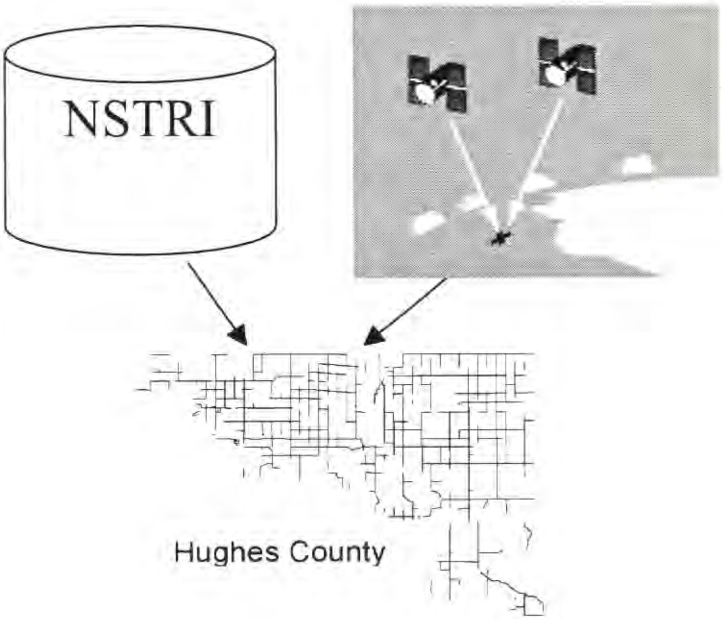
South Dakota
Department of Transportation
Office of Research

U.S. Department of Transportation
Federal Highway Administration

SD2000-03-F



Update of the Non-State Trunk Inventory

Study SD2000-03
Final Report

Prepared by

GIS/Trans, Ltd.

12414 Alderbrook Dr. Suite 102
Austin, Texas 78758

October, 2000

DISCLAIMER

ACKNOWLEDGEMENTS

This work was performed under the supervision of the SD2000-00 Technical Panel:

Greg Allen	Data Inventory	Brad Lawrence	City of Ft. Pierre
Alec Boyce	Southeast Council of Governments	Daris Ormesher	Office of Research
Mark Hoines	FHWA	Hal Rumpca	Office of Research
Rocky Hook	Data Inventory	Brian Sauer	BIT
Todd Kays	1st Planning & Development District	Dave Voeltz	Planning and Programs
Wallace Larsen	Hughes County Commissioner	Dennis Winters	BIT

The work was performed in cooperation with the United States Department of Transportation Federal Highway Administration.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SD2000-03-F		

4. Title and Subtitle	5. Report Date
Update of the Non-State Trunk Inventory	**OCTOBER 23, 2000**
	6. Performing Organization Code
7. Author(s) Christian Collier, Somitra Saxena, William K. Kuykendall	8. Performing Organization Report No.
9. Performing Organization Name and Address GIS/Trans, Ltd. 12414 Alderbook Dr. Suite 102 Austin, TX	10. Work Unit No.
	11. Contract or Grant No. **310710**
12. Sponsoring Agency Name and Address South Dakota Department of Transportation Office of Research 700 East Broadway Avenue Pierre, SD 57501-2586	13. Type of Report and Period Covered Final; April, 2000 to March, 2001
	14. Sponsoring Agency Code

15. Supplementary Notes

AN EXECUTIVE SUMMARY IS PUBLISHED SEPARATELY AS SD2000-03X.

16. Abstract

GIS/Trans Ltd. provided consultant services to integrate the existing NSTRI database with updated information from a recently completed GPS inventory. The first step was to review the current environment of the NSTRI and the data items contained in it, as well as the data items contained in the GPS inventory. Recommendations were made regarding the suitability of retaining certain data items and all data items were ranked in order of importance.

Since there was no common key field in the databases, they could not be joined using standard database techniques. It was determined that using a Geographic Information System (GIS) to join the databases based on the location of the attribute sections was the most appropriate method to use. The GPS Inventory collected the road centerlines (basemap) with accurate road lengths (measures), and certain road characteristics as attributes. The GPS attributes could be placed directly on the basemap since their measures matched those of the basemap. The NSTRI method of locating attribute sections however, had to be converted into the same measurement system as the GPS. A Linear Referencing System (LRS) was created for the NSTRI which allowed the researchers to place the NSTRI data on the same basemap as the GPS data. Finally, the two databases could be joined by matching the route identifiers, and the measures for each attribute record.

Upon determining that the databases could in-fact be joined, procedures for maintaining and updating the combined database were recommended. Resources required to maintain the database were also recommended.

17. Keywords	18. Distribution Statement
GIS, LRS, NSTRI, GPS	No restrictions. This document is available to the public from the sponsoring agency.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	78 pages	

This page intentionally left blank

TABLE OF CONTENTS

LIST OF FIGURES

This page intentionally left blank.

LIST OF TABLES

This page intentionally left blank.

Executive Summary

ES.1 PROBLEM DESCRIPTION

South Dakota has approximately 84,000 miles of highways, roads and streets, of which, South Dakota DOT (SDDOT) is directly responsible for about 10 percent of this total network. The remaining 90 percent makes up the Non-State Trunk System which includes county roads, state parks, city streets or any roadway that is not covered under the State network. The *Office of Transportation Data Inventory* of SDDOT currently maintains an inventory and an information system of all the highways, including the Non-State Trunk System. The various types of information that are currently maintained by the department include, but are not limited to, road mileage, functional classification, pavement condition, traffic accidents, number of lanes, Highway Performance Monitoring System (HPMS) data, traffic volumes, traffic counts etc.

Within most state Departments of Transportation, there exist many databases containing information relating to the roads and highways throughout the state. Very commonly, these databases are in different formats, on different platforms, and in different states of accuracy and timeliness. South Dakota Department of Transportation (SDDOT) is no exception. SDDOT currently maintains databases for the State Trunk Roadway Inventory System and the Non-State Trunk Roadway Inventory System (NSTRI) as separate files on the mainframe. The State Trunk System has been well maintained and kept up-to-date. The NSTRI, however, has received less attention, and as a result, some of the information it contains is quite out-of-date and some data items are of little value.

In an attempt to provide updated and accurate information about the Non-state roadways of South Dakota, the SDDOT has initiated a project to collect certain data items along with new road centerlines and mileage using Global Positioning System (GPS) technology. The result of this nearly completed project has been highly accurate centerlines for all the State and Non-state roadways of South Dakota. This project has also produced an updated database, which has the potential to update the roadway inventory systems, particularly for the Non-State roads.

The problem lies in that there is no common key in which to correlate the existing NSTRI and the new GPS collected information. This is the central problem that this research project is designed to address, together with a set of recommendations as to which data items currently in the NSTRI and in the GPS collected dataset should be retained and maintained in the future.

ES.2 PROJECT OVERVIEW

The primary focus of this project is on two databases: the NSTRI database on the mainframe, and the GPS Inventory Database stored as ESRI ArcInfo coverages on the PC.

A review of the current database environment at SDDOT presents a scenario that is common to several State DOTs. There are "islands" of data that serve specific applications or needs. The data islands in most cases are stored and managed independently, in different formats and environments. This has lead to data redundancy, duplication of effort and lack of proper linkages between logically related datasets. A key goal of this project is to create a linkage between two such disparate datasets.

ES.2.1 Review of Current Databases

ES.2.1.1 Non-State Trunk Roadway Inventory

The Non-State Trunk Roadway Inventory System provides federal and state mandated data, such as that submitted for HPMS, Mileage Reporting and for Highway Performance Planning/Monitoring. Updates to the NSTRI database are currently performed directly on the mainframe using the on-line screens.

Over the last several years, even though the State Trunk Database has been kept current, many of the various elements in the NSTRI database have been neglected and have become woefully out of date. At least one other mainframe data file, the Railroad Crossing file, accesses the NSTRI to obtain information needed to produce a necessary report.

The NSTRI is in an ADABASE flat-file database on the DOT's mainframe. Currently there is no consistent process for maintaining this database. As a result, some of the information in this database has not been updated in over ten years. Logically the NSTRI database can be divided into two parts: county roads and city streets.

ES.2.1.2 GPS Inventory

The SDDOT has enlisted the help of the various Planning and Development Districts throughout South Dakota to collect an inventory of all the streets, roads, and highways in the state. This inventory project used Global Positioning System (GPS) technology to collect accurate centerlines of each of the roadways and field data collectors to collect selected attribute information. The road centerlines are in an ArcInfo format and can easily be displayed using Geographic Information Systems (GIS) software. As the linear data was collected using the GPS, accurate measures were recorded for each data item using a distance-measuring instrument (DMI).

There are 23 data items included in the GPS inventory. All 23 items were collected for State highways, county roads and city streets. If a field does not apply to a segment of road e.g. city_code for a county road, that field is left blank.

Because there is duplication between the data items collected as part of the GPS effort and the existing NSTRI database, an associated task of this research was to review the data elements in both data sets, and recommend a comprehensive list of data elements to be maintained in the future.

Due to changing needs and responsibilities as well as limited resources, the usefulness of some of the fields currently being maintained is questionable. At the same time, several of the NSTRI data items are used for reporting purposes, and to populate a database for the HPMS that is administered by the Federal Highway Administration (FHWA). As a result, some data fields should be discarded, while others must be retained and included in any future database developed for the Non-State trunk system.

Based on the current needs of the SDDOT and other potential users, the following NSTRI fields have been identified as having low priority to be retained in the database because they are either no longer useful or too expensive to collect and maintain. None of the following fields are required for the Railroad Crossing file. A complete list of prioritized data items is contained in the main part of this document.

- Year Built This data item is currently not populated for most of the section records in the NSTRI database. It is doubtful that the year built information is even available for all roads and even if it was, the research required finding it would be enormous. Year Built is not required by HPMS. Furthermore, since this item is based on a 2 -digit date field, it is not Y2K compliant.

- Base Thickness, Surface Thickness, and Overlay Thickness These fields have not been populated in the NSTRI and the data for them is probably not readily available. These fields may be useful for a county or city maintenance supervisor, but the individual road maintenance sections should probably maintain them in a local database if they feel they are helpful. These fields are no longer required for HPMS and are of little use to a statewide road inventory.

- Maintenance Costs This data item was used to identify if maintenance costs were available for a section of road. This field is no longer used and not necessary for a statewide inventory.

- RideabilityThis data item is purely subjective and can be very volatile. A heavy rainstorm can change the rideability of an unpaved road overnight. Therefore this item is of very little actual value. While the attributes of this field could be modified to contain roughness data for HPMS, none of the roads represented in the NSTRI data available to GIS/Trans require roughness data be recorded according to the HPMS Field Manual.

- Population Group This field was used to produce reports for different size towns and cities and is no longer used. This field can be eliminated from the combined database.

- Driving Direction This field was used in the initial GPS data collection to determine the direction that items were collected. The procedures for maintaining the combined database will no longer require that this item be collected.

- Inter_desc and Inter_dir These fields are designed to be a text description of the intersection between the subject segment and a crossroad. These attributes will be rather time consuming to collect in the field. Since the configuration of the intersections is clearly evident in the GIS spatial data layer, collecting this as attribute information could be redundant. If information about the intersections is deemed necessary, a possible replacement field could be one field; Inter_desc, which contains a description such as: Left only, CR 36; or cross SD13, 100 foot left turn lane. The placement of the intersection information should be consistent either at the beginning or at the end of the segment.

ES.2.2 Methodology to Combine Databases

Integrating two data sets that have no common key but do have a spatial reference is a common problem that can often be solved using GIS. The solution is to convert the two different location-referencing schemes into one spatial framework that can display both data sets. (see Figure ES.1)

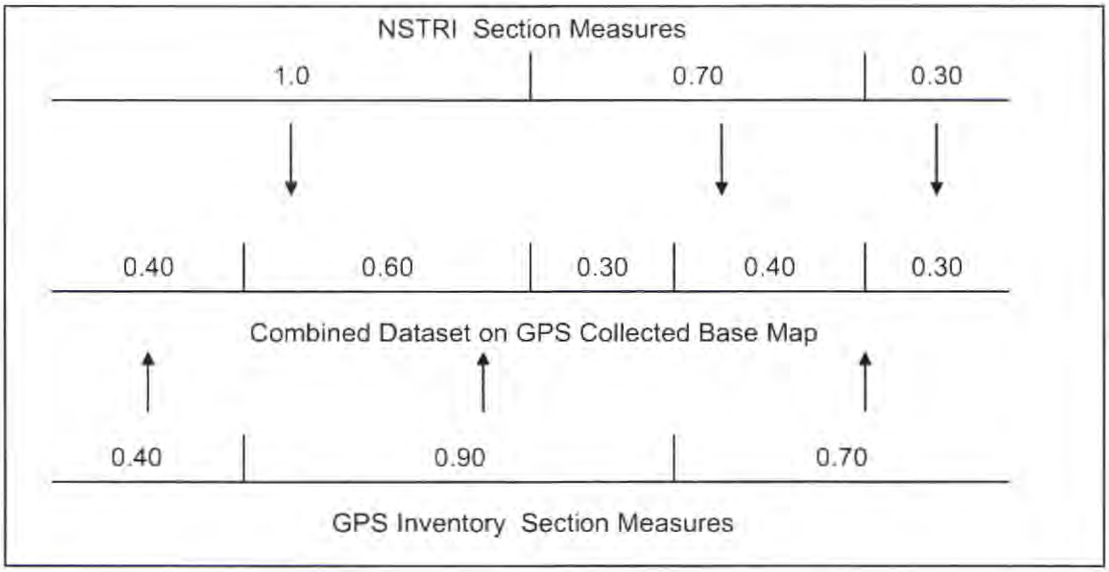


Figure ES.1 NSTRI and GPS Inventory on a Common Spatial Framework

In this project we have developed a linear referencing system (LRS) that can be used to display both the GPS inventory and the NSTRI on the base centerline network collected along with the GPS Inventory.

Bringing the GPS data into the GIS was a fairly simple matter because the data was collected using the same spatial framework as the GPS map. The measures collected using the Distance Measuring Instrument were used to assign real world lengths to the road segments in the GIS.

Using a GIS process called Dynamic Segmentation, the GPS attribute data can then be easily displayed on the map based on the distance of the beginning and ending points of the attribute along the route.

Since the NSTRI location reference is based on an entirely different spatial framework, namely route, section number, and length, the most difficult task concerned bringing the NSTRI data into the GPS map.

Given the route number, section number, and length, we can easily look at a map with a section grid overlay, find the given route, follow it to the appropriate section, then see approximately where a particular NSTRI section begins and its distance or extent. In order to display this information in the GIS, we have to convert this method of location referencing into one that the GIS will "understand".

This was accomplished by using the section number as a distance from the baseline, or origin of the section numbers, and adding the length to derive a beginning distance and an ending distance, (see Figure ES.2). This is essentially the same spatial reference as the GPS data. Since the distance from the baseline was an approximate distance, it was necessary to "calibrate" or relate those distances to real world points. The roads that cross the subject route at section corners were used as "calibration points". These calibration points also become "Virtual Reference Markers" (VRMs) for the LRS described in the methodology.

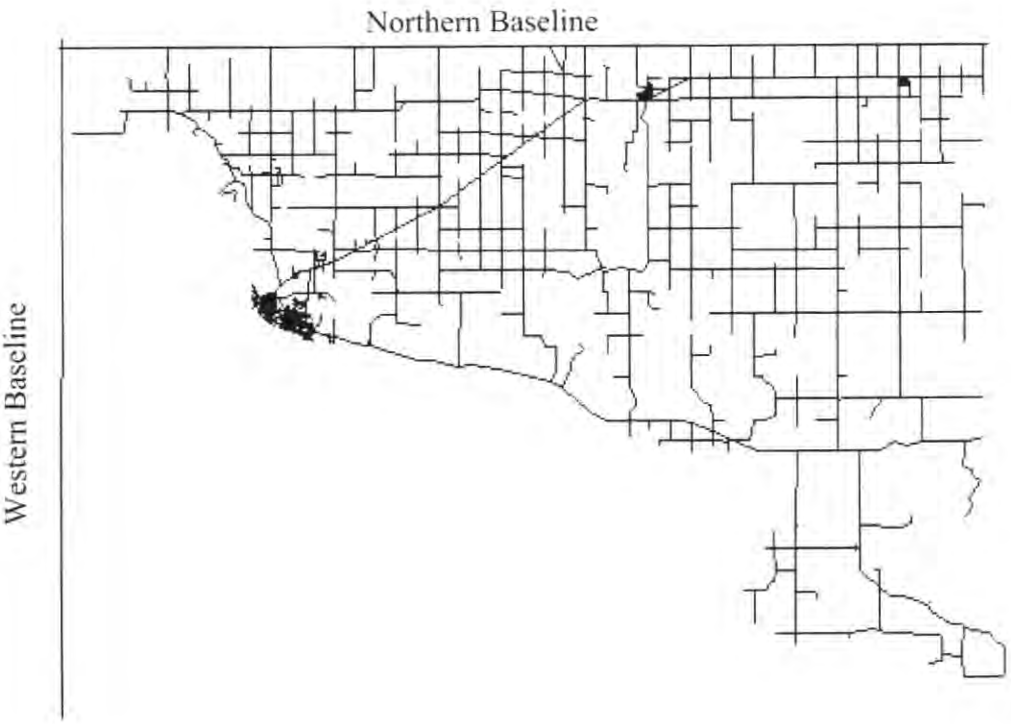


Figure ES.2 Baselines for Hughes County

By utilizing this methodology and the tools available in the GIS, we were able to bring both data sets in to the same spatial framework. Once this is accomplished we can join the two data sets based on their common location fields. This process is known as a spatial overlay.

ES.3 PROOF OF CONCEPT

The methodology described in this document was used to combine the GPS Inventory and the NSTRI data for Hughes and Brookings counties. While there are instances in which there is not a strict one-to-one match (places where there are no GPS centerlines that correspond with NSTRI data or GPS centerlines with no NSTRI data for example), for almost the entire network the process has been automated and works as expected.

The segments where there is not a one-to-one match have been analyzed, and can be attributed to two major causes. The first concerns the relatively rare instance in which the section lines are unevenly distanced, and for which we have now developed procedures to accommodate such events. A second class of discrepancies can be attributed to new roadway additions not present when the NSTRI data was originally collected.

Most of the tools and scripts that are needed to perform the required GIS procedures have been developed as a part of the proof of concept and need only to be cleaned up and a user friendly interface be developed. Using this automated methodology, each county could be processed, and validated in one to two days at most, by our estimates. While trained GIS analysts would be required to perform this effort, these are relatively simple procedures, which do not require high level GIS skills. It is quite possible that college level interns with GIS skills could implement much of this methodology.

ES.4 MAINTENANCE AND UPDATING

Future updates to the non-state trunk will be greatly simplified by maintaining the combined database using GPS and GIS tools. As changes are reported, the Planning and Development District can use the same GPS equipment used in the initial collection to record the beginning and ending locations of the changes. Then using some fairly simple Visual Basic scripts (not developed as part of this research), the changes could be inserted into the database. In this way, future changes are thus collected and maintained on the existing GPS centerline data, and refinements made successively over time. We see no reason to re-collect large segments of the database.

ES.5 CONCLUSION AND RECOMMENDATIONS

The GPS collection of the roadway centerlines and updated attribute information was an ambitious undertaking that demonstrates what can be accomplished through the combined efforts of multiple governmental agencies. The resulting data set greatly improves the accuracy and completeness of non-state highway information and provides an excellent GIS transportation layer for the State of South Dakota. Once integrated with the necessary information from the NSTRI, the combined database will provide the information necessary to serve the needs of most of the users of the non-state trunk system.

The results of this project can serve as a starting point for developing a robust GIS that will provide much tighter integration between the state and non-state trunk systems. Although not directly addressed in this project, the GPS centerline network provides an accurate base for displaying and maintaining the state trunk system. ArcInfo is capable of managing multiple linear referencing systems and the state trunk data can be readily incorporated into the GIS based on the MRM linear referencing system currently used for the state trunk data.

By initiating this project South Dakota DOT, the Planning and Development Districts and other partners have demonstrated a commitment to managing their spatial data in the most accurate and efficient way possible.

Several implications emerge from this research effort. South Dakota DOT, like other State DOT's, is engaged in the collection and maintenance of large amounts of data. Some of this information is collected and available for internal analysis, while other data is collected primarily for local or federal reporting requirements. Because these databases have often been developed for different purposes and at different times, it is not uncommon that such information may not be easily retrievable, or easily combined with other information in the most useful ways. Such is the case here.

As we have seen however, GIS technology now allows for the integration of such disparate data in ways that was never possible before. But this also points out the importance of carefully constructed GIS base data, which makes such integration possible. South Dakota DOT has a unique opportunity to build upon their GPS collection efforts, and assemble a solid infrastructure for integrating much of the agency's data and information. The following recommendations are intended to support that ultimate goal and the goals of this research project.

1. **The NSTRI and GPS Inventory data sets should be combined into a single database using the methodology described in this document.**

   The results of this research and prototype development demonstrate the viability of combining these disparate databases using location referencing. SDDOT has invested a great deal of money and resources into the collection of updated Non-State Trunk data and should make the most of the data by creating a single, comprehensive Non-State Trunk database

2. **The combined database should be developed and maintained in a PC-based, GIS environment.**

   This methodology allows for a "one-way" transfer of data attributes from the NSTRI database maintained on the mainframe, to the GIS data sets housed in an MS Windows environment. We see little use in developing mechanisms to allow data to be written back to the mainframe from the PC environment. Because the data and information is ultimately spatial in nature, we feel that the GIS environment is better suited to handle the maintenance and update functions of the linear networks and associated attribute data. As a result, any reports generated from the mainframe need to be re-written in the MS Windows and GIS environment. Given the ease of use of several of the off-the-shelf report writing products (Crystal Reports, for example), this should not be a relatively difficult task.

3. **SDDOT should commit the necessary resources to the GIS and database integration.**

   At this time SDDOT should have at least two people that can dedicate a large percentage of their time to the development of the GIS and spatial databases. Any GIS or database development project requires trained resources to manage and perform the tasks required. The current environment at SDDOT, including this project, mandate the need for at least two people, as further development and projects are initiated more trained staff may be necessary.

4. **SDDOT should train in-house staff in the application of the methodology described in this document.**

   While the concept of integrating data based on location referencing is not difficult to understand, the implementation of the procedures to accomplish the integration is often complex. If the staff being trained has a solid understanding of GIS and ArcInfo, a few days training should be sufficient.

5. **SDDOT should consider outsourcing the development of the tool set necessary to automate the update of the combined data set.**

   This document describes several GIS tools that should be developed in order to update the combined database using the GPS collection procedures. Most of these tools are not overly complex, but do require GIS programming and linear data manipulation experience. Another option would be to train in-house staff to do the programming, however this approach would require much more time before the tools could be fully operational.

6. **The Planning and Development Districts should gather updated road information on a quarterly basis.**

Quarterly reporting of road updates will allow the Planning and Development Districts better plan their GPS data collection activities. Actual GPS data collection and update to the combined database should occur at least annually.

7. **The tools required for updating the combined database should be developed in Visual Basic for Applications (VBA).**

   Based on the direction that ESRI is taking with its latest releases of ArcView and ArcInfo software, Visual Basic is the recommended development platform for GIS database update tools. ESRI training and support for AML and INFO programming is waning and object – oriented environments such as VBA are more robust and therefore preferred. SDDOT should also consider gaining in-house VBA programming capabilities for future GIS development activities.

8. **SDDOT should adopt the GPS road track as the common base map for the agency.**

   One spatial centerline file must be designated as the agency standard, and to which all future efforts are oriented. Currently there at least two centerline files, which exist in separate software / hardware platforms. Managed properly, a single centerline file could be shared among various software packages and applications.

9. **SDDOT should adopt a master linear referencing system.**

   Currently there are multiple linear referencing systems in use at South Dakota DOT. This is compounded by the use of at least two GIS software packages, each of which references linear data in a different manner. While this condition itself is not fatal, it does require that a master linear referencing schema be developed, which allows for the translation of linear events from one system to another. The start of that process has been developed with this project.

10. **SDDOT should develop an agency-wide plan for integrating spatial transportation data.**

    The need for a common base network and a carefully developed master linear referencing schema also point out the need for a carefully devised plan for systematically integrating the various applications and data sets across the agency. Increasingly State DOTs require information which is pulled from across the agency to make more effective decisions relating to the allocation of scarce resources. If data exists and is maintained in separate applications which do not "speak" to each other, much of this information becomes difficult to pull together in a timely way for effective management support. Many agencies have come to realize they can no longer afford to continue to do business in this manner, and have begun the process of strategically implementing agency-wide data integration efforts. We would urge South Dakota DOT to begin to move in this direction.

Upon implementation of this research, South Dakota will have a fully updated Non-State Database that includes all of the required fields from both the NSTRI and the GPS inventory. Updates and maintenance of this database will be performed in a modern GIS and relational database environment and take advantage of the accuracy potential of GPS data collection. In the process, South Dakota DOT will have expanded the accuracy and detail of information available internally, as well as developed more effective ties to the local districts and agencies which are partners with South Dakota DOT in this effort.

This page intentionally left blank.

Update of the Non-state Trunk Inventory

1 PROBLEM DESCRIPTION

South Dakota has approximately 84,000 miles of highways, roads and streets, of which, South Dakota Department of Transportation (SDDOT) is directly responsible for about 10 percent of this road network. The remaining 90 percent makes up the Non-State Trunk System which includes county roads, state parks, city streets or any roadway that is not covered under the State network. The *Office of Transportation Data Inventory* of SDDOT currently maintains an inventory and an information system of all the highways, including the Non-State Trunk System. The various types of information that are currently maintained by the department include, but are not limited to, road mileage, functional classification, pavement condition, traffic accidents, number of lanes, Highway Performance Monitoring System (HPMS) data, traffic volumes, traffic counts etc.

Within most state Departments of Transportation, there exist many databases containing information relating to the roads and highways throughout the state. Very commonly, these databases are in different formats, on different platforms, and in different states of accuracy and timeliness. South Dakota Department of Transportation (SDDOT) is no exception. SDDOT currently maintains databases for the State Trunk Roadway Inventory System and the Non-State Trunk Roadway Inventory System (NSTRI) as separate files on the mainframe. The State Trunk System has been well maintained and kept up-to-date. The NSTRI however, has received less attention and as a result of that, some of the information it contains is quite out-of-date and some data items are of little value.

In an attempt to provide updated and accurate information about the Non-state roadways of South Dakota, the SDDOT has initiated a project to collect certain data items along with new road centerlines and mileage using Global Positioning Systems (GPS). The result of this nearly completed project has been highly accurate centerlines for all the State and Non-state roadways of South Dakota. This project has also produced an updated database, which has the potential to update the roadway inventory systems, particularly for the Non-State roads.

The problem lies in that there is no common key in which to correlate the existing NSTRI and the new GPS collected information. This is the central problem that this research project is designed to address, together with a set of recommendations as to which data items currently in the NSTRI and in the GPS collected dataset should be retained and maintained in the future.

2 OBJECTIVES

1. **Determine the data elements that should be maintained in the consolidated database.**

   All of the data items contained in the NSTRI and GPS inventory data sets were reviewed to determine their usefulness to the consolidated database. Section 6 of this document describes each data item and gives recommendations regarding their inclusion in the final consolidated database.

2. **Determine a common reference between the NSTRI and the GPS collected data for all of South Dakota's counties.**

   The research project determined that the most suitable method for referencing between the two databases was to use the location information to provide a common geographic reference. Geographic Information Systems are particularly well suited for managing this type of referencing. Section 7 of this document describes the methodology used by the researchers to create this type of relationship between the NSTRI and GPS databases.

3. **Determine standards and procedures for collecting and maintaining data in a consolidated database.**

   The researchers recommend using the same GPS equipment that was used to collect the GPS Inventory to update and maintain the consolidated database. The procedures described in Section 8 of this document, illustrate a simplified data collection process and describe GIS tools that will automate the integration of updated information into the database.

4. **Determine resources necessary to collect and maintain data for a consolidated NSTRI database.**

   The researchers recommendations regarding resources required to maintain the consolidated database are based on in-depth knowledge of GIS and GPS data collection techniques. The recommendations given in Section 8.4 of this document describe the resources required by the Planning and Development Districts (data collection) and the DOT (GIS/database maintenance).

3 TASK DESCRIPTIONS

1. **Review and summarize literature relevant to data collection and maintenance of Non-State Trunk data.**

   The researchers reviewed significant literature relevant to transportation data collection, GPS, GIS, and linear referencing systems. Appendix A of this document contains a full literature review.

2. **Meet with the technical panel to review project scope and work plan.**

   A meeting was held on May 10, 2000 in Pierre, SD at which the project scope and work plan were reviewed with the technical panel.

3. **Conduct interviews of SDDOT, FHWA, local government representatives, and the State Planning and Development Districts to determine data items that need to be collected and maintained in a consolidated Non-State Trunk database.**

   Subsequent to the technical panel review meeting, interviews were held in Pierre with representatives of the SDDOT –Data Inventory, Office of Research, and Planning and Programs. Also interviewed were members of the 1st Planning and Development District, Southeast Council of Governments Bureau of Information and Telecommunications, and the Hughes County Commissioner.

4. **Develop a list of data items that should be stored in the consolidated database and rank in order of importance. The ranking should include cost of data collection, quality, accuracy, need and effort to collect and maintain a consolidated NSTRI database.**

   In Section 6.3 of this document, a list was compiled in which items were ranked in order of importance/priority along with the relative cost to maintain the database and collection effort required. Those data items deemed low or moderate priority are further explained. The issue of data accuracy is also addressed.

5. **Develop and document the policies and procedures for collecting and maintaining data for the consolidated NSTRI database and submit a technical memorandum to the technical panel.**

   The procedures for collecting new data and integrating that data into the combined database are fully explained in Section 8 of this document. Tools necessary to automate the integration are also described.

6. **Meet with the technical panel to review the proposed list of data items that need to be collected and the proposed methods to test the recommended maintenance standards and procedures.**

   A meeting was held August 31st, 2000 in Pierre, SD at which the draft project report describing the proposed data items and methods for integrating and maintaining the databases were discussed.

7. **Identify a common key or method for all South Dakota counties to interface between or consolidate the GPS collected data and the current NSTRI database.**

   The common link between the NSTRI and the GPS Inventory is the geographic location of the data items. By developing a location-referencing scheme that can place the attribute sections from the NSTRI and the GPS Inventory on a common "basemap", the databases can be joined using a GIS. This process is described in Section 7 of this document.

8. **Define and develop the procedure to consolidate or interface the two databases using the common key or interface method so that the consolidated NSTRI data will be available for use on all required computing platforms.**

   The methodology for developing the necessary location referencing scheme and the procedures for placing the attribute data items on the base map are fully described in Section 7 of this document.

9. **Recommend a plan to verify that the new data collection standards and procedures can be used to update the consolidated database. SDDOT will contract with the Planning and Development Districts to collect the necessary data for verification of the new data collection standards and procedures.**

   The procedures for updating the consolidated database are fully described in Section 8 of this document. An ArcInfo pilot project was developed to demonstrate the validity of the procedures. All tools developed to automate the procedures have been delivered to SDDOT

10. **Evaluate work completed in previous tasks and recommend the type, quantity, and cost of resources necessary to maintain the consolidated NSTRI database.**

    Based on the researchers knowledge of GIS, GPS data collection for GIS, and the results of the previous tasks and pilot project, recommendations have been made regarding the type and quantity of resources necessary to maintain the consolidated database in Section 8.4 of this document.

11. **Prepare final report and executive summaryof the literature review, research methodology, findings, conclusions and recommendations.**

A final report and executive summary have been prepared.

12. Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

Executive presentation scheduled for November 30, 2000 in Pierre, SD.

4 ORGANIZATION OF THIS REPORT

There are four main elements to this project:

- Review and document current database environment and processes
- Conduct a needs assessment and in-depth review of the two key databases, NSTRI and the GPS database, to determine key information requirements and necessary data components
- Develop an integration methodology for NSTRI and GPS Inventory GIS Database
- Develop policies and procedures for long-term data maintenance

This report format largely follows those four elements. Following this section, a review of the current database environment is presented. This is followed by an in-depth review and analysis of the two key databases, the NSTRI and GPS Inventory. The recommended methodology to integrate the NSTRI and GPS Inventory GIS database is presented in the section following this. Policies and procedures for long-term data maintenance are presented in the final section.

A word of warning to the reader is in order. Because the main task was to identify a methodology for integrating two disparate data sets, and because this methodology draws heavily from GIS technology and linear referencing concepts, what follows may be quite technical to the casual reader. This could not be avoided if the methodology is to be specific enough to be implemented by a trained GIS analyst. As a result, the following text does draw on technical GIS commands, and recommendations for data base elements that may not be clear to all readers. We have tried to explain all concepts in common as well as technical language, and a glossary is included of common GIS terminology used throughout the report.

5 CURRENT DATABASE ENVIRONMENT

Figure 5.1 provides a conceptual view of the current database environment at SDDOT. This conceptual view has been established based on a diagnostic process that involved interviews with staff from various key departments at the SDDOT. The Departments at SDDOT and partner agencies that were represented during these interviews included: SDDOT Data Inventory, SDDOT Office of Research, Bureau of Information and Telecommunications, SDDOT Planning and Programs, Hughes County, and representatives from two of the four Planning and Development Districts. This group represents the majority of the staff who interact with these databases for use in other applications/reports or for maintenance/update.

The primary focus of this project is on two of the databases highlighted in the current database environment, i.e. the Non-State Trunk Roadway Inventory (NSTRI) database and the GPS Inventory Database, which will provide the basis for the GIS datasets in the ArcInfo environment. For sake of completeness, any associated databases that interact with or could potentially have a relationship with these two databases have also been represented in the current view of the database environment. This will allow GIS/Trans to not only make specific recommendations as they relate to integrating the two focus datasets, but also provide some high-level recommendations for future further integration of the agency databases SDDOT may want to pursue.

A review of the current database environment at SDDOT presents a scenario that is common to several State DOTs. There are "islands" of data that serve specific applications or needs. The data islands in most cases are stored and managed independently, in different formats and environments. This has led to data redundancy, duplication of effort and lack of proper linkages between logically related datasets. A key goal of this project is to create a linkage between two such disparate datasets.

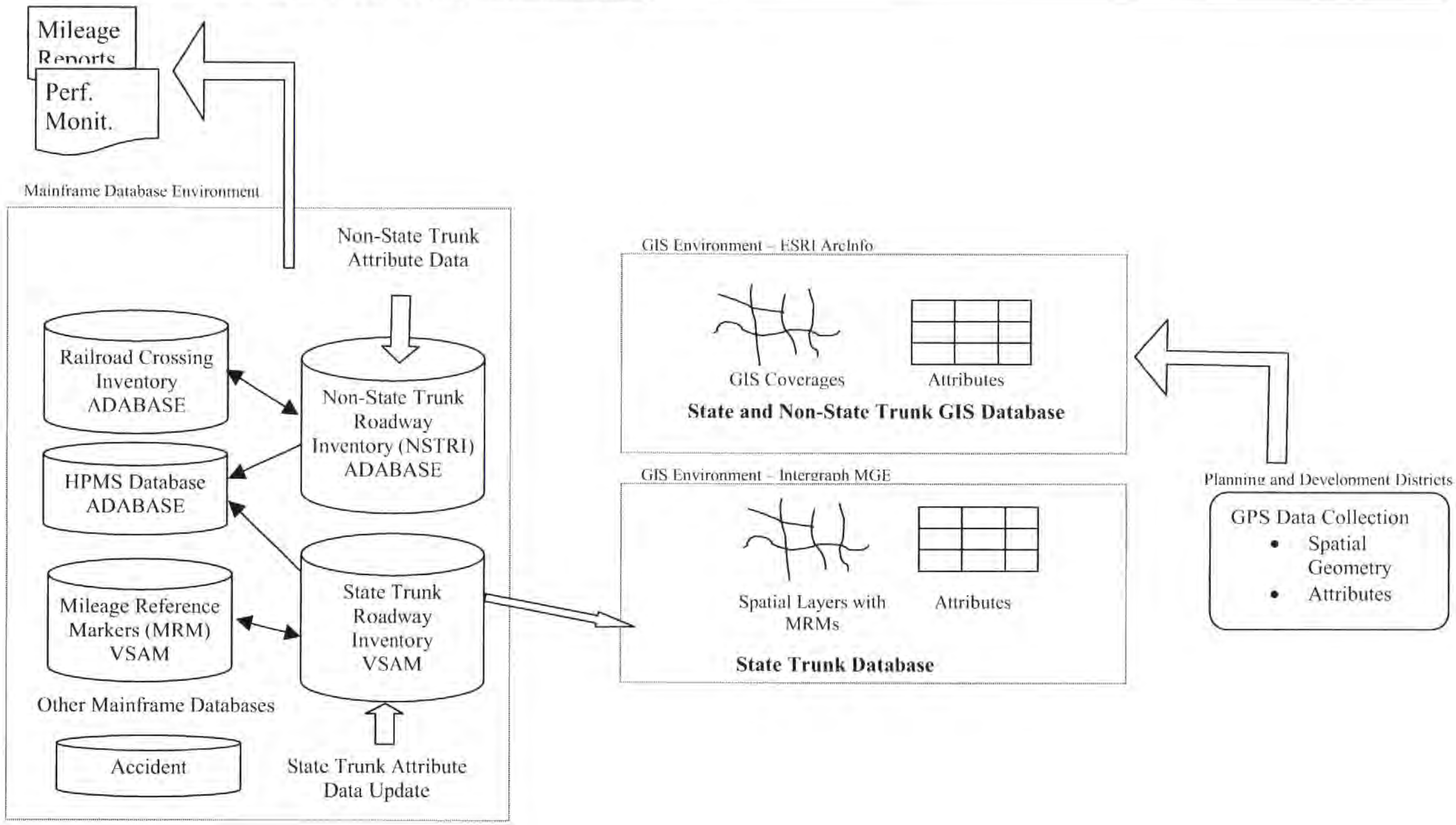
Over the years, the State's mainframe computer has been the primary source for data storage, maintenance and reporting. Several databases including the Non-State Trunk Roadway Inventory (NSTRI), as well as the State Trunk Roadway Database are stored and managed on the mainframe. Other databases on the mainframe include the Railroad Crossing Inventory, Mileage Reference Markers (MRM) Inventory, and Accident Database. On-line access is available to users via the network. Access to the system is limited to a screen-by-screen basis with which display and update capabilities are controlled.

The NSTRI provides federal and state mandated data, such as that submitted for HPMS, Mileage Reporting, and for Highway Performance Planning/Monitoring. Any updates to the NSTRI database are performed directly on the mainframe using the on-line screens. It should be noted from Figure 5.1 that there is currently no connection between the NSTRI and the GIS environment. Over the last several years, even though the State Trunk Database has been kept current, many of the various elements in the NSTRI database have been neglected and have become woefully out of date. At least one other mainframe data file, the Railroad Crossing file, accesses the NSTRI to obtain information needed to produce a necessary report.

SDDOT also maintains spatial datasets with associated attribute information in two different GIS environments. ESRI's ArcInfo is used by the Office of Data Inventory to maintain some statewide State Trunk and Non-State Trunk spatial data layers. The spatial geometry and associated attributes for these datasets are based on the GPS data collection effort initiated by SDDOT in 1994. Since then, SDDOT has partnered with the Regional Planning and Development Districts to do the actual GPS data collection for the 66 counties. By the end of this project, all 66 counties will have been collected by the Planning and Development Districts, and quality checked/approved by SDDOT.

The Planning and Programs group uses an Intergraph MGE GIS environment to store and manage spatial data sets. For the State Trunk (ST) the attributes are directly maintained on the mainframe through the on-line screens and are periodically downloaded to the GIS environments and referenced to the ST spatial network using the MRM based Linear Referencing System (LRS). There is currently no LRS or GIS based Route Systems for the Non-State Trunk database in this environment.

Figure 5.1 SD DOT Current Agency Database Environment



6 REVIEW OF CURRENT DATABASES

6.1 Non-State Trunk Roadway Inventory System

6.1.1 Overview

The Non-State Trunk Roadway Inventory System is a system that has been in place at SDDOT for many years. It is in an ADABASE flat-file database on the mainframe. The NSTRI contains data used for federal HPMS submittals and is accessed by the Railroad Crossing file to obtain values for ADT.

Updates to the NSTRI can only be entered via mainframe input screens. However, there is currently no consistent process for obtaining current information to update this database. Some of the information in this database is ten years old. The NSTRI database can be logically divided into two parts: County roads and City Streets. A full description of all fields is available in the SDDOT NSTRI Coding Manual (see Appendix C).

Each road section has a single corresponding record in the database. Therefore any time an attribute changes the section ends and a new section is started. This is known as a static segmentation scheme. A statically segmented database has an enormous amount of redundant data due to the fact that many attributes do not change for the entire length of the road yet are repeated in the database for each section. Another characteristic of a static segmentation scheme is that whenever a new attribute change is recorded, the corresponding line segment in the GIS base map must be split or appended to the beginning or end of an existing line segment. **This also means that the section lengths of all affected sections must be updated with every attribute change.**

Of particular interest to this project are the Road/Street Number, Section Number, and Section Length fields of the NSTRI. These are the fields that tie the record to a specific road segment. Each county road is numbered by the SDDOT according to a grid that covers the county based on section lines. Roads that run east-west are given even numbers beginning with 2 at the northern most county line and roads running north-south are given odd numbers beginning with 1 at the western most county line. Roads that follow section lines are given a alpha character suffix of O. Roads that run diagonally across a section, or occur in the middle of a section are given an alpha character suffix of A-Z, "A" being the first occurrence of such a road measured from the western or northern county boundary. Often slight deviations from the section lines have been ignored and the road segments have continued with the O character suffix. (see Figure 6.1)

The Section length field contains the length of the section in miles and hundredths of miles. Since the sections are continuous, the sum of the section lengths should equal the length of the road. Upon initial inspection, the lengths appear to be accurate to within a quarter mile in most cases. There are some discrepancies in the sample data sets of Hughes and Brookings counties that must be resolved through manual intervention. These discrepancies are discussed in detail later in this document in the section pertaining to gaps. They do not preclude the use of these measures in developing a spatial referencing scheme.

In cases where a road stops, then starts over again further down the section line, the Section Number can be used as a sort of reference point to locate the road where it begins again.

The record layout described above does contain an inherent linear measurement system, which can be used to identify events in the field, and could be applied to a spatial network, even though to date it has not been linked to the GIS.

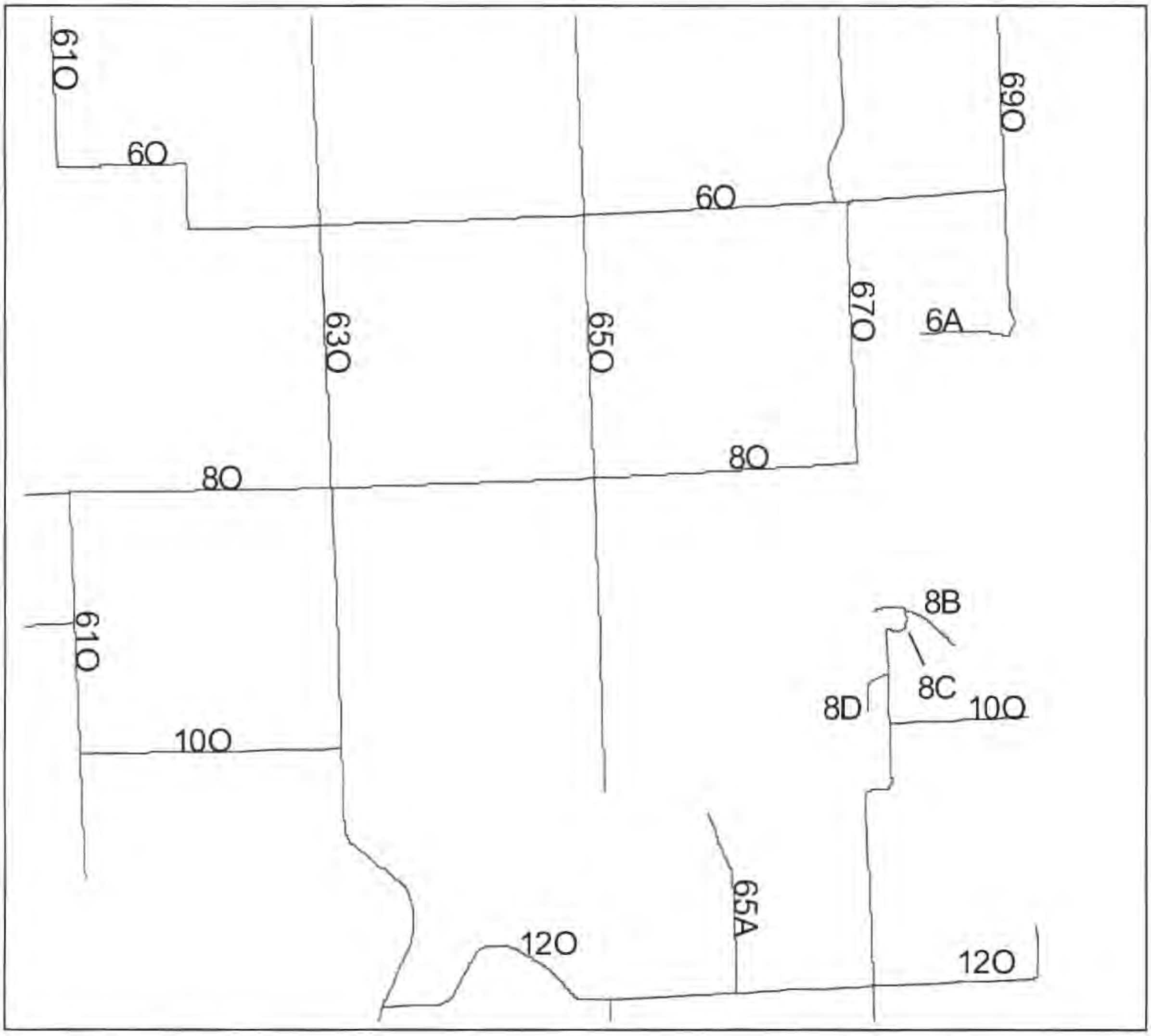


Figure 6.1 County Road Numbering Scheme

6.2 GPS Highway Inventory Data

6.2.1 Overview

The SDDOT has enlisted the help of the various Planning and Development Districts throughout South Dakota to collect an inventory of all the streets, roads, and highways in the state. This inventory project used Global Positioning System (GPS) technology to collect accurate centerlines of each of the roadways, and field data collectors to collect selected attribute information. The road centerlines are in ESRI's ArcInfo format and can easily be displayed using

GIS software. These centerlines should be used as the new GIS base map for South Dakota DOT. As the linear data was collected using the GPS, accurate measures were recorded for each data item using a distance-measuring instrument (DMI).

Many of the data items collected by the GPS inventory also exist in the NSTRI, however there is no direct correspondence between the sections defined in the NSTRI and the GPS inventory.

The GPS inventory collected both point and linear features. The point features collected mostly consist of cultural features such as buildings, airports, cemeteries etc. Since this project is only concerned with the linear data items; those that must be combined in the database with the NSTRI features, the point features were not used in any way. However, the point features can be easily integrated in to the map and will be a valuable addition to the GIS.

6.3 Prioritized List of Data Items

Table 6.1 represents all of the data items of the combined NSTRI and GPS inventory. Each item has been prioritized as either:

Required – Key field or necessary to derive data set for HPMS.

High – Items that contain information that is of great importance to the Non-State inventory and should be included in the final database.

Medium – Items that contain information that is useful to a Non-State inventory and is cost effective to retain in the final database

Low- Items that were used for the initial GPS collection but are no longer necessary or items that are of limited value to the Non-State inventory, are cost prohibitive to maintain, or have not been populated in the existing datasets.

This prioritization has been determined based upon interviews with staff, as well as an assessment of what data items are required under existing reporting requirements, which are needed within the agency, and which are either too expensive or of so little value that they were assigned a low priority.

Also included in the table are the relative cost to maintain, and collection effort.

The relative cost to maintain refers to the ongoing costs associated with keeping this data item current. The rankings are based on collection effort required, frequency of changes and procedures required to update the database.

Collection effort refers to the actual effort required by the crew in the field to collect this data item.

Those items rated as Moderate or Low priority have been further explained below.

Key Fields	
Route_ID	Required
Begin_DMI	Required
End_DMI	Required
City_code	Required
County_code	Required

Data Item	Priority	Original Source	Relative Cost to Maintain	Collection Effort
SDDOT_ID	Required	GPS	Low	Low
Year Inventoried	Required	NSTRI	Low	Low
Data Class	Required	NSTRI	Low	Low
Lanes	Required	GPS	Low	Low
Surface Width	Required	GPS	Low	Moderate [1]
Surface Type	Required	GPS	Low	Low
Surface Condition	Required	GPS	Moderate [2]	Low
Speed Limit	Required	GPS	Low	Low
Curb and Gutter configuration	Required	GPS	Low	Low
Shoulder Type	Required	GPS	Low	Low
Shoulder Width	Required	GPS	Low	Moderate [1]
Parking	Required	GPS	Low	Low
Terrain	Required	GPS	Low	Low
Current ADT	Required	NSTRI	Moderate [2]	Low
Local System	Required	NSTRI	Low	Low
STP	Required	NSTRI	Low	Low
STP Route	Required	NSTRI	Low	Low
Federal Domain	Required	NSTRI	Low	Low
Reservation/Park Designation	Required	NSTRI	Low	Low
Functional Classification	Required	NSTRI	Low	Low
Rural/Urban Designation	Required	NSTRI	Low	Low
State Administration	Required	NSTRI	Low	Low
Year Last Surfaced	Required	NSTRI	Low	Low
Road Name	High	GPS	Low	Low
Private	High	GPS	Low	Low
Open/Closed Code	High	NSTRI	Low	Low
ROW Width	Moderate	NSTRI	High	High [1]
Drainage	Moderate	GPS	Low	Low
Base Thickness	Low	NSTRI	Low	High [3]
Surface Thickness	Low	NSTRI	Moderate	Moderate [2]
Overlay Thickness	Low	NSTRI	Moderate	Moderate [2]
Rideability	Low	GPS	Low	Low
City Population Group	Low	NSTRI	Low	Moderate
Intersection Direction	Low	GPS	Low	Low

Intersection Description	Low	GPS	Low	High [1]
Driving Direction	Low	GPS	Low	Low
Maintenance Costs	Low	NSTRI	Moderate	Moderate [3]

Table 6.1 Prioritized List of Data Items

[1] Items that require field measurements or otherwise require the field collection crew to stop the vehicle.

[2] Items that will require more frequent updates.

[3] Items that information for updates may not be readily available.

6.3.1 Review of Non-State Data Items

The NSTRI Database was developed to track information on the Non-state highways of South Dakota. There are currently 28 data items included in the NSTRI that pertain to all non-state roads. There are an additional 5 data items maintained for county roads and 5 for the city streets.

Several of the NSTRI data items are used to populate a database for the HPMS that is administered by the Federal Highway Administration (FHWA). These data items must be retained and included in any future database developed for the Non-State trunk system although some of the location referencing fields will change.

There are 23 data items included in the GPS inventory. All 23 items were collected for State highways, county roads and city streets. If a field does not apply to a segment of road e.g. city_code for a county road, that field is left blank. Most of the items collected also exist in the NSTRI. In the combined list of data items, those collected during the GPS Inventory have superceded the equivalent NSTRI items.

The NSTRI database was designed many years ago. Due to changing needs and responsibilities as well as limited resources, the usefulness of some of the fields currently being maintained is questionable. There were also items collected by the GPS Inventory that are not necessary for the long-term maintenance of the combined database. Based on the current needs of the SDDOT and other potential users of Non-State Trunk data, the following fields have been identified as moderate or low priority. None of the following fields are required for the Railroad Crossing file.

6.3.1.1 Moderate Priority Data Items

ROW Width This data item is useful and if possible should probably be included in the final Non-State dataset. The drawback to maintaining ROW width is the cost of collection. This is not easily collected using the current GPS data collection method used for the GPS inventory. ROW width is populated for most of the records in the NSTRI and these could be retained. Future changes to ROW width should be reported to the Planning and Development Districts by supplying the new width and the location of the change so that the Planning and Development District field crew does not have to re-measure the width.

Drainage This data item is also useful for planning purposes. Although the method of collecting drainage is somewhat subjective, the cost of collection this information in the field is relatively low. The crew in the field can easily populate this item.

6.3.1.2 Low Priority Data Items

Year Built This data item is currently not populated for most of the section records in the NSTRI database. It is doubtful that the year built information is even available for all roads and even if it was, the research required finding it would be enormous. Year Built is not required by HPMS. Furthermore, since this item is based on a 2 -digit date field, it is not Y2K compliant.

Base Thickness, Surface Thickness, and Overlay Thickness These fields have not been populated in the NSTRI and the data for them is probably not readily available. These fields may be useful for a county or city maintenance supervisor, but the individual road maintenance sections should probably maintain them in a local database if they feel they are helpful. These fields are no longer required for HPMS and are of little use to a non-state road inventory.

Maintenance Costs This data item was used to identify if maintenance costs were available for a section of road. This field is no longer used and not necessary for a non-state road inventory.

Rideability This data item is purely subjective and can be very volatile. A heavy rainstorm can change the rideability of an unpaved road overnight. Therefore this item is of very little actual value. While the attributes of this field could be modified to contain roughness data for HPMS, none of the roads represented in the NSTRI data available to GIS/Trans require roughness data be recorded according to the HPMS Field Manual.

Population Group This field was used to produce reports for different size towns and cities and is no longer used. This field can be eliminated from the combined database.

Driving Direction This field was used in the initial GPS data collection to determine the direction that items were collected. The procedures for maintaining the combined database will no longer require that this item be collected.

Inter_desc and Inter_dir These fields are designed to be a text description of the intersection between the subject segment and a crossroad. While these fields were useful in the initial GPS data collection and QA/QC process, they are rather time consuming to collect in the field. Since the configuration of the intersections is clearly evident in the GIS spatial data layer, continuing to collect and maintan this as attribute information could be redundant. If information about the intersections is deemed necessary, a possible replacement field could be one field; Inter_desc, which contains a description such as: Left only, CR 36; or cross SD13, 100 foot left turn lane. The placement of the intersection information should be consistent either at the beginning or at the end of the segment.

6.3.2 Accuracy

In evaluating the existing and required accuracy of the data items several issues come into play. In general, any items collected during the GPS Inventory can be considered to be of sufficient accuracy to support the needs of the non-state database. A review of the data collection manual for the GPS Inventory, reveals that the procedures used in the collection should result in data with a spatial accuracy of 1-3 meters based on the published accuracy of differential GPS and the DMI. Furthermore, since the GPS inventory was done recently, the data is up-to-date.

The accuracy of the NSTRI data is much more difficult to determine. The methodology to bring the two databases together preserves the accuracy of the NSTRI data items as much as possible, however the Section_#/Section Length method of referencing does not have the accuracy of the GPS. In reviewing the NSTRI data, GIS/Trans discovered several instances of overlapping Section Lengths or cumulative Section Lengths that did not closely match the GPS lengths. These discrepancies occurred most frequently in the city data (possibly due to recent changes in city boundaries). Also in question is the temporal aspect of the NSTRI data. Since most of it is several years old, many changes could have occurred since it was last collected. Fortunately, most of the NSTRI data items retained in the combined database are items that apply to the entire route, or are administrative items that do not require a high level of spatial accuracy and do not require field data collection to populate. Any NSTRI data items in the combined database should be considered suspect until SDDOT can review them carefully and update any that are found to be in error.

6.4 Combined Database Definition

Once combined, the new non-state database will require fields from both the NSTRI and the GPS Inventory. The location fields must reflect the GPS collected dataset in order to display properly on the GIS map. Figure 6.2 gives the entity relationships of the combined GIS-based dataset.

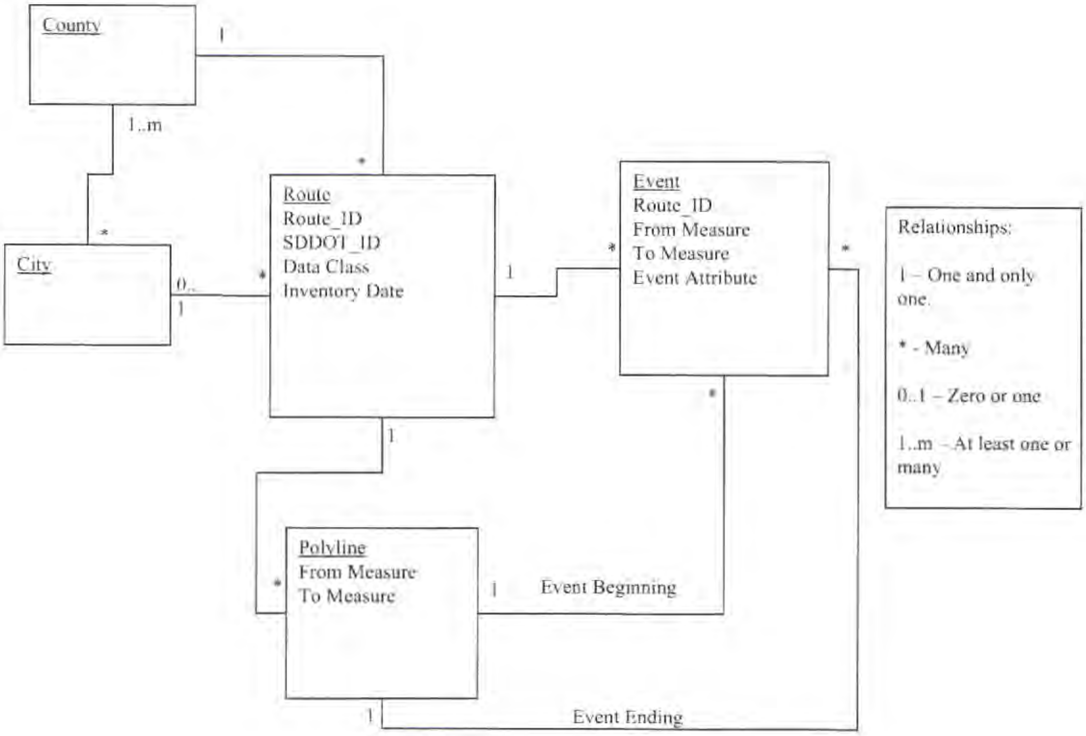


Figure 6.2 Entity Relationship Diagram for Combined Database

In order to manage linear data items in a more efficient manner using the GIS, the combined database will use *FROM* and *TO* measures based on actual distance from origin (DFO) measurements for the GPS Inventory items and derived DFO measurements for the NSTRI data items. The method for deriving DFO measurements from the location keys in the original datasets is described in more detail later in this document. The result will be a single database containing all the necessary data items that can be more easily maintained using the GIS to manage location keys based on future GPS data collection or more traditional DMI derived measurements.

Arc Attribute Table*

Cover#
10001
10007
10013
10026
10055
10112
10200
10211
10225
10333

Event Table - Speed Limit

Event Table - Drainage

Event Table - Surface Width

Event Table - Lanes

ROUTE_ID	Lane	From Measure	To Measure
10	1	0.00	5.50
10	2	5.50	10.00
10	1	10.00	15.75
11	2	0.00	12.00
12	2	0.00	3.50
12	3	3.50	4.75

Arc Section Table*

Arc link#	Route_Link#	From Measure	To Measure
10001	10	0.00	1.00
10007	10	1.00	6.00
10013	10	6.00	12.50
10026	10	12.50	15.75
10055	11	0.00	5.00
10112	11	5.00	10.00
10200	11	10.00	12.00
10211	12	0.00	1.50
10225	12	1.50	3.00
10333	12	3.50	4.75

Route Attribute Table*

ROUTE_ID	SDDOT ID	Data_ Class	Inv_Yr
10	34	2	1999
11	16	2	1999
12	26	2	1999

* indicates tables created and maintained by ARC/INFO

Figure 6.3 Combined NSTRI and GPS Inventory Database Design

Data items included in the combined database will each be a separate table[1] with each record having a route identifier with a *FROM* measure and a *TO* measure. (See Figure 6.3)

Since the new, combined database will be maintained in a GIS/RDBMS (relational database management system) environment, and there is a new method of maintaining the location keys, a new procedure for submitting the non-state HPMS data from the GIS will be necessary.

Upon implementation, procedures will also have to be developed to ensure that the "Current ADT" values are made available to the Railroad Crossing File that will still remain on the mainframe.

This combined database can be maintained more efficiently in a relational database management system, and edits to the spatial network can seamlessly update the relational tables. As such, we do not recommend transferring data back to the mainframe environment solely to produce existing reports. Instead, we recommend the use of commercially available off-the-shelf report writing packages (ie. Crystal reports) to produce these existing reports. These can be easily formatted, and derived dynamically from the database.

[1] Upon actual development of the database tables, some de-normalization of the database may be necessary to enhance performance and simplify report generation.

7 NSTRI/GPS INVENTORY GIS DATABASE INTEGRATION METHODOLOGY

The objective of this methodology is to assign common locational keys to the NSTRI mainframe dataset and the GPS Inventory dataset, thereby allowing the two datasets to be joined. In simple terms, by using the location information from each of the datasets, we can place them on the GPS collected map using the GIS. Once both datasets are locationally referenced to the same map, we can transfer data items between them. (see Figure 7.1)

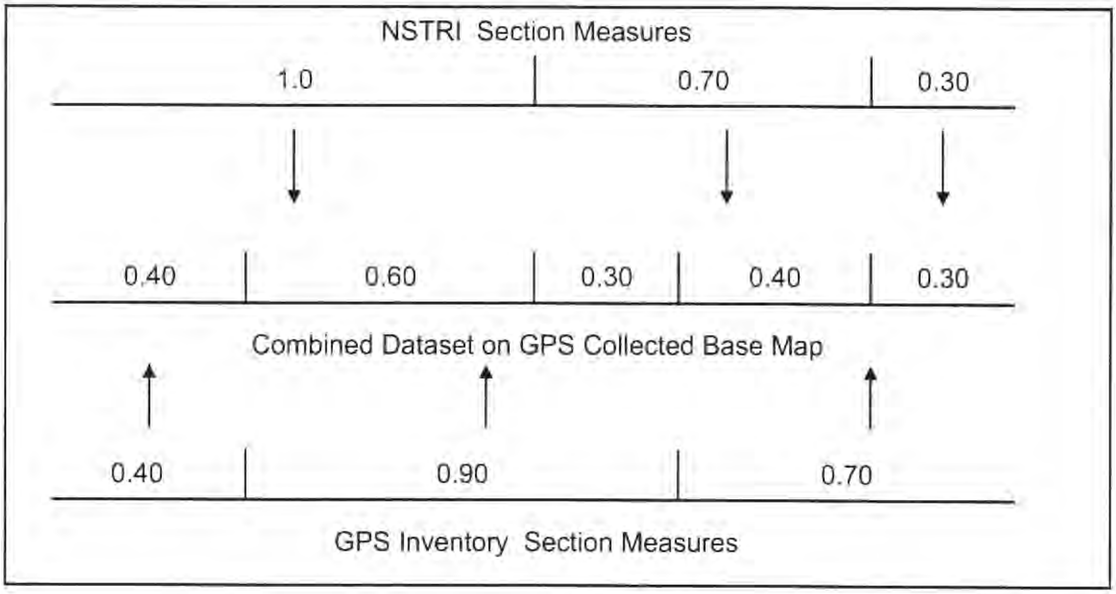


Figure 7.1 NSTRI and GPS Inventory on a Common Spatial Framework

7.1 Proof of Concept

The following discussion regarding the methodology to integrate the NSTRI and GPS Inventory is a direct result of a proof of concept project that was developed as a deliverable of this project. SDDOT provided GIS/Trans with NSTRI and GPS Inventory data along with the GPS centerline files for Hughes and Brookings counties. These data sets were used to develop an LRS that can be applied to all non-state roadway information for South Dakota. This chapter describes how this LRS was developed and the procedures used to apply it to the NSTRI and GPS Inventory. Most of the tables and figures used to illustrate the methodology in this chapter were taken directly from the proof of concept project. All of the data sets and tools used in developing the proof of concept project are to be delivered to SDDOT.

All scripts and tools developed for this project were written in Arc Macro Language (AML) and INFO.

7.2 Locational Keys for Transportation

Roadway information is often best managed using a key combined from Route ID, *FROM* measure and *TO* measure. Measures must be "monotonic" along a route, i.e., they must increase or decrease over the full extent of the route. Measures are usually based on mileage, but as long as they are monotonic, they may be based on other units, such as time.

A table with a locational key is called in GIS terms, an event table. Line coverages that have a locational key are called route systems. Event tables may be joined to each other in a process called "overlay". Events may also be joined with route systems in the GIS to create maps or geographic features. In this way, selected attributes (events) such as surface type, can be mapped along a spatial network (routes) with the correct distances reflected from the spatial/tabular data within the GIS.

At SDDOT different measurement systems are used in NSTRI mainframe files and the GPS roadway inventory. The NSTRI files use a measurement based on distance from the county line, or more accurately distance from a "baseline" (DFB) and a section length; the GPS inventory uses a distance measuring instrument (DMI), to collect a beginning and an ending measurement for each record based on driving distance.

The strategy used in this project creates two different types of locational keys: one based on DFB for the NSTRI and the other based on DMI for GPS collected items. Using the GPS collected map as a common "base" a cross-reference table is then created that allows DFB to DMI measurement conversion.

7.2.1 Roadway Identifiers

The NSTRI and GPS Inventory use similar but not identical methods of identifying roadways. The NSTRI database uses a 4 character field called ROAD NUMBER that includes leading zeros and a suffix as explained in Section 6.1.1 of this document. The GPS Inventory uses an abbreviated version of the same number. In the GPS inventory database, leading zeros are left off and so is the O suffix (normal east-west or north-south roads). All other suffix characters are included. In order to have consistency, GIS/Trans developed a routine to run against the NSTRI ROAD NUMBER field that creates an SDDOT_ID value for all NSTRI records by removing leading zeros and trailing O's.

Table 7.1 gives some examples of NSTRI ROAD_NUMBERS and equivalent GPS Inventory SDDOT_IDs.

NSTRI ROAD NUMBER	GPS Inventory SDDOT_ID
009O	9
010O	10
010A	10A
010B	10B

Table 7.1 ROAD NUMBER to SDDOT_ID Cross reference

The SDDOT_ID in conjunction with the appropriate city or county code creates a unique roadway identifier for all roads in South Dakota.

7.3 NSTRI DFB Measurement System: Distance From Baseline

The NSTRI mainframe tables have a column (SECTION#) describing location along a route by the number of Public Land Survey Sections (PLSS) the location is from a reference or "base" line. The straighter the road, the closer the SECTION# will approximate the actual distance along the road, assuming that it begins at the county line. We have called this type of measurement system "distance from baseline" (DFB). For even numbered (east-west) roads, distances are measured from the baseline passing along the western edge of the county; for odd numbered (north-south) roads the base line passes along the northern edge. These two baselines are easily generated for each county using ArcInfo. (See Figure 7.2)

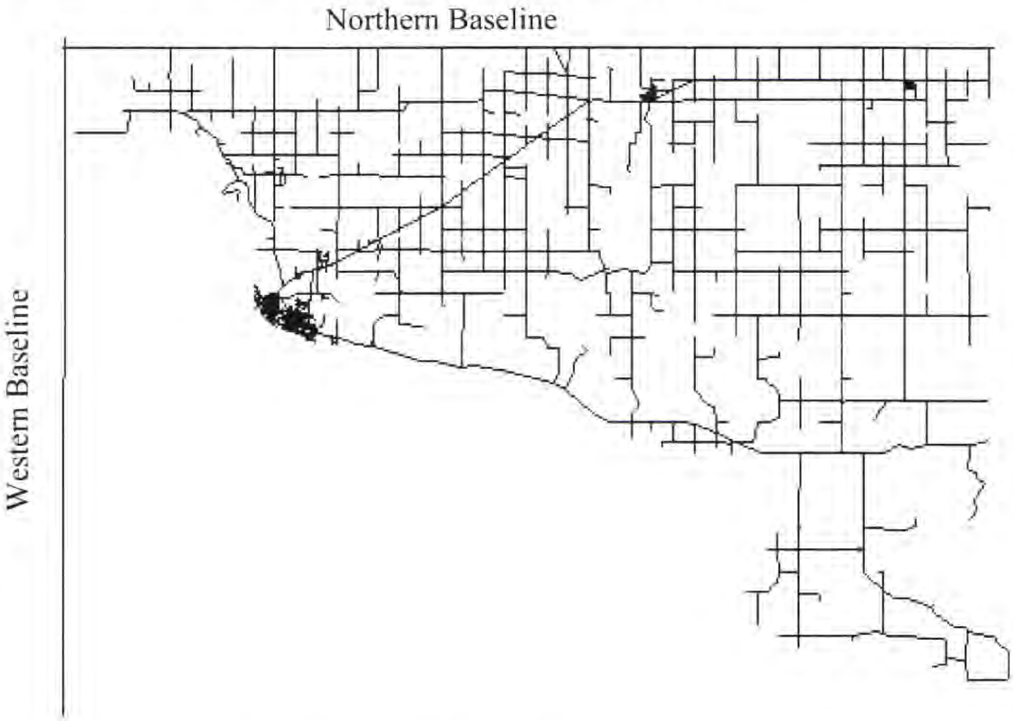


Figure 7.2 Baselines for Hughes County

Each NSTRI dataset record is assigned a FDFB value, representing the "From" DFB of the record, and is calculated as SECTION# / 100. (see Table 7.2)

SDDOT_ID	SECTION#	FDFB	ADT	FUNC_CLASS
26	0	0.00	25	09
26	700	7.00	1	09
26	800	8.00	15	09
26	1130	11.30	17	09
26	1600	16.00	10	09
26	1700	17.00	1	09
26	1900	19.00	1	09
26	2200	22.00	1	09
26	2340	23.40	1	09
26	2970	29.70	10	09

Table 7.2 FDFB is derived from Section#

7.4 GPS Inventory Measurement System: Distance Measuring Instrument

The measurements collected with the DMI are described as BEGIN and END DMI. Because the DMI operator would stop and reset the DMI to zero occasionally, these values are not monotonic. In order to produce distance measures that increase from the beginning of the route to the end, GIS/Trans developed a procedure to assign FROM and TO DMI (FDMI & TDMI) values based on cumulative ROAD_LENGTH. (see Table 7.3)

SDDOT_ID	FDMI	TDMI	BEGIN_DMI	END_DMI
26	0.00	1.03	0.000	1.034
26	1.03	2.04	1.034	2.038
26	2.04	3.04	2.038	3.041
26	3.04	4.05	3.041	4.050
26	4.05	5.06	4.050	5.059
26	5.06	5.63	5.059	5.631
26	5.63	5.77	5.631	5.765
26	6.98	7.99	0.000	1.003
26	7.99	9.01	1.003	2.023
26	9.01	10.01	2.023	3.026
26	10.01	10.55	3.026	3.569
26	11.01	11.51	0.000	0.496
26	11.51	12.01	0.496	1.003
26	12.01	12.95	1.003	1.940
26	12.95	13.95	1.940	2.943
26	13.95	14.96	2.943	3.945
26	15.96	16.96	0.000	1.004
26	16.96	17.03	1.004	1.074
26	17.03	17.97	1.074	2.010
26	17.97	18.43	2.010	2.470
26	21.96	22.96	0.000	1.004
26	22.96	23.97	1.004	2.010
26	29.64	29.91	0.000	0.277

Table 7.3 Begin_DMI and End_DMI are converted to FDMI and TDMI measures

7.5 GIS Route Identifiers

In order to uniquely identify routes within a single field in the GIS, a new key is created called ROUTE_ID. Since each SDDOT_ID and city/county code combination uniquely identifies a route, these fields are used to populate the ROUTE_ID. This is accomplished by sorting the routes by county/city codes and SDDOT_ID then simply sequentially numbering them. (Table 7.4)

ROUTE_ID	SDDOT_ID	County/City Code
21	20	06
22	20A	06
23	21	06
24	22	06
25	23	06
26	23A	06
27	24	06
28	242	CZ
29	243	CZ
30	243A	CZ
31	243B	CZ
32	243C	CZ
33	244	CZ
34	244A	CZ
35	245	CZ
36	246	CZ
37	246	DB
38	246	GX
39	246A	CZ
40	247	CZ
41	247	DB
42	247	GX
43	247A	CZ
44	248	BH
45	248	CZ
46	248	DB
47	248	GX
48	248	SV
49	248	VJ

Table 7.4 Creation of Unique ROUTE_IDs

7.6 Data Set Integration Based on Linear Referencing

Once the measures have been prepared in the NSTRI and GPS datasets, and the ROUTE_IDs populated, the process of bringing the two together can begin. The first step is to assign FDMI and TDMI values to the polylines that make up the route in the GIS. The measures of any arc originally collected toward its baseline (east to west or south to north) are flipped so that they increase going away from its baseline. The arcs are then sorted by the DFB value of their from-node (FDFB). The FDMI and TDMI values are then calculated by accumulating the ROAD_LENGTH value (the DMI based value measured in the field). When a gap is encountered the FDMI value of the first arc after the gap is calculated by adding the straight-line distance from the end node of the preceding arc. The accumulation is then resumed. This results in DMI values that increase along the entire length of the route regardless of curves or gaps. (See Figure 7.3)

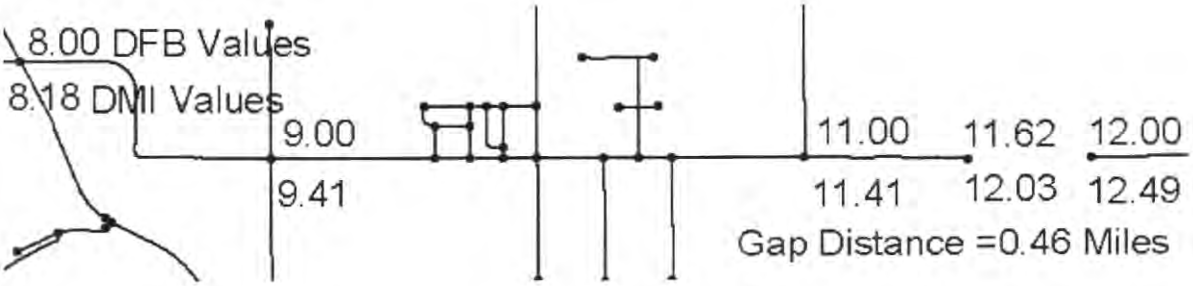


Figure 7.3 DMI Values Based on Driving Distance

Event tables are then written based on from and to DMI measures. (See Table 7.5)

SDDOT_ID	FDMI	TDMI	LANES	SURFACE_W	SURFACE_TY
26	0.00	1.03	2	22	GRAVEL
26	1.03	2.04	2	22	GRAVEL
26	2.04	3.04	2	22	GRAVEL
26	3.04	4.05	2	22	GRAVEL
26	4.05	5.06	2	18	GRAVEL
26	5.06	5.63	2	16	GRAVEL
26	5.63	5.76	1	10	PRIMITIVE
26	5.76	6.98	(gap)		
26	6.98	7.99	1	10	PRIMITIVE
26	7.99	9.01	2	18	GRAVEL
26	9.01	10.01	2	18	GRAVEL
26	10.01	10.55	2	16	GRAVEL
26	10.55	11.01	(gap)		
26	11.01	11.51	1	10	PRIMITIVE
26	11.51	12.01	2	16	GRAVEL
26	12.01	12.95	2	16	GRAVEL
26	12.95	13.95	2	18	GRAVEL
26	13.95	14.96	2	18	GRAVEL
26	14.96	15.96	(gap)		
26	15.96	16.96	2	18	GRAVEL
26	16.96	17.03	2	18	GRAVEL
26	17.03	17.97	2	16	GRAVEL
26	17.97	18.43	1	10	PRIMITIVE
26	18.43	21.96	(gap)		
26	21.96	22.96	1	10	PRIMITIVE
26	22.96	23.97	1	10	PRIMITIVE
26	23.97	29.64	(gap)		
26	29.64	29.91	1	16	GRAVEL

Table 7.5 Event table derived from GPS Inventory

7.6.1 Virtual Reference Markers

Once event tables have been created for the GPS Inventory dataset, event tables for the NSTRI dataset must be created using the same measurement system: FROM and TO DMI.

In order to accomplish this, DFB based measurements from the NSTRI dataset are assigned to the GPS roadway segments using what we have called Virtual Reference Markers (VRMs). VRMs are GPS point locations for which DFB values can be inferred. Roadway intersection points that occur at section corners are the primary VRM locations. ArcInfo is used create the points representing the VRMs and to determine the distance (as the crow flies) from the baseline to the VRM. Calibrated DFB values at these VRMs are then calculated by rounding the measured straight-line distance to the nearest whole integer. (see Figure 7.4) Due to the fact that Section Numbers are used for referencing in the NSTRI, all section lines that cross a given route must become a VRM.

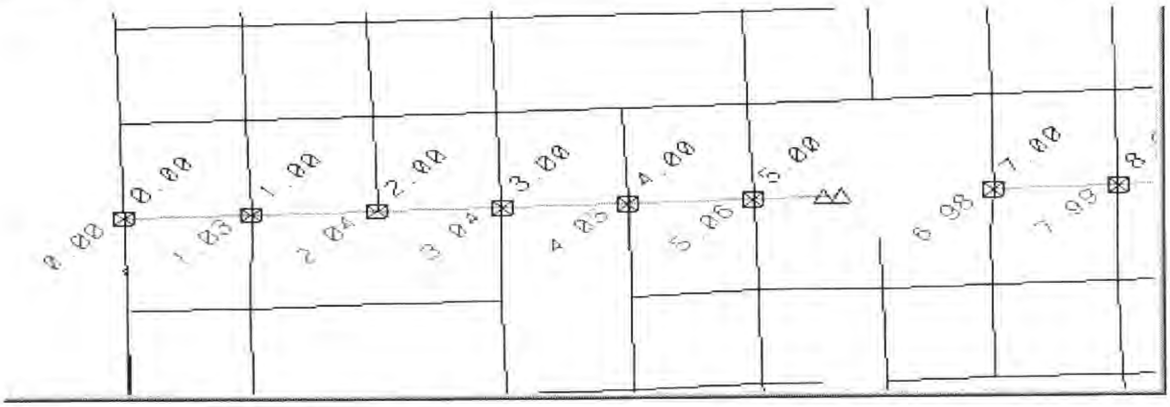


Figure 7.4 VRMs with raw (below) and calibrated (above) DFB values

The VRMs for each route are then used to assign the Calibrated From and To DFB values to each GIS line segment belonging to the route. Once From and To DFBs are assigned to the roadway inventory, a cross-reference table, DMI to calculated DFB, may be derived. (See Table 7.6)

SDDOT_ID	FDMI	TDMI	FDFB	TDFB	CALFDFB	CALTDFB
26	0.00	1.03	0.063	1.088	0.00	1.00
26	1.03	2.04	1.088	2.089	1.00	2.00
26	2.04	3.04	2.089	3.087	2.00	3.00
26	3.04	4.05	3.087	4.092	3.00	4.00
26	4.05	5.06	4.092	5.096	4.00	5.00
26	5.06	5.63	5.096	5.665	5.00	5.65
26	5.63	5.77	5.665	5.796	5.65	5.80
26	6.98	7.99	7.016	8.012	7.00	8.00
26	7.99	9.01	8.012	9.029	8.00	9.00
26	9.01	10.01	9.029	10.027	9.00	10.00
26	10.01	10.55	10.027	10.567	10.00	10.57
26	11.01	11.51	11.024	11.522	11.00	11.50
26	11.51	12.01	11.522	12.028	11.50	12.00
26	12.01	12.95	12.028	12.958	12.00	13.00
26	12.95	13.95	12.958	13.955	13.00	14.00
26	13.95	14.96	13.955	14.952	14.00	15.00
26	15.96	16.96	15.955	16.957	16.00	16.94
26	16.96	17.03	16.957	17.022	16.94	17.00
26	17.03	17.97	17.022	17.955	17.00	18.00
26	17.97	18.43	17.955	18.413	18.00	18.41
26	21.96	22.96	21.945	22.943	22.00	23.00
26	22.96	23.97	22.943	23.944	23.00	24.00
26	29.64	29.91	29.611	29.882	29.61	30.00

Table 7.6 DMI to Calibrated DFB Cross Reference Table

FDMI values for the NSTRI sections are then interpolated by finding the row in the cross-reference table whose DFB range contains the FDFB value of the NSTRI section.

The TDMI for each NSTRI record is then computed by adding SECTION_LENGTH and FDMI.

Event tables for the NSTRI data items can now be created using FDMI and TDMI as the location reference. (Table 7.7)

SDDOT_ID	SECTION_	SECTION_LENGTH	FDMI	TDMI	ADT	FUNC_CLASS
26	0	563	0.00	5.63	25	09
26	700	99	6.98	7.97	1	09
26	800	256	7.99	10.55	15	09
26	1130	344	11.31	14.75	17	09
26	1600	100	15.96	16.96	10	09
26	1700	101	17.03	18.04	1	09
26	2200	142	21.96	23.38	1	09
26	2340	58	23.37	23.95	1	09
26	2970	30	29.70	29.91	10	09

Table 7.7 Event table records for Brookings County Route 26 derived from NSTRI

7.6.2 Overlay (Join)

Once event tables have been created for both the NSTRI and GPS Inventory based on DMI measures, the two event tables are joined (or overlaid) using the common keys; SDDOT_ID, FDMI and TDMI. (Table 7.8)

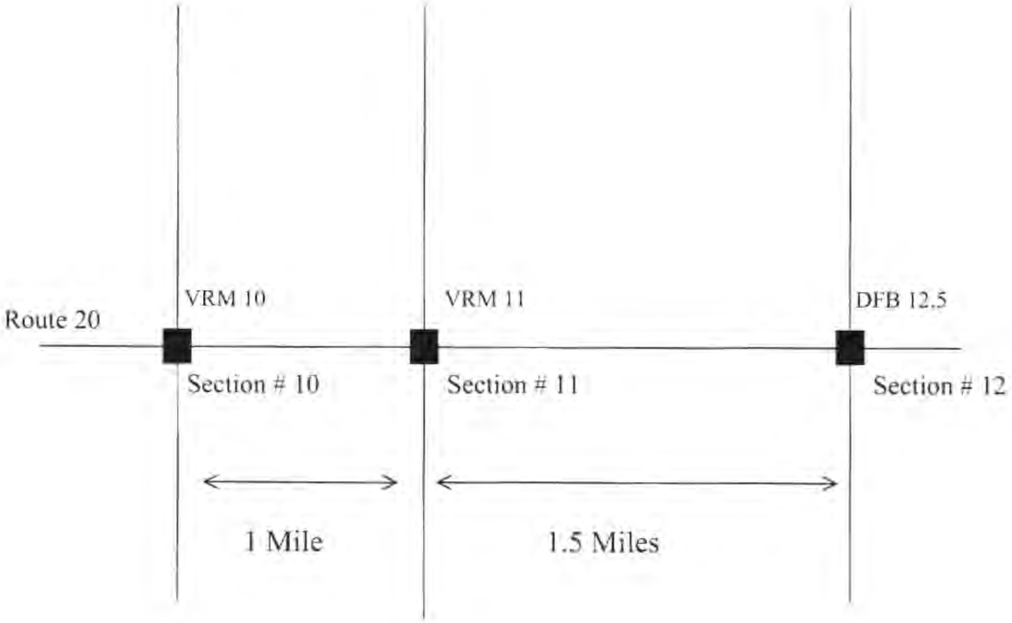
SDDOT_ID	FDMI	TDMI	ADT	FUNC_CLASS	LANES	SURFACE_WI	SURFACE_TY
26	0.00	1.03	25	09	2	22	GRAVEL
26	1.03	2.04	25	09	2	22	GRAVEL
26	2.04	3.04	25	09	2	22	GRAVEL
26	3.04	4.05	25	09	2	22	GRAVEL
26	4.05	5.06	25	09	2	18	GRAVEL
26	5.06	5.63	25	09	2	16	GRAVEL
26	6.98	7.97	1	09	1	10	PRIMITIVE
26	7.99	9.01	15	09	2	18	GRAVEL
26	9.01	10.01	15	09	2	18	GRAVEL
26	10.01	10.55	15	09	2	16	GRAVEL
26	11.31	11.51	17	09	1	10	PRIMITIVE
26	11.51	12.01	17	09	2	16	GRAVEL
26	12.01	12.95	17	09	2	16	GRAVEL
26	12.95	13.95	17	09	2	18	GRAVEL
26	13.95	14.75	17	09	2	18	GRAVEL
26	15.96	16.96	10	09	2	18	GRAVEL
26	17.03	17.97	1	09	2	16	GRAVEL
26	17.97	18.04	1	09	1	10	PRIMITIVE
26	21.96	22.96	1	09	1	10	PRIMITIVE
26	22.96	23.37	1	09	1	10	PRIMITIVE
26	23.37	23.38	1	09	1	10	PRIMITIVE
26	23.37	23.38	1	09	1	10	PRIMITIVE
26	23.38	23.95	1	09	1	10	PRIMITIVE
26	29.70	29.91	10	09	1	16	GRAVEL

Table 7.8 Overlay of NSTRI events and GPS Inventory events.

7.7 Gaps

Thorough inspection of the NSTRI and GPS Inventory datasets revealed spatial discrepancies between the two. These discrepancies are called gaps. Two types of gaps are identified: GPS gaps and NSTRI gaps. A GPS gap is an apparent physical discontinuity in a route that has NSTRI dataset records that fall within it. An NSTRI gap is a stretch of GPS inventory roadway that has no corresponding NSTRI data. Some gaps are probably legitimate due to the out-dated nature of some of the NSTRI records. For example, the GPS inventory may have collected sections of road that did not exist when the NSTRI was last updated. Others could be the result of the GPS collection process inadvertently missing a section of road. While the methodology places most of the NSTRI records in the most accurate position possible, occasionally, some NSTRI records are not correctly placed. This is most often due to land survey sections that are not 1 mile by 1 mile. For example, the northeastern most survey sections of Hughes County are 1.5 miles north to south but the Section_# is coded as 1 in the NSTRI. The DFBs for the odd numbered (north-south) roads had to be adjusted by a half mile.

Reports and maps depicting both types of gaps are generated by ArcInfo tools developed by GIS/Trans. These reports should be reviewed to determine the cause of the gaps. In the case of roads that did not exist in the NSTRI, fields not collected by the GPS Inventory, such as ADT, will need to be populated. If it is determined that the GPS Inventory missed a segment, that segment will need to be collected with the GPS and added to base map. Gaps that are the result of inconsistent land sections are easily identified using these reports and the DFB values can be adjusted to match the NSTRI Section_# and are then considered to be a VRM. (see Figure 7.5)



DFB 12.5 for Route 20 gets adjusted to 12 and becomes a VRM to match Section #

Figure 7.5 Adjustment of DFB Values

It is the best estimate of GIS/Trans staff that through the use of the automated tools which were developed as part of the proof of concept, the average time to validate the automated procedures, together with the time to correct the "gaps" in the data base should average between one and two days per county. This holds true for all gaps except in those cases where GPS centerline data was not collected.

The use of the GIS provides a good mechanism to visually identify such gaps, and should in turn be used as a QA/QC mechanism to check the GPS collected data from the Districts in the future. With some slight modification to the automated scripts, together with the development of a user friendly graphical interface, the skill level required to perform such editing would be relatively minimal, and could easily be assisted through the use of interns.

Given the relative level of effort required to complete the full integration of the two data sets, and the resultant value of having an accurate centerline spatial network, we strongly recommend that South Dakota DOT undertake the effort to complete this data integration project. Further, this project can serve as a model for future integration efforts, and can help facilitate such agency-wide data integration.

7.8 City Streets Data

The discussion of the methodology in this document has focused mainly on the county roads because the concept is easier illustrated using the county as the subject data set. The city streets are handled in the exact same manor as the county roads. The only difference is that a new set of baselines will have to be created for each city. The scripts that were written for the proof of concept project will handle the city data at the same time and in the same manor as the county data.

The researchers did find that the NSTRI city data (in this case Brookings) had more discrepancies (gaps, overlaps, missing data, etc.) than the county data. This is understandable due to the dynamic nature of streets in many cities. As a result counties containing larger cities such as Sioux Falls, Brookings, Pierre, Aberdeen, or Rapid City, will require more manual inspection to determine the cause of discrepancies and therefore more time to complete.

8 CONSOLIDATED DATABASE MAINTENANCE

To retain its usefulness, the consolidated NSTRI database must be maintained. The challenge to achieving this goal is establishing effective communication between the county road departments, the Planning and Development Districts, and the SDDOT Planning and Programs.

It is recommended that the counties report their roadway maintenance activities to the Planning and Development Districts on at least a quarterly basis. Only activities that result in changes to the consolidated database will need to be reported. The location of the counties' activities must be described well enough so the Planning and Development District GPS data collectors can find the stretch of roadway that needs collecting. Note that re-collecting roadway centerline is not recommended unless the road has been re-aligned. Instead, only beginning and ending GPS points are needed for each new or updated data item.

8.1 Tools

Once created, the consolidated NSTRI database will require some tools be developed to maintain it. This chapter describes several scenarios that will arise requiring the consolidated NSTRI database to be updated. It is recommended that the following tools be developed to support the functionality described in the scenarios.

GPSDATACOLLECTOR
This application is used for field data collection. The GeoLink software will need to be configured to allow the collection of BEGIN and END points that will later be paired to create linear events.
Creates: GPS_PointShapefile, GPS_LineShapefile

CONSOLIDATE
Creates the original roadway inventory route systems and roadway attribute tables. A prototype version of the routine has been developed using AML as a part of this research project. Given

the new linear referencing capabilities coming soon in ArcMap 8.1 it may be worth re-writing this in Visual Basic for Applications (VBA).
Creates RoadwayCoverage, EventTableXX (EventTable_Lanes, EventTable_AAT, etc.)

ROADEDIT
Changes roadway centerlines and updates DMI values downstream from the re-alignment. The DMI values in the EventTables will be adjusted accordingly.
This will be written in AML.
Updates: RoadwayCoverage, EventTableXX
Writes records to EventTable

GPS2EVENT
This application will use the GPS latitude and longitude location to find the Route-ID and DMI of the closest roadway. It will then sort the points by Route-ID and DMI and pair up adjacent BEGIN and END records.

This application will be written as an ArcView Extension, allowing it to run in the field on a standard laptop.
Inputs: GPS_PointShapefile
Creates: EventUpdateTableXX
The conversion routine will:

Load the GPS shapefile into ArcView.
Add ROUTE-ID and DMI columns to the shapefile's table.
Populate ROUTE-ID and DMI based on proximity to roadway centerlines.
Create a point event table for each type of attribute collected
Pair BEGIN and END points.
Flag unpaired BEGIN/END points.
Create a linear event table based on paired BEGIN and END point events.

EVENTLOAD
This application reads records from the GPSPointEventTable and loads the new events into their respective tables. This requires that new records be inserted, sometimes splitting existing records. Old records will also deleted or updated as necessary.
This can be written as either VBA or SQL.
The Event Load routine will:

Overlay (intersect) the new linear events with the existing linear events.
Create line shapes from the intersected events.
Delete events from the attribute table that are completely beneath update events.
Split events in the attribute table that are partially beneath update events.
Append updated events to the attribute table.

Table 8.1 describes the level of effort and expertise required to develop the above tools.

Tool	Platform	Type of Effort Required	Level of Expertise Required
GPSDATACOLLECTOR	GeoLink	Config. Of GeoLink Data collector	Knowledge in configuring GeoLink equipment and software
CONSOLIDATE	ArcInfo	VBA or SQL programming	Significant VBA or SQL programming expertise
ROADEDIT	ArcInfo	AML programming	Significant AML and understanding of DynSeg
GPS2EVENT	ArcView	Avenue programming	Moderate expertise in Avenue programming
EVENTLOAD	ArcInfo or SQL	VBA or SQL programming	Moderate expertise in VBA or SQL

Table 8.1 Tools for Maintenance of the Non-State Database

8.2 Use Case Scenarios

Use case scenarios are helpful to determine requirements. Below are the anticipated scenarios.

1) The county has informed the Planning and Development District of locations where they have resurfaced roads and performed other maintenance activities needing to be reflected in the consolidated database. (resurface)

The field crew uses the GPSDATACOLLECTOR to create GPS_PointCoverage(s) containing BEGIN and END points for each stretch of roadway that has been maintained. They do not necessarily collect them in order.

ID	INVENTORY_ DATE	X	Y	BEGIN_END	ATTR_NAME	ATTR_VALUE
1	9/13/2000	1234	1234	BEGIN	SURF_TYPE	BITUM
2	9/13/2000	1234	1234	END	SURF_TYPE	BITUM

Table GPS_PointCoverage (note coordinates have been truncated)

The Field crew uses GPS2EVENT ArcView script to create EventUpdateTables for the GIS technician. The script will flag any BEGIN points that lack END points, allowing verification of completeness in the field.

ROUTE-ID	FDMI	TDMI	INVENTORY_ DATE	FX	FY	TX	TY	SURF_TYPE
33	3.12	5.61	9/13/2000	1234	1354	1234	1234	BITUM

Table EventUpdateTable_Surface_Type

The GIS technician uses the EVENTLOAD routine to update the consolidated database with information in the EventUpdateTables.

ROUTE-ID	FDMI	TDMI	INVENTORY_ DATE	FX	FY	TX	TY	SURF_TYPE
33	0	2.9	7/21/1999	1234	1234	1234	1234	BITUM
33	2.9	6.1	7/21/1999	1234	1354	1234	1234	GRAVEL
33	6.1	8.0	7/21/1999	1323	1323	1234	1234	BITUM

Table EventTable_Surface_Type before the update

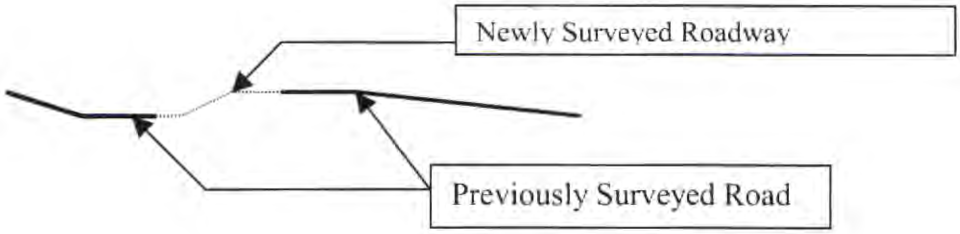
ROUTE-ID	FDMI	TDMI	INVENTORY_ DATE	FX	FY	TX	TY	SURF_TYPE
33	0.0	2.90	7/21/1999	1234	1234	1234	1234	BITUM
33	2.90	3.12	7/21/1999	1234	1354	1234	1234	GRAVEL
33	3.12	5.61	9/13/2000	1234	1234	1234	1234	BITUM
33	5.61	6.10	7/21/1999	1234	1234	1234	1234	GRAVEL
33	6.10	8.00	7/21/1999	1323	1323	1234	1234	BITUM

Table EventTable_Surface_Type after the update

GPS field crew will collect all attributes during the same pass. GPS2EVENT will sort the update table by attribute and correctly match beginning points with ending points.

2) It has been determined that part of a roadway was missed in the original GPS survey. (recollect)

The Field crew uses the GPSDATACOLLECTOR to create GPS_PointShapefile and GPS_LineShapefile. (Following the same procedures as original data collection).

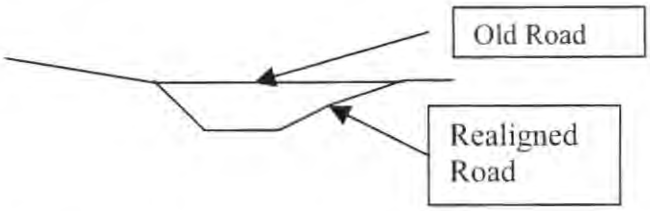


The GIS technician uses the ROADEDIT routine to:

Display GPS_LineShapefile in the background.
Append the new roadway from the inventory GPS_LineShapefile
Update FDMI and TDMI values in the Roadway Coverage downstream from the newly collected stretch of road.
Update FDMI and TDMI values in the EventTableXX's.

3) A roadway has been re-aligned to go around (instead of through) an area subject to local flooding. (realign)

The Field crew uses the GPS data collector to create GPS_PointShapefile and GPS_LineShapefile of the realign stretch of road. (Following the same procedures as the original data collection).



The GIS technician uses the ROADEDIT routine to:

Display GPS_LineShapefile in the background.
Delete the retired stretch of road from the RoadwayCoverage
Append the new roadway from the inventory GPS_LineShapefile
Update FDMI and TDMI values in the RoadwayCoverage downstream from the new roadway.
Update FDMI and TDMI values in the EventTableXX's.

5) A stretch of road between two intersecting roads is decommissioned, and allowed to be plowed under. (decommission)

The GIS Technician uses ROADEDIT to:

Identify the stretch of road,
Identify all events overlapped by the newly created gap
Split those events (add records, update DMI's)
Update DMI values downstream from the deleted stretch of road

8.3 Datasets

8.3.1 RoadwayCoverage

Created by the CONSOLIDATE routine.
Updated by the ROADEDIT routine.

ROUTE-ID	unique route identifier
FDMI	from DMI measure
TDMI	to DMI measure
DATE	date the GPS centerline was collected

8.3.2 EventTableXX

Represents the current condition of the roadway.
Created by CONSOLIDATE
Records are added, deleted and updated by EVENTLOAD and ROADEDIT

ROUTE-ID	unique roadway identifier
FDMI	from DMI position
TDMI	to DMI position
FROMX	from GPS x position
FROMY	from GPS y position
TOX	to GPS x position
TOY	to GPS y position
D_SURVEY	date the attribute was surveyed
D_EFFECT	date the attribute became effective
XX	the attribute being described by the table (ADT, LANES, etc.)

8.3.3 GPS_LineCoverage

Description: contains only the roadway centerline for use in updating geometry. This is not used when the geometry has not changed.
Created by: GPSDATACOLLECTOR
Read by: ROADEDIT (to update the RoadwayCoverage)

ROUTE-ID	unique roadway identifier
LENGTH	length (as measured with DMI)
DATE	date of collection (or re-alignment?)

8.3.4 GPS_PointCoverage

Description: This is a point shapefile containing many types of attributes. The Roadway geometry is not contained in this file. The coordinate is used only to determine Route-ID and DMI measure.
Created by: GPSDATACOLLECTOR.
Read by: GPS2EVENT

ID	sequential record number
D_SURVEY	date surveyed
D_EFFECTIVE	date the road was actually resurfaced (or whatever)
X	GPS x position
Y	GPS y position
BEG_END	BEGIN END (other codes OK for other purposes)
ATTR_NAME	name of attribute (LANES, SPEEDLIMIT ...)
ATTR_VALUE	value of the attribute

8.3.5 EventUpdateTableXX

Each attribute will be in its own table (XX = SURFACE_TYPE, ADT, etc.)
Created by: GPS2EVENT
Read by: EVENTLOAD

ROUTE-ID	unique roadway identifier
FDMI	from DMI position
TDMI	to DMI position

FROMX	from GPS x position
FROMY	from GPS y position
TOX	to GPS x position
TOY	to GPS y position
D_SURVEY	date the attibute was surveyed
D_EFFECT	date the attribute became effective
XX	the attribute being described by the table (ADT, LANES, etc.)

8.4 Resources

In order to maintain the consolidated Non-State Trunk database, trained personnel will be necessary to carry out the required tasks.

Database Integration: SDDOT will should train at least two GIS analysts to perform the integration of the NSTRI and the GPS Inventory databases. Working full time, the integration based on the methodology described here should take about 1-2 days per county. Counties with larger cities or that require additional GPS data collection will obviously take a little more time. Resources to provide the data from the NSTRI and provide technical expertise on NSTRI data will also be necessary. Ideally the GIS analysts will have expertise in the NSTRI and have access to the original NSTRI tables.

Data Collection: It would be preferable for each of the Planning and Development Districts that are involved in data collection to have at least 2 GPS operators per collection vehicle. (At a minimum, one must be trained in GeoLink, and another person must drive the vehicle). These operators must be trained in the GeoLink software and hardware used for collection. The operators should also have a solid understanding of relational database concepts and some background in GIS would be helpful.

Database Maintenance: Maintaining the consolidated GIS database at the DOT will require a Lead GIS Analyst with significant experience using ArcInfo, ArcView and relational databases and database design. The lead analyst should have a solid understanding of dynamic segmentation in ArcInfo, linear referencing, and AML. Knowledge of Avenue and possibly VBA will be necessary if the tools described in this document are to be written in-house.

In addition to the Lead GIS Analyst, a GIS Technician will be necessary to run the scripts, create reports and prepare specialty maps from the GIS database. The GIS Technician should have a through knowledge of ArcView and a working knowledge of ArcInfo.

9 CONCLUSION AND RECOMMENDATIONS

The GPS collection of the roadway centerlines and updated attribute information was an ambitious undertaking that demonstrates what can be accomplished through the combined efforts of multiple governmental agencies. The resulting data set greatly improves the accuracy and completeness of non-state highway information and provides an excellent GIS transportation layer for the State of South Dakota. Once integrated with the necessary information from the NSTRI, the combined database will provide the information necessary to serve the needs of most of the users of the non-state trunk system.

The results of this project can serve as a starting point for developing a robust GIS that will provide much tighter integration between the state and non-state trunk systems. Although not directly addressed in this project, the GPS centerline network provides an accurate base for displaying and maintaining the state trunk system. ArcInfo is capable of managing multiple linear referencing systems and the state trunk data can be readily incorporated into the GIS based on the MRM linear referencing system currently used for the state trunk data.

By initiating this project South Dakota DOT, the Planning and Development Districts and other partners have demonstrated a commitment to managing their spatial data in the most accurate and efficient way possible.

Several implications emerge from this research effort. South Dakota DOT, like other State DOT's, is engaged in the collection and maintenance of large amounts of data. Some of this information is collected and available for internal analysis, while other data is collected primarily for local or federal reporting requirements. Because these databases have often been developed for different purposes and at different times, it is not uncommon that such information may not be easily retrievable, or easily combined with other information in the most useful ways. Such is the case here.

As we have seen however, GIS technology now allows for the integration of such disparate data in ways that was never possible before. But this also points out the importance of carefully constructed GIS base data, which makes such integration possible. South Dakota DOT has a unique opportunity to build upon their GPS collection efforts, and assemble a solid infrastructure for integrating much of the agency's data and information. The following recommendations are intended to support that ultimate goal and the goals of this research project.

1. **The NSTRI and GPS Inventory data sets should be combined into a single database using the methodology described in this document.**

   The results of this research and prototype development demonstrate the viability of combining these disparate databases using location referencing. SDDOT has invested a great deal of money and resources into the collection of updated Non-State Trunk data and should make the most of the data by creating a single, comprehensive Non-State Trunk database

2. **The combined database should be developed and maintained in a PC-based, GIS environment.**

   This methodology allows for a "one-way" transfer of data attributes from the NSTRI database maintained on the mainframe, to the GIS data sets housed in an MS Windows environment. We see little use in developing mechanisms to allow data to be written back to the mainframe from the PC environment. Because the data and information is ultimately spatial in nature, we feel that the GIS environment is better suited to handle the maintenance and update functions of the linear networks and associated attribute data. As a result, any reports generated from the mainframe need to be re-written in the MS Windows and GIS environment. Given the ease of use of several of the off-the-shelf report writing products (Crystal Reports, for example), this should not be a relatively difficult task.

3. **SDDOT should commit the necessary resources to the GIS and database integration.**

   At this time SDDOT should have at least two people that can dedicate a large percentage of their time to the development of the GIS and spatial databases. Any GIS or database development project requires trained resources to manage and perform the tasks required. The current environment at SDDOT, including this project, mandate the need for at least two people, as further development and projects are initiated more trained staff may be necessary.

4. **SDDOT should train in-house staff in the application of the methodology described in this document.**

   While the concept of integrating data based on location referencing is not difficult to understand, the implementation of the procedures to accomplish the integration is often complex. If the staff being trained has a solid understanding of GIS and ArcInfo, a few days training should be sufficient.

5. **SDDOT should consider outsourcing the development of the tool set necessary to automate the update of the combined data set.**

   This document describes several GIS tools that should be developed in order to update the combined database using the GPS collection procedures. Most of these tools are not overly complex, but do require GIS programming and linear data manipulation experience. Another option would be to train in-house staff to do the programming, however this approach would require much more time before the tools could be fully operational.

6. **The Planning and Development Districts should gather updated road information on a quarterly basis.**

   Quarterly reporting of road updates will allow the Planning and Development Districts better plan their GPS data collection activities. Actual GPS data collection and update to the combined database should occur at least annually.

7. **The tools required for updating the combined database should be developed in Visual Basic for Applications (VBA).**

   Based on the direction that ESRI is taking with its latest releases of ArcView and ArcInfo software, Visual Basic is the recommended development platform for GIS database update tools. ESRI training and support for AML and INFO programming is waning and object – oriented environments such as VBA are more robust and therefore preferred. SDDOT should also consider gaining in-house VBA programming capabilities for future GIS development activities.

8. **SDDOT should adopt the GPS road track as the common base map for the agency.**

   One spatial centerline file must be designated as the agency standard, and to which all future efforts are oriented. Currently there at least two centerline files, which exist in separate software / hardware platforms. Managed properly, a single centerline file could be shared among various software packages and applications.

9. **SDDOT should adopt a master linear referencing system.**

   Currently there are multiple linear referencing systems in use at South Dakota DOT. This is compounded by the use of at least two GIS software packages, each of which references linear data in a different manner. While this condition itself is not fatal, it does require that a master linear referencing schema be developed, which allows for the translation of linear events from one system to another. The start of that process has been developed with this project.

10. SDDOT should develop an agency-wide plan for integrating spatial transportation data.

The need for a common base network and a carefully developed master linear referencing schema also point out the need for a carefully devised plan for systematically integrating the various applications and data sets across the agency. Increasingly State DOTs require information which is pulled from across the agency to make more effective decisions relating to the allocation of scarce resources. If data exists and is maintained in separate applications which do not "speak" to each other, much of this information becomes difficult to pull together in a timely way for effective management support. Many agencies have come to realize they can no longer afford to continue to do business in this manner, and have begun the process of strategically implementing agency-wide data integration efforts. We would urge South Dakota DOT to begin to move in this direction.

Upon implementation of this research, South Dakota will have a fully updated Non-State Database that includes all of the required fields from both the NSTRI and the GPS inventory. Updates and maintenance of this database will be performed in a modern GIS and relational database environment and take advantage of the accuracy potential of GPS data collection. In the process, South Dakota DOT will have expanded the accuracy and detail of information available internally, as well as developed more effective ties to the local districts and agencies which are partners with South Dakota DOT in this effort.

APPENDIX A: LITERATURE REVIEW

The primary objective of this research effort is to develop an integration methodology for two disparate datasets, mainframe based NSTRI and the GPS database. Due to the lack of a common referencing key between the two datasets, to a large extent the research focus is on developing a Linear Referencing System (LRS) that is managed in the GIS and would serve as an integrator of these disparate datasets. There is a vast amount of literature that exists on this and related subjects that deal with LRS, GIS/LRS, Data Integration, Data Translation between multiple Linear Referencing Methods (LRM), and GPS. GIS/Trans has been a leading player in this arena, and has either been a prime author or a key contributor on several of the publications on this subject. This section of the report provides a concise listing of some of the relevant national publications for reference by SDDOT.

The two primary resources for information on LRS/GPS activities at various State DOT's are the Resource Guide on Implementation of Linear Referencing Systems in GIS, Bureau of Transportation Statistics (BTS), US DOT, and the Linear Referencing Practitioners Handbook, published by FHWA. The Resource Guide, published by BTS, includes several on-going research efforts and case studies from various states, including Utah DOT, Wisconsin DOT, Washington State DOT and Minnesota DOT. GIS/Trans developed the Linear Referencing Practitioners Handbook, under contract with FHWA. The handbook includes the case study of GPS and LRS data integration at Washington State DOT, among others. These integration methodologies are also described in detail in the Washington DOT GPS-LRS Project Summary Book.

Besides these resource guides, the National Cooperative Highway Research Project (NCHRP), effort titled Quality and Accuracy of Positional Data in Transportation, NCHRP 20-47 is aimed at evaluating the impacts of positional data accuracy on data transformation between GPS and linear referencing systems. Several other publications, including URISA Journal Volume 10 #1, The Case for a Unified Linear Reference System, and Integrating Governments for Transportation Purposes Using a Geospatial Framework, GIS-T Symposium, 1995 explore the requirements of a single LRS model for all areas of transportation information management. A Primer on GIS-T Databases provides a discussion on the development of GIS-T databases and the issues related to utilizing GPS for LRS base map maintenance. FGDC Ground Transportation Subcommittee Position and Recommendations on Linear Referencing describes the Federal Geographic Data Committee's views on LRS development and standards for inclusion in the National Spatial Data Infrastructure (NSDI).

Literature from several other projects GIS/Trans has completed is also relevant to this effort. The Texas Linear Measurement System (TLMS) developed by GIS/Trans for Texas DOT can support multiple LRMs and supports three types of data inputs, including absolute locations collected using GPS (Refer TLMS Design and Implementation Manual, Texas DOT). Integrating Disparate Transportation Data for the Puget Sound Regional Council (PSRC) makes a case for a common base road network as a requirement for integrating disparate transportation data. Based on our review of the State Trunk and Non-State Trunk databases this could be an issue at SDDOT.

SDDOT has also in the past undertaken specific projects that address the need and issues relating to a common location referencing system. A Location Referencing System to Support Data Integration, SDDOT, Report SD96-04, recommends the development of a standard location referencing system. Prior to this, an earlier SDDOT research effort, Historical Database Feasibility Study, Report SD90-09, identified the need for location specific data to be readily available for different department functions and historical trend analysis. Location of Highway Attributes by Global Positioning, Report SD92-05-F1, demonstrated the use of GPS technology in the context of SDDOT's Mileage Reference Markers (MRM) on State Highways.

Besides these references, the HPMS Field Manual and the Highway Performance Monitoring System Reassessment Report provides a good explanation of LRS calibration and data fields required for the annual submission by States.

APPENDIX B: METHODOLOGY SCRIPTS AND PROCEDURES

The following table contains a list of the AML scripts that were developed to integrate the NSTRI and GPS Inventory data set for the proof of concept. A narrative list of the steps required to implement the methodology is included after the table. The actual code for all AML scripts has been provided to SDDOT on a floppy disk

Name	Description	Called By	Lines of Code
proof.aml	proof of concept using hughes county as an example	command-line	15
nstrigps.aml	Top level aml for integrating nstri & gps	proof.aml	182
adjust.aml	Adjusts VRM DFBs based on adjustment polygons	proof.aml	76
recalibrate.aml	re-processes the data based on updated VRM dfb's	proof.aml	68
deliver.aml	Creates shapefiles and tables for an arcview project that shows the results of the processing	proof.aml	80
import_cover.aml	imports cover from e00 files, flips arcs to point away from baseline. Defines route-ids based on sddot_id, city/county code combinations	nstrigps.aml	236
import_nstri.aml	Creates an info table from the NSTRI ascii file dumped from mainframe	nstrigps.aml	312
make_vrm.aml	makes a vrm coverage for the specified city (or county)	nstrigps.aml	398
dfb_routes.aml	Creates route systems based on DFB for the GPS coverage.	nstrigps.aml	155
calibrate.aml	Calibrates the DFB route system using DFB measures on the VRM coverage.	nstrigps.aml recalibrate.aml	88
make_chn.aml	make the cross-reference table from DFB's & DMI's on the AAT	nstrigps.aml recalibrate.aml	168
dmi_routes.aml	creates routesystems and gps events based on dmi	nstrigps.aml	201
Make_gap.aml	Makes a table representing gaps in gps	nstrigps.aml recalibrate.aml	94
Dfb2dmi.aml	Determines DMI based on DFB	nstrigps.aml recalibrate.aml	683
Gaplines.aml	Makes nstri lines where there is no gps	nstrigps.aml recalibrate.aml	182
overlay.aml	Overlay events from GPS survey and NSTRI mainframe table	nstrigps.aml recalibrate.aml	190
doc.aml	creates tables for figures in the final report.	command-line	129
killall.aml	deletes all coverages and infofiles from the current workspace	command-line	15
killem.aml	Deletes all info tables matching a wildcard	command-line	13
route2polylinem.am	Convert a route-system coverage to a measured shapefile.	deliver.aml	105
sdb.aml	interactive browser for viewing nstrigps datasets	command-line	719
sdb_chart.aml	draws charts on the screen using nstrigps data	sdb.aml	230
		Total	2266

REQUIRED DATA

GPS Coverage
This is the coverage created by the GPS data collection effort. This coverage needs to be in state plane feet (any zone is fine). The items need to be in the same format found on the Hughes coverage. Export files for these coverages need to be loaded into the rawdatafiles directory.

NSTRI ASCII files
An ASCII file for the NSTRI data needed to be combined with GPS. The AMLs were written to work with the format of the files provided, which had some field widths that differed from the formats as they were documented – the files provided contained periods which probably shouldn't have been there. This script was written to expect these periods.

Baseline Coverages
For each NSTRI file there needs to be two baseline coverages, named ODD_XX and EVEN_XX where XX represents the city or county code. These coverages will both need to have an item called OFFSET on their AAT. The offset is used in calculating the distance from baseline. The ODD coverage is used to calculate DFBs for odd-numbered (north south) roads, while the EVEN coverage is used to calculate DFBs for even-numbered (east-west) roads. The line in the ODD coverage needs to be north of all lines in the coverage belonging to the particular city (or county) to which it applies. Likewise the line in the EVEN coverage needs to be west of all lines to which it applies. (This requirement could be eliminated by enhancing the AMLs to make them aware of which side of the baseline a road segment falls.)

Adjustment Polygon Coverages
This coverage must be named ADJ_XX where XX represents the county or city code. The PAT must contain two columns: ODD_EVEN and OFFSET. ODD_EVEN must contain either 'ODD' or 'EVEN' and OFFSET must contain a number. For each polygon in the coverage the adjust aml finds all the VRMs that are within it and belong to an odd (or even) numbered route, and then it applies the OFFSET to each of those VRMs' DFB value.

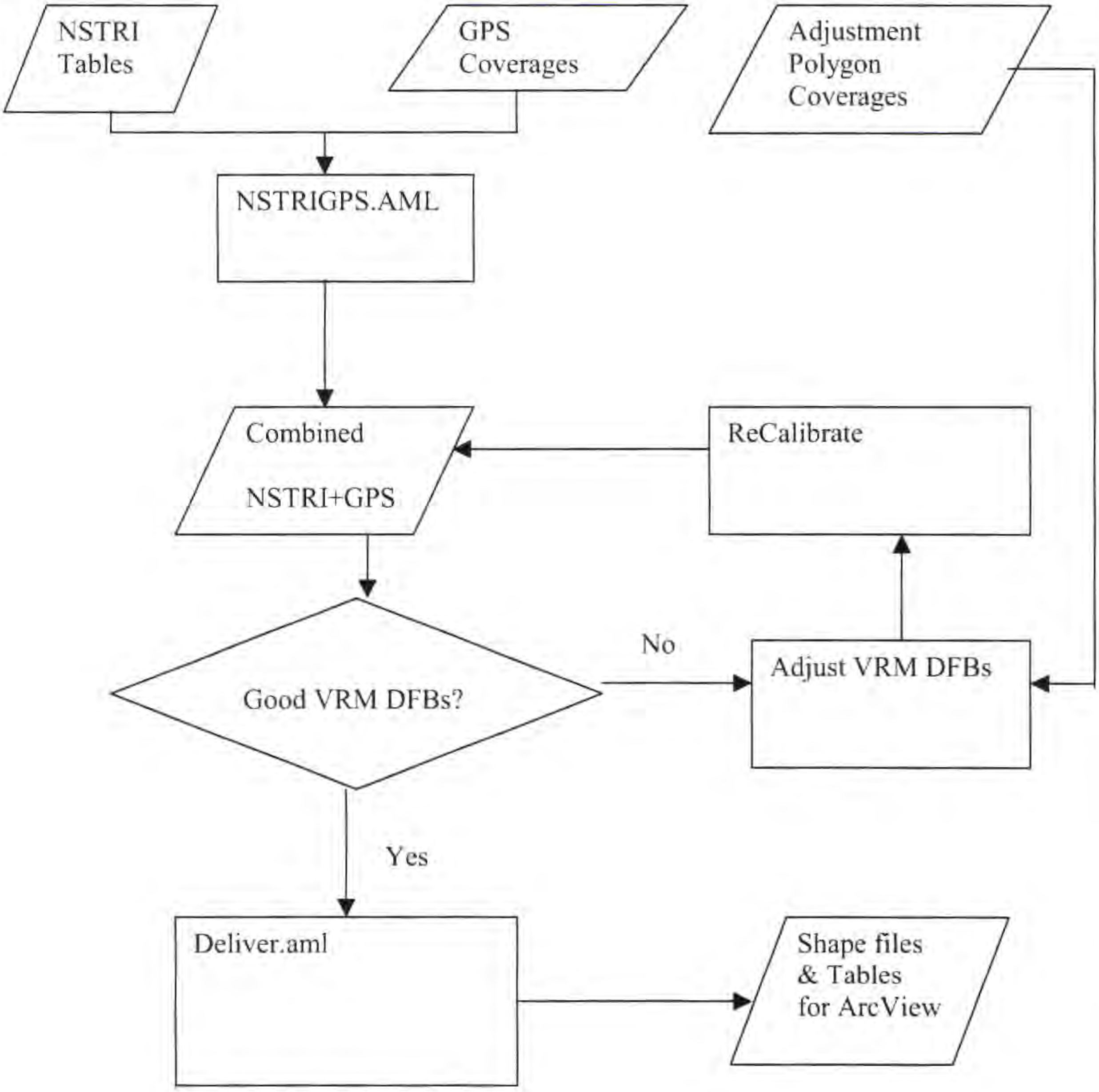
PROCESSING STEPS

NSTRIGPS

Run the NSTRIGPS AML for the county, specifying any city codes on the command line for which NSTRI data is available. The AML will create route systems based on distance from baseline (DFB) as well as DMI along with a cross-reference table that allows conversion between the two measurement systems. This "first pass" combines NSTRI and GPS based on the assumption that PLSS sections are square (1 mile by 1 mile).

Adjust VRM DFB's
The DFBs of the VRMs should then be examined. Any areas downstream from non-square sections will need to be adjusted, either manually or through the use of adjustment coverages. The adjustment coverage is basically a box drawn around all of the VRMs that need adjustment. These non-square sections are easily identified on existing paper maps. The user will need to run

the adjustment using the adjustment coverage as the input to the Adjust AML followed by a re-calibration.
The NSTRIGPS is run only once for a coverage while the recalibrate AML is run each time the VRM DFBs are changed.



APPENDIX C: NSTRI CODING MANUAL

I. Record Key

This group of data elements make up the record key for both county road and city street sections.

Data Class — 1 position

Code	Class
2	County Road
3	City Street

County/City Code — 2 positions

1) County - Enter the number of the county the road is located in.
2) City - Enter the special 2 character NSTRI city code.

Road/Street Number and Alpha — 4 positions

1) Road -- Enter the assigned county road number.
2) Street -- Enter the assigned city street number.

Enter the road or street number in the first three positions and the alpha character in the fourth position.

Section Number — 5 positions

Enter the miles and hundredths of miles that the beginning of the section of road or street is located from the county line. Code a 5-digit number with 2 decimal places. Leading zeroes need not be coded.

II. SECTION DESCRIPTION

This area of data elements applies to both county road and city street sections.

Item A01 - Section Length — 4 positions

Enter the actual length of the section of road or street in miles and hundredths of miles. Code a 4-digit number with 2 decimal places. Leading zeroes need not be coded.

Item A02 - Current ADT — 5 positions

Enter the annual daily traffic from the latest data count. Leading zeroes need not be coded.

Item A03 - ROW Width — 3 positions

Enter the right-of-way width in feet. When the width is over 999 feet, code '999'. Leading zeroes need not be coded.

Item A04 - Surface Type 1 position

Code	Type
1	"A" Primitive (Trail)
2	"B" Unimproved
3	"C" Graded & Drained Earth
4	"D" Brick
5	"E" Gravel or Crushed Rock
7	"F" Bit. Surf-treated (1" or less)
8	"G" Mixed Bit. (more than 1" thick)
9	"J" Concrete

Item A05 - Surface Width 2 position

The measurement of width should be based on the prevailing width of the road or street, curb to curb, including parking lanes, but excluding shoulders and median.

The curb to curb measurement, including shoulder width, should be used whenever a curb and gutter exists. If there is no curb, the width will be only the prevailing width, excluding shoulders.

Code the surface width to the nearest foot. When the width is over 99 feet, code '99'.

Item A06 - Shoulder Type 1 positio

Code	Type
0	No Shoulders
1	"C" Earth Shoulder which supports the growth of vegetation.
2	"E" Gravel or Crushed Stone.
3	"F" Blotter type surface on a gravel or crushed stone base.
4	"G" One inch or more of Type "F" hot mix asphalt on a gravel or stabilized soil base.

Item A07 - Shoulder Width 2 positions

Enter one-half the difference between the surface and roadway width to the nearest foot. Code '00' when there are no shoulders.

Item A08 - Rural/Urban Designation 1 positior

Code the rural-urban designations according to the following classifications:

Code	
1	Entirely rural.
2	Incorporated place, but not part of a FA urban area.

3	Unincorporated areas included as a part of a FA urban area.
4	Incorporated place included in FA urban areas.

Item A09 - Local System — 1 position

Code	
0	No Local Administration
3	County Secondary System
4	County System
6	Township System
7	City Street

Item A10 - STP System — 1 position

Code		For HPMS Samples
0	Non Federal-aid	
1	Federal-aid Secondary	6
4	Federal-aid Urban	9

Item A11 - STP Route Number — 4 positions

Code the federal-aid route assigned to the roadway. Right justify the number. Leading zeroes need not be coded. If the roadway has no federal-aid route number, code the entire field with zeroes.

Item A13 - State Administration — 1 position

Code	
0	No State Administration
1	State Trunk Designated (State Maintained)
2	State Trunk Designated (Not State Maintained)
3	Interstate not on Designated State Trunk System
4	State Institutional Roads
5	State Park Roads
6	Other State Roads

Item A14 - Federal Domain — 1 position

Code	
0	Not Federally Administrated
1	National Indian Reservation System
2	National Forest Highway System
3	Forest Development Road System
4	National Park System
5	Other Federal Roads

Item A15 - Reservation/Park Designation — 2 positions

Code	
00	No Reservation and Park
01	Black Hills National Forest
02	Custer National Forest
10	Crow Creek Indian Reservation
11	Cheyenne Indian Reservation
12	Lower Brule Indian Reservation
13	Pine Ridge Indian Reservation
14	Rosebud Indian Reservation
20	Fort Meade Veterans Administration Area
30	Wind Cave National Park
40	Badlands National Monument
41	Jewel Cave National Monument
42	Rushmore National Memorial
50	Custer State Park
60	Belle Fourche Game Refuge
61	La Creek Game Refuge
62	Lake Andes Game Refuge
63	Sand Lake Game Refuge
64	Waubay Game Refuge
65	Standing Rock Indian Reservation

Item A16 - Functional Classification — 2 positions

Code	Description
Rural	
01	Principal Arterial - Interstate
02	Principal Arterial - Other
06	Minor Arterial
07	Major Collector
08	Minor Collector
09	Local Road
Small Urban or Urbanized	
11	Principal Arterial - Interstate
12	Principal Arterial - Other Freeways or Expressways - Connecting Link
14	Principal Arterial - Other Connecting Link
16	Minor Arterial
17	Collector
19	Local Street

Item A17 - Year Built — 2 positions

Code the last 2 digits of the year the road was graded and built. Code '00' for no year.

Item A18 - Year Last Surfaced — 2 positions

Code the last 2 digits of the year the road was last surfaced. Code '00' for no year.

Item A20 - Year Inventoried — 2 positions

Enter the last two digits of the year the most recent inventory was made for this section of road or street.

Item A21 - Number of Lanes — 1 position

Enter the number of lanes in this section of county road or city street.

Item A22 - Speed Limit — 3 positions

Enter the legal speed limit for this section of county road. A maximum value of 55 can be coded.

Item A23 - Base Thickness — 3 positions

Enter the thickness of the granular base of the roadway in inches. A maximum value of 24 inches can be coded.

Item A24 - Surface Thickness — 3 positions

Enter the thickness of the surface layer of the roadway in inches to the nearest half inch. A maximum value of 24 inches can be coded.

Item A25 - Overlay Thickness — 3 positions

Enter the thickness of a subsequent asphalt concrete layer placed on top of the existing pavement surface in inches to the nearest half inch. A maximum value of 6 inches can be coded.

Item A26 - Open/Closed Code — 1 position

Code a value of 1 if the road is closed (non-existent). Leave blank for all other roads.

III. ROAD FEATURES

This area of data elements apply to sections of county roads only.

Item B01 - Terrain 1 position

Code

1	Level
2	Rolling
3	Hilly
4	Mountainous

Item B02 - Surface & Base Condition 1 position

Code

1	Excellent
2	Good
3	Fair
4	Poor

Item B04 - Drainage Adequacy 1 position

Code

1	Excellent
2	Good
3	Fair
4	Poor

Item B09 - Rideability 1 position

Code

1	Excellent
2	Good
3	Fair
4	Poor

Item B10 - Maintenance Costs 1 position

Code

0	Zero Costs
1	With Costs

IV. STREET FEATURES

This area of data elements apply to sections of city streets only.

Item C01 - Parking 1 position

Code	
1	Parallel parking left and parallel parking right.
2	Parallel parking left and diagonal parking right.
3	Parallel parking left and no parking right.
4	Diagonal parking left and diagonal parking right.
5	Diagonal parking left and parallel parking right.
6	Diagonal parking left and no parking right.
7	No parking left and no parking right.
8	No parking left and parallel parking right.
9	No parking left and diagonal parking right.

Item C02 - Surface Condition — 1 position

Code	Condition
1	Excellent
2	Good
3	Fair
4	Poor

Item C04 - Curb-Shoulder Designation — 1 position

Code	
1	Curb on the left and curb on the right.
2	Curb on the left and shoulder on the right.
3	Curb on the left and neither on the right.
4	Shoulder on the left and curb on the right.
5	Shoulder on the left and shoulder on the right.
6	Shoulder on the left and neither on the right.
7	Neither on the left and curb on the right.
8	Neither on the left and shoulder on the right.
9	Neither on the left and neither on the right.

Item C07 - City Population Group — 1 position

Using information from the latest U.S. Census, enter one of the following codes:

Code	
1	Under 2,500
2	2,500 thru 4,999
3	5,000 thru 9,999
4	10,000 thru 24,999
5	25,000 thru 49,999
6	50,000 thru 99,999
7	100,000 and over

Item C09 - County 2 positions

Enter the number of the county within which the section of city street is located.

NSTRI City Codes and City Names

Code	City
AB	Aberdeen
AD	Agar
AF	Akaska
AH	Albee
AJ	Alcester
AL	Alexandria
AN	Alpena
AP	Altamont
AR	Andover
AT	Ardmore
AV	Arlington
AX	Armour
AZ	Artas
BB	Artesian
BD	Ashton
BF	Astoria
BH	Aurora
BJ	Avon
BL	Badger
BN	Baltic
BP	Bancroft
BQ	Batesland
BR	Belle Fourche
BT	Belvidere
BV	Beresford
BX	Big Stone City
BZ	Bison
CB	Blunt
CD	Bonesteel
CF	Bowdle
CH	Box Elder
CJ	Bradley
CL	Brandon
CN	Brandt
CP	Brentford
CR	Bridgewater
CT	Bristol
CV	Britton
CX	Broadland
CZ	Brookings
DB	Bruce
DD	Bryant
DF	Buffalo
DH	Buffalo Gap
DI	Buffalo Ridge
DJ	Burke
DL	Bushnell
DN	Butler
DP	Camp Crook
DR	Canistota
DT	Canova
DV	Canton
DZ	Carthage
EB	Castlewood
ED	Cavour
EF	Centerville
EH	Central City
EJ	Chamberlain
EL	Chancellor
EN	Chelsea
EP	Claire City
ER	Claremont
ET	Clark
EV	Clear Lake
EX	Colman
EZ	Colome
FB	Colton
FD	Columbia
FF	Conde
FH	Corona
FJ	Corsica
FL	Cottonwood
FN	Cresbard
FO	Crooks
FP	Custer
FR	Dallas
FT	Dante
FV	Davis
FX	Deadwood
FZ	Dell Rapids
GB	Delmont
GD	DeSmet
GE	Dimock
GF	Doland
GH	Dolton
GJ	Draper
GL	Dupree
GN	Eagle Butte
GP	Eden
GR	Edgemont

GT	Egan
GV	Elk Point
GX	Elkton
GZ	Emery
HB	Erwin
HD	Esmond
HF	Estelline
HH	Ethan
HJ	Eureka
HL	Fairburn
HN	Fairfax
HP	Fairview
HR	Faith
HT	Farmer
HV	Faulkton
HX	Flandreau
HZ	Florence
IB	Fort Pierre
ID	Frankfort
IF	Frederick
IH	Freeman
IJ	Fruitdale
IL	Fulton
IN	Garden City
IP	Garretson
IR	Gary
IT	Gayville
IV	Geddes
IX	Gettysburg
IZ	Glenham
JB	Goodwin
JD	Gregory
JF	Grenville
JH	Groton
JJ	Harrisburg
JL	Harrold
JN	Hartford
JP	Hayti
JR	Hazel
JT	Hecla
JV	Henry
JX	Hermosa
JZ	Herreid
KB	Herrick
KD	Hetland
KF	Highmore
KH	Hill City
KJ	Hillview
KL	Hitchcock
KN	Hosmer
KP	Hot Springs
KR	Hoven
KT	Howard
KV	Hudson
KX	Humboldt
KZ	Hurley
LB	Huron
LD	Interior
LF	Ipswich
LH	Irene
LJ	Iroquois
LL	Isabel
LN	Java
LP	Jefferson
LR	Kadoka
LT	Kennebec
LU	Keystone
LV	Kimball
LX	Kranzburg
LZ	Labolt
MB	Lake Andes
MD	Lake City
MF	Lake Norden
MH	Lake Preston
MJ	Lane
ML	Langford
MN	Lead
MP	Lebanon
MR	Lemmon
MT	Lennox
MV	Leola
MX	Lesterville
MZ	Letcher
NB	Lily
ND	Long Lake
NF	Lowry
NH	Loyalton
NJ	McIntosh
NL	McLaughlin
NN	Madison
NP	Marion
NR	Martin
NT	Marvin
NV	Mellette
NX	Menno
NZ	Midland
OB	Milbank
OD	Miller
OF	Mission
OH	Mission Hill
OJ	Mitchell
OL	Mobridge

ON	Monroe
OP	Montrose
OR	Morristown
OT	Mound City
OV	Mount Vernon
OX	Murdo
OZ	Naples
PB	New Effington
PD	Newell
PF	New Underwood
PH	Nisland
PJ	N. Sioux City
PL	Northville
PN	Nunda
PP	Oacoma
PR	Oelrichs
PT	Oldham
PV	Olivet
PX	Onaka
PZ	Onida
QB	Orient
QD	Ortley
QF	Parker
QH	Parkston
QJ	Peever
QL	Philip
QN	Pierpont
QP	Pierre
QR	Pine Ridge
QT	Plankinton
QV	Platte
QX	Pollock
QY	Prairie Village
QZ	Presho
RB	Pringle
RD	Pukwana
RF	Quinn
RH	Ramona
RJ	Rapid City
RL	Ravinia
RN	Raymond
RP	Redfield
RR	Ree Heights
RT	Reliance
RV	Revillo
RX	Rockham
RZ	Roscoe
SB	Rosholt
SD	Roslyn
SF	Roswell
SH	St. Francis
SJ	St. Lawrence
SL	Salem
SN	Scotland
SP	Selby
SR	Seneca
ST	Sherman
SV	Sinai
SX	Sioux Falls
SZ	Sisseton
TB	South Shore
TD	Spearfish
TF	Spencer
TH	Springfield
TJ	Stickney
TL	Stockholm
TN	Strandburg
TP	Stratford
TR	Sturgis
TT	Summit
TV	Tabor
TX	Tea
TZ	Timber Lake
UB	Tolstoy
UD	Toronto
UF	Trent
UH	Tripp
UJ	Tulare
UL	Turton
UN	Twin Brooks
UP	Tyndall
UR	Utica
UT	Valley Springs
UV	Veblen
UX	Verdon
UZ	Vermillion
VB	Viborg
VD	Vienna
VF	Vilas
VH	Virgil
VJ	Volga
VL	Volin
VN	Wagner
VP	Wakonda
VR	Wall
VT	Wallace
VV	Ward
VW	Warner
VX	Wasta
VZ	Watertown
WB	Waubay
WD	Webster

WF	Wentworth
WH	Wessington
WJ	Wessington Sprgs.
WK	Westport
WL	Wetonka
WN	White
WP	White Lake
WR	White River
WT	White Rock
WV	Whitewood
WX	Willow Lake
WZ	Wilmot
XB	Winfred
XD	Winner
XF	Witten
XH	Wolsey
XJ	Wood
XL	Woonsocket
XN	Worthing
XP	Yale
XR	Yankton

County Codes and County Names

Code	County
01	Statewide
02	Aurora
03	Beadle
04	Bennett
05	Bon Homme
06	Brookings
07	Brown
08	Brule
09	Buffalo
10	Butte
11	Campbell
12	Charles Mix
13	Clark
14	Clay
15	Codington
16	Corson
17	Custer
18	Davison
19	Day
20	Deuel
21	Dewey
22	Douglas
23	Edmunds
24	Fall River
25	Faulk
26	Grant
27	Gregory
28	Haakon
29	Hamlin
30	Hand
31	Hanson
32	Harding
33	Hughes
34	Hutchinson
35	Hyde
36	Jackson
37	Jerauld
38	Jones
39	Kingsbury
40	Lake
41	Lawrence
42	Lincoln
43	Lyman
44	McCook
45	McPherson
46	Marshall
47	Meade
48	Mellette
49	Miner
50	Minnehaha
51	Moody
52	Pennington
53	Perkins
Code	County
54	Potter
55	Roberts
56	Sanborn
57	Shannon (unorg.)
58	Spink
59	Stanley
60	Sully
61	Todd (unorg.)
62	Tripp
63	Turner
64	Union
65	Walworth
68	Yankton
69	Ziebach

This page intentionally left blank.

APPENDIX D: GLOSSARY

AML – Arc Macro Language. A scripting language that allows an ArcInfo analyst to manipulate ArcInfo coverages and databases to automate repetitive or time-consuming activities.

Arc – an ArcInfo coverage feature class that models linear features as ordered vertices.

ArcInfo Section – an ArcInfo feature class where a section describes a portion of an arc that and assigns it a from-measure, to-measure, from-position and to-position. The measures may represent things such as milepost values. The positions represent a percentage along the arc where 0 is at the from end of the arc and 100.0 is at the to end of the arc.

Avenue – the object oriented programming language for customizing ArcView and manipulating ArcView shapefiles.

Baseline – an ArcInfo generated north-south or east-west line that represents the northern or western-most extent of a county. Baselines are used to automatically assign approximate Section_# values to VRMs.

Distance From Baseline (DFB) – the distance as the crow flies that a point is from a baseline.

Dynamic Segmentation – the process used by the GIS to display and manage data based on its distance along a linear feature as opposed to geographic (X,Y) coordinates.

Calibration Point Coverage - A coverage containing a point feature class where each point has a route and milepoint. It is used by ArcInfo to assign new measures to the ArcInfo sections.

Coverage – An ArcInfo file that stores geographic features and their attributes. A coverage contains one or more different feature classes.

Linear Referencing System (LRS) - A method of identifying a location on a network or part of a network by reference to the known positions of spatial objects. An LRS is usually based on mileage reference markers or similar known points.

Polyline – Any line in the GIS of 3 or more points.

Route System – a coverage feature class that contains routes as collections of ArcInfo sections. Route Systems are used to display linearly referenced data (begin measure and end measure) in the GIS.

Section_# - A location key used by the NSTRI. Secition_# refers to the number of Public Land Survey Sections south or east of a base line.

Section Length – the length in miles of a stretch of road as it is described in the NSTRI.

Survey Section – An area of land, typically one mile square, based on the United States Public Lands Survey System (PLSS -Township and Range).

SQL – Structured Query Language. A standardized set of instructions for querying and manipulating Relational Database Management Systems (RDBMS).

VBA – Visual Basic for Applications. A Microsoft programming environment for customizing applications and integrating them with existing data and systems.

Virtual Reference Marker (VRM) – a calibration point coverage created at locations having known measures, such as at a roadway intersections along section lines. The measures at VRMs created at roadway intersections were initialized to the distance from baseline (DFB).