ATIS STANDARD

ATIS-0500031.v002

ATIS Standard on -

TEST BED AND MONITORING REGIONS DEFINITION AND METHODOLOGY

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ATIS Standard on

Test Bed and Monitoring Regions Definition and Methodology

Alliance for Telecommunications Industry Solutions

Approved February 13, 2017

Abstract

This document describes and provides the technical details of the approach of characterizing wide scale indoor wireless location performance, for the purposes of E911, through representative testing in a test bed and subsequently applying its results to live wireless network emergency call statistics gathered from a number of diverse monitoring regions.

Foreword

The Alliance for Telecommunications Industry Solutions (ATIS) serves the public through improved understanding between carriers, customers, and manufacturers. The Emergency Services Interconnection Forum (ESIF) provides a forum to facilitate the identification and resolution of technical and/or operational issues related to the interconnection of wireline, wireless, cable, satellites, Internet, and emergency services networks.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes an optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, ESIF, 1200 G Street NW, Suite 500, Washington, DC 20005.

At the time of consensus on this document, ESIF, which was responsible for its development, had the following leadership:

S. Sherwood, ESIF Chair (Verizon Wireless)

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The **Emergency Services & Methodologies [ESM]** Subcommittee was responsible for the development of this document.

Revision History

Date	Document Number	Description
6/16/2016	ATIS-0500031	Document approved.
2/13/2017	ATIS-0500031.v002	Document updated to include new Appendix B, additional supporting materials, and supporting text in Clause 4.

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1 Scope, Purpose, & Application

1.1 Scope

This document describes and provides the technical details of the approach of characterizing wide scale indoor wireless location performance, for the purposes of E911, through representative testing in a test bed and subsequently applying its results to live wireless network emergency call statistics gathered from a number of diverse monitoring regions.

This document provides the definition of the six wireless network monitoring regions across the U.S. and the detailed definition of the test bed with its two test areas in and around the San Francisco and Atlanta metropolitan regions. The document describes in detail the test bed morphologies and their boundaries in the test areas, the test building types, the test cases within the test buildings, and the general test methodology. The detailed mathematical procedures to apply the benchmark results from the test bed to the live emergency call statistics in the monitoring regions are also presented.

1.2 Purpose

It is intended that through the application of the concepts and techniques defined in this document, the wireless industry and public safety will have a uniform consensus methodology that is both sound and efficient, that can be used in establishing wireless E911 indoor location performance in a consistent and repeatable manner.

1.3 Application

All stakeholders involved in indoor wireless E911 location performance characterization will find the contents of this document applicable to their efforts. It defines for wireless carriers, location technology vendors, test services vendors, and experts in the field the network monitoring regions to be used in establishing compliance with FCC location accuracy requirements, the test bed with its two distinct regions and characteristics, the test methodology, and the mathematical procedures to apply the test bed results to the live network call statistics obtained from the monitoring regions. It is anticipated that technical teams involved in planning, performing, and overseeing field testing related to the test bed and analyzing its results, as well as wireless carrier technical personnel involved in applying the results of the test bed to their networks, will make frequent use of the techniques described in this document.

2 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

FCC 15-9, PS Docket No. 07-114, 4th Report and Order, *Fourth Report and Order In the Matter of Wireless E911 Location Accuracy Requirements*[1]

ATIS-0500013, *Approaches to Wireless E911 Indoor Location Performance Testing*[2]

ATIS-0500022, *Test Plan Input for a Location Technology Test Bed*[3]

ATIS-0500027, *Recommendations for Establishing Wide Scale Indoor Location Performance*[4]

ATIS-0500030, *Guidelines for Testing Barometric Pressure-Based Z-Axis Solution*[5]

3 Acronyms & Abbreviations

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < http://www.atis.org/glossary >.

3.1 Acronyms & Abbreviations

AGNSS	Assisted Global Navigation Satellite System
A-GPS	Assisted-Global Positioning System
AP	Access Point (i.e., Wi-Fi Base Station)
ATIS	Alliance for Telecommunications Industry Solutions
BLE	Bluetooth Low Energy
CMRS	Commercial Mobile Radio Services
CMA	Cellular Market Areas
CSRIC	Communications Security, Reliability and Interoperability Council
CTIA	Cellular Telephone Industries Association, now known as CTIA-The Wireless Association
DL	Dispatchable Location
E911	Enhanced 911
ESIF	Emergency Services Interconnection Forum
ESM	Emergency Services & Methodologies
FCC	Federal Communications Commission

[1] This document is available from the Federal Communications Commission, 445 12th Street, SW, Washington, DC 20554: < http://www.fcc.gov >.

[2] This document is available from the Alliance for Telecommunications Industry Solutions, 1200 G Street, NW Suite 500 | Washington, DC, 20005: < https://www.atis.org/docstore/product.aspx?id=25009 >.

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FIPS	Federal Information Processing Standard (A FIPS Code is a 5 digit code assigned to each county)
GDOP	Geometric Dilution of Precision
GPS	Global Positioning System
ISP	Internet Service Provider
OS	Operating System
OTDOA	Observed Time Difference of Arrival
PSAP	Public Safety Answering Point
RF	Radio Frequency
RTT	Round Trip Time
TBS	Terrestrial Beacon System
TTFF	Time to First Fix
Wi-Fi	Wireless Fidelity

4 Approach to Indoor Location Performance Establishment

ESIF ESM has provided recommendations for indoor location performance characterization based on representative indoor testing and monitoring in select regions in ATIS-0500027. That document outlines the key parameters that need to be characterized for a wide selection of existing and emerging indoor location technology solutions. It also identifies six market regions as candidates for indoor test bed implementation. Those regions are Metropolitan San Francisco, Denver, Chicago, Atlanta, and Philadelphia, in addition to Manhattan in New York City because of its unique dense urban environment.

The FCC, in its 4th Report and Order, adopted the approach of representative evaluation and testing of indoor location technology performance for wireless E911. In the Order, the FCC placed indoor location performance benchmarks to be met by wireless carriers (CMRS providers) over a multi-year time frame. It also required that CMRS providers certify at certain timeframes that they have deployed compliant technology throughout their network "consistent with the compliant technology's performance in an independent test bed". Moreover, "to demonstrate further compliance with these metrics, CMRS providers must submit aggregated live 911 call data from the six cities recommended for indoor testing by the Alliance for Telecommunications Industry Solutions Emergency Services Interconnection Forum (ATIS ESIF)."

Accordingly, through the regulatory process, the six market regions identified in ATIS-0500027 have been used interchangeably, either as candidate areas for establishing a test bed to represent the entire U.S., or as areas to monitor live E911 location performance across the U.S., when coupled with the appropriate representative test bed data.

Subsequent to the 4th Report and Order and in response to its requirements, ESIF re-examined and refined the test bed locations for representative testing. It also began work to define blending methodologies for assessing accuracy compliance. Through technical contributions to ESM and extensive dialogue within it related to the resolution of this issue, convergence was reached on using a two-region test bed, with one region in the eastern U.S. and one on the West Coast, to capture the representative indoor location test data. Metropolitan San Francisco and Metropolitan Atlanta as well as the areas surrounding them were selected as the two test bed regions. Each of these two test regions would have good, albeit distinct, representation of the four basic morphologies (environments) where wireless calls are placed, namely, the dense urban, urban, suburban, and rural morphologies.

The rationale for selecting Metropolitan San Francisco as a test bed region is obvious, since it served very well as a representative area with diverse morphologies and building types during the CSRIC III testing. The rationale for selecting Atlanta, for example over Philadelphia (which was used as an example in ATIS-0500027), is that Atlanta more closely resembles many typical U.S. metropolitan areas where the wireless carriers have national coverage. This is in contrast to the very high levels of urbanization encountered in Philadelphia. Also, such extreme dense urbanization is reflected in the City of San Francisco already selected as a test bed.

The indoor location test bed regions are intended to serve three broad goals: first chronologically, they provide test data to be used by the wireless carriers to ascertain their compliance with the early performance benchmarks mandated by the FCC in its 4th Report and Order; secondly, and shortly thereafter, to test new and emerging (yet to be deployed or adopted) indoor location technology solutions; and thirdly, which is somewhat in conjunction with the second goal, to test candidate z-axis technologies and dispatchable location and help determine an appropriate metric for z-axis accuracy performance to propose to the FCC.

To derive network compliance results from the test bed, the results from the test bed are to be weighed appropriately according to the distribution of live wireless 911 calls in the six so-called monitoring regions. Technical approaches to identifying the distribution of the live 911 calls among the underlying indoor location technologies and the distinct morphologies and to blending and weighting the test results according to those distributions are described in later clauses of this document.

The following two clauses will first define the six regions of live wireless 911 location performance monitoring and the two test bed regions selected among those six monitoring areas to perform controlled indoor location testing. Clause 8 describes the detailed process for weighting the live 911 calls in the 6 monitoring regions with benchmark per morphology test results from the test bed. Appendix A provides additional illustrative details of the weighting process. Appendix B contains the detailed morphology polygons and corresponding shape files for the 6 monitoring regions to be used in the call weighting process.

5 Indoor Location Performance Monitoring Regions

Paramount in the selection of the wireless 911 performance monitoring regions is that they reflect the varying environments around the country, especially relating to prevailing building architectures and construction materials, as well as distinct urban layouts, densities, and vegetation that could impact indoor location performance. Moreover, those few monitoring regions need to be sufficiently dispersed around the country to be of reasonable “regional proximity” to PSAPs in each part of the country.

The recommended six areas, as chosen in ATIS-0500027, are centered around six metropolitan hubs and are to have sufficient surrounding areas included in each case to account for as many morphologies as required in the monitoring region. They provide a good mix of the different location-affecting parameters identified in ATIS-0500027, are distributed across the country, have good local mixes of the various morphologies as well as building construction materials, building densities and heights. They also span the range of latitudes and average cell site radii seen across the country, and include coastal edge-of-coverage effects.

Another important factor in definition of the monitoring regions is that they be consistent with how the FCC views cellular markets so that no arbitrary selection of boundaries might be perceived. Accordingly, all counties within the Cellular Market Area (CMA) surrounding the core of the city around which a monitoring region is centered are included. Additionally, for the case of the San Francisco region, since the CSRIC III test bed included areas in three CMAs (7, 27, and 339) all nine counties in the three CMAs will be included in the San Francisco Region monitoring area.

The inclusion of all the counties for all monitoring regions shifts the emphasis from narrow dense urban and urban scenarios targeted during the CSRIC III testing to larger, more balanced statistical samples of E911 calling in the reporting areas.

5.1 Morphology Classification & Considerations for Application of Results

5.1.1 Application from Test bed to Monitoring Regions

The derivation of live wireless 911 call performance in any of the monitoring regions will rely on the weighting of the test call results observed in each morphology type in the test bed by the proportion of live indoor wireless 911 calls in each corresponding morphology in the monitoring region. It is necessary therefore that the test bed regions closely resemble the broader monitoring markets and that the classification of morphologies in the test bed and the monitoring markets be consistent.

The classification of morphologies in the test bed polygons as shown in Clause 6 has been performed manually and reviewed extensively within ESM to ensure its accuracy as a reference. This approach also provides high resolution where necessary to the city block level (e.g., in the urban and dense urban areas). For the broader monitoring regions which are jointly comprised of 61 counties, the manual approach to splitting the area into four morphologies can be labor intensive and therefore undesirable. If results are to be extended from the monitoring regions beyond their boundaries to other areas of the U.S., then it is even less desirable to rely exclusively on a manual classification scheme, which may become somewhat subjective depending on the analyst.

An automated objective method is therefore sought to implement the classification of morphologies across the monitoring areas and where it may become needed in the rest of the country. Attempts at demonstrating this type of automated technique have been proposed to ESM. Unfortunately the data source used with the automated technique proved to be unsuitable for the purpose. That data source was the National Land Cover Database, which is a free source of data. It diverged in its morphology definitions from the basic attributes of the morphologies as used in the wireless E911 context. This resulted in widespread major errors in classifying the source data that were not practical to correct manually. A better source of morphology data, especially one that captures the height or number of floors of buildings, is still sought. Building heights can be a very useful input in morphology class determination. Such data sources are understood to be available but are not free. The investigation of data sources and the associated automated method for their utilization is still underway and specific recommendations will be provided in future revisions to this document.

Regardless of the chosen data source or the morphology segmentation technique used in processing the data source, the outcome has to resemble the classifications used in the test bed, i.e., be a reasonable approximation in the context of its desired use. The different test polygons in both the San Francisco and Atlanta areas defined in Clauses 6.2 and 6.3 respectively provide good test cases to gauge the accuracy and reliability of any automated morphology determination technique.

5.1.2 Application from Monitoring Regions to other Areas

The following list provides the metropolitan areas of each monitoring region and their representative characteristics that apply to a wider area in which those characteristics can be found. Geographic proximity is one factor; similarity of climate and construction methods is an even more critical factor in the applicability to the monitoring results.

Examples of cities where regional extrapolation could be applied are provided under each regional monitoring area. Results from more than one monitoring region could be applied in a target analysis area (e.g., of interest to a given PSAP) to provide the best match based on their representative characteristics.

1. San Francisco Bay Area (to Central Valley and Sierra Foothills)
    a. Pacific region
    b. Represents: Los Angeles, Seattle, San Diego, Portland, San Jose, hot climate desert southwest (e.g., Las Vegas, Phoenix), and agricultural flat lands
    c. From semi-arid to fairly densely vegetated hills and mountains surrounding populated basins, valleys and canyons
    d. Water edge and bay-surrounding cell site geometries and propagation effects
    e. Peninsula might be able to resemble an island test
2. Chicago
    a. Midwest region
    b. Lake/shoreline
    c. Dense urban core
    d. Extensive urban residential areas
    e. Extends to rural Midwest surroundings
    f. Represents: Cincinnati, Detroit, Cleveland, St. Louis, Minneapolis, St. Paul, Milwaukee, Indianapolis, Columbus, and Buffalo (lake side setting)
3. Atlanta
    a. Southeast region
    b. Newer and older construction common to the South
    c. Extends to heavily forested hilly terrain
    d. Represents: Charlotte, Richmond, Birmingham, Dallas, Nashville, Memphis, Houston, Austin, Jacksonville, Fort Worth, and non-coastal Miami
4. Denver/Front Range
    a. Mountain region
    b. Mountainous and basin terrain
    c. Elevation (1 mile high)
    d. Southwest and interior northwest region example
    e. Represents: Salt Lake City, Albuquerque, Spokane, Reno, etc.
5. Philadelphia
    a. Northeast region
    b. Typical Northeast city and its environs
    c. Denser older urban areas, dense suburbs to more sparse more heavily vegetated suburbs, flat and hilly rural areas
    d. Represents: Boston, Wilmington, Baltimore and Washington, D.C.
6. New York Metro Area
    a. Northeast region with special characteristics
    b. Extremely Large urban area and surrounding suburbs extending to rural areas
    c. Extremely dense urban morphology in Manhattan with extreme population density
    d. Extremely high cell site densities in dense urban areas
    e. Northeastern rural areas, including hilly, with possibly limited wireless coverage

5.2 San Francisco Monitoring Region

Whereas in the CSRIC III San Francisco Bay Area test polygons were only selected in San Francisco, Santa Clara, and San Benito counties, the San Francisco network monitoring region for live 911 call performance is defined to include all nine counties in the three CMAs that were involved in the CSRIC III test bed. These are shown in Table 5.2-1, including their populations, areas, and population densities. The included counties are shown highlighted in the Google Earth map in Figure 5.2-1.

In CSRIC III testing the emphasis was placed on indoor location technology evaluation particularly in urban and dense urban settings. In contrast, the wider footprint of the current monitoring area here allows for a more balanced mix of dense urban, urban, suburban, and rural morphologies over which performance can be reported. Furthermore, the inclusion of CMA 339, extending into agricultural central California and to the foothills of the Sierra, provides considerably more representation of various rural environments. It also offers considerably more options in the selection of rural test polygons to reflect the distinct rural scenarios, including agriculture and foothill communities.

The overall monitoring area provides an extensive and comprehensive representation of the different wireless environments and population densities in a sizeable portion of California. Very diverse geography and terrain are included, ranging from a hilly peninsula, to relatively flat residential and farm lands in the valleys, to more isolated coastal communities, to numerous populated and sparse foothills, and rugged, forested high mountains popular with visitors.

In extending the results from this monitoring area to others not only would the terrain and general natural morphology need to be similar, but also the man-made aspects of the morphology should be similar. This means that building construction methods and materials and building densities and heights need to be similar. For example, it would not be appropriate to extend performance from a suburban area where buildings are made mostly of wood (as in California) to other regions where suburban buildings are largely made out of brick (as in the East or Midwest).

Accordingly, the large mix of terrain and morphology in the San Francisco monitoring region reflects well the majority of terrains and morphologies along the West Coast, as well as the portions of the southwestern U.S. with hotter climates and similar construction methods (e.g., Las Vegas or Phoenix).

Table 5.2-1 – CMAs and Counties in the San Francisco Monitoring Region

CMA	County Name	STATE	Population (2012 est)	Area (sq. mi)	Population Density	FIPS
7	Alameda	CA	1,554,720	738	2,107	06001
7	Contra Costa	CA	1,079,597	720	1,499	06013
7	Marin	CA	256,069	520	492	06041
7	San Francisco	CA	825,863	47	17,572	06075
7	San Mateo	CA	739,311	449	1,647	06081
27	Santa Clara	CA	1,837,504	1291	1,423	06085
339	San Benito	CA	56,884	1389	41	06069
339	Madera	CA	152,389	2153	71	06039
339	Merced	CA	263,228	1972	133	06047

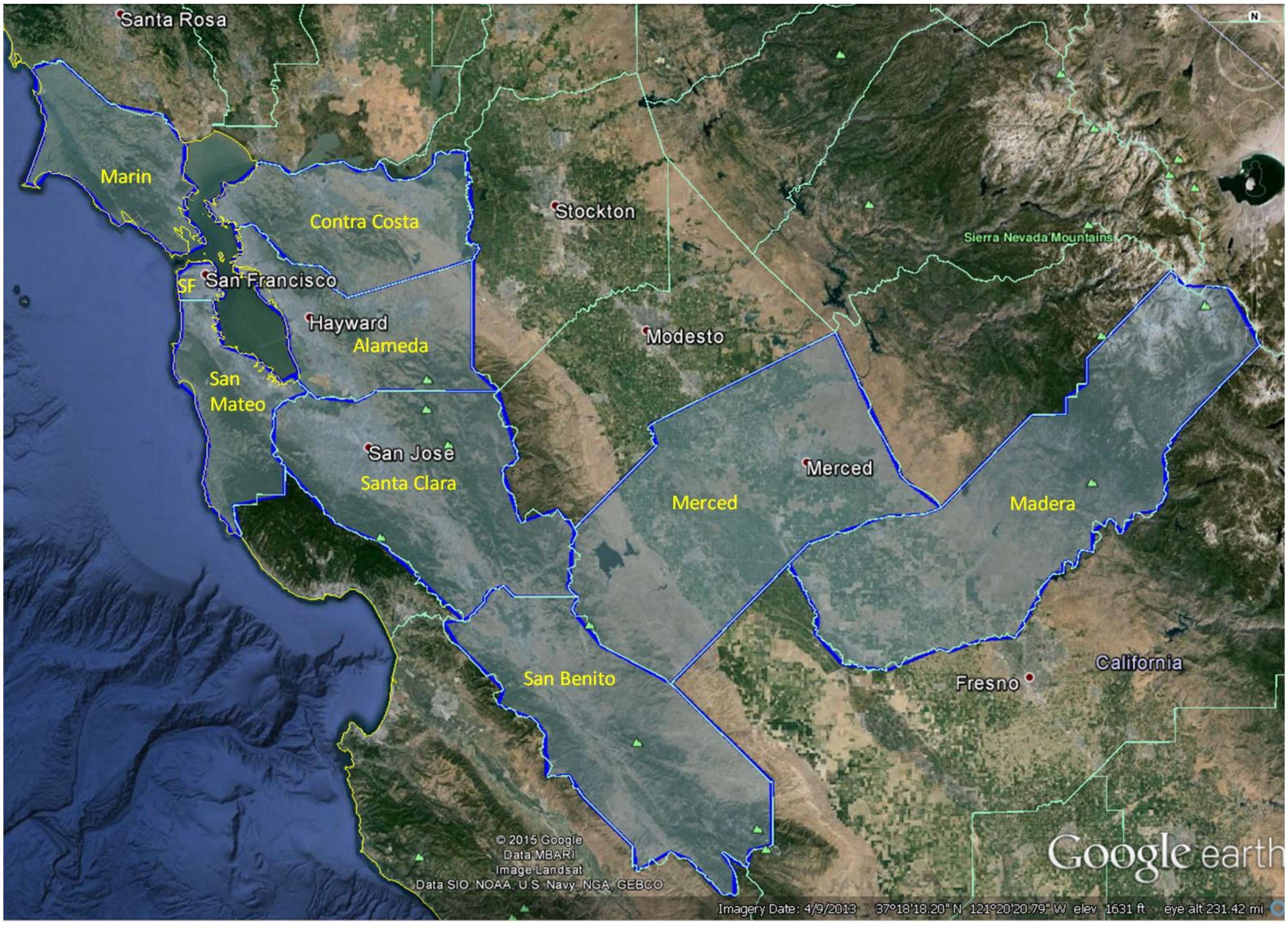

Figure 5.2-1 -- The 9 Counties Forming the San Francisco Monitoring Region

5.3 Chicago Monitoring Region

The Chicago monitoring region contains six counties that are flat in terrain as is typical throughout most of the Midwest. The population and morphology vary widely, from the density of highly urban Chicago, to its largely suburban surrounding counties, to the lighter more rural outer counties. Downtown and central Chicago have a large dense urban segment replete with tall buildings and urban canyons. Suburban sprawl, on the other hand, extends to roughly 35-45 miles from Downtown Chicago, beyond which the morphology becomes predominantly rural (see Figure 5.3-1).

The large rural portions of McHenry, Kane, and Will Counties have considerably lower population densities than the averages indicated in Table 5.3-1. They provide good morphologic representation of the more agricultural rural Midwest, although cell site densities are likely to be higher than in other areas of the Midwest away from a large metropolis.

Construction methods used are appropriate for climates with cold winters, feature brick, steel, and other suitable materials, thicker windows and glass, houses with basements in certain areas, and so on. Extension of monitoring results to areas with similar terrain and morphology (e.g., Milwaukee, Detroit, Minneapolis, St. Louise, Kansas City, etc.) would be natural.

Cook and Lake Counties provide ample water edge scenarios, both with dense tall buildings and smaller suburban structures. Those scenarios provide representation that goes beyond water edge, Midwestern counties and could, for example, represent scenarios in a number of cities along the Great Lakes or even the Eastern seaboard.

Note that many areas in the western Midwest, such as parts of Kansas, Nebraska, and South and North Dakota are physically closer to the rural counties east of Denver and its more arid climate and maybe better represented morphologically by that portion of the Denver monitoring area.

Table 5.3-1 – Counties in the Chicago CMA Monitoring Region

CMA	County Name	STATE	Population (est)	Area (sq. mi)	Population Density	FIPS
3	Cook	IL	5,231,351	946	5,530	17031
3	DuPage	IL	927,987	334	2,778	17043
3	Kane	IL	522,487	521	1,003	17089
3	Lake	IL	702,120	448	1,567	17097
3	McHenry	IL	308,145	604	510	17111
3	Will	IL	682,518	837	815	17197

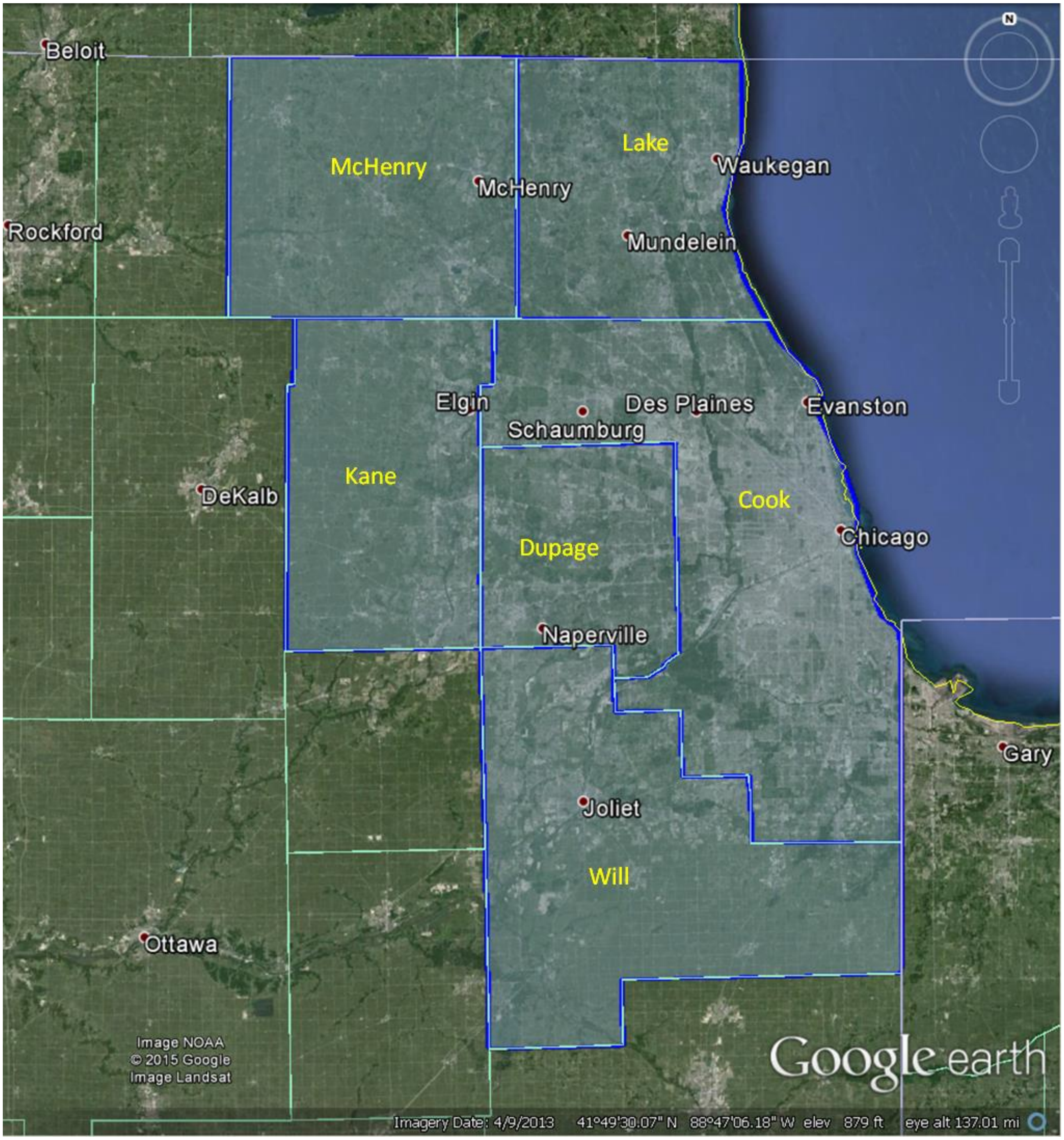

Figure 5.3-1 – The 6 Counties Forming the Chicago Monitoring Region

5.4 Atlanta Monitoring Region

The Atlanta monitoring region consists of 13 counties surrounding metropolitan Atlanta. It provides typical representation of the southeastern U.S., with its mostly flat but occasionally hilly terrain, mostly deciduous but with occasional evergreen vegetation, and eastern U.S. construction methods. The density of structures in its urban and dense urban sections is typical of many cities in the U.S., well beyond the southeast. Its suburbs also represent very well many U.S. suburbs, especially in the eastern and midwestern parts of the country. The environments and construction in the Atlanta monitoring region can be readily applied in and around many cities including those listed above in clause 5.1.2.

Most of the true urbanization (in an indoor E911 context) is found in Fulton and Dekalb counties. However, the Atlanta area has witnessed a tremendous amount of suburban sprawl, so most of the remaining counties have large suburban footprints, despite some relatively low population density in Table 5.4-1. It is necessary to go to the outer edges of the outer counties of the region to capture truly rural environments. Fortunately Butts County in the southeast of the region is still predominantly rural and a sizeable rural test polygon can be carved from it, as described in clause 6.3.

Table 5.4-1 – Counties in the Atlanta CMA Monitoring Region

CMA	County Name	STATE	Population (est)	Area (sq. mi)	Population Density	FIPS
17	Butts	GA	23,524	187	126	13035
17	Cherokee	GA	221,315	424	522	13057
17	Clayton	GA	265,888	143	1,859	13063
17	Cobb	GA	707,442	340	2,081	13067
17	DeKalb	GA	707,089	268	2,638	13089
17	Fulton	GA	977,773	529	1,848	13121
17	Gwinnett	GA	842,046	433	1,945	13135
17	Henry	GA	209,053	323	647	13151
17	Douglas	GA	136,379	200	682	13097
17	Fayette	GA	109,664	199	551	13113
17	Forsyth	GA	361,220	413	875	13117
17	Newton	GA	102,446	279	367	13217
17	Paulding	GA	146,950	315	467	13223

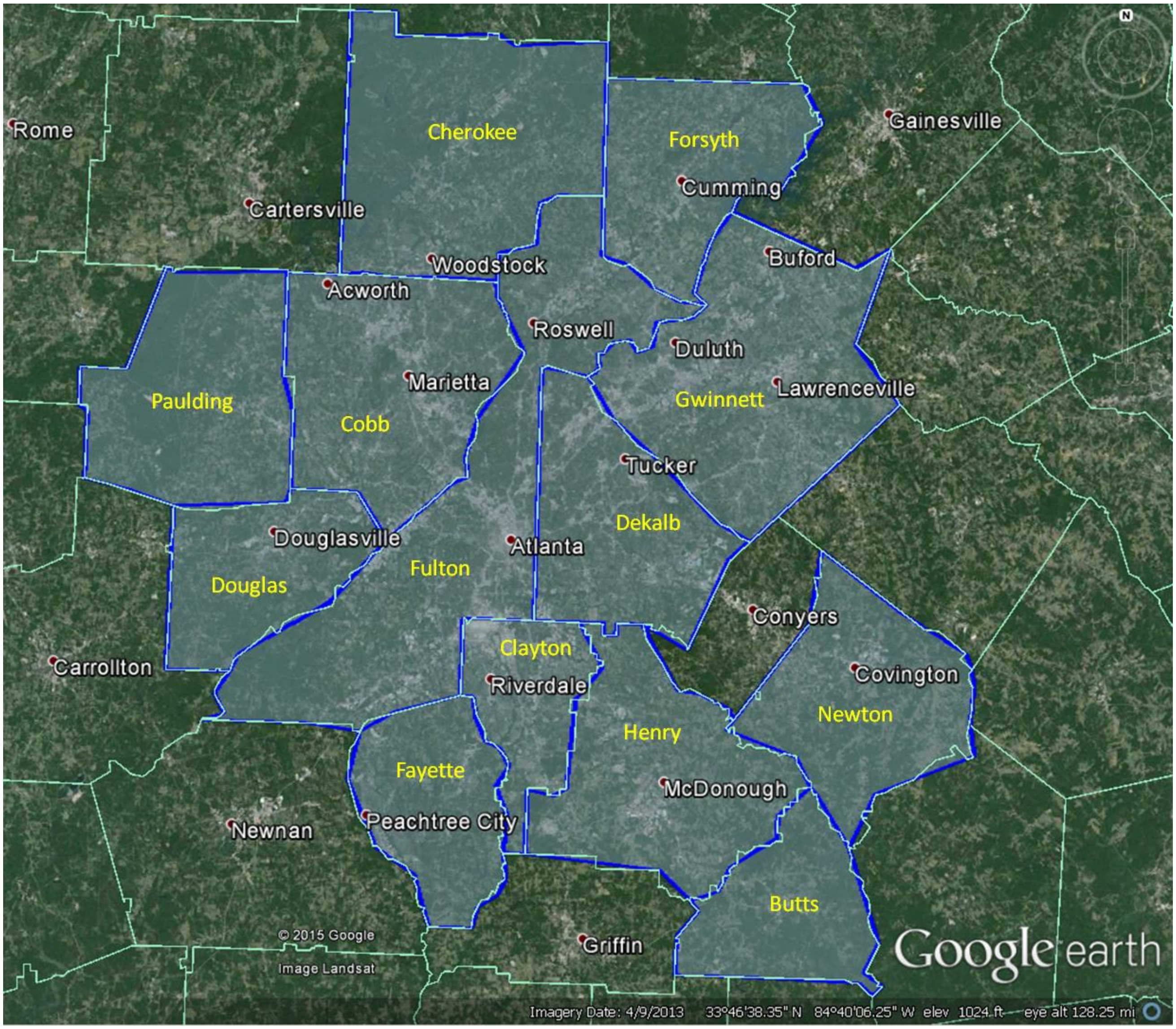

Figure 5.4-1 – The 13 Counties Forming the Atlanta Monitoring Region

5.5 Denver Monitoring Region

The Denver region covers the range of terrain and morphology from flat, sparse, mostly prairie land in its east to the rugged high mountains of the Front Range of the Rockies in its west. Elevations range from about 5000 feet to peaks over 12,000 feet. Eight counties form the region as shown in Table 5.5-1 and illustrated in Figure 5.5-1. In the middle lies the city and county of Denver, which has the typical mix of urban and suburban development and a relatively small dense urban in downtown, as seen in many medium-sized cities in the US.

As mentioned above, the eastern counties of the monitoring area offer a good representation of widespread prairie counties in the western Midwest and eastern side of the Rockies mountain range. The western counties are traversed north to south with a massive mountain range and reflect that type of terrain and morphology in the Rockies and parts of the interior northwest and higher elevation southwest.

Construction methods and materials reflect the colder winter climate found in those regions of the U.S. as well. Construction with brick and other materials, heavy insulation, thicker windows, and steel high rises in the urban center are common. Other areas in the western U.S. with similar characteristics would be well represented by Denver, e.g., Salt Lake City, Boise, Albuquerque, Spokane, Boise, etc.

Table 5.5-1 – Counties in the Denver Monitoring Region

CMA	County Name	STATE	Population (est)	Area (sq. mi)	Population Density	FIPS
19	Adams	CO	459,598	1182	389	08001
19	Arapahoe	CO	595,546	804	740	08005
19	Boulder	CO	305,318	740	412	08013
19	Broomfield	CO	58,298	34	1,737	08014
19	Denver	CO	634,265	156	4,075	08031
19	Douglas	CO	298,215	842	354	08035
19	Gilpin	CO	5,491	150	37	08047
19	Jefferson	CO	545,358	773	706	08059

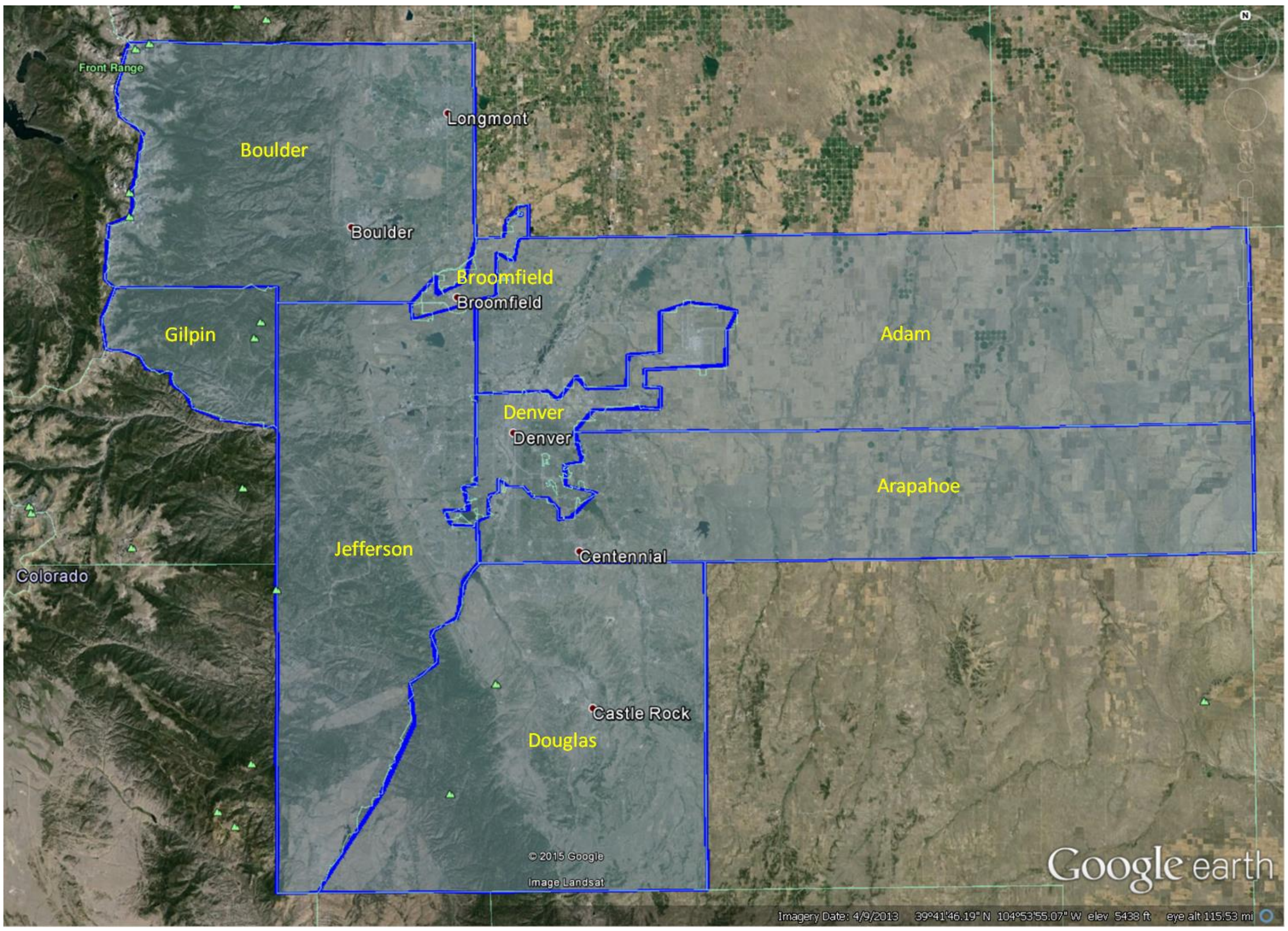

Figure 5.5.-1 – The 8 Counties Forming the Denver Monitoring Region

5.6 Philadelphia Monitoring Region

The Philadelphia monitoring region with its eight counties epitomizes the Northeast (apart from New York City and its vicinity). Philadelphia represents exceptionally well the denser, older cities that were established and grew initially in centuries past. The City with its very large urban area, spanning most of Philadelphia County, is a very good example of older urban layout and construction. As seen from Table 5.6-1, its population density is much higher than all other counties in this monitoring region. In fact its population density of almost 11,000 per square mile falls among the monitoring regions only after New York City counties and San Francisco County. Dense urban downtown Philadelphia is also a sizeable area of sky scrapers and urban canyons. Philadelphia was used in ATIS-0500027 as an illustrative candidate for a regional test bed and several pictures of its urban scenarios and sample urban polygons are provided in that document.

Most of the other counties in this monitoring region have the range of typical Eastern and Northeastern U.S. characteristics. Montgomery and Delaware Counties in Pennsylvania and Camden County in New Jersey have a wide mix of morphologies from urban to rural with the large portions of their areas being suburban. The other four counties in the region are suburban with substantial rural areas. Rural morphology is mostly agricultural although Burlington County, NJ has also extensive forestation.

As mentioned in Clause 5.1.2 the Philadelphia region with its mix of urban center and suburban and rural periphery can used to represent a number of cities in both the Northeast and the Mid-Atlantic states.

Table 5.6-1 – Counties in the Philadelphia Monitoring Region

CMA	County Name	STATE	Population (est)	Area (sq. mi)	Population Density	FIPS
4	Burlington	NJ	451,336	805	561	34005
4	Camden	NJ	513,539	222	2,313	34007
4	Gloucester	NJ	289,586	561	516	34015
4	Bucks	PA	627,053	622	1,008	42017
4	Chester	PA	506,575	760	667	42029
4	Delaware	PA	561,098	191	2,938	42045
4	Montgomery	PA	808,460	487	1,660	42091
4	Philadelphia	PA	1,547,607	143	10,822	42101

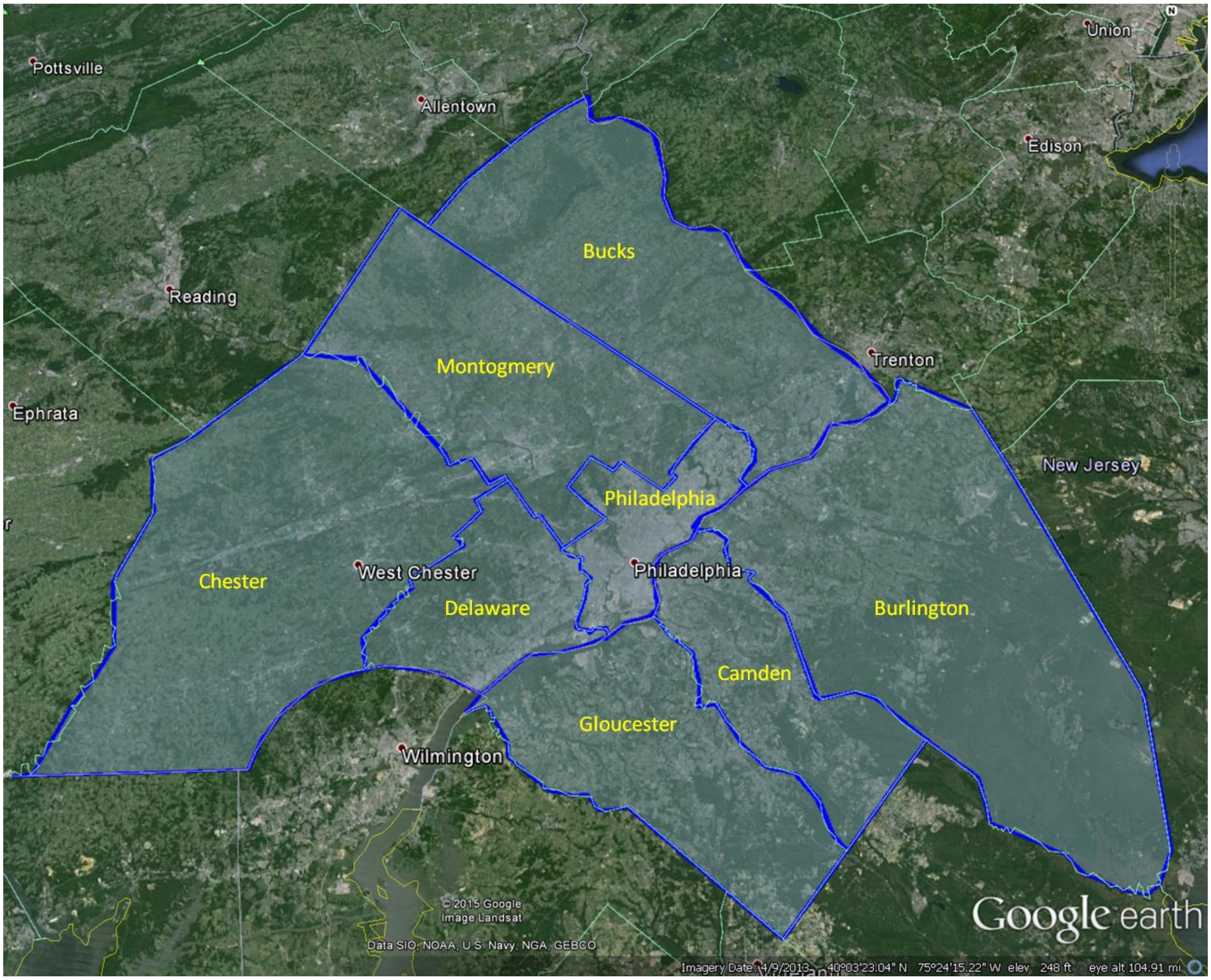

Figure 5.6-1 – The 8 Counties Forming the New Philadelphia Monitoring Region

5.7 New York Monitoring Region

The New York monitoring region not only represents the most dense urban and urban environments in the U.S., but it also provides a wide and varied collection of surrounding counties with a range of levels of suburban development, reaching to rural and hilly forested areas.

It's worth noting that the population density in New York County (Manhattan), as seen in Table 5.7-1, is 2.75 times as much as it is in San Francisco County. Kings County (Brooklyn) is 50% more dense than San Francisco County. Both Queens and Hudson County across the Hudson River in New Jersey are also homes to high population densities that are actually higher than the density in urban Philadelphia County, which is considered especially urban. Hence, all these counties in the New York monitoring region represent the ultimate in high population density urbanization.

The overall New York monitoring region (CMA 1), however, has the rather large number of 17 counties. As can be seen from Figure 5.7-1, the suburban counties have a range of population densities, most of which are higher than the highest densities in other places, e.g., Atlanta. This, again, highlights the highly populated nature of this unique region.

Some of the counties with peripheral extent, including Putnam, Passaic, and Westchester, have significant rural and nearly rural, hilly, and forested areas, which are distinct from rural areas in other monitoring regions.

With these unique attributes, the New York monitoring region completes the mosaic of morphologies and population densities in the 6 monitoring regions, reflecting the indoor and outdoor environments in the majority of the U.S.

Table 5.7-1 – Counties in the New York Monitoring Region

CMA	County Name	STATE	Population (est)	Area (sq. mi)	Population Density	FIPS
1	Bronx	NY	1,408,473	533	2,643	36005
1	Kings	NY	2,565,635	97	26,477	36047
1	Nassau	NY	1,249,233	453	2,758	36059
1	New York	NY	1,619,090	34	47,945	36061
1	Putnam	NY	99,607	246	405	36079
1	Queens	NY	2,272,771	178	12,748	36081
1	Richmond	NY	470,428	103	4,590	36085
1	Rockland	NY	317,757	199	1,597	36085
1	Suffolk	NY	1,499,273	2373	632	36103
1	Westchester	NY	961,670	500	1,923	36119
1	Bergen	NJ	905,116	234	3,868	34003
1	Essex	NJ	783,969	126	6,222	34013
1	Hudson	NJ	634,266	47	13,495	34017
1	Morris	NJ	492,276	469	1,050	34027
1	Passaic	NJ	501,226	185	2,709	34031
1	Somerset	NJ	323,444	305	1,060	34035
1	Union	NJ	536,499	103	5,209	34039

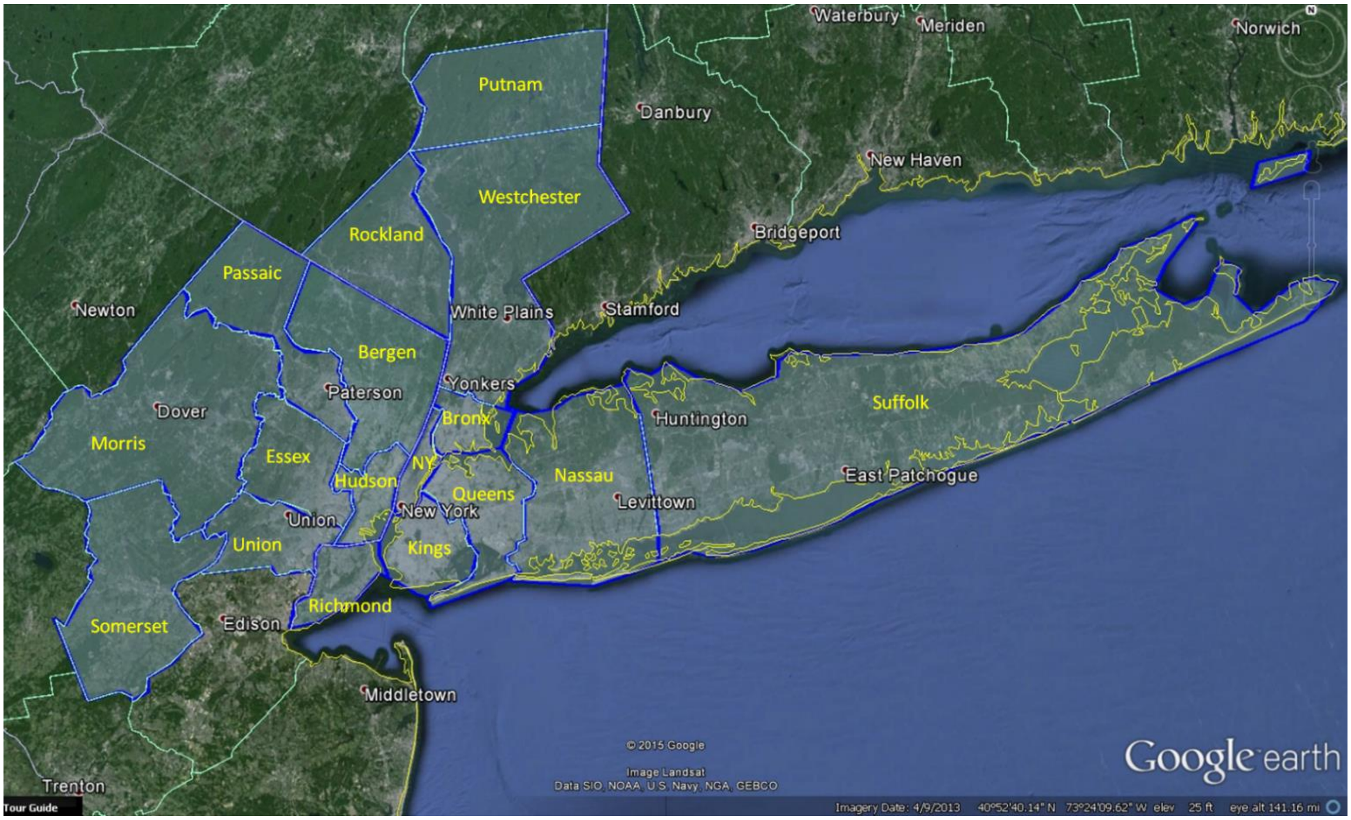

Figure 5.7-1 – The 17 Counties Forming the New York Monitoring Region

5.8 Special Considerations for Non-National Wireless carriers

In the 2015 4th Report and Order, the FCC directed nationwide wireless carriers to establish an indoor location accuracy test bed to demonstrate compliance with enhanced location requirements for wireless calls to 911 emergency services. In the Order, the Commission made allowance for non-nationwide wireless carriers to benefit from the test bed process without being required to directly participate. This concept is important as many non-nationwide carriers do not provide service in the two regions selected for the test bed.

The concept is for non-nationwide wireless carriers to receive summary test bed performance results relevant to their deployed location technologies (where applicable) based upon test bed data generated by participating nationwide carriers. Non-nationwide wireless carriers can then apply these test bed results to their own live 911 call yield figures (by location technology) to assess their compliance with the Order. In addition, any non-nationwide wireless carrier with service in the test bed regions has the option to participate directly in the test bed process.

One special case has been noted where a non-nationwide wireless carrier deploys a location technology that is unique (i.e., not deployed or tested in the test bed by any nationwide carrier), and the non-nationwide carrier does not offer service in either of the two test bed regions. In this case, the recommended approach is for the non-nationwide wireless carrier to engage an independent body to test compliance with the Order in representative test market(s). This testing should involve the same independently administered and transparent test methodology that ESIF ESM has recommended for the formal test bed process. In the event that the technology under test is characterized by parameters that are materially different from those addressed in ATIS-0500027, then appropriate consideration should be given to those measures by an independent test administrator in consultation with ESIF ESM.

The Order does not contemplate alternative compliance testing outside of the test bed established by the nationwide wireless carriers. The expectation is that beyond the unique circumstances described above, wireless carriers will utilize the formal indoor test bed to demonstrate compliance with the Order. In addition, the expectation is that vendors desiring to demonstrate their near-term emerging location technologies' ability to comply with the Order will also participate in the formal test bed process, so that all technologies are evaluated consistently and objectively.

6 Indoor Location Test Bed Regions

6.1 Background

The proposed test bed to be run under the aegis of the CTIA's 911 Location Technologies Test Bed, LLC (for short the "CTIA Test Bed LLC") is intended to leverage, to the extent possible, prior indoor test bed efforts and related ATIS guidelines and recommendations.

In 2012 ESIF ESM developed an indoor test plan that was published in ATIS-0500022 and was provided to the FCC's CSRIC III for the purposes of its San Francisco Bay Area Test Bed. CSRIC III WG3 accepted this test plan, although adopted the "reduced set of test cases" therein to ensure the testing would fit the time and budget available within the CSRIC III framework.

More recently ESIF ESM addressed the broader issue of establishing wide scale indoor location performance based on representative indoor testing and monitoring in select areas. Those recommendations are provided in ATIS-0500027. That document outlines the key parameters that need to be characterized for a wide selection of existing and emerging indoor location technology solutions. It also identifies the six regions described in clause 5 above as candidates for indoor test bed implementation. ATIS-0500027 also provides the definition of sample test polygons and indoor test cases for two examples: Metropolitan San Francisco and Philadelphia, to illustrate and guide on-going indoor test bed specification.

In what follows the two test bed regions selected and recommended for the CTIA Test Bed LLC, which are in the San Francisco and Atlanta regions, are further defined using similar principles to those followed in ATIS-0500022 and ATIS-0500027.

6.2 San Francisco Test Bed Region

The polygons defined in ATIS-0500022 test plan have been used as a starting point for the definition of the current, more permanent test bed. Some significant changes have been adopted, however, to enhance the test bed, both from an operational and technical representation perspective. Since the current test bed will be used to establish compliance with FCC required performance benchmarks, and as explained in Clause 5 above, all the counties within the CMAs in which test polygons were selected in the CSRIC III testing are included, the new boundary of the region is used in defining the various test polygons, particularly for the rural case.

6.2.1 Dense Urban Test Polygon

The dense urban polygon in the City of San Francisco has not been changed from that identified during the CSRIC III testing and remains centered around the financial district in the city. It is shown in Figure 6.2-1 in light blue along with the urban polygon.

6.2.2 Urban Test Polygons

The urban test polygon in San Francisco in the CSRIC III test campaign was fairly confined in its geographic extent within the city. This resulted in increased challenges in identifying accessible buildings to test in, particularly of the residential category. The original urban polygon used in CSRIC III is shown in Figure 6.2-1 in the light magenta color. A significant expansion of this polygon is defined here which extends the old polygon to include the adjacent boundary in the dark purple color in the figure.

The expanded San Francisco urban test area allows for:

1. A significantly wider initial selection of urban structures, including a significantly wider selection of representative urban buildings spanning the spectrum of commercial, public, residential, and mixed use buildings, with diverse construction types and materials.
2. A much higher number and wider selection of residential buildings. One example of the diverse residential structures is shown in Figure 6.2-2. A second example is that of row houses as seen in Figure 6.2-3. Although those row houses are not quite as dense as in a city such as Philadelphia, and they are not made of brick like in the older cities, they provide a reasonably good representation of such urban residential use.
3. Inclusion of significant hilly city terrain, which can have an impact on a number of location technologies (e.g., z-axis). An example of a steep hill is shown in Figure 6.2-4.

4. A wider socioeconomic representation within the selected urban area.
5. More representation of coastal scenarios (emulating to the extent feasible one-sided outdoor emitters).

The overall urban San Francisco polygon will therefore include as a subset the old polygon (shown in lighter magenta) used originally in the CSRIC III testing.

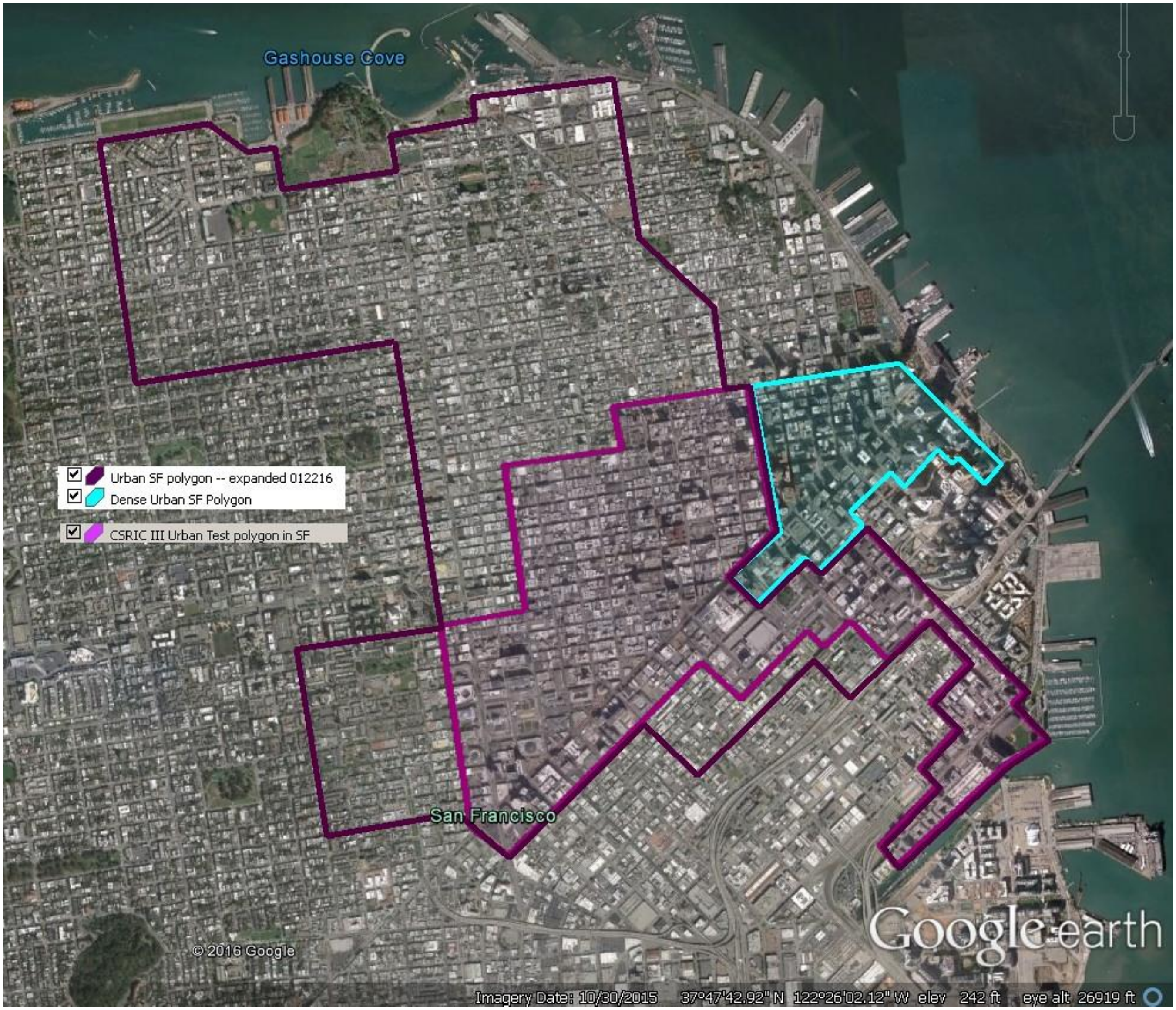

Figure 6.2-1 – Urban and Dense Urban Test Polygons in San Francisco

Figure 6.2-2 – A Wide Variety of Residential Structures in the Expanded Urban SF Polygon

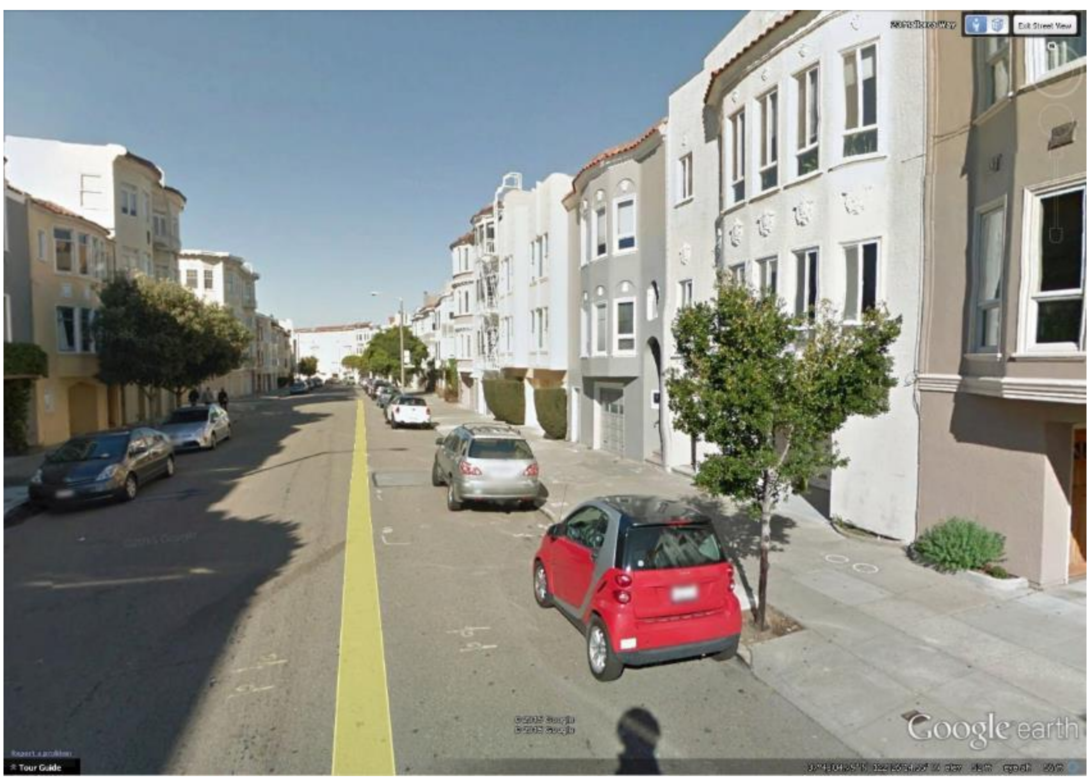

Figure 6.2-3 – Example of San Francisco Row Houses in the Expanded Urban Polygon

Figure 6.2- 4 – Example of Steep Terrain in the Expanded Urban Polygon

In addition to the expanded urban polygon in San Francisco, the urban polygon in downtown San Jose is closely based on the old urban San Jose polygon from ATIS-0500022 and the CSRIC III test bed. It contains a mild expansion to include the local sports arena, convention center, and university campus, which were actually targets for urban test building identification (but not used) during the CSRIC III campaign. The old polygon is shown in Figure 6.1-5 in orange along with the new test polygon boundary in brown.

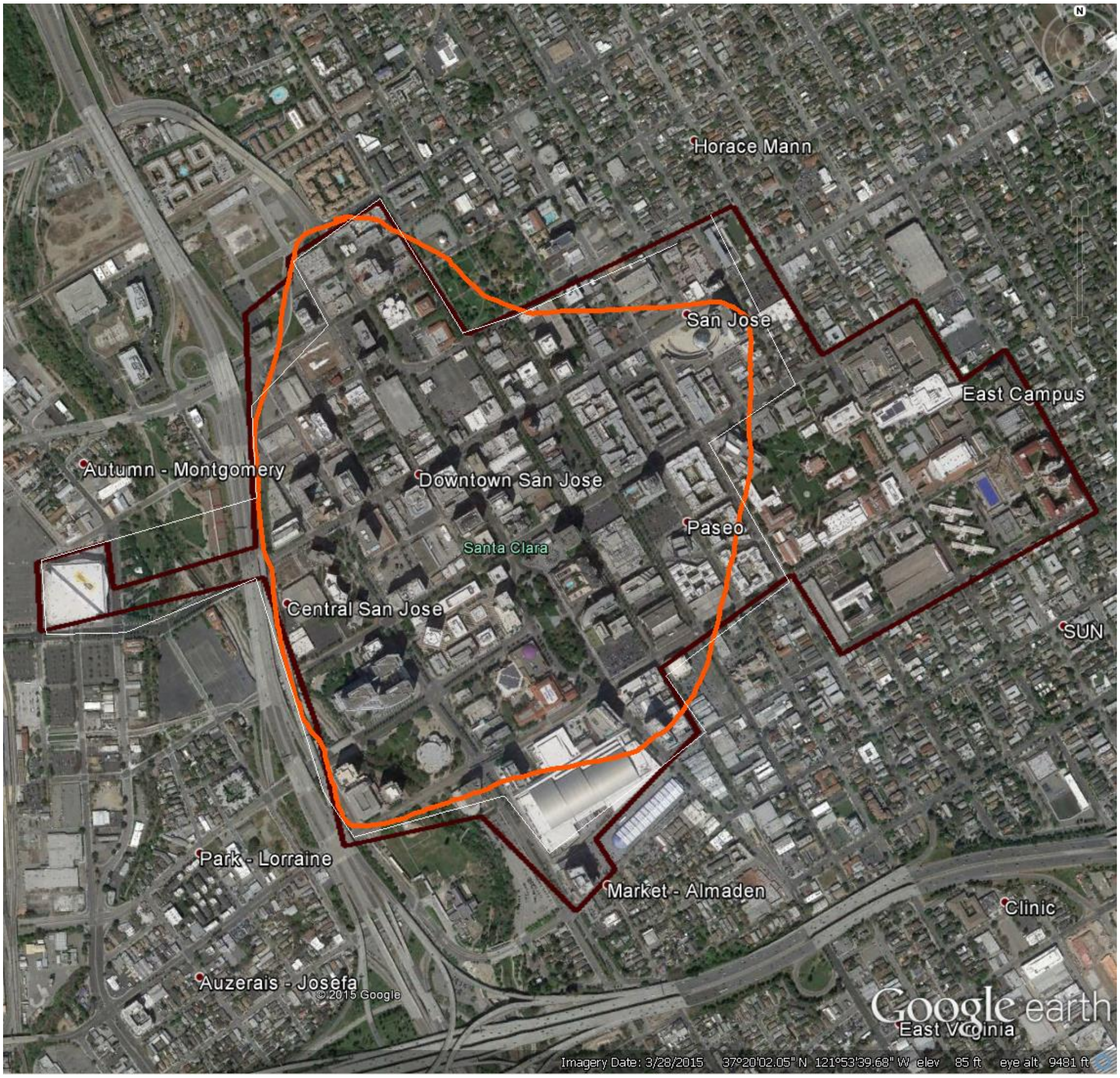

Figure 6.2-5 – San Jose Urban Polygon—New (Brown) and Old (Orange)

6.2.3 Suburban Test Polygon

The suburban polygon is essentially unchanged from ATIS-0500022 and the CSRIC III test bed. It is depicted in Figure 6.2-6 and spans large portions of suburban Santa Clara, Sunnyvale, Cupertino, and San Jose, excluding its urban downtown outlined in brown in the figure.

Figure 6.2-6 – Suburban Polygon in Silicon Valley (Blue)

6.2.4 Rural Test Polygons

The old rural polygon defined in ATIS-0500022 for the CSRIC III testing was found to be severely lacking in candidate structures that could be used for indoor testing. The current definition of the E911 live call monitoring region in California encompasses the counties in 3 CMAs: 7, 27, and 339, which is a significantly larger overall area. CMA 339 extends the rural reach of the test area across a section of the agricultural San Joaquin Valley and into the foothills of the Sierra Nevada, even reaching to the high country above 12,000 feet.

The inclusion of CMA 339 in the overall test area makes possible the definition of two rural polygons with a far superior selection of structures to capture two important rural use cases. These are: (1) flat agricultural land with small towns in it, which is a use case present in very large areas of the United States, and (2) popular foothills with mild to moderate hilly terrain and light to moderate forestation and small towns with tourist-type facilities. Combined, these two rural polygons would provide a solid representation of very large portion of the rural settings in the Midwestern and western U.S.

The first rural polygon, representing the flat agricultural area, is shown in Figure 6.2-7 and lies between the cities of Merced and Madera. (Both cities have populations between 50 and 100,000 inhabitants; hence both cities and their immediate surroundings are excluded from the rural polygon.) Some small towns with populations around 2,000 are included.

In the CSRIC III test bed, a rural area was required to have sparse cellular tower coverage. This is still a requirement if the rural polygons are to reflect large swaths of the lightly populated rural areas in the U.S. An attempt has been made here to choose an area that is likely to have a low cell site density. However, this low site density, as well as adequate wireless coverage, should be confirmed with wireless carriers providing coverage in the area prior to the selection of actual test buildings and test points in this agricultural rural polygon.

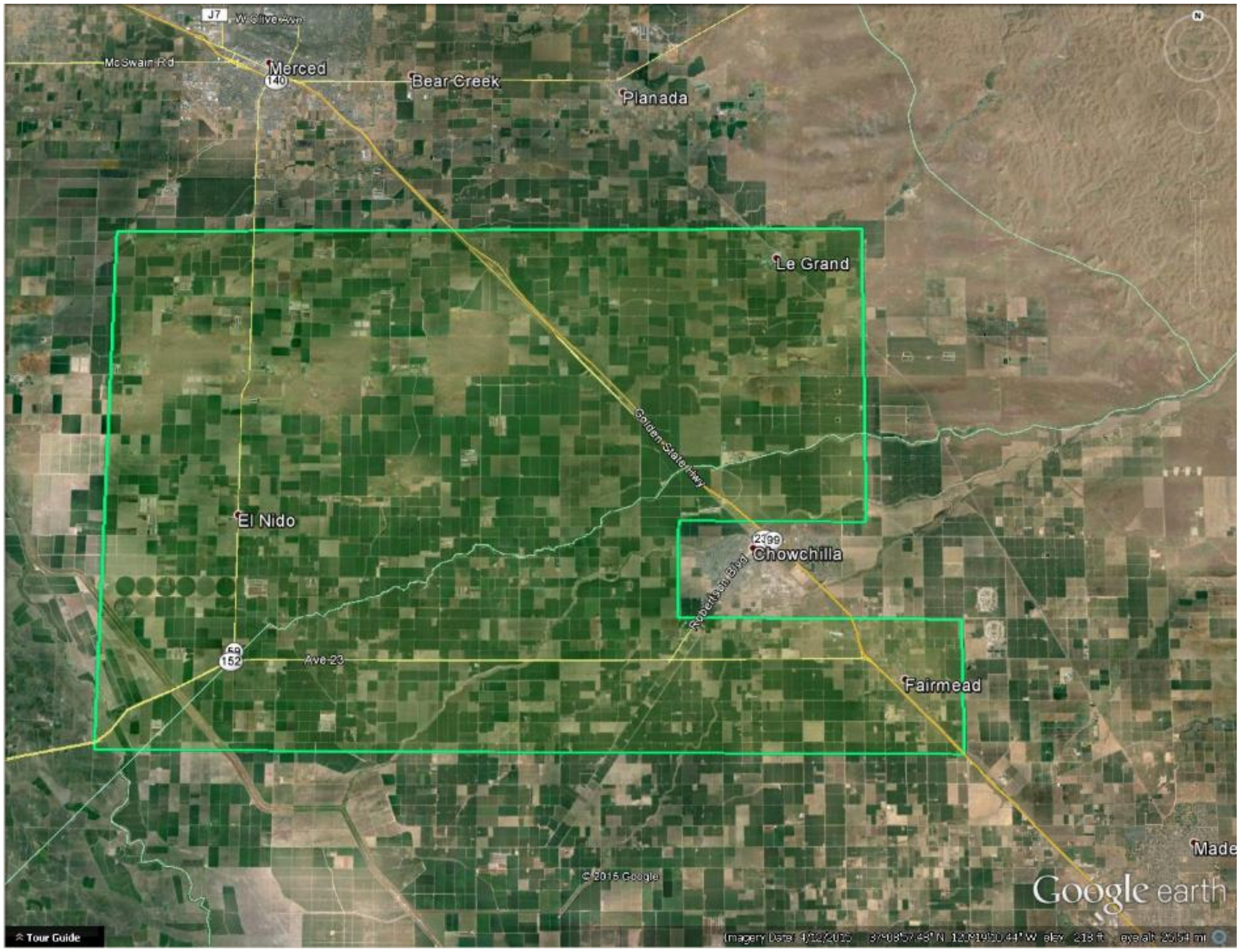

Figure 6.2-7 – Rural Polygon No. 1 (Flat Agricultural)

The second rural polygon is defined in the popular foothill area south of Yosemite and is shown in Figure 6.2-8. This polygon includes the two towns of Coarsegold and Oakhurst, population 2000-3000, which are quite popular as stopovers for visitors to Yosemite along Route 41 which leads to the park's southern entrance. Their population increases dramatically in the summer. The polygon also contains Bass Lake, a recreation area with a retirement community. This area provides a wide sample of mildly to moderately-forested hilly terrain, with vegetation ranging from sparse evergreen, through deciduous, to pine trees. It should be kept in mind that true rugged mountain terrain or heavy forestation are not intended to be the focus of this polygon. Again, low cell site density and adequate wireless coverage should be verified prior to selection of actual test buildings and points in the test polygon.

Two examples of structures and surrounding vegetation from the Bass Lake area are provided in Figure 6.2-9 and Figure 6.2-10 for illustration. Seasonal occupants in such structures often rely exclusively on wireless phones for communication, including possible dialing of 911 in an emergency. These examples of structures in mild to moderate hilly terrain and variable forestation represent widely available indoor scenarios in many parts of the Western/Northwestern US.

The distribution of test points among the two rural polygons should represent where E911 calls actually take place and is to be addressed elsewhere in a more detailed test plan for the test bed.

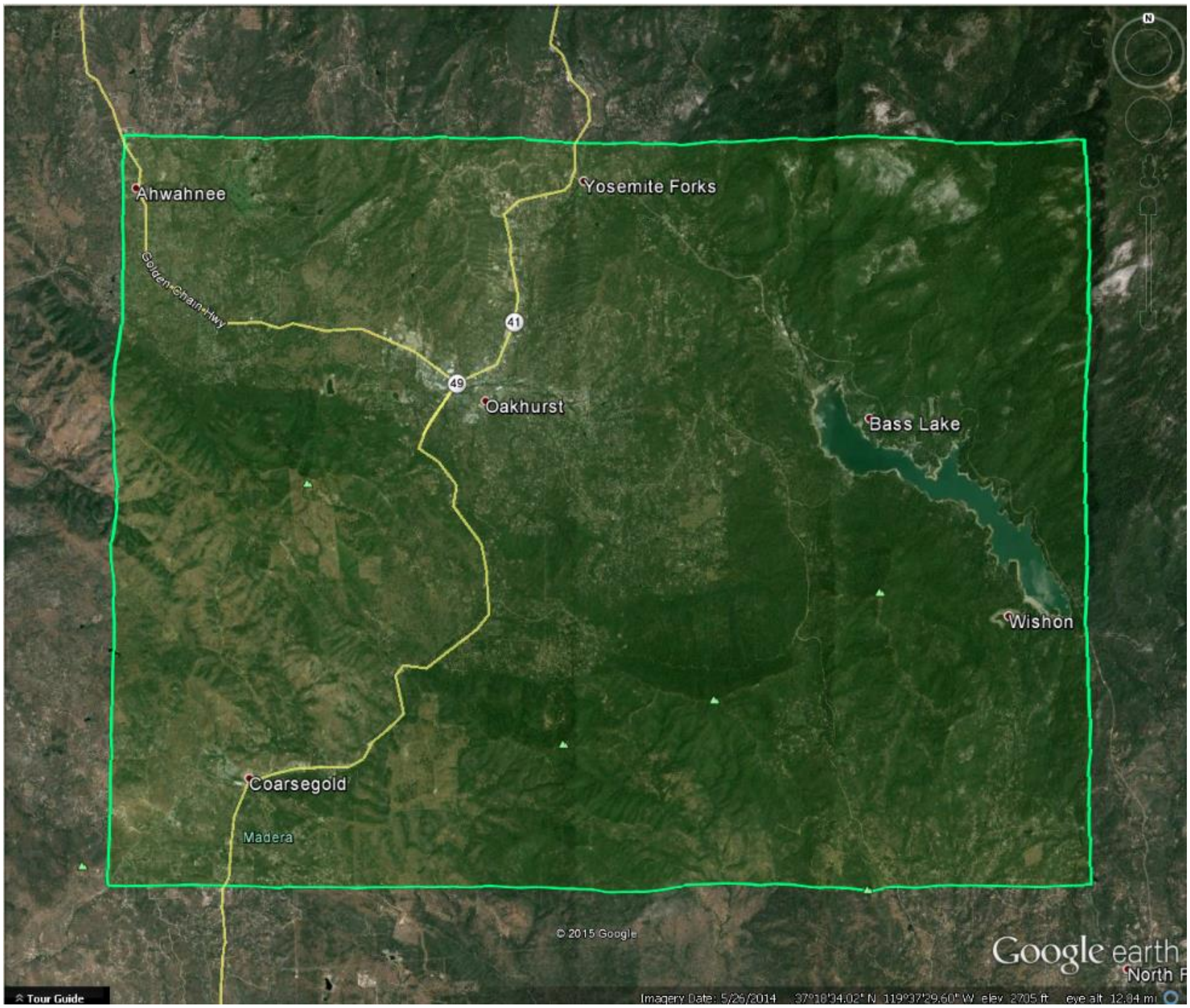

Figure 6.2-8 – Rural Polygon No. 2 (Foothills)

As a convenient reference, the actual boundaries of the different San Francisco region test polygons are provided in the attached Google Earth .kmz file entitled **"SF TEST Bed Polygons - 012616.kmz"**.

Figure 6.2-9 – Example of Structures and Mild Forestation in Rural Polygon No. 2

Figure 6.2-10 – Example of Structures with More Forestation in Rural Polygon No. 2

6.3 Atlanta Test Bed Region

The criteria used in defining the San Francisco test bed polygons were applied as closely as possible to the Atlanta area to achieve a consistent definition of morphologies, test environments, and subsequently test results. However, some salient differences remain due to the inherently wide differences between San Francisco and Atlanta.

In the financial district of Downtown San Francisco the target dense urban polygon was designed to exclude border cases where tall buildings had sides that where completely open, rather than fully or partially blocked. This ensured the presence of urban canyons in the dense urban polygon. In Atlanta the dense urban areas are significantly smaller and sparser, so at times inclusion of such border buildings was necessary. Occasionally the boundary of a dense urban polygon is drawn to exclude the wide open side of a border building. Two dense urban polygons are identified, one in Downtown and one in Midtown Atlanta, to increase the opportunities of identifying suitable test buildings lying in a true dense urban setting.

The urban polygon contains a substantial corridor in central Atlanta, from 1-1.5 mile south/southwest of Downtown to Buckhead about seven miles north of Downtown. This is to maximize the options in selecting test buildings. It also includes a wide variety of the buildings that are encountered in the urban area, from low to mid rise structures and isolated high rise buildings, to medium and large commercial, educational and government buildings, to arenas and a congress center. It also provides a wide selection of socioeconomic urban settings to test in.

The Atlanta area, including its surrounding counties, contains a tremendous amount of urban and suburban sprawl. The selection of the current test bed polygons is obviously not intended to be a comprehensive division of the Atlanta area into the four distinct morphologies. The suburban polygon, for example, is a subset of the expansive suburban sprawl surrounding central Atlanta. The selected polygon is sizeable and includes ample selections of the typical building and land use types encountered in the suburban area, e.g., single family residential, multifamily residential, commercial, industrial, educational, and transportation type buildings or facilities. It also includes a very wide representation of socioeconomic levels, which could conceivably have an effect on the performance of some location technologies using internal emitters (e.g., Wi-Fi), whose density could correlate with income levels.

Where the selection of a certain area could be open to interpretation as to whether it is urban or suburban, that area was excluded from the suburban and urban polygons, e.g., Downtown Decatur, Emory University.

Where practical, an attempt has been made to leave a buffer of border buildings between the dense urban and urban polygons that is not included in either. The same follows for border cases between suburban and either the urban or dense urban polygons.

Because of the suburban sprawl around Atlanta, the rural polygon is chosen in Butts County, 40-50 miles away from Downtown Atlanta. Cell site densities and wireless coverage should be verified prior to selection of actual test buildings and points in different parts of this test polygon.

The following clauses show the different test polygons in the Atlanta area. A Google Earth .kmz file entitled "**Atlanta TEST Bed Polygons 012616.kmz**", which contains the actual polygon boundaries, is attached as a convenient reference.

6.3.1 Dense Urban Atlanta Test Polygons

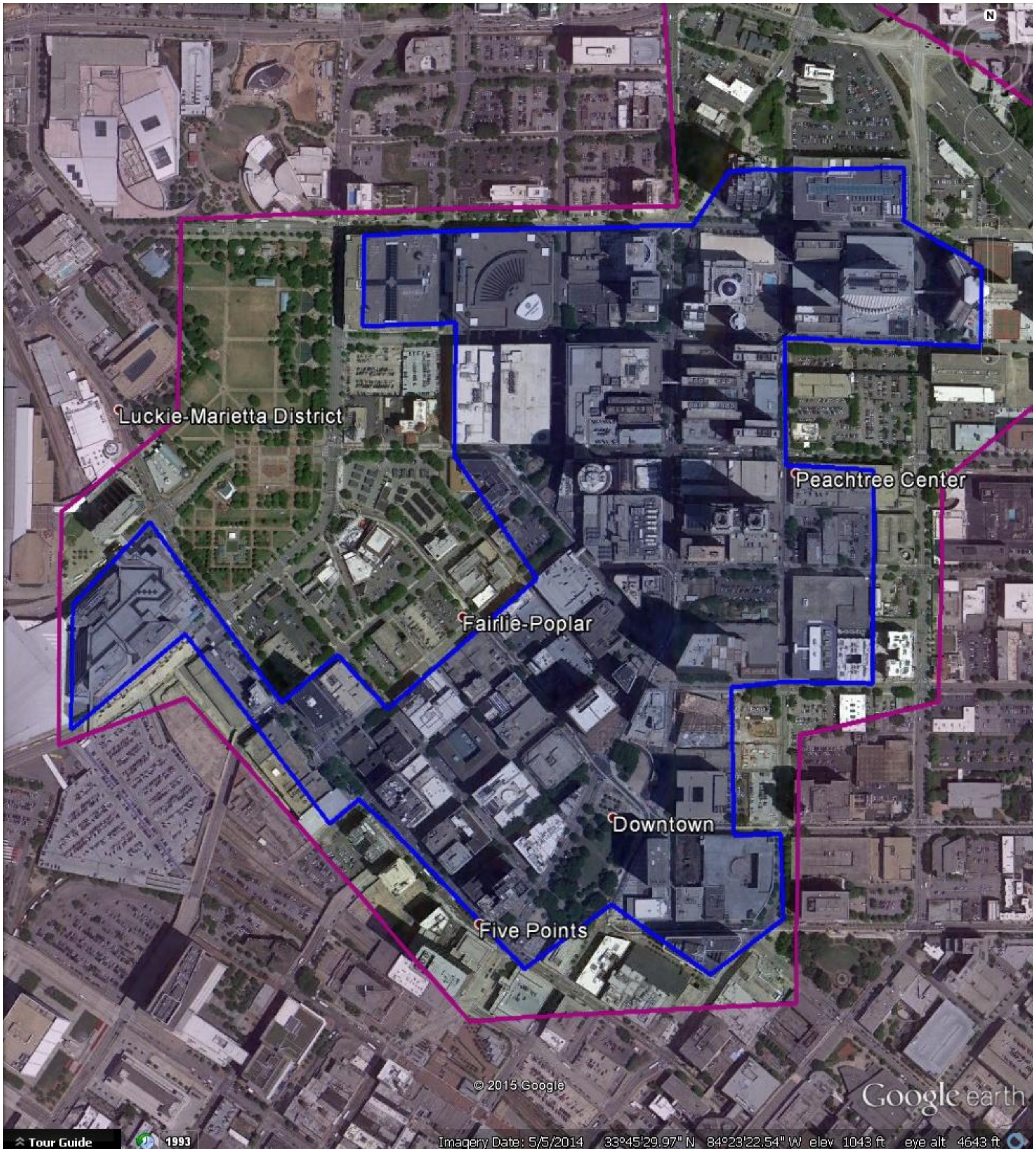

Figure 6.3-1 – Dense Urban Polygon—Downtown Atlanta

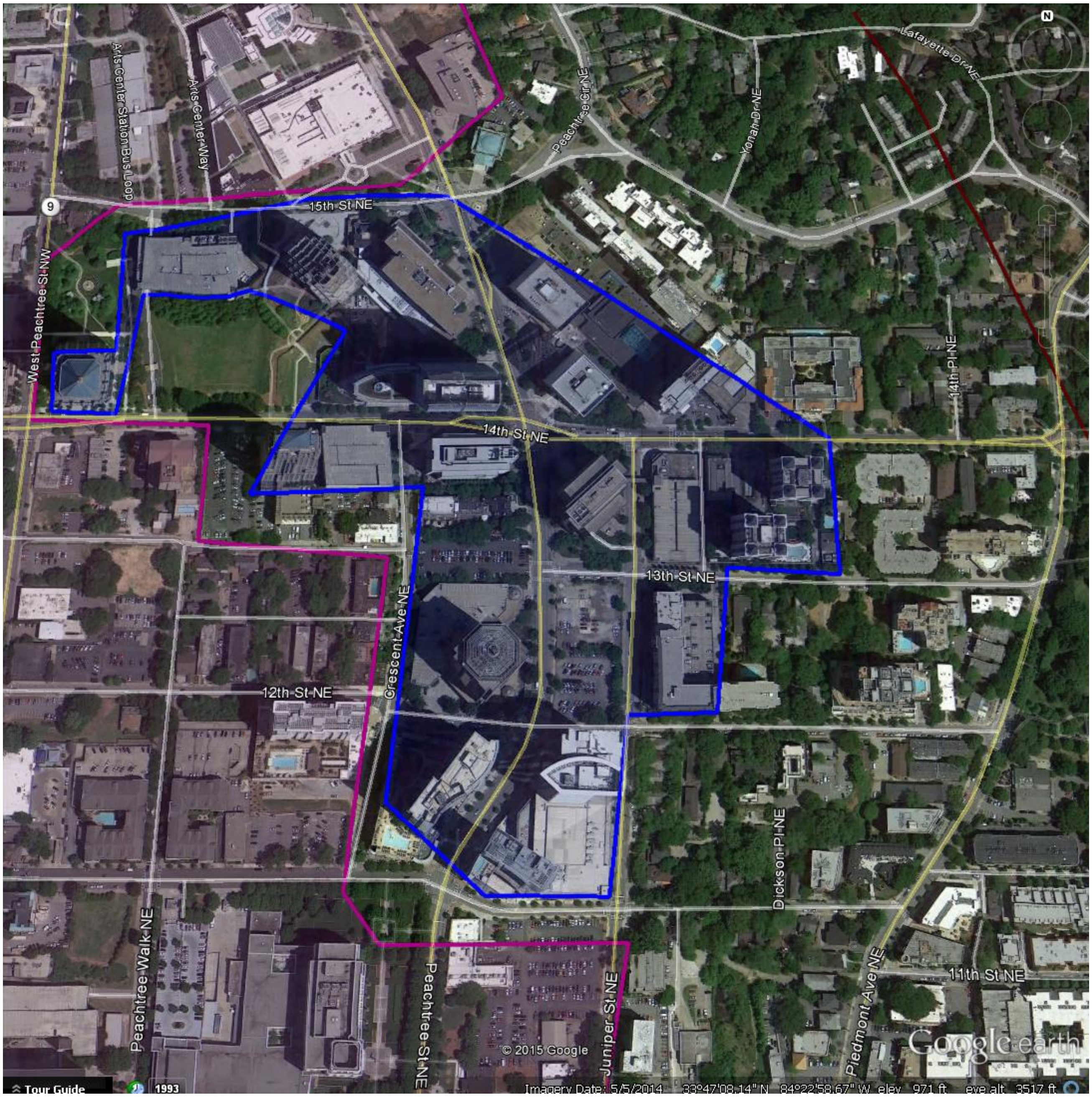

Figure 6.3-2 – Dense Urban Polygon—Midtown Atlanta

6.3.2 Urban Atlanta Test Polygon

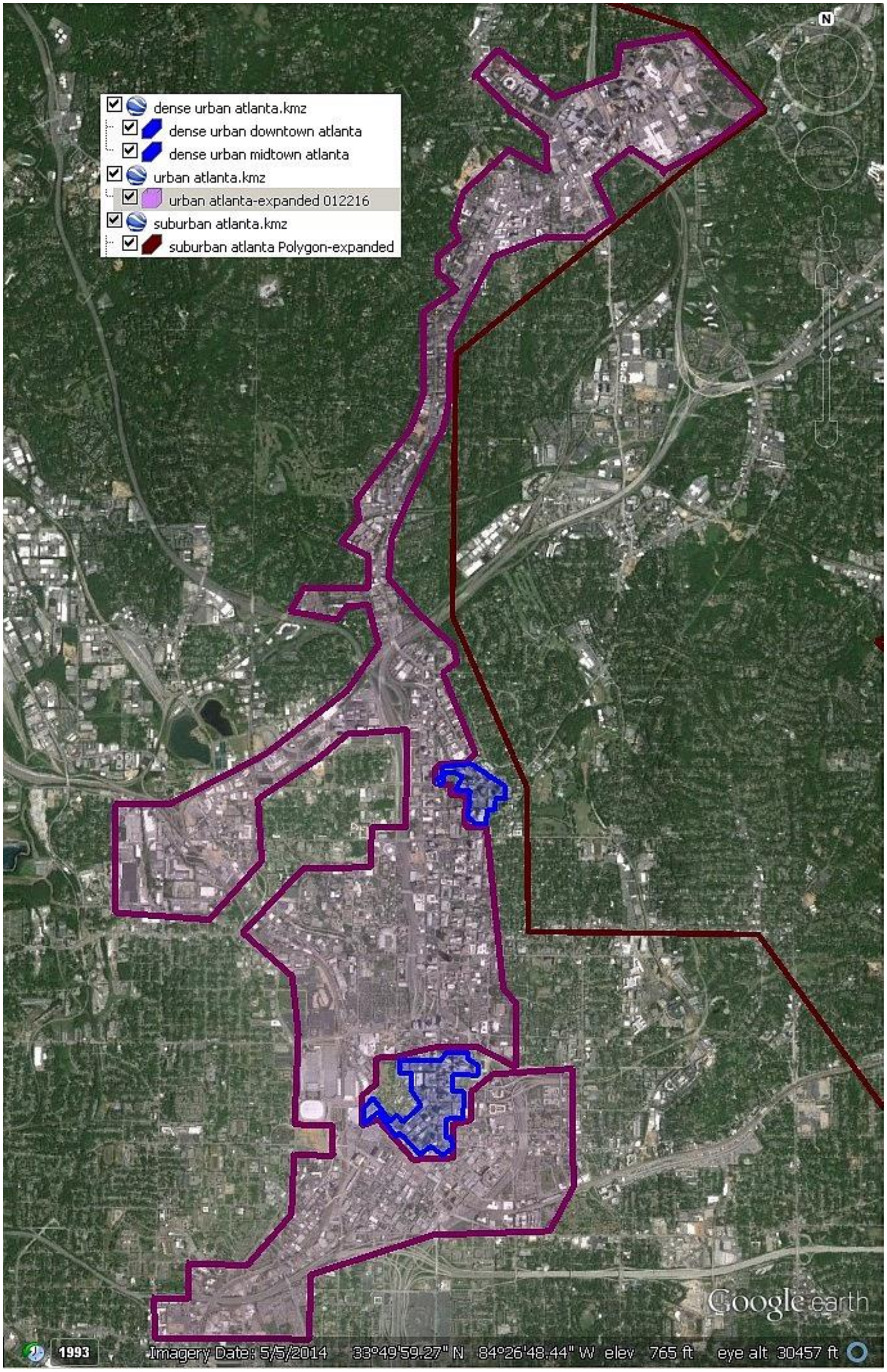

Figure 6.3-3 – Urban and Dense Urban Polygons in Atlanta and Suburban Polygon Boundary

6.3.3 Suburban Atlanta Test Polygon

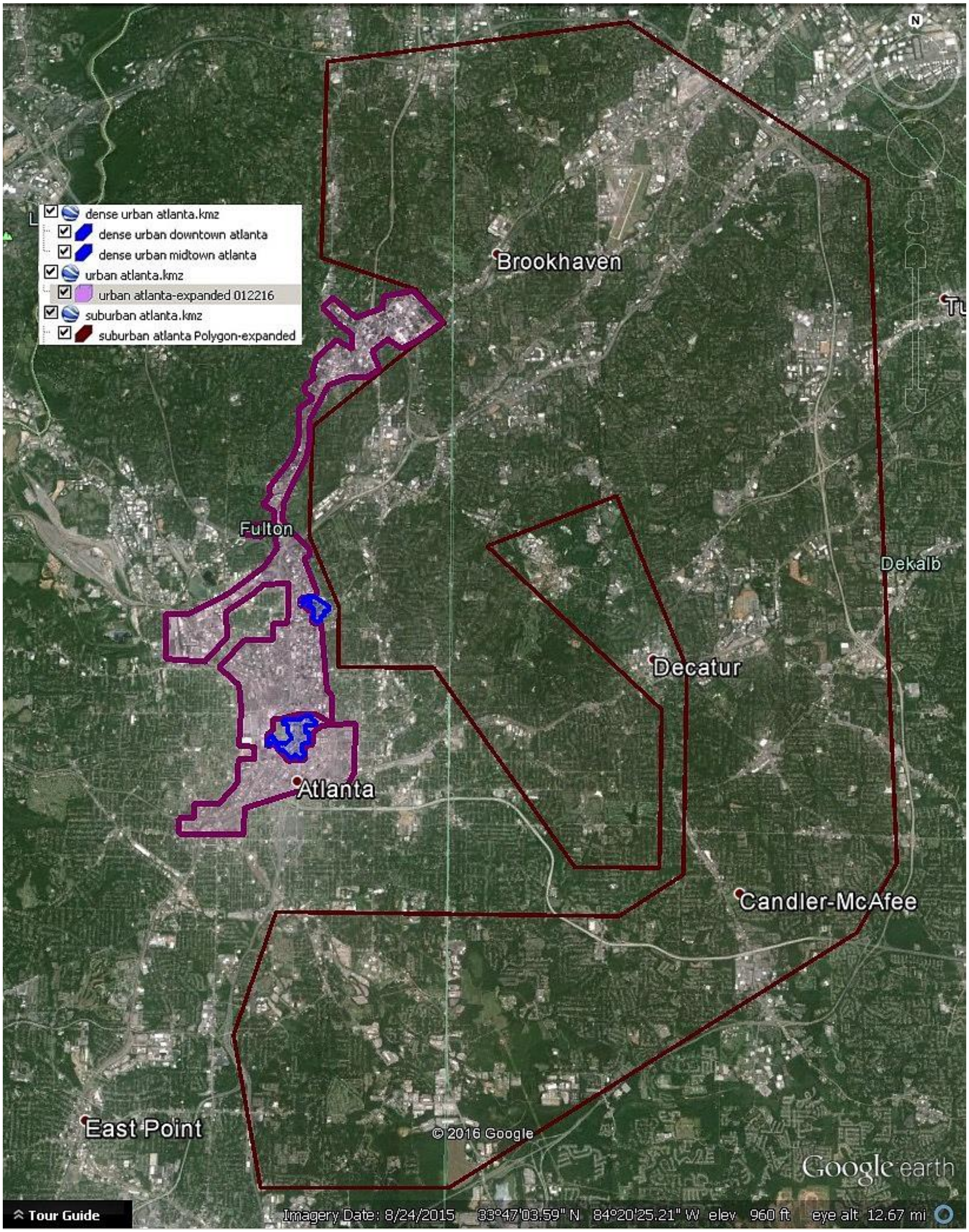

Figure 6.3-4 – Suburban Atlanta Test Bed Polygon

6.3.4 Rural Atlanta Area Test Polygon

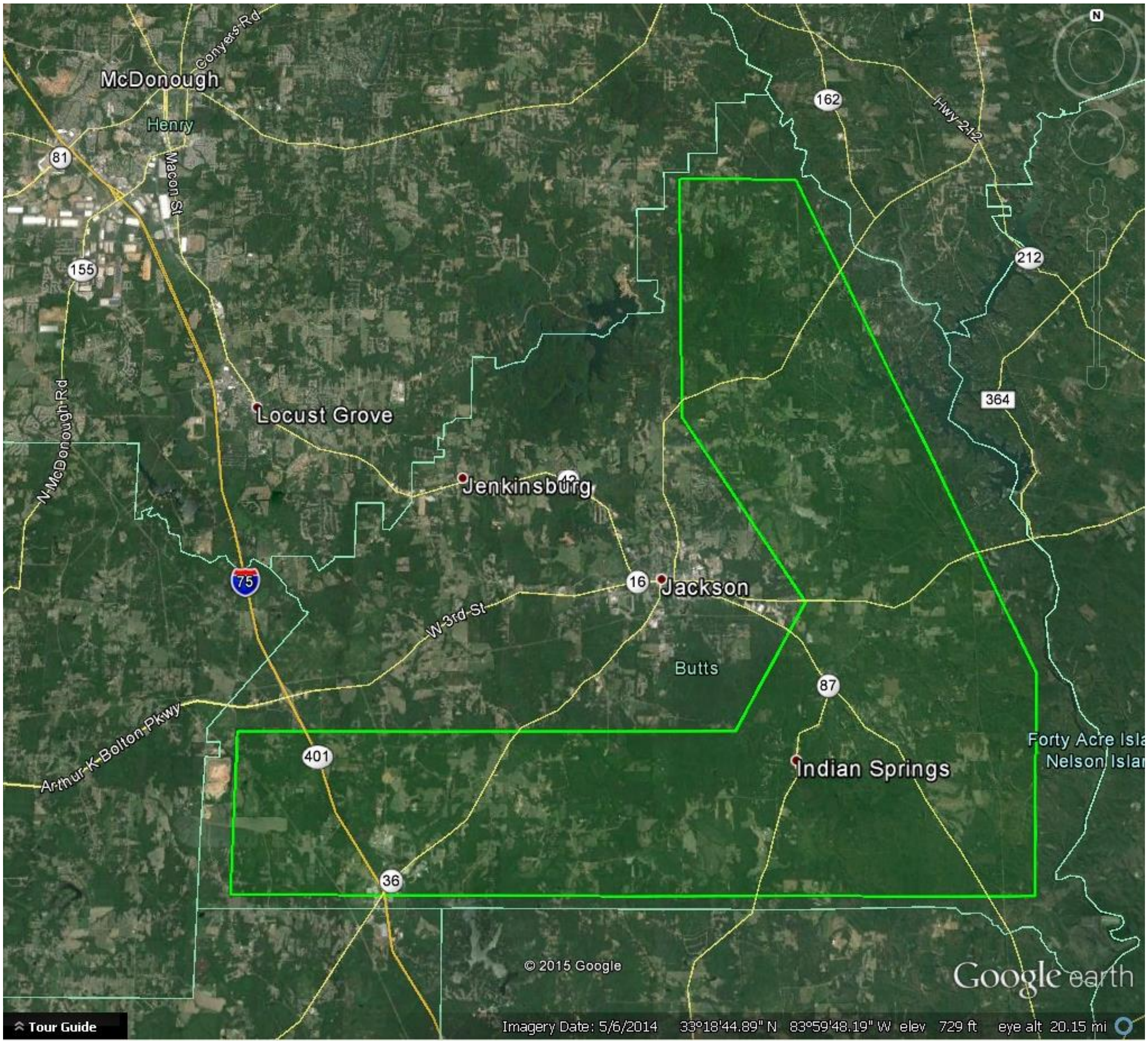

Figure 6.3-5 – Rural Atlanta Area Test Bed Polygon (in Butts County)

6.4 Test Building Types and Test Cases

For each of the Atlanta and San Francisco test bed areas, a set of 30 candidate test building types have been identified. For each building type, a set of distinct test cases have also been defined. These test building types and test cases are provided in the two attached Excel spreadsheets entitled:

SF Test Buildings and Cases.xlsx

Atlanta Test Buildings and Cases.xlsx

In selecting the candidate test building types, consideration was given to the type of structures available and typical in the different test polygons that have been identified in the clause above. It is recommended that in each test bed area, 30 candidate buildings be identified and surveyed, but a subset of at least 20 test buildings be selected among them for actual testing during a given indoor test campaign.

7 Testing Methodologies

The test methodology established within ESIF for indoor testing was embodied in ATIS-0500013 and subsequently ATIS-0500027. The latter document identified the unique challenges of testing in indoor environments, which prohibit wide scale indoor testing.

Performance of any location system varies widely in indoor environments because of the morphology where the indoor location is situated, the building construction type, its surrounding building density, and where inside the building the tests are being conducted. Also of significant impact is the type of emitter being considered – a wide area emitter or a local area emitter – and the combination of the emitter and the morphology in which the device is being observed.

A variety of factors contribute to the differences between indoor and outdoor testing. Building access is one major challenge. The second is cost. Since this testing is indoors, surveying indoor locations to obtain accurate ground truths is significantly more expensive than the outdoors, where use of vehicle-based differential GPS most often suffices. A good balance between these two constraints was struck by an approach of 'representative testing' in different environments. This approach was successfully trialed in 2012 by CSRIC III during its San Francisco Bay Area Test Bed and was memorialized in the 4th Report and Order by the FCC.

When characterizing the performance across the nation, it does become important to characterize the unique local conditions. For instance, residences on the west coast are typically built out of wood and lack a basement. Residences on the east coast, on the other hand, often have a basement and are made of brick. ATIS-0500027 envisioned testing in six different regions (5 of various morphologies + 1 dense urban); however due to cost and efficiency of testing, ESIF ESM now recommends testing in two test bed regions – San Francisco and Atlanta. The rationale is that these locations strike the appropriate balance between these constraints of representation and cost. Representative testing across both these metropolitan hubs involves testing in distinct wireless usage morphologies – including dense urban, urban, suburban, and rural environments.

The general consensus is also to test all technologies in the same test bed so a true comparative assessment of the different technologies in the same environment can be made. In other words wide area technologies such as GPS, OTDOA, TBS, etc., and hybrid technologies such as 'Crowd Sourced', Wi-Fi, 'Device Based Hybrid', and unique technologies and solutions such as Dispatchable Location and Barometric Pressure sensors are all tested in the same test bed and morphologies and in similar if not the same buildings and test points. This is optimum from a technology evaluation perspective, cost, and repeatability perspective.

It is also generally accepted that the test bed is there to evaluate 'compliance' of the technology to the rules. Any unique consideration of the technology(s) to be tested will be done so by selecting a wide enough selection of test points or sufficient number of devices to ensure that any results from a given technology are not biased in any one direction. A good example of this is in testing technologies such as the barometric pressure sensor in both managed and unmanaged (sealed and unsealed) buildings to ensure the systems are sufficiently characterized across such natural building variation. Similarly, for Wi-Fi, areas with relatively high broadband/Wi-Fi penetration will need to be tested along with locations with lower broadband/Wi-Fi density to mitigate potential bias in the results. For wide area radiators such as GPS, OTDOA, and Metropolitan Beacon Systems, different morphologies will be tested to understand the effect of RF propagation in different environments. In addition for GPS types of systems with a Satellite component, different floors of a building will be studied to again understand the impact of signal propagation in benign to challenging conditions – in this case High, Medium, and Lower floors of the building will be tested.

On the device side a sufficient number of devices should be considered such that device to device variations can be captured – this is consistent with the CTIA Z-Axis Working Group recommendations and ATIS-0500030 where it has been proposed that a sufficient number of devices should be tested to account for variations in sensor type and handset manufacturers. This is expected to be less of an impact for testing X-Y technologies. Although for X-Y technologies, device configuration of whether it is operating under 'Cold' start, 'Warm Start', and 'Hot Start' will make a difference and should be appropriately accounted for.

Finally all technologies will need to be tested in the system they operate as part of – in other words, a crowd sourced Wi-Fi database vs. one that does not or one that is based on drive testing will perform quite differently and therefore need to be identified as such. Similarly a GPS/OTDOA hybridized system vs. a system using just GPS will behave differently and so the 'system' level understanding and characterization of these hybrid systems is important and should be identified.

Key parameters specified in ATIS-0500027 (clause 6) and relevant to a particular technology should be specified by its vendor as part of their technology description to the carriers, public safety, and the FCC. This information can then be used to guide the development of the test procedures.

In summary, the following is proposed as the key aspects of the test methodology

1. Test Regions to be used for testing: San Francisco and Atlanta.
2. Test Point selection considerations:
   a. Select a sufficient number of test points across the two test bed regions to assess all the technologies in the context of an E911 system.
   b. The test points need to be across dense urban, urban, suburban, and rural morphologies in both the test regions.
   c. Identify any gaps in test point selections in one city and ensure they are captured in the other (e.g., basements).
   d. Ensure managed and unmanaged (sealed and unsealed) buildings are included in the test points.
   e. Ensure that areas with a range of high and low broadband/Wi-Fi densities are included in the testing in each test bed region as applicable.
   f. Ensure areas of good and poor GDOP are included in each of the test bed regions as applicable (e.g., deployment boundaries and coastlines).
   g. Ensure test points do not carry an inherent bias (e.g., All coffee shop locations or only frequently traveled malls).
3. Device Considerations:
   a. To the extent it affects possible performance, select ‘Higher and Lower’ classes of Devices. Given the OS and the appropriate database is different, appropriate Android and iOS based handsets need to be tested when factors such as the databases can affect performance.
   b. To the extent possible, ensure sufficient diversity of barometric devices.
   c. Ensure device is configured appropriately for statistical independence of measurements and the device is configured for warm start operations.
   d. Device is expected to be operating in a typical ‘Commercial’ configuration.
4. System Considerations:
   a. System is expected to operate in its typical commercial network mode; however, unique considerations for a given technology may require some modifications from a normal mode of operation (e.g., ensuring that a device under test does not alter the behavior of the location solution being tested.) .
   b. Technologies to be tested as part of the ‘System Under Test’ need to be documented (e.g., GPS + OTDOA, GPS+OTDOA+Wi-Fi, Wi-Fi+GPS, TBS, TBS+GPS, etc.).
   c. Devices that support a combination of technologies and are normally operated that way should not be locked to prevent certain prevalent modes from occurring during testing. This would result in certain modes providing performance where they are not normally used, e.g., RTT in a benign 1-story structure environment, where GPS would normally be available. This can abnormally color the results.
   d. Key parameters affecting the performance of a given technology under test and identified in ATIS-0500027 (clause 6) need to be documented and made available to the appropriate parties (Carriers, Public Safety, FCC, etc.) involved in the testing.

The test methodologies described in ATIS-0500013 and ATIS-0500027 focused on location systems using wide-area emitters external to the buildings under test. Certain general precautions need to be built into the testing methodology for location systems that utilize indoor local emitters, particularly for those systems whose emitters are catalogued by using crowd-sourcing techniques. The broad intent is to avoid the testing activity itself altering the characteristics of the system under test.

It is helpful to first identify the factors that can affect the accuracy and reliability of such location methods. Table 7.1-1 outlines the various device, infrastructure, and environmental factors that can affect the accuracy and reliability of location technologies that rely on local emitters which are derived from crowd-sourced techniques.

Table 7.1-1 – Factors Affecting Crowd-Sourced Wi-Fi Location Performance

Attributes of the Wi-Fi Access Point (AP) Device:

- Ownership and maintenance of physical AP
    - Wireless carrier owned/maintained APs (AT&T, Verizon, T-Mobile, Sprint, etc.)
    - ISP owned/maintained APs (Comcast, Time Warner, etc.)
    - General Public owned/maintained (Individual residence, small business, etc.)
    - Enterprise (Starbucks, College campus, Office complex, etc.)
- Operating Characteristics
    - Bands (2.4/5.0 GHz)
    - Operating modes (802.11 b/g/n/a)
    - Transmit Power Levels

Attributes of the Mobile Device Wi-Fi:

- Operating Characteristics
    - Bands (2.4/5.0 GHz)
    - Operating modes (802.11 b/g/n/a)
    - Receiver Sensitivity

Attributes of how Wi-Fi AP database is populated:

- Direct insertion of the owners AP information into database
- Crowd sourcing with dedicated driving
- Crowd sourcing via general consumer traffic

Attributes of Wi-Fi AP deployment environment:

- Quantity/density of surrounding Wi-Fi access points
- Geometry of surrounding Wi-Fi access points
- Building-under-test
    - Construction materials - influences RF attenuation and reflections
    - Building usage (commercial or retail, residential, industrial, special use facility) - influences interior walls, wireless deployment, and 911 use case scenarios

Attributes of Wi-Fi positioning algorithm:

- Maintain history/perform smoothing of locations
- Use of other sensors to augment history/trajectory of locations
- Self-learning from test scenarios

The current test methodologies designed for wide scale emitters (AGNSS, OTDOA, etc.) already account for many of the factors that also affect local emitter technologies. For example, selecting a relatively large number of test points in various morphologies (urban, suburban, rural) will ensure that the various type (enterprise, ISP, residential, etc.) and densities of Wi-Fi Access points will be well represented in the observed test results. Likewise, the use of multiple devices during the testing will ensure a diversity of device operating characteristics.

The selection of various building construction types, as well as neighborhoods of various socio-economic standing, which is already a part of the test methodology design, will serve to provide a balanced assessment of the expected performance of the location technology as applied across a wide ranging set of environments.

Regardless of the location technology that is being tested, it is important to make sure there are a sufficient number of independent test samples to achieve statistical significance of the test results. Various location technologies require different test execution procedures to maintain statistical independence across successive location attempts. For example, OTDOA systems may treat each location as an atomic operation, so no special procedures are required to maintain independence but, as mentioned earlier, an AGNSS system may require the receiver to be put into a cold (or warm) start state between successive location attempts in order to prevent one location attempt to benefit from satellite acquisition efforts made during the previous location attempt. Similarly, for local emitters (Wi-Fi, BLE beacons), statistical independence across test samples can be achieved by ensuring each location attempt relies on a fresh scan of local emitters (rather than using stored results from previous scans).

If a particular implementation also uses other sensor information (e.g., motion detection/tracking) to smooth position estimation between successive fixes, the test methodology may need to be updated to better reflect how 911 calls are handled by devices using that technology, including how a given location estimate is inherently dependent on historical location measurements.

Location technologies that rely on crowd-sourced databases have a unique characteristic that can affect test results. They are inherently designed to learn from all previous location attempts to improve the accuracy of future location attempts. This is a desirable feature that can, in some scenarios, skew the test results by enabling early test samples to impact later test samples in a positive way. There are a few precautions that can be taken to eliminate or minimize such impacts. The most effective approach would be to disable this feedback capability, if feasible, for the devices under test during the duration of the testing protocols. This option may not be readily available in some system designs. An alternate approach would be to design the test protocols to complete testing in each building in a single session as quickly as possible. For a variety of reasons, the learning mechanisms in most crowd-sourced methods are not instantaneous, so reducing the duration of the test (particularly avoid spanning multiple days), can reduce the impact of the self-learning process on the test results.

An assessment can be made of the potential influence of this self-learning mechanism, or more generally statistical dependence between consecutive test calls, by analyzing the location error statistics at the beginning of a test sequence as compared to the same statistics at the end of a test sequence. For example, consider the case where 100 successive locations are computed at the same test point. If the location system benefits from smoothing or self-learning, or more generally exhibits statistical dependence of successive test calls, the variance and mean, respectively, of the early locations (e.g., first 25 locations) would be higher than those of later locations (e.g., last 25 locations). This type of analysis can be performed during a dry run to verify expected performance as well as during the full test, as needed.

8 How to Analyze Test Results

8.1 Test Bed Results

Paragraphs 129 and 130 of the 4th Report and Order, and Part 20 of the Code of Federal Regulations, 2(i)(3)(i) (contained as Appendix D to the 4th Report and Order) provide instructions regarding the output of the test bed. The specific components of the test bed are to be:

1) The proportion of fixes that are either Dispatchable Locations (as defined in the 4th Report and Order) or are coordinate-based locations less than or equal to 50 meters from the ground truth of the test call compared to the total proportion of completed test calls using that technology. This accuracy metric will be measured separately for each morphology, and will be based upon the specific positioning methods to be deployed in those morphologies;

2) Per-fix position error, the composite of which will determine each technology's accuracy in each morphology, defined in Paragraph 129, footnote 325 as: "the test bed must compute the error in estimating the location of the device under test by comparing each vendor's reported horizontal position

to the surveyed ground truth position of the test location (determined through a precise land survey). Each test call (or equivalent) must be independent from prior calls and accuracy will be based on the first location delivered by the vendor after the call is initiated."; and,

3) "Latency" or time-to-first-fix ("TTFF"), which "must be measured from the time the user presses SEND after dialing 911, to the time the location fix appears at the location information center."

It should be observed that "1" ensures the proportion of test calls placed in each morphology is not relevant to the test bed output. Rather, each morphology requires only a sufficient number of test calls to characterize the performance of the positioning methods to be deployed in that morphology. The test bed output merely characterizes technical performance within each of the morphologies. "2" is covered more fully in ATIS Issue 84 as it relates to specific test methodology.

The following clauses describe:

1) The final test-bed outputs; and,

2) How to apply the test-bed outputs to live calls from a given area of interest (e.g., the six monitored areas, a nationwide footprint, or some other geography subject to performance analysis).

8.1.1 High-Level Process Flow

The basic methodology consists of capturing in-building location data for the technologies to be used to serve 911 calls in the various cities and areas that constitute the indoor Test Bed. This information must be consolidated with outdoor data collected in the same test regions. The outdoor data must measure the same characteristics (e.g., accuracy, TTFF) distinctly for each of the four identified morphologies. The indoor test data is combined across the test bed areas, the outdoor data is combined across the test bed areas, and then the indoor and outdoor data are consolidated. This will produce, for each technology (or combination of technologies), a morphology-specific accuracy performance parameter, i.e., the percentage of calls in a given morphology in which a specific location technology produces a location estimate compliant with the required level of accuracy.

This is illustrated through the "funnel" diagram of Figure 8.1-1, which for illustrative purposes assumes two test bed locations and three technologies. There could be an arbitrary number of test beds and technologies:

Figure 8.1-1 – Test Bed Data Consolidation Process Flow

The mechanics of combining the test bed accuracy performance statistics to create a set of parameters applicable to live wireless 911 calls are addressed more fully below.

Live 911 call statistics will be collected, and to each call the morphology-based accuracy parameter from the test bed process will be assigned. For the area and collection period of interest, the arithmetic mean of these assigned parameters will be the accuracy of a given location system.

Figure 8.1-2 illustrates the translation of live call data to a single accuracy metric for a given area of interest.

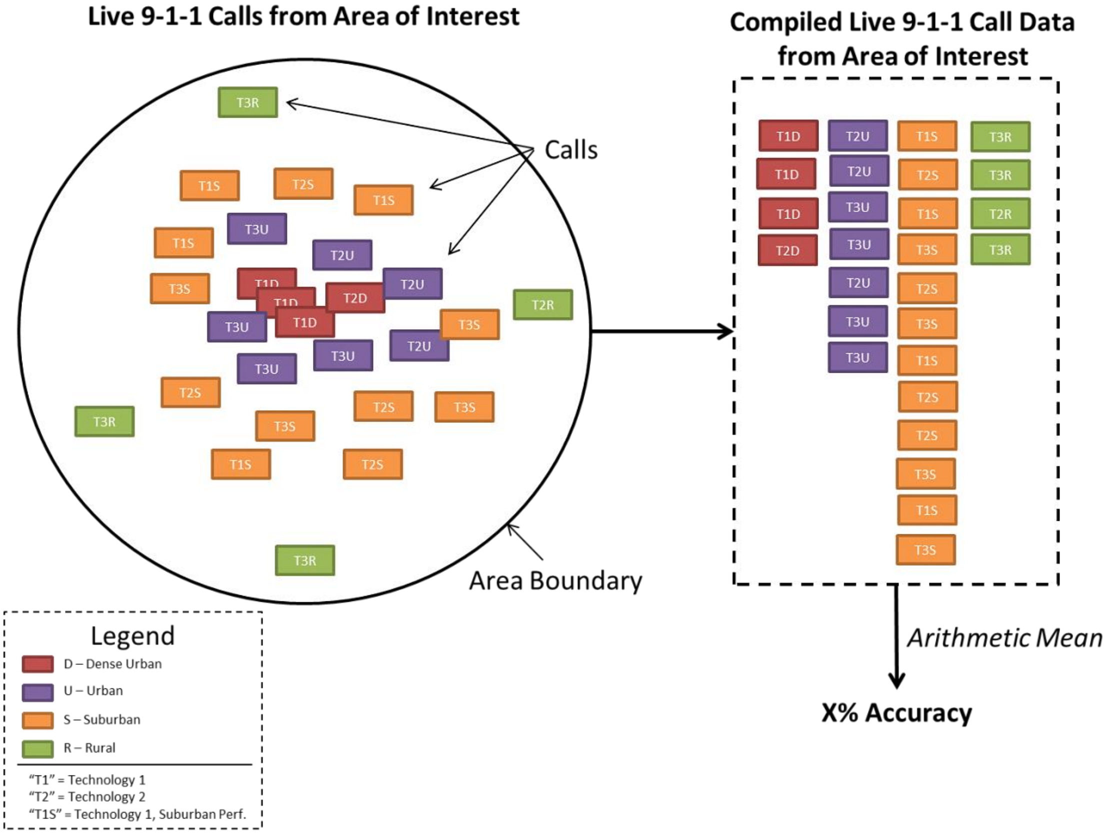

Figure 8.1-2 – Depiction of Collection and Compilation of Live 911 call Statistics

Numerical examples are provided below.

8.1.2 Test Bed Outputs

Table 8.1-1 illustrates the final accuracy output for a set of N technologies deployed in a system, including some hybrid combinations, from the test bed program. The following notation is adopted:

- "T*N*" – Technology *N*; e.g., "T1" means Technology 1 and in practice could be GPS, OTDOA, etc.
- D, U, S, and R – Dense Urban, Urban, Suburban, and Rural morphologies.
- ACC – proportion of fixes with positioning error less than or equal to 50 meters, or which constitute a dispatchable location.
- "T1_U_ACC" means the proportion of accurate fixes from Technology 1 in the Urban morphology, and which would be assigned to any future live 911 call from the urban morphology using Technology 1 for the purpose of establishing the performance of a location system within a given area of interest

Table 8.1-1 – Minimum Accuracy Data from Test-Bed to Evaluate Live Calls

Test Bed Technologies		% of Fixes <= 50m, or Dispatchable Locations			
Technology	***Description***	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	"A"	T1_D_ACC	T1_U_ACC	T1_S_ACC	T1_R_ACC
Technology 2	"B"	T2_D_ACC	T2_U_ACC	T2_S_ACC	T2_R_ACC
Technology 3	"C"	T3_D_ACC	T3_U_ACC	T3_S_ACC	T3_R_ACC
Technology 4	"B+C"	T4_D_ACC	T4_U_ACC	T4_S_ACC	T4_R_ACC
…		…	…	…	…
Technology *N*	Dispatchable	TN_D_ACC	TN_U_ACC	TN_S_ACC	TN_R_ACC

This table of final outputs must be created from the raw data generated through the test bed process, which will include:

1) Sufficient indoor test data from the test bed to characterize each technology to be deployed in a given morphology;
2) Sufficient outdoor test data to characterize each technology to be deployed in a given morphology;
3) A variable number of representative areas to be tested, ranging from a minimum of one representative area (e.g., an initial test bed) to any arbitrary number of representative areas (subsequent test bed results);
4) Satisfaction of the conditions that need to apply for test bed parameters to be extrapolated beyond the test area(s) (see ATIS-0500027).

Given radio propagation of signals is affected by the environment they have to travel through, evaluation by morphology is a key measure of performance. Further aggregation would render unusable the parameters established in the test bed for the purposes of establishing widespread live 911 call performance.

A similar table could also be developed for TTFF or yield performance, although as this analysis is straightforward and has no implications for accuracy determination (the key parameter required from the test bed to assess compliance with the regulations), these derivations are not included here. If desired, a TTFF or yield table may be constructed using identical techniques to the construction of the accuracy table.

The following clauses describe how to convert the raw test data into a single table, and then a single value for a given area of interest.

8.1.2.1 Consideration for Multiple Test Bed Areas

The final test bed result for Technology 1 in dense urban is characterized as T1-D-ACC. Further, T1-D-ACC is the combination of indoor and outdoor results (T1-D-ACC-IN and T1-D-ACC-OUT). In general, combining the indoor and outdoor test results is the last step in establishing the table that spans T1-D-ACC …T*N*-R-ACC. In the case where the technology was tested in only one geographic area, then T1-D-ACC-IN is the indoor accuracy performance metric for that technology in dense urban. In the case where there are multiple geographic areas, for example San Francisco (Test Bed Area 1) and Atlanta (Test Bed Area 2), then the results from each morphology in each test bed area would be combined (unless dramatically different results dictate an alternate approach).

Each test bed area will result in data that can be described in tabular form such as in Tables 8.1-2 and 8.1-3.

NOTE: indoor-only shown, but the same format for outdoor can be applied).

Table 8.1-2 – Indoor Test Bed Results from Test Bed Area 1

Test Bed Area 1 Technologies		**% of Indoor Fixes <= 50m, or Dispatchable Locations**			
Technology	***Description***	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	"A"	T1_D_ACC_IN_A1	T1_U_ACC_IN_A1	T1_S_ACC_IN_A1	T1_R_ACC_IN_A1
Technology 2	"B"	T2_D_ACC_IN_A1	T2_U_ACC_IN_A1	T2_S_ACC_IN_A1	T2_R_ACC_IN_A1
Technology 3	"C"	T3_D_ACC_IN_A1	T3_U_ACC_IN_A1	T3_S_ACC_IN_A1	T3_R_ACC_IN_A1
Technology 4	"B+C"	T4_D_ACC_IN_A1	T4_U_ACC_IN_A1	T4_S_ACC_IN_A1	T4_R_ACC_IN_A1
…		…	…	…	…
Technology *N*	Dispatchable	TN_D_ACC_IN_A1	TN_U_ACC_IN_A1	TN_S_ACC_IN_A1	TN_R_ACC_IN_A1

Table 8.1- 3 -- Indoor Test Bed Results from Test Bed Area 2

Test Bed Area 2 Technologies		**% of Indoor Fixes <= 50m, or Dispatchable Locations**			
Technology	***Description***	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	"A"	T1_D_ACC_IN_A2	T1_U_ACC_IN_A2	T1_S_ACC_IN_A2	T1_R_ACC_IN_A2
Technology 2	"B"	T2_D_ACC_IN_A2	T2_U_ACC_IN_A2	T2_S_ACC_IN_A2	T2_R_ACC_IN_A2
Technology 3	"C"	T3_D_ACC_IN_A2	T3_U_ACC_IN_A2	T3_S_ACC_IN_A2	T3_R_ACC_IN_A2
Technology 4	"B+C"	T4_D_ACC_IN_A2	T4_U_ACC_IN_A2	T4_S_ACC_IN_A2	T4_R_ACC_IN_A2
…		…	…	…	…
Technology *N*	Dispatchable	TN_D_ACC_IN_A2	TN_U_ACC_IN_A2	TN_S_ACC_IN_A2	TN_R_ACC_IN_A2

Provided sufficient test points have been utilized to completely characterize the morphology in each test bed area, the arithmetic mean of each technology's accuracy in each morphology among the test bed areas could simply be computed. Technology 1 in Dense Urban from two test bed areas is illustrated below in Equation 1.

Equation 1: Combining Results from Two Test Bed Areas Using Arithmetic Mean Method

$$\frac{T1\_D\_ACC\_IN\_A1 + T1\_D\_ACC\_IN\_A2}{2} = T1\_DU\_ACC\_IN$$

Alternatively, particularly if there were an insufficient number of test points from either individual test bed area, the raw results from each test point in the same morphology could be combined, although care should be taken to ensure a relatively comparable number of test points are included from each test bed area.

This more direct approach involves combining all of the test points directly – that is, simply count the number of fixes that are <= 50 meters or which are dispatchable locations compared to the total number of successful fixes across all tested points within a given morphology, irrespective of the locality of the test point. Using the example above, the results can be summarized as shown in Table 8.1-4.

Table 8.1-4 – Combining Results from Two Test Bed Areas Using Direct Method

T1_D_ACC_IN	**Number of Fixes <=50m or Dispatchable**	**Total Successful Fixes**	**% Fixes <= 50m or Dispatchable**
Test Bed Area 1	80	100	80%
Test Bed Area 2	75	90	83.3%
Total	**155**	**190**	**81.6%%**

A similar table can be constructed for each technology and morphology, and the number of test bed areas is arbitrary so long as the conditions for result extrapolation are satisfied (see ATIS-0500027). This consolidation method is also required for outdoor data collected in each of the test bed areas.

When combined as described above, the final indoor and outdoor tables will be as follows in Table 8.1-5 and Table 8.1-6.

Table 8.1-5 – Minimum Indoor Accuracy Data

Test Bed Technologies		**% of Indoor Fixes <= 50m, or Dispatchable Locations**			
Technology	***Description***	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	"A"	T1_D_ACC_IN	T1_U_ACC_IN	T1_S_ACC_IN	T1_R_ACC_IN
Technology 2	"B"	T2_D_ACC_IN	T2_U_ACC_IN	T2_S_ACC_IN	T2_R_ACC_IN
Technology 3	"C"	T3_D_ACC_IN	T3_U_ACC_IN	T3_S_ACC_IN	T3_R_ACC_IN
Technology 4	"B+C"	T4_D_ACC_IN	T4_U_ACC_IN	T4_S_ACC_IN	T4_R_ACC_IN
…		…	…	…	…
Technology *N*	Dispatchable	TN_D_ACC_IN	TN_U_ACC_IN	TN_S_ACC_IN	TN_R_ACC_IN

Table 8.1-6 – Minimum Outdoor Accuracy Data

Test Bed Technologies		**% of Outdoor Fixes <= 50m, or Dispatchable Locations**			
Technology	***Description***	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	"A"	T1_D_ACC_OUT	T1_U_ACC_OUT	T1_S_ACC_OUT	T1_R_ACC_OUT
Technology 2	"B"	T2_D_ACC_OUT	T2_U_ACC_OUT	T2_S_ACC_OUT	T2_R_ACC_OUT
Technology 3	"C"	T3_D_ACC_OUT	T3_U_ACC_OUT	T3_S_ACC_OUT	T3_R_ACC_OUT
Technology 4	"B+C"	T4_D_ACC_OUT	T4_U_ACC_OUT	T4_S_ACC_OUT	T4_R_ACC_OUT
…		…	…	…	…
Technology *N*	Dispatchable	TN_D_ACC_OUT	TN_U_ACC_OUT	TN_S_ACC_OUT	TN_R_ACC_OUT

8.1.2.2 Indoor-Outdoor Considerations

The 4th Report and Order does not address the proportion of test calls to be placed from indoor vs. outdoor environments, and the actual proportion of wireless 911 calls made indoors is generally not known. After ample discussion and careful consideration, ATIS recommends that a 50% indoor/50% outdoor mix of test results be used to approximate the blending of actual 911 calls.

It is important to recognize, however, that because some location technologies inherently perform better outdoors than indoors, an overall 50/50 indoor/outdoor test call mix does not mean that each individual positioning method will contribute the same indoor/outdoor mix. For example, A-GPS is very accurate outdoors and generates a high percentage of fixes. It generates a lower percentage of fixes indoors and the location system may default to a higher yield secondary positioning method, such as OTDOA. To properly reflect the accuracy and proportion of fixes from each positioning method, the resultant percentage of indoor vs. outdoor test calls completed for each location technology must be determined through the test bed process in order to blend those call percentages appropriately. Further, the supervisory function in the carrier network that determines which location technology to use must be consistently applied to both indoor and outdoor data collection in the same manner as for live 911 calls.

The proportion of test calls placed indoors vs. outdoors in a given morphology is not strictly relevant, so long as (i) the total indoor calls and the total outdoor calls are separately sufficient; and (ii) the technologies are used in the manner they will be deployed. The appropriate 50/50 proportion of indoor and outdoor calls can be adjusted by calculation without re-testing, by scaling the number of indoor and outdoor fixes to match. Alternatively, the proportionate number (that is, 50/50) of indoor and outdoor test points can be collected in each morphology. For example, an outdoor test could be conducted in the desired morphology that includes exactly the same number of total valid fixes as were achieved in the indoor test bed in the same morphology. Note, however, that this approach is likely not practical to implement.

Written generally, the calculation for any given technology in a given morphology is described in Equation 2.

Equation 2: Combining Indoor and Outdoor Data

$$\frac{P(Tech.1|Outdoors) \times P(All\ Calls|Outdoors) \times P(Tech.1|Outdoors \leq 50m) + P(Tech.1|indoors) \times P(All\ Calls|indoors) \times P(Tech.1|indoors \leq 50m)}{P(Tech.1|Outdoors) \times P(All\ Calls|Outdoors) + P(Tech.1|Indoors) \times P(All\ Calls|Indoors)}$$

In CSRIC III, it was observed that the percentage of fixes from A-GPS indoors was 10% indoors in the Dense Urban morphology, while the accuracy of A-GPS indoors was 68%. For the purposes of illustration, the percentage of fixes from A-GPS outdoors might be 90% and the accuracy might be 85%. Applying Equation 2, and the 50% indoor/50% outdoor split yields the following estimate for blended A-GPS accuracy in Dense Urban:

Equation 3: Illustrative Combination of Indoor and Outdoor A-GPS Data in Dense Urban

$$\frac{90\% \times 50\% \times 85\% + 10\% \times 50\% \times 68\%}{90\% \times 50\% + 10\% \times 50\%} = 83.3\%$$

Note that this outcome is heavily weighted toward outdoor accuracy, which is appropriate for A-GPS, since in Dense Urban areas, it is predominately an outdoor technology. Actual test bed results will differ due to differing implementations, technology evolution, and other factors.

This formula can be applied in the same manner to TTFF, by simply replacing the term “<=50m” above with “TTFF”. Likewise, it can be applied to Dispatchable Location by replacing the term “<=50m” with “dispatchable location” or more compactly, “DL”.

8.1.2.3 Intermediate Outputs

Given the need to combine (blend) indoor and outdoor measurements, in addition to blending accuracy metrics for each technology across morphologies, the proportion of fixes delivered by the system under test from each technology is also required to compute the appropriate overall accuracy. Table 8.1-7 is a simplified indoor table (using the general format described above) using illustrative data in a 2-technology/2-morphology system. A more complete example, using four technologies and four morphologies, can be found in Appendix A.

Table 8.1-7 – Illustrative Indoor Accuracy Data

INDOOR ACCURACY (%<=50m) / AVAILABILITY RESULTS (% of Fixes) (ILLUSTRATIVE)		
Technology	**Morphology 1**	**Morphology 2**
Technology 1	65% / 10%	60% / 15%
Technology 2	100% / 90%	100% / 85%

"Availability" here is the proportion of time a fix is returned with a given positioning method, i.e., yield. For each morphology, this by definition will add to 100%. As described in 8.1.2.2 above, this is required to properly combine the indoor and outdoor metrics. Similarly, an illustrative example is provided in Table 8.1-8 for outdoor.

Table 8.1-8 – Illustrative Outdoor Accuracy Data

OUTDOOR ACCURACY (%<=50m) / AVAILABILITY RESULTS (% of Fixes) (ILLUSTRATIVE)		
Technology	**Morphology 1**	**Morphology 2**
Technology 1	82% / 85%	83% / 90%
Technology 2	50% / 15%	50% / 10%

Similar tables are required for TTFF, but are excluded for simplicity.

8.1.2.4 Combining Indoor and Outdoor Outputs

The following tables combine the outputs from indoor and outdoor test results into a single value for each technology tested. The output from these tables is then recorded in the summary table as depicted in Table 8.1-1 above.

Table 8.1-9 – Computing Performance in Morphology 1

Morphology 1	% Calls Originating from Environment	Technology Usage	% of Fixes <= 50m	% of Total Fixes <= 50m	% of Total Fixes	
	A	**B**	**C**	**A x B x C**	**A x B**	
Technology 1	50%	85%	82%	34.8%	42.5%	Outdoor Sys.
Technology 2	50%	15%	50%	3.8%	7.5%	Fixes <=50m
Total Outdoor				38.5%	50.0%	77.0%
Technology 1	50%	10%	65%	3.3%	5.0%	Indoor Sys.
Technology 2	50%	90%	100%	45.0%	45.0%	Fixes <=50m
Total Indoor				48.3%	50.0%	96.5%

Individual Technology Performance	% of Total Fixes <= 50m	% of Fixes	**% of Tech. Fixes <= 50m**
Technology 1	38.0%	47.5%	**80.0%**
Technology 2	48.8%	52.5%	**92.9%**

Table 8.1-10 – Computing Performance in Morphology 2

Morphology 2	% Calls Originating from Environment	Technology Usage	% of Fixes <= 50m	% of Total Fixes <= 50m	% of Total Fixes	
	A	B	C	A x B x C	A x B	
Technology 1	50%	90%	83%	37.5%	45.0%	Outdoor Sys.
Technology 2	50%	10%	50%	2.5%	5.0%	Fixes <=50m
Total Outdoor				40.0%	50.0%	80.0%
Technology 1	50%	15%	60%	4.5%	7.5%	Indoor Sys.
Technology 2	50%	85%	100%	42.5%	42.5%	Fixes <=50m
Total Indoor				47.0%	50.0%	94.0%

Individual Technology Performance	% of Total Fixes <= 50m	% of Fixes	**% of Tech. Fixes <= 50m**
Technology 1	42.0%	52.5%	**80.0%**
Technology 2	45.0%	47.5%	**94.7%**

In the case where a proportionate number of test calls (i.e., 50/50) is placed indoors and outdoors, the results are the same, as is seen in Table 8.1-12. Table 8.1-11 restates the performance results for indoor and outdoor identified above. Only Morphology 1 is shown for simplicity.

Table 8.1-11 – Test Bed and Other Data with Fix Counts in Morphology 1

Test Data from Test Bed and Other Sources

Morphology 1 Outdoor	**Outdoor Fixes**	**% of Outdoor Fixes**	**% of Outdoor Fixes <= 50m**
Technology 1	850	85%	82%
Technology 2	150	15%	50%
Total Outdoor	**1000**	**100%**	

Morphology 1 Indoor	**Fixes**	**% of Indoor Fixes**	**% of Indoor Fixes <= 50m**
Technology 1	100	10%	65%
Technology 2	900	90%	100%
Total Indoor	**1000**	**100%**	

Table 8.1-12 – Indoor/Outdoor Blending Using Fix Counts in Morphology 1

Technology		Total Fixes	Indoor / Outdoor Fix Rate Occurrence	% Fixes <= 50m	% of Blended Indoor / Outdoor Fixes <= 50m
		A	B	C	B x C
Technology 1	Outdoor Fixes	850	89.5%	81.8%	73.2%
	Indoor Fixes	100	10.5%	65.0%	6.8%
	Total Tech. 1 Fixes	950			**80.0%**
Technology 2	Outdoor Fixes	150	14.3%	50.0%	7.1%
	Indoor Fixes	900	85.7%	100.0%	85.7%
	Total Tech. 2 Fixes	1,050			**92.9%**

As noted above, the number of position fixes indoor and outdoor do not need to be identical at test time, and can be easily scaled in the highly likely event the proportion of fixes collected between indoor and outdoor for a given morphology does not match the desired proportion (e.g., 50/50). For example, if 2,000 outdoor fixes are available and 1,000 indoor fixes are available, then the *number* of fixes from outdoor for each technology would simply be divided by 2 to achieve a 50/50 indoor/outdoor split. Likewise, if there only 500 outdoor fixes, then the number of fixes could be multiplied by 2. The *proportion* of fixes <= 50m will be remain identical in either case.

Based on these calculations, it is possible to create a sample final test output table as shown in Table 8.1-13.

Table 8.1-13 – Technology Performance Table

Test Bed Technologies		% of Fixes <= 50m, or Dispatchable Locations	
Technology	***Description***	**Morphology 1**	**Morphology 2**
Technology 1	"A"	80%	80%
Technology 2	"B"	93%	95%

These results are sufficient to establish the performance in any given area, with an arbitrary mix of morphologies, subject to the constraints described in ATIS-0500027.

8.2 Applying Test Bed Data to Live Calls

The test bed determines the accuracy performance of each deployed technology (or combination of technologies) by morphology, but it is not possible in the test bed to measure in general the frequency with which any technology might actually be used in practice, nor is it possible in the test bed to determine the actual mix of morphologies from which wireless 911 calls might be placed. To address this issue, the Order requires monitoring of live 911 calls to establish the availability (yield) of a given location technology (or combination of technologies) across the specified monitoring regions.

Test bed accuracy performance metrics are then combined with location technology yield figures derived from live 911 call monitoring to assess compliance with the rules.

The key wireless 911 call parameters on a per-call basis are:

1) The technology (or combination of technologies) used to locate the call;

2) The morphology from which the call was placed.

Then it is a simple matter to cross-reference the test bed final output to assign each call its appropriate accuracy metric. The overall system accuracy for a given area of interest is simply the arithmetic mean of the accuracy metrics from each call, while the accuracy from any given technology is the arithmetic mean of that technology from all wireless 911 calls using that technology. Likewise the accuracy for a given morphology can also be determined in the same manner.

In practice, to assess compliance, the relevant statistics (i.e., location technology yield figures) obtained from live 911 call monitoring will be based upon large quantities of 911 calls.

8.2.1 Assigning Live Wireless 911 Calls to a Given Morphology

Live wireless 911 calls, or wireless calls in the case where there are an insufficient number of wireless 911 calls, must be assigned a morphology classification (dense urban, urban, suburban, rural) to determine morphology-specific location technology yields. The most appropriate technique should balance administrative burden with sufficient accuracy to have reasonable confidence that the correct morphology is identified.

The envisioned approach would characterize the predominate area covered by the cell sector from which a call originates. Because the CMRS providers know where cell sites are located and antenna orientation, the primary morphology served by a given sector can be identified, and subsequently any call placed from that sector can be assigned to that morphology.

Figure 8.2-1 illustrates the value of using cell sector, as opposed to cell site location, to determine morphology.

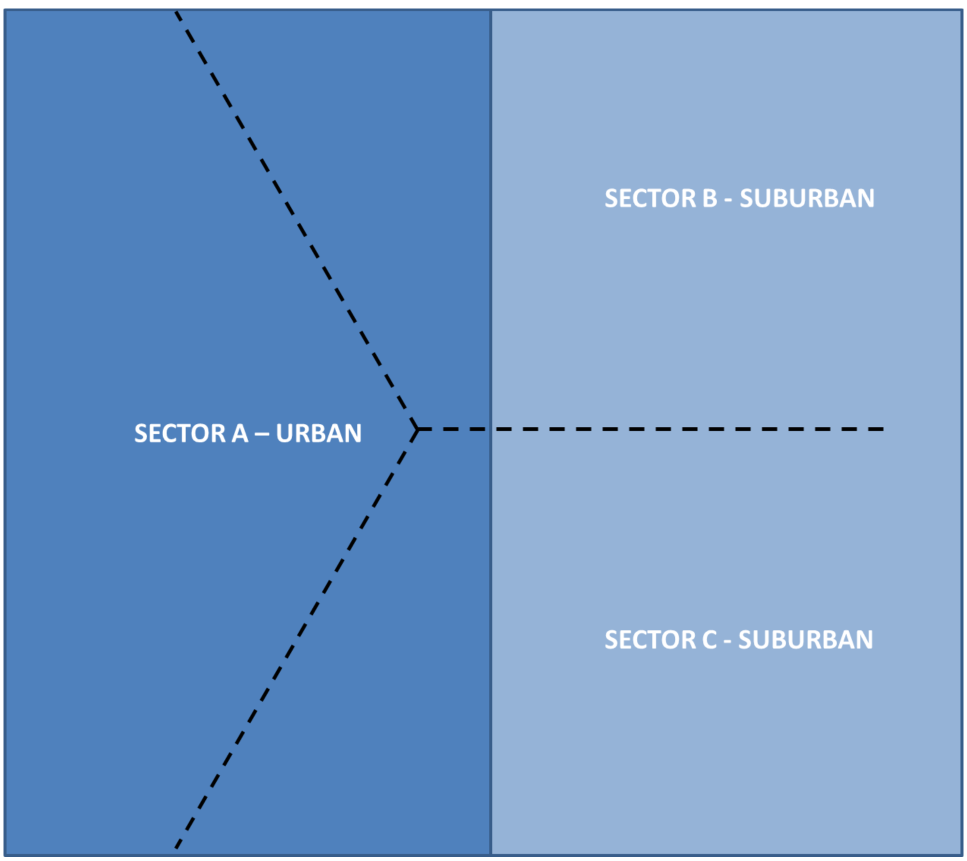

Figure 8.2-1 – Diagram Illustrating Use of Cell Sectors in Morphology Assignments

Note that the cell site is in an urban area, but two out of three sectors are suburban. By delineating the site by sector, inappropriately assigning calls from this site to either suburban or urban areas is mitigated, although not completely eliminated.

8.2.2 Applying Test Data to Live Wireless 911 Calls

To illustrate a simple system-level accuracy computation, a 2-technology/2-morphology table is repeated here in Table 8.2-1 for convenience (identical to Table 8.1-13 above). A more complete example, using four technologies and four morphologies, is included in Appendix A.

Table 8.2-1 – Technology Performance Table

Test Bed Technologies		% of Fixes <= 50m, or Dispatchable Locations	
Technology	***Description***	**Morphology 1**	**Morphology 2**
Technology 1	"A"	80%	80%
Technology 2	"B"	93%	95%

Therefore, a wireless 911 call with Technology 1 as the positioning method from Morphology 1 would have a Yield of 80%. A call with Technology 2 as the positioning method from Morphology 2 would have a Yield of 95%. If these were the only two wireless 911 calls placed from a given monitored area, the overall accuracy would be the arithmetic mean: (80% + 95%)/2 = 87.5%.

In general, the positioning method and morphology of each live wireless 911 call within the monitoring regions will be logged over time. Statistics for position method yield by morphology will be extracted from these logs, and the results may look like those shown in Table 8.2-2, for an example summary of live wireless 911 call data collected for a given area of interest with 10 calls.

Table 8.2-2 – Illustrative Summary Live Wireless 911 Call Data from an Area of Interest

9-1-1 Location Accuracy Live Call Data - Area of Interest A

	Total 9-1-1 Calls		% of Total 9-1-1 Calls	
	Morphology 1	**Morphology 2**	**Dense Urban**	**Urban**
Technology 1	2	4	20.0%	40.0%
Technology 2	3	1	30.0%	10.0%
Total Calls - All Technologies		10	**% of All Calls**	**100.0%**

This provides sufficient information to combine the test bed accuracy data with the live call data. The following Table 8.2-3 illustrates how such data should be combined to generate a performance figure for a given compliance area by using the arithmetic mean of the accuracy attributable to the live wireless 911 calls.

Table 8.2-3 – Location Accuracy for an Area of Interest

9-1-1 Location Accuracy - Area of Interest A

	% of Total 9-1-1 Calls by Morphology and Technology		Test Bed Performance - % of Fixes <= 50 meters or DL by Morphology		Proportion of 9-1-1 Calls <= 50 meters, or DL	
	Morphology 1	**Morphology 2**	**Morphology 1**	**Morphology 2**	**Morphology 1**	**Morphology 2**
Technology 1	20.0%	40.0%	80.0%	92.9%	16.0%	37.2%
Technology 2	30.0%	10.0%	80.0%	94.7%	24.0%	9.5%
Total Calls - All Technologies		100.0%			**AREA ACCURACY**	86.6%

Thus Area of Interest "A" in this example has an overall accuracy of 86.6%. Note that Area of Interest "A" could be a PSAP jurisdiction, the county, or a monitored region (e.g., a CMA).

Note that this is identical to simply taking the arithmetic mean of the accuracy of each individual call, were it to be listed in tabular format as shown in Table 8.2-4.

Table 8.2-4 – Location Accuracy for an Area Showing Individual Call Accuracy Assignments

9-1-1 Location Accuracy Live Call Data - Area of Interest A

	Total Calls				
	Positioning Source Technology	Cell Sector	Reported X,Y	Determined Morphology	% <=50m
Call 1	Technology 1	10	-81, 45	2	92.9%
Call 2	Technology 1	6	-3, 64	2	92.9%
Call 3	Technology 2	1	-41, 89	1	80.0%
Call 4	Technology 2	4	-11, 89	1	80.0%
Call 5	Technology 1	4	-77, 14	1	80.0%
Call 6	Technology 1	8	-89, 32	2	92.9%
Call 6	Technology 2	12	-28, 89	1	80.0%
Call 8	Technology 1	6	-77, 40	2	92.9%
Call 9	Technology 1	1	-88, 67	1	80.0%
Call 10	Technology 2	11	-13, 53	2	94.7%

As can be observed, the arithmetic mean of the column labeled “%<=50m” is 86.6%.

8.2.2.1 Sufficiency of Call Volume

ATIS requires the use of wireless 911 calls to determine the proportional distribution by morphology with any given area of interest (e.g., PSAP, County, Monitored Market, etc.). ATIS acknowledges, however, that, if a given area of interest has fewer than 300 total wireless 911 calls for the preceding 12 months, then it is appropriate to utilize all wireless voice calls to determine the proportion of calls from each individual morphology within that area of interest. For example, if a given area of interest has 125 suburban wireless 911 calls and 125 rural wireless 911 calls, then it would be appropriate for that area to use all wireless calls. If the same area had 150 suburban wireless 911 calls and 150 rural wireless 911 calls, then the wireless 911 calls should be used because it meets the 300-call threshold.

Appendix A
(Normative)

Appendix A. Detailed Calculations with 4 Technologies and 4 Morphologies

The following example and the related spreadsheets embedded with it provide a more complete illustration of combining test bed data and applying it to a set of hypothetical live calls. This example utilizes four technologies and four morphologies, and 100 calls within the area of interest for which a performance metric is sought. There is no upper limit to the number of potential technologies that could be utilized within this process.

The following tables describe the indoor and outdoor performance, and frequency with which fixes were generated, from each technology in the example location system.

Table A.1 – Illustrative Indoor Test Bed Results

INDOOR ACCURACY (%<=50m) / AVAILABILITY RESULTS (% of Fixes) (ILLUSTRATIVE)				
Technology	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	65% / 10%	60% / 15%	80% / 45%	95% / 85%
Technology 2	80% / 70%	80% / 70%	80% / 15%	80% / 5%
Technology 3	10% / 10%	5% / 5%	0% / 20%	0% / 5%
Technology 4	100% / 10%	100% / 10%	100% / 20%	100% / 5%

Table A.2 – Illustrative Outdoor Test Results

OUTDOOR ACCURACY / AVAILABILITY RESULTS (ILLUSTRATIVE)				
Technology	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	82% / 85%	83% / 90%	95% / 95%	95% / 95%
Technology 2	80% / 15%	80% / 10%	80% / 5%	80% / 5%
Technology 3	0% / 0%	0% / 0%	0% / 0%	0% / 0%
Technology 4	0% / 0%	0% / 0%	0% / 0%	0% / 0%

The following tables combine the outputs from indoor and outdoor test results into a single value for each technology tested, for each of the dense urban, urban, and suburban morphologies. A similar table could be created for rural, but has been eliminated for simplicity. The output from these tables is then recorded in the summary table.

Table A.3 – Computing Dense Urban Performance

Dense Urban	% Calls Originating from Environment	Technology Usage	% of Fixes <= 50m	% of Total Fixes <= 50m	% of Total Fixes	
	A	B	C	A x B x C	A x B	
Technology 1	50%	85%	82%	34.8%	42.5%	Outdoor Sys.
Technology 2	50%	15%	80%	6.0%	7.5%	Fixes <=50m
Technology 3	50%	0%	0%	0.0%	0.0%	
Total Outdoor				40.8%	50.0%	81.5%
Technology 1	50%	10%	65%	3.3%	5.0%	
Technology 2	50%	70%	80%	28.0%	35.0%	Indoor Sys.
Technology 3	50%	10%	10%	0.5%	5.0%	Fixes <=50m
Technology 4	50%	10%	100%	5.0%	5.0%	
Total Indoor				36.8%	50.0%	73.5%

Individual Technology Performance	% of Total Fixes <= 50m	% of Fixes	% of Tech. Fixes <= 50m
Technology 1	38.0%	47.5%	**80.0%**
Technology 2	34.0%	42.5%	**80.0%**
Technology 3	0.5%	5.0%	**10.0%**
Technology 4	5.0%	5.0%	**100.0%**

Table A.4 – Computing Urban Performance

Urban	% Calls Originating from Environment	Technology Usage	% of Fixes <= 50m	% of Total Fixes <= 50m	% of Total Fixes	
	A	B	C	A x B x C	A x B	
Technology 1	50%	90%	83%	37.5%	45.0%	Outdoor Sys.
Technology 2	50%	10%	80%	4.0%	5.0%	Fixes <=50m
Technology 3	50%	0%	0%	0.0%	0.0%	
Total Outdoor				41.5%	50.0%	83.0%
Technology 1	50%	15%	60%	4.5%	7.5%	
Technology 2	50%	70%	80%	28.0%	35.0%	Indoor Sys.
Technology 3	50%	5%	5%	0.1%	2.5%	Fixes <=50m
Technology 4	50%	10%	100%	5.0%	5.0%	
Total Indoor				37.6%	50.0%	75.3%

Individual Technology Performance	% of Total Fixes <= 50m	% of Fixes	% of Tech. Fixes <= 50m
Technology 1	42.0%	52.5%	**80.0%**
Technology 2	32.0%	40.0%	**80.0%**
Technology 3	0.1%	2.5%	**5.0%**
Technology 4	5.0%	5.0%	**100.0%**

Table A.5 – Computing Suburban Performance

Suburban	% Calls Originating from Environment	Technology Usage	% of Fixes <= 50m	% of Total Fixes <= 50m	% of Total Fixes	
	A	B	C	A x B x C	A x B	
Technology 1	50%	95%	95%	45.1%	47.5%	Outdoor Sys.
Technology 2	50%	5%	80%	2.0%	2.5%	Fixes <=50m
Technology 3	50%	0%	0%	0.0%	0.0%	
Total Outdoor				47.1%	50.0%	94.3%
Technology 1	50%	45%	80%	17.9%	22.5%	
Technology 2	50%	15%	80%	6.0%	7.5%	Indoor Sys.
Technology 3	50%	20%	0%	0.0%	10.0%	Fixes <=50m
Technology 4	50%	20%	100%	10.0%	10.0%	
Total Indoor				33.9%	50.0%	67.8%

Individual Technology Performance	% of Total Fixes <= 50m	% of Fixes	% of Tech. Fixes <= 50m
Technology 1	63.0%	70.0%	**90.0%**
Technology 2	8.0%	10.0%	**80.0%**
Technology 3	0.0%	10.0%	**0.0%**
Technology 4	10.0%	10.0%	**100.0%**

NOTE: Rural example excluded for simplicity.

In the case where a proportionate number of test calls (i.e., 50/50) is placed indoors and outdoors, the results are the same, as is seen in Table A.7. Table A.6 restates the performance results for indoor and outdoor identified above. Only dense urban is shown for simplicity.

Table A.6 – Test Bed and Other Data with Fix Counts

Test Data from Test Bed and Other Sources

Dense Urban Outdoor	Outdoor Fixes	% of Outdoor Fixes	% of Outdoor Fixes <= 50m
Technology 1	850	85%	82%
Technology 2	150	15%	80%
Technology 3	0	0%	0%
Technology 4	0	0%	0%
Total Outdoor	**1000**	**100%**	

Dense Urban Indoor	Fixes	% of Indoor Fixes	% of Indoor Fixes <= 50m
Technology 1	100	10%	65%
Technology 2	700	70%	80%
Technology 3	100	10%	10%
Technology 4	100	10%	100%
Total Indoor	**1000**	**100%**	

Table A.7 – Indoor/Outdoor Blending Using Fix Counts

Technology		Total Fixes	Indoor / Outdoor Fix Rate Occurrence	% Fixes <= 50m	% of Blended Indoor / Outdoor Fixes <= 50m
		A	B	C	B x C
Technology 1	Outdoor Fixes	850	89.5%	81.8%	73.2%
	Indoor Fixes	100	10.5%	65.0%	6.8%
	Total Tech. 1 Fixes	950			**80.0%**
Technology 2	Outdoor Fixes	150	17.6%	80.0%	14.1%
	Indoor Fixes	700	82.4%	80.0%	65.9%
	Total Tech. 2 Fixes	850			**80.0%**
Technology 3	Outdoor Fixes	0	0.0%	0.0%	0.0%
	Indoor Fixes	100	100.0%	10.0%	10.0%
	Total Tech. 3 Fixes	100			**10.0%**
Technology 4	Outdoor Fixes	0	0.0%	0.0%	0.0%
	Indoor Fixes	100	100.0%	100.0%	100.0%
	Total Tech. 4 Fixes	100			**100.0%**

As noted above, the number of position fixes indoor and outdoor does not need to be identical at test time, and can be easily scaled in the highly likely event the proportion of fixes collected between indoor and outdoor for a given morphology does not match the desired proportion (e.g., 50/50). For example, if 2,000 outdoor fixes are available and 1,000 indoor fixes are available, then the *number* of fixes from outdoor for each technology would simply be divided by 2 to achieve a 50/50 indoor/outdoor split. Likewise, if there only 500 outdoor fixes, then the number of fixes could be multiplied by 2. The proportion of fixes <= 50m will be remain identical in either case.

The live spreadsheet for each table is attached and entitled **"Indoor Outdoor Combinations v2.xlsx"**.

Based on these calculations, it is possible to create a sample final test output table.

Table A.8 – Technology Performance Table

Test Bed Technologies		% of Fixes <= 50m, or Dispatchable Locations			
Technology	***Description***	**Dense Urban**	**Urban**	**Suburban**	**Rural**
Technology 1	"A"	80%	80%	90%	95%
Technology 2	"B"	80%	80%	80%	80%
Technology 3	"C"	10%	5%	0%	0%
Technology 4	"D"	100%	100%	100%	100%

These results are sufficient to establish the performance in any given area, with an arbitrary mix of morphologies, subject to the constraints described in ATIS-0500027.

A summary of the live wireless 911 call data collected for a given area of interest with 100 calls could look as depicted in Table A.9.

Table A. 9 – Illustrative Summary Live Wireless 911 Call Data from an Area of Interest

9-1-1 Location Accuracy Live Call Data - Area of Interest A

	Total 9-1-1 Calls				% of Total 9-1-1 Calls			
	Dense Urban	Urban	Suburban	Rural	Dense Urban	Urban	Suburban	Rural
Technology 1	4	6	12	12	4.0%	6.0%	12.0%	12.0%
Technology 2	7	4	8	6	7.0%	4.0%	8.0%	6.0%
Technology 3	0	0	8	1	0.0%	0.0%	8.0%	1.0%
Technology 4	8	8	9	7	8.0%	8.0%	9.0%	7.0%
Total Calls - All Technologies				100	% of All Calls (Should be 100%)			100.0%

This provides sufficient information to combine the test bed accuracy data with the live call data. The following table illustrates how such data should be combined to generate a performance figure for a given compliance area by using the arithmetic mean of the accuracy attributable to the live wireless 911 calls.

Table A.10 – Location Accuracy for an Area of Interest

9-1-1 Location Accuracy - Area of Interest A

	% of Total 9-1-1 Calls by Morphology and Technology				Test Bed Performance - % of Fixes <= 50 meters or DL by Morphology				Proportion of 9-1-1 Calls <= 50 meters, or DL			
	Dense Urban	Urban	Suburban	Rural	Dense Urban	Urban	Suburban	Rural	Dense Urban	Urban	Suburban	Rural
Technology 1	4.0%	6.0%	12.0%	12.0%	80.0%	80.0%	90.0%	95.0%	3.2%	4.8%	10.8%	11.4%
Technology 2	7.0%	4.0%	8.0%	6.0%	80.0%	80.0%	80.0%	80.0%	5.6%	3.2%	6.4%	4.8%
Technology 3	0.0%	0.0%	8.0%	1.0%	10.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technology 4	8.0%	8.0%	9.0%	7.0%	100.0%	100.0%	100.0%	100.0%	8.0%	8.0%	9.0%	7.0%
Total Calls - All Technologies (Should be 100%)				100.0%					COMBINED ACCURACY METRIC			82.2%

Thus Area of Interest "A" has an overall accuracy of 82.2%. Note that Area of Interest "A" could be a PSAP jurisdiction, the county, or a monitored region (e.g., a CMA).

Note that this is identical to simply taking the arithmetic mean of the accuracy of each individual call, were it to be listed in tabular format as shown in Table A.11.

Table A.11 – Location Accuracy for an Area Showing Individual Call Accuracy Assignments

9-1-1 Location Accuracy Live Call Data - Area of Interest A

	Total Calls					
	Positioning Source Technology	Cell Sector	Reported X,Y	Reported Dispatchable Location	Determined Morphology	% <=50m
Call 1	Technology 4	10	-81, 45	27 Holly	R	100.0%
Call 2	Technology 1	6	-3, 64	N/A	R	95.0%
Call 3	Technology 2	1	-41, 89	N/A	U	80.0%
Call 4	Technology 4	4	-11, 89	8952 Oak Suite 75B	D	100.0%
Call 5	Technology 4	4	-77, 14	27 Oak	D	100.0%
Call 6	Technology 1	8	-89, 32	N/A	R	95.0%
Call 6	Technology 1	12	-28, 89	N/A	U	80.0%
Call 8	Technology 1	6	-77, 40	N/A	R	95.0%
Call 9	Technology 4	1	-88, 67	123 Oak	U	100.0%
Call 10	Technology 3	11	-13, 53	N/A	S	0.0%
Call 11	Technology 2	15	-37, 9	N/A	S	80.0%
Call 12	Technology 4	17	-82, 62	123 Holly Apt. 5	D	100.0%
Call 13	Technology 1	17	-72, 11	N/A	D	80.0%
…						
Call 100	Technology 2	5	-55, 41	N/A	S	80.0%

The preceding tables and calculations can be followed in the attached spreadsheet entitled **"Live 911 Performance Evaluation.xlsx"**.

Appendix B
(Normative)

Appendix B. Morphology Definitions for the Six E911 Performance Monitoring Regions

For illustration purposes Figures B.1 through B.6 provide a top level view of the morphology polygons that have been defined for the 6 performance monitoring regions: San Francisco, Philadelphia, Chicago, Denver, Atlanta, and New York, which contain a total of 63 counties.

The detailed polygons for the 6 regions are included in the Google Earth format in the composite .kmz file attached as "**Attachments - 6 Regions KMZ"**. The polygons are named and organized in an orderly logical manner to assist in easily identifying and tracking any of the many polygons defined in each of the monitoring regions.

The corresponding MapInfo and Shape files for the 6 regions, suitable for easy importation into various GIS or network planning tools, are provided in the 6 separate zip archives that are attached and named according to each region. Although the MapInfo and Shape files consolidate the different polygons belonging to each morphology type in a given county, the number of files in an archive can still be significant depending on the number of counties in that region. Thus, for simplicity and convenience, the archives have been maintained separate for the different monitoring regions. If needed, each morphology layer for a county can be easily split into its constituent polygons using standard GIS tools.

Review within ATIS ESM of available tools and data sources relevant to the task of morphology definition showed that a significant amount of manual intervention and correction would be required in any attempt to automate the process of morphology boundary creation. Moreover, no credible or reliable automated methods were found to date to perform such a task. Accordingly, in view of the time criticality of the needed morphology definitions, the consensus was to proceed with manual methods for the 6 monitoring regions.

The morphology polygon definition task was undertaken by ATIS relying primarily on a manual process performed by experienced engineers who relied on publically available geographic visual tools and underlying data, including, where available and useful, building and land parcel information.

Among the most useful visual tools used was Google Earth, and in urban areas its 3-D building imagery. However, relying exclusively on visual means in some of the heavily urbanized cities, particularly older cities, proved to be an arduous, time consuming task. Fortunately, publically available building height and number of floor databases were found for the 5 boroughs (counties) of New York City and for the City of Chicago. This substantially reduced the difficulty in determining and drawing the urban-suburban boundaries around many urban clusters and corridors within the official boundaries of those cities. Unfortunately, no such data was publically available for the other heavily urbanized counties in those regions, e.g., for Hudson, Essex and Union Counties in NJ, within the New York Monitoring region.

Privately owned and/or purchased building height and number of floor information exists for all metropolitan areas of the U.S. but was not available during the current morphology definition process. If and when needed, future morphology definitions for other metropolitan areas with significant urban enclaves could significantly benefit from the availability of such assistive data.

Another type of public data found useful in counties with extended suburbia, especially containing a significant degree of suburban sprawl and newer growth, was land parcel shape files. Those polygons when overlaid on visual imagery help in discriminating between rural and suburban morphology boundaries in expanses of lighter suburban sprawl in otherwise rural surroundings. One county where this assistive approach was put to use was Morris County, NJ. As more suburban counties make that type of information available through their web sites, this data could be put to use in future efforts that may be needed to define morphology boundaries in those counties.

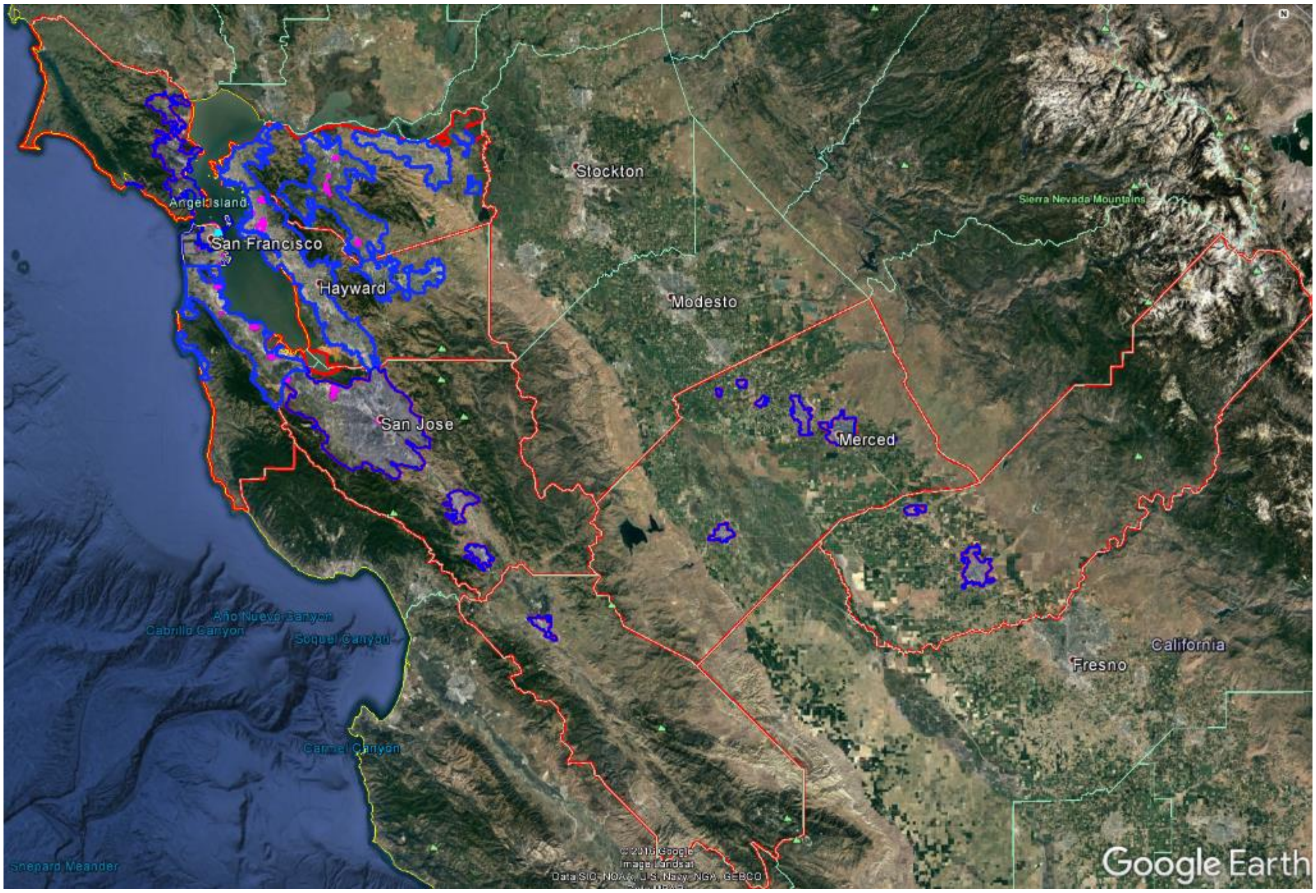

Figure B.1 – Morphology Polygons for the San Francisco Monitoring Region

Note: Cyan: Dense Urban; Purple: Urban; Blue: Suburban; Red: Rural

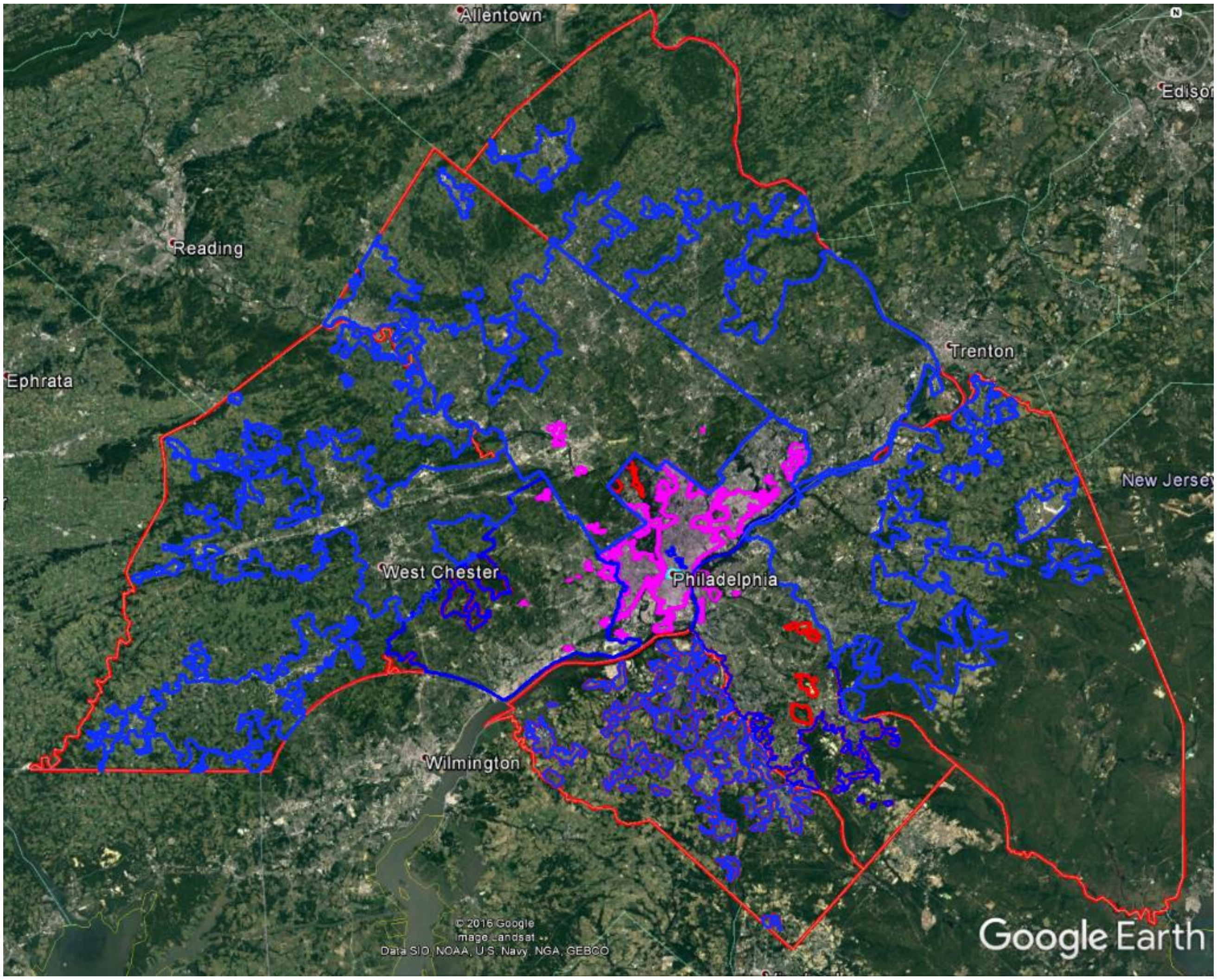

Figure B.2 – Morphology Polygons for the Philadelphia Monitoring Region

Note: Cyan: Dense Urban; Purple: Urban; Blue: Suburban; Red: Rural

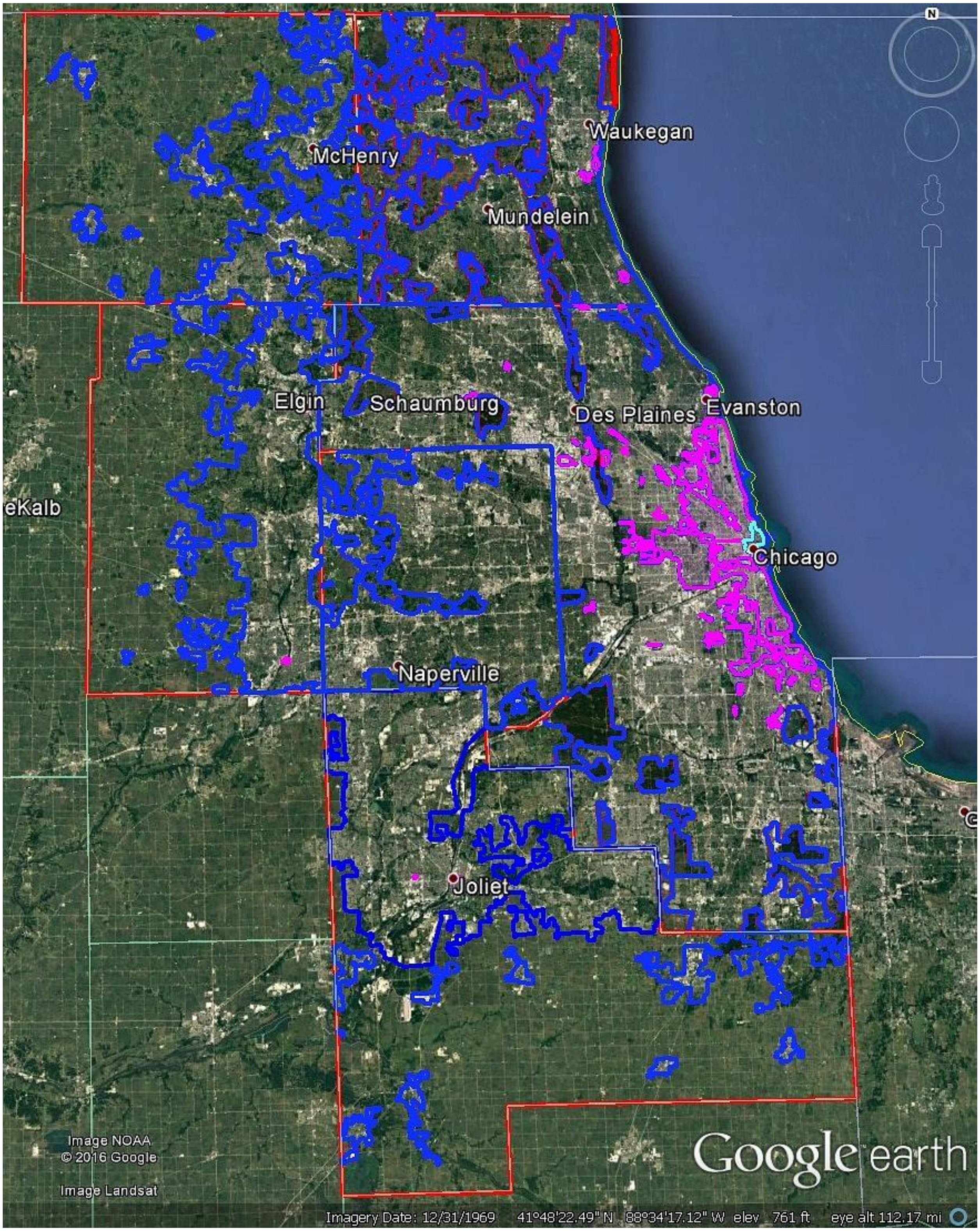

Figure B.3 – Morphology Polygons for the Chicago Monitoring Region

Note: Cyan: Dense Urban; Purple: Urban; Blue: Suburban; Red: Rural

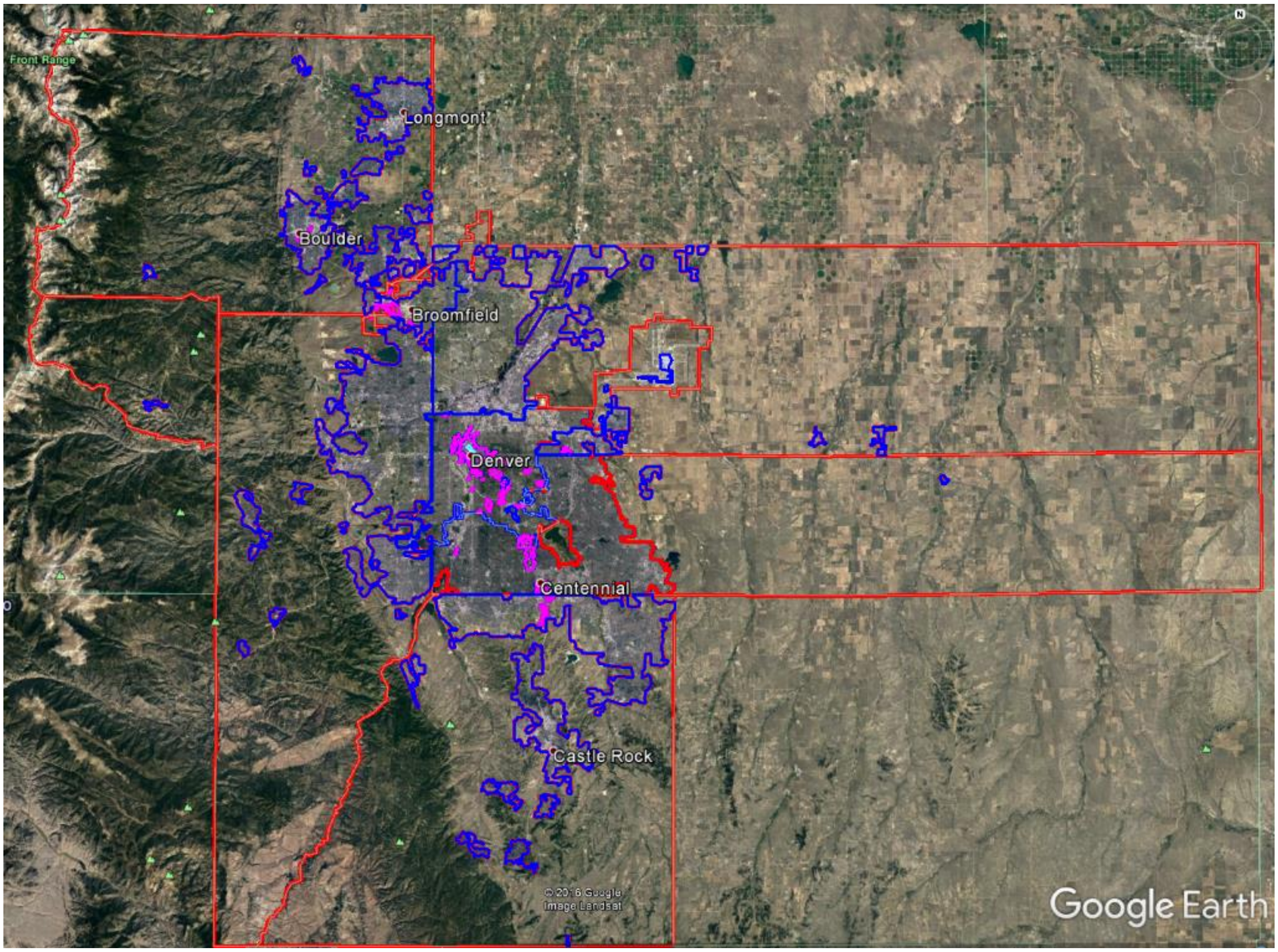

Figure B.4 – Morphology Polygons for the Denver Monitoring Region

Note: Cyan: Dense Urban; Purple: Urban; Blue: Suburban; Red: Rural

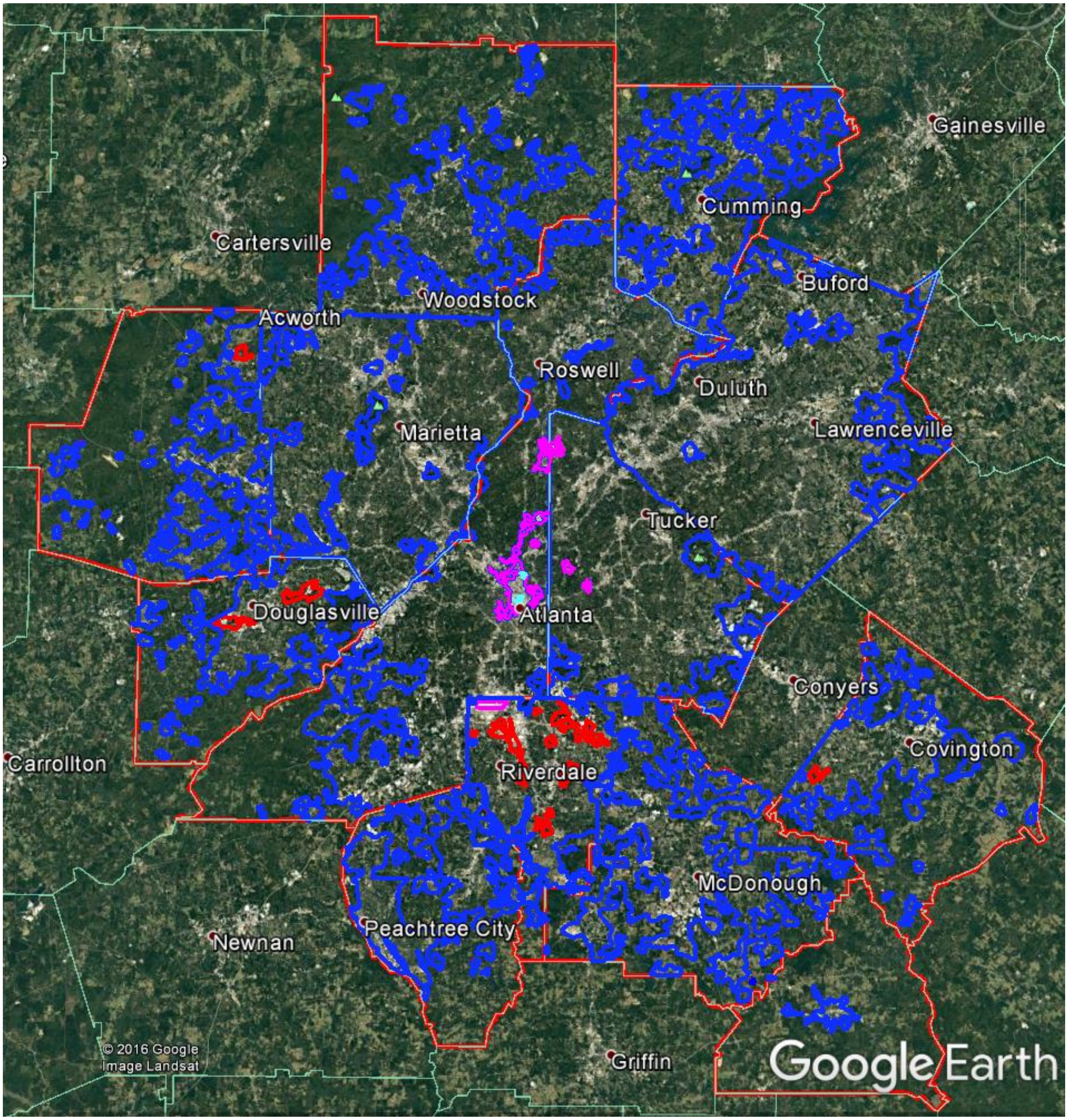

Figure B.5 – Morphology Polygons for the Atlanta Monitoring Region

Note: Cyan: Dense Urban; Purple: Urban; Blue: Suburban; Red: Rural

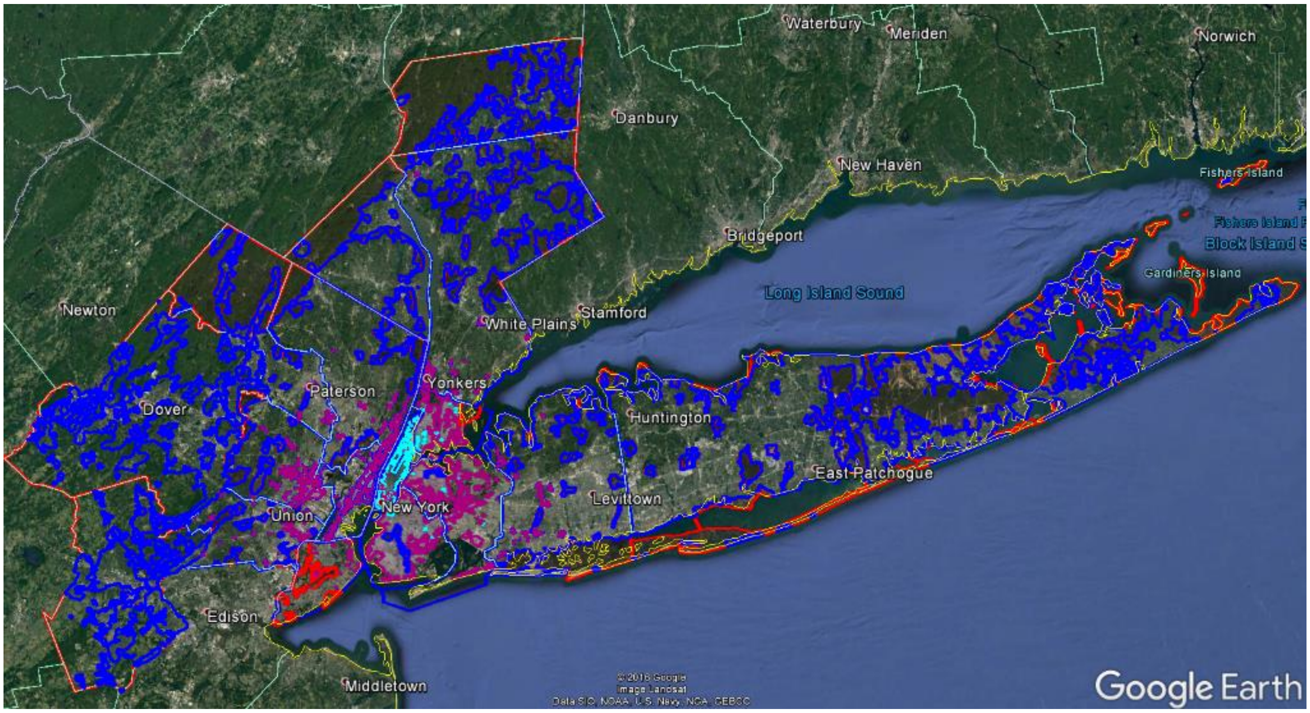

Figure B.6 – Morphology Polygons for the New York Monitoring Region

Note: Cyan: Dense Urban; Purple: Urban; Blue: Suburban; Red: Rural