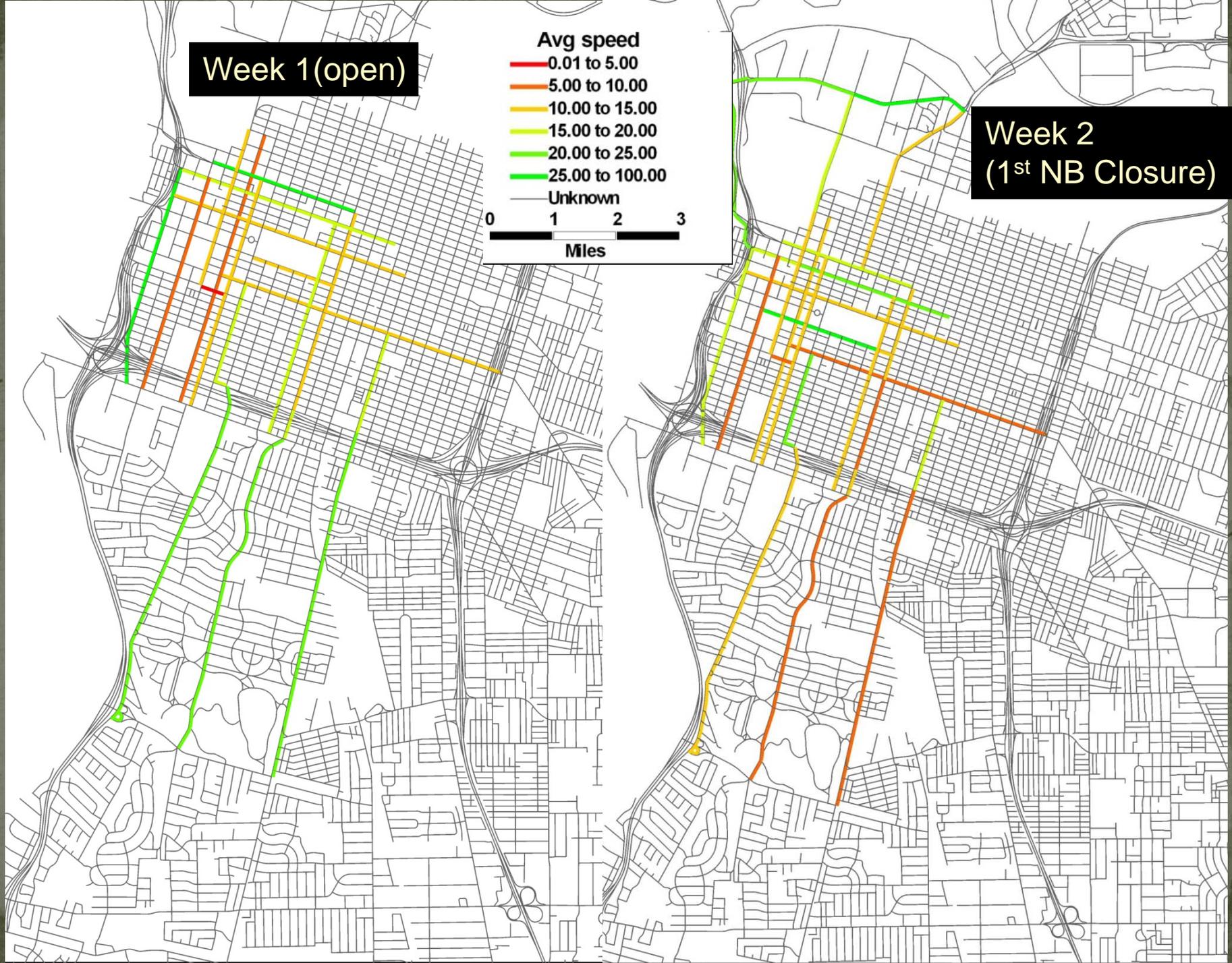
Travel time on Freeway and Arterial Routes

- Floating car with GPS
 - Covers major detour routes
 - Riverside, Land Park, Freeport in the South
 - Jibboom, Richards, 7th, I, J, 12th, 16th in the North
- Buses with GPS
 - Uses bus routes on major downtown streets

Week 1 (open)



**Week 2
(1st NB Closure)**



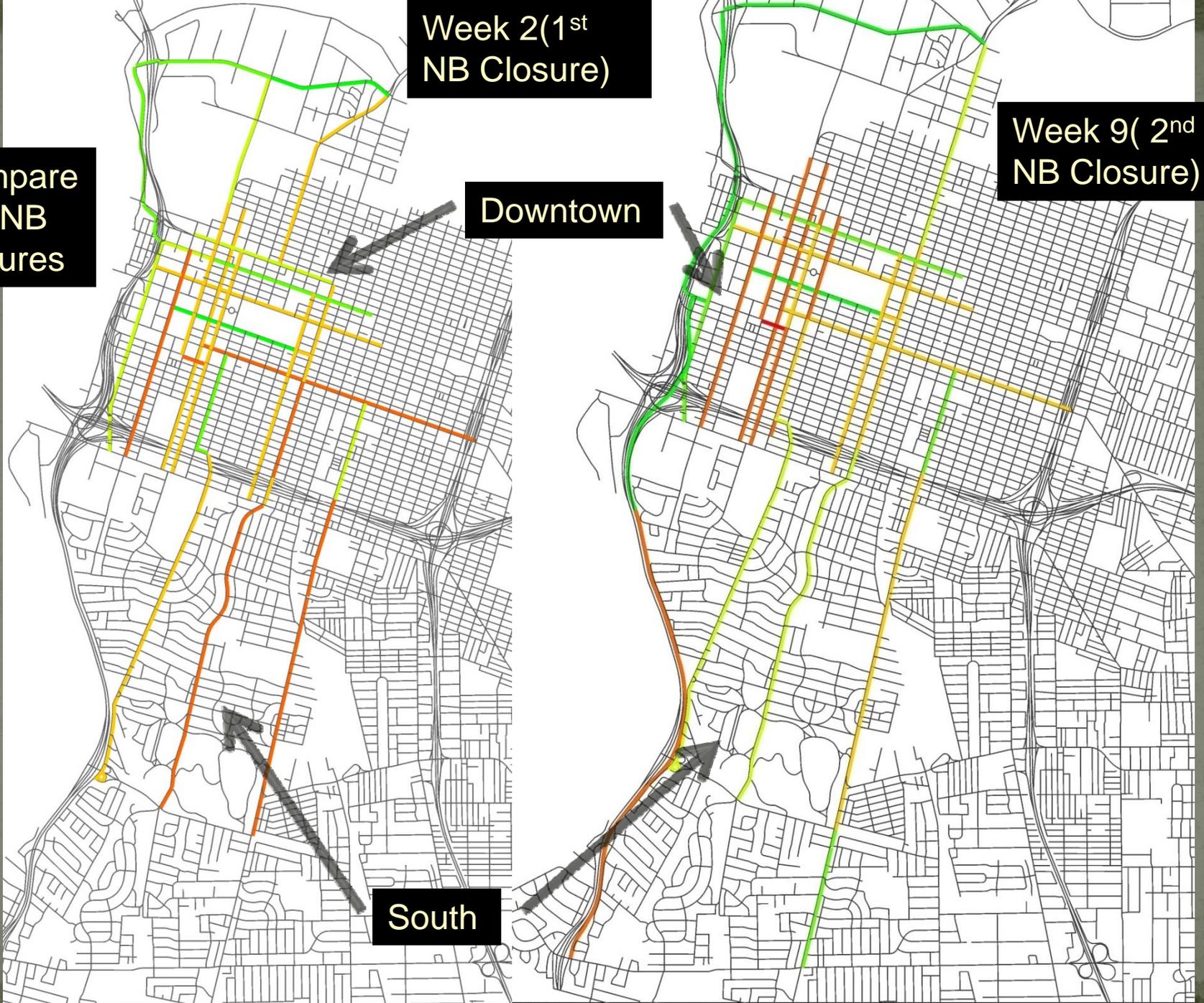
Compare
two NB
closures

Week 2(1st
NB Closure)

Downtown

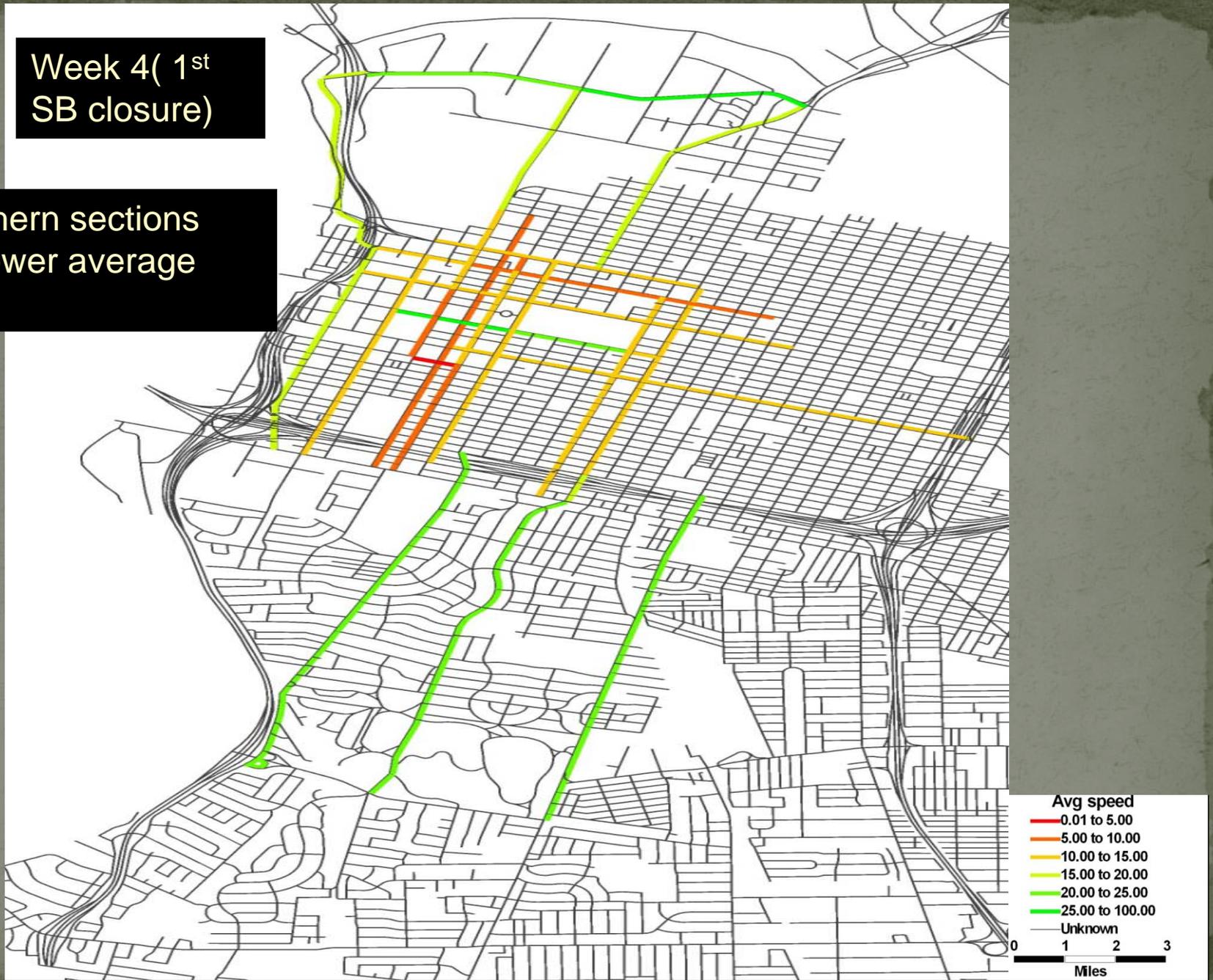
Week 9(2nd
NB Closure)

South



Week 4(1st
SB closure)

Most northern sections
showed lower average
speed



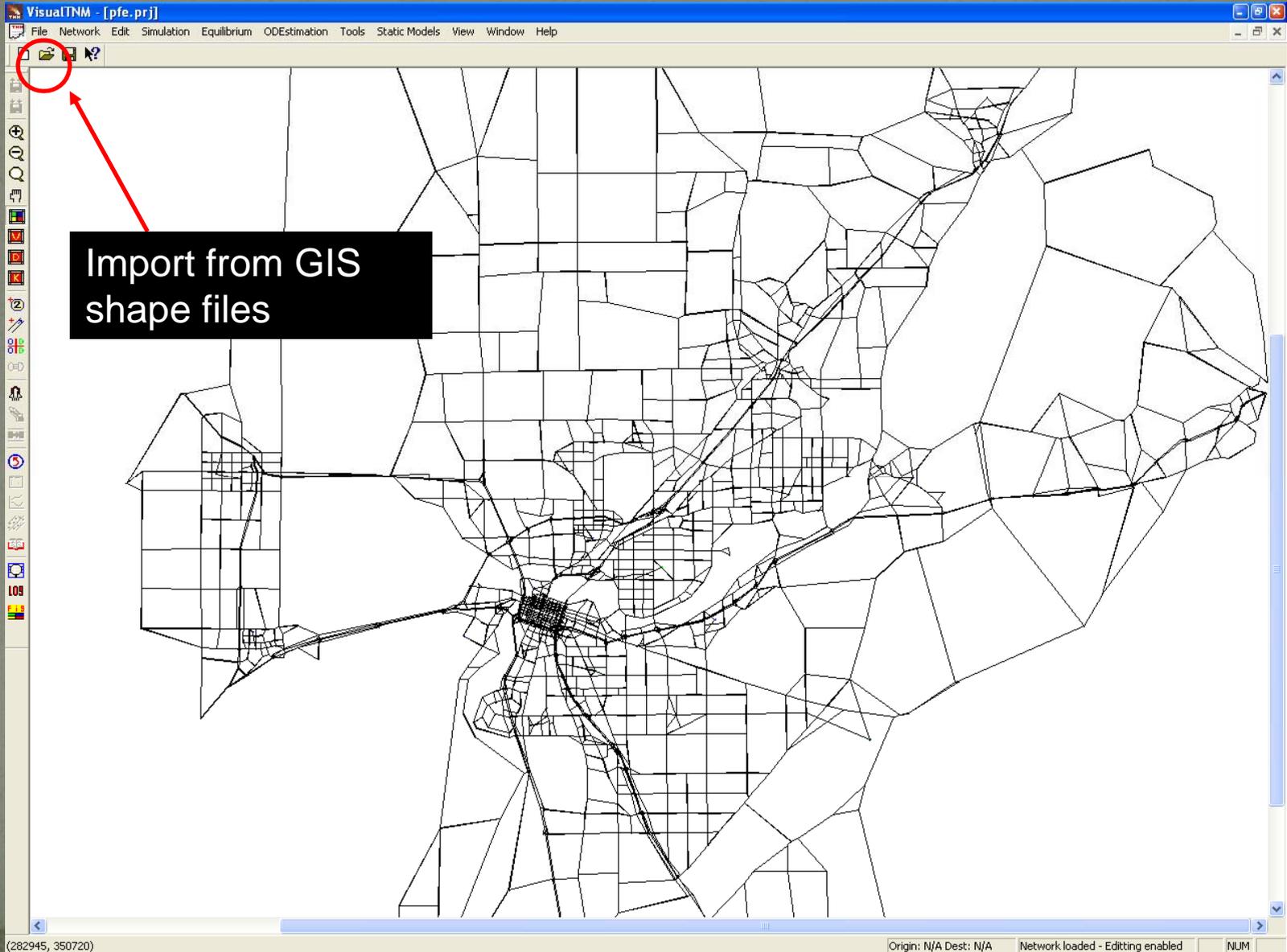
Results

Section IV: VMT, VHT and Emissions

Modeling VMT Changes with NetZone

- Network generation
 - Import the Sacramento network from standard GIS shape files, and edit the network using NetZone GUI
- Calibration
 - Create TAZs
 - Dynamic O-D estimation
- Dynamic network simulation
- Results
 - Dynamic link/path flows
 - VMT/VHT
 - Average Delay,

NetZone GUI



Dynamic O-D Estimation

Path Flow Estimator [X]

Input files Output files Options

Problem definition

Path enumeration

Cost scalar:

Algorithm: Iterative Balancing MSA

Dispersion parameter:

Link performance function: [v]

Additional input for O-D estimation

Measured link travel times

Observed O-D flows (AVL)

Consider AVL error

Consider link counts error

Please reconfigure your new problem.

Solve

Retain iteration history

Output

Report

Include links Include path topology

Include paths Include iteration history

Traffic counts (freeway/arterials)
Historical O-D information
Planning O-D information
Travel time measurements
Error bounds

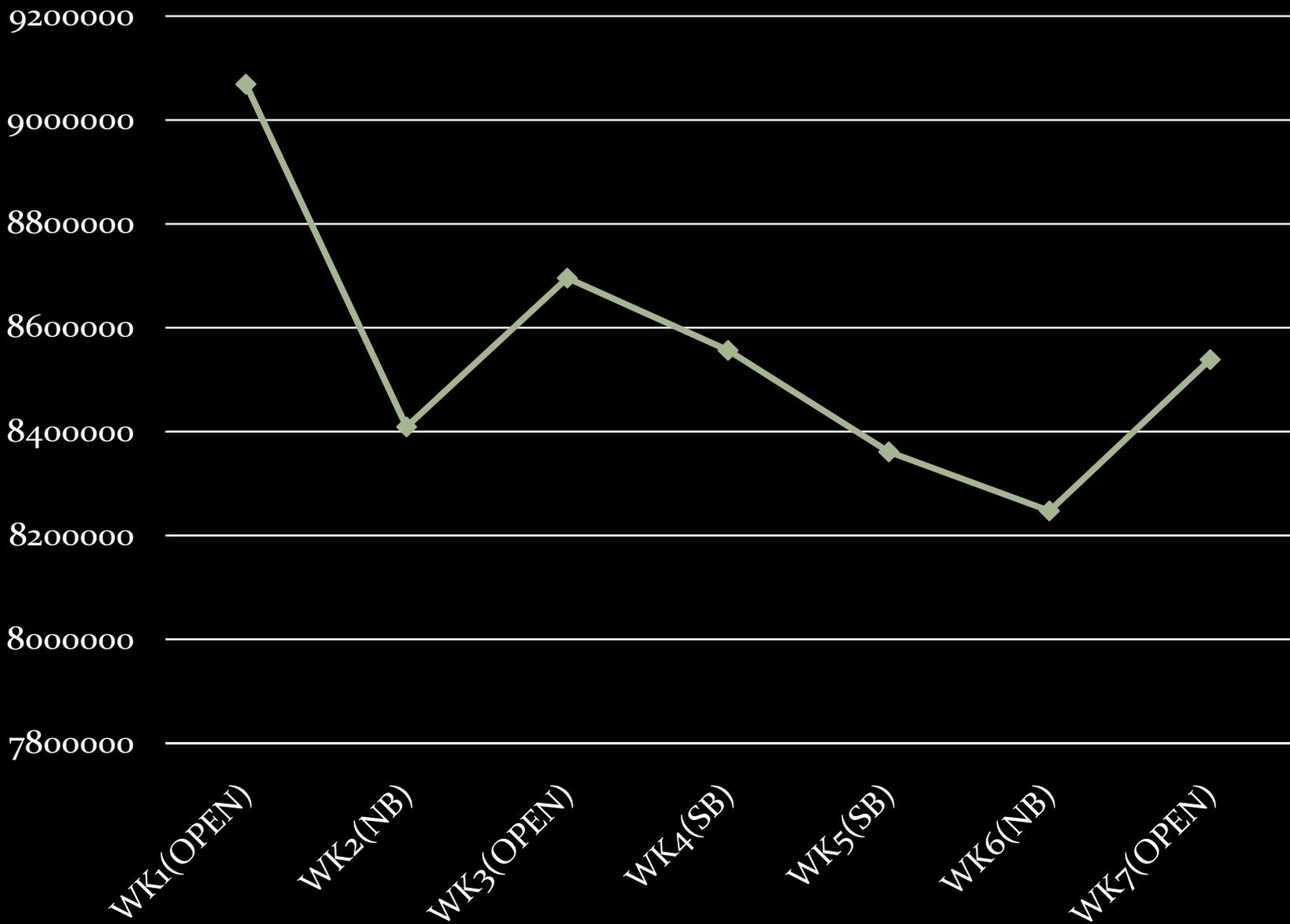
Estimated Travel Times of Some O-D Pairs during AM Peak

- Elk Grove > US-50
 - Open: 22min
 - NB closure: 26min
 - SB closure: 23min
- Davis > Sacramento Downtown
 - Open: 24min
 - NB closure: 36min
 - SB closure: 38min

Delays, VMT and VHT During AM Peak

		Total trips (veh)	Total queuing delay (hr)	Average travel distance (mile)	Average travel time (min)	Average travel delay (min)	Average travel speed (mph)	VMT (veh*mile)	VHT (veh*hr)
Wk1	Baseline	359372	60052	25.24	36.57	10.03	41.41	9069100	219025
Wk2	NB	331016	46316	25.40	35.49	8.40	42.95	8409136	195791
Wk3	OPEN	354755	51557	24.51	34.42	8.72	42.93	8695680	203499
Wk4	SB	340287	50081	25.14	35.34	8.83	42.69	8556488	200436
Wk5	SB	330935	50702	25.27	35.93	9.19	42.19	8361132	198188
Wk6	NB	327462	49357	25.19	35.57	9.04	42.49	8247389	194104
Wk7	OPEN (AUG)	349013	45556	24.47	33.47	7.83	43.85	8538736	194715

AM Peak VMT (vehicle-miles)

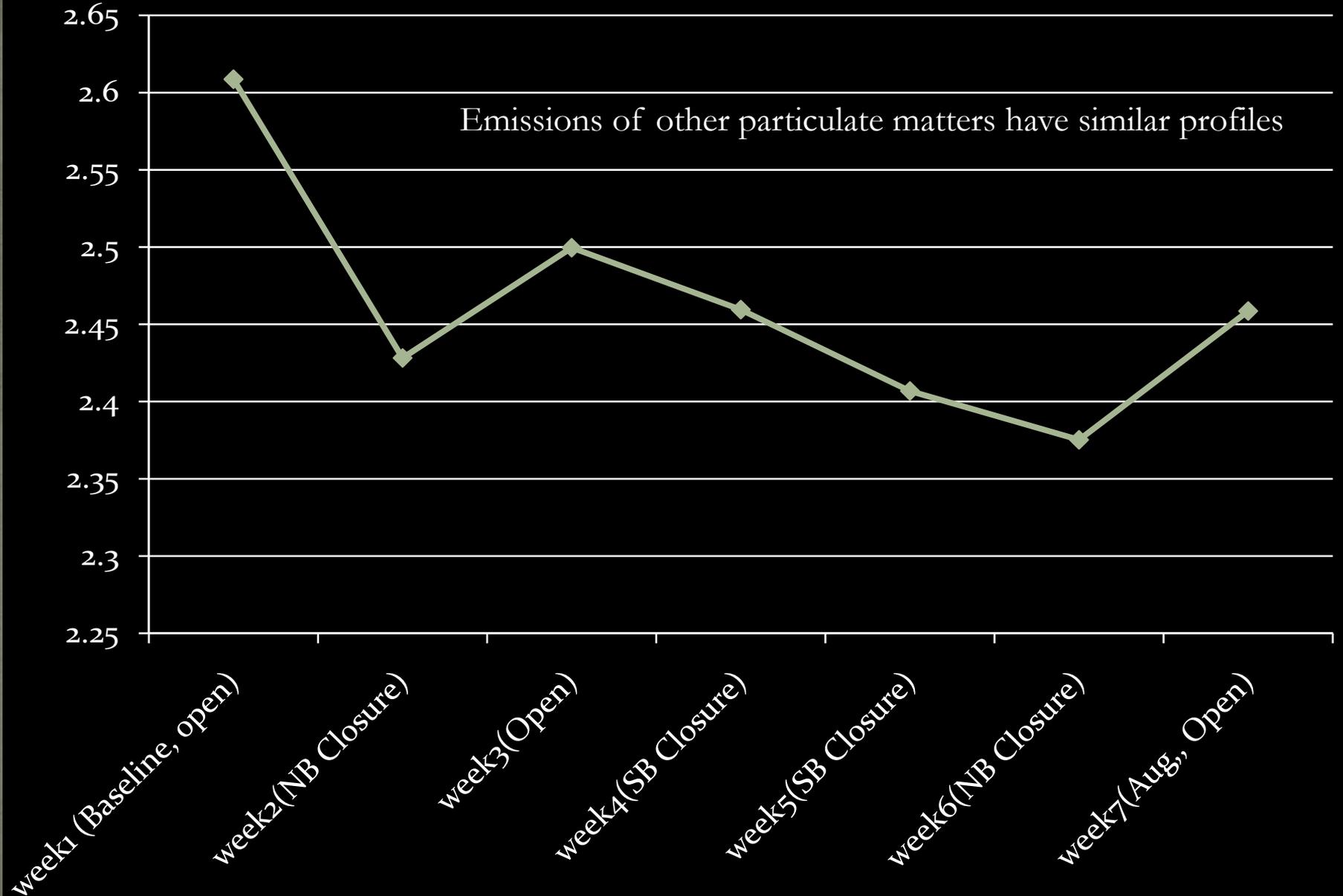


Estimate Vehicle Emissions

- VMT-based emission in MOBILE 6.2
 - Use the hourly-based VMT distribution and the speed-based VMT distribution from NetZone, over the required 14 speed bins in MOBILE 6 for two road types (freeway and arterial roads)
- Microscopic emission models in NETZONE
 - Fuel consumption rate and CO₂ rate from Transportation Energy Data Book
 - Regression-based micro-scopic emission models

Total CO₂ emission (billion g)

Emissions of other particulate matters have similar profiles



Summary and Conclusions

- Although some routes saw significant reductions/increases of traffic , the total reduction of auto trips was not as high as was anticipated, and ranged from 3% to 6%
- Instead of changing to alternative modes, such as light rail and bus transit, the majority of commuters and truckers who changed their travel patterns shifted to alternative routes
- Transit services saw a significant increase in their ridership from 2007 all the way to the end of the Fix-I5 project, but the main cause of this increase was the rise of gas prices. Fix-I5 contributed minor changes in bus transit ridership
- An adequate amount of redundant capacity in a transportation network is critical in handling large-scale disruptions to the network, since mode shift is not likely to be significant in the short run.
- When there is adequate redundant capacity, and with proper project timing and traffic management, full closure (close one entire direction) is both practical and effective.

Acknowledgements

- Agencies

- California Environmental Protection Agency
- California Department of Transportation (D3)
- City of Sacramento
- RT, YoloBus, Roseville Transit, Yuba Sutter Transit, North Natomas Flyer and E-Tran

- Research Assistants

- Zhen Qian, Rachel Carpenter, Yi-Ru Chen, Robert Lim, Feng Xiao and Changmo Kim
- The 30+ graduate and undergraduate students who participated in the light rail ridership surveys, and travel time measurements