Research Report
KTC-04-08/SPR 276-04-1F

KENTUCKY TRANSPORTATION CENTER

College of Engineering

EVALUATION OF THE ACCURACY OF GPS AS A METHOD OF LOCATING TRAFFIC COLLISIONS

UNIVERSITY OF KENTUCKY

UNIVERSITY OF KENTUCKY

College of Engineering

Kentucky Transportation Center

Our Mission

We provide services to the transportation community
through research, technology transfer and education.
We create and participate in partnerships to promote
safe and effective transportation systems.

We Value...

Teamwork -- Listening and Communicating, Along with Courtesy and Respect for Others
Honesty and Ethical Behavior
Delivering the Highest Quality Products and Services
Continuous Improvement in All That We Do

For more information or a complete publication list, contact us at:

KENTUCKY TRANSPORTATION CENTER

176 Raymond Building
University of Kentucky
Lexington, Kentucky 40506-0281

(859) 257-4513
(859) 257-1815 (FAX)
1-800-432-0719
www.engr.uky.edu/ktc
ktc@engr.uky.edu

The University of Kentucky is an Equal Opportunity Organization

Research Report
KTC-04-08/SPR276-04-1F

EVALUATION OF THE ACCURACY OF GPS AS A METHOD OF LOCATING TRAFFIC COLLISIONS

by

Eric R. Green
Research Engineer

and

Kenneth R. Agent
Research Engineer

Kentucky Transportation Center
University of Kentucky
Lexington, Kentucky

in cooperation with

Kentucky Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U.S. Department of Transportation

The contents of this report reflect the views of the authors who are
responsible for the facts and accuracy of the data presented herein.
The contents do not necessarily reflect the official views or policies
of the University of Kentucky or the Kentucky Transportation Cabinet.
This report does not constitute a standard, specification, or regulation.

June 2004

1. Report Number KTC-04-8/SPR276-04-1F	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Evaluation of the Accuracy of GPS Coordinates Used on Traffic Collision Reporting Forms	5. Report Date June 2004 6. Performing Organization Code
7. Author(s) Eric R. Green, Kenneth R. Agent	8. Performing Organization Report No. KTC-04-8/SPR276-04-1F
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, Kentucky 40506-0281	10. Work Unit No. 11. Contract or Grant No. KYSPR-04-276
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, Kentucky 40602	13. Type of Report and Period Covered Final 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Kentucky Transportation Cabinet and the Federal Highway Administration

16. Abstract

The objectives of this study were to determine the accuracy of GPS units as a traffic crash location tool, evaluate the accuracy of the location data obtained using the GPS units, and determine the largest sources of any errors found.

The analysis showed that the currently used GPS unit is capable of obtaining accurate latitude and longitude data at a crash site that would allow the site to be properly located. However, substantial differences were found between the location of some crashes as identified with the GPS and milepoint (CRMP) data. Of a sample of 100 random crashes, 55 percent were found to have an accurate GPS reading and 58 percent were found to have an accurate CRMP location. There was a large range in the difference between the GPS and CRMP data by county and police agency. This shows both the accuracy that can be obtained with proper training and use as well as the lack of proper training and/or use of the GPS units at some jurisdictions. The source of errors found for the GPS data was related to the operator rather than the equipment or environment. The actions necessary to significantly improve the accuracy of the GPS data are manageable and relate to training, proper use of the GPS unit, care when placing the GPS data onto the crash report, and a minor modification to the crash report. The source of errors related to the CRMP data primarily dealt with improper interpretation of the milepoint log, inaccurate use of the available mileposts and lack of knowledge of current data available. A few edits of the crash data could be used which would significantly improve the accuracy of both the GPS and CRMP data.

Recommendations were made to improve the accuracy of both GPS and CRMP data. These included additions to the GPS procedure pamphlet, a minor modification to the crash report, additional training in the use of the GPS unit, providing up-to-date milepoint logbooks, and using an edit which checks the accuracy of the GPS and CRMP data.

17. Key Words Global Positioning System Traffic Crash Milepoint	18. Distribution Statement Unlimited, with approval of the Kentucky Transportation Cabinet

19. Security Classification (report) Unclassified	20. Security Classification (this page) Unclassified	21. No. of Pages 64	22. Price

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The objectives of this study were to determine the accuracy of GPS units as a traffic crash location tool, evaluate the accuracy of the location data obtained using the GPS units, and determine the largest sources of any errors found. The findings were used to recommend changes to reduce or eliminate these errors. The accuracy of the GPS units was evaluated based on the procedures provided to police agencies in Kentucky. The largest sources of errors were identified in order to recommend modifications to improve the quality of the data.

The analysis showed that the currently used GPS unit is capable of obtaining accurate latitude and longitude data at a crash site that would allow the site to be properly located. However, substantial differences were found between the location of some crashes as identified with the GPS and County-Route-Milepoint (CRMP) data. Of a sample of 100 random crashes, 55 percent were found to have an accurate GPS reading and 58 percent were found to have an accurate CRMP location. There was a large range in the difference between the GPS and CRMP data by county and police agency. This shows both the accuracy that can be obtained with proper training and use of the unit as well as the lack of proper training and/or use of the GPS units at some jurisdictions. The source of errors found for the GPS data was related to the operator rather than the equipment or environment. The actions necessary to significantly improve the accuracy of the GPS data are manageable and relate to training, proper use of the GPS unit, care when placing the GPS data onto the crash report, and a minor modification to the crash report. The source of errors related to the CRMP data primarily dealt with improper interpretation of the milepoint log, inaccurate use of the available mileposts and lack of knowledge of current data available. A few edits of the crash data could be used which would significantly improve the accuracy of both the GPS and CRMP data.

Recommendations were made to improve the accuracy of both GPS and CRMP data. These included additions to the GPS procedure pamphlet, a minor modification to the crash report, additional training in the use of the GPS unit, providing up-to-date milepoint logbooks, and using an edit which checks the distance between the GPS and CRMP crash locations.

ACKNOWLEDGMENTS

An expression of appreciation is extended to the following members of the advisory committee from the Kentucky Transportation Cabinet for their involvement towards the success of this project.

JoAnne Tingle	KYTC, Advisory Committee Chair
Boyd Sigler	KYTC, Advisory Committee Vice-Chair
Brad Bates	Kentucky State Police
John Carrico	Kentucky State Police
Terry Chism	FHWA
Kevin Corman	Jessamine County Sheriff's Office
Keith Dotson	KYTC Planning
Steve Gibson	Henderson Police Department
Joe Hornek	Louisville Metro Police Department
Peter Rogers	KYTC Planning
John Smoot	LFUCG, Division of Police
Ted Stumbur	Kentucky State Police
Greg Witt	KYTC Planning
Tony Young	FHWA

1.0 INTRODUCTION

1.1 Background

The current Kentucky Uniform Police Traffic Collision report, which was implemented on January 1, 2000, provides spaces for recording the latitude and longitude of a traffic crash. In December 2001, the Kentucky Transportation Cabinet, in cooperation with the Federal Highway Administration, purchased Global Positioning Satellite (GPS) devices that were distributed to all police agencies in Kentucky to be used for identifying locations of crash sites. The Kentucky Transportation Cabinet also provided training in the use of the GPS unit to law enforcement agency trainers during the distribution of the units. These trainers then provided training to each officer in their agency. As of June 1, 2002, every crash report was required to include latitude and longitude readings using the issued GPS unit. There is a need to evaluate the accuracy of the GPS data before it is accepted as the method to locate traffic crashes.

The accurate location of crash sites ensures that transportation, law enforcement, and other highway safety professionals will have the quality data needed to improve the safety of Kentucky's highways. Locating crashes accurately enables high crash locations to be identified for engineering and enforcement countermeasures. Hazard elimination funding is based on the identification of high crash locations that can only be accomplished with reliable crash location data. If an agency is not providing accurate crash location data, it will not have the opportunity to obtain funds for improvements to reduce crashes at high crash locations. Also, proper reporting will also allow problems to be identified for police agencies to obtain 402 Funding.

1.2 Research Study Objectives

The objectives of this study were to determine the accuracy of GPS units as a traffic crash location tool, evaluate the accuracy of the location data obtained using the GPS units, and determine the largest sources of any errors found. The findings were used to recommend changes to reduce or eliminate these errors.

2.0 PROCEDURE

2.1 Terminology and Background

The currently used method to identify a crash location is in the format of county, route and milepoint (CRMP). The location of the crash, as given by the current method, was compared to that using GPS data to determine the magnitude of the difference in the locations and the reason for the difference. For non-state maintained roads, no route or milepoint is available so crashes on these roads could not be used to compare CRMP and GPS data. For state-maintained roads, the reporting officer is required to record the route, including the two-digit prefix, the route number and the route suffix, if applicable. In addition, the officer uses lists from the milepoint log book and milepoint reference posts placed along the roadway to determine the crash location on the road. The officer indicates either an entry from the logbook or a milepoint reference and then estimates the distance and direction of that reference from the crash location. These three fields (reference milepoint and distance from that reference and direction) are used to calculate a field called "milepoint derived" which is automatically calculated in the CRASH database. The county, route, and milepoint data are then used to identify high crash locations.

Crash reports in Kentucky are now required to contain additional location data in the form of latitude and longitude. The crash report currently contains spaces for degrees, minutes and seconds (DMS) for latitude and longitude. However, the officers have been instructed to record the data in degrees and decimal minutes. The following table shows examples of three popular formats used.

Format	Example
Degrees Minutes Seconds (DMS)	37^o 25' 35.0''
Degrees Decimal Minutes (D DM)	37^o 25.583'
Decimal Degrees (DD)	37.42639^o

Seconds are converted to minutes by dividing by 60 and minutes are converted to degrees by dividing by 60. The Magellan GPS units display the coordinates in the D DM format by default. Police officers are not required to report sign or direction because of the range of Kentucky's latitude and longitude (e.g. 37^o 25.583 N or -87^o 25.123).

Kentucky police agencies were provided with approximately 6,000 Magellan 315 GPS units and 1,000 SporTrak GPS units. The cost of the units was approximately $140 each for a total cost of about one million dollars. Below is an image of the SporTrak unit.

Figure 1. Magellan SporTrak GPS Unit (left) and 315 (right).

The SporTrak units have a higher accuracy than the Magellan 315 when a geo-stationary satellite is available. The SporTrak units use the Wide Area Augmentation System (WAAS) that gives an accuracy of about three meters when that system is available. Both units have an accuracy of about seven meters when a geo-stationary satellite is not available. A pamphlet explaining the proper usage of the GPS units was sent to all police agencies in Kentucky. The recommended procedure to use in the operation of the GPS units is shown in Appendix A.

2.2 Data Preparation

A previous study by the Kentucky State Police indicated that the major errors in the use of GPS units had been minimized after the first six months (July through December 2002) of GPS data collection (1). Therefore, crash data were obtained from January 1, 2003 to July 30, 2003 from the CRASH database to use in the analysis. Since an objective of the study was to compare GPS and CRMP data, only records with both types of location data could be used. The location data included the fields describing the county, route and milepoint where the crash occurred and the latitude and longitude values recorded. Therefore, records without these fields were eliminated from the study. The database contained separate fields for degrees, minutes and seconds for latitude and longitude. The "seconds" field was used only when the coordinates were interpreted by the keyer as being in a DMS format. The database also contained typical crash data including date and time, number killed, and number injured.

The database was imported into ArcView 8.2. The data were plotted as an event theme first using the county, route and milepoint (CRMP) and then using GPS data. The plot used ArcView's event theme function in which the data is plotted along a specific route. Any data that did not plot were excluded from the database. Data did not plot when it was outside the milepoint range (out of range for a milepoint for a route and county) or had no GPS data. An extension called AddXY (ArcView 3.2) was used to calculate GPS coordinates for the plotted CRMP data.

The distance between the latitude and longitude values of the GPS and the CRMP plots was calculated. This distance was calculated using the following formula:

$$D = R\cos^{-1}\left(\cos\left(long_1 - long_2\right)\cos\left(lat_1\right)\cos\left(lat_2\right) + \sin\left(lat_1\right)\sin\left(lat_2\right)\right)$$

where:
D = distance in miles
R = radius of Earth (3963.19 miles)
lat_1 = latitude of GPS location
$long_1$ = longitude of GPS location
lat_2 = latitude of CRMP location
$long_2$ = longitude of CRMP location

This distance, in units of both miles and feet, was added to the database.

2.3 Data Analysis

The database was used to analyze several different aspects of the location data in order to quantify the accuracy of the units for this application and to determine the sources of error. The results were used to recommend improvements. The steps involved in the analysis included:

- Comparison of GPS and CRMP data
- Data collection at high crash intersections

- Evaluation of longitudinal/latitudinal errors
- Manual examination of random sample
- Analysis by police agency
- Interviews with police agencies
- CRASH database edits
- GPS unit analysis

2.3.1 Comparison of GPS and CRMP Data

A database containing the county number, intersection code (yes or no indication) and the distance calculated between the GPS and CRMP plots was imported into the Statistical Package for Social Sciences (SPSS). The RECODE function was used to categorize the data into different distance groups. The distance groups were cross-tabbed with the county number. The same process was used for intersection crashes. The cumulative distributions were calculated and used to determine the distance groups for various percentiles.

The next step was to calculate the 50^{th} and 85^{th} percentiles of the differences found between the GPS and CRMP data. This was accomplished using the PERCENTILE function in Microsoft Excel. Percentile distances for all crashes were calculated by county and statewide. The same process was used for intersection crashes.

2.3.2 Data Collection at High Crash Intersections

The distance calculated provides the distance between the crash location as plotted using both CRMP and GPS data. Large distances between these two locations would indicate that one of these procedures had incorrectly reported the crash location. However, the distance between the two procedures would not indicate which location is incorrect. Intersection crashes were analyzed in an effort to reduce the likelihood that the CRMP location was incorrect. When a crash occurs at an intersection, police officers are able to find the exact milepoint in the milepoint logbook. Crashes that occurred at an intersection were identified using the "intersection indicator" field in the crash database.

A list of all intersection crashes was created as a subset of the total database. Intersection crashes occurring at the same location (as defined by county, route and milepoint) were counted. A list was created which was sorted in descending order by the frequency of crashes at each intersection. Several of the intersections with the highest number of crashes were visited and GPS data were collected to compare to the GPS data on the crash reports.

Data were collected at the high-crash intersections using a Magellan SporTrak GPS unit. Data points were obtained at the four corners of the intersection. The data were collected following the same procedure given to the police agencies (Appendix A). These data points were plotted on an ArcView map along with the GPS location for all of the crash records reported at the intersection. Aerial photographs were obtained from the Kentucky Office of Geographic Information in MrSID format. These photographs were added to the map as a reference for the collected GPS data and the GPS location given on the crash reports.

2.3.3 Evaluation of Longitudinal/Latitudinal Errors

Examination of several plots showing the GPS and CRMP locations revealed that, in a substantial number of cases, the difference in the location using the two procedures was nearly horizontal or vertical. That is, almost all the difference was related to only the latitude or longitude coordinate. In these cases it was probable that either the latitude or the longitude coordinate was recorded incorrectly. A percentage was calculated giving the percent of the difference between the GPS and CRMP plotted locations in the horizontal or vertical direction. This percentage was used to identify possible reporting errors in the GPS data. When this percentage was 90 percent or more it would indicate the possibility of a recording error.

2.3.4 Manual Examination of Random Sample

A random sample of 100 crashes was selected from the database. This was a manageable number given the amount of analysis required for each crash. The crash report was examined to determine if there were any inaccuracies in the GPS or CRMP data. The milepoint logbook, street maps and plots made in ArcMap were used along with the crash report to determine the errors. All inaccuracies were categorized as either GPS or CRMP errors. Several fields on the crash report were used to determine the actual crash location (such as the names of the road or street along with adjacent roads or the name of any intersecting road). The categorized errors were summarized and used as a representation of the database.

2.3.5 Analysis by Police Agency

The 50^{th} and 85^{th} percentile differences in the distance between the GPS and CRMP crash locations were calculated for three police agency groups: state police, county sheriff and local police. The agency code in the crash database was used to group each crash record into one of the three categories. Percentile distances were also calculated for each county in the three groups.

2.3.6 Interviews with Police Agencies

The police agencies with the smallest and largest differences in the distance between GPS and CRMP crash site locations were identified. Telephone interviews were conducted with representatives of several of these agencies to determine their experience with the use of the GPS units and placing milepoints on crash reports. They were asked to identify problems and to make suggestions for improvements. The format used for the interviews is shown in Appendix B.

2.3.7 CRASH Database Edits

An analysis was performed to determine the feasibility of adding edits to the CRASH system to improve the quality of the crash location data. The crash data were used to determine and evaluate these possible edits. The calculated distance between the GPS and CRMP crash site locations was used as one type of edit in which crash reports with a large distance could be identified with corrections then made. Additionally, the milepoint derived could be checked to ensure that it is within range for the reported route.

2.3.8 GPS Unit Analysis

The usage and accuracy of the GPS unit was evaluated by collecting field data and through phone interviews with a representative of Thales Navigation (the manufacturer of the GPS units). Data were collected at the same position over a two-month period to determine the variability of the location. Questions were asked of a representative of the GPS manufacturer relating to the accuracy and usage of the unit and possible improvements.

2.4 Literature Review

A review of literature was conducted to determine other studies that evaluated the use of GSP technology to locate crash locations.

3.0 RESULTS

3.1 Database Description

The database contained 71,693 crash records (from January 1, 2003 through June 30, 2003) on the date the extract was obtained. A milepoint was required in this study in order to compare the crash milepoint location to the GPS location. There were 32,122 records without a milepoint and 227 with negative milepoints with these records removed from the database. The CRASH database contains a field called RSE_UNIQUE. This field indicates the reported county and route. There were 2,800 records without an RSE_UNIQUE. However, approximately half of these records (1,436 records) had data in the county and route fields. An RSE_UNIQUE was created from those fields. These edits resulted in a usable database of 37,980 crash records.

The database was imported into ArcView 8.2. The data were plotted as an event theme first using county, route and milepoint (CRMP) and then using GPS data. There were 32 records that did not plot because they had no GPS data. Fayette County had 23 of the records with no GPS data with these typically hit-and-run crashes. There were 1,603 records that did not plot because they were outside of the milepoint range of the reported route. This resulted in a usable database of 36,345 crash records.

Latitude and longitude coordinates were calculated for each record using the CRMP location information. The distance between the GPS and CRMP coordinates was calculated using the formula described in section 2.2. The distances ranged from 3 feet to 283 miles. The records with the largest distances were reviewed. Most of the errors that resulted in the highest differences (over 20 miles) resulted from inaccurate recording of the GPS data from the unit to the crash report. Latitudes and longitudes were recorded that the officer should have known was not in the range of appropriate values for his jurisdiction.

3.2 Data Analysis

3.2.1 Comparison of GPS and CRMP Data

The distance between the plotted locations of the crash as shown by the GPS and CRMP data was determined for each crash and placed into several distance groups. The number of crashes in each distance group is shown in Table 1. The categories range from 0 to 1,000 feet (in 100-foot intervals), from 1,000 to 5,000 feet (in 500-foot intervals) and from 5,000 to 10,000 feet (in 1,000-foot intervals). These intervals were used because the data were more sporadic above 1,000 feet. There is also a category for distances greater than 10,000 feet. The percentages and the cumulative percentages are also shown. The groups closest to the 50th and 85th percentiles are shown in bold. Table 2 shows the same statewide results for intersection crashes. As a comparison, Table 3 shows these results for intersection crashes in Fayette County that shows the difference between the GPS and CRMP crash location can be less than 300 feet. However, even when the average was low, there were still several with a difference over 10,000 feet.

Excel's PERCENTILE function was used to calculate exact percentiles. The following table summarizes the 50th and 85th percentile difference between the GPS and CRMP locations for all crashes and intersection crashes. As expected, the difference was less for intersection crashes. This would be related to more accurate CRMP data at intersections.

	Frequency	**Percentile Distance (feet)**	
		50th	**85th**
All Crashes	36,345	864	7,224
Intersection Crashes	10,157	559	6,605

The 50th and 85th percentile distances between the GPS and CRMP plotted crash locations were calculated for each county (for all crashes and intersection crashes). The results are shown in Table 4. Considering all crashes, there were 40 counties that had 250 or more crashes. In those counties, the range in the 50th percentile distance difference for all crashes ranged from 379 feet in Fayette County to 3,201 feet in Perry County with the range in 85th percentile distance from 2,524 feet in Franklin County to 17,833 feet in Boyd County. Considering only intersection crashes, there were 26 counties that had 100 or more crashes. In those counties, the range in the 50th percentile distance for intersection crashes ranged from 221 feet in Franklin County to 1,709 feet in Bullitt County with the range in 85th percentile distance from 1,201 feet in Franklin County to 39,044 feet in Boyd County.

A comparison was made between the paper and electronic crash reporting formats with the results shown in the following table. About one-third of the data sample used the electronic format. Considering intersections, where the CRMP data could be assumed to have the same accuracy for either the electronic or paper format, the difference between the GPS and CRMP locations decreased from 579 feet using the paper format to 511 feet using the electronic format. This shows that the accuracy of the GPS data was improved using the electronic reporting format. The percentage of crashes using the electronic format is expected to increase dramatically which will have a positive effect on the accuracy of the GPS data.

Report Type	Crash Type	Frequency	Percentile Distance (feet)	
			50th	85th
Electronic	**All Crashes**	11,525	716	5,636
	Intersection Crashes	3,233	511	5,186
Paper	**All Crashes**	24,820	949	8,239
	Intersection Crashes	6,924	579	7,542

A separate analysis was made of fatal crashes since these crashes are typically investigated in more detail and a logical assumption would be that the location data should be more accurate than for all crashes. There were 313 fatal crashes on roads with CRMP data in the six-month study period. The 50th percentile of the difference between the GPS and CRMP location was 614 feet with the 85th percentile 4,916 feet. The range in this distance was from 10 feet to almost 29 miles. While these distances are less than for all crashes, substantial differences were still present with 123 (about 39 percent) over 1,000 feet.

3.2.2 Data Collection at High Crash Intersections

The intersections with the largest number of crashes in the study period were used as case studies. Special attention was given to Fayette, Jefferson, Henderson and Jessamine Counties since there were representatives from police agencies in each of these counties on the study's advisory committee. Site visits were made to each of the selected intersections. GPS data were obtained at each corner of the selected intersections and plotted in ArcView containing aerial photographs. The plots showed that the GPS data obtained during the site visits were accurate since they plotted at or near the corners of the intersection. This verified the accuracy of the GPS equipment when used following the procedures outlined in Appendix A.

Following is a list of the intersections visited giving the location, the number of crashes coded as occurring at the intersection, and the number of crash locations plotted with GPS data that were less than 500 feet from the intersection. The difference between the GPS and CRMP locations was less than 500 feet for two-thirds of the crashes at these intersections.

County	Intersection Location	Number of Crashes	Number of Crashes < 500 feet	Percentage
Bourbon	US-27 @ MP 6.765	11	7	63.6
Boyd	US-60 @ MP 11.594	11	4	36.4
Campbell	KY-9 @ MP 17.63	10	8	80.0
Christian	US-41A @ MP 0.051	7	1	14.3
Fayette	US-68 @ MP 3.11	10	10	100.0
Fayette	US-27 @ MP 0.956	10	7	70.0
Fayette	US-27 @ MP 2.035	13	8	61.5
Henderson	US-41A @ Watson	4	3	75.0
Henderson	US-41A @ Washington	4	3	75.0
Henderson	US-41A @ Gardenmile	4	2	50.0
Henderson	US-41A @ First	4	4	100.0
Henderson	US-41A @ Klutey Park	5	4	80.0
Henderson	US-41A @ North Alves	5	4	80.0
Henderson	US-41A @ Second	5	4	80.0
Henderson	US-41A @ MP 15.406	10	5	50.0
Henderson	US-41A @ Clay	10	5	50.0
Jefferson	Hurstbbourne @ Linn	4	2	50.0
Jefferson	Broadway @ 2nd	6	6	100.0
Jefferson	Bardstown @ Grinstead	6	5	83.3
Jefferson	Brownsboro @ Crescent	7	3	42.9
Jefferson	Ky-155 @ MP 11.395	10	9	90.0
Jefferson	Brooks @ Jeferrson	13	5	38.5
Jessamine	US-27X @ MP 4.504	3	1	33.3
Jessamine	US-27X @ MP 2.150	4	4	100.0
Jessamine	US-27X @ MP 3.450	7	4	57.1
McCracken	US-60 @ MP 10.626	9	7	77.8
McCracken	US-60 @ MP 10.981	14	11	78.6
Warren	US-231 @ MP 13.188	10	8	80.0

A percentage was calculated for each intersection showing the percentage of the crashes that were plotted within 500 feet of the actual crash site. All of the crashes were within 500 feet of the intersection at four of the 28 intersections. The following image displays plotted GPS crashes at an intersection in Warren County compared to the actual location of the intersection. The GPS data for eight of the ten crashes at this location were within 500 feet of the intersection.

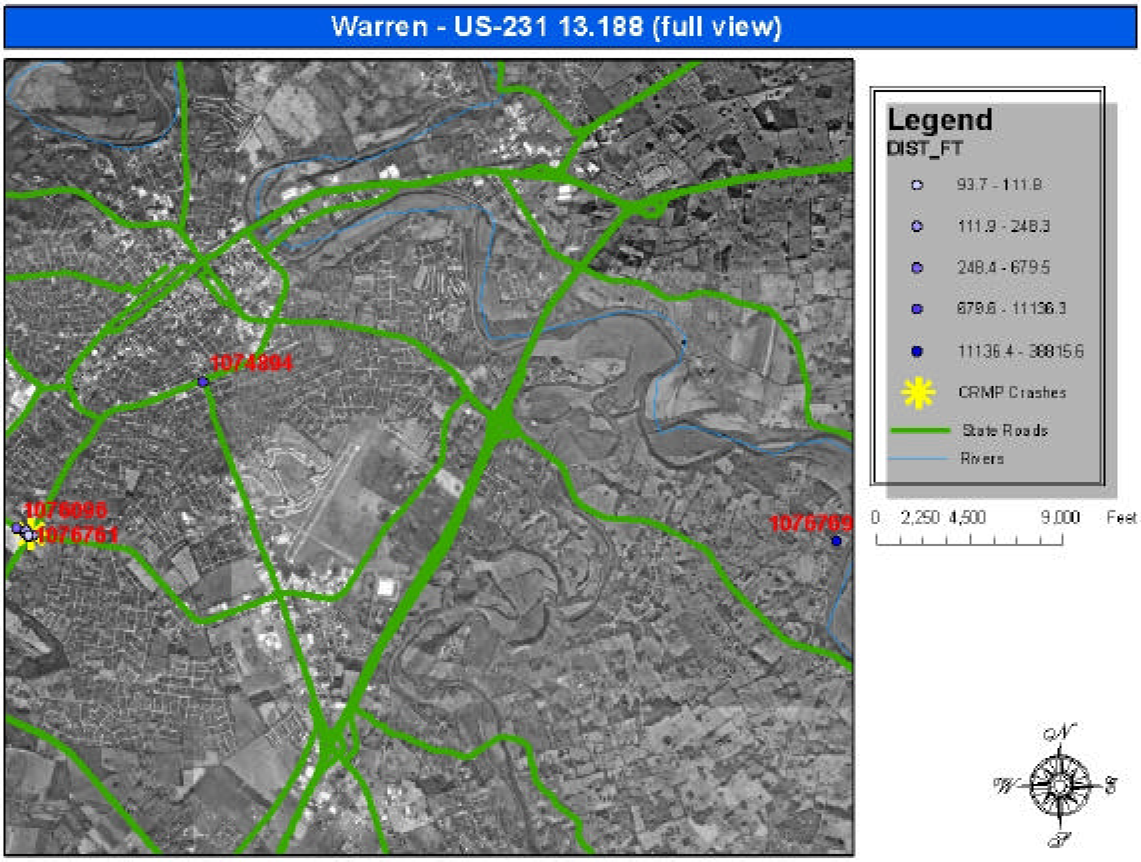


Figure 2. Plot of GPS data in Warren County (all ten data points cannot be seen at this zoom extent)

More detailed plots are shown in Appendix C for a sample of intersections in Fayette, Jefferson, Jessamine and Henderson Counties. Each plot is displayed using a scale to show all GPS crashes (blue dots) and a plot showing more detail near the actual crash location. The darkness of the dots is related to the distance away from the actual crash site which is marked by a yellow star. All distances are shown in feet. The master file number of each crash is shown in red. Not all data points can be seen in the full view when the data points are plotted very close to each other. The more detailed plots indicate the locations of the collected data.

3.2.3 Evaluation of Longitudinal/Latitudinal Errors

The distance between the GPS and CRMP locations that had been previously calculated was used along with the following formulas to calculate the vertical and horizontal components of this distance.

$$D_{horz} = R\cos^{-1}\left(\cos(lat_1)\cos(lat_2) + \sin(lat_1)\sin(lat_2)\right)$$

$$D_{vert} = \sqrt{D^2 - D_{horz}{}^2}$$

where:
D = straight line distance (miles)
D_{horz} = horizontal component (miles)
D_{vert} = vertical component (miles)
R = radius of earth (3963.19 miles)
lat_1 = latitude of GPS location
lat_2 = latitude of CRMP location

These distances were used to calculate a percentage describing how much of the straight line distance was in the horizontal direction. The following formula was used to calculate this percentage because the components are related by the Pythagorean Theorem.

$$Percent_{horz} = \frac{D_{horz}^2}{D^2} \times 100$$

For example, if the straight line distance was five miles, the horizontal distance was three miles and the vertical distance was four miles, then the horizontal percentage would be 36 percent (9/25*100). These values were also calculated for intersection crashes.

Crashes with the “horizontal percentage difference” component higher than 90 percent are possibly due to GPS recording errors in longitude. Conversely, crashes with a “horizontal percentage component” lower than 10 percent are possibly due to GPS recording errors in latitude. A misleading instance of this error can exist in cases where roads are oriented either east-west or north-south. In these cases, either the GPS reading could have been measured down the road from the actual crash location or the milepoint may have been reported at an incorrect distance from the actual crash location and, in either case, the results could be perceived as a latitudinal/longitudinal type of error. Errors in the CRMP data that could contribute to this error occur when the wrong direction is given from the reference milepoint.

The following figure is a visual example of the latitudinal/longitudinal type of error where the difference between the GPS and CRMP locations is likely due to the officer mistakenly reporting one of the GPS coordinates. The actual crash is plotted on the road (on the right) and the GPS is plotted about five miles directly west of the crash. Both crash site locations are colored red.

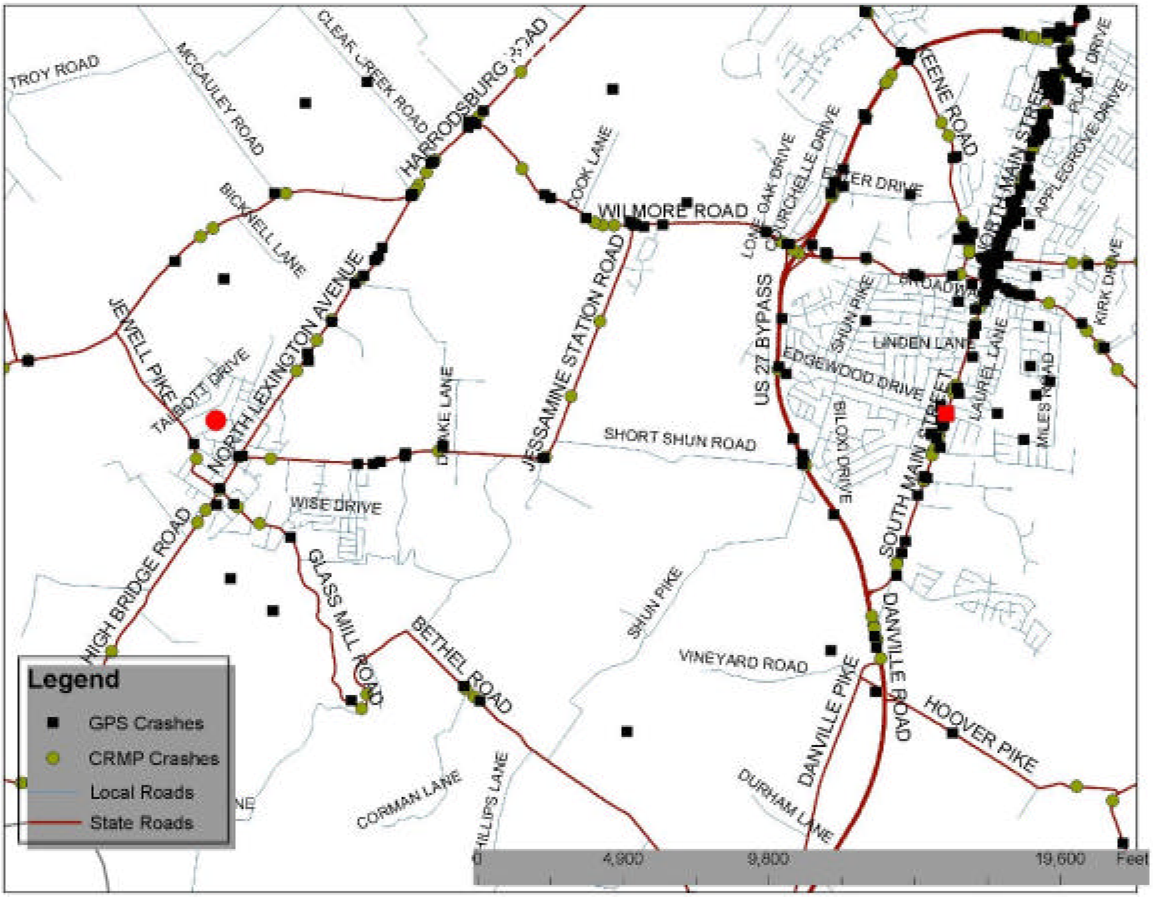


Figure 3. Plot of a crash with a 90/10 longitudinal/latitudinal difference between GPS and CRMP data

Crashes where the horizontal or vertical component percentage of the difference was greater than 90 percent were counted. When the difference between the locations is relatively small (under 500 feet), it is more probable that the GPS data is correct. Therefore, crashes with a distance greater than 500 feet were summarized. There were 36,345 total crashes (10,157 intersection), 22,156 crashes (5,282 intersection) with a distance greater than 500 feet. The following table shows the number and percentage of crashes that had horizontal or vertical components above 90 and 95 percent.

	All		Intersection	
	Count	**Percentage**	**Count**	**Percentage**
Lat/Long Error (90/10)	10,005	45.2	2,407	45.6
Lat/Long Error (95/5)	7,402	33.4	1,806	34.2

The data show that, in crashes where there was a large distance between the GPS and CRMP locations, an unexpectedly high percentage involved a very high percentage of the difference in only the latitude or longitude. This result indicates that a large number of the crashes in which the GPS data were incorrect were due to either the latitude or longitude being incorrectly written from the GPS unit to the crash report.

3.2.4 Manual Examination of Random Sample

A random sample of 100 crashes was identified in order to review in detail the difference between the locations indicated by the GPS and CRMP data and determine the reason for any difference. The time required to analyze each crash limited the number of crashes that could be included in the random sample. The crash report was reviewed for each of these crashes and the GPS and CRMP locations were plotted on an aerial photograph. Each of the 100 randomly selected crashes was examined to determine the accuracy of the GPS and CRMP locations. Of the 100 random crashes, 55 percent were found to have an accurate GPS reading and 58 percent were found to have an accurate CRMP location. An error category was assigned to all crashes that did not have what was determined to be an accurate GPS or CRMP location. Following is a list of the categories used and a description for GPS errors.

Averaging – The unit did not average long enough to provide accurate data.
Data Location – The measurement was not collected at the crash location.
Establishing Position – The unit was not on for the time necessary to establish a new position.
Format – The GPS data were not recorded in the proper format.
Keying Error – The data were keyed incorrectly from the police report to the CRASH database.
Misread – The GPS data were misread from the unit onto the crash report.
Unknown – No logical reason could be identified.

The following is a list of the categories used and a description for CRMP errors.

Keying Error – The data were keyed incorrectly from the police report to the CRASH database.
Log Book Error – The data in the milepoint logbook were incorrect.
MP Derived Error – The magnitude, direction or MP reference was misjudged or misapplied.
No MP Needed – A milepoint and route were reported on a local road or parking lot.
Roadway Number – The roadway number or suffix was incorrect.
Unknown – No logical reason could be found.

The following tables show the percentages found for each error type.

GPS Category*	Count
Correct	55
Data Location	15
Format	13
Averaging	10
Establishing Position	7
Keying Error	2
Misread	2
Unknown	1

CRMP Category	Count
Correct	58
MP Derived Error	29
Roadway Number	4
No MP Needed	3
Log Book Error	3
Keying Error	2
Unknown	1

*Some crashes had errors in more than one category.

Thirty of these crashes were in an electronic format that is a very similar percentage to that for the total sample. Of these 30 crashes, 60 percent were determined to have correct GPS data with 63 percent having correct CRMP data. These percentages were slightly higher than the total sample.

The crashes with a distance greater than 500 feet were also examined to determine the errors that contributed to the largest distances between the GPS and CRMP locations. The percentages of these errors are shown below. The data show that, for the largest differences, the GPS data were correct more often than the CRMP data.

GPS Category*	Percentage	CRMP Category	Percentage
Correct	51.0	Correct	40.8
Format	22.4	MP Derived Error	36.7
Establishing Position	14.3	Roadway Number	8.2
Averaging	4.1	Log Book Error	6.1
Data Location	4.1	Keying Error	4.1
Keying Error	4.1	No MP Needed	2.0
Misread	4.1	Unknown	2.0
Unknown	2.0		

*Some crashes were put into more than one category.

The format error typically involved using the DMS format rather than the correct D DM format. In several instances, a review of the crash report data for an officer found that the same latitude and longitude was input for several weeks because the officer did not allow the GPS unit to reestablish a position. The averaging category involved not allowing time for the unit to obtain the optimum data. Data location referred to the officer not collecting the data at the crash site.

Most of the CRMP errors were the result of problems with interpretation of the logbook or mileposts. The milepoint increases in the north and east directions and placing an incorrect direction in reference to a milepost resulted in significant errors. There were numerous errors related to the several roads that had a suffix. For example, when a route bypasses a town there would be separate route numbers for the route and its bypass. This results in a route number with a "B" suffix for the bypass or business route. Not placing the suffix on the report, although the correct milepoint was listed, resulted in major errors in locating the crash. Other problems related to a route suffix occurred when there was a one-way couple along a route and for route numbers such as US 41 and US 41A that occur in some of the same counties.

A sample of fatal crashes was reviewed. The same types of errors were found. The most common GPS error was an averaging error with a few where there were format problems or a failure to establish a new position. The milepoint errors dealt with interpretation of the milepoint logbook.

3.2.5 Analysis by Police Agency

Each crash in the database was grouped into one of three groups by type of investigating police agency: state police, county sheriff, or local police. Determining the type of police agency that investigated the crash was based on a code in the CRASH database. All crashes handled by the state police had no value in the agency field (this field was intentionally left blank). All crashes handled by the county sheriff had an agency code ending in four zeros (e.g. "0010000" signifies the Adair County sheriff). The remaining agency codes were grouped into the local police category.

The database contained 7,557 crashes investigated by state police with 8,561 crashes investigated by the county sheriff and 20,227 crashes investigated by local police in the six-month analysis period. A separate list comprised of only intersection crashes was analyzed to minimize the CRMP location errors. In the intersection subset there were 849 crashes investigated by state police compared with 1,847 by the county sheriff and 7,461 by local police. The 50th and 85th percentile distances between the GPS and CRMP locations of the crash as identified by the investigating officer were calculated for each agency type using both all crashes and intersection crashes. The following table lists these results.

	All*		Intersections*	
	50th	85th	50th	85th
State Police	1,214	9,067	528	8,346
County Sheriff	1,375	9,960	912	10,532
Local Police	633	5,753	510	6,063

*Distances are shown in feet.

In each instance the smallest difference was for the local police category followed by the state police with the data collected by the sheriff having the highest difference between GPS and CRMP locations.

These distances were calculated for each county for all crashes and intersection crashes. The results are shown in Table 5 for all crashes and in Table 6 for intersection crashes. Considering all crashes, there were 22 counties where the state police investigated 100 or more crashes, 26 counties where the county sheriff investigated 100 or more crashes, and 39 counties where the local police investigated 100 or more crashes. For counties with at least 100 total crashes investigated, the lowest 50th percentile distances were 599 feet in Graves County for state police, 600 feet for the sheriff in Henderson County, and 168 feet in Bell County for local police while the highest 50th percentile distances were 2,691 feet for Letcher County for state police, 3,657 feet in Logan County for the sheriff, and 2,891 feet in Mason County for local police. For intersection crashes, there were 10 local police agencies with 100 or more crashes with a range in the 50th percentile distances from 186 in Hopkins County to 2,042 in Bullitt County.

This comparison, by county, shows that the crash location can be identified accurately. However, the range in the distance between the GPS and CRMP locations shows there is a wide variety in the training and ability of police officers to properly locate crashes. Some format issues were noted at some locations having the largest difference between GPS and CRMP data. For example, many reports were noted that had minutes with no decimals.

3.2.6 Interviews with Police Agencies

Telephone interviews were conducted with several local police and sheriff offices. Questions about the use of the GPS units and milepoint logbooks to locate traffic crashes were asked. The training in use of the GPS units has been conducted by individuals in each department who had been given training when the units were received. Issues related to the use of the GPS units included the following.

- The battery life is limited. Power adapters for use in the police vehicle have been purchased at some locations and are being considered in several others. The use of an alternative power source both reduces the cost of batteries and allows the units to remain on which increases accuracy since the problem with allowing time to establish position is eliminated.
- GPS measurements are typically taken at the location where the report is completed and this position can be a substantial distance from the initial area of impact.
- The numbers on the unit can be hard to read, especially in the sun, which can result in placing an incorrect measurement on the crash report.
- Data may be recorded using seconds rather than decimal minutes due to the format given on the crash report.
- Some agencies noted that the GPS unit was reprogrammed when officers were having a problem with data collection.
- In some agencies, the GPS unit will be interfaced with the laptop computer used to input the crash data.
- Some GPS data has been obtained in the office, rather than at the crash site, using an enhanced version of 911 or other computer programs that give latitude and longitude coordinates for a location.
- Additional training in the use of the units would be beneficial.
- There has been no problem with obtaining an adequate number of satellites to obtain GPS data.
- In some instances, all officers do not have access to a GPS unit.

The following issues related to the accuracy of the milepoint system were noted.

- Up-to-date milepoint logs are not routinely supplied at many agencies.
- A mile post near the crash site may not be available to use as a reference.
- Some agencies are obtaining up-to-date milepost data from the internet.

3.2.7 CRASH Database Edits

Consideration was given to possible edits that could be added to the CRASH database to flag crash location data that may be erroneous. The following situations were examined.

- GPS data reported in DMS format
- GPS data with minutes greater than 59.999
- GPS data with degrees outside of Kentucky's range (36.5º to 39.5º latitude and 82º to 89.5º longitude)
- GPS data plotted outside of the reported county
- A straight line distance greater than 500 feet between the CRMP and GPS data locations

The original, unedited database was used to summarize possible CRASH edits. There were 6,038 crashes (8.4 percent) reported in the DMS (degrees-minutes-seconds) format. This data show that some officers were not using the proper GPS format. There were 307 crashes (0.4 percent) with a GPS coordinate outside of the range of Kentucky (32 of which had no GPS data). There were only 16 crashes with minutes over 59.999.

The edited database was used to determine how many crashes were plotted in a county other than the county on the police report. ArcView's spatial join function was used to append the plotted county number to a list of the reported county. There were 398 crashes that had a discrepancy in the county numbers. However, 26 of these crashes occurred near the county line. There is a current procedure used by the Kentucky State Police to identify crashes where the GPS measurements place the crash outside a bounding box used to represent the county. Crashes outside the county bounding box are sent back to the reporting agency for their review.

There were 22,156 crashes with a distance between the GPS and CRMP locations greater than 500 feet. These distances can be attributed to errors in either the GPS or the CRMP data. The following table shows the number of crashes with various distances between GPS and CRMP data.

Distance	Count
> 500	22,156
> 750	19,146
> 1000	17,132
> 1250	15,620
> 1500	14,477

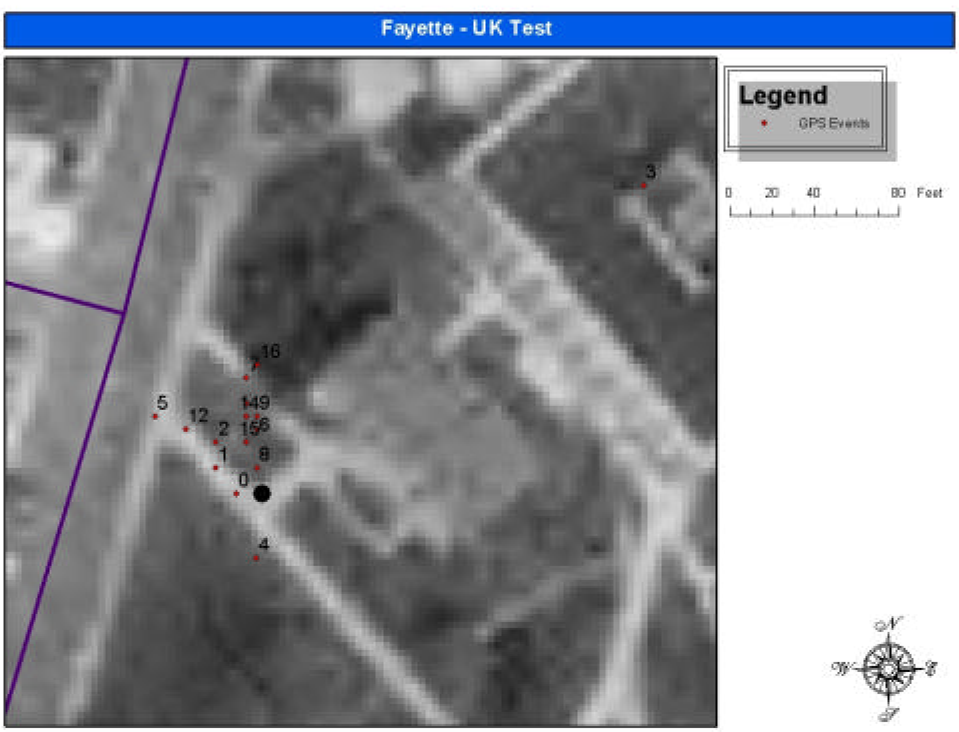
These numbers can be significantly reduced by implementing the suggestions discussed in the recommendations section.

A list was created containing all milepoints along all state-maintained routes in Kentucky in increments of 0.01 mile (approximately 50 feet). This list was plotted along the routes in ArcView and GPS data was added. This resulted in a list of latitude and longitude values based on CRMP.

A sample program was developed which could be used to provide instant feedback to officers using the electronic reporting (ecrash system). The program searches the above-mentioned list for the latitude and longitude coordinates based on the milepoint derived data the officer has provided. The program then calculates the distance between the collected GPS and the GPS from the list using the formula discussed in section 3.2.3. The proposed program currently reports the calculated distance to the user by way of a message box. If the distance is above a specific length the user will be prompted with suggestions to improve the GPS or CRMP data. The program will also check for latitudinal or longitudinal errors by calculating the percentage discussed in section 3.2.3. The program can also validate the CRMP data in addition to the GPS data. The program determines if the reported route exists in the reported county. This would reduce errors related to route number and route suffix. The program also checks to ensure that the milepoint derived is within the range for the reported route in the reported county. A list of routes and their milepoint ranges can be generated for the user upon request. Separate databases have been created for each county to keep the file size of this program minimized (around 1 Megabyte for each county).

3.2.8 GPS Unit Analysis

Data were collected 18 times between December 2003 and February 2004 at the same location on the University of Kentucky campus. The data included the latitude and longitude, time to establish a position, and sky and weather conditions. The data collected are shown in Table 7. The data were plotted in ArcView including an aerial photograph as a point of reference. A black dot was used to represent the location where the data was collected (based on references shown on the aerial photographs). The map datum was purposefully changed to GRB36 during the last data collection. This was done to document the effect the map datum has on the plotted data. The following diagram shows the data plotted excluding the altered map datum point (which was plotted approximately 1,500 feet from the reference point).



Data point 3 was the only data point plotted at an unusual distance from the actual location. This data again show that GPS data can be collected consistently with a reasonable amount of error.

Following is a summary of the information obtained during telephone interviews with the Thales Navigation representative and a review of available equipment enhancements.

- Typically the GPS receiver will take one to two minutes to compute a "new" position fix. If the GPS receiver is not allowed to compute a "new" position before saving a waypoint, the coordinate saved will be of the previous location (last computed position).
- Environmental conditions such as tall buildings and inside parking structures will block the satellite signals. Conditions such as tree canopies will not block the satellite signals from being received by the GPS. The environment should not cause a problem with locating traffic crashes in Kentucky.
- The GPS receiver can be receiving three satellites but not have computed a position fix. When viewing the satellites status screen, the visible identifier of a current position fix is when there is "2D" or "3D" displayed in the upper corner of the display. If the display is manually changed as indicated above, there may or may not be a current computed position. If there is not a current computed position, the accuracy will be inaccurate and will be the last computed position.
- A key factor for incorrect location data is not allowing the GPS to compute a current position. The GPS receiver must be allowed time (approximately two to three minutes) to compute a current position. A second factor is the format of the coordinates to be recorded. By default, the GPS receiver is set to LAT/LON in a format of deg,min.min.
- A power adaptor is available to connect to the cigarette lighter to eliminate the problem of excessive battery usage.
- A serial cable is available to connect the GPS unit to a laptop computer that would eliminate errors where the GPS data is incorrectly recorded.

3.3 Literature Review

A few reports were found which involved an evaluation of the use of GPS to locate traffic crashes. Several GPS units were tested in an Alabama study (2). The conclusion was that the accuracy of crash location data can be improved using GPS technology with an accuracy of crash location data of within eight meters obtained in less than three minutes. Another use of GPS units at 32 crash locations in Virginia found a difference of only 16 to 130 feet between the GPS and conventional methods of identifying crash locations (3). A suggestion was made that a space should be provided on the police report to indicate where the GPS reading was taken (first harmful event, first point of impact, final rest, or other). In Virginia, recording the crash location with GPS receivers was one method considered for obtaining crash locations with GIS (4). The Louisiana state police are using GPS units (5).

The automated crash location system in Iowa does not rely on GPS for positioning (6) although an officer can enter GPS coordinate data from a handheld GPS unit. Potential problems noted were that it may be impractical to place the receiver in the precise crash location, inaccuracies in GPS positioning, limited availability of a signal in certain areas, and varying base map scales and accuracy. GPS technology has been used in North Carolina by motor vehicle enforcement to locate enforcement activity (7). The GPS receiver was placed as an in-vehicle installation.

4.0 CONCLUSIONS

1. The analysis shows that the currently used GPS unit is capable of obtaining accurate latitude and longitude data at a crash site that would allow the site to be properly located.

2. Substantial differences were found between the location of some crashes as identified with the GPS and milepoint (CRMP) data.

3. There was a large range in the difference between the GPS and CRMP data by county and police agency. This shows both the accuracy that can be obtained with proper training and use of the unit as well as the lack of proper training and/or use of the GPS units at some jurisdictions.

4. The source of errors (refer to section 3.2.4) found for the GPS data was related to operator error rather than problems related to the equipment or environment.

5. The GPS data contained on the electronic reporting format was somewhat more accurate than that provided on the paper crash report. About one-third of the data contained in this sample was in the electronic format.

6. The actions necessary to significantly improve the accuracy of the GPS data are manageable and relate to training, proper use of the GPS unit, care when placing the GPS data onto the crash report, taking the measurement at the impact area, and a minor modification to the crash report. Additional equipment, such as using a power supply to replace batteries, would also increase accuracy.

7. The source of errors related to the CRMP data primarily dealt with improper interpretation of the milepoint logbook, inaccurate use of the available mileposts, and lack of knowledge of current milepoint data availability.

8. A few edits of the crash data could be used which would significantly improve the accuracy of the GPS and CRMP data.

5.0 RECOMMENDATIONS

Errors were found in the location of the crash on the crash report using both GPS and milepoint (CRMP) data. The analysis identified the improvements that can be made to address the identified problems. The source of error affecting the accuracy of the GPS data is failure to properly use the GPS unit since it was found that the GPS unit is very accurate. This type of error included not following the procedures to allow the unit to average the location data (10 percent of a random sample of crashes) and not allowing the unit to establish contact with at least three satellites that results in recording the last established location (7 percent of the random sample). Another frequent error is not collecting data at the actual crash site (15 percent of the random sample). The type of error that resulted in the largest discrepancy in location was not using the proper GPS data format (13 percent of the random sample). Data were reported in degree-decimal-minutes (DDM) and in degrees-minutes-seconds (DMS). In some cases the data were reported in DMS but were interpreted by the CRASH database coder as DDM, and vise-versa. This misinterpretation in format would cause an error of between 30 to 2,000 feet.

Steps can be taken to reduce or eliminate most of the GPS errors identified. A combination of additional training and hardware improvements would dramatically reduce the errors in the GPS and CRMP data. The following recommendations address the errors found in the random sample.

1. The procedure pamphlet (Appendix A) can be updated to include or emphasize the following:
    a. Indicate that the GPS data is not accurate until a “2D” or “3D” icon is displayed in the upper-left hand corner of the unit on the Status screen. Users can use the X button to verify that the icon is present and the Globe button to return to the Navigation screen.
    b. Emphasize the need to check the EPE value to ensure accurate averaging.
    c. Emphasize the statement that officers should get as close as possible to the crash site which would be the first area of impact.
    d. Note that the GPS measurements should be checked on the GPS unit after being placed on the crash report.
    e. Describe how the user can periodically verify that the unit is set to a map datum of WGS84. The map datum can be affected by changing the unit’s coordinate system (e.g. any non-US coordinate system) even if the unit is returned to LAT/LONG.
    f. Examples can be shown of how much the data can be affected by various errors. The importance of accurate GPS readings should be emphasized.
    g. It should be emphasized that the GPS data should be collected at the location of first impact. The procedure should explain how waypoints may optionally be saved so that the officer can fill out the police report away from the scene and still have GPS data from the crash location. It should be clarified that the SporTrak unit has a thumbtack button and the 315 unit has a button named “mark”, both used to save a waypoint.

2. The police report should be modified to reflect the proper GPS data format. The latitude and longitude fields should allow for degrees and minutes with no space for seconds. Furthermore, the degrees field should only have space for two digits and the minutes field should have spaces for two digits before the decimal and three digits after. Appendix D shows a possible format for this change.

3. Continuous training should be given to all officers with emphasis on the types of errors previously identified that contribute to inaccurate GPS data. Information contained in Tables 5 and 6 can be used to identify agencies with the largest difference between GPS and CRMP data where additional training should be considered.

4. Use of a power supply in the police vehicle instead of batteries would reduce problems that contributed to inaccuracies. An alternative power supply would be cost effective compared to the use of batteries. New technology could be used to reduce human error. An example would be the use of a GPS unit integrated into the automated reporting program that is used for most crash reports. At the time of writing this report four accessories are available to improve the usage of the GPS units. A power supply that connects the unit to a vehicle cigarette lighter prevents batteries from being used but allows the unit to stay on throughout an entire shift. This adapter will let the unit constantly keep a fixed position. The adapter is available for approximately $17. A power adapter is also available with a data cable allowing the init to be plugged into a serial port of a laptop or desktop computer. This cable will allow the GPS data to be transmitted without the possibility of transcription errors. The power and data cable combination is available for approximately $30. An adapter is also available to convert the serial data cable into a USB interface to allow laptop or desktop computers to communicate with the GPS unit in the event that no serial ports are available. This adapter would need to be purchased in addition to the above and is available for approximately $15. The following are images of the three accessories respectively.



5. Improvements can be made in the CRMP data with training concerning the proper use of both the milepoint logbook and mileposts. An up-to-date milepoint logbook must be provided to each police agency. The milepoint log should be hyperlinked to the CRASH database.

6. An edit should be added to check the accuracy of the GPS and CRMP data. Several options exist for this edit. A possible edit which could be added to the input procedure using the electronic format would calculate the distance between the location of the crash as recorded by the GPS and CRMP data. This edit would inform the police officer when this distance becomes excessive and encourage any change necessary to improve the accuracy of both types of location data. When this distance is greater than a specified value (such as 500 feet), a message would be given to check the data. The analysis shows that it is reasonable to obtain this level of accuracy. This would allow a correction to be made to either the GPS or CRMP data. Proper use of the GPS equipment and the available information for determining CRMP data allow an accuracy of the location of the crash that should not result in a large number of crashes identified using this type of edit. Most crashes are currently reported using the electronic format with this percentage increasing. A program has been developed for this edit that can be used during data input when the electronic format is used. This interactive program would inform the officer of the distance between the GPS and CRMP locations so any necessary corrections could be made before the report is filed. The program provides suggestions to assist the officer when a correction is necessary along with several other checks for GPS and CRMP data. The supervisor could also check to see if an officer is reporting the same GPS data for several crashes, indicative of not letting the unit establish a position. This type of edit could also be used by the supervisor when the report is checked which would allow the location data to be verified even if it was not collected using the electronic format. Another option for this edit would involve collecting the GPS measurement and then use a file that would search for all nearby CRMP locations. The officer could then choose the appropriate location. After a location is chosen, the distance between the CRMP and GPS data could then be calculated and displayed.

6.0 IMPLEMENTATION

Following is a list of the anticipated implementation from the preceding recommendations. This list is placed in order by the anticipated order of implementation.

1. The crash report will be revised to reflect the proper GPS data input format (refer to Appendix D).

2. The milepoint logbook will be linked to the CRASH database.

3. A committee will be established to revise and test the procedure pamphlet (Appendix A) used to describe the proper GPS procedure for collecting data.

4. Police agencies will be encouraged to purchase an alternate power supply for the GPS unit to replace batteries.

5. A training subcommittee will be established to develop appropriate training for use of the GPS units and milepoint data to properly locate traffic crashes.

6. A subcommittee will be established to develop an edit to check the accuracy of the GPS and CRMP data.

7.0 REFERENCES

1. "Crash GPS Data: 2002 Quality Report," Kentucky State Police, March 2003.

2. Graettinger, A.J.; Rushing, T.W.; and McFadden, J.; "Evaluation of Inexpensive Global Positioning System Units to Improve Crash Location Data, Transportation Research Record 1746, 2001.

3. Miller, J.S. and Karr, D.; "Experimental Application of Global Positioning System to Locate Motor Vehicle Crashes," Transportation Research Record 1625, 1998.

4. Miller, J.; "What Value May Geographic Information Systems Add to the Art of Identifying Crash Countermeasures?" Virginia Transportation Research Council, VTRC 99-R13RB, April 1999.

5. Traffic Records Alert, Louisiana, Summer 2001.

6. Souleyrette, R.R. and Gieseman, D.J.; "Development of an Automated Crash-Location System for Iowa," Iowa State University.

7. Hughes, R.; Gray, G.; and Higgins, H.; "An Application of GIS and GPS to Enforcement Targeting," 9th ITS World Congress, 2002.

TABLES 1-3. CUMMULATIVE PERCENTAGES FOR DISTANCE GROUPS

(Distance between plotted location of crash as shown by CRMP and GPS data)

Table 1. All Crashes

Range (ft)	Count	Percent	Cumulative Percent
0-100	3,723	10.2	10.2
100-200	3,900	10.7	21.0
200-300	2,745	7.6	28.5
300-400	2,187	6.0	34.5
400-500	1,633	4.5	39.0
500-600	1,372	3.8	42.8
600-700	1,119	3.1	45.9
700-800	987	2.7	48.6
800-900	**801**	**2.2**	**50.8**
900-1000	746	2.1	52.9
1000-1500	2,655	7.3	60.2
1500-2000	1,876	5.2	65.3
2000-2500	1,395	3.8	69.2
2500-3000	1,144	3.1	72.3
3000-3500	817	2.2	74.6
3500-4000	747	2.1	76.6
4000-4500	699	1.9	78.5
4500-5000	598	1.6	80.2
5000-6000	965	2.7	82.8
6000-7000	**678**	**1.9**	**84.7**
7000-8000	451	1.2	85.9
8000-9000	413	1.1	87.1
9000-10000	347	1.0	88.0
>10000	4,347	12.0	100.0

Table 2. Intersection Crashes

Range (ft)	Count	Percent	Cumulative Percent
0-100	1,778	17.5	17.5
100-200	1,350	13.3	30.8
200-300	754	7.4	38.2
300-400	602	5.9	44.1
400-500	390	3.8	48.0
500-600	**338**	**3.3**	**51.3**
600-700	269	2.6	54.0
700-800	214	2.1	56.1
800-900	181	1.8	57.9
900-1000	169	1.7	59.5
1000-1500	588	5.8	65.3
1500-2000	426	4.2	69.5
2000-2500	320	3.2	72.6
2500-3000	234	2.3	75.0
3000-3500	180	1.8	76.7
3500-4000	173	1.7	78.4
4000-4500	162	1.6	80.0
4500-5000	159	1.6	81.6
5000-6000	236	2.3	83.9
6000-7000	**160**	**1.6**	**85.5**
7000-8000	111	1.1	86.6
8000-9000	95	0.9	87.5
9000-10000	84	0.8	88.3
>10000	1,184	11.7	100.0

Table 3. Intersection Crashes (Fayette)

Range (ft)	Count	Percent	Cumulative Percent
0-100	169	21.6	21.6
100-200	152	19.4	41.0
200-300	**75**	**9.6**	**50.6**
300-400	70	9.0	59.6
400-500	27	3.5	63.0
500-600	26	3.3	66.4
600-700	18	2.3	68.7
700-800	14	1.8	70.5
800-900	9	1.2	71.6
900-1000	9	1.2	72.8
1000-1500	34	4.3	77.1
1500-2000	43	5.5	82.6
2000-2500	**16**	**2.0**	**84.7**
2500-3000	8	1.0	85.7
3000-3500	8	1.0	86.7
3500-4000	5	0.6	87.3
4000-4500	5	0.6	88.0
4500-5000	5	0.6	88.6
5000-6000	8	1.0	89.6
6000-7000	9	1.2	90.8
7000-8000	5	0.6	91.4
8000-9000	10	1.3	92.7
9000-10000	4	0.5	93.2
>10000	53	6.8	100.0

TABLE 4. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY

	All Crashes			Intersection Crashes		
County	Frequency	50th	85th	Frequency	50th	85th
Adair	103	974	8,888	11	146	5,036
Allen	155	956	6,225	24	122	18,658
Anderson	180	368	4,892	37	146	4,780
Ballard	78	574	4,752	12	307	1,578
Barren	362	887	4,684	85	573	3,317
Bath	96	1,589	9,715	11	1,068	6,126
Bell	249	428	3,632	66	129	3,022
Boone	1,424	640	4,068	452	365	2,587
Bourbon	222	902	20,723	88	441	7,407
Boyd	622	1,541	17,833	277	1,581	39,044
Boyle	328	825	13,507	129	678	14,904
Bracken	76	796	8,097	10	206	1,470
Breathitt	194	570	6,322	24	124	3,857
Breckinridge	86	874	25,848	23	1,086	25,916
Bullitt	498	1,677	9,057	153	1,709	8,022
Butler	97	555	2,183	29	146	2,552
Caldwell	116	516	4,296	25	139	3,137
Calloway	355	795	4,236	136	455	3,656
Campbell	876	669	3,980	295	661	4,840
Carlisle	49	1,083	8,640	11	732	4,576
Carroll	164	581	4,462	42	437	4,110
Carter	212	2,438	14,033	19	1,309	11,112
Casey	72	734	3,396	8	128	274
Christian	652	556	9,176	230	423	6,742
Clark	218	1,213	5,732	29	1,241	4,256
Clay	152	1,035	26,903	21	1,927	27,794
Clinton	92	638	9,766	11	570	6,470
Crittenden	90	472	2,383	15	541	4,057
Cumberland	27	3,738	7,618	2	2,892	4,154
Daviess	405	896	12,472	122	499	6,168
Edmonson	85	2,047	6,920	27	874	4,082
Elliott	59	1,021	3,307	6	90	568
Estill	56	679	6,891	14	751	8,321
Fayette	2,700	379	3,095	782	289	2,637
Fleming	107	3,214	50,336	35	2,552	49,742
Floyd	404	1,113	10,019	63	623	12,856
Franklin	588	395	2,524	159	221	1,201
Fulton	41	639	3,307	7	141	5,208
Gallatin	77	1,158	3,465	14	1,276	2,936
Garrard	126	1,029	8,571	23	261	9,408
Grant	275	946	8,444	39	351	2,879
Graves	246	821	14,545	54	530	27,384
Grayson	282	494	5,226	27	126	1,332
Green	57	1,294	5,670	3	1,053	4,099
Greenup	192	1,925	9,500	45	1,833	6,573
Hancock	25	1,464	14,912	6	3,756	16,459

TABLE 4. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY (CONTINUED)

	All Crashes			Intersection Crashes		
County	Frequency	50th	85th	Frequency	50th	85th
Hardin	1,054	622	5,354	299	289	4,850
Harlan	280	1,385	7,037	77	505	3,646
Harrison	151	600	3,637	29	242	1,601
Hart	173	1,091	7,866	24	191	1,226
Henderson	549	815	4,889	174	800	5,448
Henry	160	1,317	6,995	17	823	14,719
Hickman	37	1,538	28,426	8	4,123	6,436
Hopkins	570	472	3,945	147	234	2,856
Jackson	96	1,822	26,105	8	1,706	21,610
Jefferson	3,717	1,439	10,742	1,285	1,310	13,015
Jessamine	487	746	6,388	128	445	4,073
Johnson	197	673	4,820	25	519	18,375
Kenton	1,422	768	3,285	439	801	3,387
Knott	153	1,663	12,513	14	2,731	15,406
Knox	264	1,003	10,871	55	186	3,641
Larue	125	317	2,597	42	100	856
Laurel	577	912	9,461	217	596	10,790
Lawrence	75	4,230	27,986	24	5,421	39,851
Lee	13	3,339	11,348	5	761	35,096
Leslie	83	1,271	10,752	5	637	1,212
Letcher	157	3,455	29,566	19	1,377	19,689
Lewis	99	994	4,739	17	266	2,593
Lincoln	126	3,153	56,332	33	3,430	48,818
Livingston	119	291	4,275	21	215	4,395
Logan	232	2,541	9,402	81	506	41,168
Lyon	91	758	4,027	17	452	4,666
McCracken	853	1,081	9,423	453	971	10,109
McCreary	103	3,468	20,642	22	2,261	23,043
McLean	66	1,514	5,244	14	1,691	4,871
Madison	839	1,095	7,703	237	810	11,726
Magoffin	83	3,156	18,419	4	16,769	41,886
Marion	169	801	6,045	33	191	1,378
Marshall	372	697	6,622	102	556	11,161
Martin	61	2,745	13,837	2	2,099	3,533
Mason	243	1,883	16,671	68	1,471	14,008
Meade	183	2,684	7,274	49	2,694	37,713
Menifee	24	610	2,994	1	51	51
Mercer	138	2,569	17,184	50	4,745	12,992
Metcalfe	109	2,500	21,645	19	2,731	5,800
Monroe	8	321	1,005	4	321	447
Montgomery	241	1,031	6,663	81	881	7,000
Morgan	109	1,007	4,515	5	933	3,043
Muhlenberg	349	568	4,433	66	203	1,888
Nelson	483	781	3,877	145	716	3,599
Nicholas	26	532	3,213	0	N/A	N/A
Ohio	261	770	6,871	32	432	5,060

TABLE 4. 50TH AND 85TH PERCENTILE DISTANCES BY COUNTY (CONTINUED)

	All Crashes			Intersection Crashes		
County	**Frequency**	**50th**	**85th**	**Frequency**	**50th**	**85th**
Oldham	343	1,313	5,067	106	957	6,048
Owen	88	2,972	9,440	3	11,192	12,046
Owsley	32	2,782	27,093	7	3,149	13,621
Pendleton	129	731	4,965	27	235	4,515
Perry	283	3,201	14,566	69	4,343	31,380
Pike	779	1,813	13,605	91	391	8,961
Powell	71	2,594	4,756	6	3,035	3,718
Pulaski	627	601	4,814	259	443	3,839
Robertson	6	2,709	8,163	0	N/A	N/A
Rockcastle	165	2,206	21,112	17	1,330	7,229
Rowan	276	707	4,357	58	101	1,221
Russell	64	444	4,147	13	343	538
Scott	477	2,470	11,270	104	1,176	11,321
Shelby	395	1,158	8,445	110	672	4,356
Simpson	194	613	5,785	43	245	3,346
Spencer	59	1,148	11,259	5	3,080	41,268
Taylor	253	629	6,409	94	433	3,691
Todd	64	1,096	23,129	15	322	25,078
Trigg	85	717	14,870	19	130	4,033
Trimble	66	790	4,398	9	120	3,907
Union	140	560	5,639	38	576	10,729
Warren	1,345	480	5,251	479	267	2,244
Washington	111	521	6,779	33	104	6,147
Wayne	143	760	11,675	50	319	8,809
Webster	143	1,572	33,200	25	390	8,951
Whitley	354	682	5,354	82	317	5,123
Wolfe	76	582	5,484	12	1,054	42,279
Woodford	280	1,263	10,503	85	1,111	9,398
All	36,345	864	7,224	10,157	559	6,605

*Distance (in feet) between plotted location of crash as shown by CRMP and GPS data

TABLE 5. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR ALL CRASHES

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Adair	64	840	7,412	32	1,800	35,274	7	146	8,483	103	974	8,888
Allen	16	5,632	67,454	95	1,106	4,943	44	435	3,574	155	956	6,225
Anderson	66	1,027	5,665	34	836	13,243	80	146	866	180	368	4,892
Ballard	4	276	40,498	64	688	4,531	10	1,153	4,946	78	574	4,752
Barren	69	975	5,911	162	1,367	4,396	131	573	3,443	362	887	4,684
Bath	51	1,644	9,476	18	1,363	16,277	27	1,534	7,169	96	1,589	9,715
Bell	81	1,646	6,679	35	2,070	10,359	133	168	1,393	249	428	3,632
Boone	2	1,740	2,583	812	1,088	7,736	610	376	2,112	1,424	640	4,068
Bourbon	62	2,073	21,018	47	4,666	44,822	113	502	7,137	222	902	20,723
Boyd	59	1,415	21,695	225	1,107	12,468	338	1,744	33,681	622	1,541	17,833
Boyle	11	440	36,223	59	3,472	9,532	258	487	13,322	328	825	13,507
Bracken	22	2,398	14,537	43	716	7,909	11	112	1,455	76	796	8,097
Breathitt	65	886	7,610	19	20,420	53,966	110	373	1,548	194	570	6,322
Breckinridge	7	662	1,085	64	830	39,163	15	1,260	22,700	86	874	25,848
Bullitt	34	1,390	2,575	185	1,151	9,030	279	1,971	9,366	498	1,677	9,057
Butler	32	1,115	2,052	36	737	2,927	29	140	1,200	97	555	2,183
Caldwell	32	540	4,062	44	865	9,268	40	267	1,248	116	516	4,296
Calloway	26	1,573	18,769	129	1,024	5,991	200	626	2,652	355	795	4,236
Campbell	0	N/A	N/A	0	N/A	N/A	876	669	3,980	876	669	3,980
Carlisle	3	230	473	39	1,722	10,032	7	96	3,347	49	1,083	8,640
Carroll	63	967	4,058	44	558	4,021	57	478	4,878	164	581	4,462
Carter	169	2,465	12,116	24	2,216	13,483	19	1,309	26,858	212	2,438	14,033
Casey	42	600	3,554	0	N/A	N/A	30	1,050	3,154	72	734	3,396
Christian	129	2,362	47,890	70	564	5,858	453	384	5,049	652	556	9,176
Clark	13	668	5,134	172	1,293	6,062	33	1,141	4,927	218	1,213	5,732
Clay	80	738	41,022	27	2,722	27,504	45	379	5,328	152	1,035	26,903
Clinton	15	729	16,390	0	N/A	N/A	77	573	9,265	92	638	9,766
Crittenden	30	499	3,552	34	389	1,511	26	680	5,997	90	472	2,383
Cumberland	7	531	22,587	11	4,599	7,911	9	3,738	5,393	27	3,738	7,618
Daviess	88	959	5,965	262	980	12,436	55	603	17,755	405	896	12,472
Edmonson	27	1,335	13,369	57	2,047	6,342	1	12,189	12,189	85	2,047	6,920
Elliott	23	1,958	10,353	36	571	2,513	0	N/A	N/A	59	1,021	3,307

TABLE 5. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR ALL CRASHES (CONTINUED)

	State			Sheriff			Local			All		
County	Freq	50th	85th	Freq	50th	85th	Freq	50th	85th	Freq	50th	85th
Estill	38	478	3,723	7	1,511	6,932	11	3,677	36,297	56	679	6,891
Fayette	8	1,415	48,914	0	N/A	N/A	2,692	378	3,067	2,700	379	3,095
Fleming	36	1,565	15,591	42	4,800	47,696	29	3,089	51,799	107	3,214	50,336
Floyd	202	1,392	10,779	78	976	7,134	124	1,111	10,609	404	1,113	10,019
Franklin	197	877	7,178	38	656	6,756	353	289	1,393	588	395	2,524
Fulton	4	461	10,315	25	1,184	3,124	12	318	14,402	41	639	3,307
Gallatin	13	1,038	2,945	55	1,247	3,394	9	152	4,735	77	1,158	3,465
Garrard	67	1,058	15,040	24	1,110	2,783	35	884	9,235	126	1,029	8,571
Grant	121	966	7,344	100	634	7,666	54	1,193	13,469	275	946	8,444
Graves	125	599	7,502	98	2,706	31,350	23	1,398	5,575	246	821	14,545
Grayson	43	450	4,289	114	1,028	9,701	125	334	1,862	282	494	5,226
Green	8	368	4,308	45	1,409	6,589	4	925	3,676	57	1,294	5,670
Greenup	107	1,199	8,711	34	4,289	22,572	51	2,648	8,030	192	1,925	9,500
Hancock	5	3,527	7,978	20	1,428	16,465	0	N/A	N/A	25	1,464	14,912
Hardin	340	1,161	5,942	37	1,343	5,434	677	464	4,864	1,054	622	5,354
Harlan	180	1,515	7,016	14	2,367	20,858	86	593	4,690	280	1,385	7,037
Harrison	17	3,261	24,748	67	1,330	3,938	67	295	1,259	151	600	3,637
Hart	100	1,559	7,827	35	497	5,883	38	997	13,221	173	1,091	7,866
Henderson	77	864	4,130	137	601	2,809	335	926	5,573	549	815	4,889
Henry	130	1,168	5,721	6	507	1,354	24	5,202	17,272	160	1,317	6,995
Hickman	17	710	4,954	19	4,134	42,317	1	150	150	37	1,538	28,426
Hopkins	245	1,002	6,334	48	420	3,055	277	310	2,184	570	472	3,945
Jackson	24	538	1,556	62	2,635	30,917	10	3,777	14,418	96	1,822	26,105
Jefferson	3	1,257	2,214	8	2,284	23,188	3,706	1,436	10,739	3,717	1,439	10,742
Jessamine	11	685	2,176	182	1,425	16,112	294	470	2,846	487	746	6,388
Johnson	13	1,742	7,877	77	1,057	18,471	107	493	1,280	197	673	4,820
Kenton	2	4,208	5,130	17	408	2,179	1,403	768	3,305	1,422	768	3,285
Knott	115	2,002	13,465	35	1,344	8,045	3	2,608	4,116	153	1,663	12,513
Knox	137	1,545	11,974	26	3,287	22,254	101	598	2,470	264	1,003	10,871
Larue	25	1,143	6,102	65	420	1,695	35	142	2,262	125	317	2,597
Laurel	108	881	6,485	266	1,263	10,171	203	668	9,401	577	912	9,461
Lawrence	21	1,213	19,693	35	6,934	56,871	19	5,617	13,004	75	4,230	27,986

TABLE 5. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR ALL CRASHES (CONTINUED)

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Lee	6	1,844	3,715	0	N/A	N/A	7	4,290	30,650	13	3,339	11,348
Leslie	69	1,088	8,566	7	5,736	22,827	7	2,162	60,810	83	1,271	10,752
Letcher	113	2,691	31,806	31	11,148	33,495	13	1,196	5,381	157	3,455	29,566
Lewis	33	885	5,367	46	1,675	4,545	20	362	2,412	99	994	4,739
Lincoln	65	2,876	68,743	59	2,619	47,833	2	3,914	3,914	126	3,153	56,332
Livingston	39	736	5,459	80	241	3,396	0	N/A	N/A	119	291	4,275
Logan	18	2,847	32,689	121	3,657	7,318	93	290	16,471	232	2,541	9,402
Lyon	53	1,303	3,422	19	512	8,893	19	452	5,466	91	758	4,027
McCracken	22	2,001	5,575	332	2,087	14,985	499	808	5,567	853	1,081	9,423
McCreary	30	375	4,911	72	4,783	24,874	1	313	313	103	3,468	20,642
McLean	38	690	4,047	27	2,574	5,316	1	81	81	66	1,514	5,244
Madison	299	1,440	7,450	90	1,558	12,189	450	791	7,251	839	1,095	7,703
Magoffin	35	2,972	12,567	47	3,335	23,519	1	467	467	83	3,156	18,419
Marion	75	1,292	10,884	22	948	1,203	72	254	4,644	169	801	6,045
Marshall	63	475	4,248	232	1,625	16,476	77	258	1,487	372	697	6,622
Martin	17	2,298	10,493	43	2,745	13,729	1	45,892	45,892	61	2,745	13,837
Mason	12	756	7,880	87	609	7,171	144	2,891	31,202	243	1,883	16,671
Meade	48	893	3,643	111	3,146	7,632	24	1,967	16,795	183	2,684	7,274
Menifee	20	639	3,752	2	539	550	2	807	1,354	24	610	2,994
Mercer	39	1,024	12,842	29	4,428	42,702	70	3,786	12,751	138	2,569	17,184
Metcalfe	6	1,911	4,259	61	4,540	48,014	42	749	2,677	109	2,500	21,645
Monroe	6	321	640	0	N/A	N/A	2	986	1,641	8	321	1,005
Montgomery	41	1,181	11,108	125	958	4,267	75	947	9,509	241	1,031	6,663
Morgan	84	942	4,426	0	N/A	N/A	25	2,008	18,716	109	1,007	4,515
Muhlenberg	155	655	4,664	75	2,231	8,777	119	234	2,298	349	568	4,433
Nelson	36	930	3,913	252	776	4,789	195	776	2,826	483	781	3,877
Nicholas	11	556	3,395	13	526	3,385	2	738	1,017	26	532	3,213
Ohio	96	650	6,356	118	1,149	9,211	47	261	4,570	261	770	6,871
Oldham	1	4,495	4,495	34	1,527	4,205	308	1,241	5,187	343	1,313	5,067
Owen	39	1,292	3,722	32	4,380	13,378	17	8,834	10,206	88	2,972	9,440
Owsley	2	350	509	19	3,304	44,417	11	1,759	7,162	32	2,782	27,093
Pendleton	60	704	4,783	56	668	4,620	13	3,421	9,851	129	731	4,965

TABLE 5. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR ALL CRASHES (CONTINUED)

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Perry	97	4,336	10,842	122	1,081	6,328	64	9,186	37,999	283	3,201	14,566
Pike	589	2,059	17,233	28	2,562	4,638	162	801	6,082	779	1,813	13,605
Powell	23	2,110	3,988	25	3,127	17,086	23	2,873	3,875	71	2,594	4,756
Pulaski	34	409	1,529	272	2,237	9,066	321	245	2,621	627	601	4,814
Robertson	5	2,963	8,202	0	N/A	N/A	1	2,455	2,455	6	2,709	8,163
Rockcastle	102	2,032	25,356	27	2,350	25,783	36	2,231	4,183	165	2,206	21,112
Rowan	174	1,168	6,125	0	N/A	N/A	102	211	1,606	276	707	4,357
Russell	25	279	1,326	18	2,098	12,569	21	413	1,143	64	444	4,147
Scott	60	5,754	13,099	228	1,196	10,526	189	7,737	11,004	477	2,470	11,270
Shelby	70	978	3,176	184	2,100	14,964	141	502	4,272	395	1,158	8,445
Simpson	45	1,841	8,507	60	1,075	5,966	89	234	1,955	194	613	5,785
Spencer	49	935	5,988	10	5,120	13,229	0	N/A	N/A	59	1,148	11,259
Taylor	10	388	8,082	107	890	8,079	136	600	6,252	253	629	6,409
Todd	36	1,041	7,956	11	1,351	9,806	17	5,023	31,419	64	1,096	23,129
Trigg	49	851	9,919	8	258	2,570	28	209	78,691	85	717	14,870
Trimble	54	794	3,687	12	551	4,565	0	N/A	N/A	66	790	4,398
Union	54	518	5,614	39	681	4,727	47	729	9,188	140	560	5,639
Warren	258	1,682	12,080	198	1,180	6,591	889	329	2,140	1,345	480	5,251
Washington	42	2,063	8,289	33	870	4,398	36	162	7,875	111	521	6,779
Wayne	9	176	1,438	37	988	6,879	97	771	45,903	143	760	11,675
Webster	61	1,503	10,421	60	941	34,939	22	2,939	52,489	143	1,572	33,200
Whitley	85	841	11,372	111	1,318	4,851	158	403	3,356	354	682	5,354
Wolfe	46	596	5,580	30	582	3,110	0	N/A	N/A	76	582	5,484
Woodford	18	796	3,202	4	3,194	11,092	258	1,340	10,834	280	1,263	10,503
All	**7,557**	**1,214**	**9,067**	**8,561**	**1,375**	**9,960**	**20,227**	**633**	**5,753**	**36,345**	**864**	**7,224**

*Distance (in feet) between plotted location of crash as shown by CRMP and GPS data

TABLE 6. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR INTERSECTIONS

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Adair	3	378	1,263	2	113	155	6	114	8,562	11	146	5,036
Allen	1	115	115	6	543	8,884	17	99	20,181	24	122	18,658
Anderson	7	4,514	4,664	5	10,720	30,100	25	121	201	37	146	4,780
Ballard	0	N/A	N/A	11	376	1,593	1	162	162	12	307	1,578
Barren	4	1,843	14,674	32	1,347	5,073	49	547	1,565	85	573	3,317
Bath	5	1,723	44,902	1	1,068	1,068	5	34	2,689	11	1,068	6,126
Bell	7	1,822	4,280	1	3,157	3,157	58	128	1,863	66	129	3,022
Boone	1	536	536	239	562	4,214	212	267	1,760	452	365	2,587
Bourbon	6	4,158	15,760	5	9,071	44,488	77	441	5,998	88	441	7,407
Boyd	10	903	16,555	70	1,122	27,168	197	1,797	53,994	277	1,581	39,044
Boyle	5	191	40,852	11	5,062	7,922	113	505	14,963	129	678	14,904
Bracken	1	2,878	2,878	4	298	585	5	100	856	10	206	1,470
Breathitt	5	67	16,239	1	30,841	30,841	18	124	2,188	24	124	3,857
Breckinridge	0	N/A	N/A	16	990	26,701	7	1,988	10,918	23	1,086	25,916
Bullitt	4	1,695	2,377	45	804	16,765	104	2,042	6,295	153	1,709	8,022
Butler	4	166	30,910	11	239	737	14	127	3,009	29	146	2,552
Caldwell	4	44	105	4	4,124	13,127	17	104	2,140	25	139	3,137
Calloway	6	4,687	14,520	31	1,455	5,452	99	320	2,218	136	455	3,656
Campbell	0	N/A	N/A	0	N/A	N/A	295	661	4,840	295	661	4,840
Carlisle	0	N/A	N/A	7	2,004	4,458	4	401	13,533	11	732	4,576
Carroll	6	369	1,483	9	483	4,341	27	292	2,711	42	437	4,110
Carter	8	878	19,302	2	921	1,531	9	1,309	7,058	19	1,309	11,112
Casey	5	114	196	0	N/A	N/A	3	231	2,464	8	128	274
Christian	18	6,169	88,286	12	1,812	31,619	200	382	4,405	230	423	6,742
Clark	0	N/A	N/A	18	1,367	4,217	11	370	4,149	29	1,241	4,256
Clay	4	20,715	88,605	0	N/A	N/A	17	1,927	10,143	21	1,927	27,794
Clinton	3	615	1,853	0	N/A	N/A	8	544	8,375	11	570	6,470
Crittenden	1	355	355	4	292	523	10	982	6,843	15	541	4,057
Cumberland	0	N/A	N/A	1	4,695	4,695	1	1,090	1,090	2	2,892	4,154
Daviess	19	742	1,233	64	402	7,274	39	405	14,365	122	499	6,168
Edmonson	4	249	1,603	23	1,246	4,621	0	N/A	N/A	27	874	4,082
Elliott	0	N/A	N/A	6	90	568	0	N/A	N/A	6	90	568

TABLE 6. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR INTERSECTIONS (CONTINUED)

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Estill	7	713	9,585	2	13,801	20,932	5	340	1,945	14	751	8,321
Fayette	2	1,290	2,029	0	N/A	N/A	780	289	2,638	782	289	2,637
Fleming	8	1,625	26,810	14	4,800	15,167	13	2,552	50,906	35	2,552	49,742
Floyd	30	1,284	22,888	12	1,013	11,129	21	406	4,830	63	623	12,856
Franklin	26	266	3,229	3	64	279	130	201	1,153	159	221	1,201
Fulton	1	18,232	18,232	1	3,760	3,760	5	92	186	7	141	5,208
Gallatin	1	2,151	2,151	10	1,276	2,618	3	54	3,960	14	1,276	2,936
Garrard	4	377	705	1	69	69	18	404	10,951	23	261	9,408
Grant	21	489	4,870	13	343	1,325	5	155	282	39	351	2,879
Graves	26	537	29,715	16	448	22,503	12	972	8,219	54	530	27,384
Grayson	5	380	1,962	6	327	9,680	16	102	318	27	126	1,332
Green	1	1,053	1,053	0	N/A	N/A	2	2,796	4,621	3	1,053	4,099
Greenup	12	2,164	9,474	4	2,312	3,635	29	1,773	5,320	45	1,833	6,573
Hancock	0	N/A	N/A	6	3,756	16,459	0	N/A	N/A	6	3,756	16,459
Hardin	43	569	8,206	9	1,301	2,600	247	249	4,187	299	289	4,850
Harlan	22	942	3,461	4	9,499	17,590	51	474	3,314	77	505	3,646
Harrison	0	N/A	N/A	10	730	1,741	19	135	498	29	242	1,601
Hart	9	117	1,183	5	132	231	10	470	1,328	24	191	1,226
Henderson	9	207	7,295	22	465	1,263	143	855	5,715	174	800	5,448
Henry	7	467	4,270	1	40	40	9	2,598	15,027	17	823	14,719
Hickman	4	2,990	5,603	4	4,123	20,443	0	N/A	N/A	8	4,123	6,436
Hopkins	20	405	5,195	15	480	3,448	112	186	1,843	147	234	2,856
Jackson	2	597	758	5	17,348	27,695	1	1,009	1,009	8	1,706	21,610
Jefferson	0	N/A	N/A	2	21,673	35,358	1,283	1,305	12,998	1,285	1,310	13,015
Jessamine	1	120	120	42	632	15,687	85	395	2,724	128	445	4,073
Johnson	2	585	928	15	848	25,382	8	165	1,201	25	519	18,375
Kenton	0	N/A	N/A	6	489	886	433	812	3,519	439	801	3,387
Knott	9	701	26,484	3	4,904	6,099	2	2,441	4,066	14	2,731	15,406
Knox	14	318	4,237	4	7,429	16,884	37	167	1,503	55	186	3,641
Larue	2	474	768	22	100	556	18	93	14,480	42	100	856
Laurel	24	522	5,461	85	1,124	11,782	108	509	9,370	217	596	10,790
Lawrence	4	123	34,928	7	10,767	70,994	13	3,457	12,838	24	5,421	39,851

TABLE 6. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR INTERSECTIONS (CONTINUED)

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Lee	1	85	85	0	N/A	N/A	4	14,965	37,318	5	761	35,096
Leslie	5	637	1,212	0	N/A	N/A	0	N/A	N/A	5	637	1,212
Letcher	11	1,377	8,988	4	28,263	51,327	4	394	3,607	19	1,377	19,689
Lewis	4	274	356	9	266	3,221	4	354	25,146	17	266	2,593
Lincoln	17	2,706	70,549	16	4,257	34,245	0	N/A	N/A	33	3,430	48,818
Livingston	4	382	5,350	17	215	3,668	0	N/A	N/A	21	215	4,395
Logan	6	295	67,153	25	2,858	5,728	50	184	42,244	81	506	41,168
Lyon	3	95	1,585	3	129	2,781	11	698	5,667	17	452	4,666
McCracken	6	356	3,027	160	1,830	13,645	287	782	5,650	453	971	10,109
McCreary	7	356	612	15	4,985	30,748	0	N/A	N/A	22	2,261	23,043
McLean	4	1,258	1,440	10	2,735	5,033	0	N/A	N/A	14	1,691	4,871
Madison	27	1,440	12,599	7	325	10,527	203	810	10,241	237	810	11,726
Magoffin	3	19,887	47,886	1	13,650	13,650	0	N/A	N/A	4	16,769	41,886
Marion	8	400	537	3	51	734	22	160	4,290	33	191	1,378
Marshall	16	473	2,631	58	1,868	19,332	28	252	1,028	102	556	11,161
Martin	1	4,148	4,148	1	50	50	0	N/A	N/A	2	2,099	3,533
Mason	1	105	105	18	523	5,713	49	2,158	28,215	68	1,471	14,008
Meade	11	605	4,840	28	2,792	40,078	10	4,199	35,460	49	2,694	37,713
Menifee	1	51	51	0	N/A	N/A	0	N/A	N/A	1	51	51
Mercer	6	1,289	9,138	4	18,254	37,853	40	4,897	12,528	50	4,745	12,992
Metcalfe	1	2,731	2,731	12	4,755	20,650	6	247	929	19	2,731	5,800
Monroe	4	321	447	0	N/A	N/A	0	N/A	N/A	4	321	447
Montgomery	10	632	1,451	20	391	4,624	51	950	9,223	81	881	7,000
Morgan	3	1,521	4,185	0	N/A	N/A	2	621	840	5	933	3,043
Muhlenberg	10	116	411	13	568	18,074	43	166	1,178	66	203	1,888
Nelson	2	173	248	42	521	7,509	101	777	2,815	145	716	3,599
Nicholas	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A
Ohio	9	164	432	7	3,142	5,909	16	502	4,955	32	432	5,060
Oldham	0	N/A	N/A	8	1,471	4,393	98	930	6,409	106	957	6,048
Owen	1	8,564	8,564	2	11,802	12,230	0	N/A	N/A	3	11,192	12,046
Owsley	0	N/A	N/A	3	3,149	36,992	4	2,961	7,779	7	3,149	13,621
Pendleton	6	226	282	12	251	1,803	9	3,462	5,681	27	235	4,515

TABLE 6. 50TH AND 85TH PERCENTILE DISTANCES* BY COUNTY FOR EACH POLICE AGENCY FOR INTERSECTIONS (CONTINUED)

	State			Sheriff			Local			All		
County	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**	**Freq**	**50th**	**85th**
Perry	13	2,082	8,054	25	353	8,644	31	9,537	35,789	69	4,343	31,380
Pike	61	498	8,360	1	717	717	29	305	11,342	91	391	8,961
Powell	0	N/A	N/A	1	3,477	3,477	5	2,594	3,719	6	3,035	3,718
Pulaski	5	213	220	108	1,839	8,564	146	208	1,863	259	443	3,839
Robertson	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A
Rockcastle	6	335	1,923	3	5,544	7,283	8	3,597	20,061	17	1,330	7,229
Rowan	19	852	2,350	0	N/A	N/A	39	79	239	58	101	1,221
Russell	3	233	1,266	3	392	495	7	343	392	13	343	538
Scott	3	12,137	47,190	29	182	8,121	72	7,605	11,314	104	1,176	11,321
Shelby	10	279	767	37	1,192	10,891	63	421	4,362	110	672	4,356
Simpson	3	2,697	2,875	6	166	3,197	34	222	3,602	43	245	3,346
Spencer	3	244	36,763	2	18,459	29,224	0	N/A	N/A	5	3,080	41,268
Taylor	1	317	317	15	353	3,406	78	488	3,293	94	433	3,691
Todd	5	95	3,687	1	129	129	9	5,023	27,460	15	322	25,078
Trigg	7	2,478	18,865	1	315	315	11	97	161	19	130	4,033
Trimble	5	2,127	12,316	4	57	95	0	N/A	N/A	9	120	3,907
Union	8	2,757	5,469	9	255	5,498	21	424	11,324	38	576	10,729
Warren	29	519	5,131	53	385	4,827	397	248	1,485	479	267	2,244
Washington	4	4,313	26,933	9	95	409	20	86	2,538	33	104	6,147
Wayne	2	70	72	8	138	660	40	525	13,906	50	319	8,809
Webster	3	1,786	7,831	16	151	10,663	6	2,221	4,343	25	390	8,951
Whitley	5	979	21,181	22	177	6,205	55	323	3,814	82	317	5,123
Wolfe	7	1,551	41,686	5	925	18,403	0	N/A	N/A	12	1,054	42,279
Woodford	2	1,336	1,992	1	17,023	17,023	82	1,082	8,591	85	1,111	9,398
All	**849**	**528**	**8,346**	**1,847**	**912**	**10,532**	**7,461**	**510**	**6,063**	**10,157**	**559**	**6,605**

*Distance (in feet) between plotted location of crash as shown by CRMP and GPS data

TABLE 7. FIELD DATA COLLECTION RESULTS

OID	DATE	START TIME	END TIME	SKY	LAT	LONG
0	12/8/03	1:10	1:11	Partly	38.037500	-84.507117
1	12/8/03	1:10	1:11	Partly	38.037533	-84.507150
2	12/8/03	11:18	11:19	Cloudy	38.037567	-84.507150
3	12/10/03	12:58	1:00	Rainy	38.037900	-84.506450
4	12/10/03	1:02	1:03	Rainy	38.037417	-84.507083
5	12/12/04	2:03	2:03	Mostly Sunny	38.037600	-84.507250
6	1/5/04	2:43	2:44	Cloudy	38.037600	-84.507083
7	1/6/04	1:54	1:55	Sunny	38.037650	-84.507100
8	1/7/04	3:24	3:25	Sunny	38.037533	-84.507083
9	1/8/04	2:57	2:58	Cloudy	38.037600	-84.507083
10	1/12/04	1:06	1:07	Cloudy	38.037583	-84.507083
11	1/16/04	1:31	1:32	Sunny	38.037617	-84.507100
12	1/23/04	1:50	1:52	Cloudy	38.037583	-84.507200
13	1/28/04	12:05	12:06	Cloudy	38.037600	-84.507083
14	2/4/04	12:35	12:36	Partly	38.037600	-84.507100
15	2/6/04	1:34	1:35	Partly	38.037567	-84.507100
16	2/16/04	10:00	10:01	Sunny	38.037667	-84.507083
17	2/16/04	10:01	10:02	Sunny	38.034583	-84.511183

APPENDIX A.

GPS PROCEDURE FOR COLLECTING DATA

APPENDIX A. GPS DATA COLLECTION PROCEDURE

Locating A Point Using GPS Unit

1. Get as close to the crash site as possible with the GPS unit. ***The unit requires adequate view of the sky – it won't locate satellites sufficiently inside a vehicle.***

2. Press the **Power** PWR button in the lower right corner.

3. Press ENTER within 10 seconds to continue. Unit will display **Status** screen (which displays satellite reception).

4. Allow unit to search for satellites and establish a fixed position. The amount of time this takes varies, but could take a few minutes.

5. When the unit determines a position, the display will change to the **Position** screen.

6. Once a position is displayed, move slightly (5-10 feet), an "Averaging" line on display will briefly change from *Averaging* to *EPE* (estimated position error).

   Example: **EPE _35_** (number in feet)

   If EPE is greater than 100 feet, adjust your location of the unit to improve line of sight to the sky to get another reading.

7. Record the *Latitude* {first number on position screen (N) and *Longitude*, second number (W)} **with minutes out to three decimals** on the CRASH report. ***Three decimals are essential.***

   Example: Latitude: (N)38°12.123
   Longitude: (W) 84°52.456

8. **To power off** press the PWR button. It allows you 5 seconds to change your mind. To leave it on press any key on the unit and it will remain on.

IMPORTANT: You should turn off unit to conserve batteries.

Note: Reporting consistency is essential for statewide uniformity and accurate crash locations. The **default position format and datum** for the Magellan 315 should be used when reporting crash data:

Position Format = DD°MM.MMM
Map Datum = WGS84

To reset defaults to the above format refer to the top of page 46 of the User Manual. For technical assistance, call 800/669-4477 or 800/707-9971.

APPENDIX B

FORMAT FOR POLICE AGENCY INTERVIEWS

APPENDIX B. FORMAT FOR POLICE AGENCY INTERVIEWS

Date:

Agency:

1. Describe the training given to officers related to the use of the GPS units.

2. Describe any problems encountered in the use of the GPS units.

3. Where are officers told to stand at the accident scene when they obtain GPS data?

4. How many officers are using the GPS units?

5. Are there enough GPS units for the officers who investigate crashes?

6. Do officers have a milepoint book to use for placing the milepoint on the report?

   How often are the milepoint books updated?

   What is used for reference for milepoint data placed on the crash report?

7. How are the GPS and milepoint data checked prior to sending the report to Frankfort?

8. Does the agency use or plan to use the electronic format for completing the crash report?

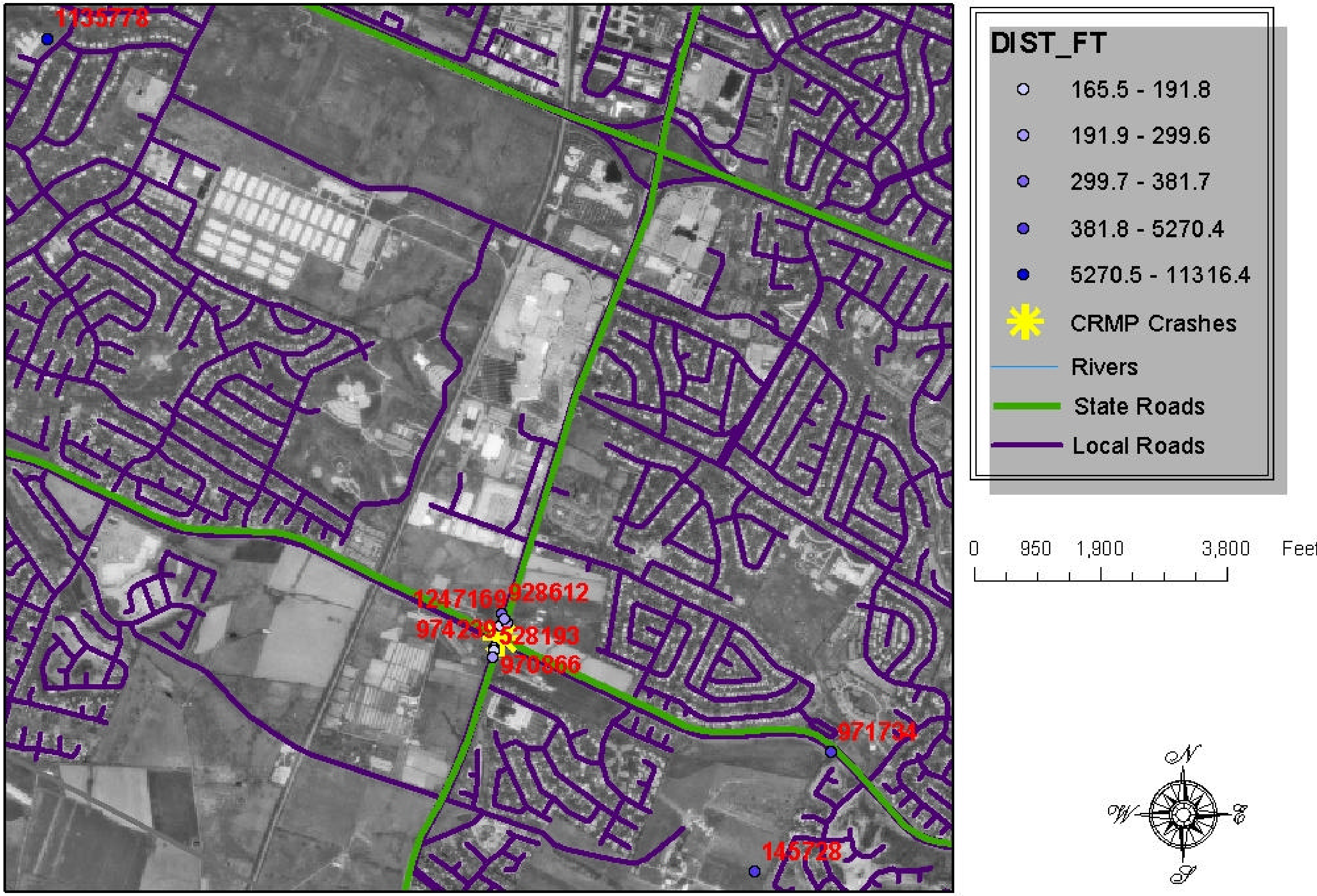
9. List any suggestions for improving the accuracy of GPS data.

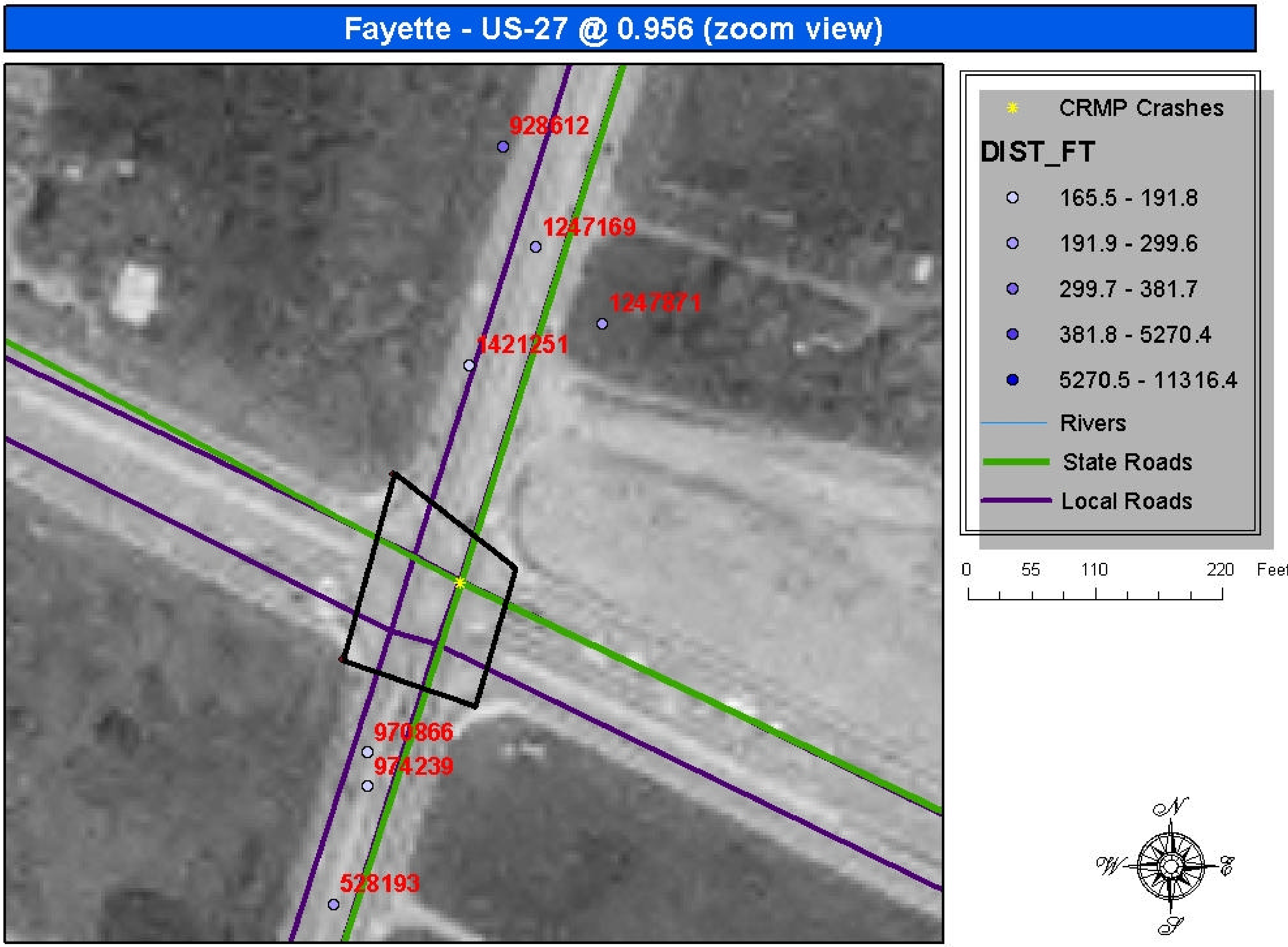
10. List any suggestions for improving the accuracy of milepoint data.

APPENDIX C

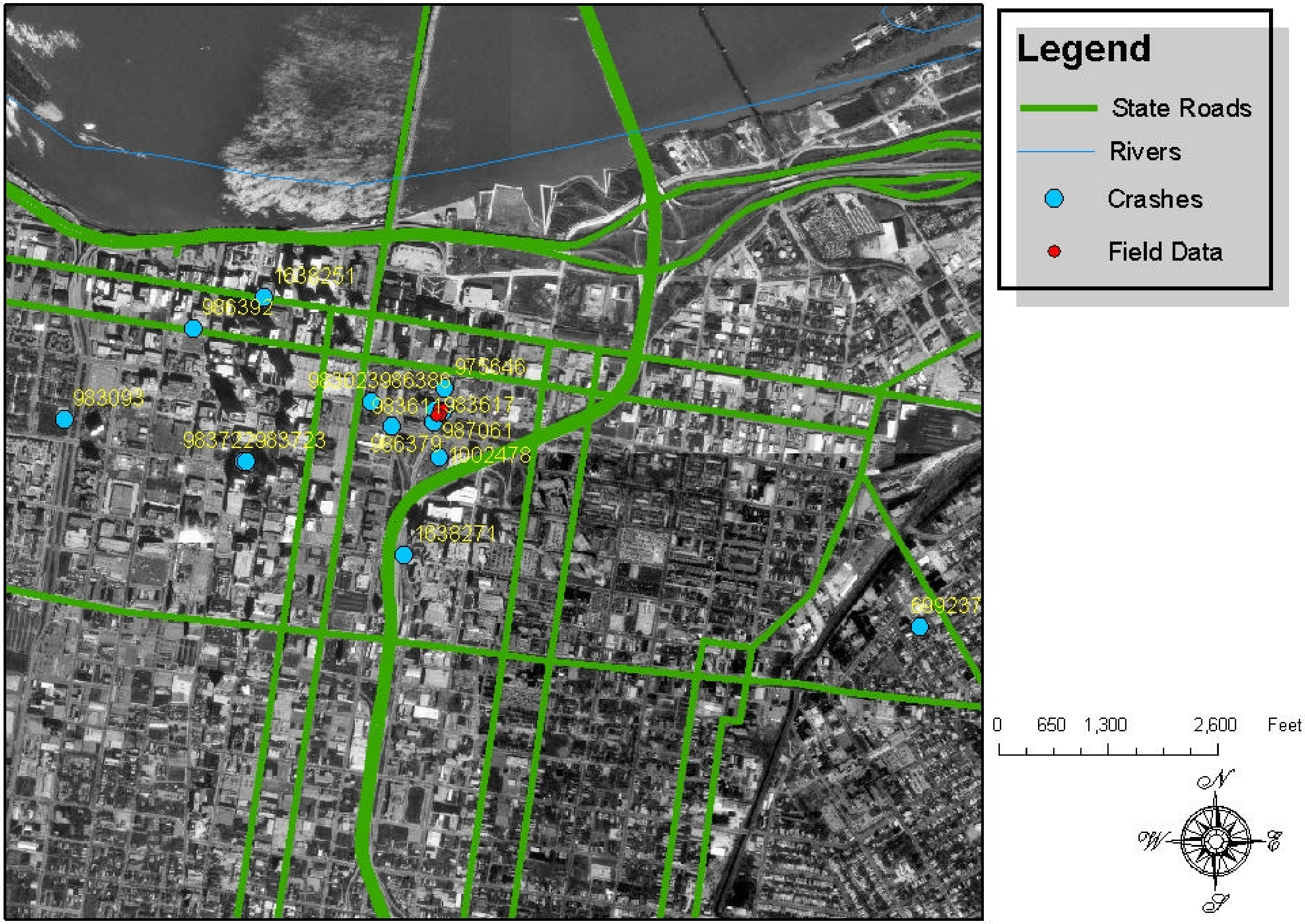
HIGH CRASH INTERSECTIONS SITE INVESTIGATION

Fayette - US-27 @ 0.956 (full view)

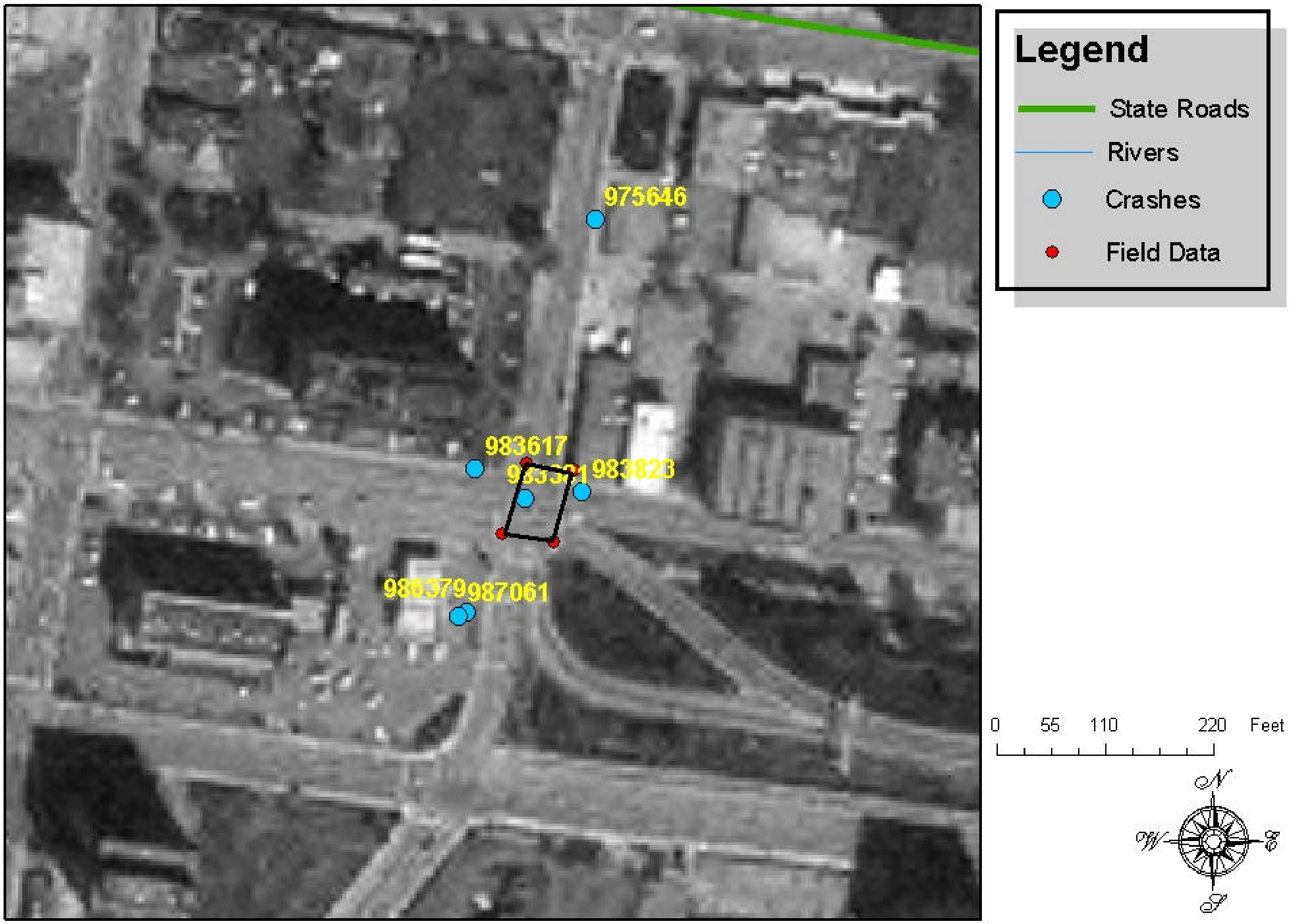



Fayette - US-27 @ 0.956 (zoom view)
928612
1247169
1247871
1421251
970866
974239
528193
CRMP Crashes
DIST_FT
165.5 - 191.8
191.9 - 299.6
299.7 - 381.7
381.8 - 5270.4
5270.5 - 11316.4
Rivers
State Roads
Local Roads
0
55
110
220
Feet
N
W
E
S

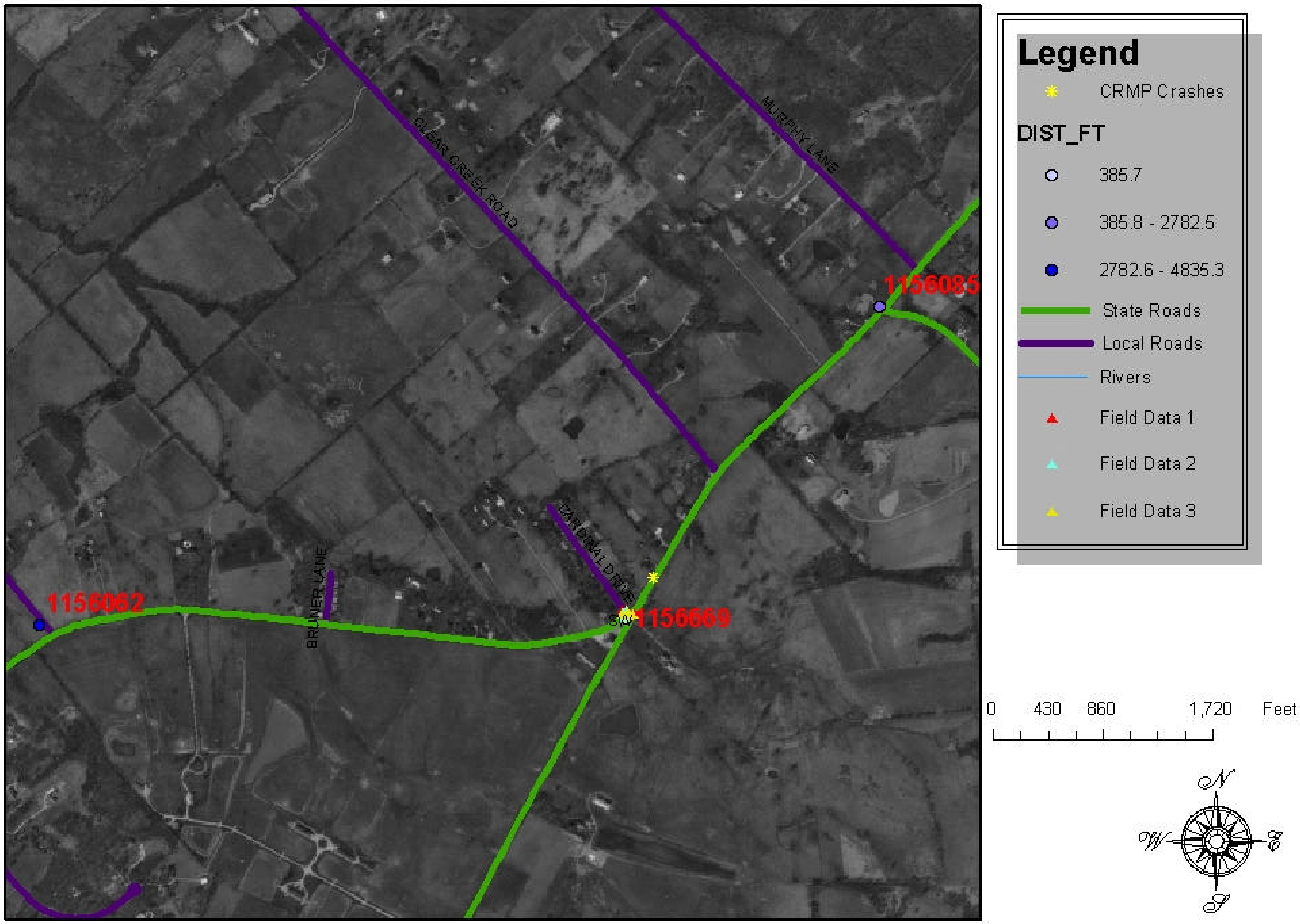
Jefferson County - Brooks @ Jefferson (full view)

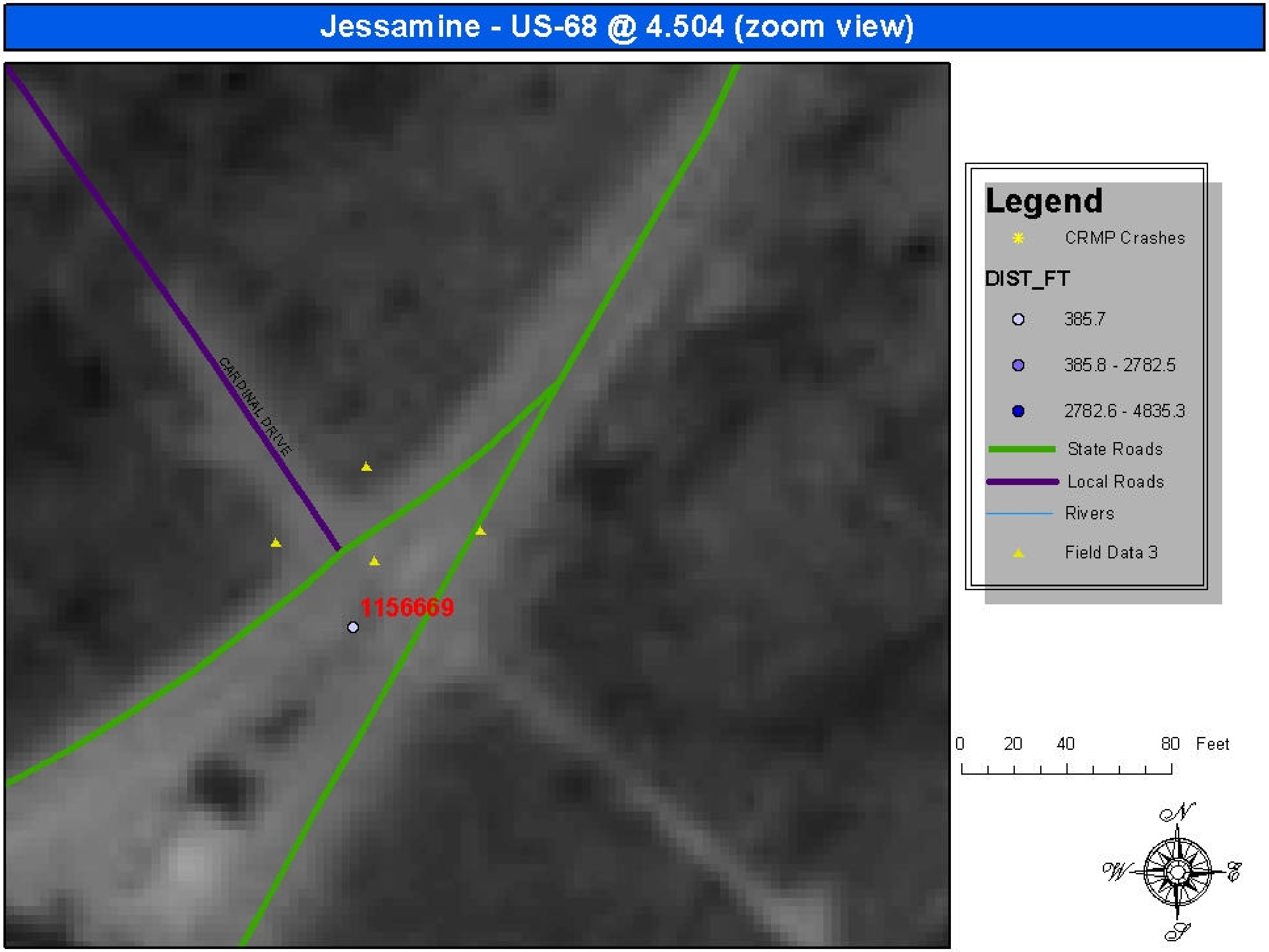


Jefferson County - Brooks @ Jefferson (zoom view)

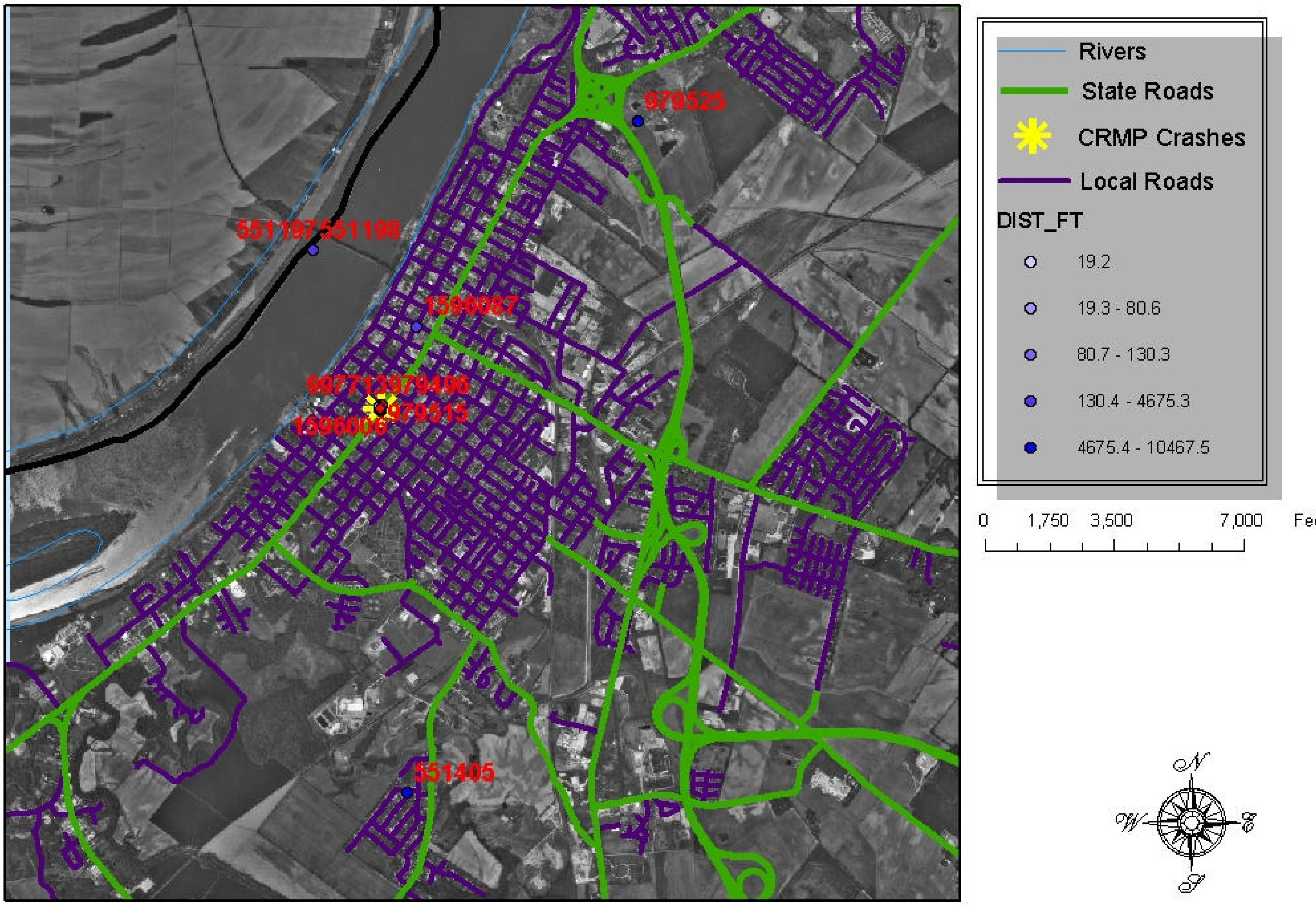


Jessamine - US-68 @ 4.504 (full view)

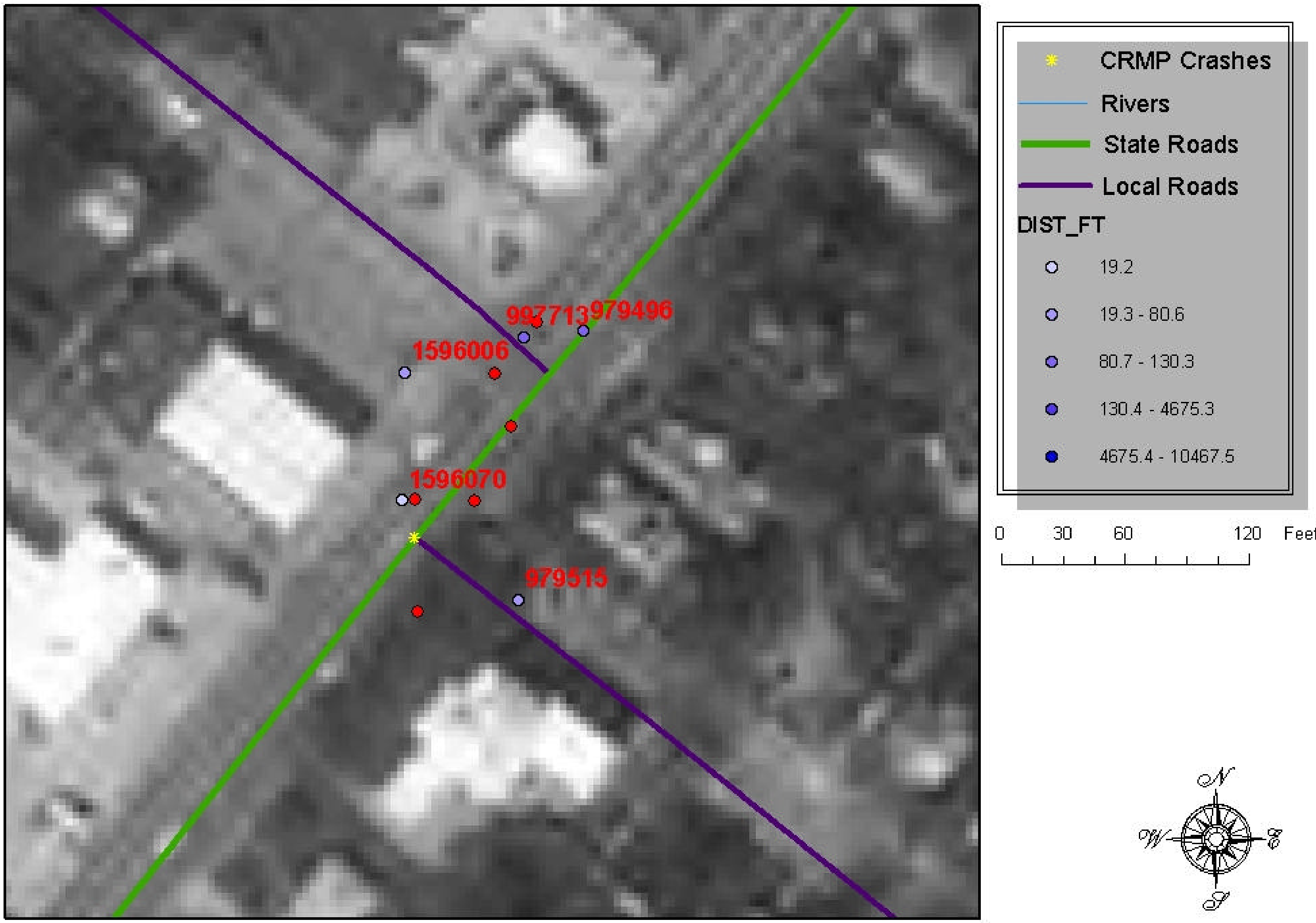



Jessamine - US-68 @ 4.504 (zoom view)
CARDINAL DRIVE
1156669
Legend
CRMP Crashes
DIST_FT
385.7
385.8 - 2782.5
2782.6 - 4835.3
State Roads
Local Roads
Rivers
Field Data 3
0 20 40 80 Feet
N
W
E
S

Henderson - US-41A @ Clay (full view)



Henderson - US-41A @ Clay (zoom view)



APPENDIX D

POSSIBLE POLICE REPORT EDITS

KENTUCKY UNIFORM POLICE TRAFFIC COLLISION REPORT

RESUB-MISSION | REPLACE-MENT | ORIGINAL MASTER FILE #

INVESTIGATING AGENCY: LOUISVILLE METRO PD
AGENCY ORI NUMBER: 0560200
LOCAL CODE: 03002529

ROADWAY NAME: S PRESTON ST
PARKING LOT (Y) (N)
INTERSECTION WITH (Y) (N): MARRET AVE
BETWEEN STREETS (Y) (N)

ROADWAY #: KY 0061
MILES / FEET (N) (S) (E) (W)
MILEPOINT #: 11.262
INJURED: 1
KILLED
UNITS INVOLVED
HIT & RUN (Y) (N)
ONE WAY (Y) (N)
SPEED LIMIT: 35

IN CITY LIMITS? (Y) (N)
MILES FROM CITY (N) (S) (E) (W)
CITY/TOWN - write name below and enter code to the right.
05602
LATITUDE Deg. Min.
LONGITUDE Deg. Min.
RAMP? (Y)
FROM (N)(S)(E)(W) TO (N)(S)(E)(W)
COLLISION DATE— Enter leading zeros. MONTH DAY YEAR: 01 21 2003
COLLISION TIME—Military: 1024

LOUISVILLE

MANNER OF COLLISION | LOCATION 1ST EVENT | TRAFFIC CONTROL

KENTUCKY UNIFORM POLICE TRAFFIC COLLISION REPORT

RESUB-MISSION | REPLACE-MENT | ORIGINAL MASTER FILE #

INVESTIGATING AGENCY: LOUISVILLE METRO PD
AGENCY ORI NUMBER: 0560200
LOCAL CODE: 03002529

ROADWAY NAME: S PRESTON ST
PARKING LOT (Y) (N)
INTERSECTION WITH (Y) (N): MARRET AVE
BETWEEN STREETS (Y) (N)

ROADWAY #: KY 0061
MILES / FEET (N) (S) (E) (W)
MILEPOINT #: 11.262
INJURED: 1
KILLED
UNITS INVOLVED
HIT & RUN (Y) (N)
ONE WAY (Y) (N)
SPEED LIMIT: 35

IN CITY LIMITS? (Y) (N)
MILES FROM CITY (N) (S) (E) (W)
CITY/TOWN - write name below and enter code to the right.
05602
LATITUDE Deg. ___ Min. ___.____
LONGITUDE Deg. ___ Min. ___.____
RAMP? (Y)
FROM (N)(S)(E)(W) TO (N)(S)(E)(W)
COLLISION DATE— Enter leading zeros. MONTH DAY YEAR: 01 21 2003
COLLISION TIME—Military: 1024

LOUISVILLE

MANNER OF COLLISION | LOCATION 1ST EVENT | TRAFFIC CONTROL

KENTUCKY UNIFORM POLICE TRAFFIC COLLISION REPORT / Electronic Format

COLLISION DATE and TIME 01/20/2003 13:08	MASTER FILE # 70054157

INVESTIGATING AGENCY	AGENCY ORI NUMBER	LOCAL CODE
PIKEVILLE POLICE DEPARTMENT	0980100	03-031

ROADWAY NAME: US 119 W
PARKING LOT N
INTERSECTION WITH Y: US0023
or BETWEEN STREETS N

ROADWAY #	MILES	FEET	DIR	MILEPOINT #	INJURED	KILLED	# UNITS INVOLVED	HIT & RUN	ONE WAY	SPEED LIMIT
US0119		25	E	26.228			2	N	N	55 KM N

IN CITY LIMITS? Y
CITY/TOWN CODE 09801
MILES FROM CITY DIR
CITY/TOWN NAME: PIKEVILLE

LATITUDE Deg. Min.
LONGITUDE Deg. Min.
RAMP? N FROM DIR
TO DIR