# NAIP 2008 Absolute Ground Control: From the Ground Up

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# Table of Contents

Page No.



# Table of Figures

# Background

In the early years of the National Agriculture Imagery Program (NAIP), the NAIP contract called for a horizontal accuracy specification that was based upon "relative" accuracy, meaning the imagery was tied to older imagery datasets. Initially this worked well, but the idea of tying NAIP imagery to potentially spatially inaccurate data was not ideal for the long run. It was decided in 2006 to gradually introduce a horizontal accuracy specification for NAIP imagery based upon "absolute" ground control. This meant that the NAIP imagery would be tied to true ground as opposed to older imagery. There were many reasons for doing this. For example, an absolute specification does not use errors and offset from former imagery. As a result, there will be less manipulation of other data sets in the future to match imagery data.

In 2006, Utah was the "pilot" state for the switch to an absolute accuracy standard. There were 410 ground control points used for assessing the horizontal accuracy of the NAIP imagery. In 2007, Arizona was the "pilot" state; there were 544 points used. Both of these horizontal accuracy "pilots" were documented with white papers available on the APFO website (http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=docs&topic=wpp). For the 2008 NAIP, seven of the 20 states were selected to migrate to "absolute" control.

A large part of the migration to an absolute specification involves obtaining control points to facilitate the inspection of the NAIP imagery. This effort is coordinated by the APFO Geospatial Services Branch. This document will discuss that process as well as analyze the horizontal accuracy inspection data for the 2008 Indiana NAIP imagery.

# Part I- Ground Control Point Database

## Ground Control Point Acquisition

In order for the horizontal accuracy inspection to occur, control points must be collected, inspected, and databased. This is an ongoing process; ideally control points are constantly "flowing" into our database. In the first two years, ground control was collected for vendor orthoimagery production as well as the APFO inspection. Beginning in 2008, this was no longer the case. For Utah (2006) and Arizona (2007), a certain number of points were provided to the NAIP vendors to assist in imagery production. This was done because the idea of switching to absolute accuracy was still in a "pilot program" stage and it theoretically helped to keep contract costs down.

The control point acquisition process has two main purposes: first, to support the horizontal accuracy assessment of the NAIP imagery and second, to help create a nationwide, photo-identifiable control database. Currently, the points that are databased are not for public use. Once the database becomes populated with an extensive amount of control, there is the potential the control points will be available to the public; however certain points that are licensed, obtained by signed agreement, or coded as private will never be released to the public.

The actual process of gathering control points begins in November or December before the NAIP year. Initial contact is made with the Farm Service Agency (FSA) state GIS specialists, often at the NAIP planning meeting. The next step is to set up a "kick-off" telecon with each state. The purpose here is to introduce the whole control point process to various individuals. Usually the main contacts are USGS Geospatial Liaisons, FSA state GIS specialists, and members of state geographic data consortiums. In these "kickoff" telecons, the whole purpose and process of what we are doing is explained. The point requirements are discussed as well as any other needs and issues. The following is a link to the point requirements: (http://www.fsa.usda.gov/Internet/FSA_File/naip_cpr_final.pdf.pdf). Telecons are then held as necessary to keep all parties involved abreast of the point acquisition process.

Control points are received at APFO in an ongoing basis. The majority of the points are from the US Geological Survey (USGS); the US Forest Service (USFS), National Geodetic Survey (NGS), National Oceanic and Atmospheric Administration (NOAA), also contribute points. Many of the points also come from state and local agencies. This includes departments of transportation, city and county governments, and other local level groups.

## Ground Control Point Database

As of May 2009, there were about 15,000 control points in our database (see figure 1). The points received are rigorously inspected to determine if they will meet the needs of the quality assurance process. This involves checking to see if the point is photo-identifiable on a 1-meter resolution image, and determining where the point falls on the image via the use of support data provided with the ground control point. Also, a point dataset must have a stated horizontal accuracy to be used in the inspection process.

Once points are deemed usable, they are ingested into the control point database via a load script. Each point is formatted to meet numerous field requirements, and then converted into a comma-separated value (csv) file to prepare for ingestion. Any supplemental data associated with a control point is stored in a different table in the database, but still linked to each respective point.

The point database must be constantly updated and checked to maintain the integrity of the data stored there. As NAIP imagery is inspected, the inspectors input a quality rating as well as comments for each point they check. This quality rating evaluates a point's "inspectability". The rating is scaled from 1 to 5, with 1 being the best value. A point rated 1 means the point is easy to inspect (good support data, easy to identify, etc.) (see figure 2). A rating of 5 means the control point should potentially be obsoleted in the inspection database.(see figure 3) At the end of the NAIP inspection for a particular year, the points that were rated 4 or 5 are examined to determine if they should be obsoleted in the inspection database. If the points are no longer feasible, they aren't actually deleted from the database, but flagged so that they cannot be used in future NAIP inspections.

## Ground Control Point Database Usage in Imagery Inspection

The horizontal accuracy assessment of the NAIP imagery involves using the control point database. The inspectors are able to access the database to retrieve control points that fall within the county boundary that is being inspected. The horizontal inspection is part of the quality assurance process. This process uses a custom ArcGIS application that allows the inspectors to digitize, rate, and comment on ground control points. Once a project is set up in the application, the inspectors can begin the horizontal accuracy check.

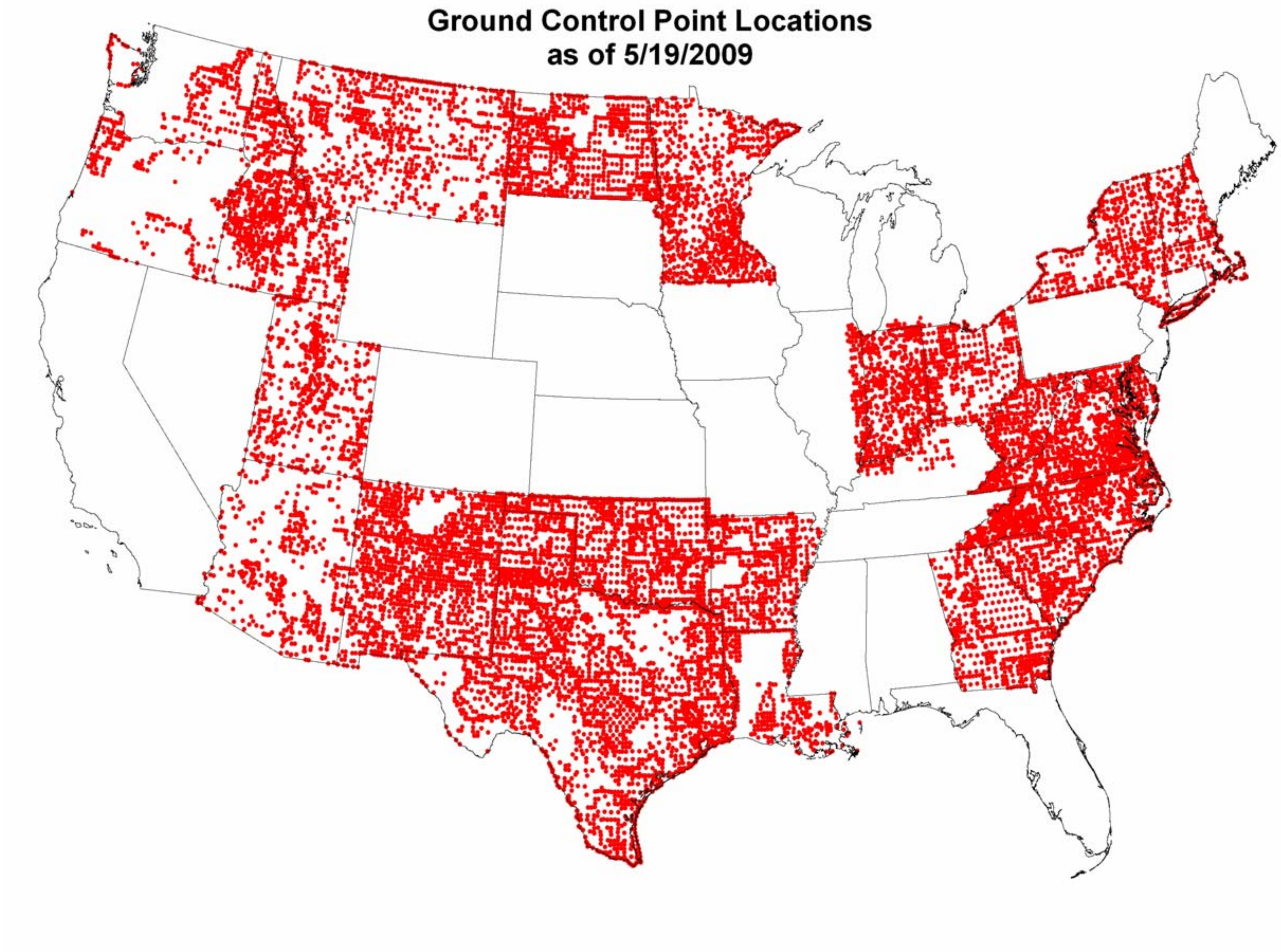


**Figure 1: Map of databased ground control points**

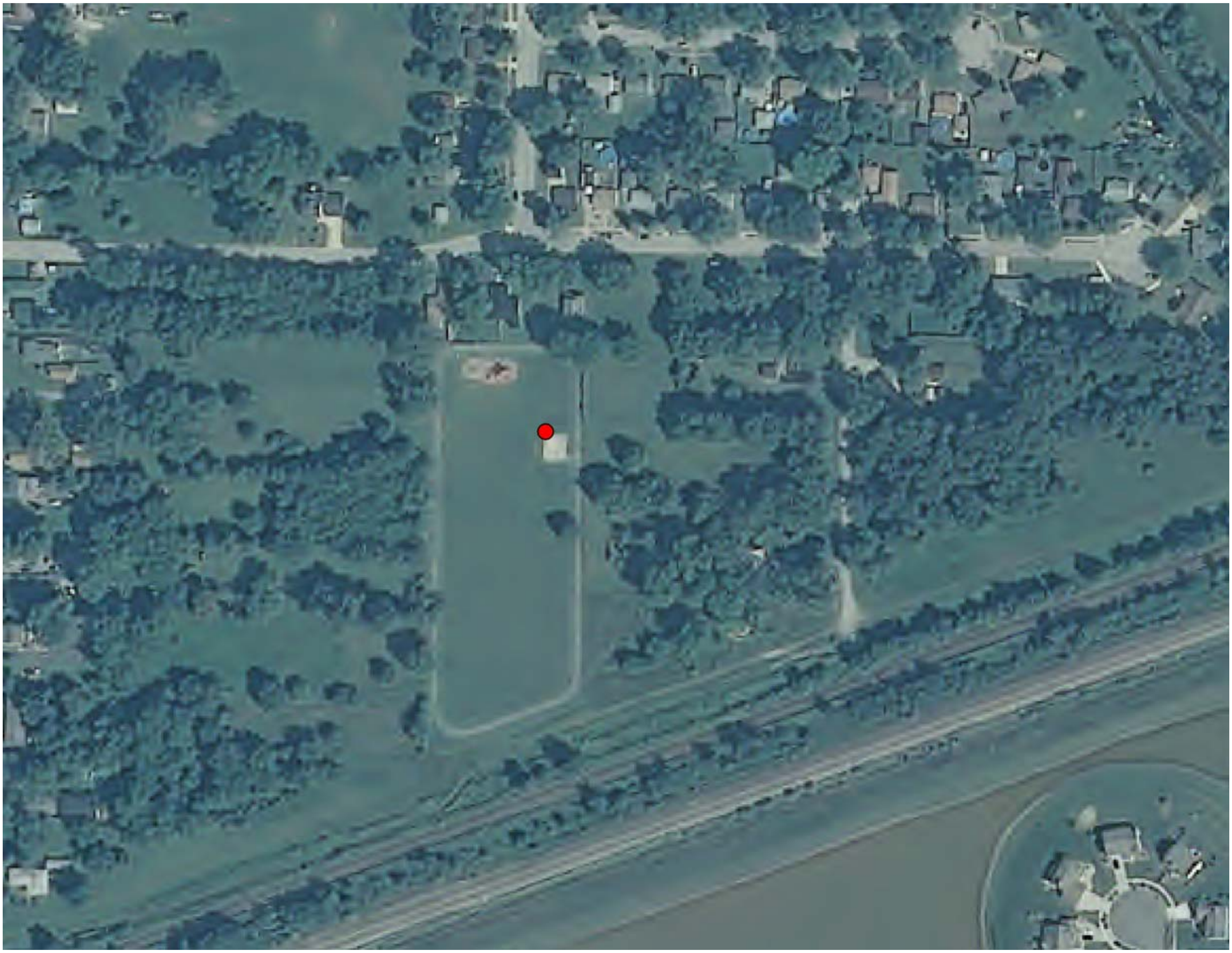

**Figure 2: Example of a ground control point with a quality rating of 1**

**Figure 3: Example of a ground control point with a quality rating of 5**

First, the corresponding control points are loaded into the application based upon a FIPS code. The inspector then “zooms” to a point location on the NAIP image (figure 4).

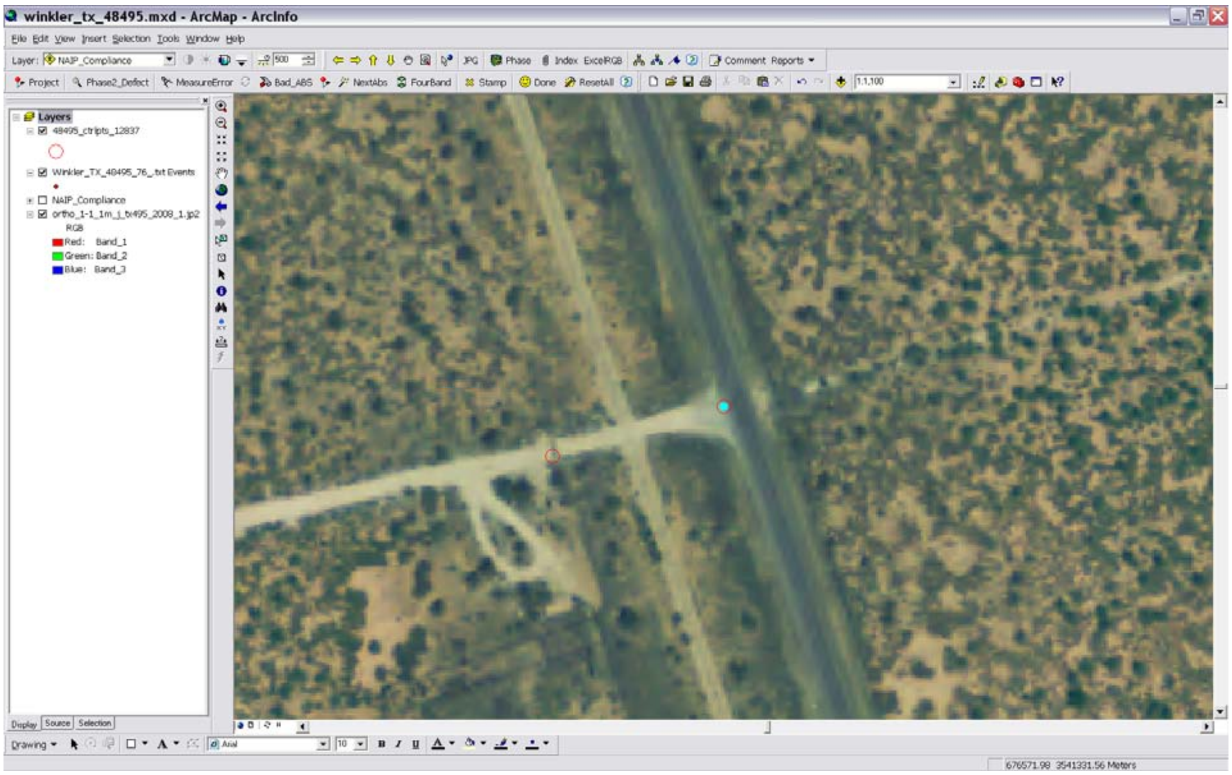


**Figure 4: Location of ground control points**

Next, the inspector accesses any associated supplemental information (figures 5 and 6). This supplemental data is stored as binary large objects in the same ORACLE table as the control points. The supplemental data can be on-site photographs, on-site drawings, observation sheets, aerial views, etc. This data is used to aid the inspectors in finding the exact location of a ground control point on a NAIP image. It is critical that the exact location of the point is determined on the image so that the “operator error” factor is minimized when calculating offset and RMSE values.

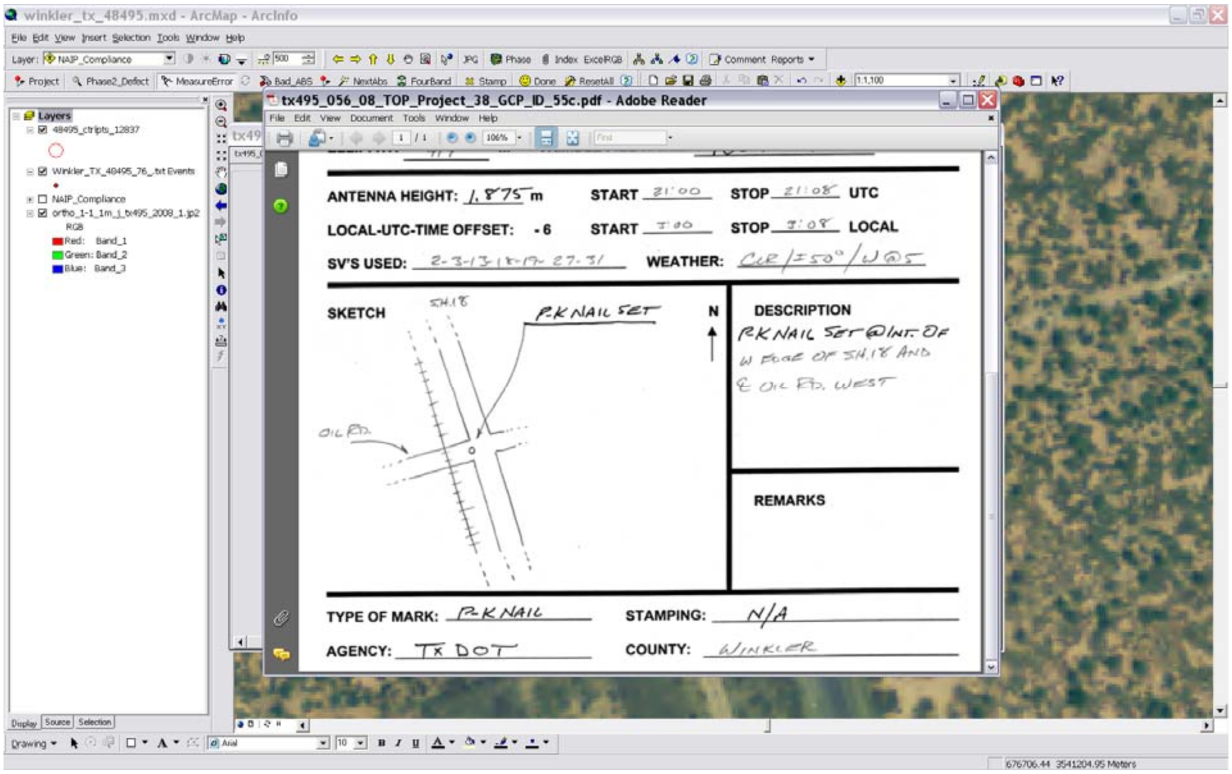


**Figure 5: Supplemental data**

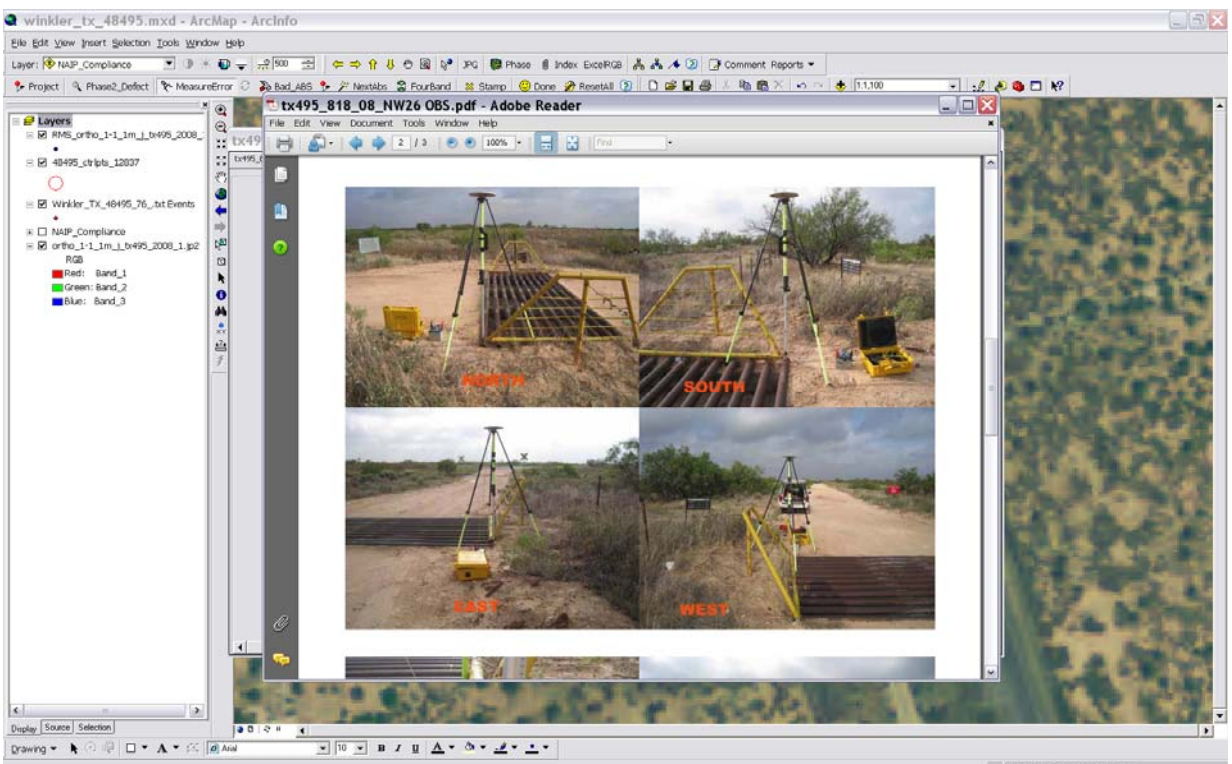


**Figure 6: More supplemental data**

Once the exact location of the point is determined, the inspector digitizes that location with a point feature. At this time, the offset distance from “true ground” is calculated (figure 7). This value is stored in an inspection database. After an entire state is inspected, this data is analyzed to determine if contract specifications were met.

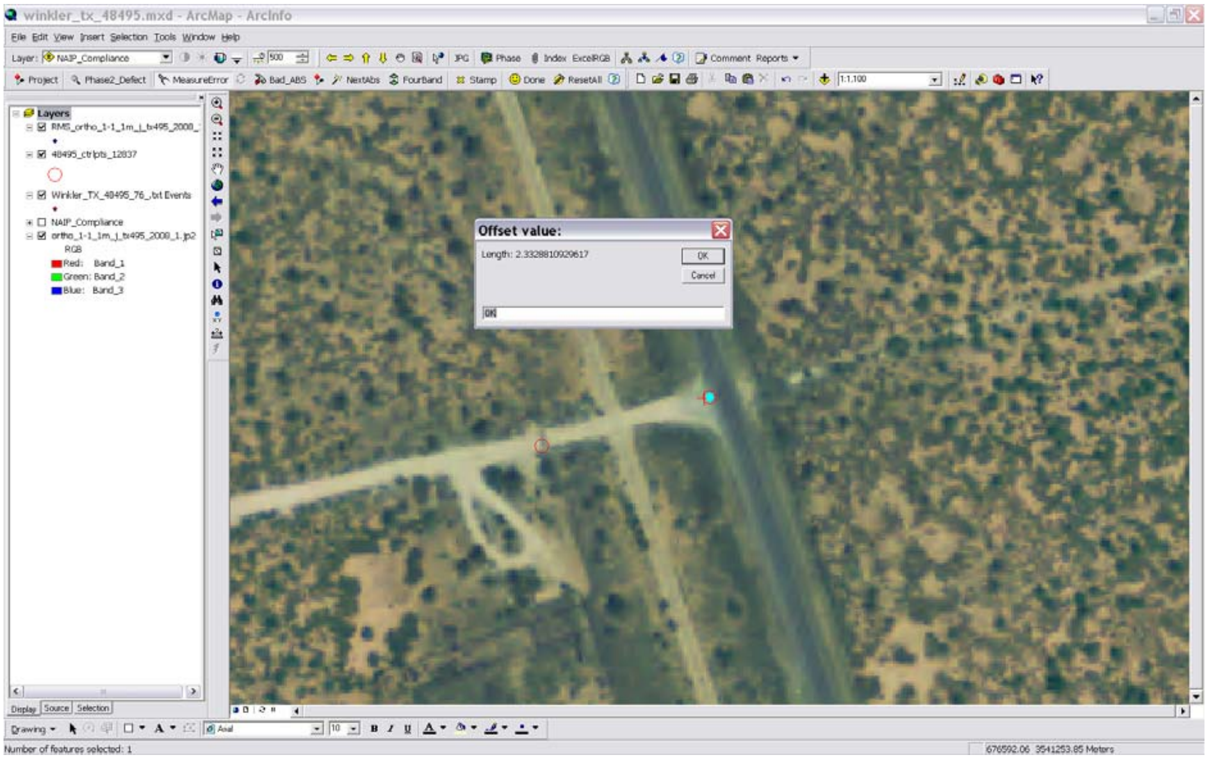


**Figure 7: Calculation of offset value**

Once the offset is determined, the inspector then uses a pop-up window to input a control point quality rating (figure 8). As previously mentioned, this rating determines the feasibility of a point in the inspection process; a poorly rated point may be obsoleted from the inspection database. The final pop-up window gives the inspectors the option to input any comments about the inspected point (figure 9).

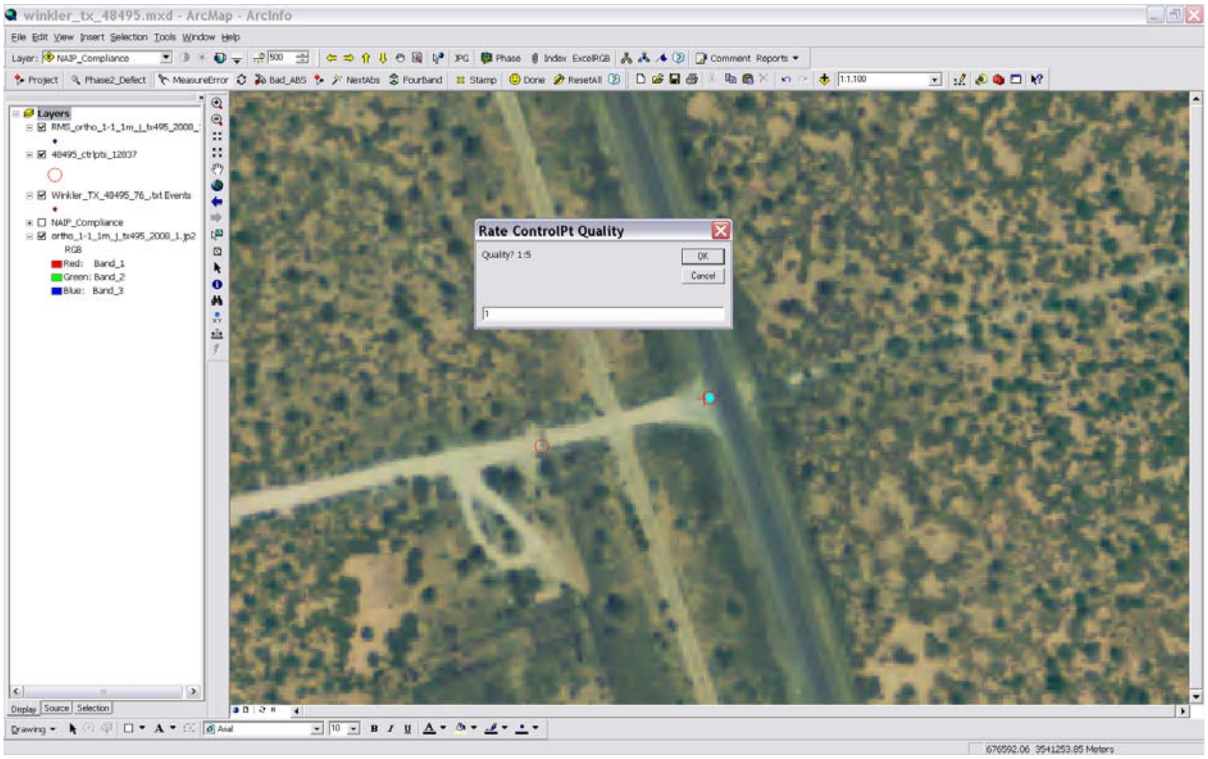


**Figure 8: Quality rating window**

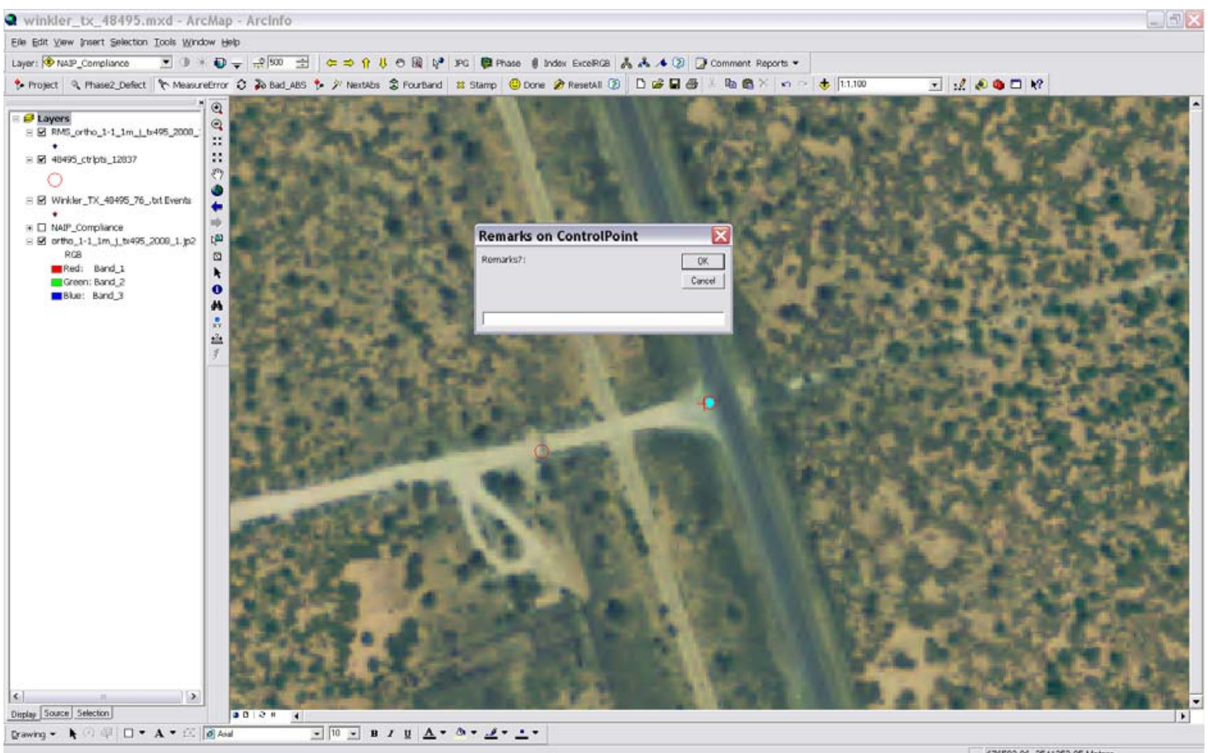


**Figure 9: Remarks window**

## Observations and Lessons Learned Regarding the Ground Control Point Database

The process of collecting, analyzing, databasing, and incorporating points into an inspection procedure requires a tremendous amount of work. Each part of the process has ups and downs. Collecting the points for the database was easier in some states than others. Often, this was due to control point availability as well as the teaming efforts of individuals assisting at the state and local levels. In some cases, states were eager to assist, even using their own resources to collect new control; in other states, resources were at a minimum. However, any amount of teaming and assistance from the state level was always appreciated. Existing control that met the current requirements was crucial to creating the database. For example, the USGS control points we receive make up 60% of the database. Some of the NAIP 2008 states had their own database of ground control and were happy to share the points with the APFO.

Inspecting the ground control points to determine if our requirements were met was a tedious process at times. Different data sets required different inspection methodologies. For example, with the USGS and USFS points, the points were consistently in the same types of locations with the same types of descriptions. This made it a little easier to inspect very large sets of points. On the other hand, some of the point data provided by state and local agencies required more work and preparation to get to an "inspection ready" format. Either way, inspecting the points was at times a monotonous process.

Databasing the points could be a long process. If the points were delivered in a format similar to the ideal control point format, the process was less difficult. If the points were formatted in a very different way, the process was extremely time-consuming and difficult. In the future, it may be a good idea to standardize the control point format to "streamline" the databasing process.

Using the points in the QA process had pros and cons. Learning to digitize a point where it should fall on an image as opposed to where it appeared took some time getting used to. Some inspectors had difficulty with the quality point rating. The ratings of "1" being the best and "5" being worst caused some confusion. The ratings have recently been updated with a number and a word description to avoid confusion in the future. Overall, the benefits of using known ground locations as opposed to older imagery in the horizontal accuracy inspection will benefit the quality assurance process greatly.

# Part II- Ground Control Point Inspection Statistics

The following part of the report will analyze the statistics from the Indiana NAIP 2008 absolute control point data. This process involved inspecting the points on the old MDOQs (Mosaicked Digital Ortho Quarter Quads) dating from the 1990's and then inspecting the same points on the 2008 Indiana NAIP CCMs (Compressed County Mosaics).

## Inspection Methodology

The inspection process was essentially the same for both the MDOQ imagery and the NAIP imagery. First, the Indiana control point shapefile from the database was loaded into ArcMap. Then, a new empty shapefile was created for the measured control points. These shapefiles had a field for the quality point rating. Next, the base imagery was loaded. This was either an Indiana NAIP 2008 CCM or the UTM Zone16 MDOQs from the APFO GDW (geodata warehouse). Inspection began once all layers were loaded. Based upon supplemental data, the photo identifiable control points were located and digitized on the associated imagery where deemed valid (figures 10 and 11). After digitizing, each point was then assigned the “quality” value from 1 to 5. Once all control points for the state were checked, then the “Point Distance” tool was used to check the offset distance between the true ground points and the points digitized on the MDOQ or CCM. This data helped to determine the horizontal accuracy of the imagery as well as the reliability of the true ground control point dataset.

**Figure 10: Digitizing a point on the NAIP 2008 image. The green point is the true ground location; the yellow point is the location on the NAIP image.**

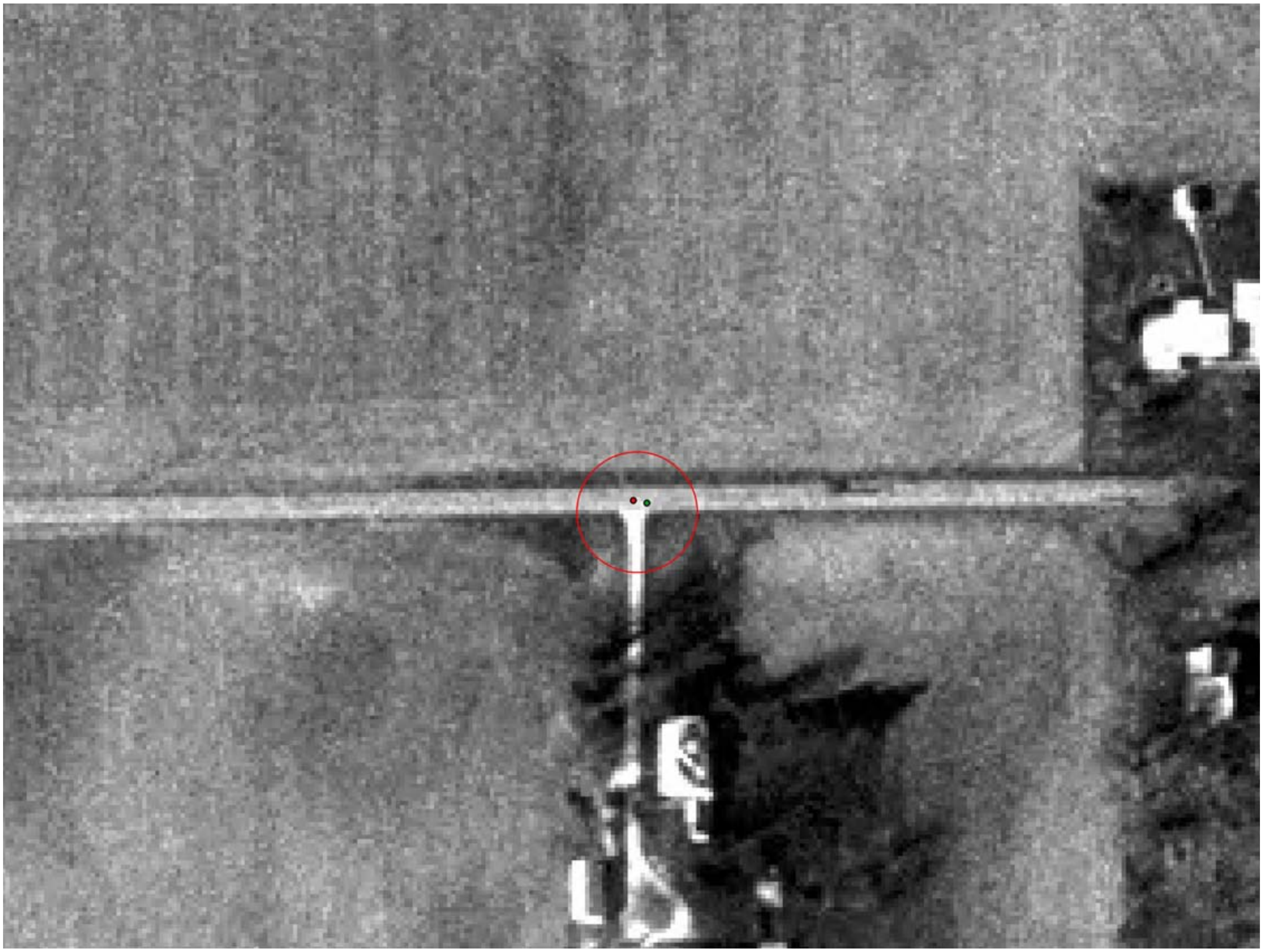

**Figure 11: Digitizing a point on the MDOQ image. The green point is the true ground location; the red point is the location on the MDOQ image**

## Inspection Statistics

As of May 2009, there were 493 control points databased for Indiana. Of the 493, 429 were used for the MDOQ inspection; 473 for the NAIP inspection. The reasons for not inspecting all the points varied. In some cases features did not exist on the MDOQ imagery, or no longer existed on the NAIP imagery. Some features were not photo-identifiable at the time of image acquisition. If the point was deemed not usable, it was left out of the inspection. In figure 12, the statistics are shown for the point offset distance from true ground for both the MDOQs and the NAIP 2008 imagery. There is not much difference between the two, other than the maximum offset distance.

| | Minimum Offset Distance in Meters | Maximum Offset Distance in Meters | Mean Offset in Meters | Standard Deviation | RMSE |
|---|---|---|---|---|---|
| **MDOQ Points** | 0.083730 | 43.160872 | 1.811658 | 2.473110 | 3.065677 |
| **NAIP 2008 Points** | 0.092780 | 17.169695 | 2.000794 | 1.583051 | 2.551319 |

**Figure 12: Control point statistics**

The overall percent accuracy (based on the standard that 95% of points tested are within 6 meters of true ground) for the points on the MDOQ imagery was **98.834%**. The percent accuracy for points on the 2008 NAIP imagery was **98.097%**. One of the reasons for the points measured on the NAIP being less horizontally accurate was because of a blurring issue with the Indiana CCMs. The blurriness sometimes inhibited the ability to see the point location clearly on the image. The histograms in figures 13 and 14 illustrate the point offset distances for the MDOQs and the NAIP imagery. Data in blue are within the 6 meter tolerance and data in red are outside the tolerance.

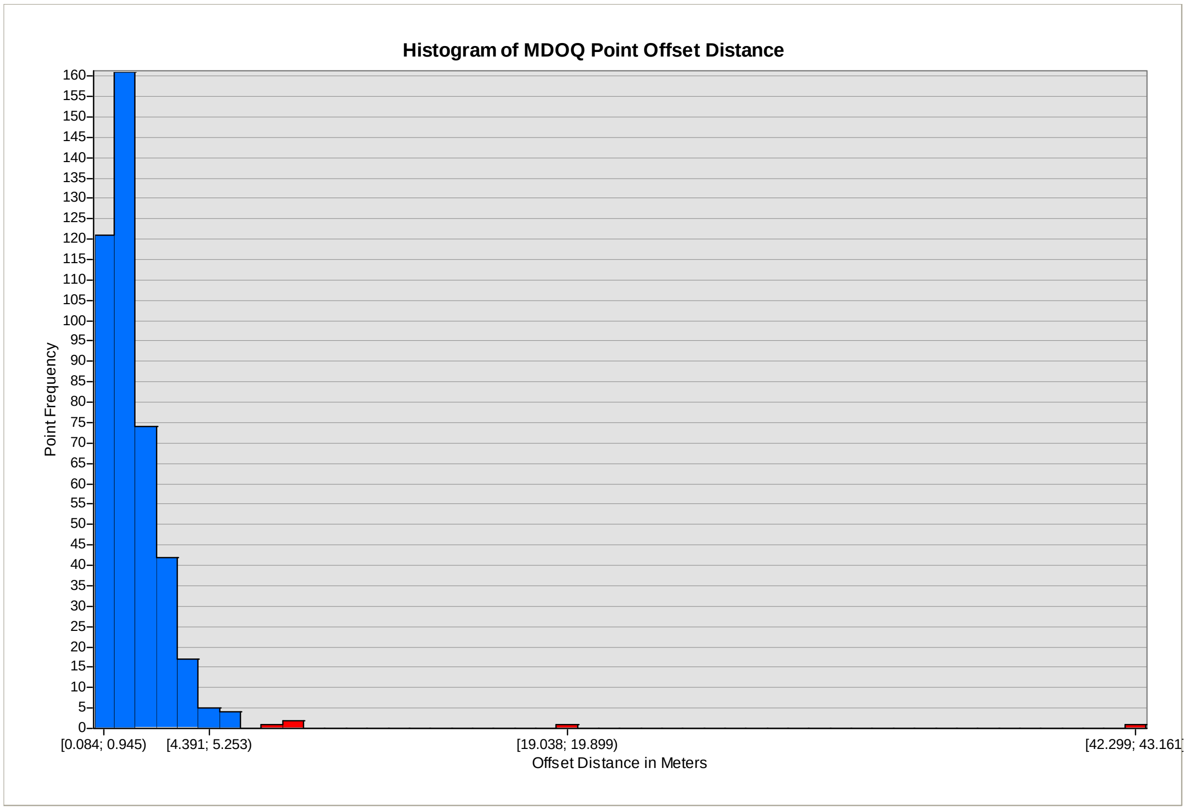


**Figure 13: Histogram showing MDOQ offset with point frequency**

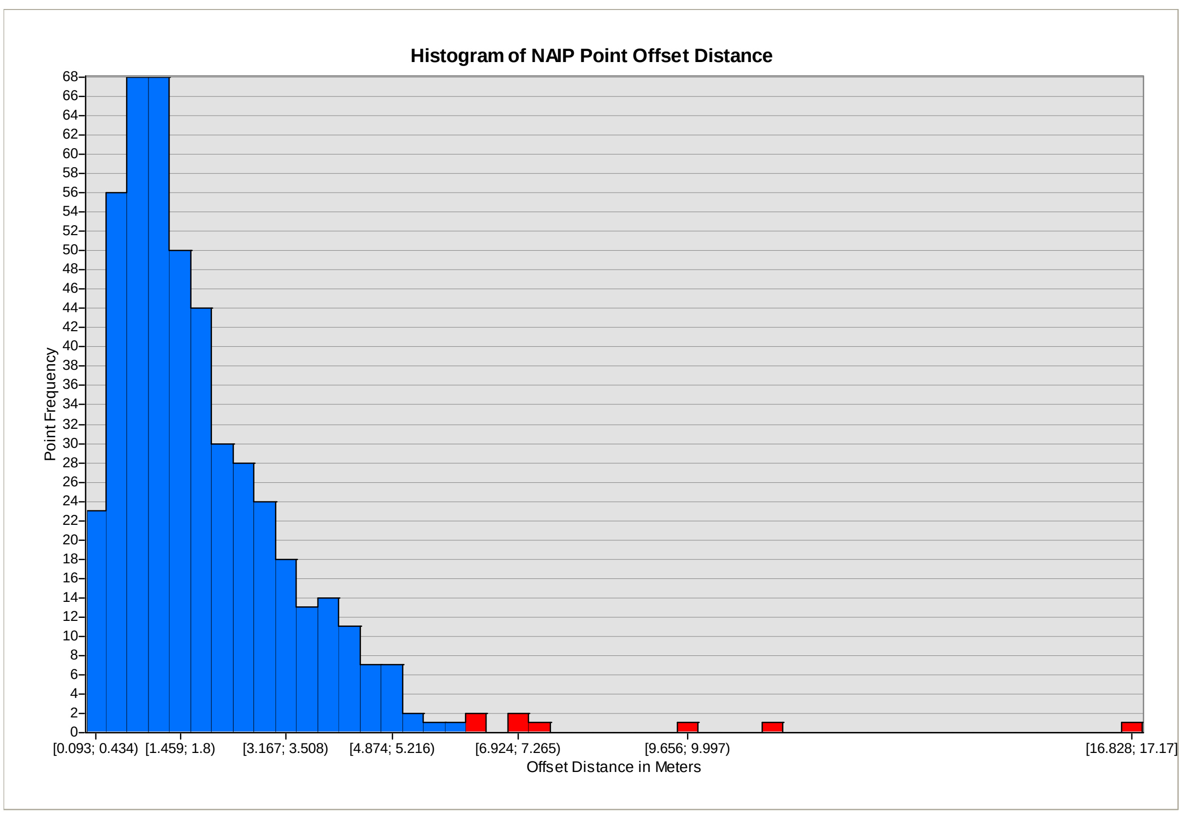


**Figure 14: Histogram showing NAIP offset with point frequency**

The quality rating is an important part of the horizontal accuracy inspection. It allows the inspector to rate the effectiveness of the point. In both the MDOQ and NAIP inspections, a rating was assigned only to points that were inspected. The graph in figure 15 illustrates the ratings. The MDOQs had a higher number of “5”s, but also had a higher number of”1”s.

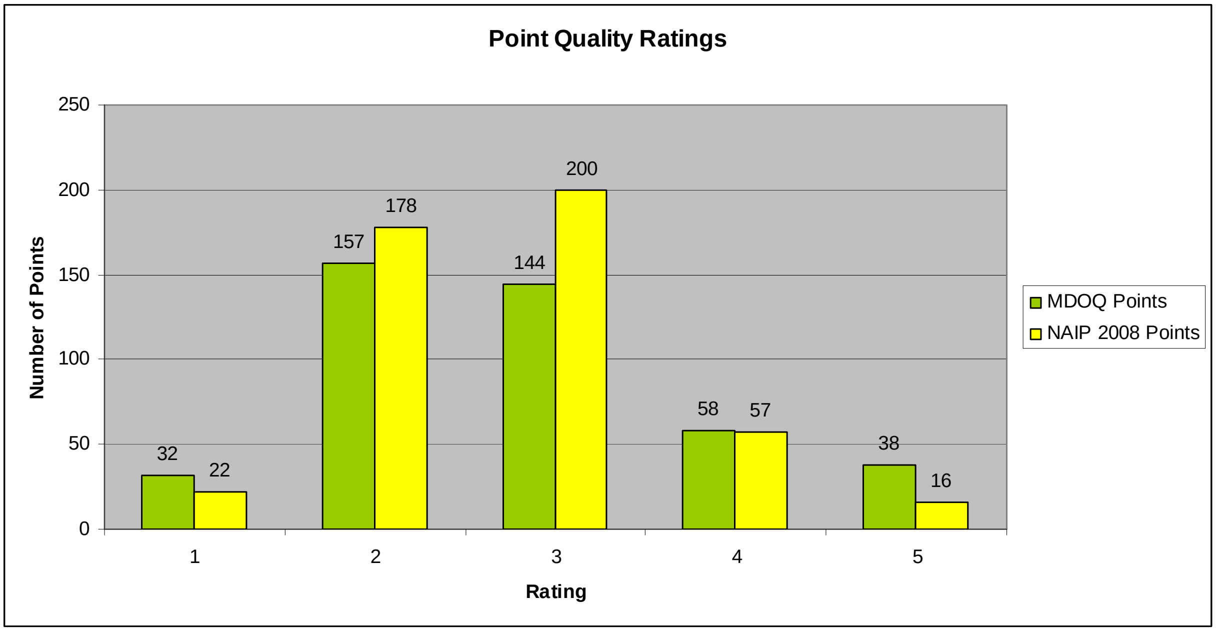


**Figure 15: Graph of quality ratings**

The NAIP points had a higher number of “2”s and “3”s and the “4” rating was about even. It can be observed that most of the points in both data sets were average or above average. It is also worthwhile to see what percentage of points have quality ratings that are within the 6 meter from true ground NAIP contract specification (figure 16). Nearly all points rated “1, 2, 3, or 4” were within the 6 meter tolerance on both sets of imagery. However, only 68.8% of points rated “5” on the NAIP imagery were within tolerance. This stands to reason since a “5” rating usually means the point should be removed from the database.


**Figure 16: Graph of quality ratings within offset tolerance**

The accuracy order for the control points ranged from sub-foot to 1.5 meters. It would be worthwhile to compare the points with the highest stated accuracy of sub-foot. Of the databased control, 9 points were listed as sub-foot. The graph in figure 17 compares the statistics between the NAIP imagery and the MDOQ imagery. All control points were within tolerance on both sets of imagery with the sub-foot points on the NAIP imagery having a lower RMSE and standard deviation. These 9 points had the lowest offset of any points checked on either imagery dataset. Figures 18 and 19 are histograms illustrating the distribution of point offsets on both NAIP 2008 and the MDOQs. The histograms show the NAIP imagery as having less offset from true ground.

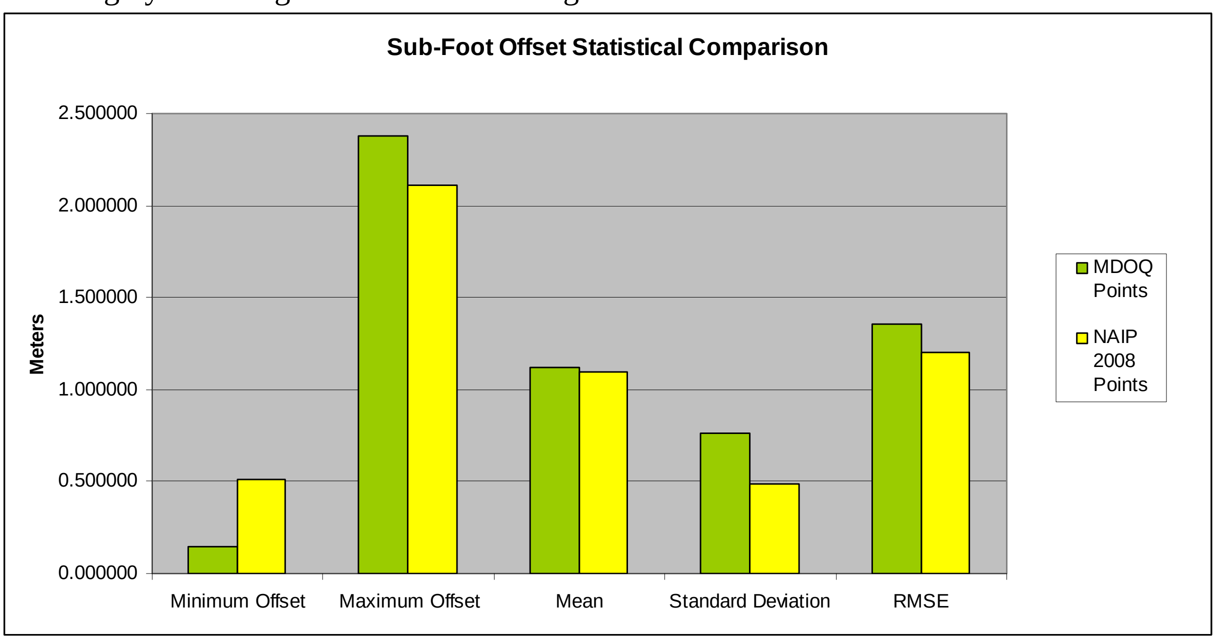


**Figure 17: Sub-foot accuracy statistical comparisons**

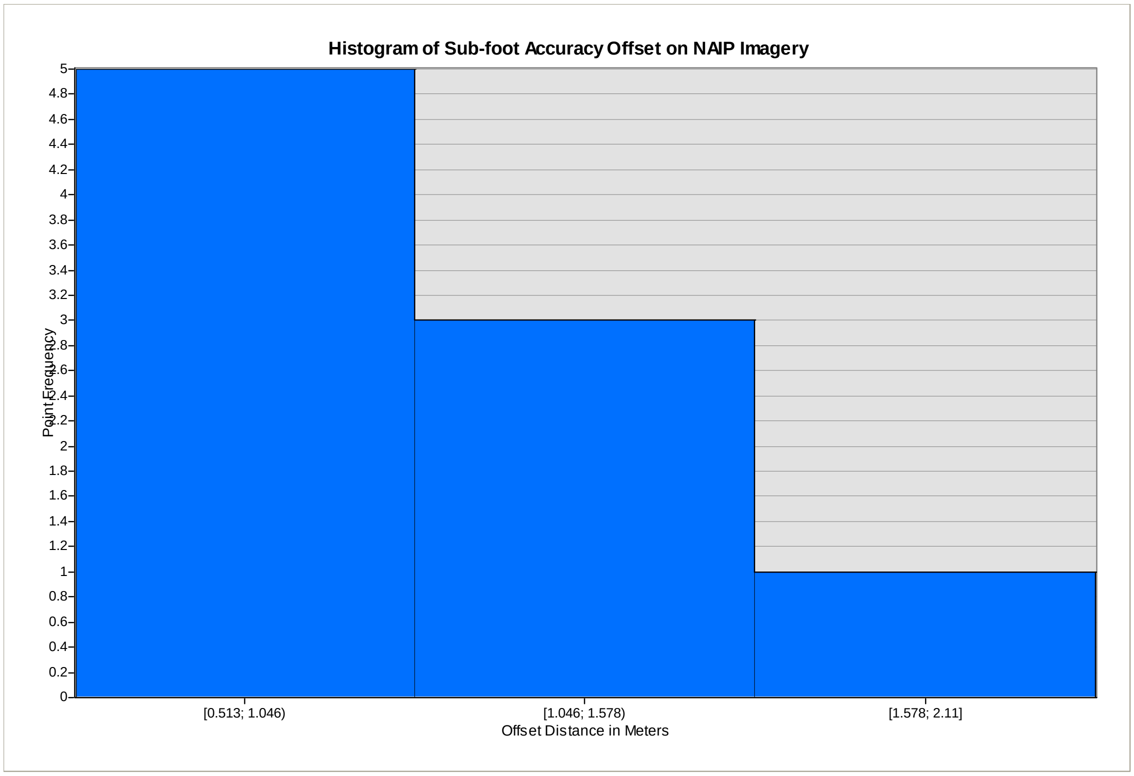


**Figure 18: Sub-foot accuracy histogram for NAIP**

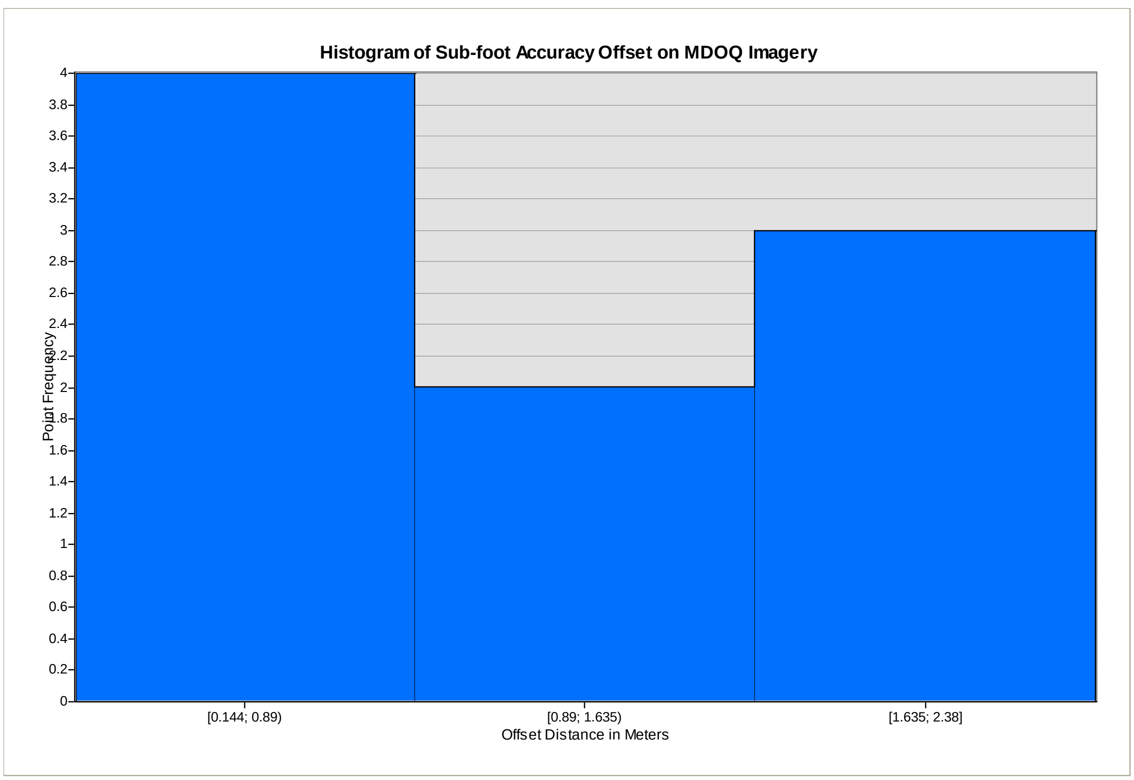


**Figure 19: Sub-foot accuracy histogram for MDOQ**

## Conclusions

As mentioned before, the “absolute” control points were analyzed for Arizona (both on the MDOQs and the 2007 NAIP imagery). The statistics for the Arizona control points were very different from Indiana. There was a greater discrepancy between the MDOQ offsets and the NAIP offsets for the Arizona data. This could be for several reasons. The terrain in Arizona was more varying than in Indiana. The mountainous areas made it more difficult to pinpoint control locations, especially on the MDOQs, whereas the mostly flat terrain of Indiana made it easier to locate control. The flat terrain of Indiana probably made it easier for the MDOQs to be more horizontally accurate when created in the 1990s, and therefore closer to the accuracy of the 2008 NAIP. An improvement of NAIP has been switching to the “absolute” accuracy specification. The differences between the Arizona and Indiana point quality ratings also support the above conclusions. There were fewer “1” ratings for Arizona and more “5” ratings. Again, much of this was due to points being in difficult terrain and more difficult to see. Some of the control points measured were out of tolerance on both the MDOQ imagery and the NAIP imagery (figures 20 and 21). There is a good chance that these points are bad, and need to be revisited, or perhaps the feature being measured was digitized incorrectly.

# Summary

The migration to an absolute horizontal accuracy specification in the NAIP contract is proving to be valuable. Obtaining control and maintaining a control point database helps to facilitate the migration. The use of the point database in NAIP imagery inspection and the potential of creating a nationwide photo-identifiable control database are now integral parts of the NAIP process. After three years of analyzing the control points on NAIP and MDOQ imagery, the statistics show that tying the NAIP imagery to true ground points creates a stronger and more horizontally accurate dataset which in turn, benefits the Farm Service Agency and USDA customers now and in the future.

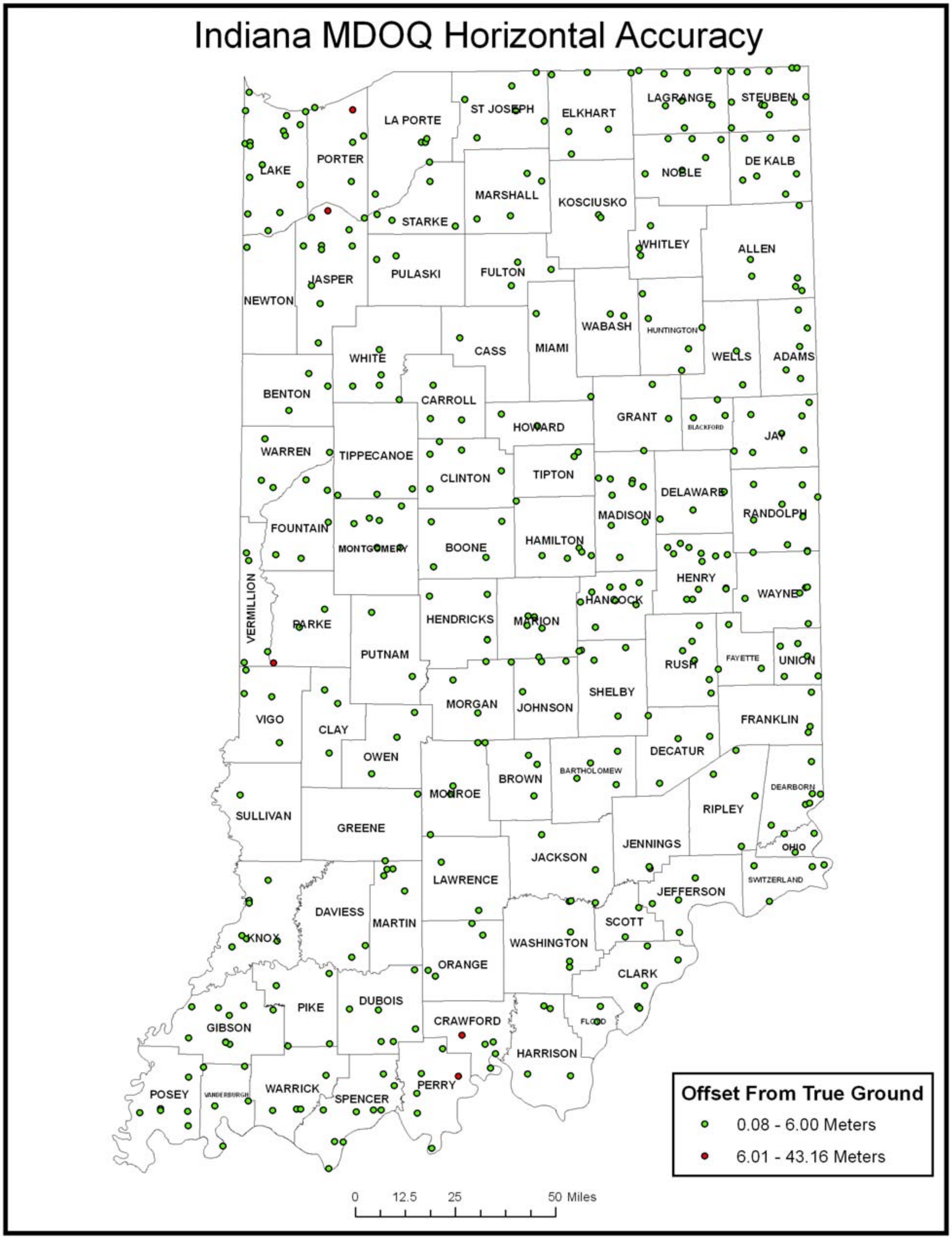


**Figure 20: Map of Indiana horizontal accuracy for MDOQs**

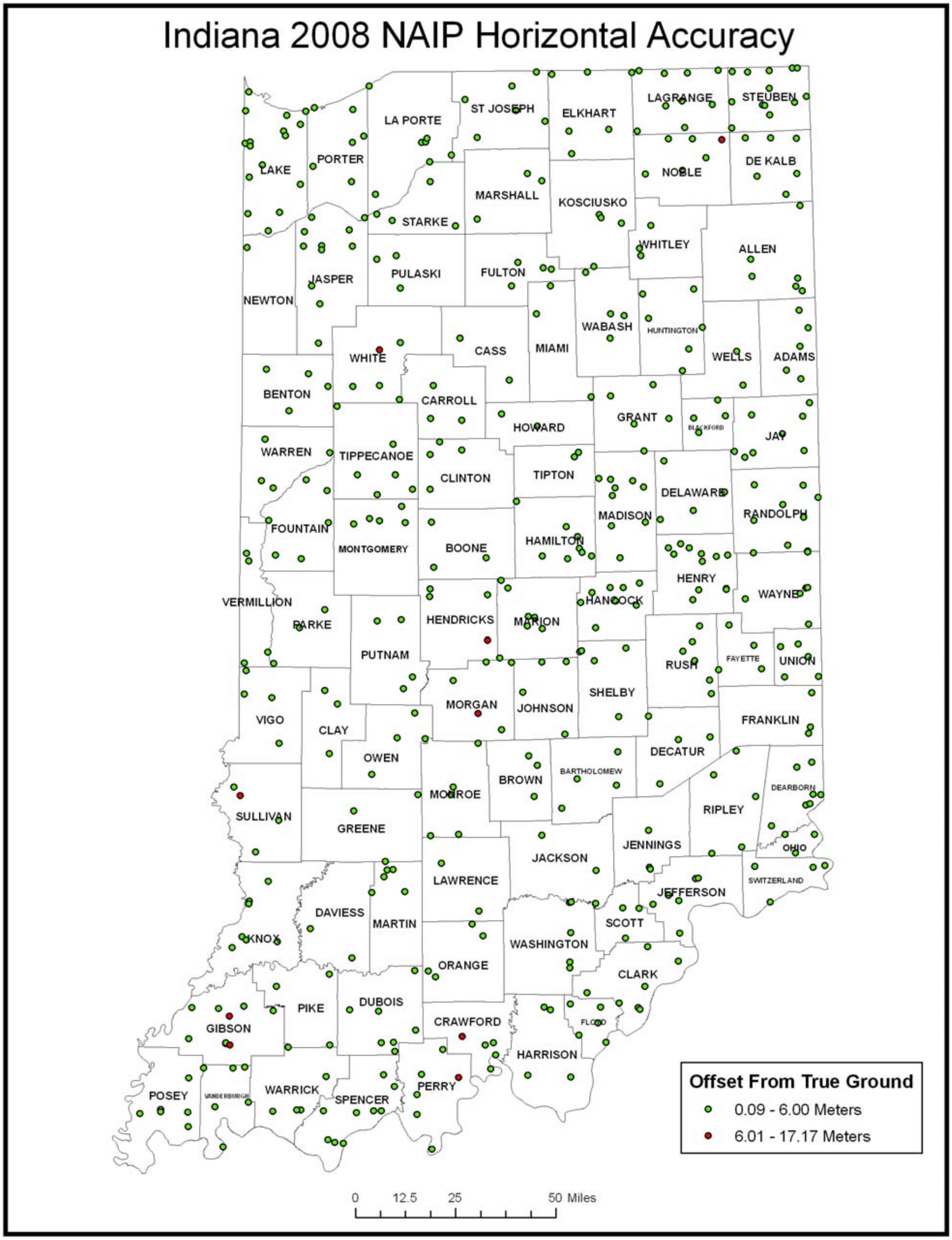


**Figure 21: Map of Indiana horizontal accuracy for 2008 NAIP**

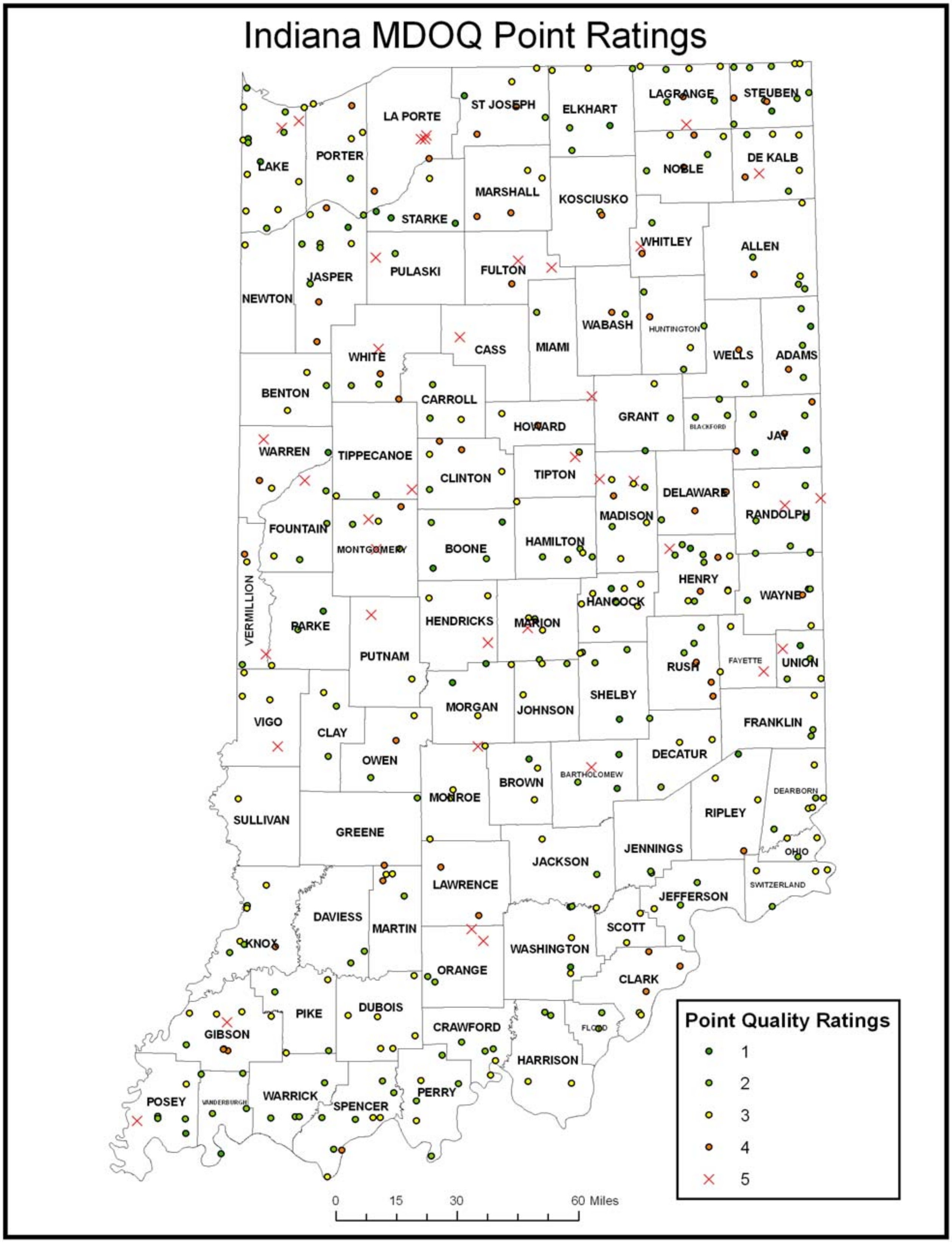


**Figure 22: Map of Indiana point quality ratings on MDOQs**

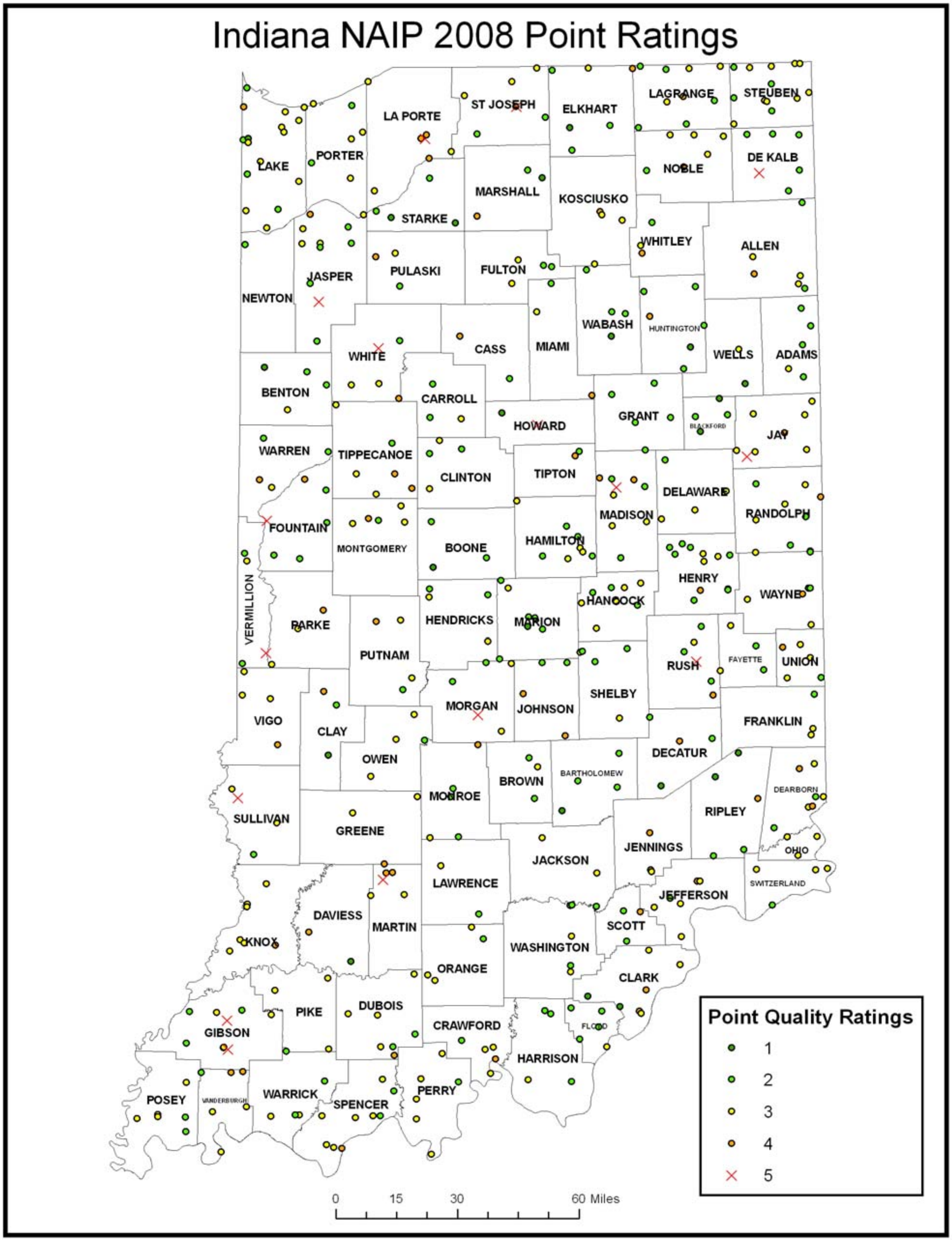


**Figure 23: Map of Indiana point quality ratings on 2008 NAIP**