PEV INFRASTRUCTURE DEPLOYMENT COSTS AND DRIVERS' CHARGING PREFERENCES IN THE EV PROJECT

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SAE INTERNATIONAL

INL Idaho National Laboratory

U.S. DEPARTMENT OF ENERGY

Idaho National Laboratory

U.S. Department of Energy (DOE) federal laboratory

890 square mile site with 4,000 staff

Support DOE's strategic goal

- Increase U.S. energy security and reduce the nation's dependence on foreign oil

Multi-program DOE laboratory

- Nuclear Energy
- Fossil, Biomass, Wind, Geothermal and Hydropower Energy
- Advanced Vehicles and Battery Development
- Homeland Security and Cyber Security

Electric Vehicle Charging Infrastructure Demonstrations

The EV Project

Purpose is to build mature EV charging infrastructure in 17 US regions and study:

- Infrastructure deployment process
- Customer driving and charging behavior
- Impact on electric grid

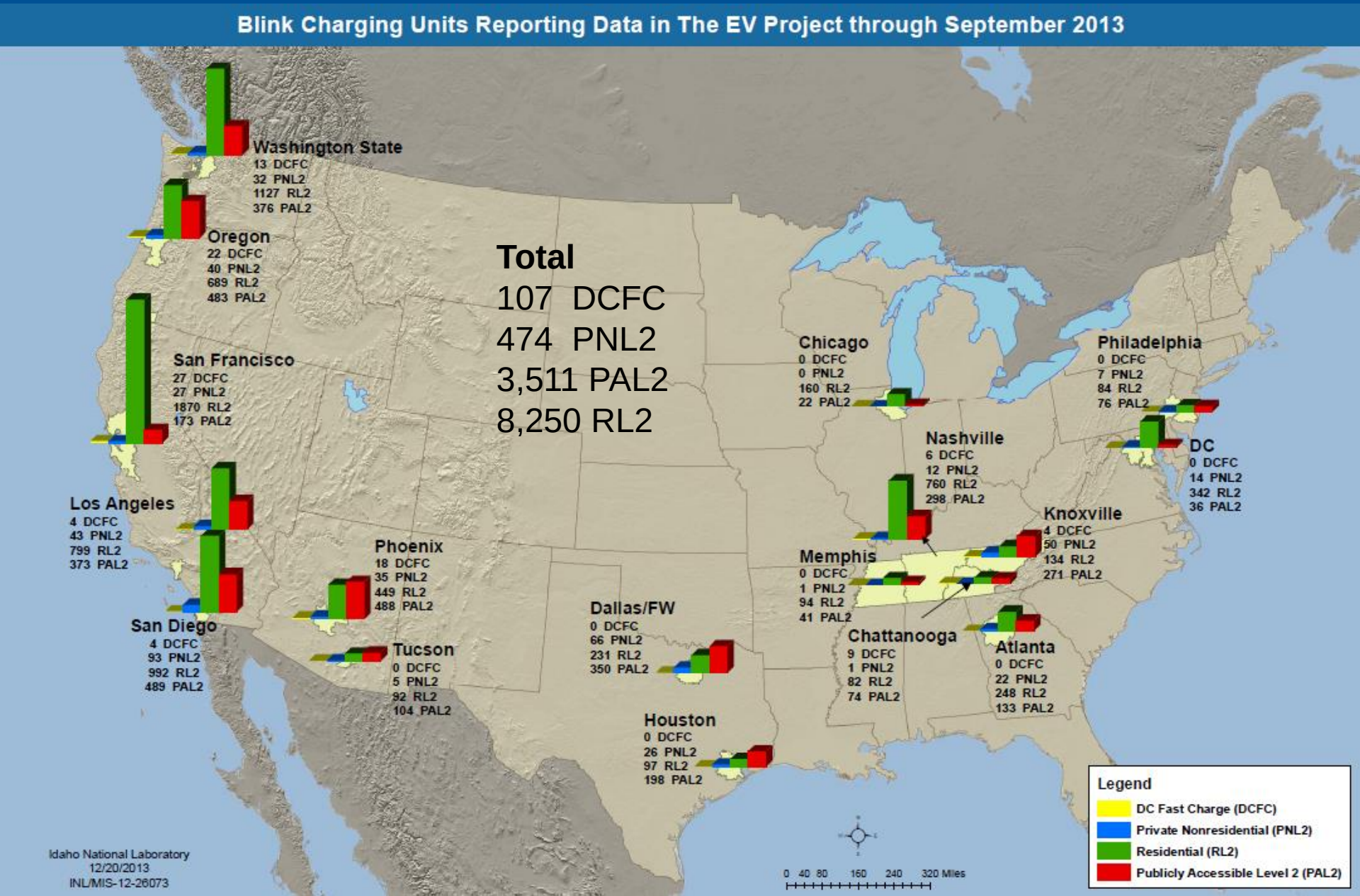
12,000+ AC level 2 charging units, 100+ DC fast chargers

8,000+ Electric drive vehicles

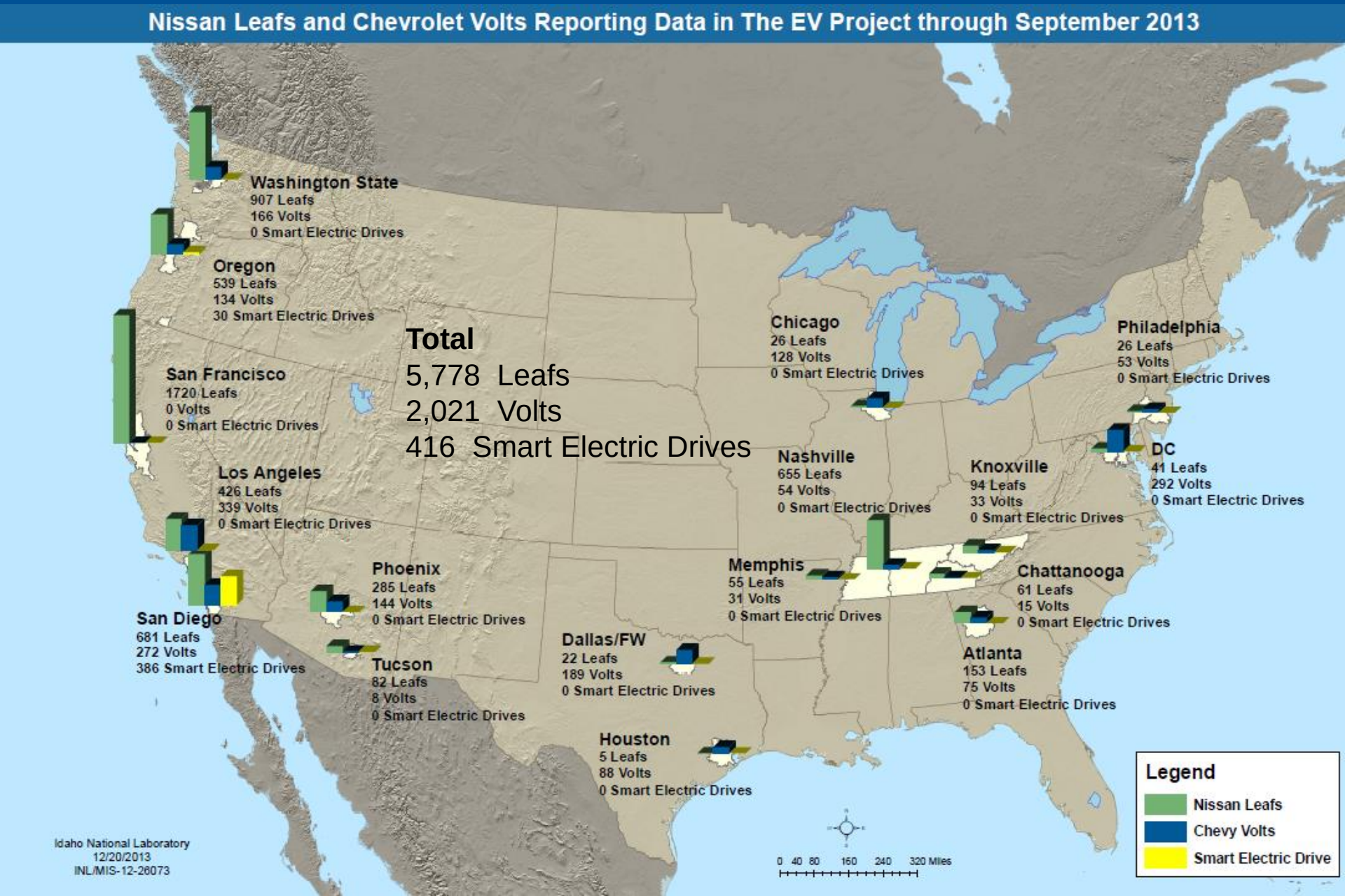
INL data collection Jan 2011 – Dec 2013

Project partners

Infrastructure Deployment in The EV Project



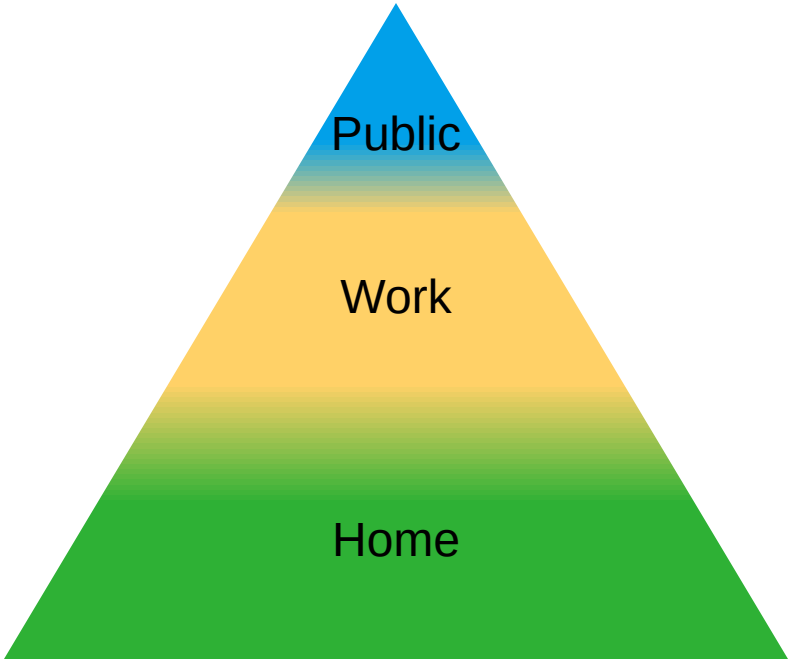
Vehicle Enrollment in The EV Project



Observations and Trends with EV Charging Infrastructure

Conventional wisdom

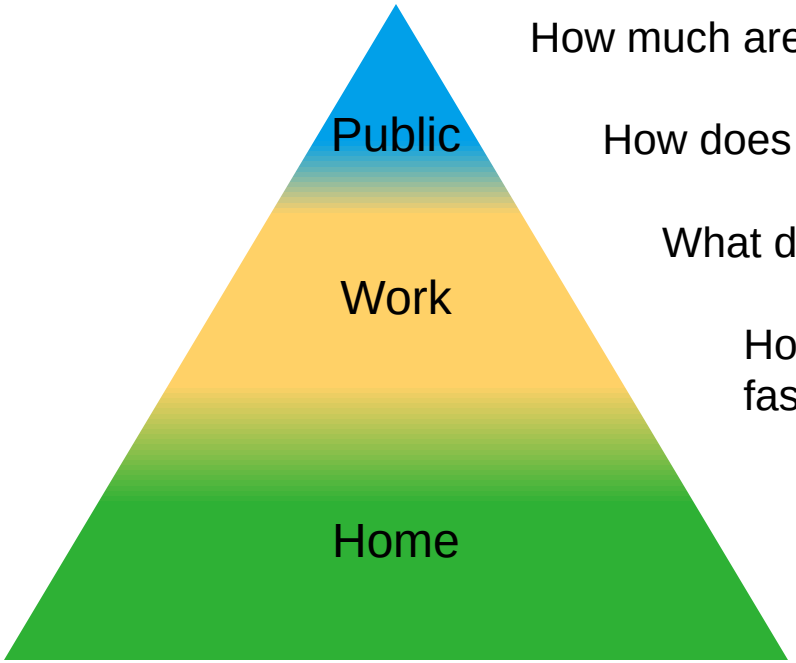
People spend most of their time at home and work, so most charging will be done there.



Observations and Trends with EV Charging Infrastructure

This presentation

Provides some insights from these infrastructure demos on actual charging behavior



How much are vehicles charged at home vs. away from home?

How does Volt charging influence EV driving range?

What do we know about workplace charging?

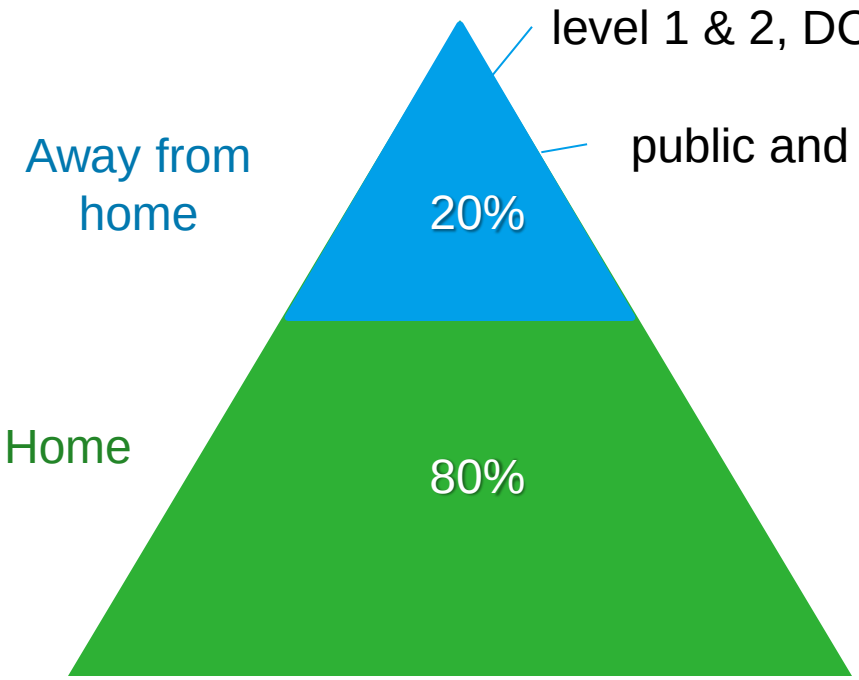
How often are residential, public level 2, and DC fast charging units being used?

What are their installation costs?

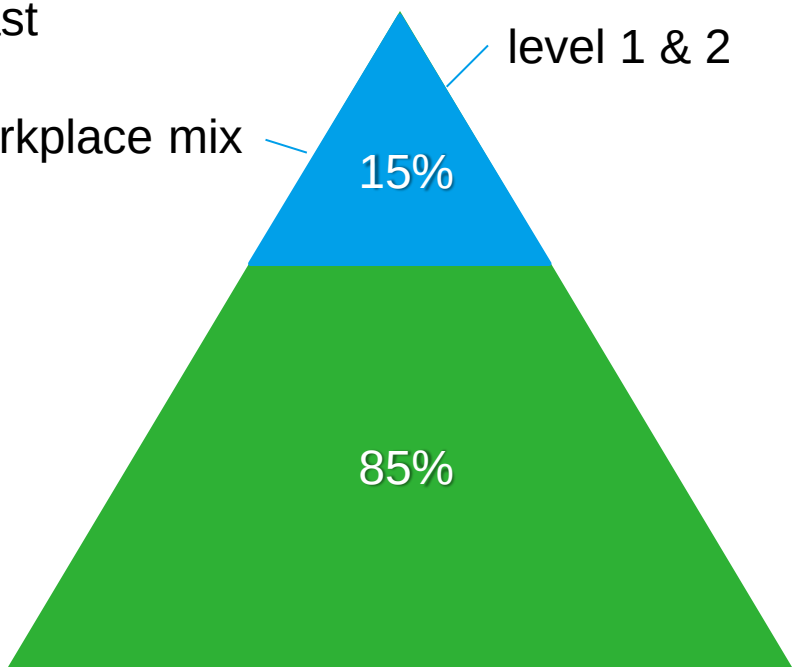
How far are Leafs traveling from home?

Charging Location Frequency

Actual vehicle charging locations between Jul 2013 – Sep 2013 in The EV Project



Nissan Leaf

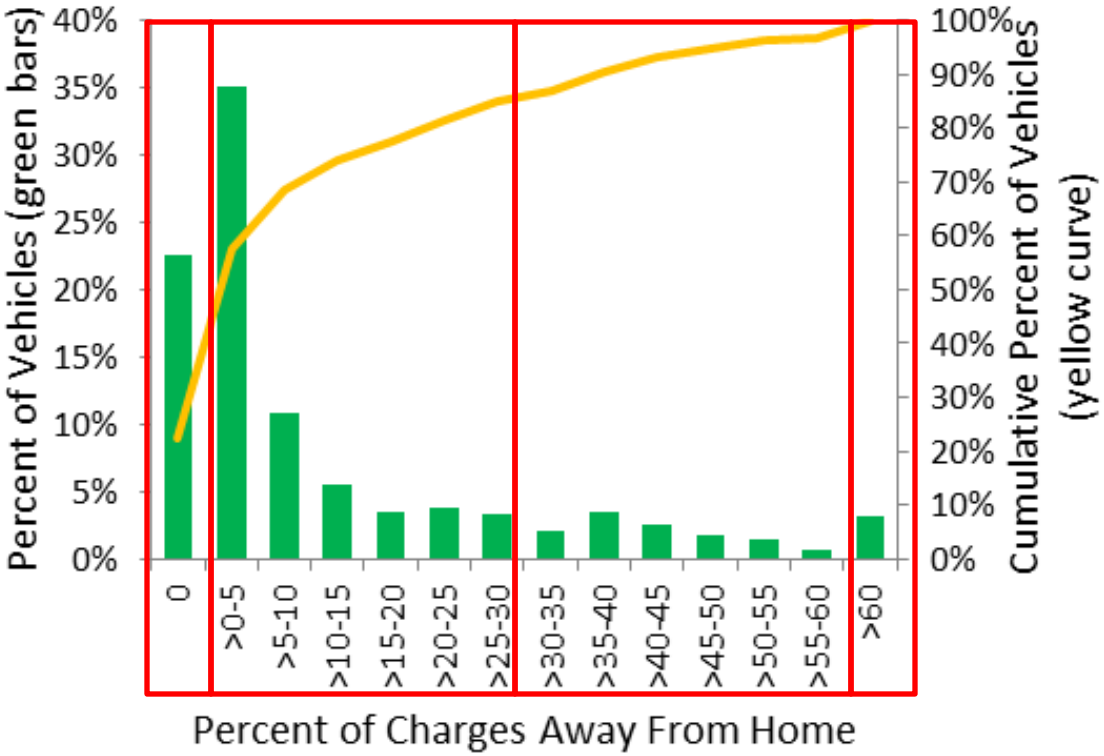


Chevrolet Volt

Based on 256,288 charging events from 4,036 Leafs and 179,681 charging events from 1,812 Volts in Q3 2013
Additional 15,099 Leaf and 11,579 Volt charging events occurred at unknown locations

Away-from-home Charging Frequency for Volts in The EV Project

Charging data from 1,405 Volts in 18 regions from Oct 2012 – May 2013



Effect of Away-from-home Charging for Volts in The EV Project

Charging data from 1,405 Volts in 18 regions from Oct 2012 – May 2013

% of Charging Away from Home:	0%
Vehicles (% of total)	259 (22%)
Home Charges Per Day	1.2
Away-from-home Charges Per Day	--
Home SOC Increase Per Charge	55.9
Away-from-home SOC Increase Per Charge	--
Average Miles Per Day Driven	34.6
Percent of Miles Driven in EV Mode	72%
Average EV Miles Per Day Driven	25.0

Effect of Away-from-home Charging for Volts in The EV Project

Charging data from 1,405 Volts in 18 regions from Oct 2012 – May 2013

% of Charging Away from Home:	0%	>0 - 30%
Vehicles (% of total)	259 (22%)	719 (62%)
Home Charges Per Day	1.2	1.3
Away-from-home Charges Per Day	--	0.1
Home SOC Increase Per Charge	55.9	54.7
Away-from-home SOC Increase Per Charge	--	45.3
Average Miles Per Day Driven	34.6	39.2
Percent of Miles Driven in EV Mode	72%	73%
Average EV Miles Per Day Driven	25.0	28.4

This group supplemented home charging with a little away-from-home charging

This group drove a little more each day

Additional charging provided energy for more EV miles per day

Effect of Away-from-home Charging for Volts in The EV Project

Charging data from 1,405 Volts in 18 regions from Oct 2012 – May 2013

% of Charging Away from Home:	0%	>0 - 30%	>30 -60%
Vehicles (% of total)	259 (22%)	719 (62%)	140 (12%)
Home Charges Per Day	1.2	1.3	1.1
Away-from-home Charges Per Day	--	0.1	0.8
Home SOC Increase Per Charge	55.9	54.7	60.5
Away-from-home SOC Increase Per Charge	--	45.3	48.3
Average Miles Per Day Driven	34.6	39.2	50.9
Percent of Miles Driven in EV Mode	72%	73%	75%
Average EV Miles Per Day Driven	25.0	28.4	38.3

Compared to vehicles with no away-from home charging…

This group supplemented home charging with a lot of away-from-home charging

This group drove a lot more each day

Additional charging provided energy for many more EV miles per day (53% increase)

Effect of Away-from-home Charging for Volts in The EV Project

Charging data from 1,405 Volts in 18 regions from Oct 2012 – May 2013

% of Charging Away from Home:	0%	>0 - 30%	>30 -60%	>60%
Vehicles (% of total)	259 (22%)	719 (62%)	140 (12%)	36 (3%)
Home Charges Per Day	1.2	1.3	1.1	0.3
Away-from-home Charges Per Day	--	0.1	0.8	1.2
Home SOC Increase Per Charge	55.9	54.7	60.5	48.5
Away-from-home SOC Increase Per Charge	--	45.3	48.3	52.7
Average Miles Per Day Driven	34.6	39.2	50.9	38.4
Percent of Miles Driven in EV Mode	72%	73%	75%	73%
Average EV Miles Per Day Driven	25.0	28.4	38.3	28.0

Compared to vehicles with no away-from home charging…

This group supplemented away-from-home charging with some home charging (*workplace charging?*)

This group drove a little more each day

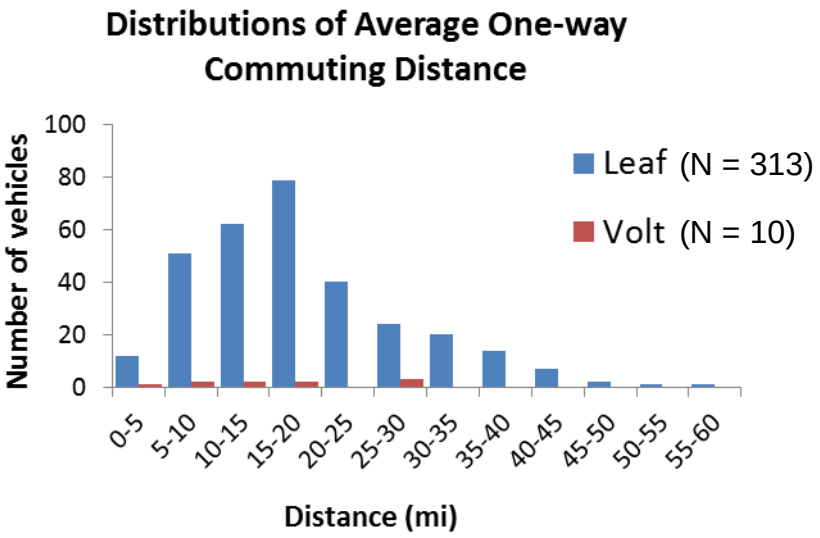
Additional charging provided energy for a little more EV miles per day

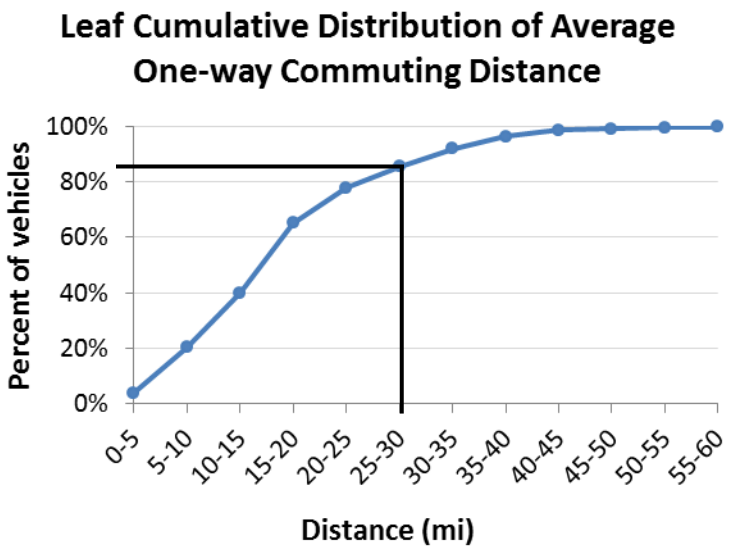
Workplace Charging Case Studies

Worksites identified where EV Project participant vehicles have parked and charged a significant number of times (excluding fleet vehicles)

Region	Number of work sites	Charging locations per site	Types of companies
Knoxville, TN	2	1, 4	Offices, manufacturing plants, and R&D facilities of companies in computer, telecom, pharmaceutical, biotech, automotive, aerospace, and other industries
Nashville, TN	6	1 - 6	
Portland, OR	2	1, 4	
Phoenix, AZ	1	5	
San Diego, CA	11	1 - 15	
San Francisco, CA	51	1 - 10	
Total	73		

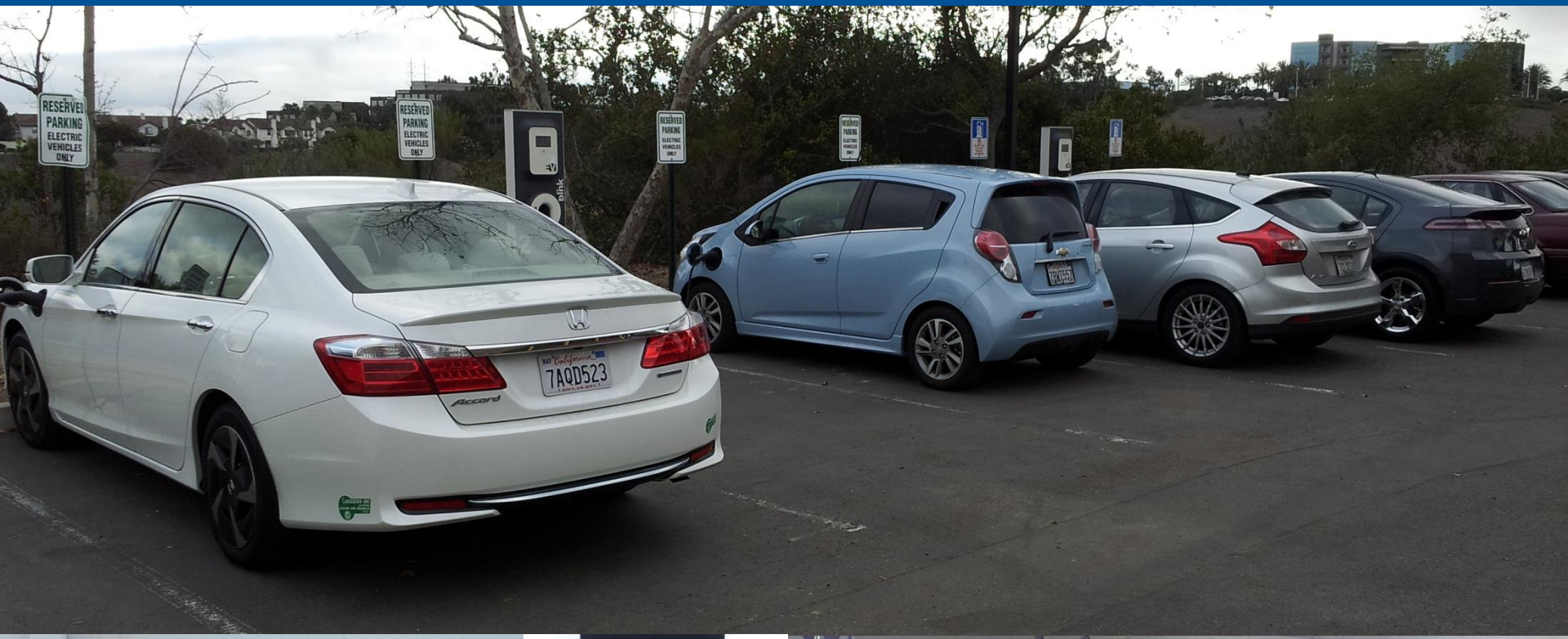
Workplace Charging Case Studies – Commuting Distance

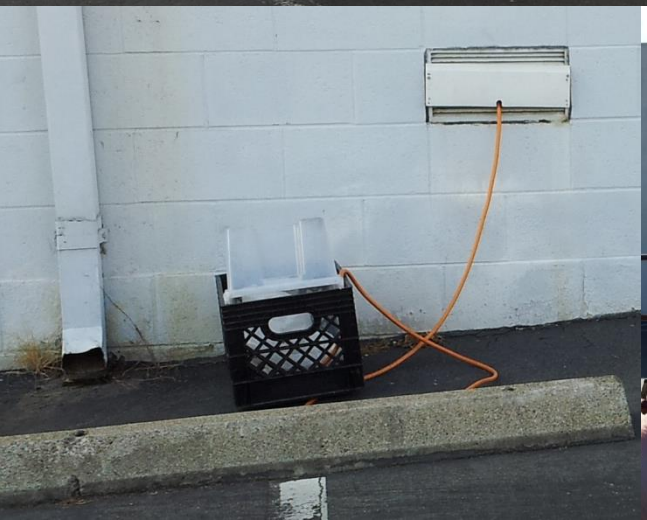




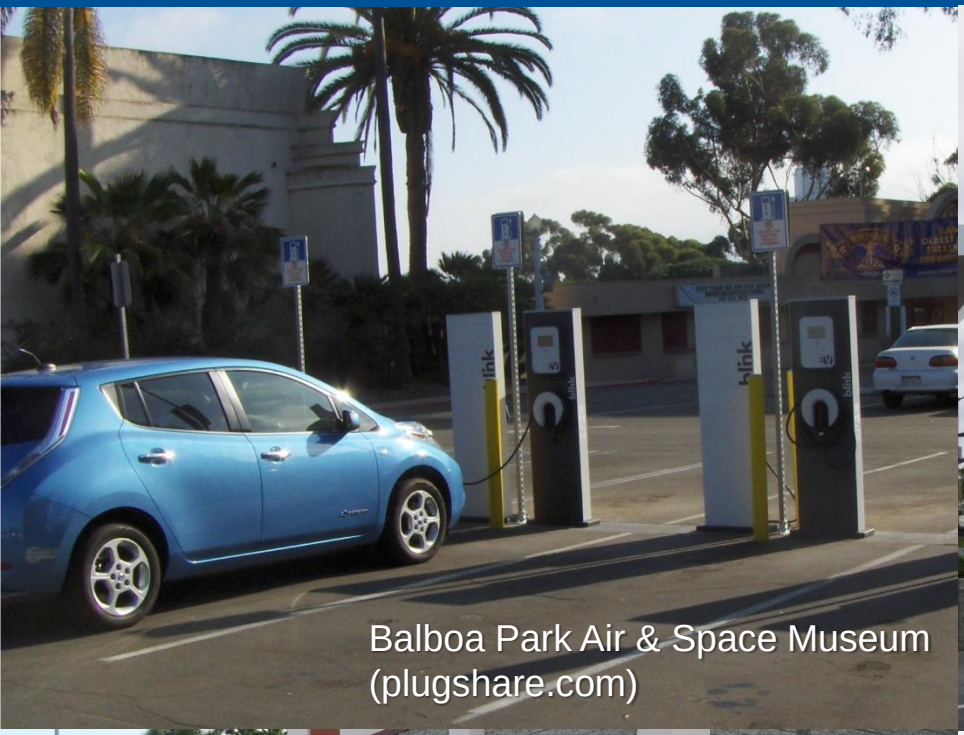
86% of EV Project Leafs parking at worksites identified average 30 miles or less between home and work

Workplace Charging Examples in San Diego





Public Level 2 Charging Examples in San Diego

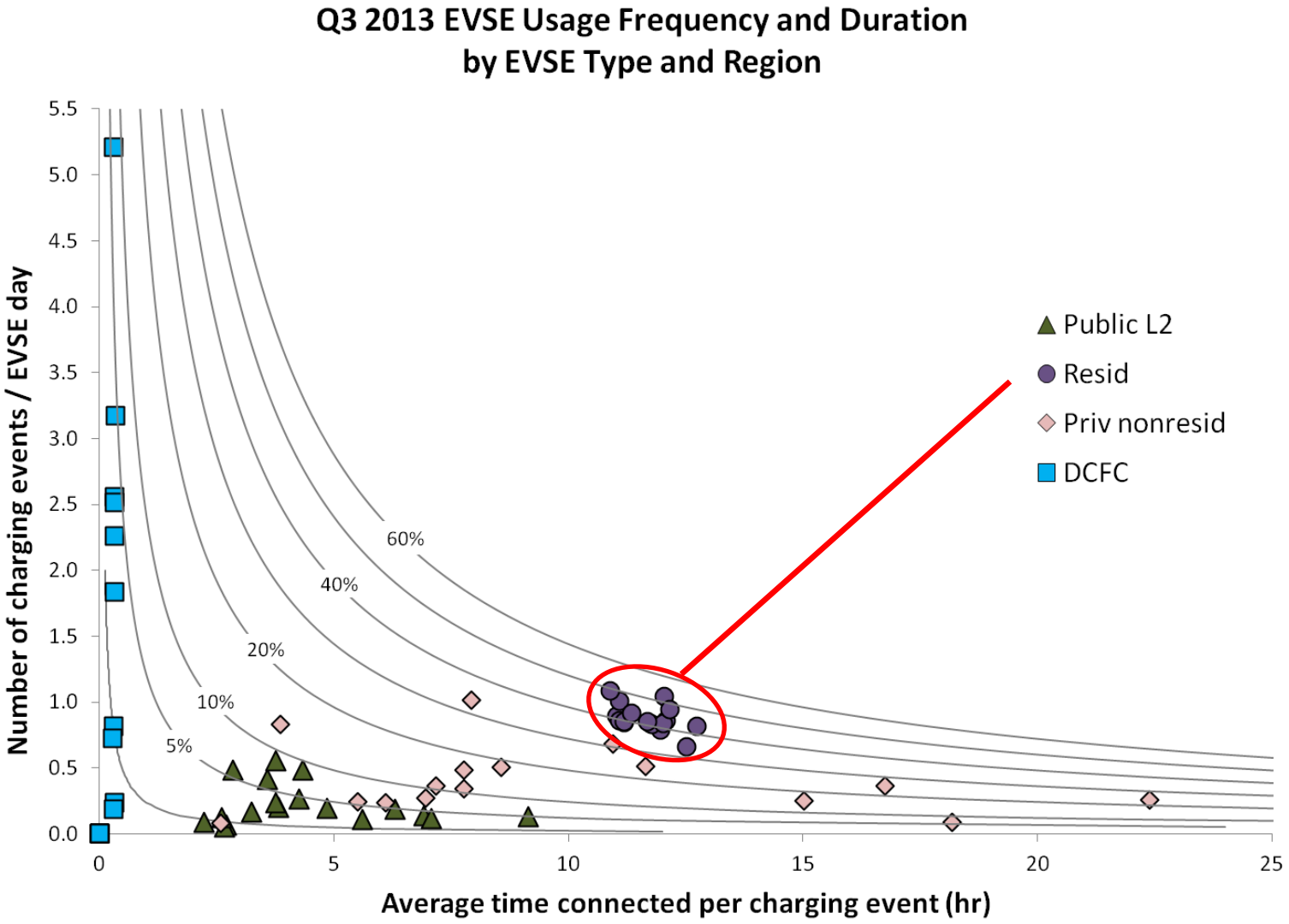


Balboa Park Air & Space Museum
(plugshare.com)

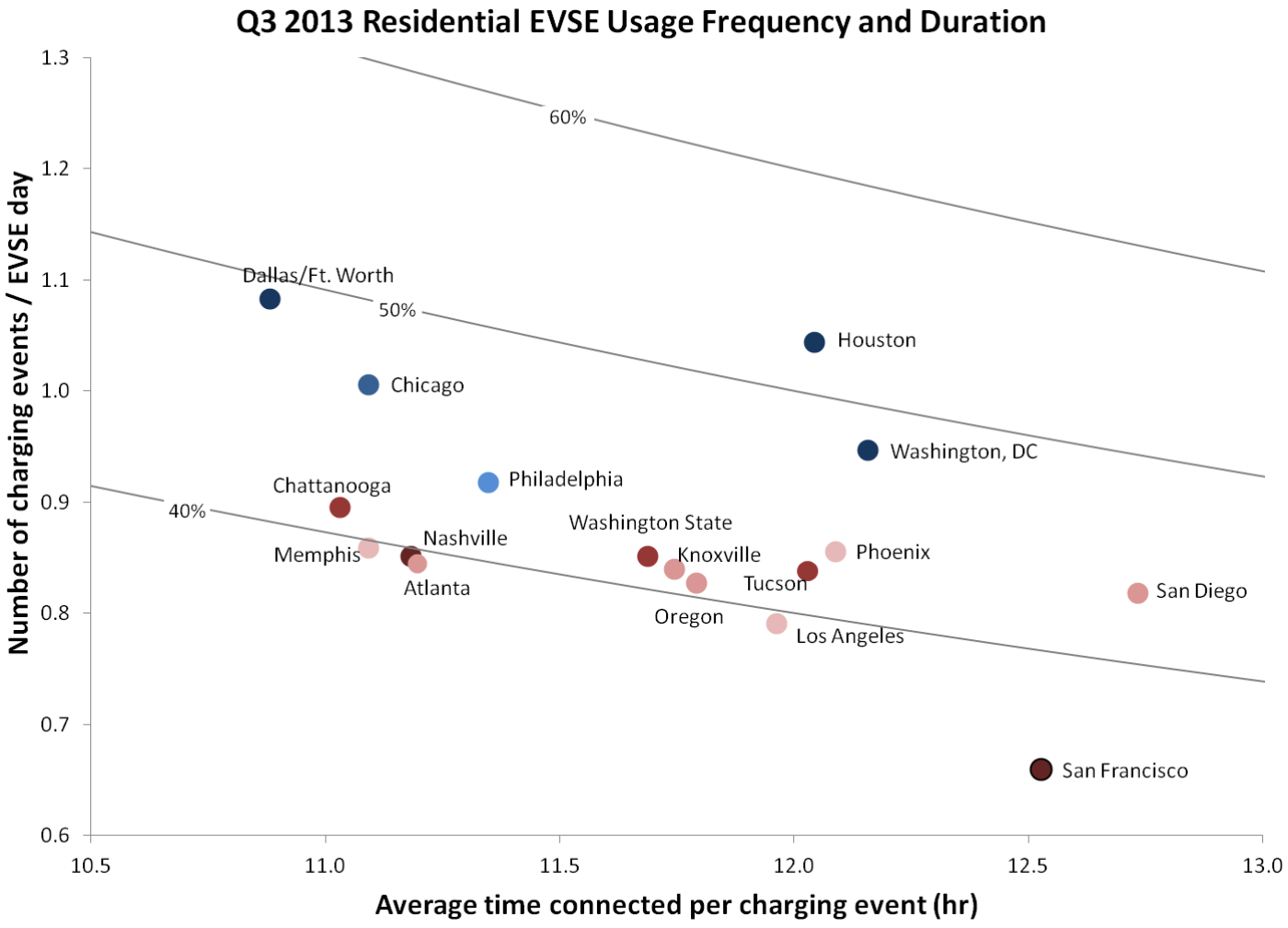
San Diego State University

West Mission Valley Mall – Macy's

Usage of AC Level 2 EVSE and DC Fast Chargers



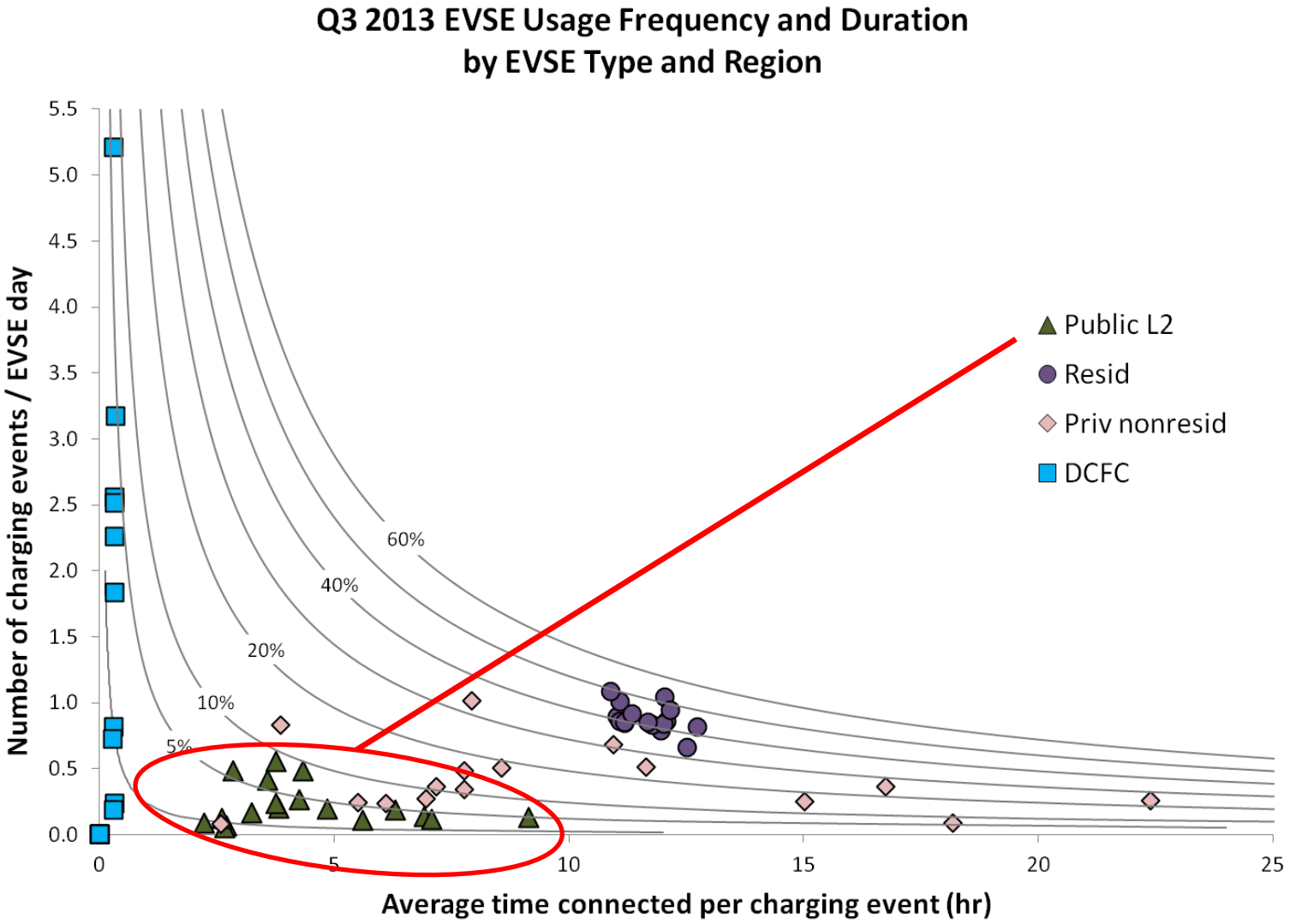
Usage of AC Level 2 EVSE and DC Fast Chargers



Percent of residential charging events by vehicle make and territory

Territory	Leaf	Volt	Plot Color
San Francisco	100%	0%	
Nashville	88%	12%	
Tucson	81%	19%	
Washington State	76%	24%	
Chattanooga	74%	26%	
Oregon	68%	32%	
Knoxville	66%	34%	
San Diego	64%	36%	
Atlanta	63%	37%	
Phoenix	53%	47%	
Memphis	52%	48%	
Los Angeles	39%	61%	
Philadelphia	28%	72%	
Chicago	14%	86%	
DC	11%	89%	
Dallas/Ft. Worth	8%	92%	
Houston	6%	94%	

Usage of AC Level 2 EVSE and DC Fast Chargers



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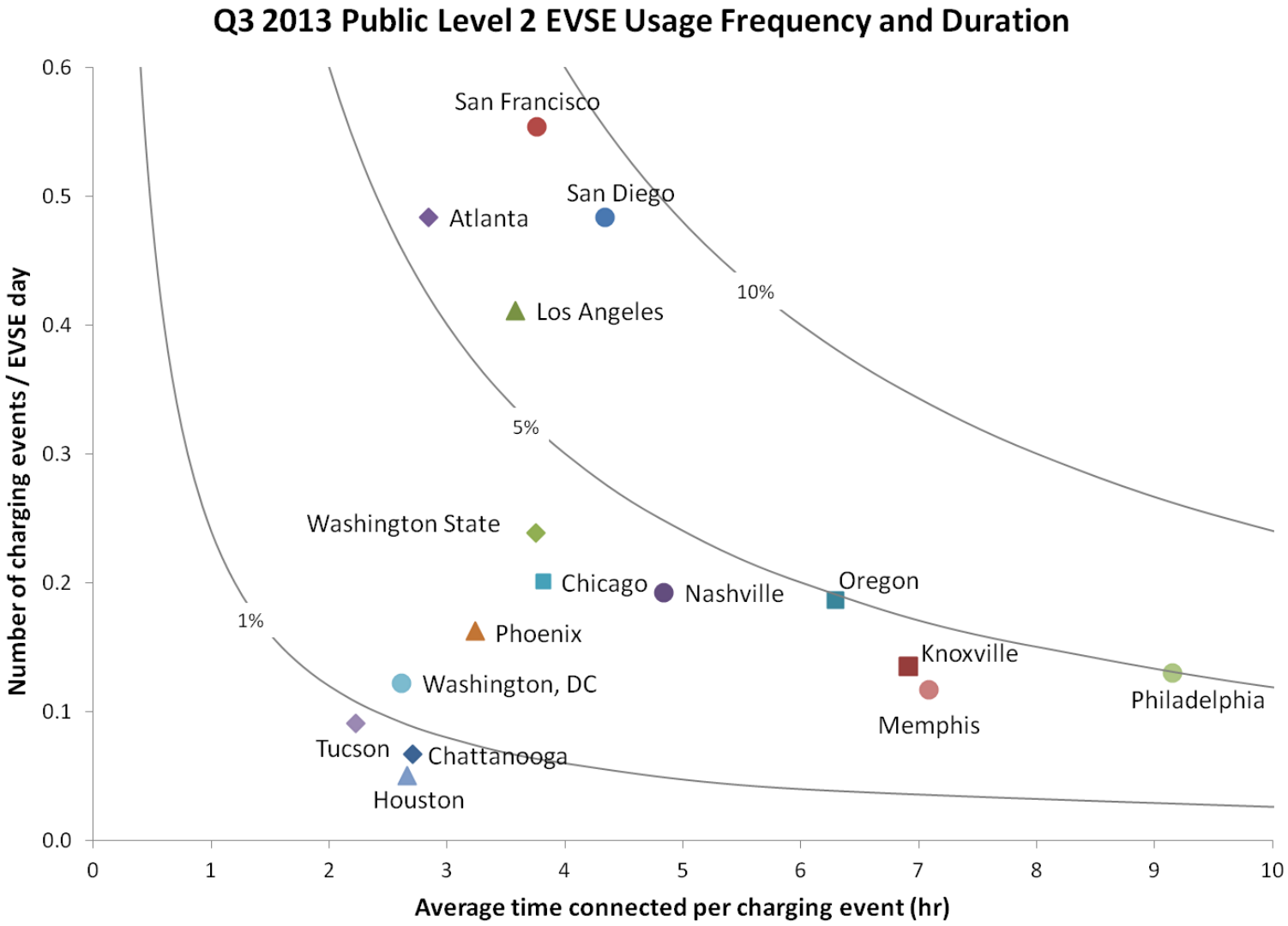

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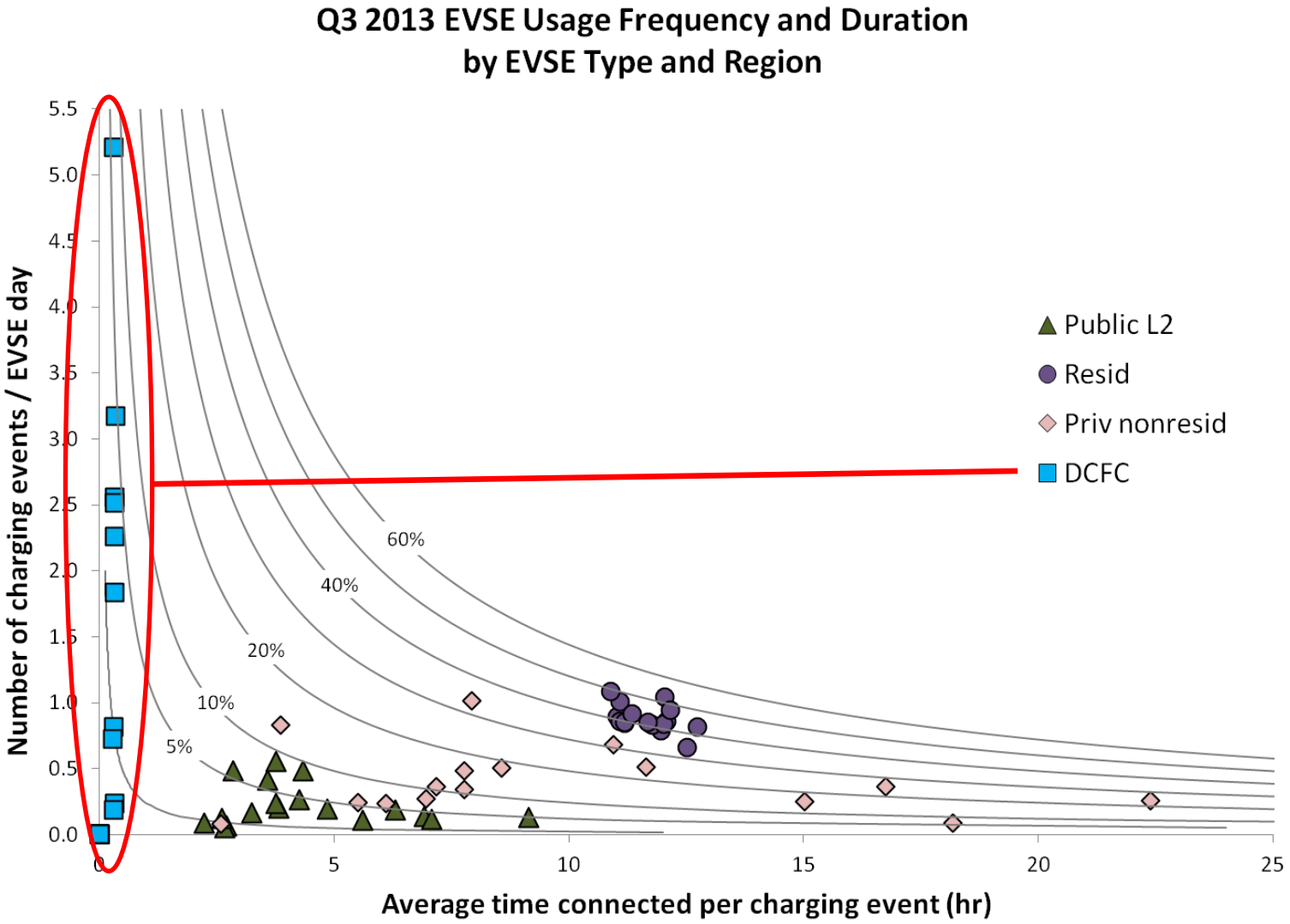

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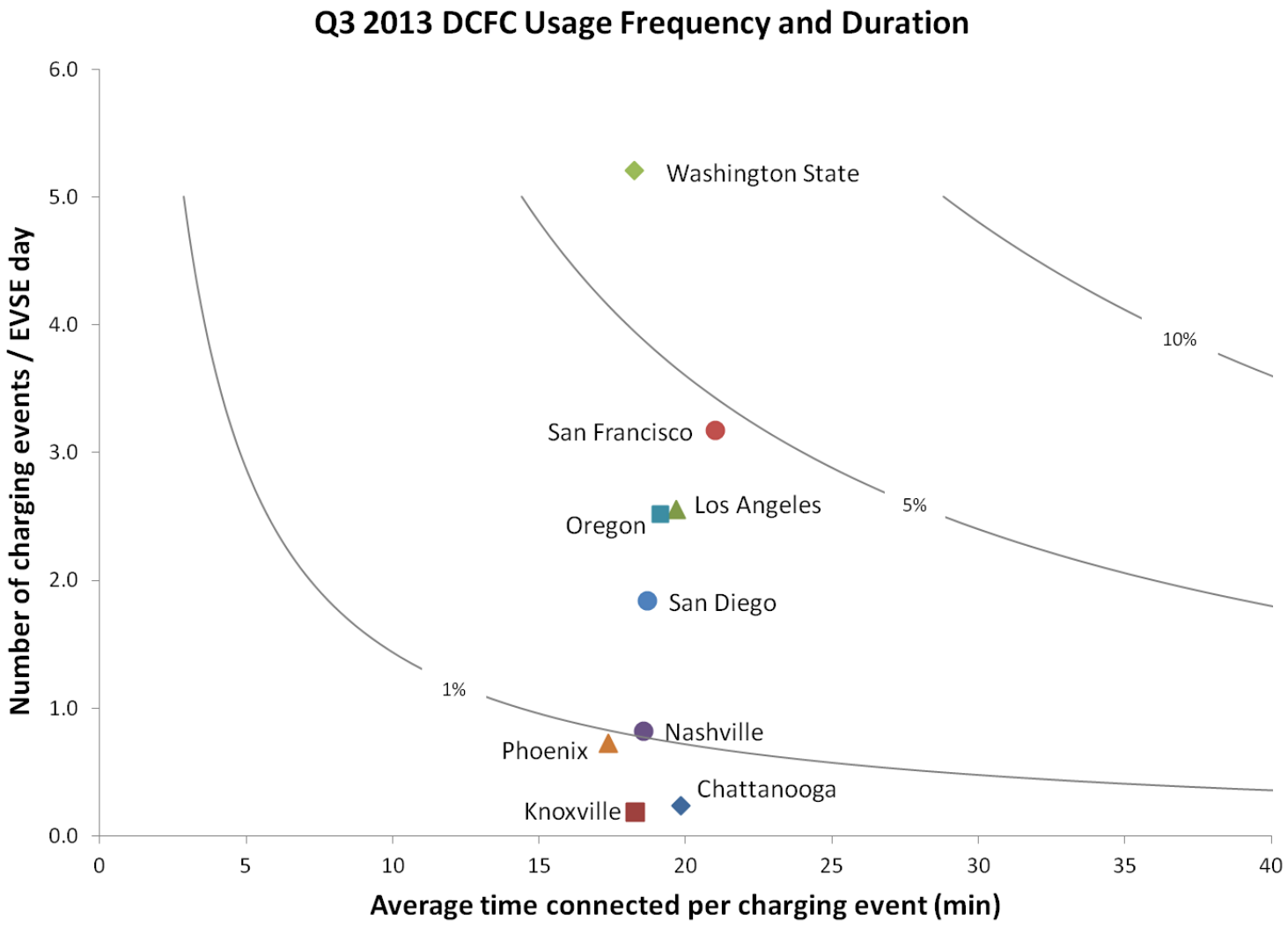
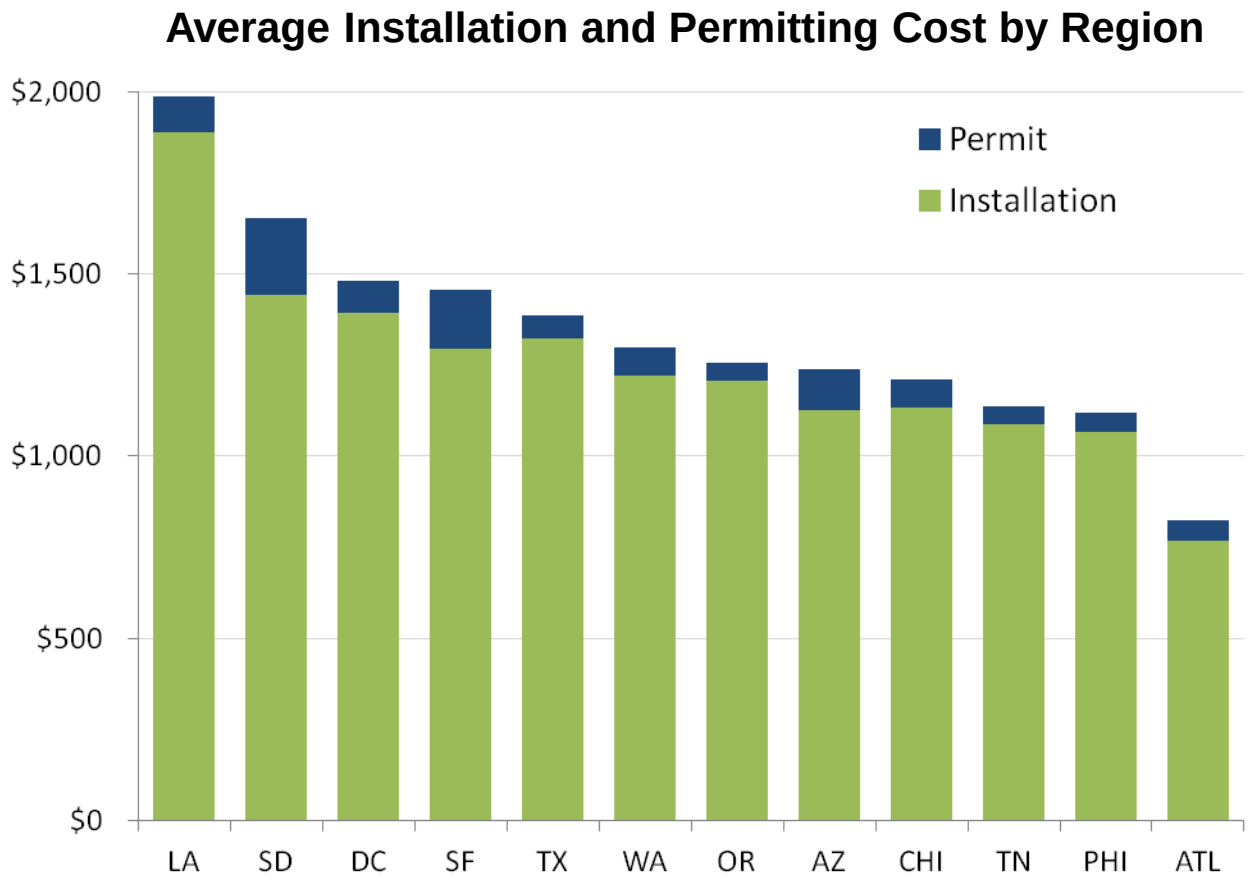


Residential Level 2 EVSE Installation and Permitting Cost (Preliminary)



N = 4,466 units installed before May 2013

Installation cost does not include cost of EVSE

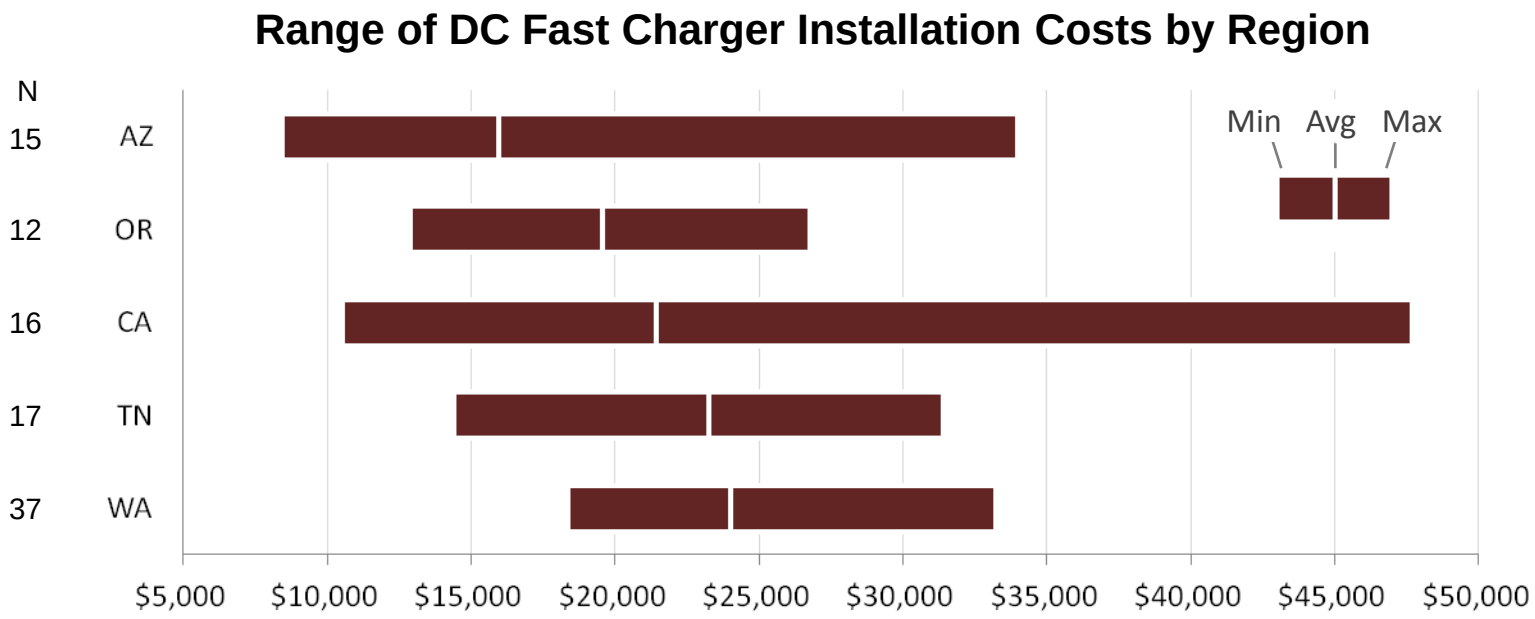
Residential Level 2 EVSE Installation and Permitting Cost (Preliminary)

- Costs are influence by project design
  - participant selection criteria
  - subsidy limit
- High costs driven by need to upgrade entire residential electrical service (worst case ex: $8,429) or other requests, such as:
  - Not installing near the service panel
  - Desire to site away from the house and concrete must be cut
- Low costs driven by things like an existing 240 V outlet in the garage

Commercial Level 2 EVSE Installation and Permitting Cost (Preliminary)

- Commercially sited level 2 EVSE averaged between $3,500 and $4,500 for the installation cost through May 2013 (excluding hardware)
- There is much variability by region and by installation
  - Tennessee and Arizona had lowest average installation costs of $2,000 to $2,500
  - Multiple Level 2 units at one location drive down the per EVSE average installation cost
- Costs are significantly driven by poor site requests
  - Example: mayor may want EVSE by front door of city hall, but electric service is located at back of building

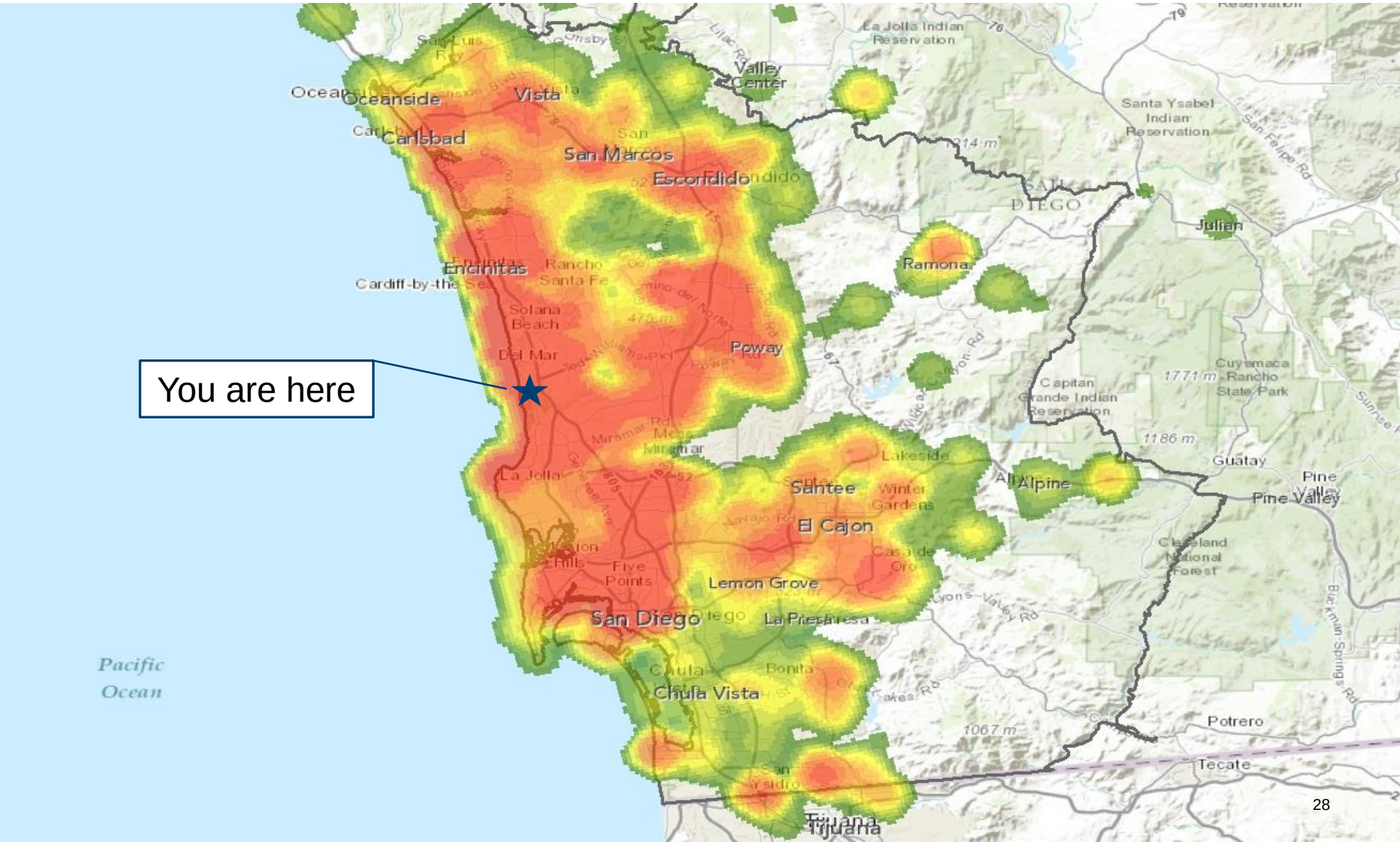
DC Fast Charger Installation Cost (Preliminary)



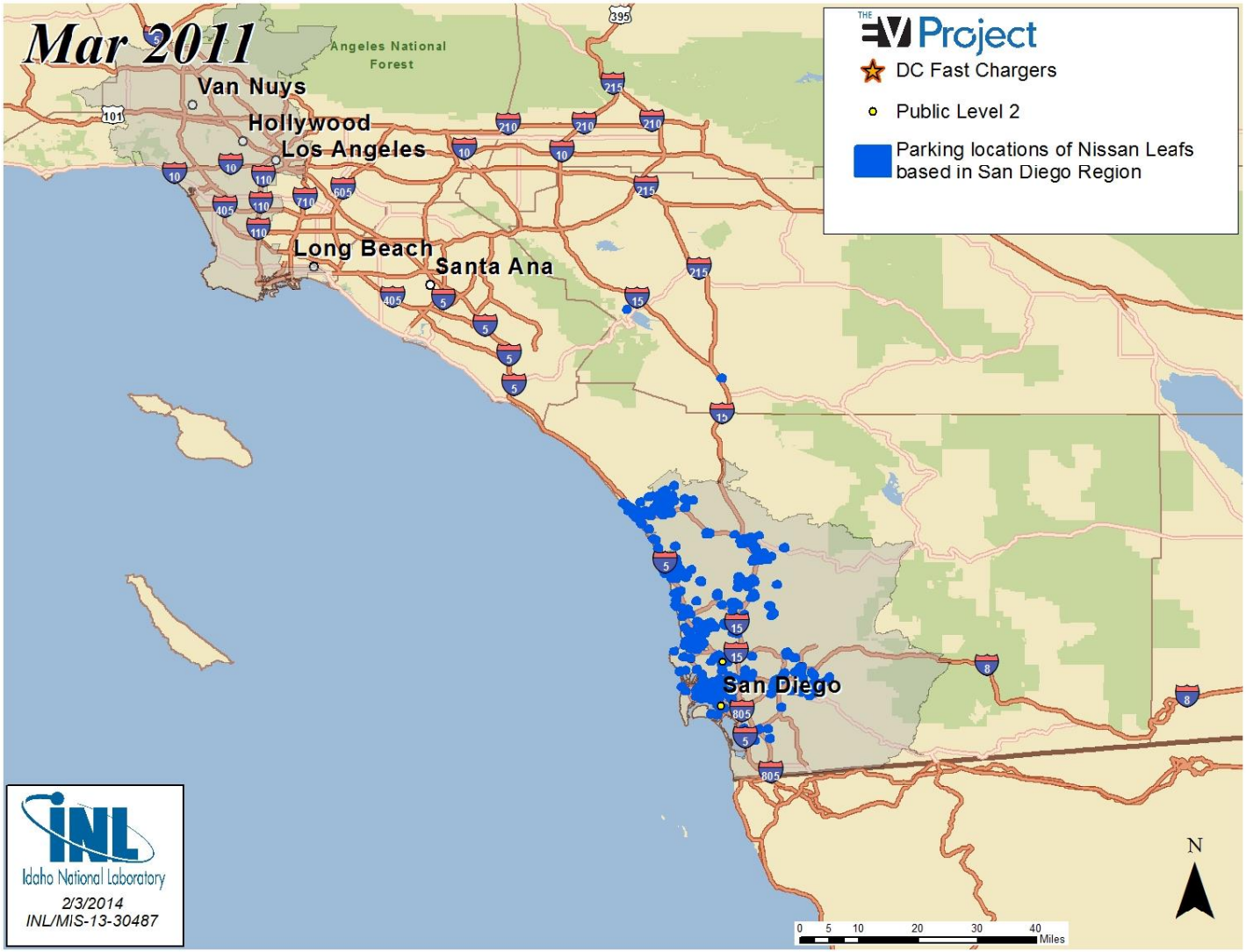
- Costs above do not include:
  - Hardware
  - Host commitment for the parking and ground space
  - Electric utility cost to evaluate/upgrade service, if necessary
- All the lower-cost sites are targeted first, so final costs may be higher

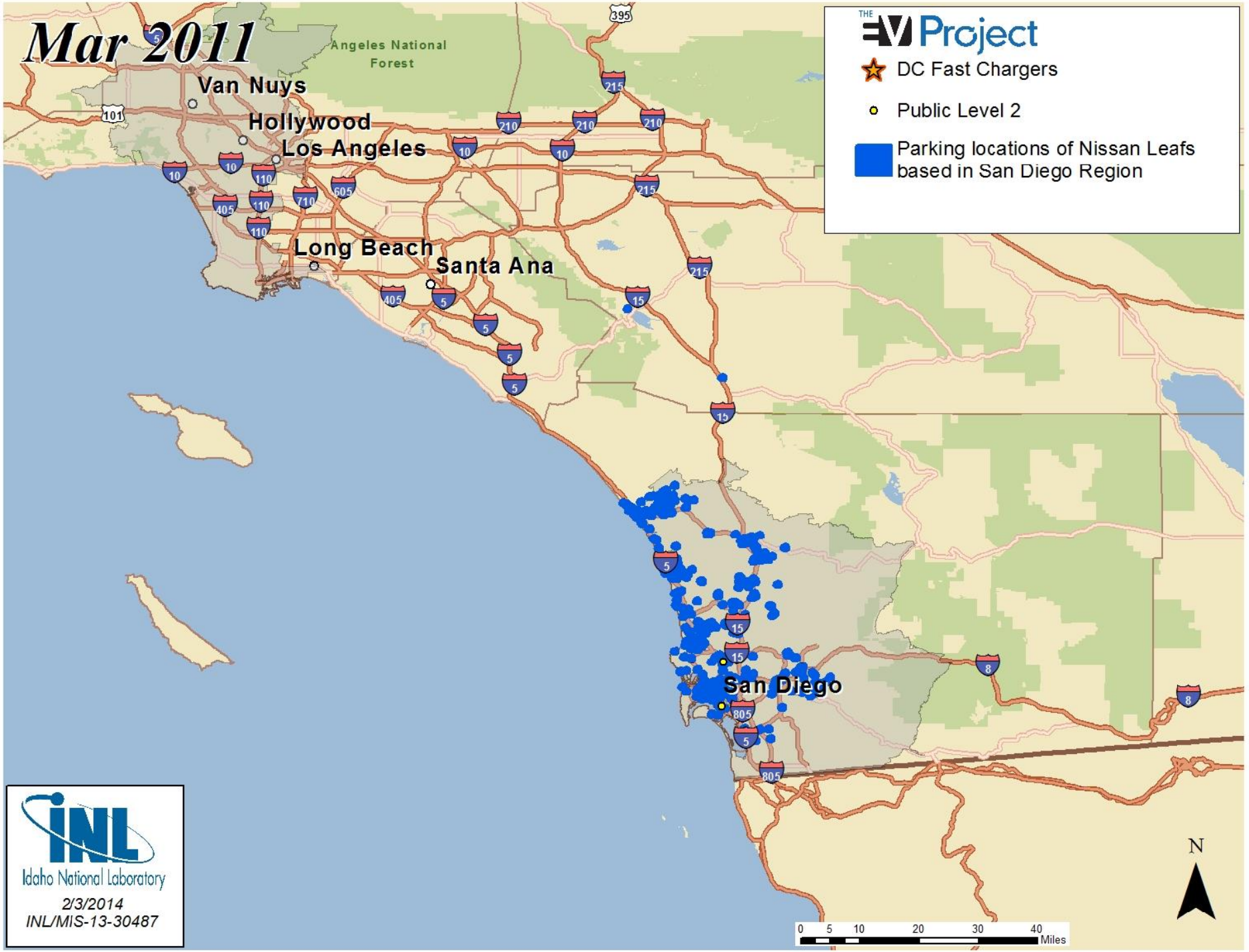
Where is the best place to put public charging stations?

San Deigo area away-from-home parking locations for Volts that average > 35 mi per day (excluding parking locations of single vehicles)



Leaf Travel Extents in the San Diego Area




Mar 2011
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Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
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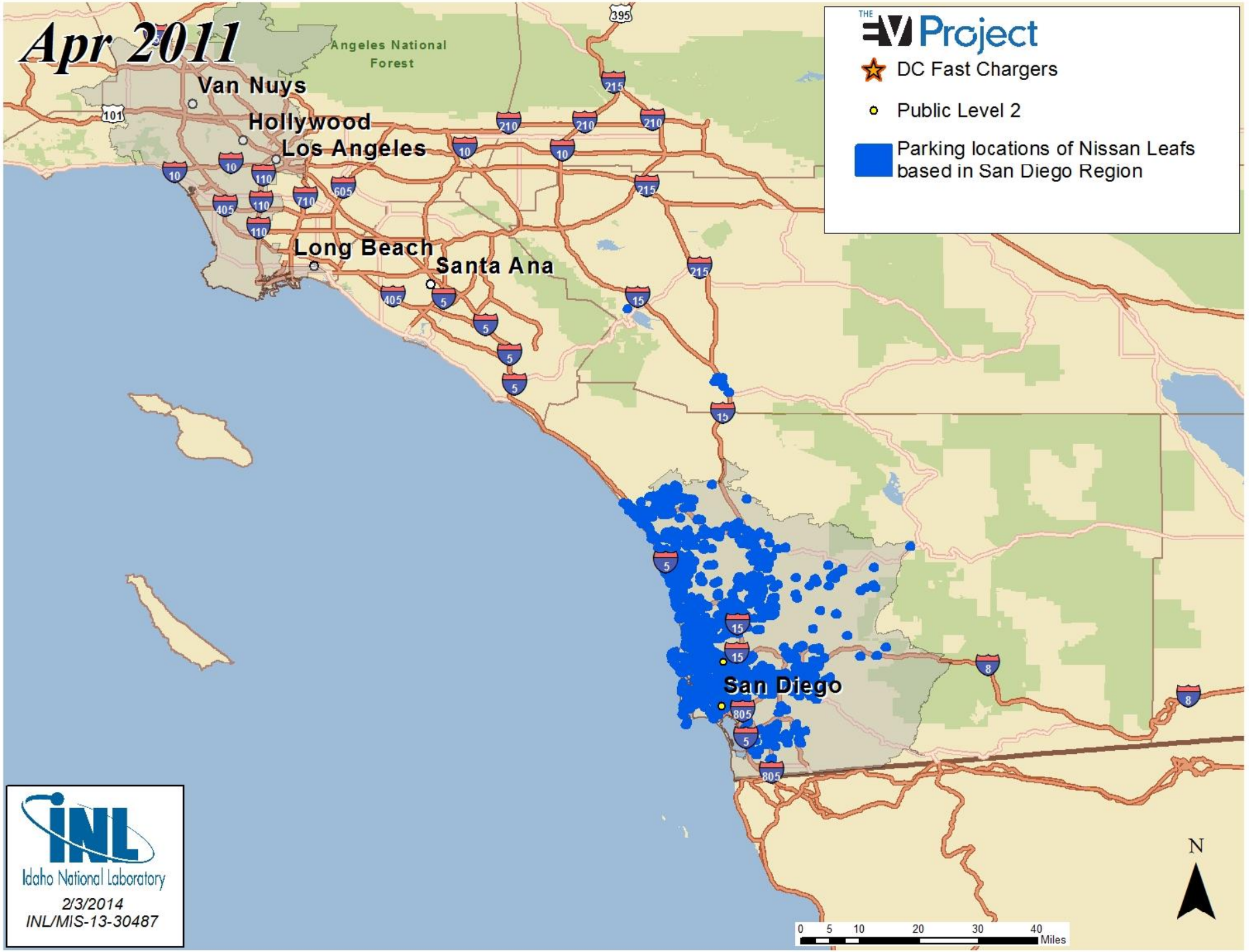
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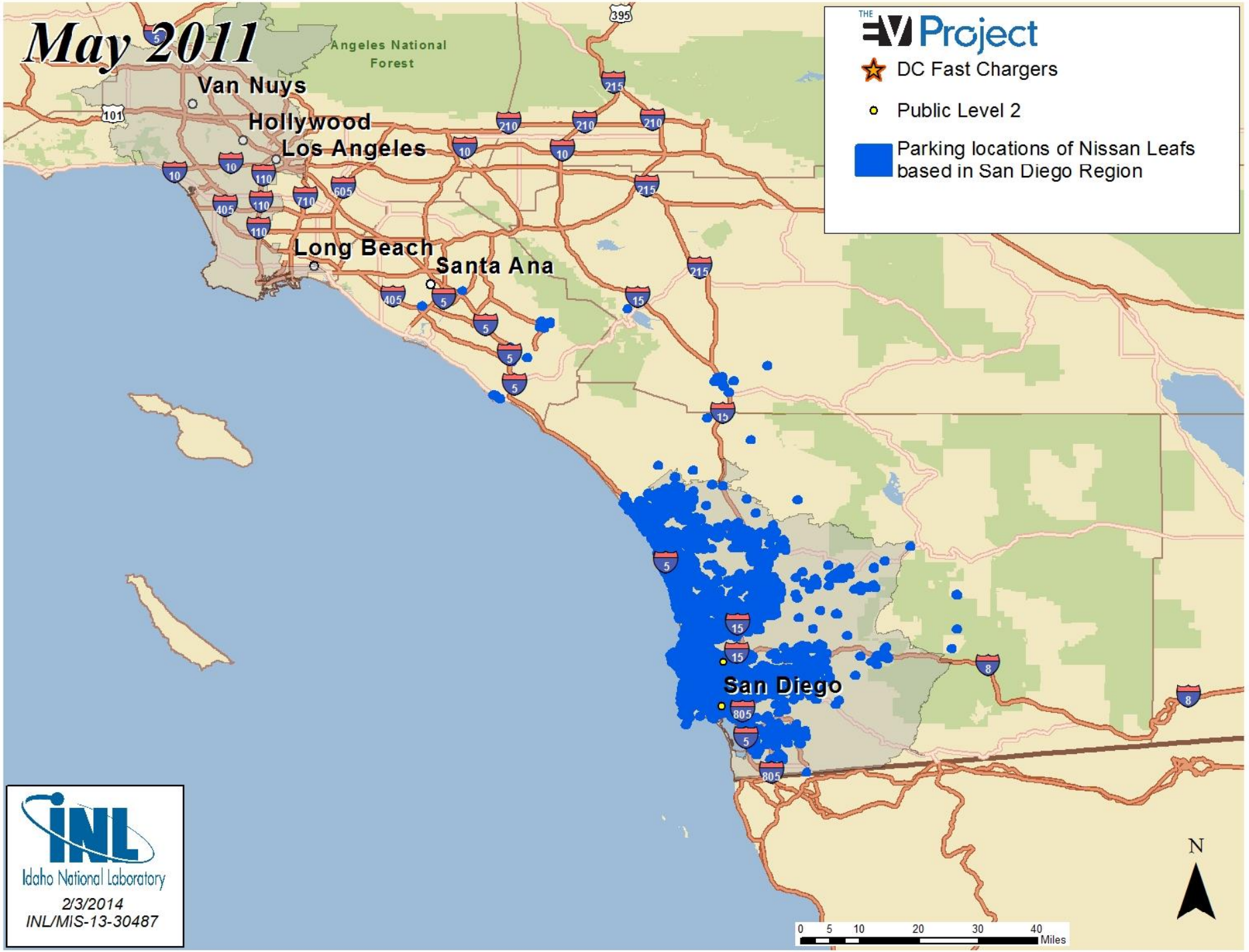
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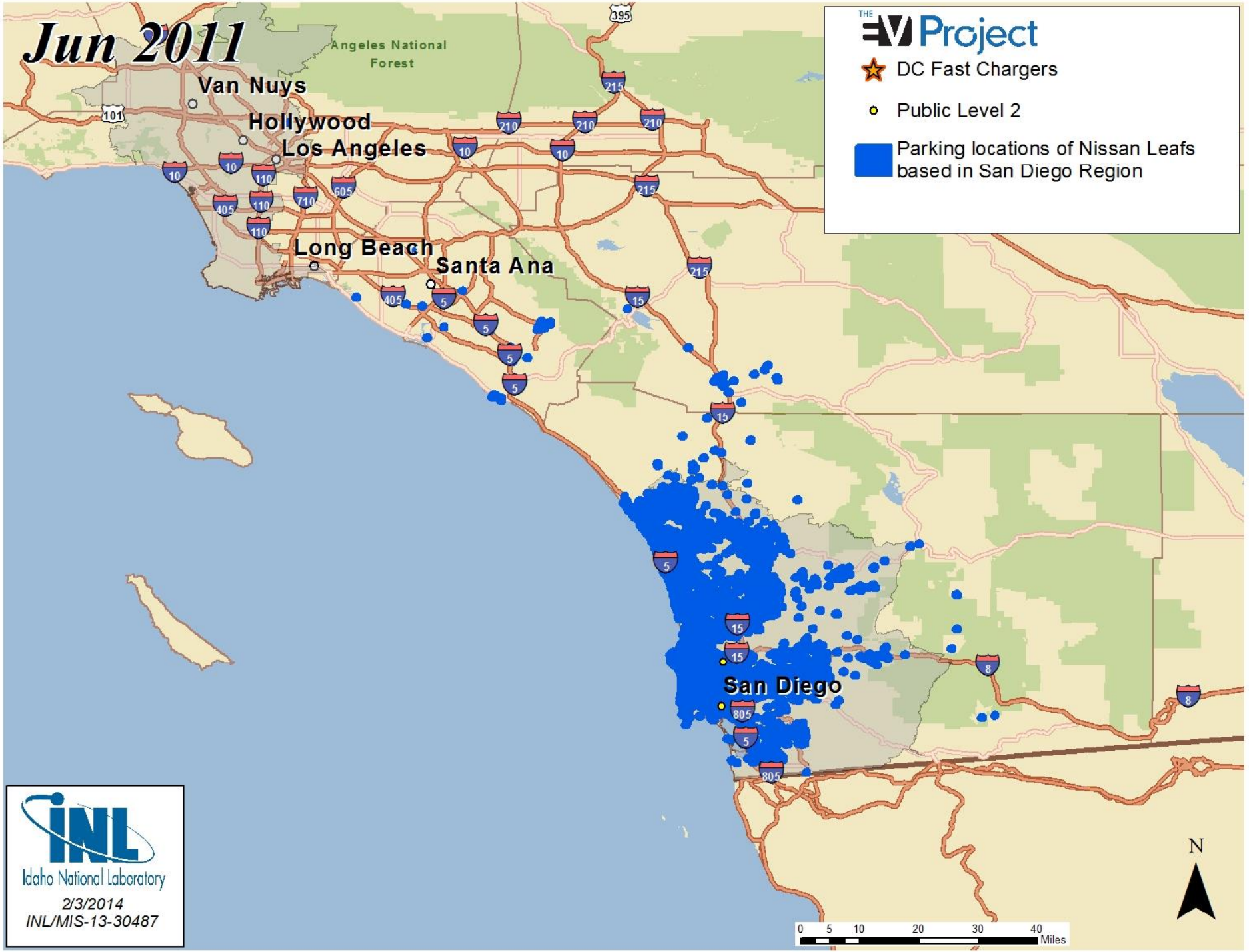
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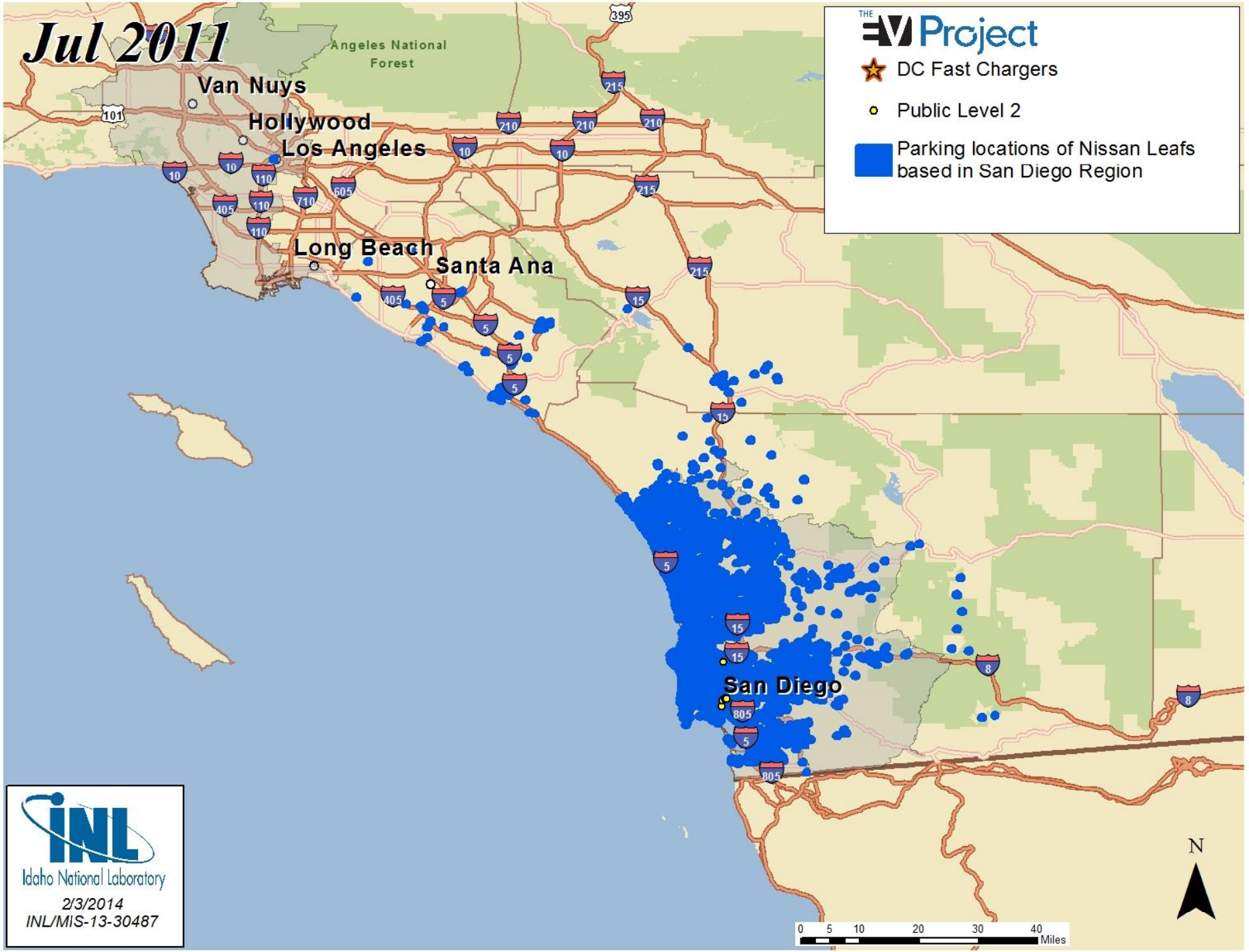
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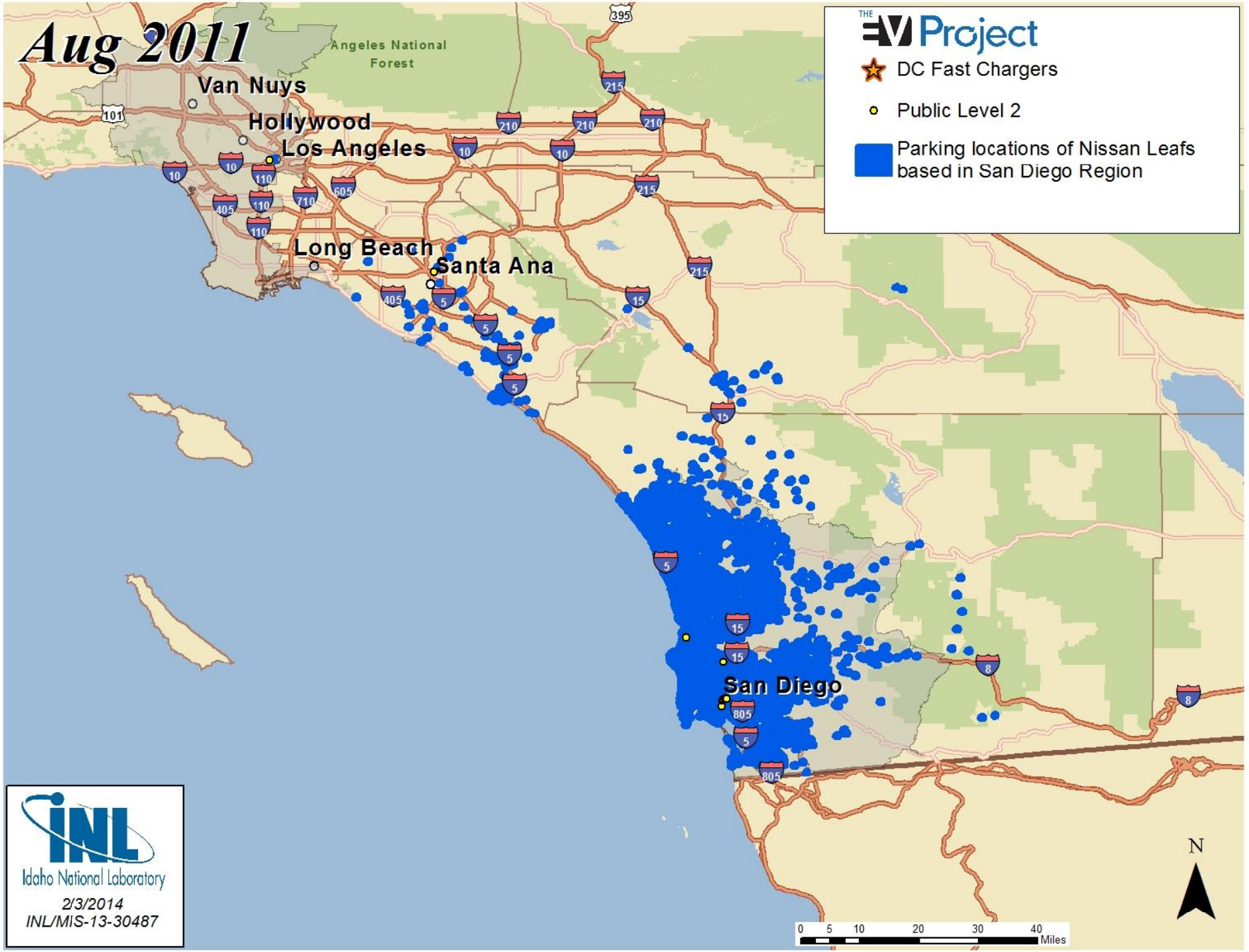
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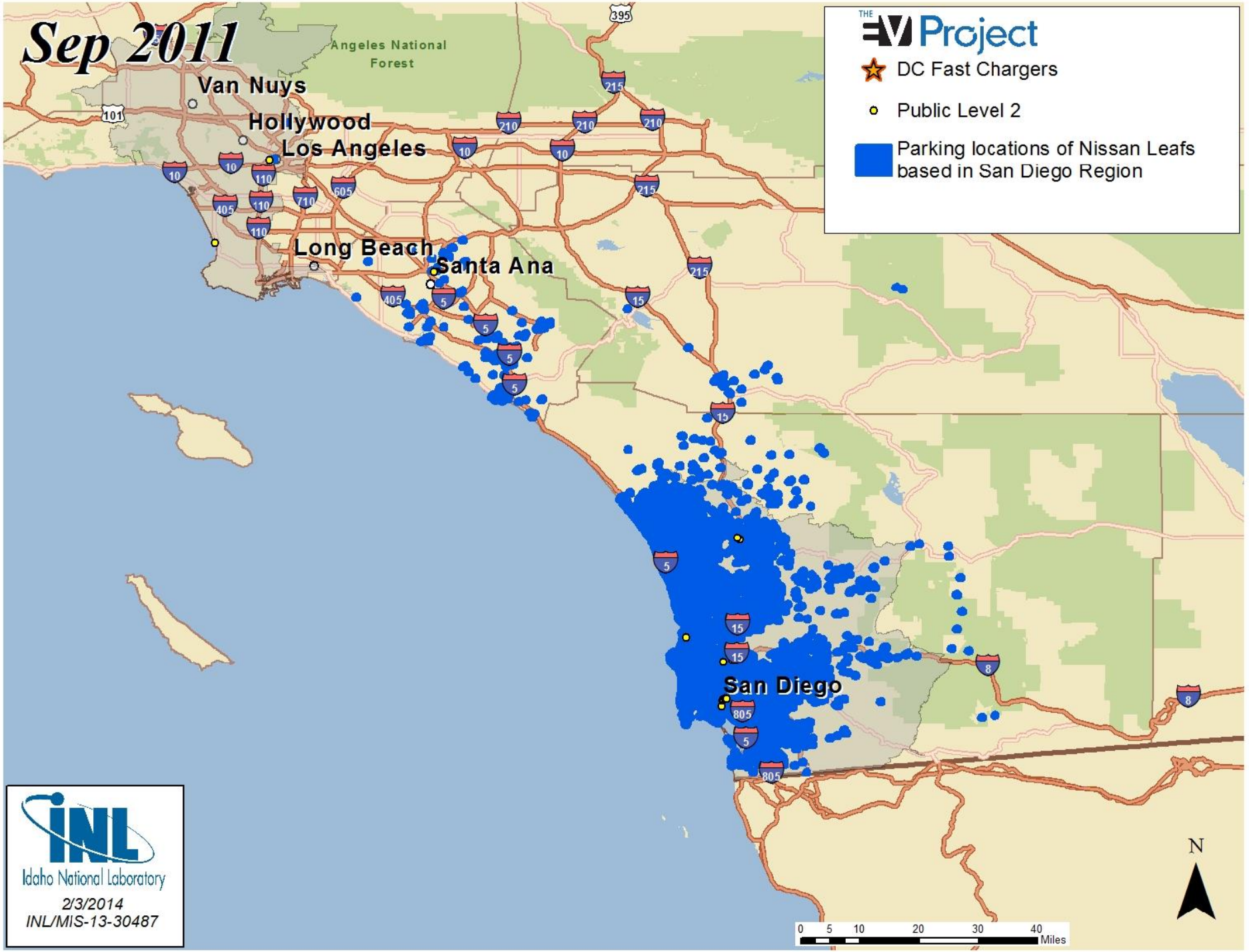
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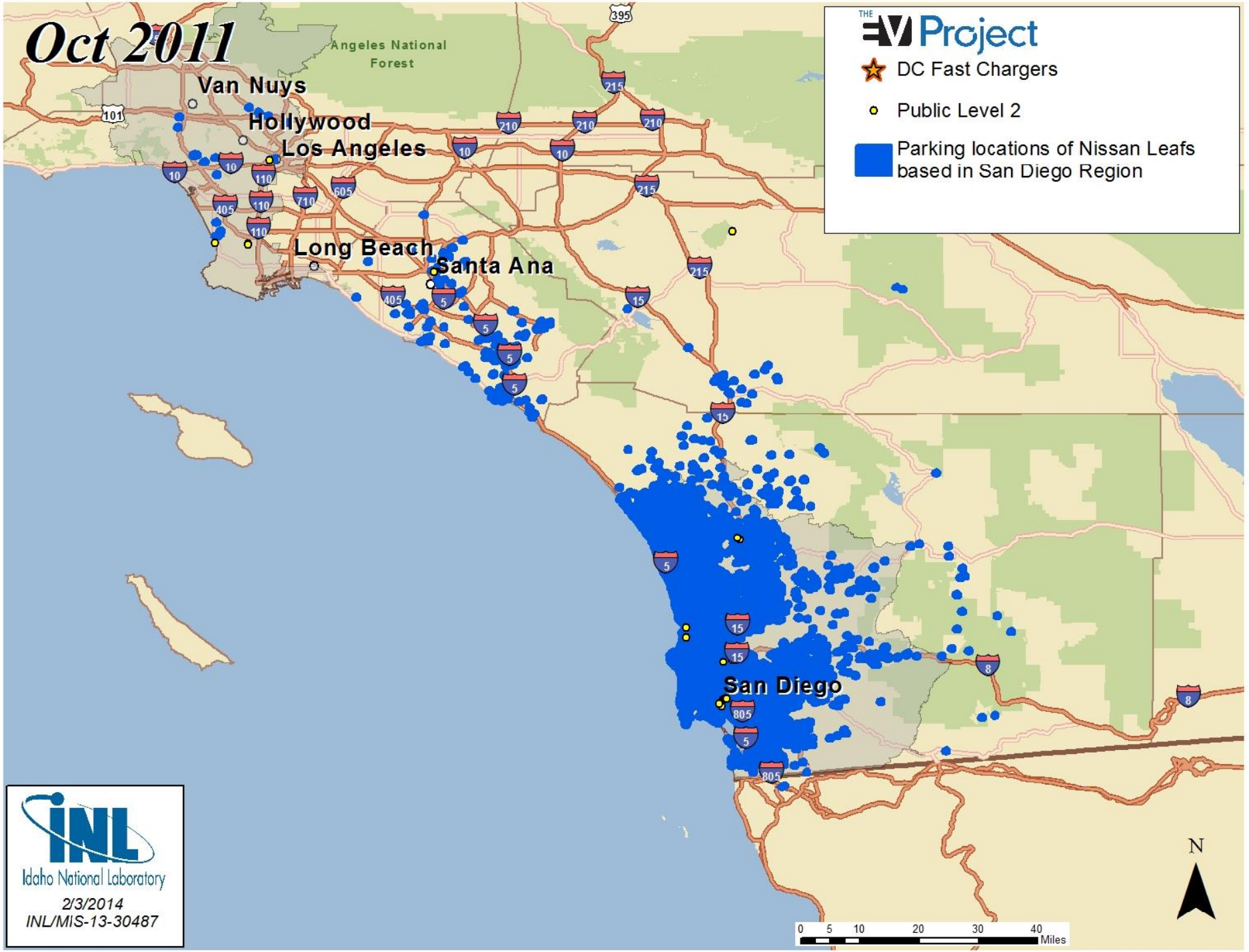
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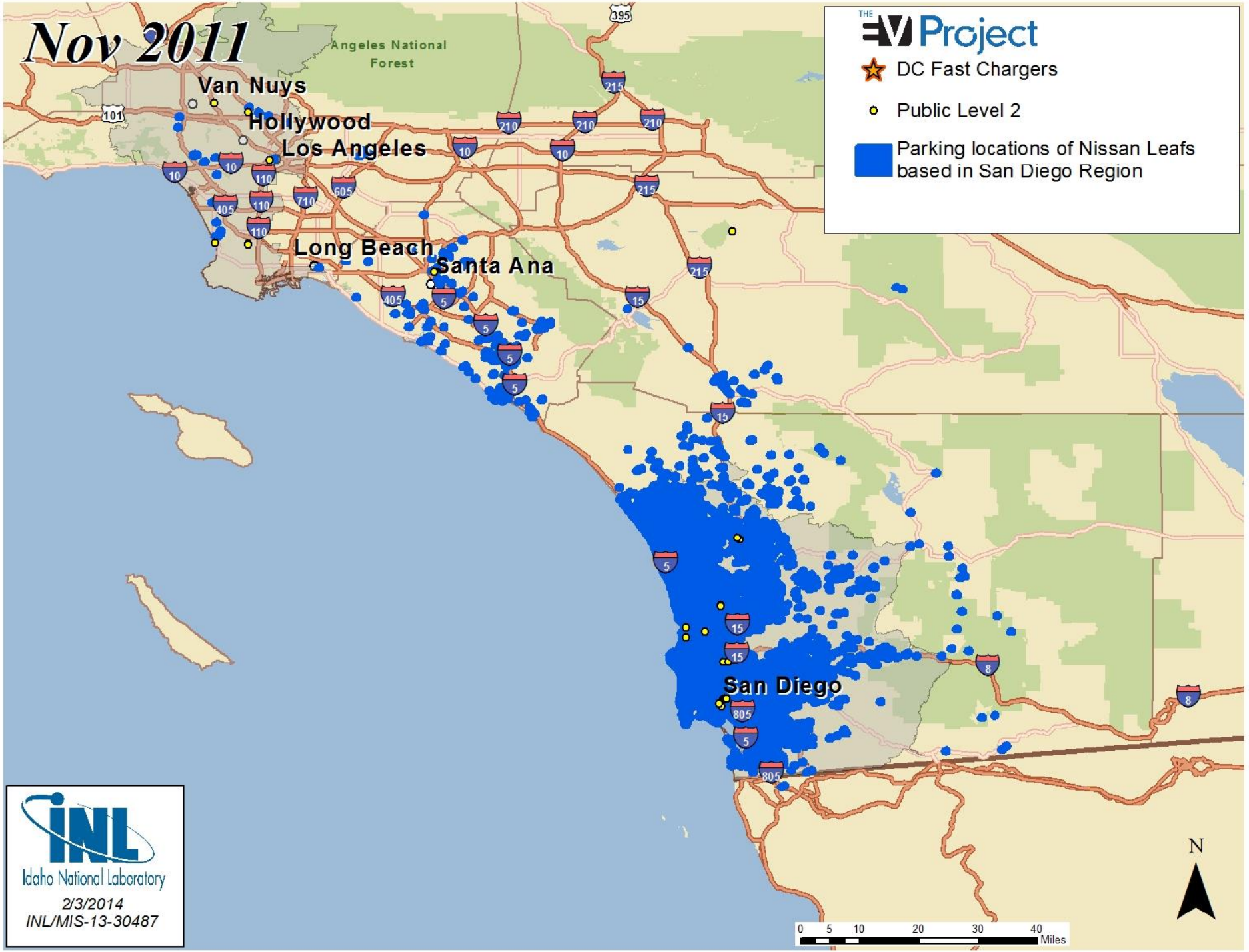
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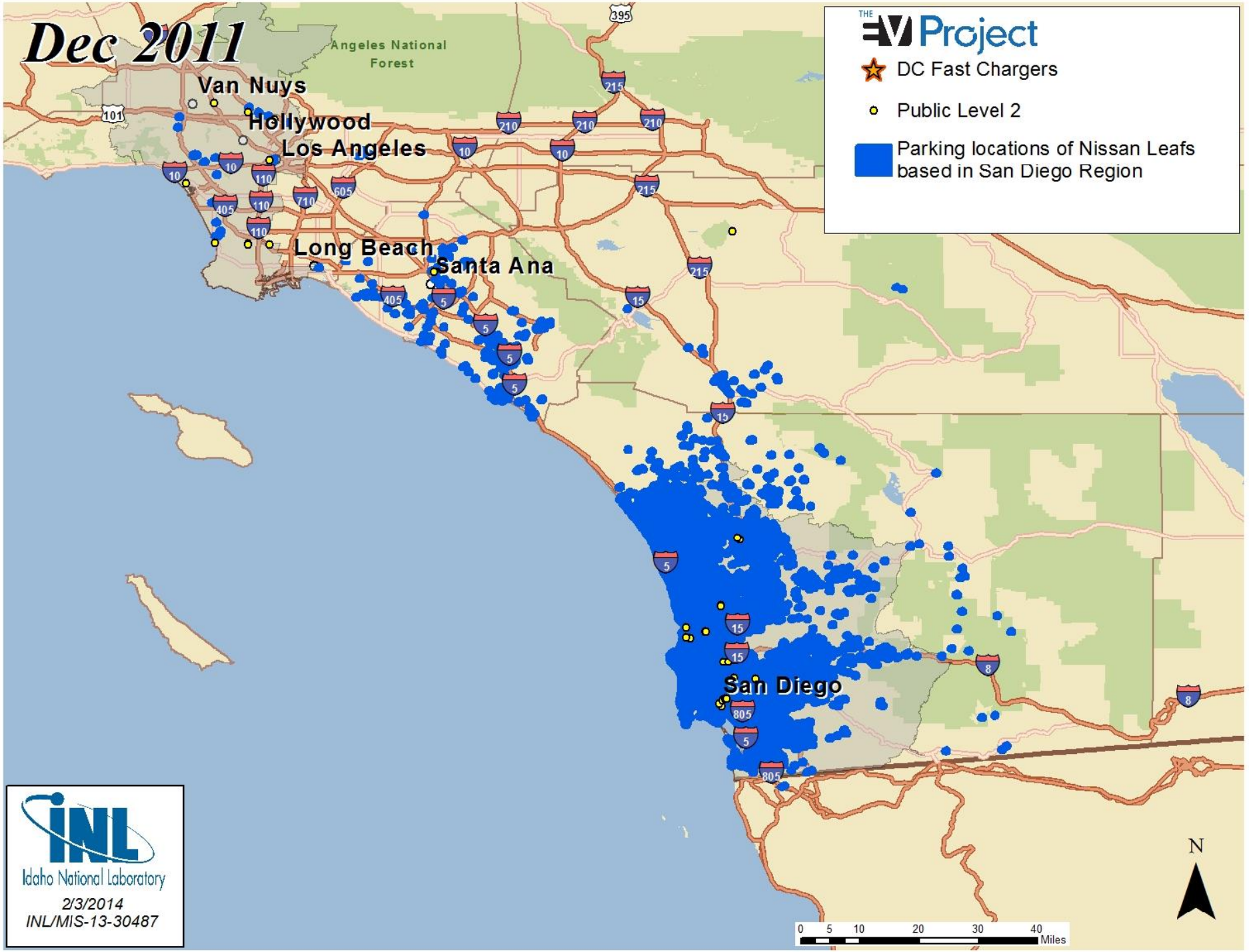
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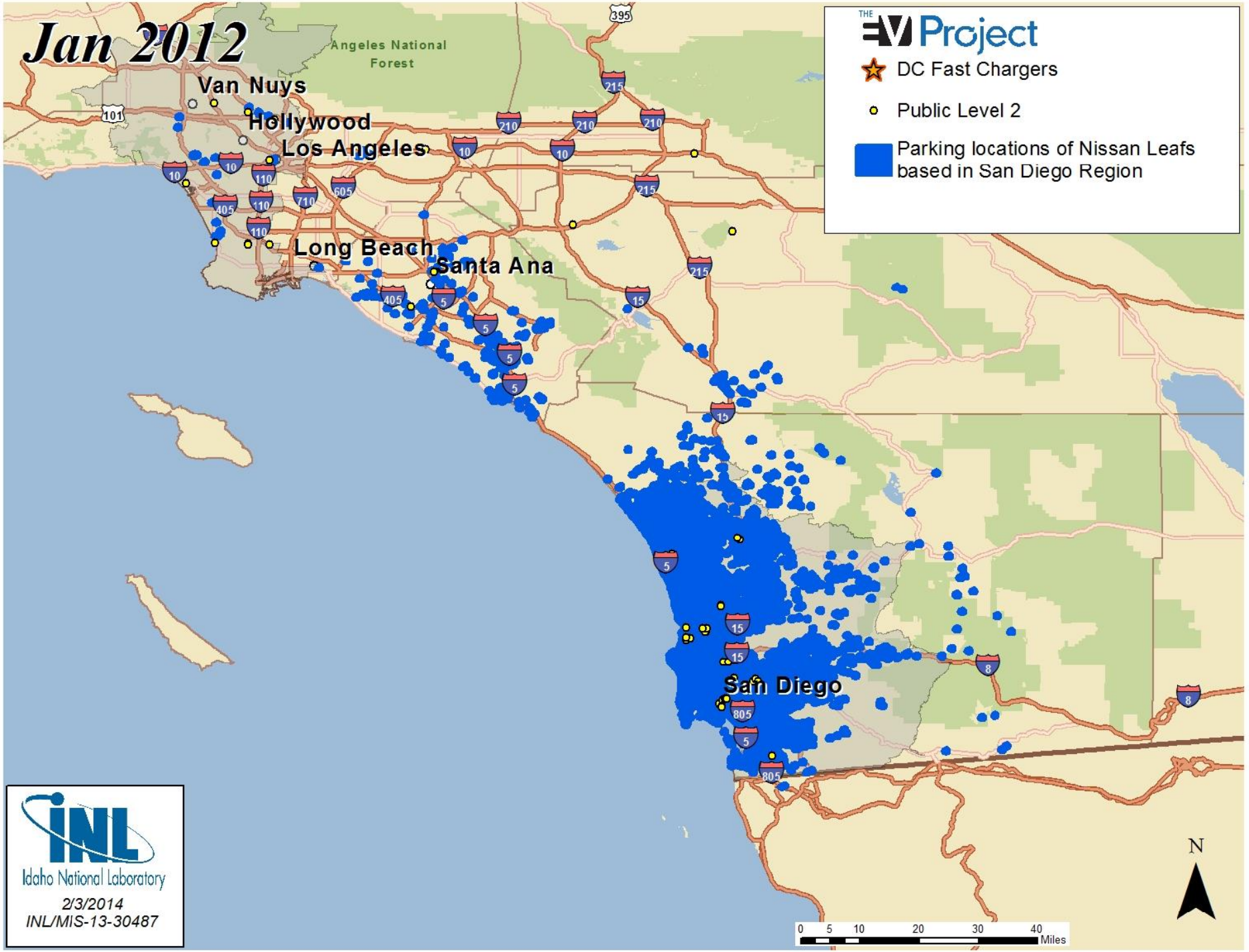
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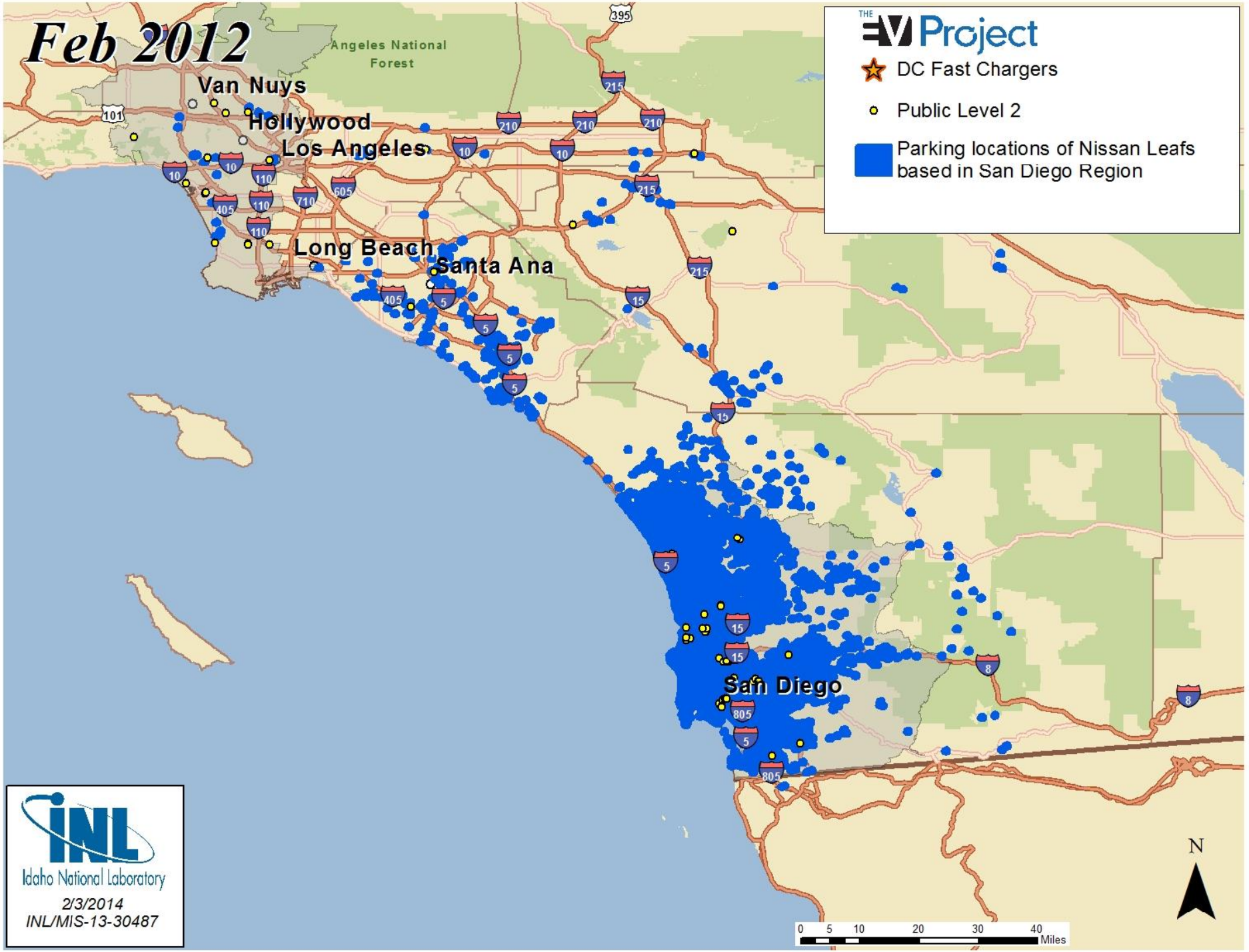
Feb 2012
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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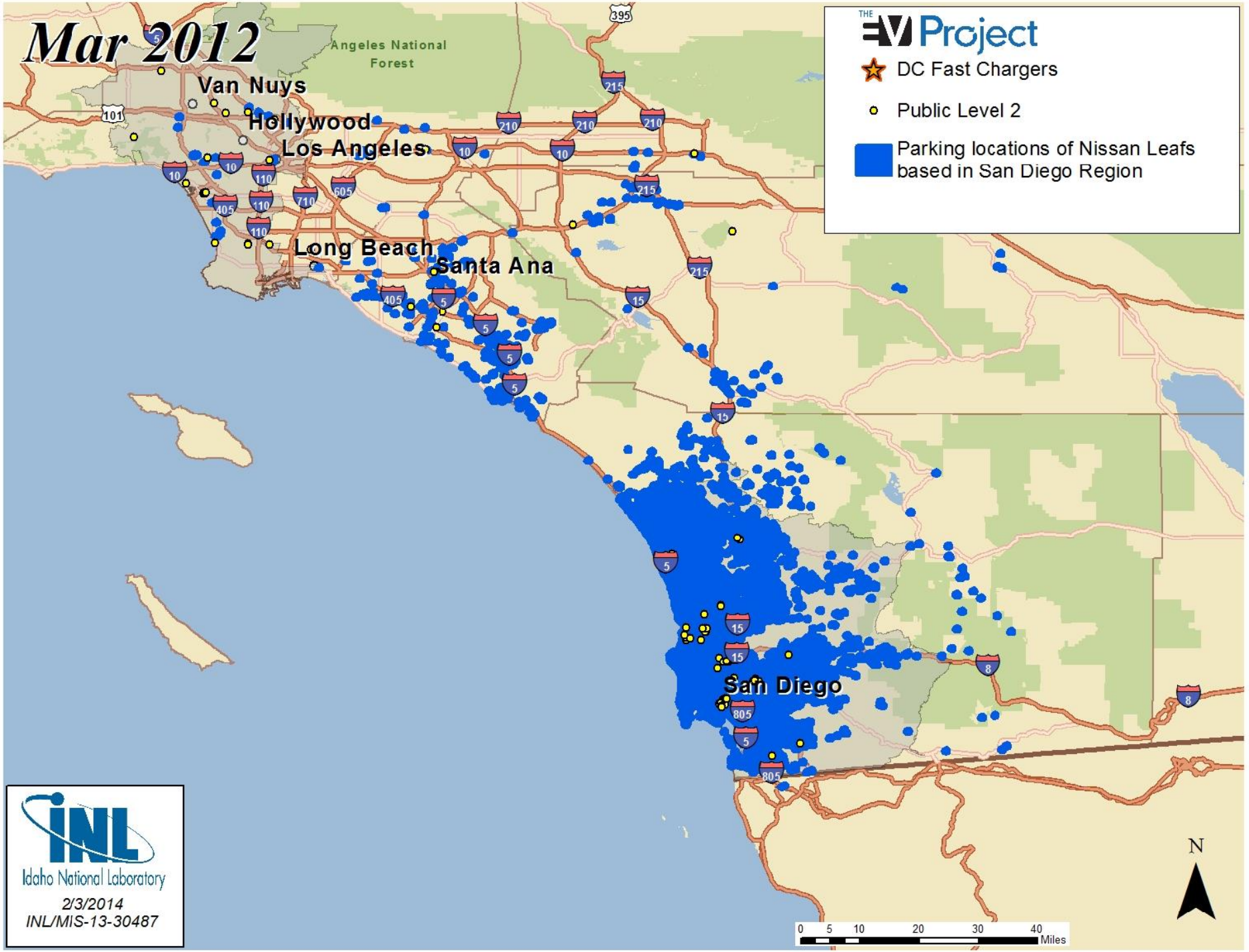
Miles


Mar 2012
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Los Angeles
Long Beach
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San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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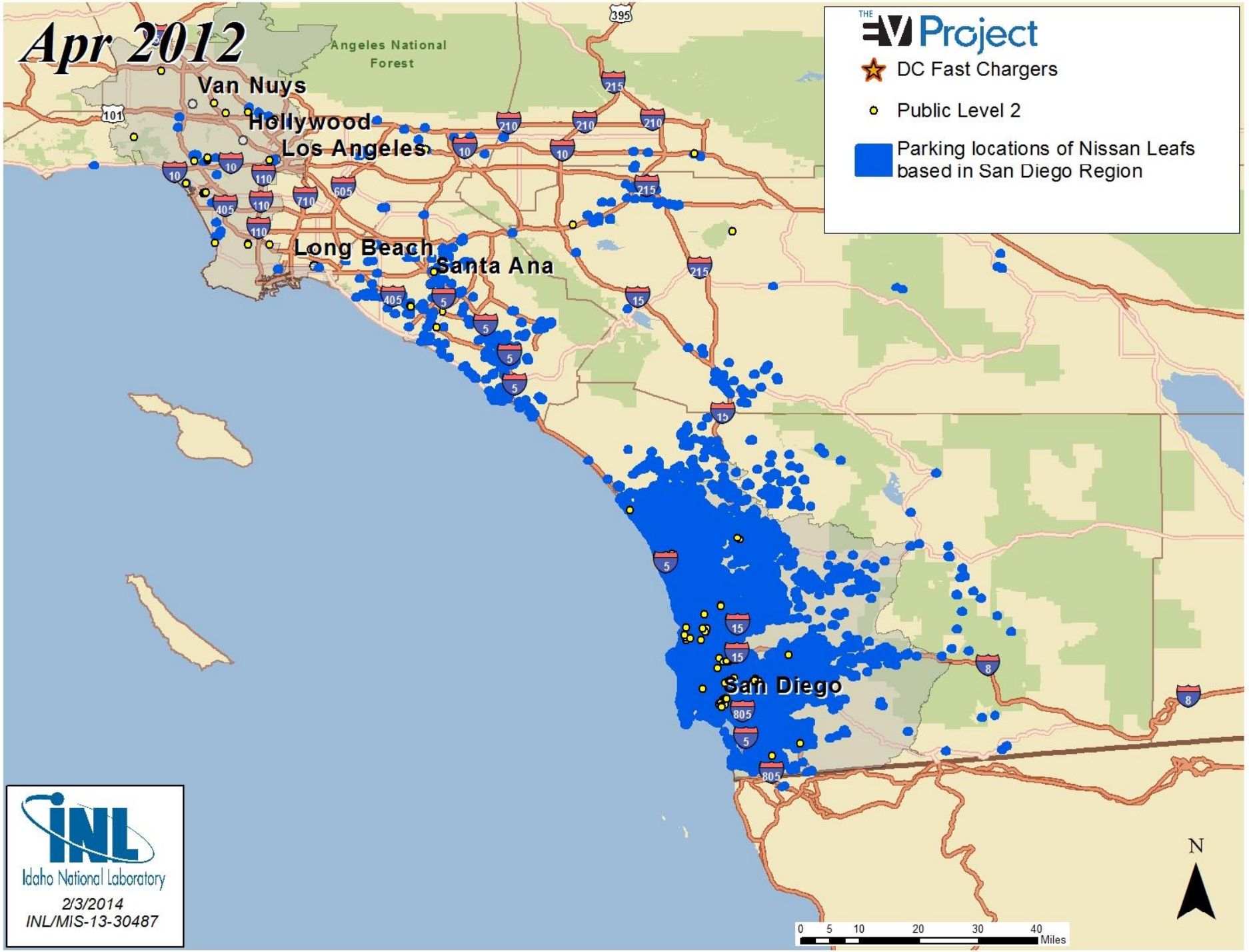
Apr 2012
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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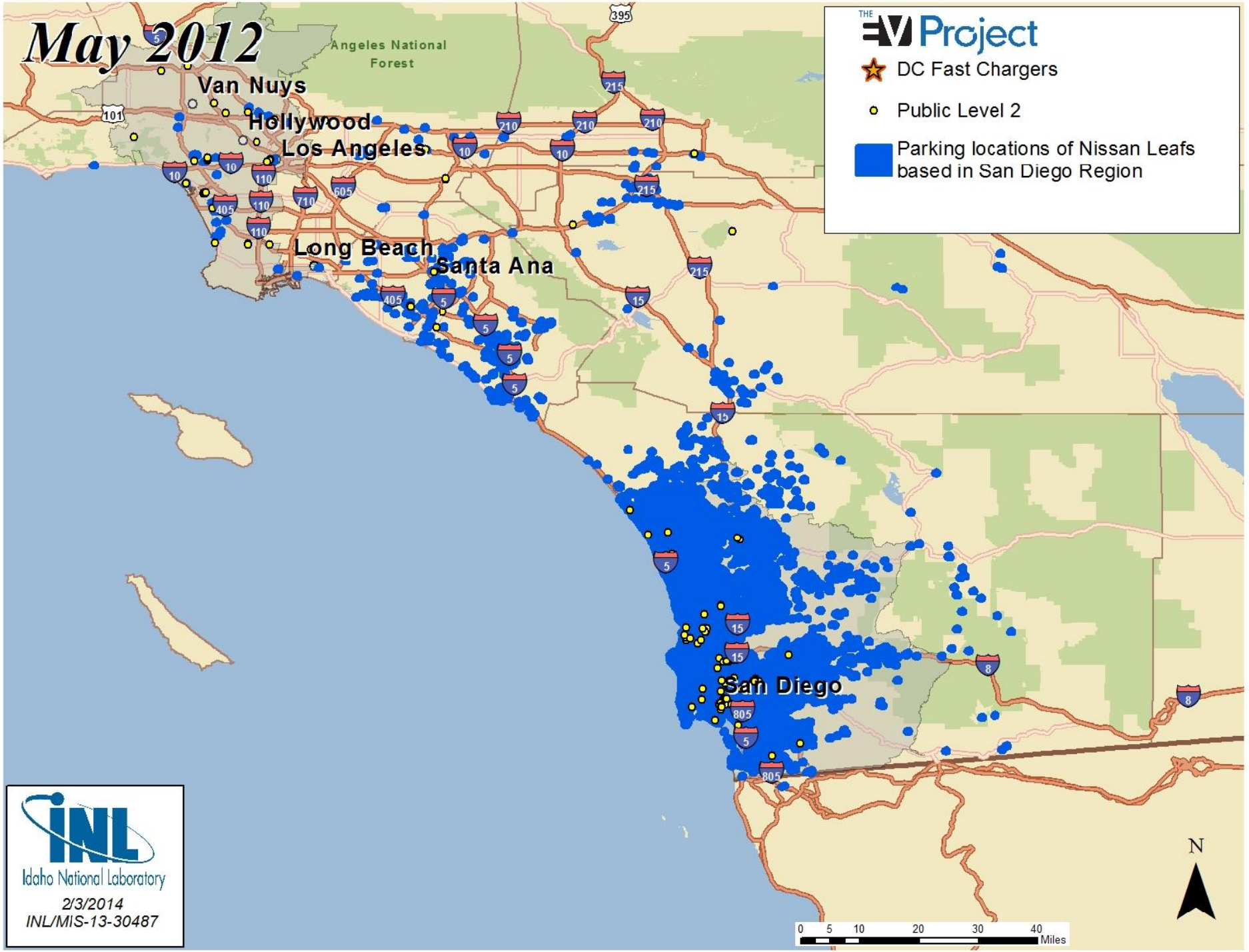
May 2012
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Angeles National Forest
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Hollywood
Los Angeles
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Santa Ana
San Diego
INL
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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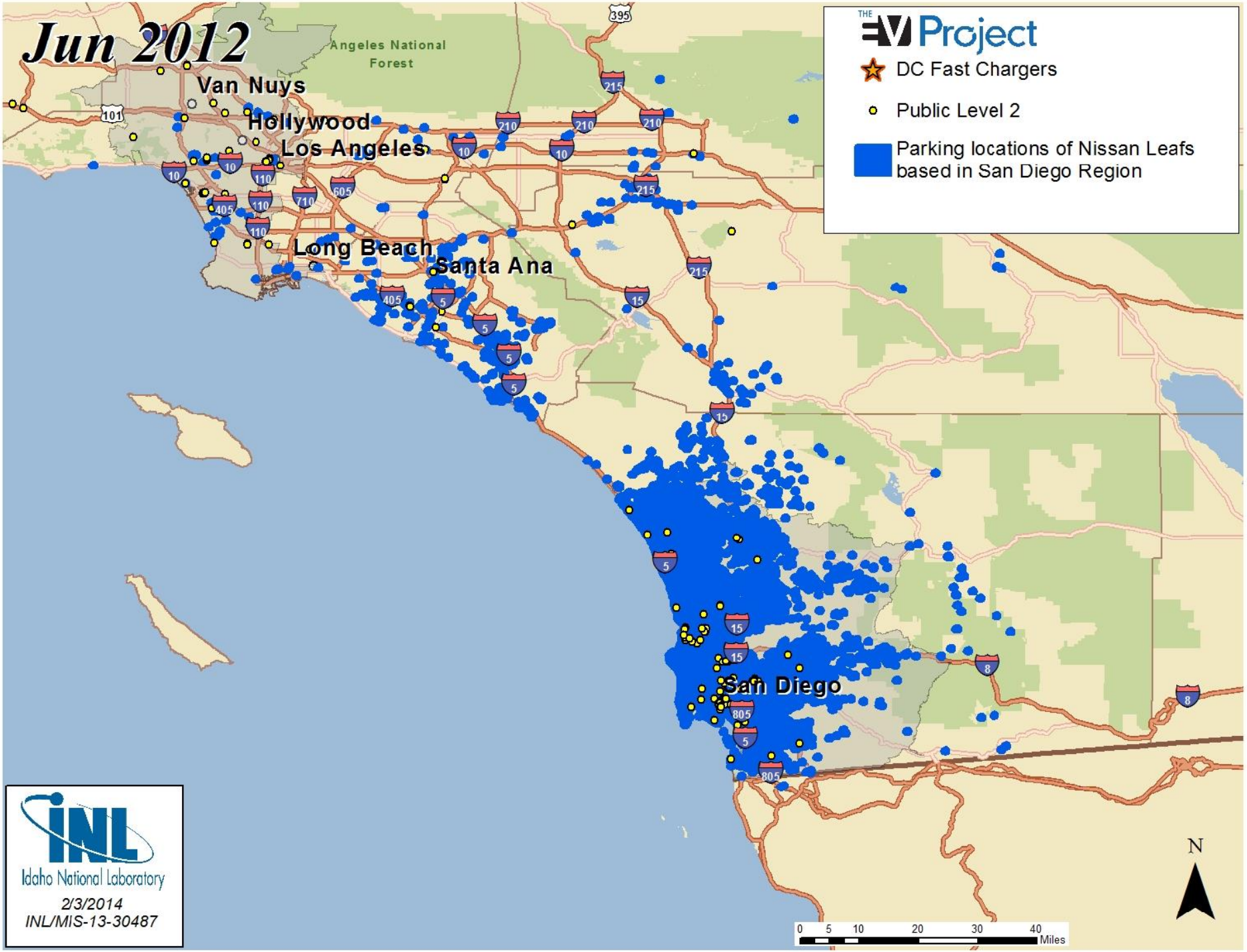
Jun 2012
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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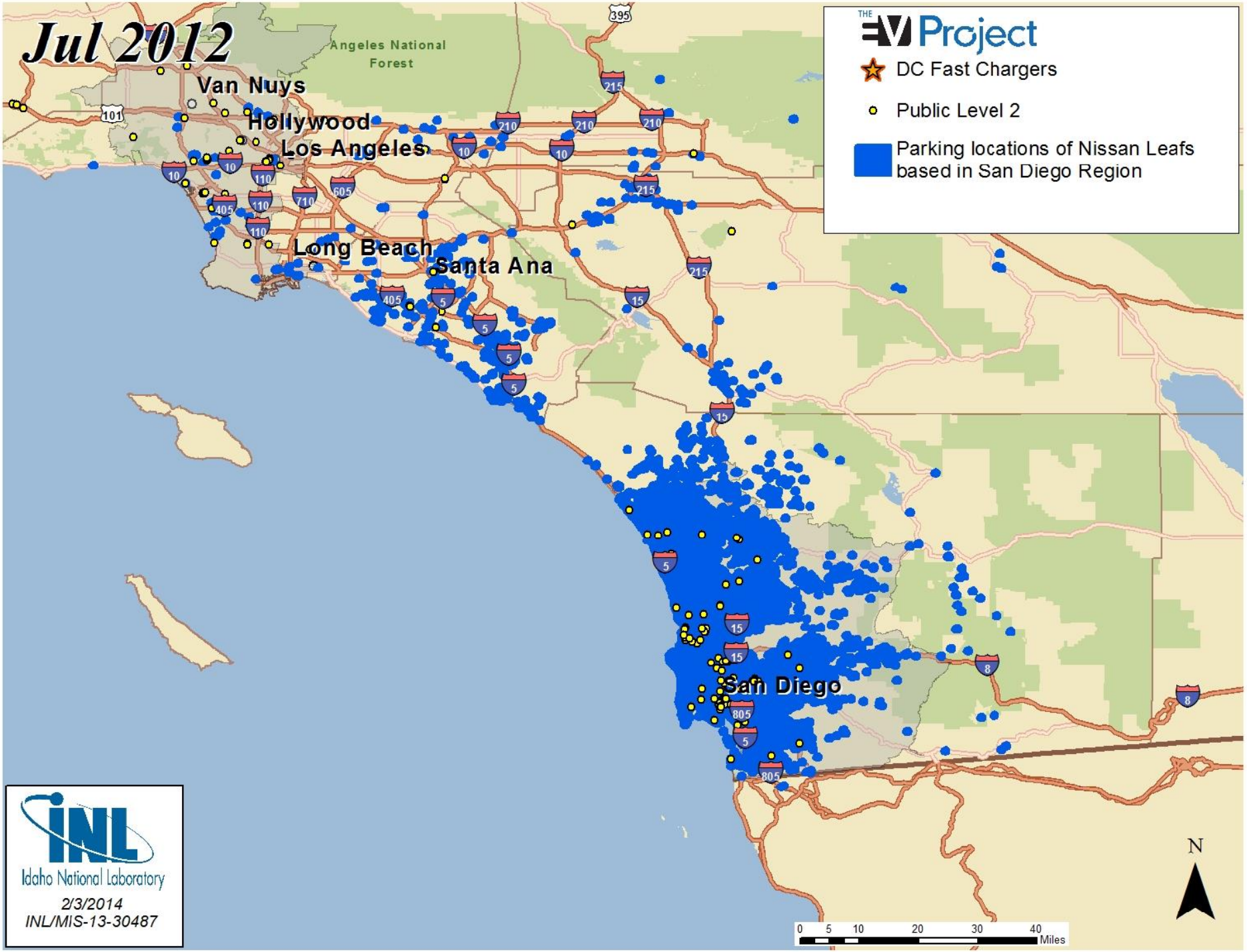
Jul 2012
Van Nuys
Hollywood
Los Angeles
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San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
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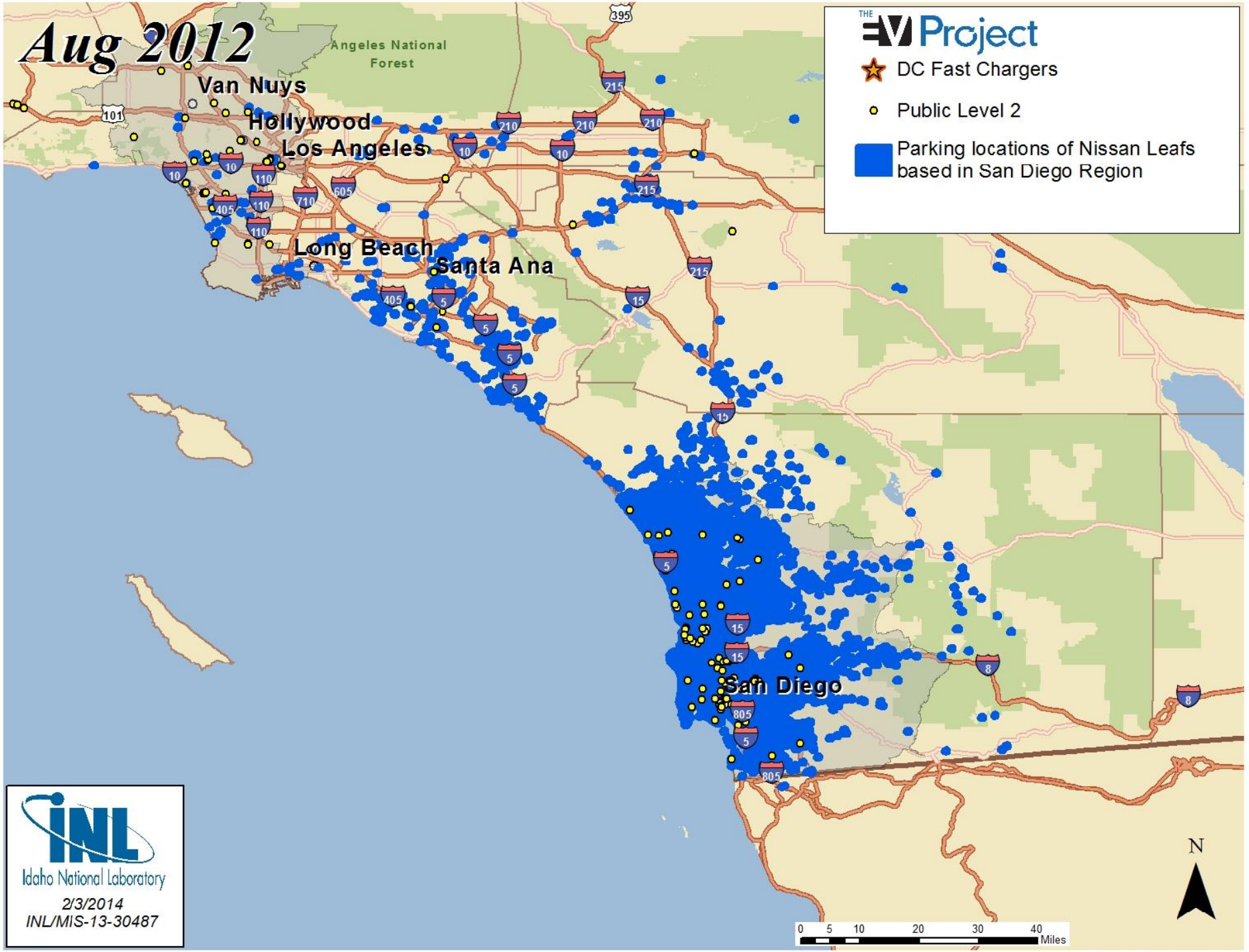
Aug 2012
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
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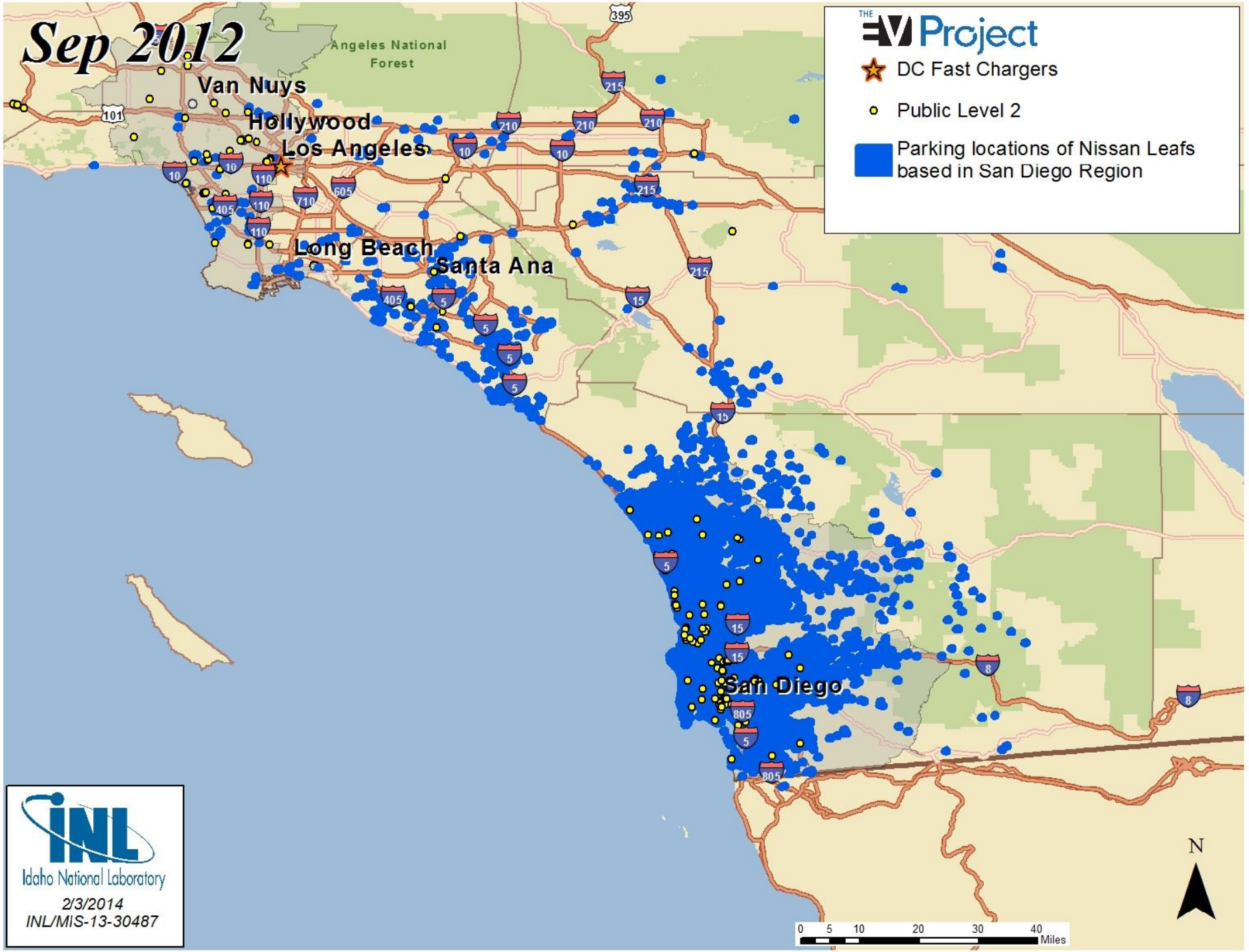
Sep 2012
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
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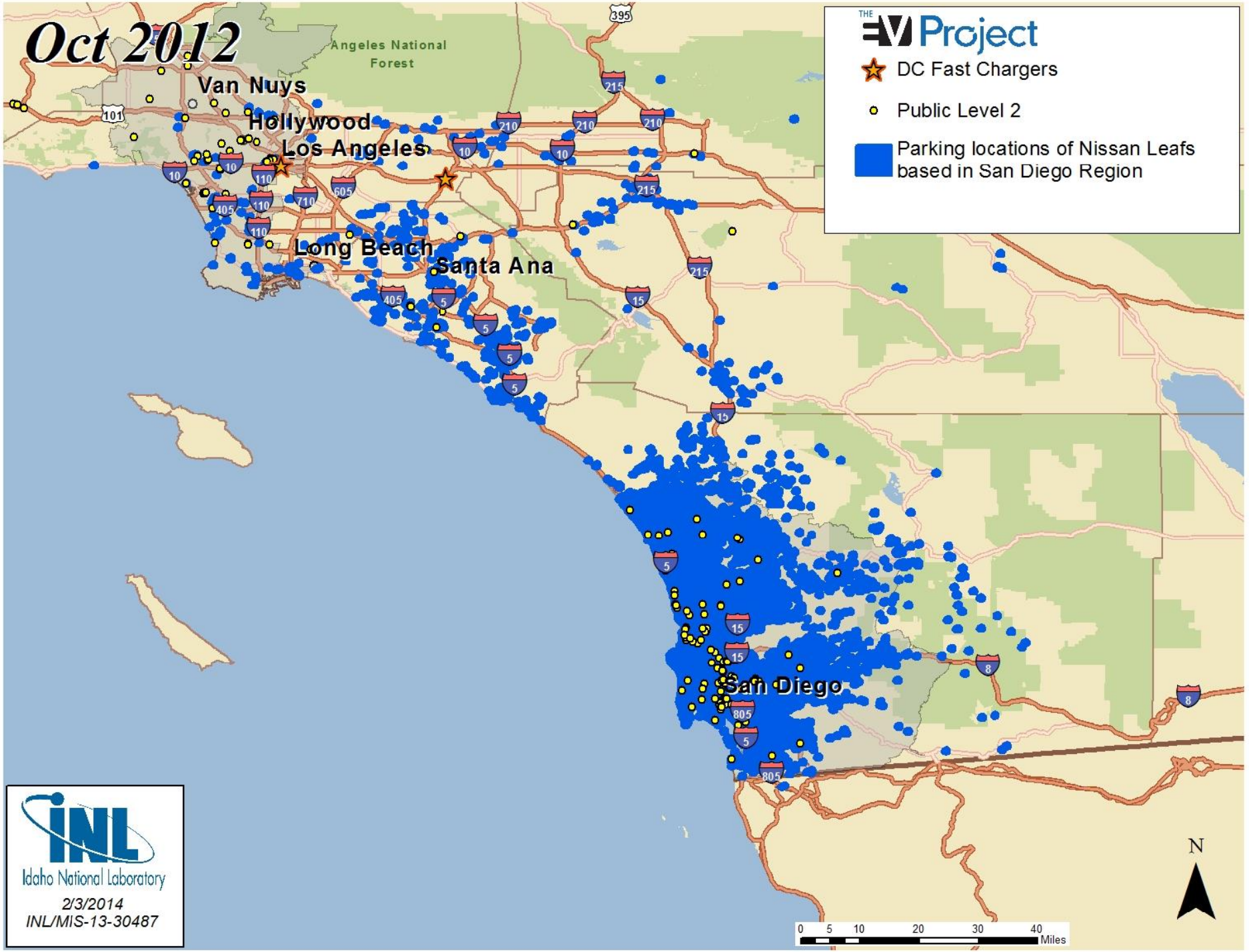
Oct 2012
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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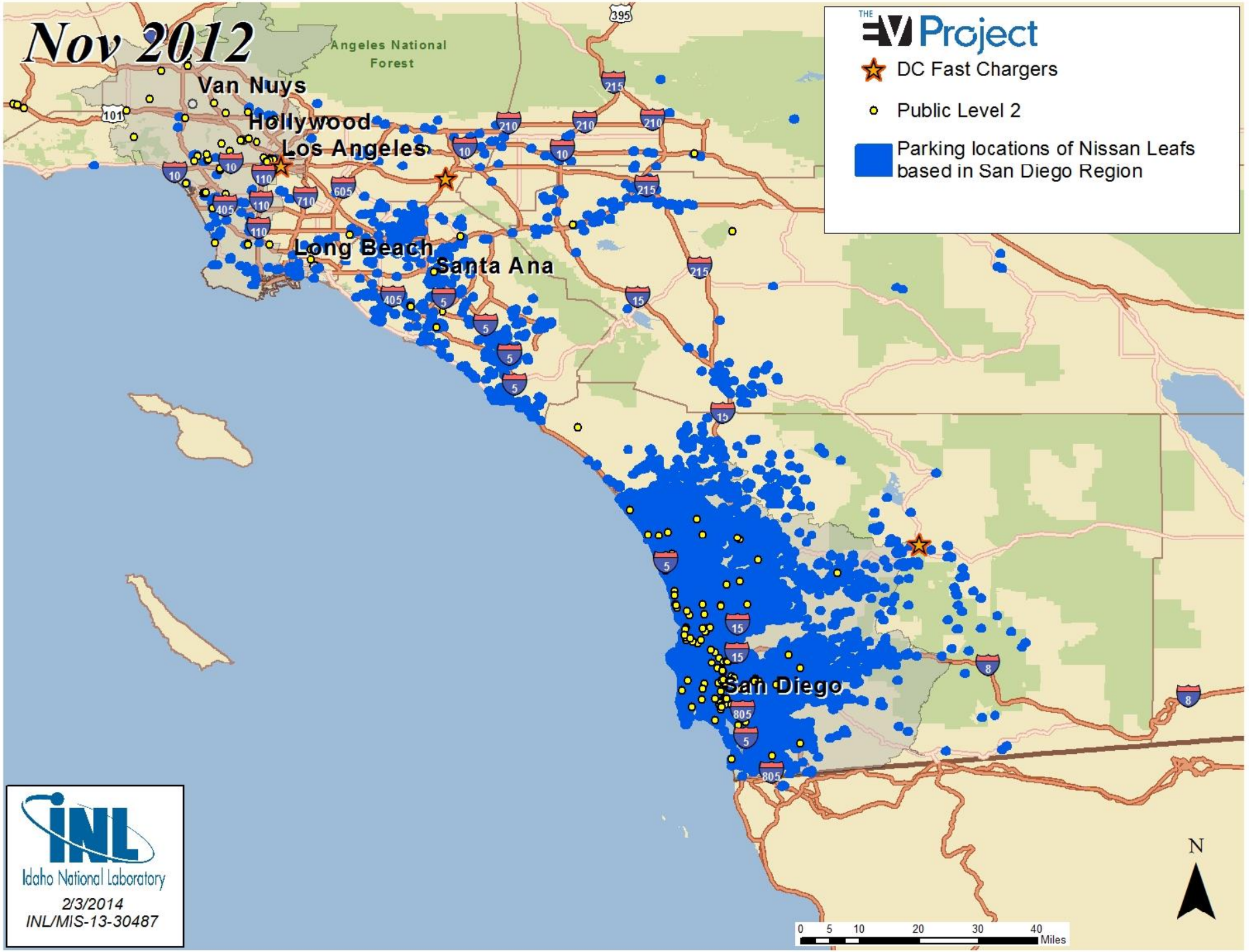
Nov 2012
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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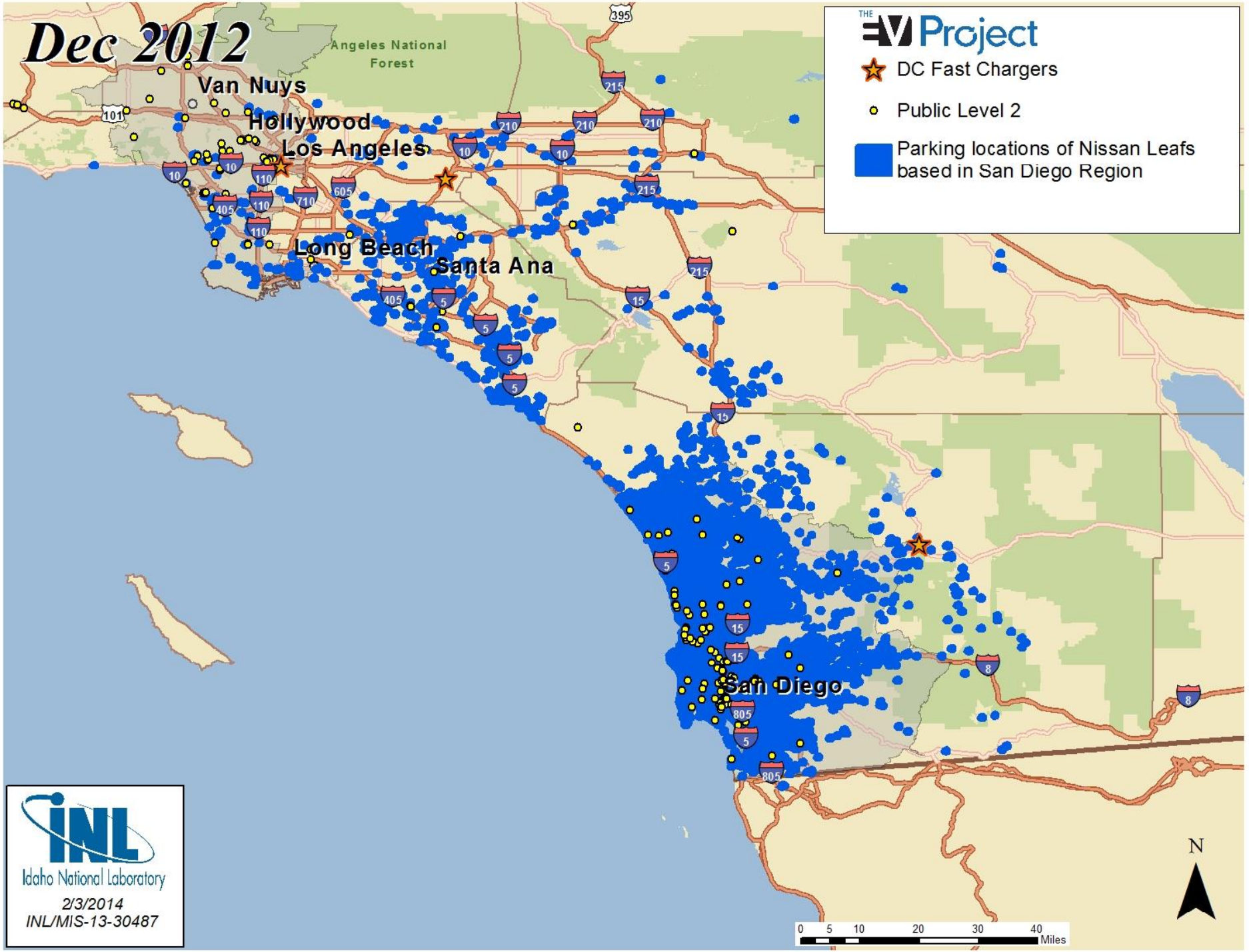
Dec 2012
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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0 5 10 20 30 40
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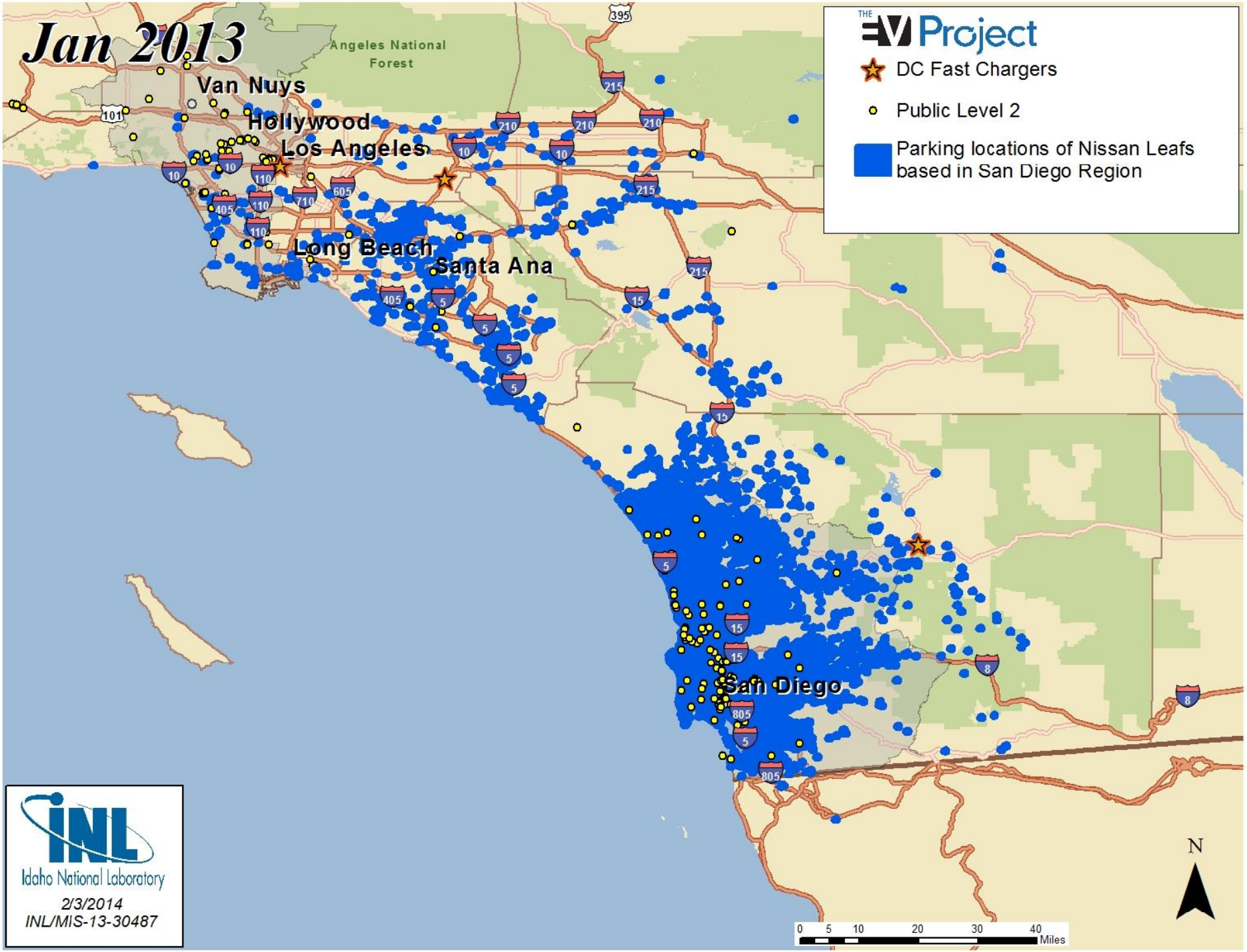
Jan 2013
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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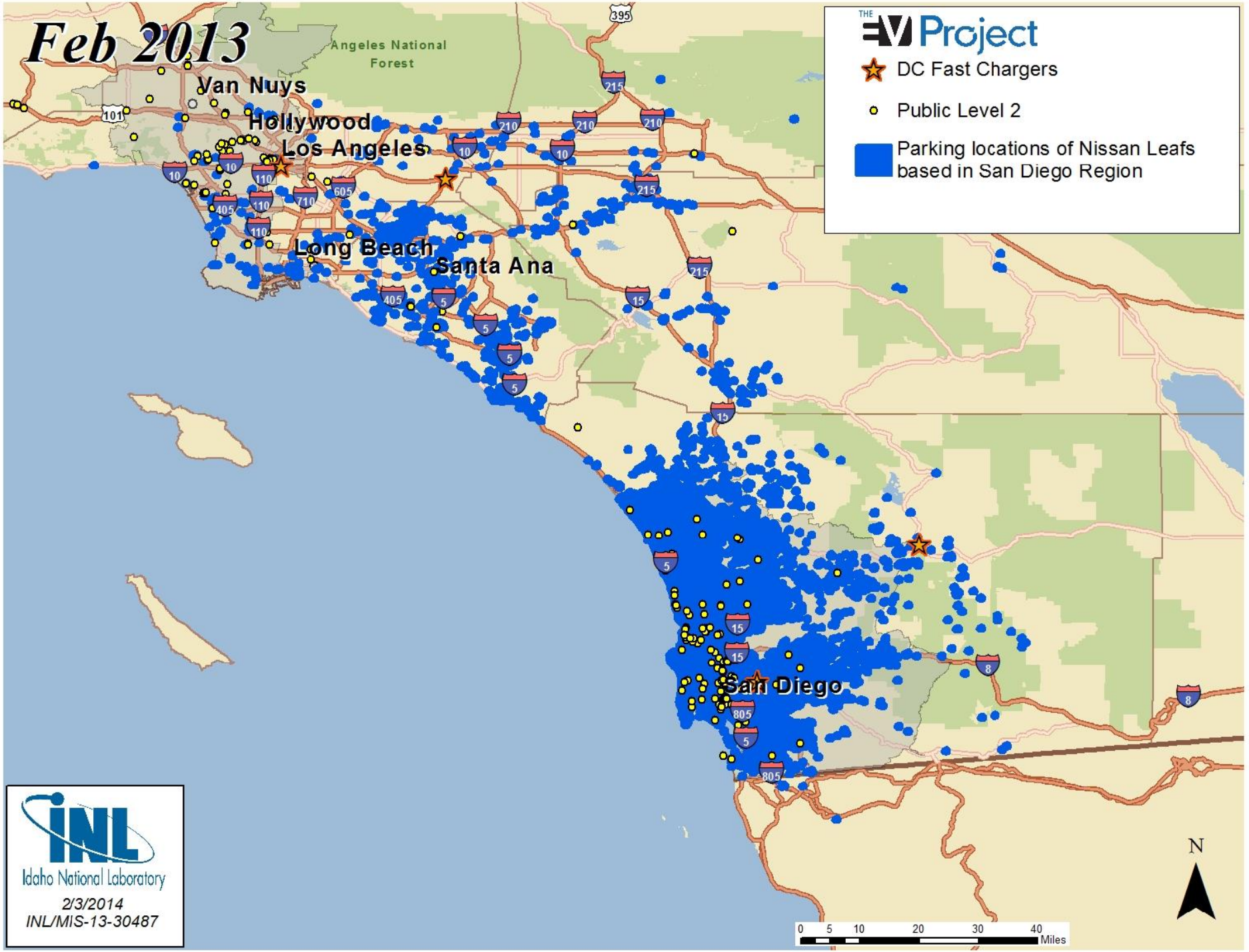
0 5 10 20 30 40
Miles


Feb 2013
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
0 5 10 20 30 40
Miles
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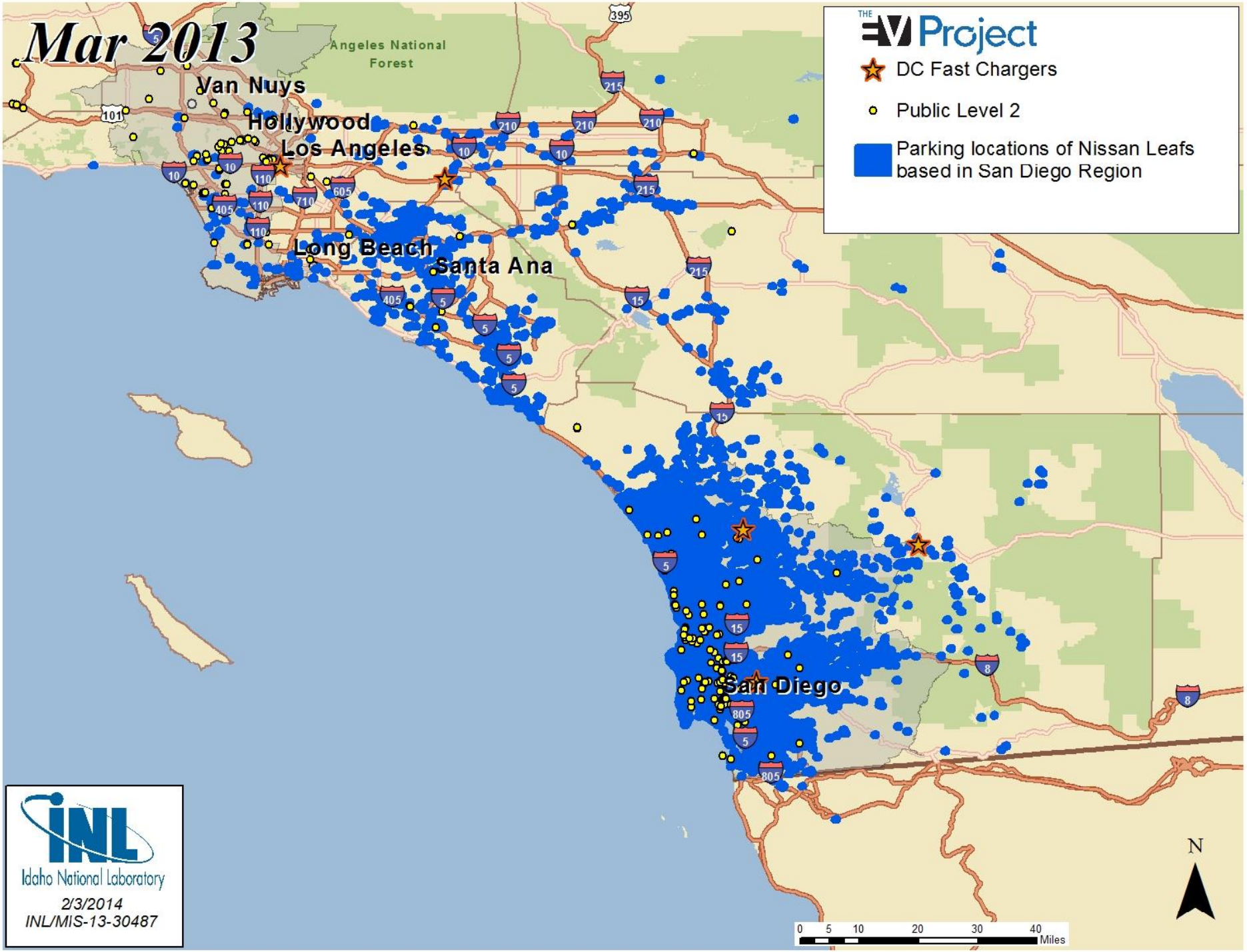
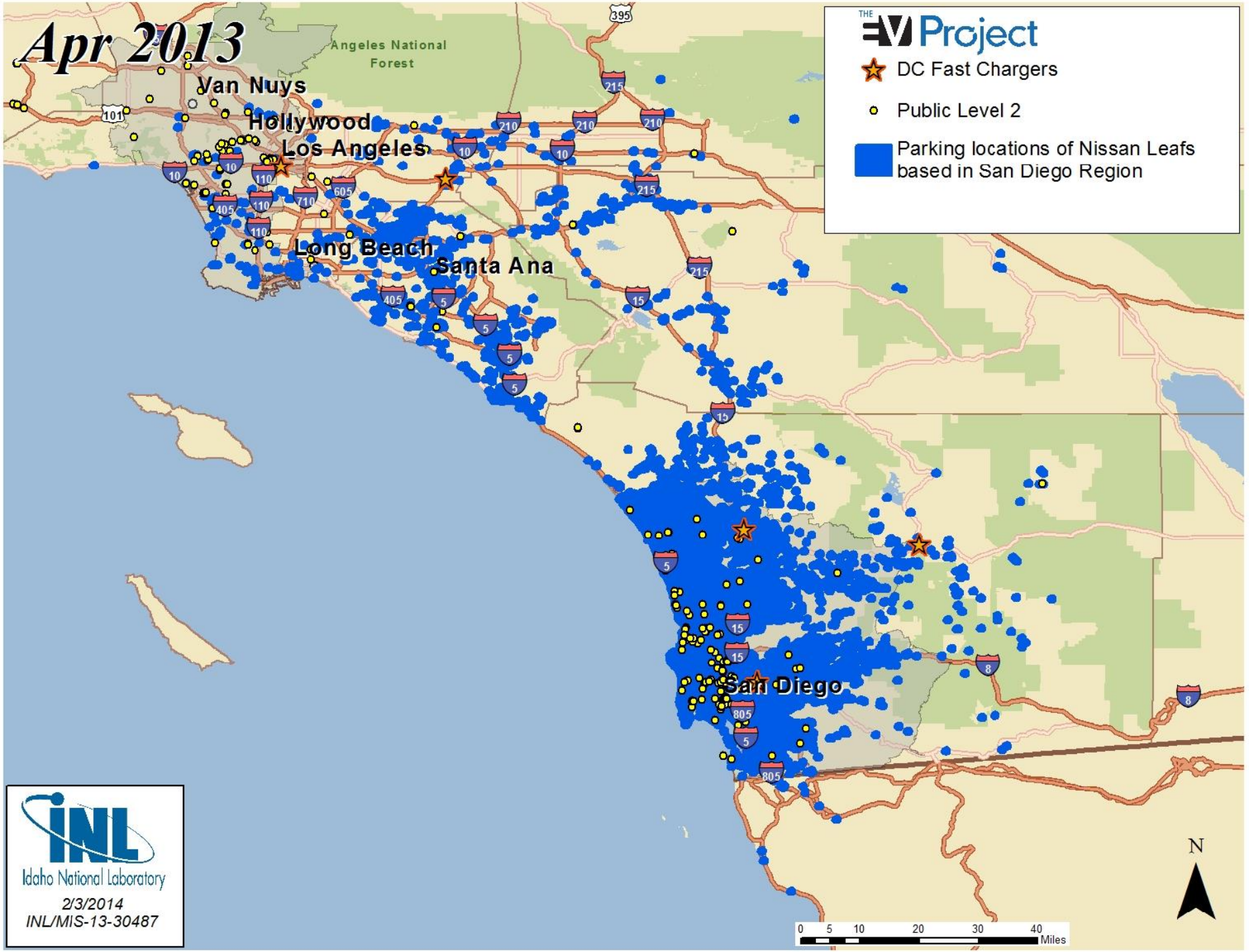

Mar 2013
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
INL
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
0 5 10 20 30 40 Miles
N


Apr 2013
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
0 5 10 20 30 40
Miles
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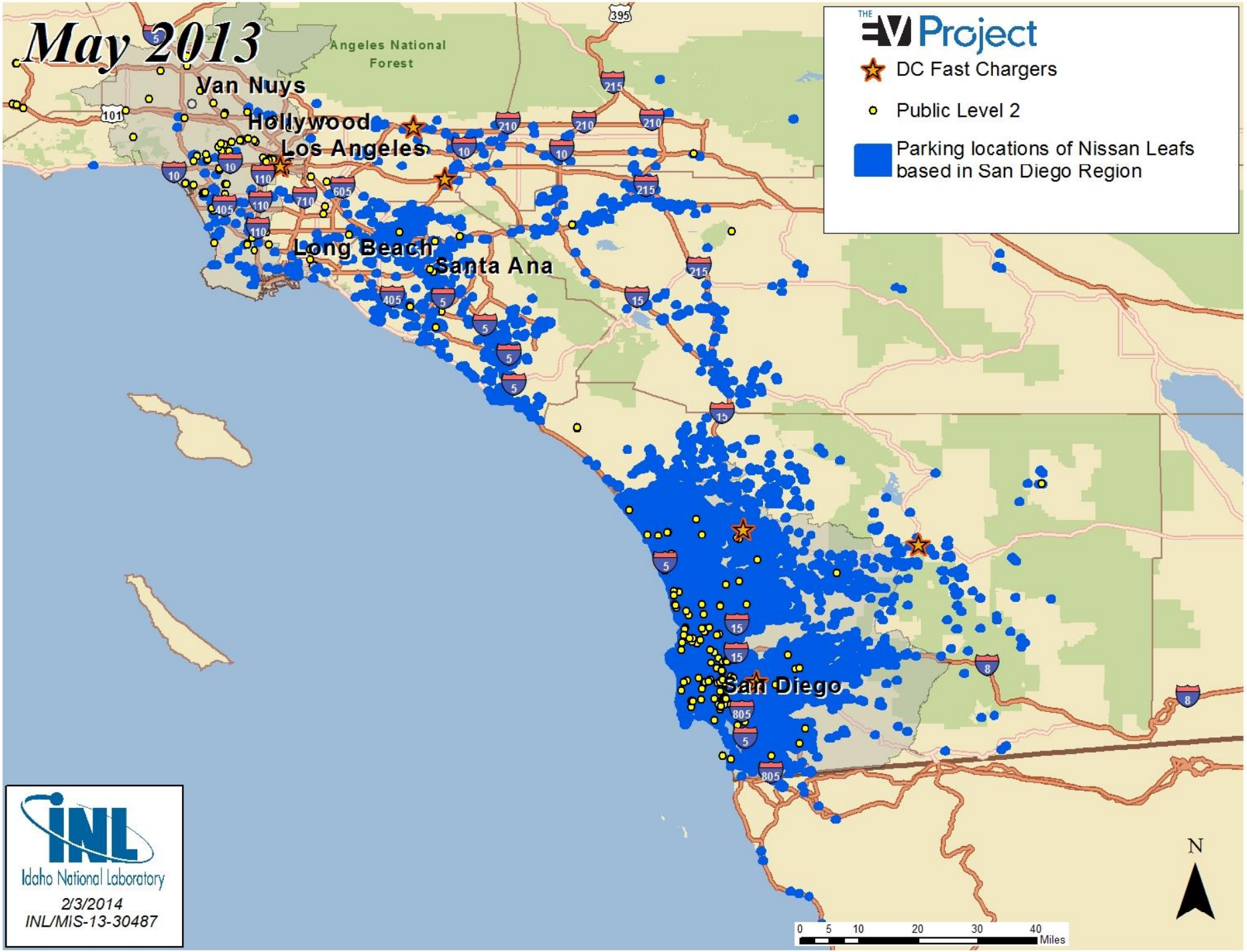
May 2013
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
INL
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
0 5 10 20 30 40
Miles
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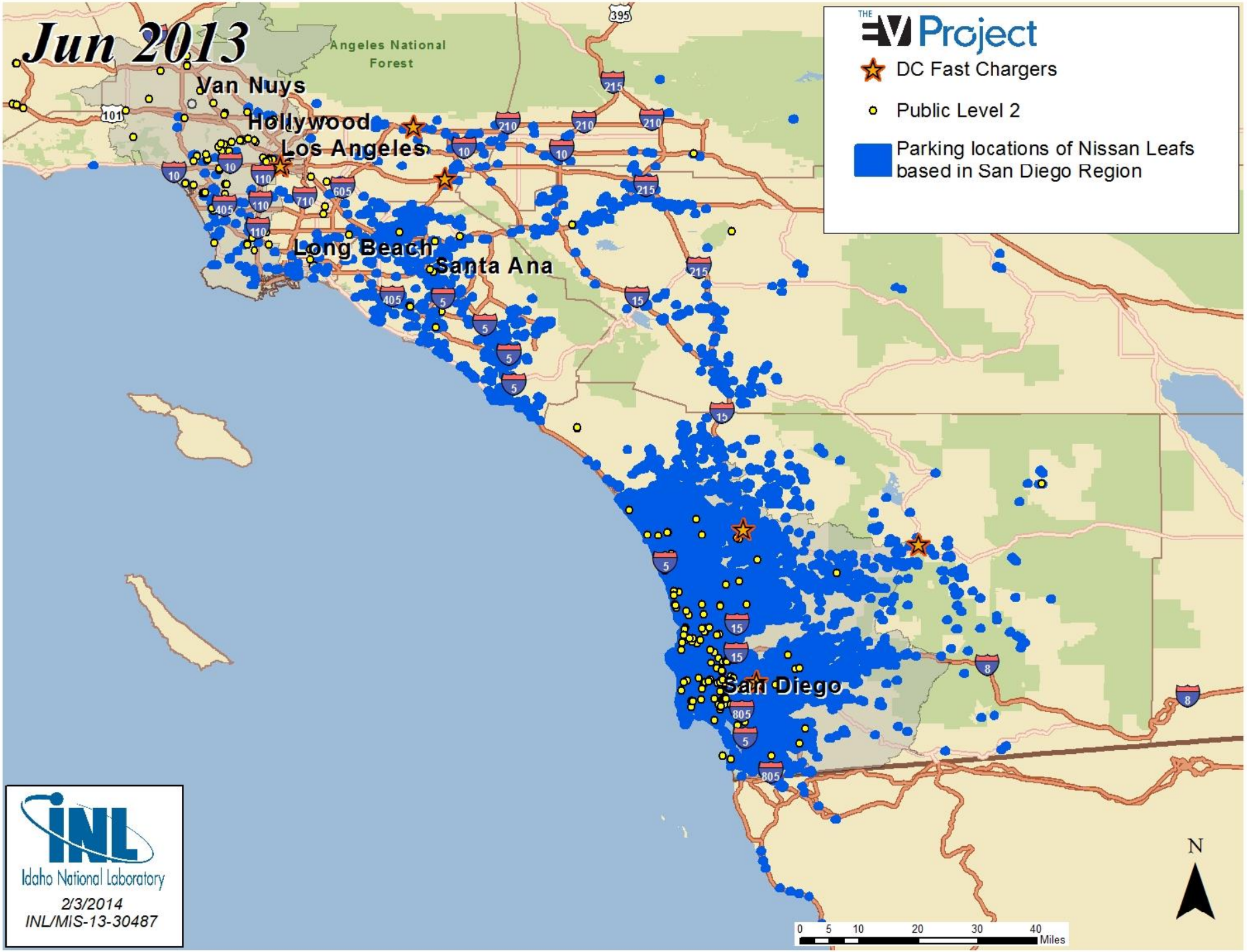
Jun 2013
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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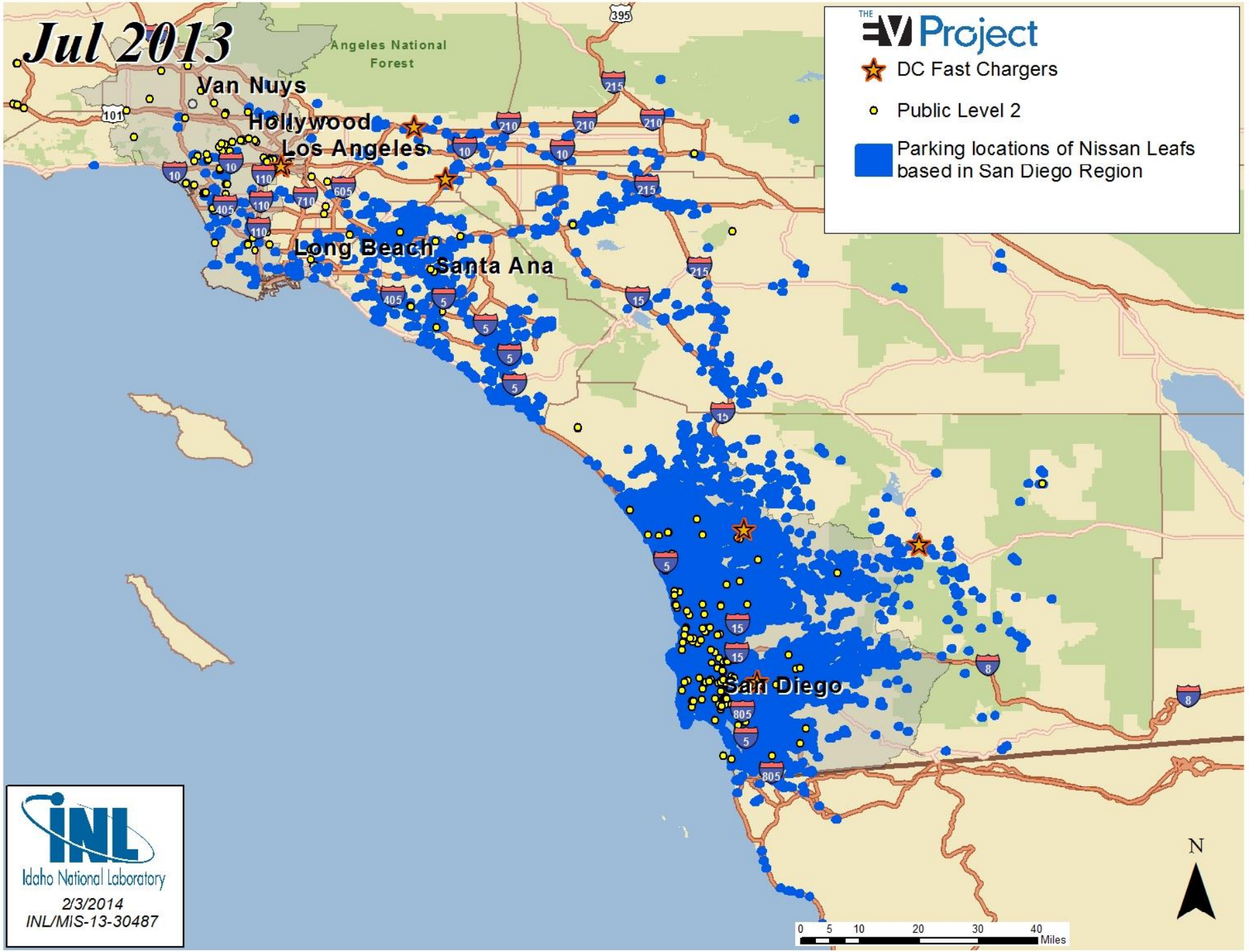
0 5 10 20 30 40
Miles


Jul 2013
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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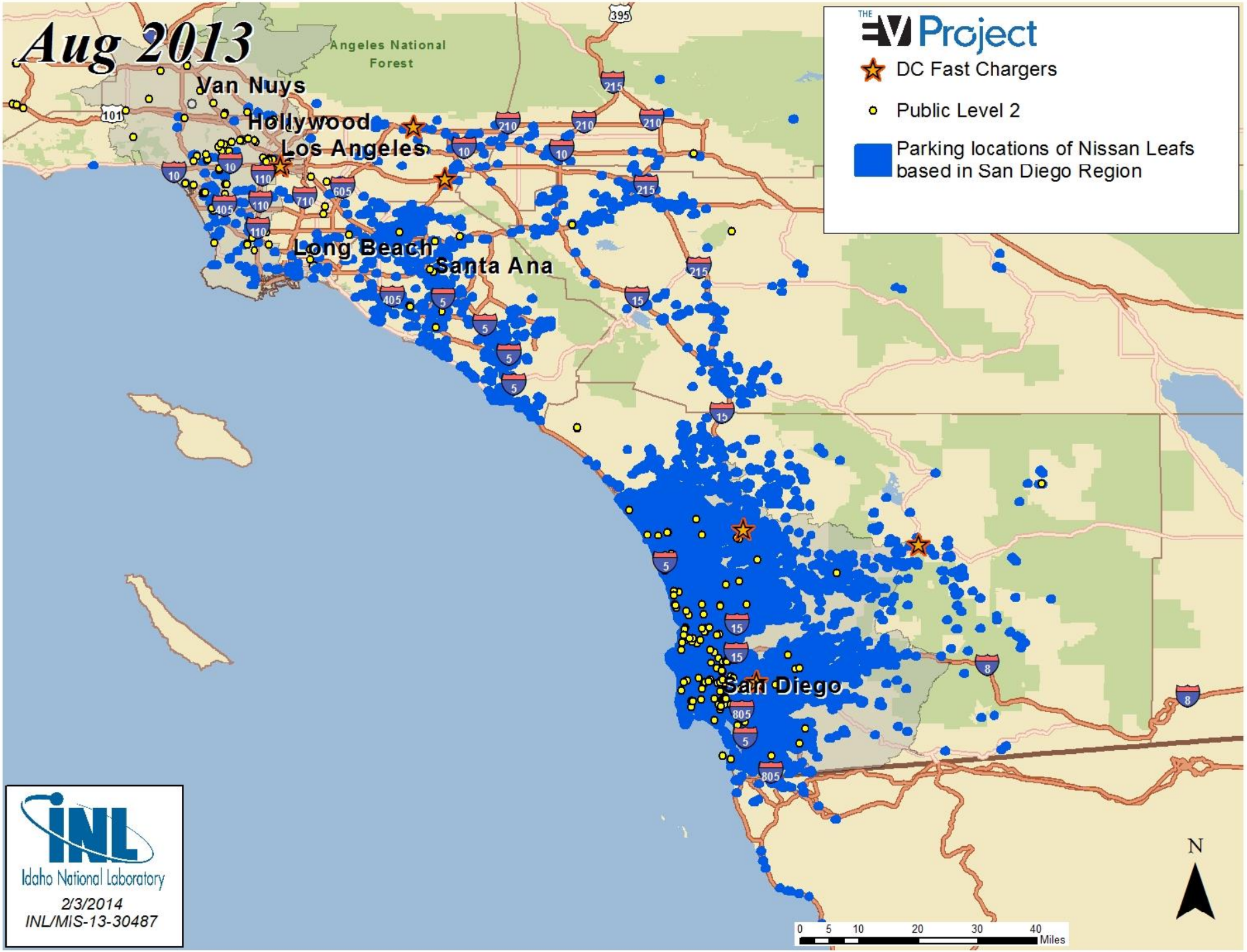
0 5 10 20 30 40
Miles


Aug 2013
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
Angeles National Forest
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
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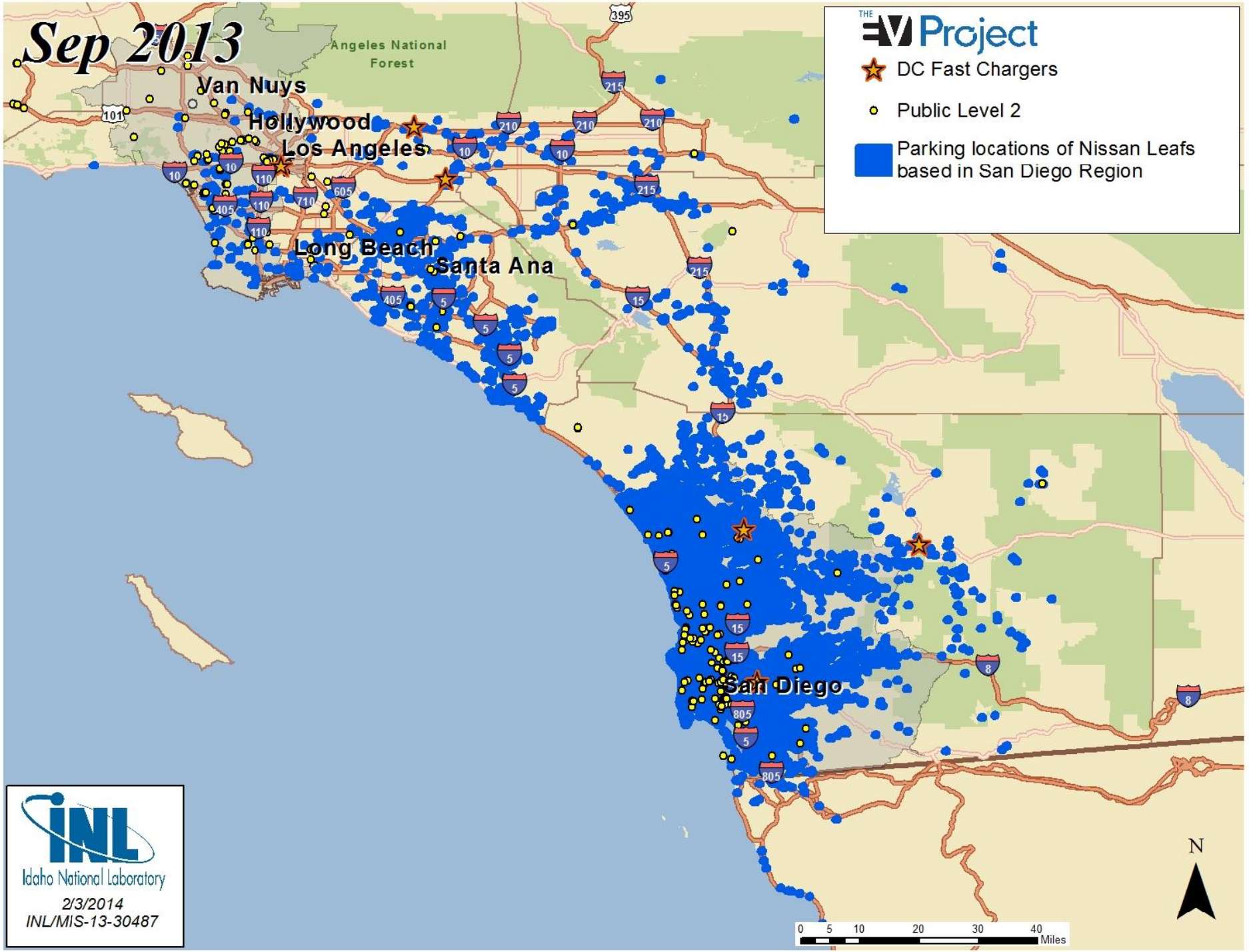
Miles


Sep 2013
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
0 5 10 20 30 40
Miles
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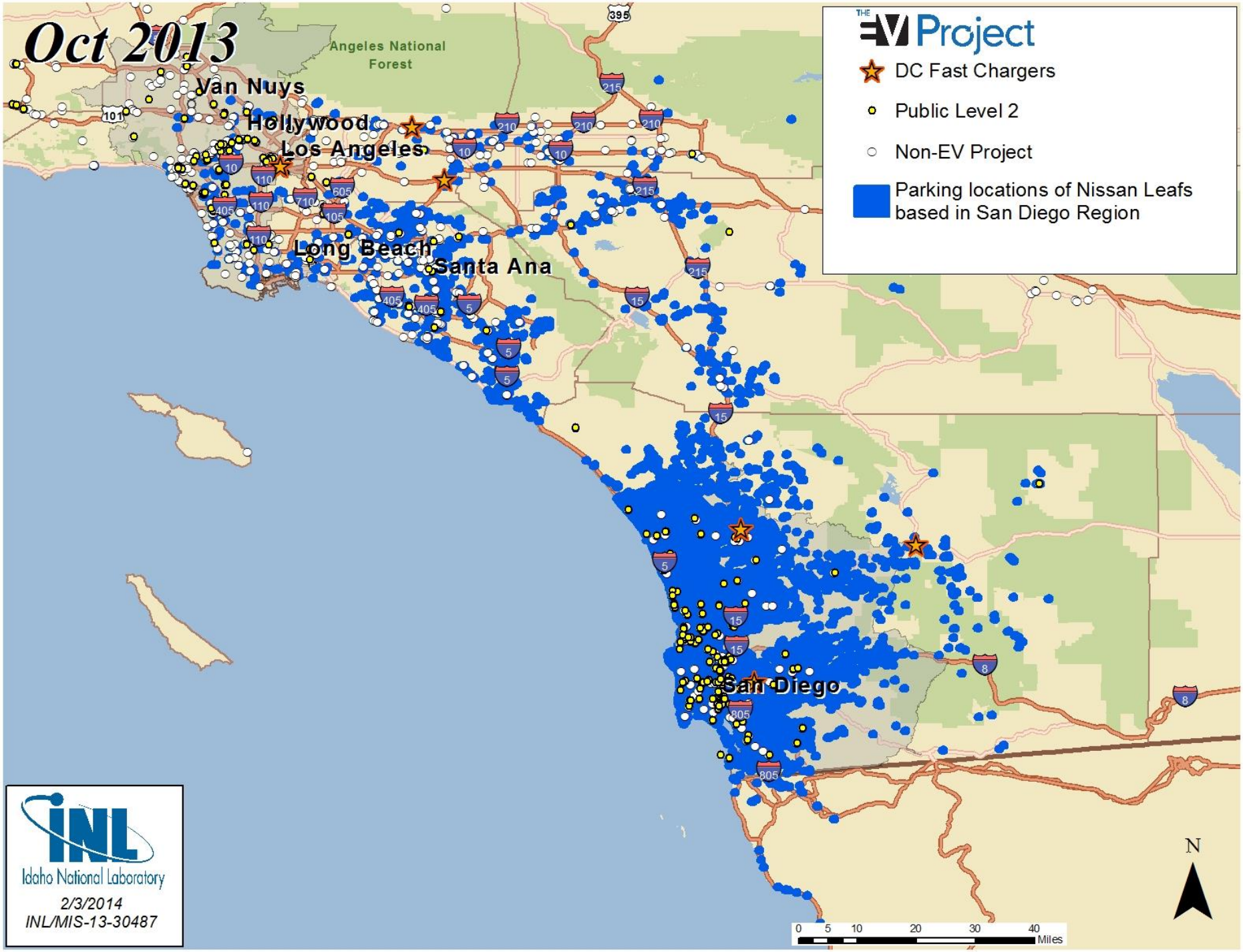
Oct 2013
Angeles National Forest
Van Nuys
Hollywood
Los Angeles
Long Beach
Santa Ana
San Diego
THE EV Project
DC Fast Chargers
Public Level 2
Non-EV Project
Parking locations of Nissan Leafs based in San Diego Region
Idaho National Laboratory
2/3/2014
INL/MIS-13-30487
N
0 5 10 20 30 40
Miles

Additional Information

Publications coming soon:

- **Q4 2013 reports**
- **White papers on**
  - Leaf L2 vs. DCFC usage
  - public charging venues
  - workplace charging case studies
  - EVSE installation costs
- **and more**

For all EV Project publications, visit

avt.inl.gov/evproject.shtml

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INL/CON-14-31124