

## TIGER 2000 and FIA

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**Abstract.**—The legal foundations of the FIA (Forest Inventory and Analysis) program are laid out. Upon those foundations are built a geographical definition of the United States and its components, and how applying that definition might change from decade to decade. Along the way, the American system of weights and measures as well as the unusual geography of the Commonwealth of Virginia are explained. Some recommendations are offered for the FIA program.

This paper is primarily about the geography of the United States as it pertains to the FIA program. Some of the details discussed may seem unimportant but are included in the interest of thoroughness.

Several maps (U.S. Census Bureau 2000a) appear throughout the paper. To conserve space, figure 1 serves as a common key.

### Legal Foundations

The Agricultural Research, Extension, and Education Reform Act of 1998, Public Law 105-185, was integrated into the United States Code as 16 U.S.C. 1642(e). The expanded citation is Title

16, Chapter 36, Subchapter II, Section 1642, Subsection (e). That law mandates the FIA program to survey the forest resources of the United States. Later in the same subchapter, 16 U.S.C. 1645(f) (Office of the Law Revision Counsel 2000) defines what the United States is:

*For the purposes of this subchapter, the terms "United States" and "State" shall include each of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands of the United States, the Commonwealth of the Northern Mariana Islands, the Trust Territory of the Pacific Islands, and the territories and possessions of the United States.*

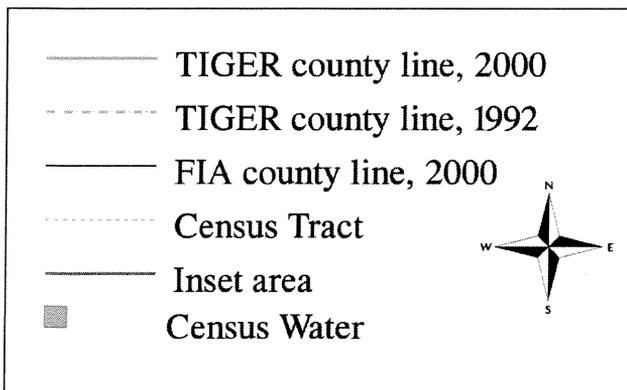
This provision was part of the Forest and Rangeland Renewable Resources Research Act of 1978 (Public Law 95-307), which became law on June 30, 1978.

The TTPI (Trust Territory of the Pacific Islands), entrusted to the United States by the United Nations in 1947, no longer exists. It consisted of what is now the NMI (Northern Mariana Islands), the RMI (Republic of the Marshall Islands), the FSM (Federated States of Micronesia), and Palau (The Republic of Palau). The NMI became a commonwealth of the United States in January 1978. The FIA program has announced its intention to survey the TTPI as it was defined at the time of the passage of Public Law 95-307 (USDA 1999).

The territories and possessions referenced in 16 U.S.C. 1645(f) are listed in table 1 (Bureau of the Census 1994, Central Intelligence Agency 2002). They are all in the Pacific Ocean except for Navassa Island in the Caribbean Sea. Also listed are the land and water area of each in mi<sup>2</sup> (square miles) and km<sup>2</sup> (square kilometers). Surface water estimates for the smaller possessions are not available, but maps and tables (Central Intelligence Agency 2002) show no inland water.

The Census Bureau (Bureau of the Census 1971) published the area of the Trust Territory at 717 mi<sup>2</sup> of land and 7,772 mi<sup>2</sup> of water. Data from Bryan (1971) suggest this estimate was primarily coastal water and did not include territorial sea. After the NMI became a commonwealth, land estimates were revised to 533 mi<sup>2</sup> for the TTPI and 184 mi<sup>2</sup> for the NMI

Figure 1.—Key for maps.



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done

(Bureau of the Census 1981). They did not issue surface water estimates, but maps (Bureau of the Census 1982) indicate little inland water, if any. In 1986, the RMI and the FSM gained independence. In the next decade, the Census Bureau's estimate for Palau was 177.3 mi<sup>2</sup> of land and 452.6 mi<sup>2</sup> of water (Bureau of the Census 1994), including 40.1 mi<sup>2</sup> of inland water. The estimates for the NMI were revised to 179.0 mi<sup>2</sup> of land and 1,770.9 mi<sup>2</sup> of water, including 2.2 mi<sup>2</sup> of inland water. In 1994, Palau gained independence.

The latest estimates from the CIA (Central Intelligence Agency) report the RMI at 181.3 km<sup>2</sup> (70.0 mi<sup>2</sup>) of land, the FSM at 702 km<sup>2</sup> (271 mi<sup>2</sup>), and Palau at 458 km<sup>2</sup> (177 mi<sup>2</sup>) of land (CIA 2002). The same source reports no inland water.

## TIGER

TIGER files (Topologically Integrated Geographic Encoding and Referencing files) are the long-awaited precise digitized boundaries of census land and census water, first released in 1992. Upon that version of TIGER was laid the hexagon grid used for placing FIA plots. A hex center was assigned to a state if it landed in that state according to TIGER 1992.

The data are hierarchical, with States and State-equivalents at the top of the hierarchy. County-equivalents are one level below. In the several States, county-equivalents are counties, but also independent cities in Maryland, Missouri, Nevada, and Virginia, as well as parishes in Louisiana, and boroughs, census divisions, and the Municipality of Anchorage in Alaska. The District of Columbia is not divided into county-equivalents. In the territories, county-equivalents are municipios in Puerto Rico,

islands in the Virgin Islands, municipalities in the NMI, and islands and districts in American Samoa. The *Census of Agriculture* (NASS 1996) reports Guam by election districts, although TIGER views such districts as minor civil divisions and all of Guam as one county-equivalent. To date, the only possession smaller than American Samoa for which TIGER files are produced is the Midway Islands, in one county-equivalent.

Several levels below the county-equivalent level are census tracts and beneath that level are census block groups and census blocks. Further details may be found in the Census 2000 TIGER/Line Technical Documentation (U.S. Census Bureau 2000b).

According to the *Geographic Areas Reference Manual* (U.S. Census Bureau 1994), area estimates were calculated from TIGER, but no further details were given, such as projection information. Raw TIGER data are in latitude and longitude. To calculate acres, one must project the data, at least indirectly.

There are many different projections. Since the users are interested in total surface area, it makes sense to use an equal-area projection. The Cylindrical Equal Area projection preserves cardinal directions in its equatorial aspect. The Lambert Azimuthal Equal Area projection, based on a plane, preserves area and distance from the projection origin. Far away from the origin, the projection starts to bend back on itself and thus should not be used for an area much larger than a continent. The Albers Equal Area projection is based on a cone. It appears that for many counties in the conterminous United States, the Albers Equal Area projection, North American Datum of 1983, GRS (Geodetic Reference System) 1980 Spheroid, standard parallels of 45° 30' N. and 29° 30' N., with projection origin at 96° W. and 23° N., gives results that are nearly equal to those in the gazetteer.

Other choices are available. Although it is not quite equal area, State Plane is popular in the land surveying community. One caveat is that in South Carolina, "State Plane Feet" means International Feet, although acres are still in U.S. Survey units. As with UTM (Universal Transverse Mercator), the zones do not stitch together.

Although the exact amount of surface area varies somewhat with the choice of projection, TIGER files confirm 2.5 mi<sup>2</sup> (6.4 km<sup>2</sup>) of land, no inland water, and estimate about 140 mi<sup>2</sup> (360 km<sup>2</sup>) of coastal water and territorial sea for the Midway

Figure 2.—*Suggested Metric Equivalents table.*

<b>Metric Equivalents (bold figures are exact)</b>
<b>1 foot = 1200/3937 meter = 0.304 800 610 meter</b>
1 acre = 4,046.87 square meters or 0.404 687 hectare
<b>1 inch = 2.54 centimeters or 0.0254 meter</b>
<b>1 foot = 0.3048 meter</b>
breast height = 1.37 meters above ground
1 square foot = 929.03 square centimeters or 0.0929 square meter
1 cubic foot = 0.028 317 cubic meter
1 square foot basal area per acre = 0.229 567 square meter per hectare
<b>1 pound = 0.453 592 37 kilogram</b>
<b>1 ton = 0.907 184 74 metric ton</b>
U.S. Survey units are in <i>italics</i> . International units are in roman.

Islands. The other small possessions of the United States are about as compact as the Midway Islands; for them, one would expect a similar amount of coastal water and territorial sea.

One might think that the various equal-area projections might give identical answers, at least for identical spheroids. They would for sufficiently densified arcs, but GIS (Geographic Information Systems) programs assume a straight line between the points of a polygon in the current projection.

## Area Measurement

Since one can get different answers depending on choice of projection as well as choice of software and computer platform, it might be best to see what areas the Census Bureau has published.

The *Area Measurement Reports* (Bureau of the Census 1970) listed land and inland water for each county-equivalent to a 10th of a square mile, as well as the number of square miles of offshore water (coastal water, territorial sea, and Great Lakes water) for each state.

The *Census of Agriculture* (e.g., NASS 1999a) publishes estimates of land in a county-equivalent to the nearest U.S. survey acre for most county-equivalents. Many independent cities in Virginia are not listed.

The *Population and Housing Unit Counts, CPH-2* (Bureau of the Census 1990) included land estimates to the nearest 10th

of a square mile and 10th of a square kilometer for each county-equivalent in the 50 States, the District of Columbia, Puerto Rico, as well as the total for other territories and possessions. The data were published electronically at the census tract level (*CPH-3*) wherein land estimates were published to the nearest 100th of a square mile for each census tract.

However, the Census Bureau (U.S. Census Bureau 2001a, b) now publishes estimates of land and water to the nearest square meter in Summary Files 1 and 2. In the previous decade, such estimates were published to the nearest thousand square meters. A simplified version of this database, with the areas of county-equivalents reported in square meters and square International Miles, may be found on the Census Bureau's Web site, at [www.census.gov/geo/www/gazetteer/places2k.html](http://www.census.gov/geo/www/gazetteer/places2k.html).

During the 1990s, FIA used an internal database. It closely followed but did not necessarily match the gazetteer or the *Census of Agriculture*.

The most precise units for area are in the gazetteer. It is in square meters, and converting it to acres is more difficult than it first appears to be.

Years before there was a National Biological Survey, there was the National Bureau of Standards. In 1988, it became the National Institute of Standards and Technology, or NIST. The agency is responsible for governing the weights and measures in the United States. In 1959, it offered refined values for the yard and the pound (National Bureau of Standards 1959). It defined the foot to be 0.3048 of a meter. Previously, it had been defined as 1200/3937 of a meter. The new unit was named the "International Foot" and the old unit would be called the "U.S. Survey Foot." Similarly, 1 International Yard was 3 International Feet, and 1 U.S. Survey Yard was 3 U.S. Survey Feet. Most measurements were to be made with International units, but geodetic measurements were to be made in Survey units. The 1959 memo envisioned retirement of the U.S. Survey units, but even now, the *NIST Handbook 44* recognizes an acre in the U.S. Survey system but not in the International (Butcher *et al.* 2001).

The acre based on the International Foot is exactly 4,046.856 4224 m<sup>2</sup> but is often reported to two or three significant digits beyond the decimal point. It is recognized by several standards boards around the world, including the Land

Table 1.—Territories and possessions of the United States

Territory	Land area		Water area	
	km <sup>2</sup>	mi <sup>2</sup>	km <sup>2</sup>	mi <sup>2</sup>
<b>Guam</b>	543.5	209.8	934.4	360.8
<b>American Samoa</b>	200.3	77.3	1310.4	505.9
<b>Palmyra Atoll</b>	11.9	4.6	(NA)	(NA)
<b>Wake Island</b>	6.5	2.5	(NA)	(NA)
<b>Midway Islands</b>	6.4	2.5	(NA)	(NA)
<b>Navassa Island</b>	5.2	2.0	(NA)	(NA)
<b>Jarvis Island</b>	4.5	—	(NA)	(NA)
<b>Johnston Atoll</b>	2.8	1.1	(NA)	(NA)
<b>Howland Island</b>	1.6	—	(NA)	(NA)
<b>Baker Island</b>	1.4	—	(NA)	(NA)
<b>Kingman Reef</b>	1.0	0.4	(NA)	(NA)

(NA) not available

Information New Zealand ([www.linz.govt.nz/staticpages/dcdb/dataquality.htm](http://www.linz.govt.nz/staticpages/dcdb/dataquality.htm)), Measurements Canada, and the United Kingdom's National Weights and Measures Laboratory ([www.nwml.gov.uk/consumer/units.asp](http://www.nwml.gov.uk/consumer/units.asp)). However, this acre is sometimes cited in American sources such as the CRC Press (Beyer 1978), the Army Corps of Engineers (Perrier *et al.* 1980), and even FIA (e.g., Smith *et al.* 2002). On the other hand, such sources as *The World Almanac* (Famighetti 1997) explain the difference between International and U.S. Survey units.

Breast height is 4.5 International Feet, exactly 1.3716 meters. While this number does round to 1.4 meters, breast height should be reported to at least three significant digits to reflect the precision with which the measurement is taken.

Table 2.—*Split independent cities*

	Census Land m <sup>2</sup>	Census Water m <sup>2</sup>
Carroll	12,020,499	—
Grayson	9,290,641	—
Galax	21,311,140	—
Dinwiddie	24,176,386	565,298
Prince George	35,084,580	224,164
Petersburg	59,260,966	789,462
Chesterfield	87,962,551	3,692,453
Henrico	67,618,812	2,725,776
Richmond	155,581,363	6,418,229

Figure 2 shows a Metric Equivalents table that incorporates the preceding recommendations, with decimals formatted according to the guidelines of the *U.S. Government Printing Office Style Manual* (U.S. Government Printing Office 2000).

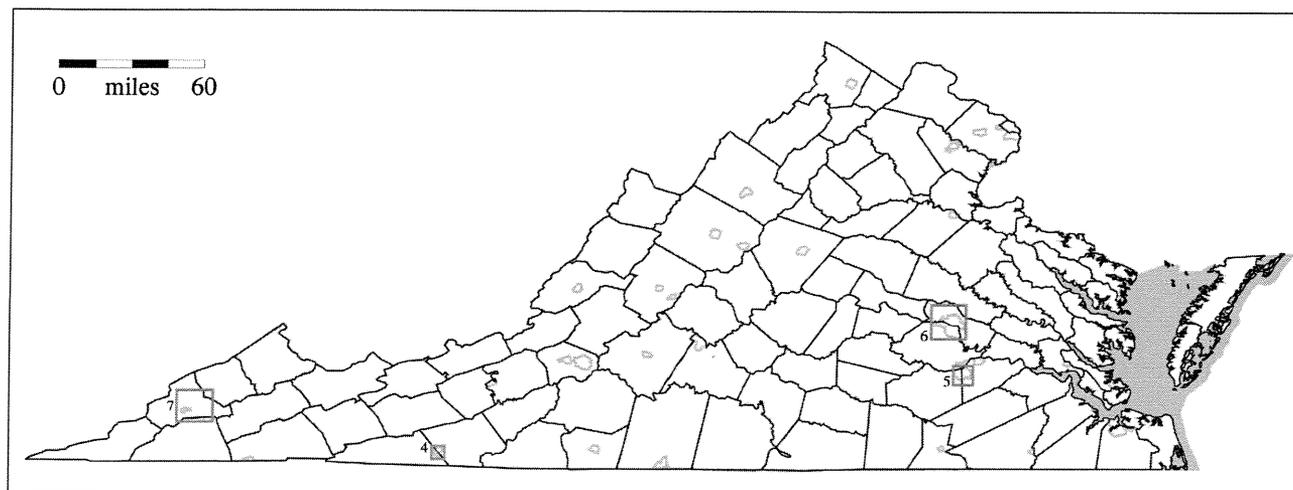
## Virginia

Although it refers to itself as the “Commonwealth of Virginia,” Virginia is one of the several States and not a Commonwealth in the sense that Puerto Rico and the NMI are.

FIA prefers to report county acreages along traditional county-equivalent lines rather than legal ones, as shown in figure 3. This convention is not purely an invention of the FIA program; a similar map may be found on the Official Commonwealth of Virginia Home Page site, at [www.vipnet.org/portal/images/vamap.jpg](http://www.vipnet.org/portal/images/vamap.jpg). Some independent cities are retained; most others are dissolved into surrounding counties or independent cities. There are three exceptions: the cities of Galax, Richmond, and Petersburg. These cities are each split between two legal counties. The distribution of land and water in square meters is shown in table 2.

One interesting result in this table is that GIS shows a disproportionately higher amount of census water in the western part of Petersburg than in the eastern part. It also shows the proportion of census water in the northern part of Richmond approximately equal to that in the southern part. The GIS technique is better than those used in the 1992 survey, where nomi-

Figure 3.—*Virginia.*



nal proportions were calculated from unrectified maps and photos and also nominal proportions were applied to census land and census water without regard to which part of the independent city they were in. Direct calculation in GIS clearly gives more accurate results.

Detailed maps of Galax, Petersburg, and Richmond are shown in figures 4, 5, and 6, respectively. Census blocks were assigned to FIA counties based on which side of the historical line the centroid was. In the case of Galax, the historical line is the line between Carroll County and Grayson County extended linearly. Census blocks whose centroids were west of this line are to be tabulated with Grayson County while those east of the line are to be tabulated with Carroll County. In the case of Petersburg, the historical line is more obscure, but it runs approximately north from the point of intersection between Petersburg, Dinwiddie County, and Prince George County. Census blocks whose centroids fall east of this line are tabulated with Prince George County while those whose centroids fall west of the line are tabulated with Dinwiddie County. In the case of Richmond, the historical line was maintained in modern-day TIGER, along census tract rather than just census block lines. The line is the James River, which is not a line, but a double-line stream. Census tracts south of this line are tabulated with Chesterfield County, while those north of the line are tabulated with Henrico County.

Another point is that Census Water polygons can be smaller than 4.5 acres, a fact that conflicts with the FIA national core

field guide (USDA 2002). Among the original sources of TIGER data were 1:100,000 Digital Line Graphs of the USGS (United States Geological Survey). The standards for those data did allude to 4.5 acres as a minimum size for a water polygon, but they also said, "In arid and semiarid areas, the presence and location of water is important as a means of orientation. In these areas, as many hydrographic features as possible should be shown" (USGS 1991). While that source supports 200 feet as the minimum width of a double-line stream, the Census Bureau used other sources of data (most notably their own Metropolitan Map Series) in constructing TIGER files. These data did not necessarily adhere to the lower bound for water polygons of 4.5 acres nor to the lower bound of double-line streams of 200 feet.

### TIGER 1992 vs. TIGER 2000

Apart from Virginia, three other States (Alaska, Maryland, and Montana) had jurisdictional changes at the county-equivalent level during the 1990s. However, there were many changes to the TIGER database between 1992 and 2000. These changes appear to have been digitizing errors being corrected. Luckily, no hex centers in the Southern Station switched States. A few hex centers went from territorial sea to international water. Figure 7 indicates two possible sites in Wise County, Virginia, that changed counties during the 1990s due to changes in the

Figure 4.—Galax.

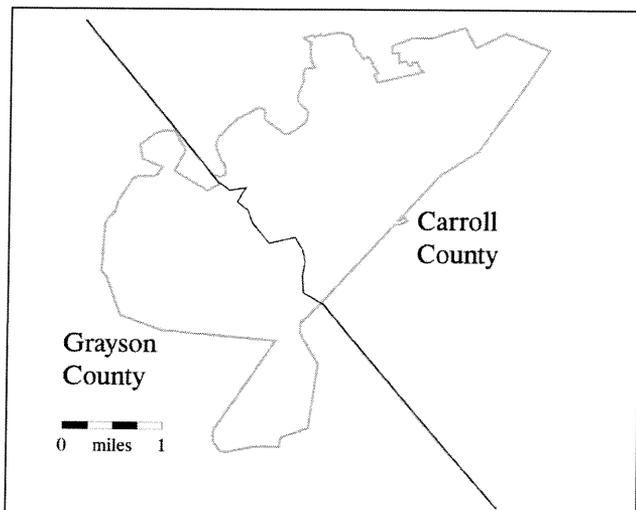


Figure 5.—Petersburg.

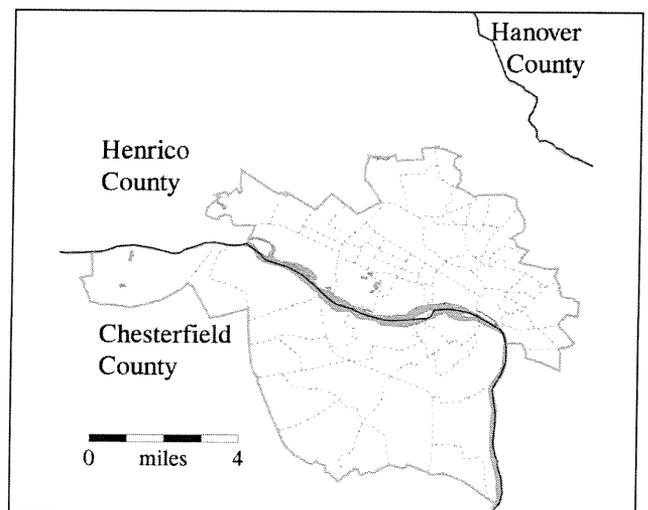
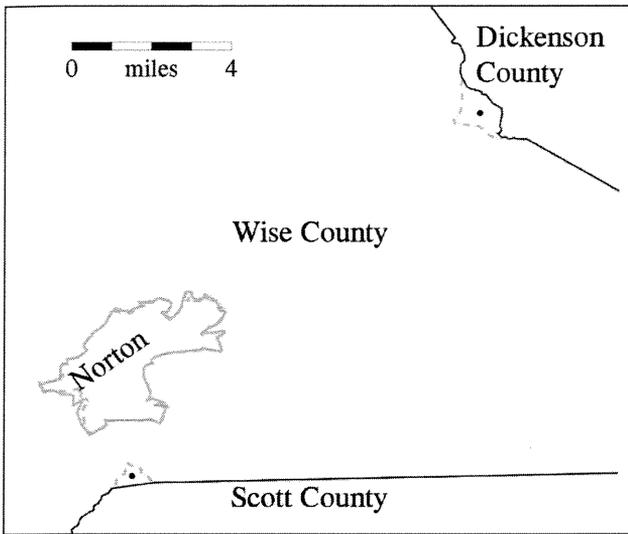


Figure 6.—Richmond.



TIGER database. Nationwide, there are hundreds, if not thousands, of such sliver polygons. Tracking them would be a monumental task.

## Summary and Recommendations

First, logistical difficulties may make areas such as Navassa inaccessible. In such areas, photointerpretation should be done by remote sensing. A site visit to Navassa could be reconsidered if its spectral signatures were significantly different from accessible areas of Puerto Rico and the U.S. Virgin Islands.

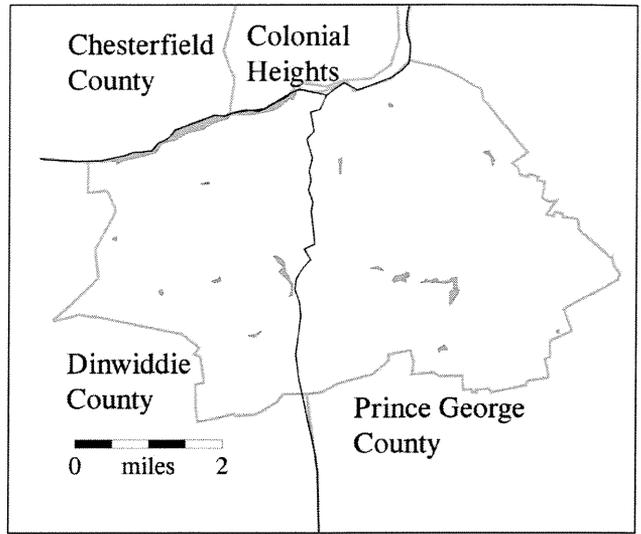
Second, a Metric Equivalents table such as in figure 1 should be adopted.

Third, the program should adopt the most precise estimates of Census Area available. Specifically, those are the gazetteer and Summary Files for the several States, the District of Columbia, and Puerto Rico; Summary Files only for the U.S. Virgin Islands, American Samoa, Guam, and the NMI. The *CIA World Factbook* is a possible source for current area estimates of other possessions and freely associated nations.

Fourth, Virginia's FIA county delineations should be as outlined in this paper.

Fifth, a policy should be constructed governing what happens if an FIA plot switches counties. This change may happen for several reasons: 1. the Census Bureau may correct the TIGER line, 2.

Figure 7.—TIGER 1992 vs. TIGER 2000.



the GIS analyst may have generated a plot coordinate based on a faulty algorithm, 3. the GIS analyst may have relied on coordinates that were inaccurate, 4. the GIS technician may have used a faulty base map or lost his or her place while digitizing, 5. coordinates from GPS (Global Positioning System) units may have been collected or transcribed incorrectly, 6. finally, the field crew may notice that the plot is in the incorrect county.

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