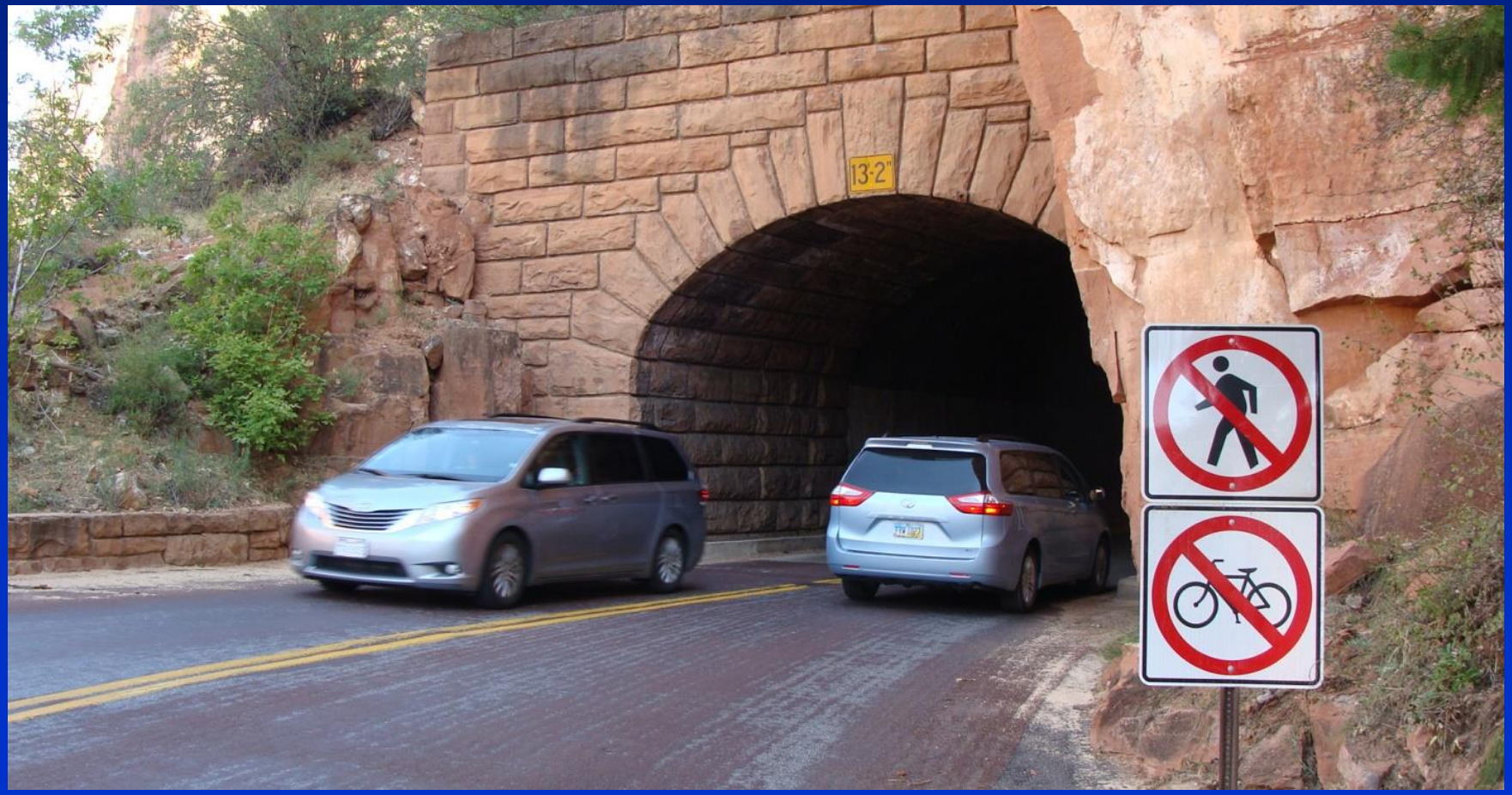
# EVALUATING CAPACITY OF THE ZION – MT. CARMEL TUNNEL IN ZION NATIONAL PARK

**Jonathan Upchurch**

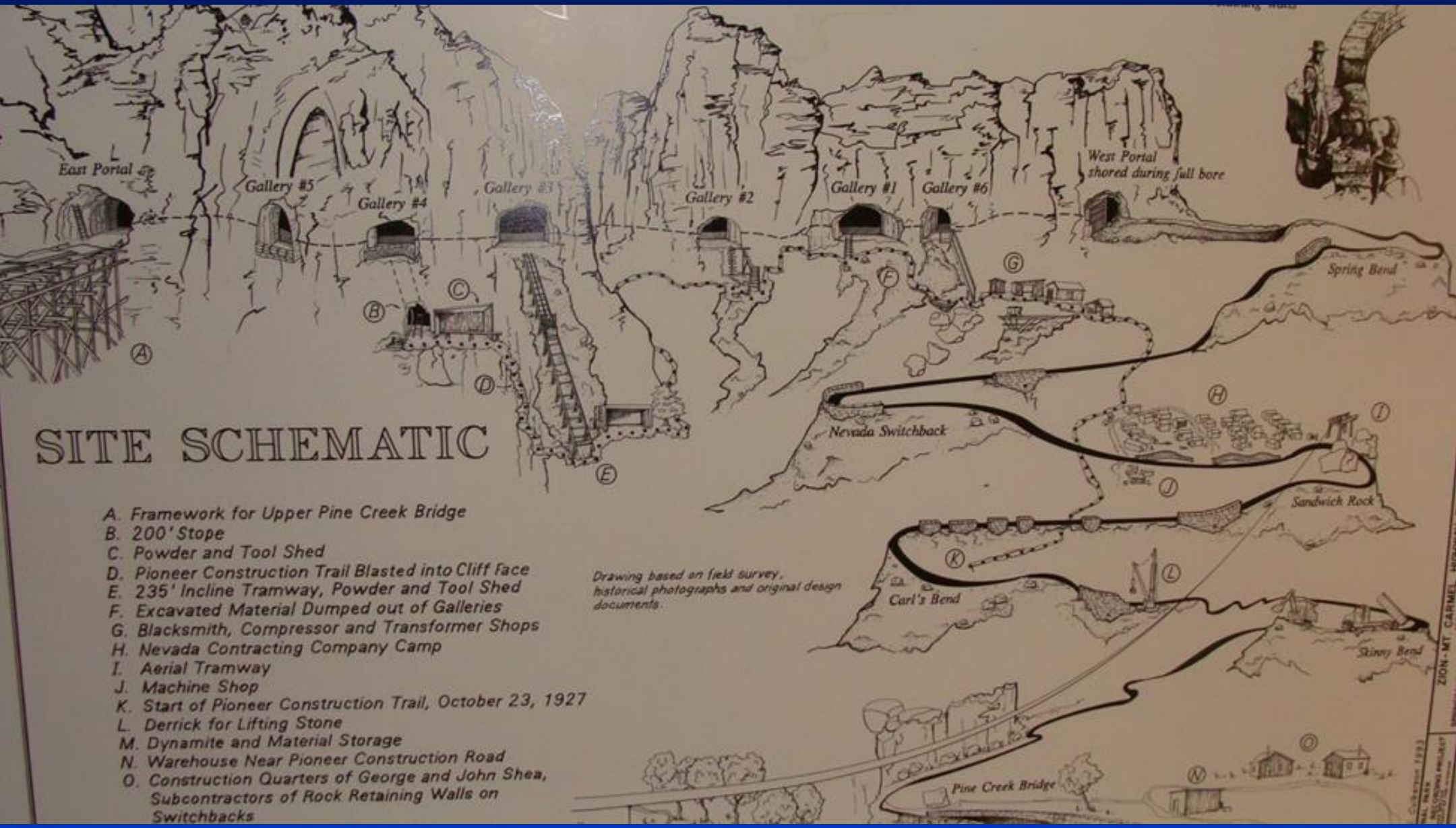
**ITE Western District Annual Meeting**

**June 21, 2017**




0 10 50 Kilometers
0 10 50 Miles
Time zones
Nevada is on Pacific Time.
Utah is on Mountain Time.
Arizona is on Mountain Time (Daylight saving time not observed).
Save as
Zion National Park
Cedar City
Cedar Breaks NM
Bryce Canyon National Park
KOLOB CANYONS
Long Valley Junction
Grand Staircase-Escalante National Monument
ZION CANYON
Snow Canyon State Park
La Verkin
Mt. Carmel Junction
Glen Canyon National Recreation Area
St. George
Hurricane
Coral Pink Sand Dunes State Park
Kanab
Lake Powell
UTAH
ARIZONA
NEVADA
Fredonia
Page
Vermilion Cliffs National Monument
Mesquite
Virgin River
Pipe Spring National Monument
Jacob Lake
Dirt roads may be impassable when wet
Road closed in winter
Kaibab National Forest
Valley of Fire State Park
Grand Canyon-Parashant National Monument
Tuweep
Grand Canyon National Park
NORTH RIM
Las Vegas
Lake Mead
Lake Mead National Recreation Area
Henderson
Colorado
Desert View
Grand Canyon Village
Cameron
Tusayan
Kaibab National Forest
To Los Angeles and San Diego


To Salt Lake City
Panguitch
143
12
63
Bryce Canyon National Park
Cedar Breaks NM
Cedar City
56
15
18
KOLOB CANYONS
14
Long Valley Junction
Zion National Park
ZION CANYON
89
Snow Canyon State Park
La Verkin
9
Mt. Carmel Junction
9
Hurricane
St. George
59
Coral Pink Sand Dunes State Park
Kanab
89
UTAH
ARIZONA
River
Fredonia
389
ALT 89
Pipe Spring


SITE SCHEMATIC
A. Framework for Upper Pine Creek Bridge
B. 200' Stope
C. Powder and Tool Shed
D. Pioneer Construction Trail Blasted into Cliff Face
E. 235' Incline Tramway, Powder and Tool Shed
F. Excavated Material Dumped out of Galleries
G. Blacksmith, Compressor and Transformer Shops
H. Nevada Contracting Company Camp
I. Aerial Tramway
J. Machine Shop
K. Start of Pioneer Construction Trail, October 23, 1927
L. Derrick for Lifting Stone
M. Dynamite and Material Storage
N. Warehouse Near Pioneer Construction Road
O. Construction Quarters of George and John Shea, Subcontractors of Rock Retaining Walls on Switchbacks
Drawing based on field survey, historical photographs and original design documents.
East Portal
Gallery #5
Gallery #4
Gallery #3
Gallery #2
Gallery #1
Gallery #6
West Portal shored during full bore
Spring Bend
Nevada Switchback
Sandwich Rock
Carl's Bend
Skinny Bend
Pine Creek Bridge
ZION - MT. CARMEL

# NATIONAL HISTORIC CIVIL ENGINEERING LANDMARK

AMERICAN SOCIETY OF CIVIL ENGINEERS

1852

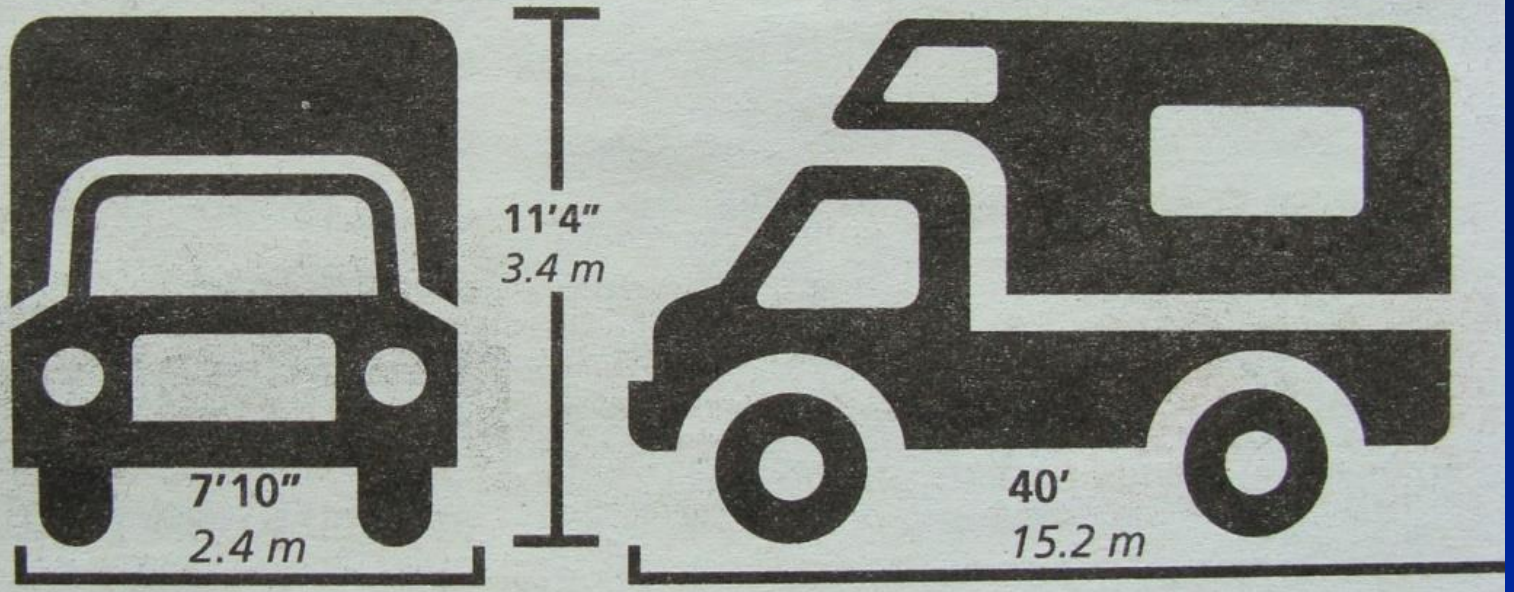
## ZION MT. CARMEL TUNNEL AND HIGHWAY, UTAH

THIS 5,613-FOOT-LONG TUNNEL, THE LONGEST VEHICULAR TUNNEL IN THE NATIONAL PARK SYSTEM, WAS BLASTED THROUGH THE TOWERING SANDSTONE CLIFFS ABOVE PINE CREEK CANYON. CONSTRUCTION REQUIRED EXTRAORDINARY ACCESS THROUGH CLIFF-FACE GALLERIES FOR BLASTING AND EXCAVATION. THE TUNNEL AND THE 25-MILE-LONG HIGHWAY, COMPLETED BETWEEN 1927 AND 1930, PROMOTED THE "NPS-RUSTIC" STYLE OF ENGINEERING AND LANDSCAPE ARCHITECTURE USED THROUGHOUT THE NATIONAL PARK SYSTEM.

Constructed: 1927 - 1930

Designated: 2011

Vehicles over 11'4" (3.4 m) tall or 7'10" (2.4 m) wide, including mirrors, awnings, and jacks, will require traffic control in the tunnel. Single-axle vehicles may not exceed 40' in length.





13' 1"
11' 4"
TAUCK
SPEED
LIMIT
25


Visitation since 1950
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
3,648,846
Visitors
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013

## AVERAGE TRAVEL TIME :

LARGE VEHICLES - 3 MINUTES 45 SECONDS

FREE-FLOWING SMALL VEHICLES - 2 MINUTES 57 SECONDS

## AVERAGE TRAVEL SPEED:

LARGE VEHICLES - 19 MPH

FREE-FLOWING SMALL VEHICLES - 24 MPH

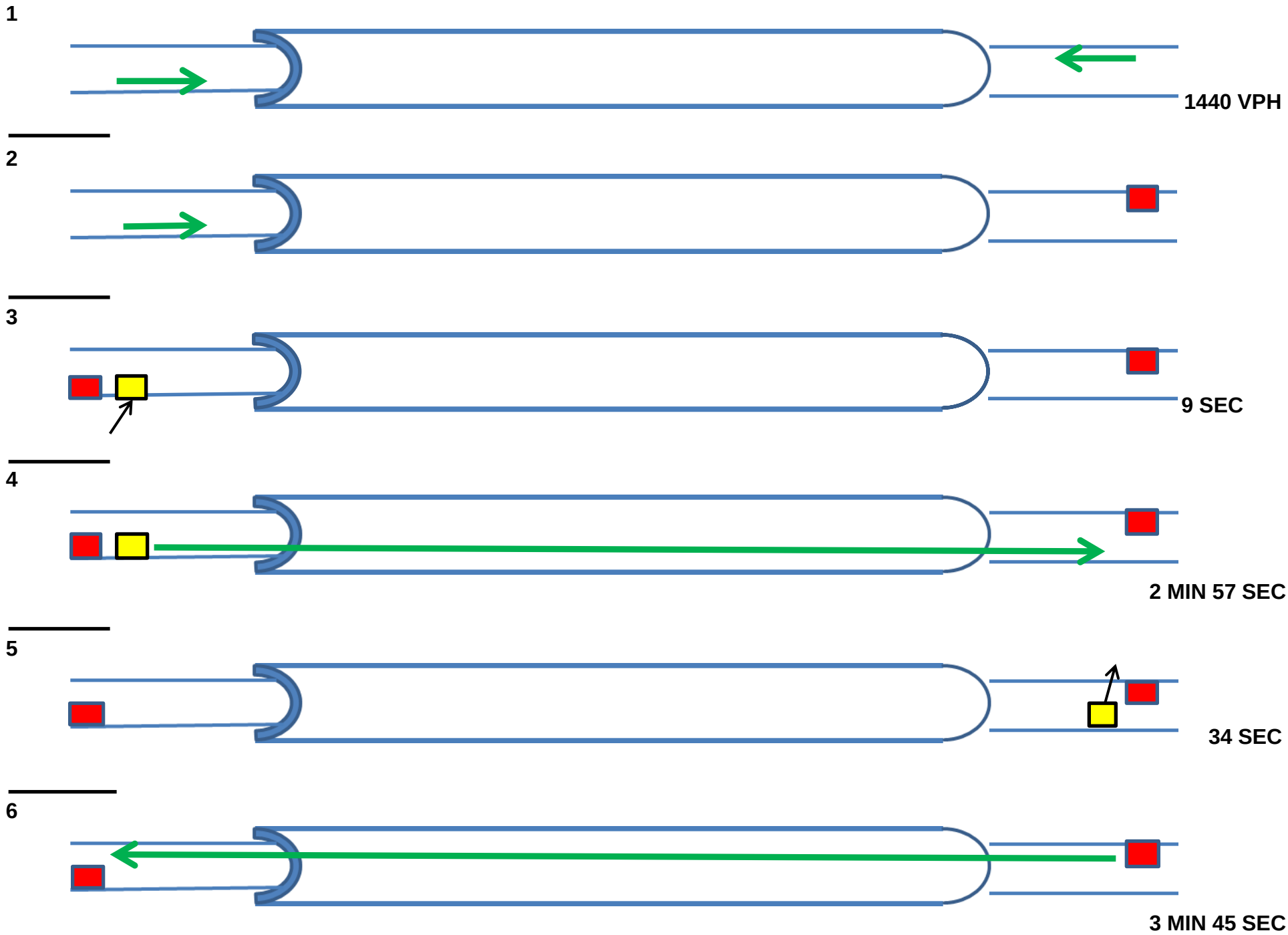
HEADWAY IN A PLATOON: 5 SECONDS

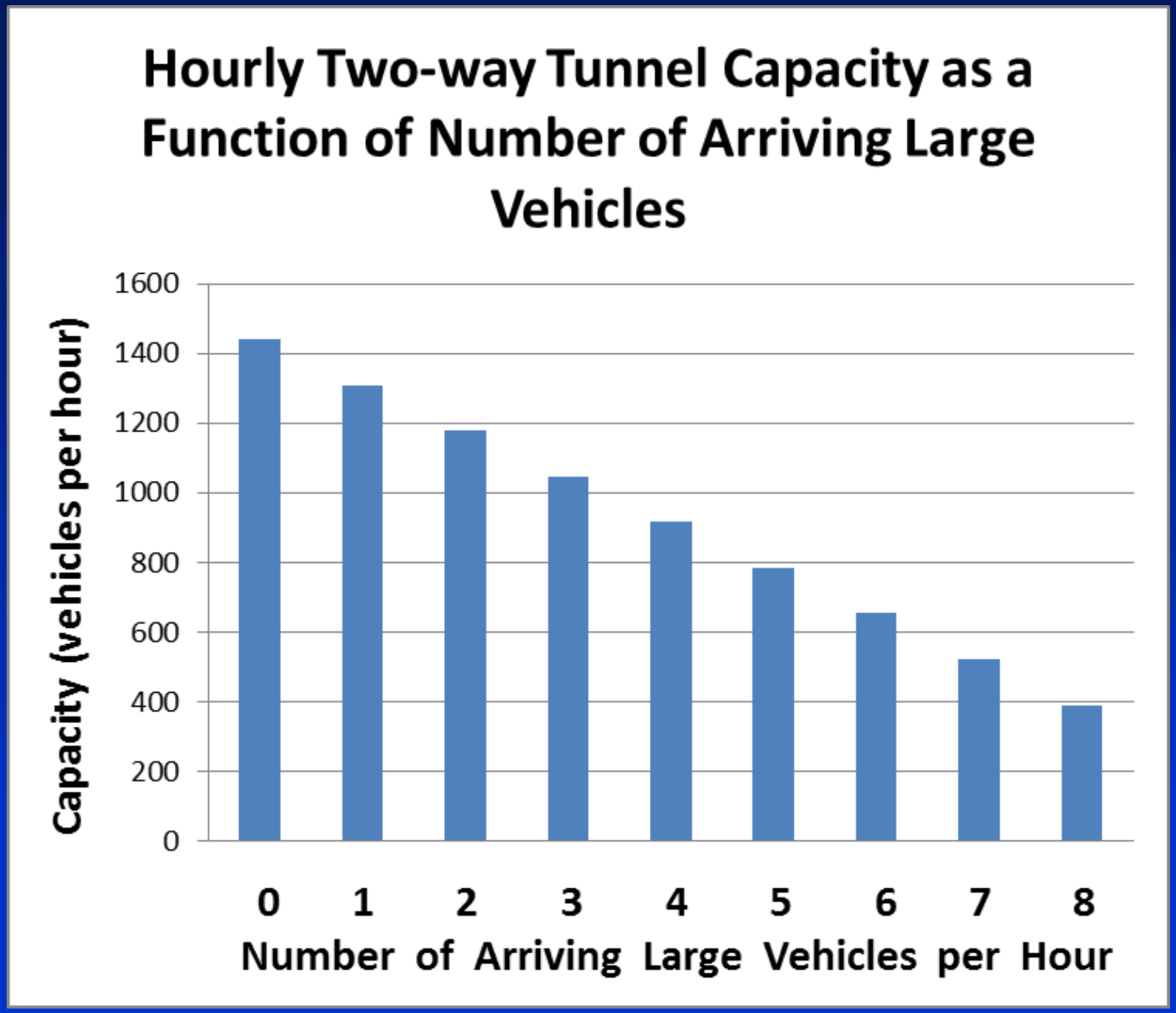
HEADWAY FOR LARGE VEHICLES: 27 SECONDS

TURNAROUND TIME: 34 SECONDS

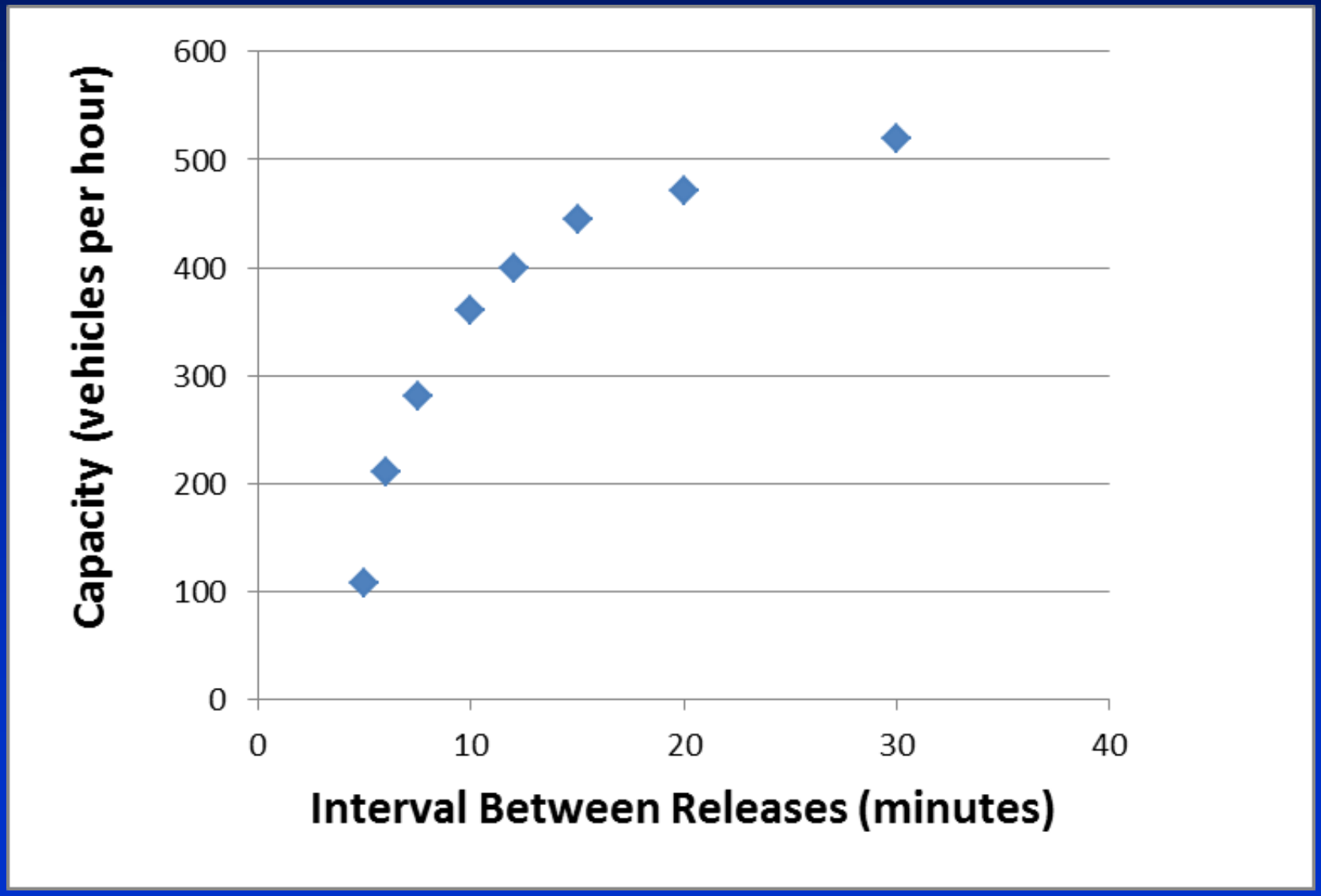
TWO-LANE RURAL HIGHWAY 3,200 PASSENGER CARS PER HOUR

TUNNEL THEORETICAL CAPACITY 1,440 PASSENGER CARS PER HOUR

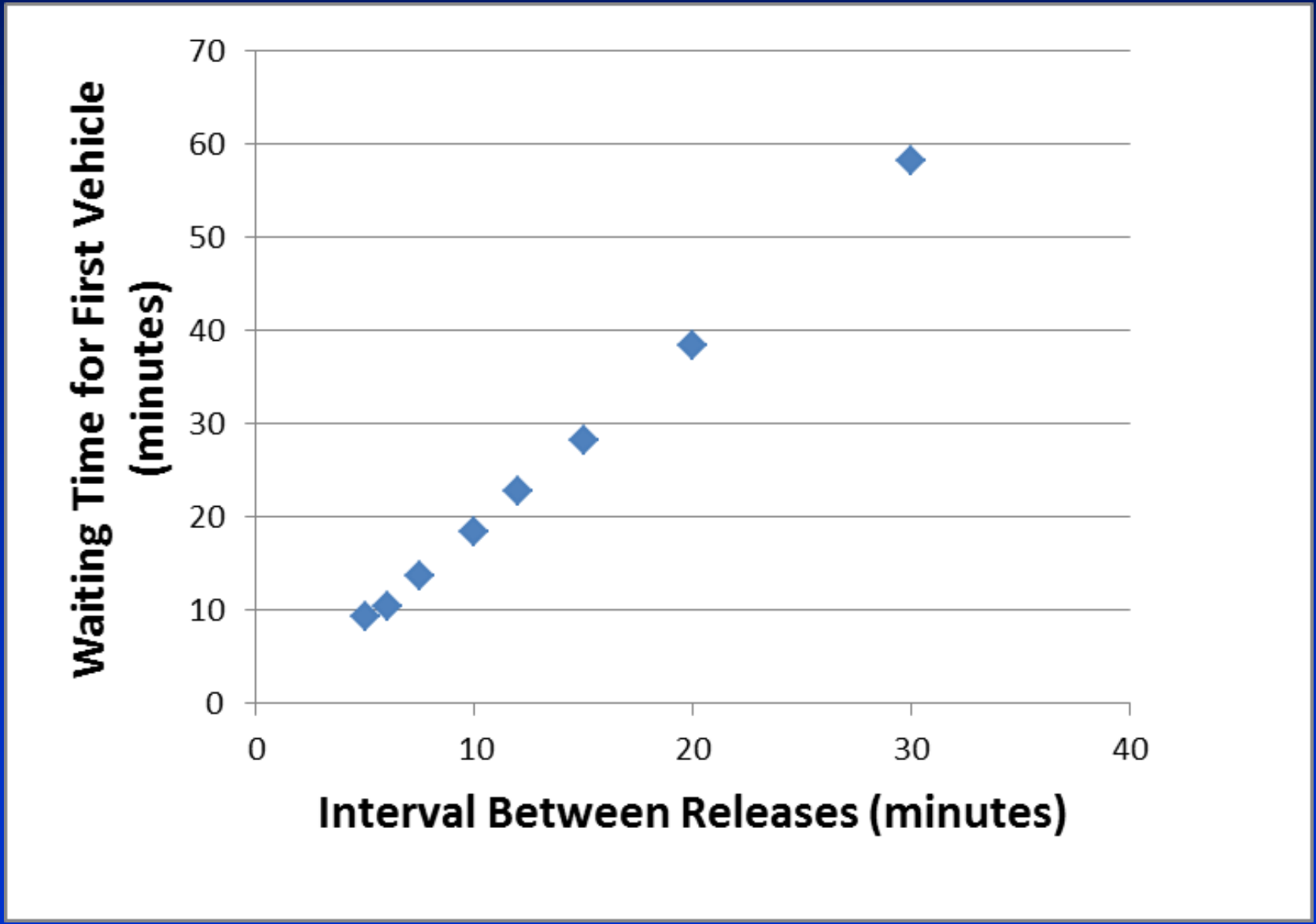

1
1440 VPH
2
3
9 SEC
4
2 MIN 57 SEC
5
34 SEC
6
3 MIN 45 SEC

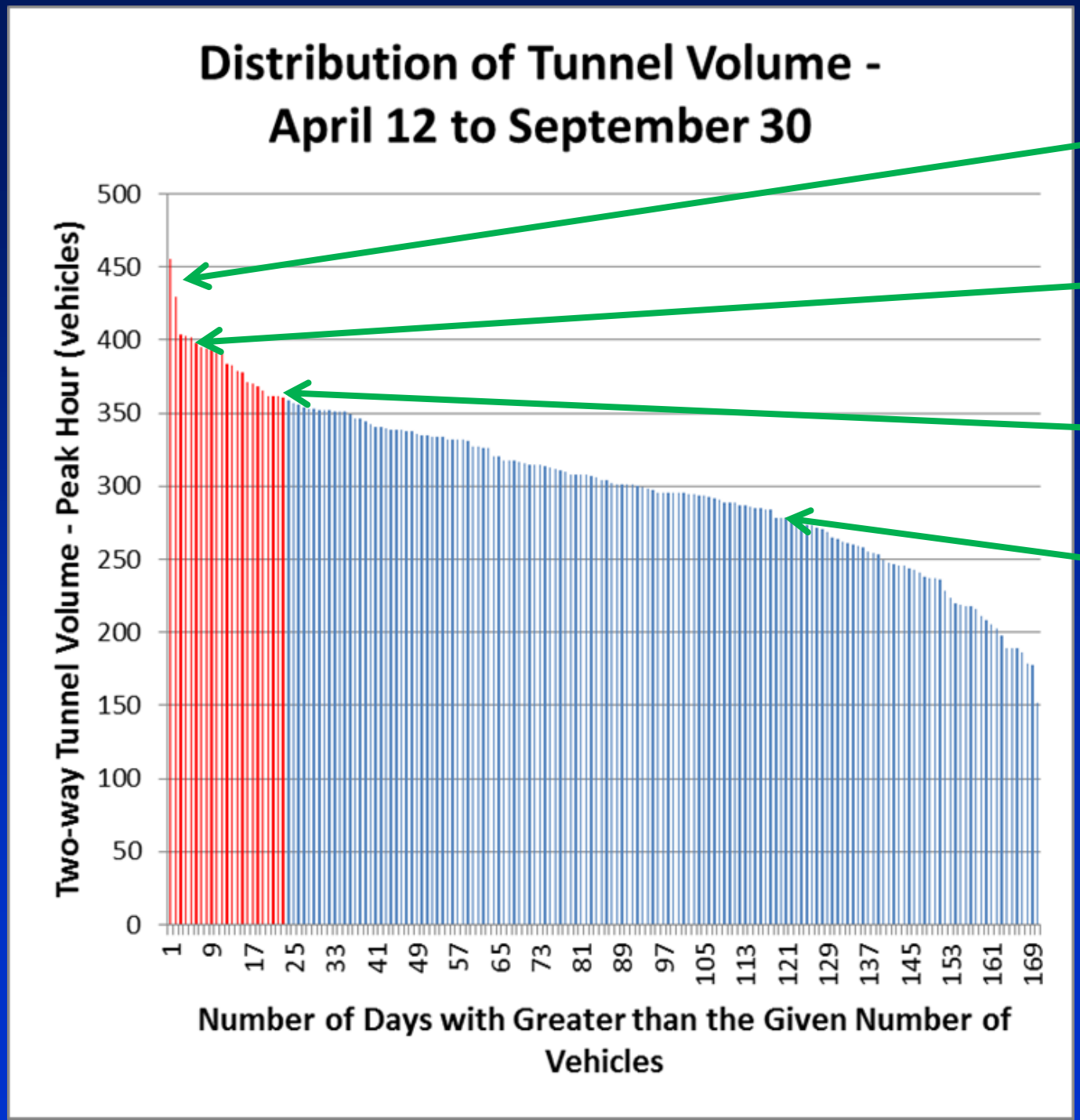

Hourly Two-way Tunnel Capacity as a Function of Number of Arriving Large Vehicles
Capacity (vehicles per hour)
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
Number of Arriving Large Vehicles per Hour

# CAPACITY AS A FUNCTION OF INTERVAL BETWEEN RELEASES



# WAITING TIME AS A FUNCTION OF INTERVAL BETWEEN RELEASES





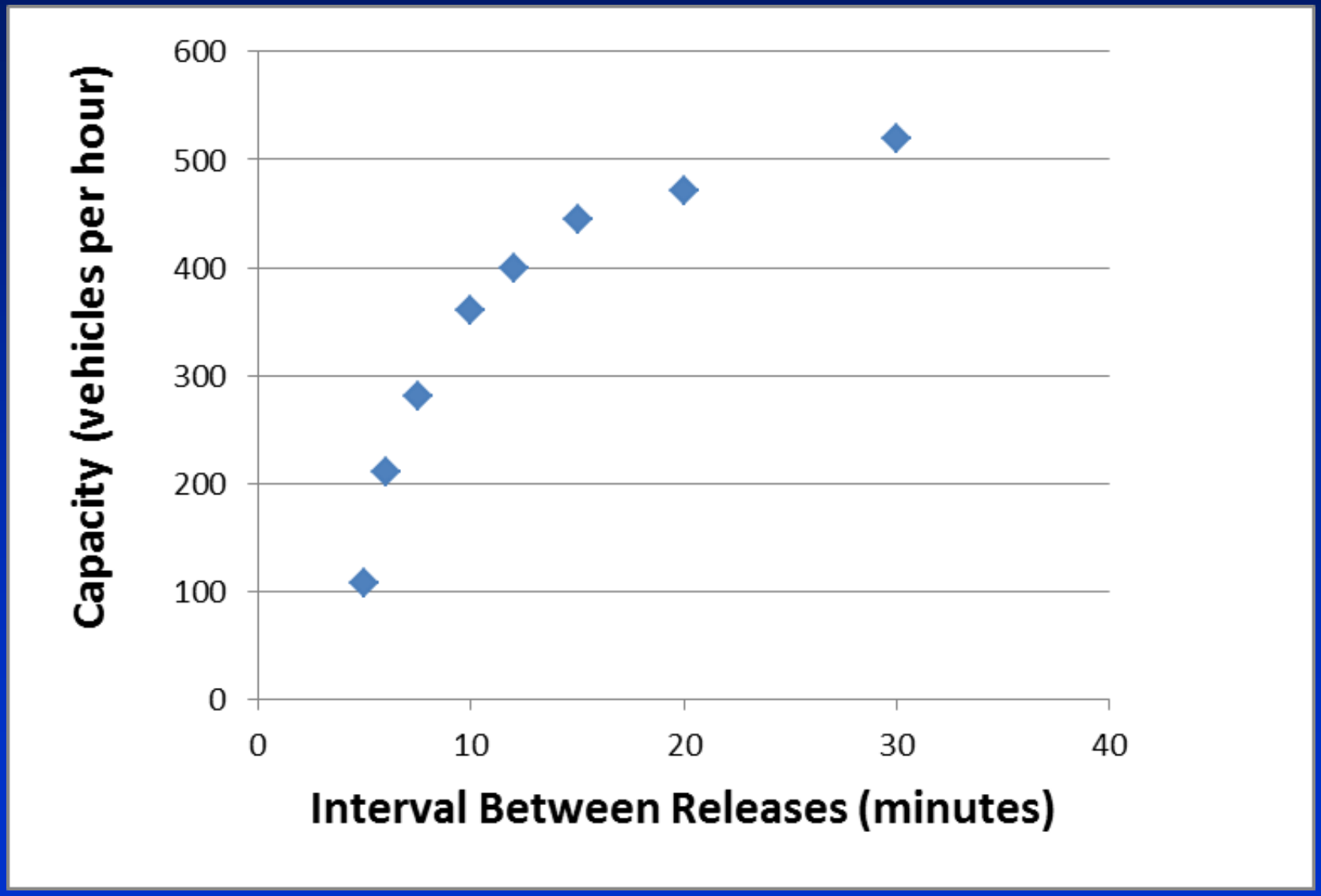

1 day with a 28:10 waiting time

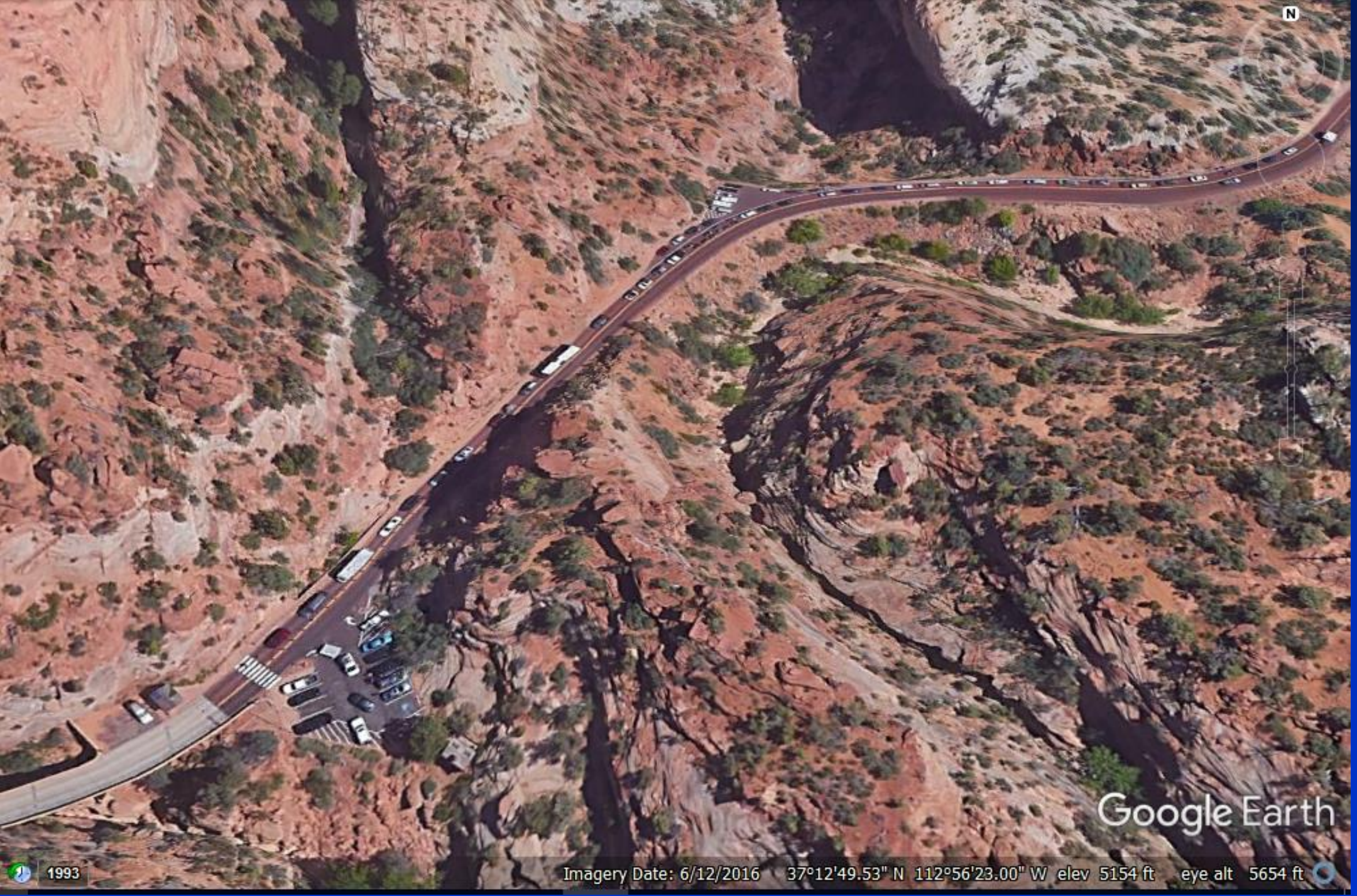
5 days with a 22:40 waiting time

23 days with a 18:20 waiting time

118 days with a 13:35 waiting time

# CAPACITY AS A FUNCTION OF INTERVAL BETWEEN RELEASES




N
Google Earth
1993
Imagery Date: 6/12/2016 37°12'49.53" N 112°56'23.00" W elev 5154 ft eye alt 5654 ft


1993
Imagery Date: 6/12/2016

# AUGUST 6 TO SEPTEMBER 23

ON AN AVERAGE DAY,
ONE-WAY OPERATION FOR AT LEAST
41 MINUTES OUT OF EVERY HOUR

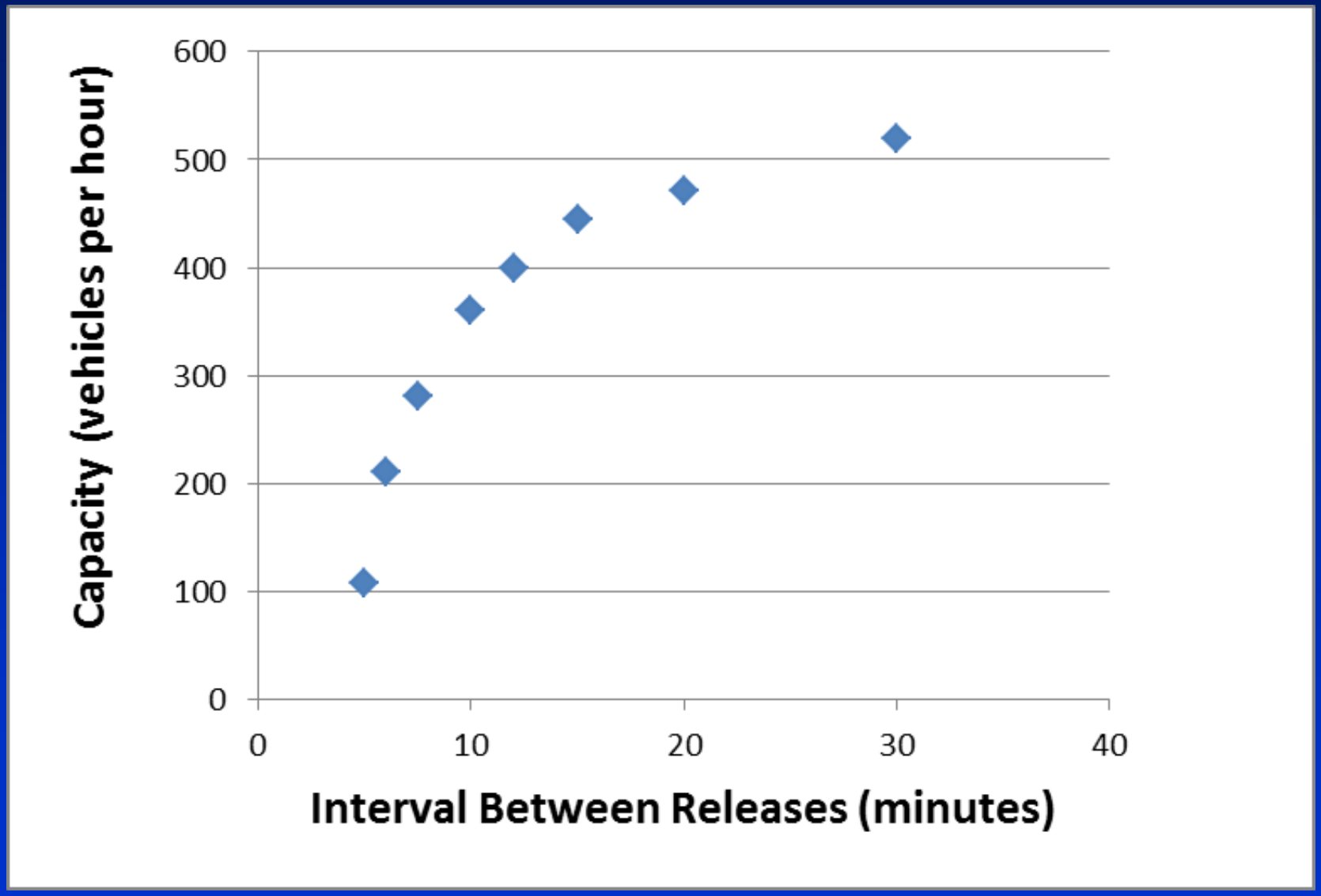
ON THE WORST DAY,
ONE-WAY OPERATION FOR AT LEAST
52 MINUTES OUT OF EVERY HOUR

# CONCLUSIONS

# RECOMMENDATIONS


# WHAT IS A TOLERABLE WAITING TIME ?

# CAPACITY AS A FUNCTION OF INTERVAL BETWEEN RELEASES



## Alternatives for Addressing the Capacity-related Issues

1. Enlarge the existing tunnel
2. Construct a parallel tunnel
3. Ban large vehicles 24/7/365
4. Ban large vehicles on a temporal basis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Kanab
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UTAH
ARIZONA
Fredonia
389
ALT 89
Pipe Spring
River

5. Restrict large vehicles to smaller time periods

6. Restrict large vehicles to only certain portions of each hour

7. Construct pulloffs to serve as large vehicle holding areas

8. Automate tunnel operation

9. Always use a “stick”, rather than a timer, to clear the tunnel

10. Increase staffing level

11. Avoid management decisions that would encourage more traffic through tunnel

12. Publicize that there will be (may be) long waiting times and otherwise do nothing

13. Utilize congestion pricing. Charge a higher fee for passage during high-volume hours

14. Other


CK