Conversion of the Statewide Noise Barrier Inventory Into a Spatially Referenced Geodatabase

Prepared for

Florida Department of Transportation
Environmental Management Office

José Abreu, P.E.
Secretary

Submitted by

Florida Atlantic University
Catanese Center for Urban & Environmental Solutions (CUES)

James F. Murley
Director

Prepared in cooperation with the State of Florida Department of Transportation

1. Report No. BD546, RPWO#2 FAU #1020-411-43	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Conversion of Florida's Statewide Noise Barrier Inventory into a Spatially Referenced Geodatabase		5. Report Date April 29, 2005 6. Performing Organization Code
7. Author(s): Mariano Berrios, Peter McGilvray, Sara L. Forelle, Scott Burton, Christina Bryk, Karen Volarich, Michael Stamm, Eric Householder, Patrick Brett, and Clifford Bragdon, PhD		8. Performing Organization Report No.
9. Performing Organization Name and Address Catanese Center for Urban and Environmental Solutions (CUES) at Florida Atlantic University (FAU) 111 East Las Olas Boulevard, Suite 709 Fort Lauderdale, Florida 33301 (954) 762-5255		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee St. MS 30 Tallahassee, Florida 32399 (850) 414-4615		13. Type of Report and Period Covered **Draft Report No. 2** 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the USDOT and FHWA

16. Abstract

In January of 2004, the Environmental Management Office of the Florida Department of Transportation (FDOT) Central Office and the Catanese Center for Urban and Environmental Solutions (CUES) at Florida Atlantic University (FAU) embarked initiated conversion of the existing statewide noise barrier inventory spreadsheet into a user-friendly geodatabase. The statewide Noise Barrier Geodatabase (NBGD) is the first and only comprehensive geodatabase designed to serve as an inventory for existing and future barriers. The geodatabase structure provides FDOT with the ability to store and share information on the job number and general location of the barrier as well as physical dimensions of each barrier; costs of each barrier; percentage of the total construction project cost; contractor; existing background levels without the walls and predictions related to future noise levels with and without the wall; construction dates; and any general information of value to FDOT. A new barrier ID was developed for the existing barriers and the addition of new ones. The NBGD will be housed at Central Office and updates will be coordinated with the individual districts and the Turnpike office.

17. Key Word: Noise barrier, geodatabase, GIS, GPS, roadway structure, roadway information management		18. Distribution Statement No Restriction This report is available to the public through the FDOT and FHWA	
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. of Pages 87	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

THIS PAGE LEFT INTENTIONALLY BLANK.

CONVERSION OF THE STATEWIDE NOISE BARRIER INVENTORY INTO A SPATIALLY REFERENCED GEODATABASE

Project Team:

Mariano Berrios, FDOT, Project Manager

Peter McGilvray, FDOT, Project Co-Manager

Clifford Bragdon, PhD, Senior Advisor, Florida Atlantic University

Sara Lira Forelle, AICP, Research Associate, *CUES*, Project Manager

Scott Burton, GIS Faculty, Department of Urban and Regional Planning
GIS Administrator, Broward County Sheriff's Office

Christina Bryk, Technology Research Associate, *CUES*

Michael Stamm, Research Associate, *CUES*

Karen Volarich, GIS Faculty, Department of Urban and Regional Planning
Systems Analyst/Programmer

Eric Householder,
GIS Faculty, Department of Geography
Senior Geographer, South Florida Water Management District

ACKNOWLEDGEMENTS

The project research team would like to thank the many individuals who provided support and their valuable time during the development of the noise barrier geodatabase project, in particular:

Florida Department of Transportation
From the Environmental Management Office

Noise Specialists:

District 1—Mark Schultz
District 2—Donald J. Dankert
District 3—Natalie Kent
District 4—Gregor Senger
District 5—Robert B. Gleason
District 6—Marjorie Bixby
District 7—Robin Rhinesmith
Turnpike Enterprise—John Post

GIS Coordinators from:

District 1—Tom Land
District 4—Michelle Chalfant
District 6—Xavier Pagan
District 7—Tom Kelly

From Central Office

Bob Crim, State Environmental Programs Engineer
Rodney M. Floyd, Manager Highway Data Collection, QC, Statistics Office
Paul O'Rourke, Manager, GIS Support Section, Transportation Statistics Office

Table of Contents

LIST OF EXHIBITS

THIS PAGE LEFT INTENTIONALLY BLANK

I. INTRODUCTION

1.1 Overview

In January of 2004, the Environmental Management Office of the Florida Department of Transportation (FDOT) Central Office and the Catanese Center for Urban and Environmental Solutions (CUES) at Florida Atlantic University (FAU) embarked on an innovative project to convert the existing statewide noise barrier inventory spreadsheet into a user-friendly geodatabase. The process of developing the geodatabase required assessing the needs of the current users of this database as well as the existing GIS environment where the geodatabase would be housed. The project was developed in collaboration with FDOT's Noise Barrier Task Team members, other EMO staff, GIS coordinators, and maintenance managers from the Districts and Turnpike Enterprise.

This report is pursuant to the FDOT "Proposal to Convert Statewide Noise Barrier Inventory into a Spatially Referenced Geodatabase" study scope of services Contract No. BD546, RPWO#2. This report contains background information related to the geodatabase conversion, a needs assessment, methodologies, and a description of the geodatabase and its components. The geodatabase itself is in electronic format.

1.2 Problem Statement

Prior to the completion of this contract, FDOT maintained a complete inventory of Florida's noise abatement barriers in spreadsheets. The statewide inventory is a compilation of information about the noise barriers maintained by each individual FDOT District as well as the Turnpike Enterprise. A summary of this information is forwarded to the FHWA on a multi-year basis.

FDOT's Environmental Management Office (EMO) at Central Office identified the need for a fully integrated statewide noise barrier inventory in the form of a personal geodatabase with the possibility to extend into an enterprise GIS database. The GIS system would provide accurate information on barrier locations within the right-of-way and to other spatially referenced features or structures. The noise barrier geodabase could then interrelate with other FDOT inventories, such as the Roadway Characteristics Inventory (RCI). This new noise barrier inventory would be accessible to authorized users at the Central Office and Districts through a GIS query interface application, allowing the user to query, map, and report information to an enterprise noise barrier geodatabase (NBGD). It would also allow Central office to more readily produce reports for Federal Highway Administration (FHWA).

1.3 Scope of Work

The design of the noise barrier geodatabase for the FDOT included the following specific steps:

1. Researched existing geodatabases that incorporated both textual and semantic data.
2. Acquired and reviewed existing noise barrier database document.
3. Researched and identified associated problems with existing geodatabase design and development processes.
4. Researched and identified the scalability, data input processes, and current and future expansion of the geodatabase for the FDOT and associated users.
5. Identified current problems involving databases, data sharing, and compatibility with other FDOT databases.
6. Designed the noise barrier geodatabase structure based on the research found in the above steps:
    a. Identified the file types and software that is included in the geodatabase.
    b. Designed the naming structure (tags) for the textual and semantic data that is stored.
    c. Organized the files in an object-oriented manner for proper hierarchical structure.
    d. Specified retrieval methods of information stored in the geodatabase.
7. Populated new database structure with information from FDOT Districts and Turnpike Enterprise:
    a. Identified file types and software currently used.
    b. Identified availability of noise barrier data in GIS format.
    c. Identified availability of orthophotographs where GIS data for individual noise barriers is not readily available
    d. Established appropriate contacts to gain access to databases, GIS data, and orthophotographs as appropriate.
8. Windshield survey of built noise barriers prior to June 2004 around the State.
9. Acquired noise barrier GIS data, when available.
10. Digitized noise barriers where little or no GIS or GPS data existed
11. Groundtruthed a selection of digitized noise barriers, particularly those barriers not fully visible in the orthophotographs.
12. Integrated geodatabase at two scales: state and individual district level
13. Developed a query interface tool using ArcMap from Environmental Systems Research Institute, Inc. (ESRI).
14. Developed recommendations for use of Noise Barrier Inventory Geodatabase (NBGD) as well as future areas of expansion of the tool.

II. Research Methodology

2.1. Research Method Employed

A multitude of methods were applied to collect noise barrier information to be included in the geodatabase, these methods included: literature review pertaining to best practices, surveys and interviews, and a needs assessment. In addition, the project team relied on the expert advice of the team members involved, particularly in the areas of GIS, GPS, acoustics, transportation planning processes, and computer systems.

2.2 Criteria Establishment

Prior to the design and development of the noise barrier geodatabase, the research team reviewed the current and future practices of the FDOT network architecture, GIS applications, interoperability capabilities and human expertise in database systems in order to provide a noise barrier geodatabase that could be integrated into the FDOT existing system. The following questions were asked in order to establish the appropriate criteria for the new system:

1. What is the current network architecture of the GIS system, distributed or centralized?
2. What server and client hardware and software are currently being used for GIS? (i.e. ESRI, Oracle, SQL, etc.)
3. What expertise currently exists in the areas of GIS, GPS, and GIS data models?
4. Does the noise barrier geodatabase (NBGD) need to be integrated with any existing GIS geodatabases maintained by the FDOT?
5. Who will need access to the NBGD? (i.e. internal departments, external state agencies, contractors)
6. Can the research team acquire information about existing noise barriers from the FDOT?
7. What are the future plans in updating and standardizing noise barrier implementations based on the completion of the NBGD?
8. Once created, could this geodatabase become the platform for advanced 3D/4D virtual simulation to assist FDOT in future environmental, planning, transportation, and related design initiatives?

The responses to the above questions determined the following criteria:

1. The FDOT maintains a distributed (n-tier) GIS network environment with the following servers in place: file server, ArcIMS server, database server, web server, and application server.
2. The FDOT utilizes a Windows environment on the client workstations, while a combination of UNIX and Microsoft servers are distributed throughout the network.
3. ESRI Suite of GIS software is licensed and used in all GIS applications and databases throughout the FDOT.

4. The noise barrier geodatabase must be interoperable with existing GIS geodatabases maintained by FDOT.
5. The geodatabase must allow both internal and external access without the lag of network speed or the inability to visualize the detail. The FDOT has not decided on specific organizations or vendors that would need access to the system.
6. Below are listed the general barrier characteristics to be stored in the geodatabase and are used in preparing the statewide reports for FHWA. Additional data may be identified in the course of the study.

    a. State Job Number (data type: number)
    b. WPI Number (data type: number)
    c. Local Name (data type: text)
    d. Contractor (data type: text)
    e. Construction Begin (data type: date)
    f. Construction End (data type: date)
    g. Barrier Type (data type: text)
    h. Barrier Material (data type: text)
    i. Barrier Length (data type: number in meters and feet)
    j. Barrier Area (data type: number in meters and feet)
    k. Barrier Height (data type: number in meters and feet)
    l. Barrier Cost (data type: number)
    m. Existing Noise Level (data type: number in dBA)
    n. Predicted Noise Level (data type: number in dBA)
    o. Average Barrier Insertion Loss Predicted (data type: number in dBA)
    p. Average barrier Insertion Loss Measured (data type: number in dBA)
    q. Comments (data type: memo)
    r. District of Barrier Location (data type: number)
    s. County, Route Barrier Location (data type: text)

III. BACKGROUND

3.1 Noise Barrier Standards and Procedures

Most of the literature available and research that has been conducted in the past fifteen years is about barrier design and the models that are used to estimate where noise mitigation measures and the barrier dimensions that will be needed. The project team found no articles on the development of a geodatabase at a statewide level that could be used to store information about the location of specific features associated with roadway construction. Some state departments maintain roadway databases in GIS format, but not of other feature classes associated with the roadways. This will probably change over the next few years as GIS use becomes more prevalent, particularly in association with the development and implementation of intelligent transportation systems. The background that follows includes information about federal and state practices and standards that govern the implementation of noise mitigation, particularly in instances where federal funds are involved. This is followed by a description of geographical information systems (GIS) and its applications as it relates to the scope of this project.

Federal and State Practices and Standards for Noise Barriers

The requirement to provide noise abatement measures in highway construction is established in the National Environmental Policy Act of 1969 (NEPA) that provides direction to Federal government agencies to “use all practical means and measures to promote the general welfare and foster a healthy environment” (NEPA, 1995). This includes responsibility for evaluating and mitigating adverse environmental effects including highway traffic noise.

The requirements were further articulated in the U.S. Department of Transportation’s Federal Highway Administration (FHWA) noise regulations that were first mandated in the Federal-Aid Highway Act of 1970 (Pub. L. 91-605, 84 Stat. 1713) and are applicable to projects in which a State department of transportation requests Federal funding for participation in the project. In 1976, FHWA issued the first regulations on noise abatement, implementing a provision of the Federal-Aid Highway Act of 1970, which called for compatibility of noise standards with adjacent land uses.

The standards to mitigate highway traffic noise were established in the United States Code of Federal Regulations Part 772 (23 CFR 772), "Procedures for Abatement of Highway Traffic Noise and Construction Noise." This regulation outlines the necessary steps that State Departments of Transportations (SDOTs) must adhere to when Federal highway funds are used, including procedures for noise studies and abatement measures, as well as noise standards.

There are two types of mitigation projects: new highway construction or Type I; retrofit measures on existing highways or Type II. The more common type I projects are also associated with significant changes in the roadway design, particularly if lanes are being added. While, Type II noise abatement projects are less common, there is increasing public pressure to provide more protection along existing highways, particularly where traffic has increased significantly.

FHWA’s Department of Planning, Environment, and Realty (HEP) receives State Department of Transportation noise barrier data. This data can be downloaded from their website (http://www.fhwa.dot.gov/environment/AB_NOISE.htm). The website offers a comprehensive inventory of technical documents, data, procedures, and findings. States are required to implement these standards.

Florida Standards and Procedures

In the State of Florida, noise abatement measures and procedures are covered in the Project Development and Environment (PD&E) Manual. The manual provides the criteria that will be used to determine whether “the construction of noise abatement measures is reasonable and feasible,” (F.S. 335.17 requires 23 CFR 772). State policy establishes that:

> *"Noise abatement will only be considered for projects on new location or for capacity expansion projects. Exceptions to this policy may be allowed on a project specific basis if approved by the Secretary and the Federal Highway Administration, for federally funded projects."(FDOT)*

Organizational Structure of Noise Abatement and GIS Functions

Each of the state's eight District offices manages their own noise abatement programs. A statewide representative coordinates between the district offices and manages the statewide noise abatement inventory, which is updated and forwarded to FHWA every two years. The duties of the district noise specialists include maintaining records of noise barriers throughout the planning and construction process, conducting and/or overseeing noise related environmental reviews during the Project Development and Environment process (PD&E), making recommendations regarding the need for and location of noise barriers based on the reviews, following up on whether the barriers are provided, participating in public hearings regarding the need for and design of noise barriers, and responding to citizen complaints regarding traffic noise. District noise specialists meet twice a year with Central Office as a task team to discuss and share information on a variety of issues including new rules or legislations, standards, materials, procedures, and processes, among other matters related to noise abatement.

Through the Project Development and Environment process, the District Environmental Management Offices (EMOs) are responsible for conducting studies that may conclude in recommending that noise abatement measures to protect the adjacent land uses per federal/state abatement criteria. Each District is also responsible for the construction of noise barriers within their boundaries.

FDOT Districts also act somewhat independently when it comes to defining the internal organizational structure of their Divisions (i.e., Planning, Environmental Management, Engineering, Construction, etc). This is generally a function of the needs and budget, as well as District size. As a result, the Districts manage their GIS with different organizational structures as well. In most Districts, GIS is an internal function of a Division, however, some Districts are currently moving towards a more centralized model.

Noise Abatement Structures in Florida

FHWA records indicate that by 2001, 2,950 kilometers (1,831 miles) of noise barriers were constructed or erected between 44 US state departments of transportation and the Commonwealth of Puerto Rico. Most of these barriers are made from concrete or masonry block and range from 9-17 feet in height with the average cost of $16-21 per square foot. Only 340 kilometers (211 miles) were constructed between 1988 and 2001. Federal Highway Administration's 2001 statistics for the State of Florida indicate that 4,337,000 sq.ft. of noise barriers were constructed or erected for the total cost of $88.7 million (2001 dollars).

3.2 About the Use of Geographic Information Systems (GIS)

A Geographic Information System (GIS) is a computer-based system that allows users to perform actions with various types of data using a spatial coordinate system that relates geo-referenced data to the Earth's surface. GIS applications can covert data between different projections and coordinate systems, thus providing relatively accurate location for spatial objects. GIS can also be used to relate other non-spatial data to the spatially located objects. It describes objects from the real world in terms of:

1) location, for example geographic positions;
2) attributes that may be related to a feature but are unrelated to position;
3) spatial relationships; and
4) temporal information, for example the evolution of both spatial and nonspatial data over time.

The structure of the spatial database is one of the most important aspects of GIS, because it will determine how easy it is for the user to retrieve and analyze information. There are three main components of a GIS system: 1) data input; 2) data handling; and 3) data output.

Most GIS data used by FDOT is stored in shapefile format. In many instances, different departments copy this single shapefile and then select out specific items from the shapefile for analysis. This is an acceptable use of GIS, although having the same shapefile stored in various locations is not necessary. Standardization problems occur when a particular shapefile is stored at various locations, since variations are being created through use, analysis, and updates by different FDOT Districts or departments within the districts. Often, it is almost impossible to recombine updates when they are returned to a centralized location, because of significant modifications to the copied shapefile. This is where GIS integration though an Enterprise Geodatabase prevents future problems.

An Enterprise Geodatabase is managed and maintained in a central location that can be shared by multiple users. In an enterprise geodatabase, the modifications, updates, and adjustments done to shapefiles (and other data) are instantly shared throughout the entire system. Duplication of many of the data themes does not occur. Additional efforts do not become necessary when reconciling the various datasets at higher levels within the organization. The aggregation becomes less difficult when the schemas for the various workgroup datasets are consistent.

An important first step in resolving the difficulties with aggregating data for agency-wide data sharing purposes is to define data standards to which all data managers are required to adhere. The standardization process, however, can be time-consuming and institutionally difficult because of differences in chain of commands, organization structuring and geographies. Depending on functionality the prospect for data standardization may be more or less challenging (Peters, 2002). Therefore, it is important to set up data standards and protocols in anticipation of use.

Use of Global Positioning System (GPS)

The Global Positioning System (GPS) is a space based navigation system maintained and operated by the Department of Defense. It consists of a nominal constellation of 24 satellites in high altitude orbits. Its primary mission is to provide passive, real-time, 3-D positioning, navigation, and velocity data for land, air and sea based applications (both military and civilian). GPS satellites orbit the earth every 12 hours at an altitude of 14,000 miles from the earth's centre. Each satellite is equipped with four atomic clocks, which keep the time to an extremely high degree of accuracy. Each satellite broadcasts precisely timed radio signals through the atmosphere and onto the earth's surface at the speed of light. The signals from each satellite arrive at any particular point on or above the earth's surface at slightly different times. This timing is proportional to the distance between the satellite and that particular point.

A ground based receiver contains a sensitive antenna and a timetable (or almanac) for the satellites. It measures the time difference between the arrivals of the signals and compares it with the timetable. With the application of trigonometry, the longitude, latitude, and altitude of the receiver can be calculated. Three satellites are needed to calculate the longitude and latitude, and a fourth satellite is needed to calculate the altitude. Additional satellites simply increase the accuracy.

The quest for greater and greater accuracy has created an assortment of variations on basic GPS technology. One technique, called "Differential GPS," involves the use of two ground-based receivers. One monitors variations in the GPS signal and communicates those variations to the other receiver. The second receiver can then correct its calculations for better accuracy. Another technique called "Carrier-phase GPS" takes advantage of the GPS signal's carrier signal to improve accuracy. The carrier frequency is much higher than the GPS signal which means it can be used for more precise timing measurements.

GPS is used freely by the military and civilian public to support land, sea, and airborne navigation, surveying, GIS Mapping, geophysical exploration, geodesy, conservation research, habitat modeling, vehicle location systems, farming, transportation systems, archaeology, fishing and a wide variety of other additional applications. Mobile GIS incorporates GPS data in order to create real time GIS layers in the field.

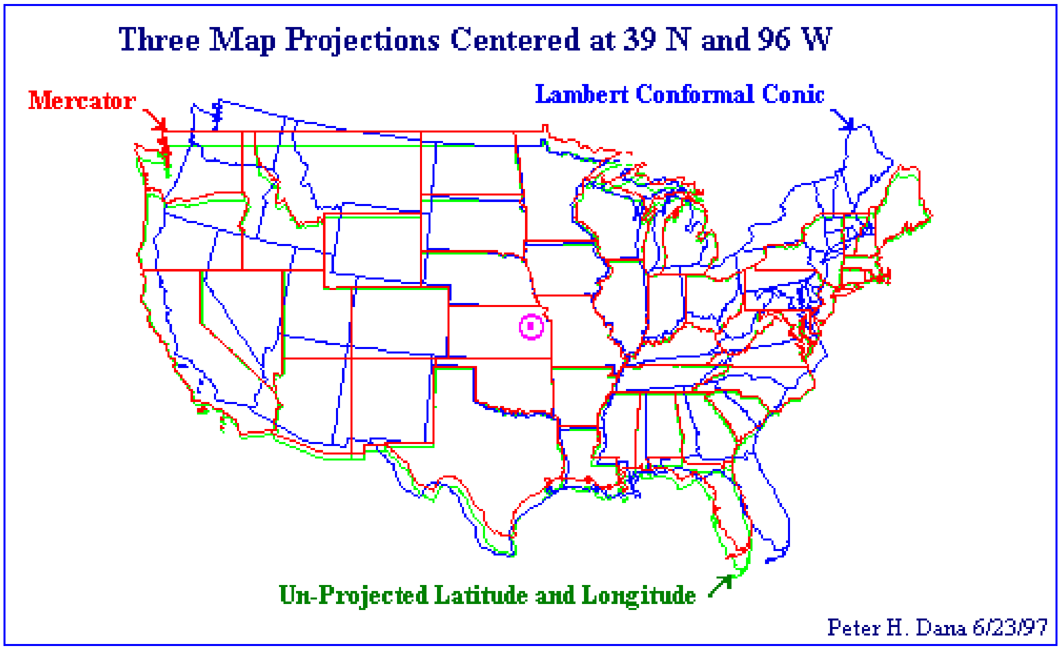
Mobile GIS is a task oriented mobile mapping and geographic information system (GIS) technology which provides database access, mapping, GIS, and global positioning system (GPS) integration to users out in the field via handheld and mobile devices. Mobile GIS software works in conjunction with all professional and resource-grade GPS systems to capture real-time GPS data on a field computer. Mobile GIS integrates:

- GIS Software
- GIS Data
- Non-GIS Data
- Global Positioning System
- Mobile Hardware (Laptop, PDA, or Tablet PC)

Differences in Map Projections

Map projections are attempts to portray the surface of the earth or a portion of the earth on a flat surface. Some distortions of shape, distance, direction, scale, and area always result from this process. Some projections minimize distortions in some of these properties at the expense of maximizing errors in others. Some projections are attempts to only moderately distort all of these properties.

Exhibit 3.2.1 Sample of the differences between map projections.



Unfortunately, different levels of governments require map projections suitable for their organizational needs. The final projection choice is largely dependent upon the map projection/coordinate system utilized by the public agency in question. For example, in South Florida, the map projection is Universe Transverse Mercator, State Plane Coordinate System, NAD83, Florida Eastern Zone (FIPS901). This projection minimizes distortion for areas that are elongated North-and-South (Miami-Dade, Broward, Palm Beach, Martin, etc). However, if one was to analyze spatial relationships for Florida as a whole, than perhaps Albers Projection would be more suitable. In the end, there are several other factors that will influence choices. The Exhibit 3.2.1 above shows what could happen when overlaying maps using different map projections.

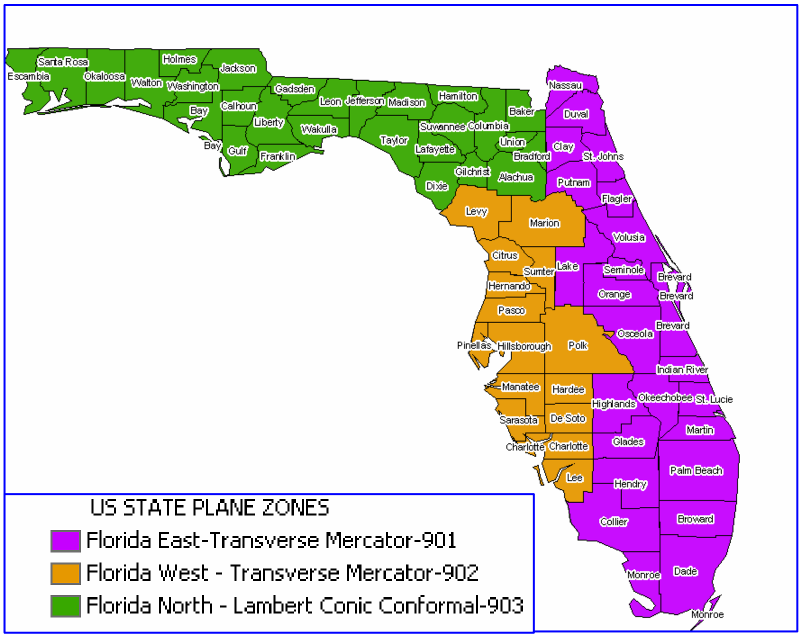
Coordinate Systems

In the Environmental Systems Research Institute, Inc. (ESRI) GIS data model, there are two types of coordinate systems: geographic and projected. The geographic coordinate system is a latitude and longitude coordinate system. It is closely identified with and related to the concept of a geodetic datum which deals with the size and shape of the earth. Whenever data is given in latitude and longitude, a geographic coordinate system is the type of coordinate system which applies.

The projected coordinate system represents the projection of a geographic coordinate system onto a plane. State Plane coordinate systems in the US, and coordinate systems based on Universal Transverse Mercator (UTM) projections are examples of projected coordinate systems.

In terms of projected coordinate systems in Florida, there are three State Plane Coordinate System zones. Florida North zone has an east-west orientation and is based upon *Lambert Conformal Conic* projection. Florida counties in the Eastern and Western zones have a north-south orientation to them and are assigned to the *Transverse Mercator* projection.

Exhibit 3.2.2 US State Plane Zones.



Global position systems (GPS) use coordinate systems. GPS devices receive radio wave transmissions from 24 satellites to triangulate the device's location. Differential global positioning systems (DGPS) improve the accuracy and integrity of GPS-derived positions. Most GPS devices allow the user to display coordinates in degrees/minutes/seconds, degree/decimal/minutes, or Universal Transverse Mercator (UTM). UTM coordinates are a military system used to display location with reasonable accuracy and is the easiest of the three GPS coordinate systems to use.

Distortion

Distortions are inaccuracies caused by the projection utilized and preciseness of the employed coordinate system. All maps distort the real world, dependent on scale and mapmaker intent. GPS devices also incur distortion, since they rely on a coordinate system. All coordinate systems distort location in varying amounts. The amount (or degree) of distortion should remain insignificant for the particular use of a map. For example, if a particular GPS device is accurate to +/- 3 meters, using this device to plot the legal boundaries of a square 1/8th acre parcel would be unwise. However, this same device would provide reasonable accuracy when identifying the boundaries of a FEMA 100 year flood plain.

Mapping Objects

Several techniques can be used to map the position of objects relative to other features on the highway network. Some methods are linear, meaning that they have only one dimension (1D). These methods include milepost referencing, distance measuring instruments (DMIs), and some types of surveying. Aerial and satellite imagery and the geographical positioning systems (GPS) are the methods used when 2D and 3D are desired or needed. For example, real-time emergency vehicle routing, automatic vehicle location (AVL), and monitoring construction equipment requires more than one dimension. Difficulties arise when databases that are in 2D and 3D format need to be linked with 1D linear reference systems, since the scale or level of accuracy may be different and cause errors (Fepke, Kovak, et al, 2003).

Digitizing orthophotographs is one of the types of methods often used to create GIS maps. An orthophotograph is *"a rasterized (scanned) aerial photo, which is fully rectified to remove all of the distortions that occur in the original image: the pitch and roll of the aircraft, the radial distortion from the camera lens, and the image displacement from the topography. The removal of these distortions results in the imagery becoming a true scale representation of the ground."* (Fepke, Kovak, et al, 2003) Orthophotographs provide a flat plane that can be used for 2D digitizing on a computer screen. Specific point, linear, or polygon features can be identified and digitized from the orthophotograph and stored in a geodatabase with the help of GIS software. However, the scale or resolution of the orthophotograph will affect the ability to define the accuracy of the digital product. It is important to be able to clearly identify the features that are going to be digitized. Digital orthophotographs can be obtained at 1.5 feet with a 0.5-foot pixel ground resolution which is ideal for features with similar dimensions. Otherwise they might not be seen.

Ground forms of mapping methods include vehicle-based methods and ground surveying methods. Some vehicle based methods are (Fepke, Kovak, et al, 2003):

- Distance Measuring Instruments (DMIs): DMIs are installed in a vehicle and combined with a data logger. It needs to be initialized at a reference point and records accurate distances as the vehicle moves.
- Mobile mapping: this requires the use of a mobile mapping van equipped with a survey-grade, kinematic GPS receiver, an inertial navigation system (INS) unit; and up to five digital cameras paired to measure the spatial location of roadway features.
- Video-logging: requires multiple cameras to be configured to provide a 130-degree panoramic view, similar to that of the driver, or a right-side only for environmental applications. Images are stored on video tapes and the distance can be measured by DMI's or real-time differential GPS.

Ground surveying techniques include:

- Wheel
- GPS
- Kinematic GPS
- Differential GPS
- Laser ranging
- Total stations (Theodolites)
- Map digitizing

Geodatabase Challenges

The challenge in developing a statewide geographic database for noise wall barriers is to utilize a data structure that is an industry-standard which is scalable for different types of uses and is based upon an object-oriented data model. Scalability and a unified, object-oriented data structure promote interoperability allowing users to access and integrate information as it relates to noise wall barriers.

Using GIS to Promote Interoperability

Over the last few years much work has been conducted in regards to the research topic "Fully Interoperable" GIS. Vckovski (1998) for example gives an overview of the issues regarding data integration and geographic information systems.

Numerous contributions within the proceedings of the 2nd International Conference on Interoperating Geographic Information Systems (Vckovski, Brassel, & Schek, 1999) are related to this topic (e. g. Wiederhold, 1992; Landgraf, 1999). GIS's share the need to store and process large amounts of diverse data, which is often geographically distributed. Most GIS's use specific data models and databases for this purpose. This implies that making new data available to the system requires the data to be transferred into the system's specific data format. This is a process which is very time consuming and tedious.

The Open GIS Consortium (OGC) is an international industry consortium whose objective is to market enablement through interoperability between commercial geoprocessing software products. Open GIS Consortium supplements the work of recognized standards organizations (such as the International Standard Organization, World-Wide Web consortium, Wireless Application Protocol, etc.) with implementation detail guidelines that promote interoperability through modularity, object-oriented GIS, and unified modeling languages (Geographic Markup Language, Unified Modeling Language). The OGC seeks to address the disparate data formats by creating open, common interfaces between software components, and letting those systems use any data format internally.

Modularity is a process by which a complex product or process can be built from smaller subsystems (or modules) that can be designed independently yet function together as a whole. Through the widespread adoption of modular designs, the computer industry has dramatically increased its rate of innovation, and the pace at which the industry has changed (Baldwin and Clark, 1997). For the various components to work together it is essential that each of the components follow the basic design rules and parameters. Modularity is only beneficial if the module is precise, unambiguous and complete.
In the United States, the Information Management Technology Reform Act of 1996 revised national policy on information technology procurements and directed federal agencies to employ modular contracting approaches where possible. Modular acquisition should foster better, more timely procurements consistent with rapidly evolving user needs and commercial product cycles. However, this does mean that modular acquisition must be framed around a modular architecture for the organization. Architectures based on interoperable modules with open interfaces are the way to achieve a modular acquisition process across organizations that strive towards interoperability.

Modular software principles ensure data flow between the different computing components in the architecture that serves the human/institutional components, and these principles make it possible for components to share network-resident software services and computing resources. Standards-based interfaces are the glue that holds modular information architecture together. Modular components, supported by standard interfaces, interoperate to provide effective and flexible communication of information.

The International Standard Organization (ISO) has adopted Unified Modeling Language (UML) as the common object-oriented language for describing implementation-neutral models (Gronmo, R., Berre, A., Soldheim, I., Hoff, H. and Lantz, K. 2002). The rules and guidelines for developing implementation-neutral UML models can be found in the ISO19103 standard. The ISO 19118 code contains rules for how to map from the implementation-neutral UML models to a corresponding representation of data according to these models in a range of Extended Markup Language (XML) formats. The goal of the ISO 19118 standard is to define implementation specific profiles of the implementation-neutral models, ensuring that there is well-defined mapping between these to ensure interoperability between different implementation platforms.

To meet industry standards, in 1997, Environmental Systems Research Institute (ESRI) reengineered all of its GIS software as a series of Component Object Model (COM) objects in an effort to meet the need for promoting interoperability. The purpose was to develop a GIS product that adheres to the principles of interoperability including a modular or scalable software product which is based upon COM objects utilizing UML, XML, GML, VML, and other COM supported languages.

In April 2001 ESRI began shipping ArcGIS 8.1, a family of Graphical User Interface (GUI) friendly software products that form a complete GIS built on industry standards that provide exceptional, yet easy-to-use capabilities right out of the box. ArcGIS is a scalable system for geographic data creation, management, integration, analysis, and dissemination for every organization, from an individual to a globally distributed network of people. The data model used to capture and model geographic features also changed from ArcInfo coverages (georelational database containing topology) and ArcView shapefiles (non-topological data structure) to an object-oriented data model known as a geodatabase.

Another benefit of the ArcGIS object model was the reduced need to understand commands to run the software. ArcGIS is a simple GUI interface that makes it easy for users to perform complex Geoprocessing and data management functions with the simple click of a mouse button and the following of a "wizard" for step-by-step instructions. The key reason for developing these GUI tools was for the ease of editing, displaying, and managing data within the geodatabase.

Furthermore, this object model, COM based, enables programmers to customize the already simplified user interface even further by combining a series of mouse-clicks into a Macro that can be run to perform multiple functions. By writing a few dozen lines of object-oriented code, in Visual Basic for example, any GIS user can perform complex query and data mining functions within a geodatabase. This custom solution can also enable the integration of other data formats into a single, interoperable platform by writing code that integrates the two (or more) formats. This can prove to be an extremely cost-effective method for integrating multiple data formats and editing within the geodatabase model.

Many organizations using GIS need to integrate data from multiple sources, organizations, and formats. GIS software requires technology to support conversion from or direct access to multiple geographic data sets in multiple formats. ESRI's reengineered scalable GIS and its object-oriented data structure has played an active role in building this interoperable technology and actively participated in open standards development to ensure that GIS data created by ESRI products can be openly accessed and supports open standards at all levels.

Mann and Daugherty (2003) describes the high level approach to integrating Bentley System's Architecture, Engineering, and Construction (AEC) applications in the fields of Civil Engineering and Transportation and the GIS information created and managed by the ESRI solution. Specifically, how the two architectures, ArcGIS and Bentley create, manage, and publish environments will interoperate within the context of AEC activities within the fields of Architecture, Civil Engineering, Construction, and Transportation.

Geodatabase: Object-Oriented Data Model

In the geodatabase model, entities are presented as objects with properties, behavior, and relationships. Support for a variety of different geographic object types is built into this system. These object types include simple objects, geographic features (objects with location), network features (objects with geometric integration with other features), and annotation features.

MacDonald (2000) describes ESRI's geodatabase as a data structure which supports a model of topologically integrated feature classes. The ArcInfo geodatabase model is implemented on standard relational databases with the ArcSDE application server. ArcSDE defines an open interface to database systems for ESRI users while offering operability with other platforms. Clark (2004) describes the ESRI ArcInfo geodatabase model that enhances interoperability by managing geographic information on a variety of different database platforms including Oracle, SQL Server, DB2, and others

The model allows the ability to define relationships between objects, together with rules for maintaining the referential integrity between objects (MacDonald, 2000). Zeiller (1999) points out that one of the advantages of using a geodatabase is that many feature classes can be associated with a topological role. This is a limitation with ESRI's coverage data format, where only one feature class is associated with a topological role, while there is no topological role for an ESRI shapefile. Another advantage of an ESRI geodatabase is that line topology is implemented through a geometric network, coverages and shapefiles are not.

The Geodatabase Transportation Model

ESRI's geodatabase model is suitable for transportation-related activities since it is based upon an object-oriented network data representation which is also scalable (Personal geodatabase v. Enterprise geodatabase). The use of relational data models for network data representation and development of spatial databases that take advantage of object-oriented approaches represent important areas for GIS research in Transportation.

Xiong (2000) discusses how the Intelligent Transportation System (ITS) relies heavily on spatial data for purposes ranging from car navigation, traveler information to flow estimations, traffic management and controls. GIS has proven to be a powerful tool for spatial data manipulation, analysis and presentation. Integrating GIS into ITS presents a major opportunity for the GIS industry and professionals and will provide an important means to handle the ever growing spatial databases for ITS. Xiong (2000) presents a perspective on some of the key issues related to GIS and ITS integration, which include spatial data management with conventional database management systems (DBMS), a standardized spatial referencing system, and real-time data exchange and communication. In particular, Xiong discusses GPS as a means for gathering and maintaining data in the spatial database. Today GPS is commonly used in transportation and provides an important alternative to current map data collection methods. Additionally, imaging technology, with recent improvement in resolution (1 meter), can potentially be used to develop and update map databases at a much lower cost and at a much higher frequency. Future efforts in database development need to incorporate these technologies as to reduce development costs and improve spatial accuracy.

Realizing the potential of the geodatabase model for transportation, ESRI formed a consortium in the spring of 2000 after the introduction of ArcGIS and the geodatabase. UNETRANS (Unified Network and Transportation) is a collaborative project led by ESRI and the University of California, Santa Barbara (UCSB) with staff from each working to develop a transportation data model based upon the geodatabase structure. They have developed a generic data model for the transportation industry using ESRI's ArcGIS software.

Goodchild, Michael, K. Curtin, S Grise, V. Noronha (2004) developed the conceptual object data model which included the development of a conceptual object model of transportation features, incorporating multiple modes of travel, and accommodating multiple scales of interpretation of the real world . The current focus has been on transportation infrastructure including roadway and railway network features as well as the interaction between them for modeling inter-modal transfers.

Another component of the model is the development of a Unified Modeling Language (UML) code that is easily integrated into an ArcGIS geodatabase. This enables users to immediately populate the geodatabase rather than having to design it, and the inherent commonality between users will facilitate data sharing.

Although ESRI's UNETRANS data model (ArcGIS Transportation Data Model) serves as a new guideline for the object data model of transportation features, it is a relatively new database technology that very few DOTs have actually implemented. Therefore, very few case studies are available at this time about the use of geodatabase models for comprehensive transportation applications. Currently, UNETRANS and ESRI are working on a case study with Natural Resources Canada to describe their National Road Network Program.

3.3 Review of the Literature

Similar Efforts

The research team conducted a search for other related projects previously conducted for FDOT and found that Florida Atlantic University (FAU) and the University of Central Florida (UCF) have conducted research pertaining to noise and noise mitigation, but do not cover the specific issues included in the scope of this study. Three separate studies conducted at FAU focused on vehicle noise levels and effectiveness of noise barriers. Dunn developed two studies on noise barriers: testing the highway noise model(Dunn and Smart, 1986) and investigating the effectiveness of the noise barriers (Dunn, 1988). Also at FAU, Glegg and Yon (1989) researched the noise source height. Wayson (1997) at UCF focused on a method to determine reasonableness of noise abatement at special use locations.

While there is a fair deal of information regarding noise barrier acoustics, engineering, design, materials, and modeling, no information could be found about the development of a geodatabase that focuses on noise barriers. It is possible that since noise barriers are considered by transportation departments as features along the roadway, they appear in roadway databases as reference items that lack spatial/locational coordinate information. However, in the literature review the research team was able to identify several studies and projects that refer to issues related to creating geodatabases. Procedures used and conclusions of these projects helped the developers of the geodatabase to foresee potential issues with the use of GPS and GIS in roadway data collection and begin to develop and refine potential options appropriate for the NBGD project.

Quality and Accuracy of Positional Data in Transportation

In a report for the National Cooperative Highway Research Program (NCHRP), Fekpe, Novak, et al (2003) begin discussing the disparities between the sources of spatial data used by state departments of transportation (DOTs). The highway network is often described in linear terms using a referencing system that is one-dimensional. On the other hand, GIS and GPS use implies two and three dimensions. A degree of uncertainty associated with the data arises when multi-dimensional data such as GIS and GPS are translated into a single dimension to relate to existing linear databases.

The study reviewed the different applications of positional data within state DOTs and looked at several studies that make reference to this issue. Table 3.3.1 shows the different applications of positional data in transportation as well as the levels of sensitivity of the applications to spatial data quality (Wayson, 1997).

In the study, the table is followed by a series of case studies related to the different subject areas. The study makes mention of the fact that the Florida DOT office of systems (Pittman and Tucker, 1998) planning uses GIS-T to manage and develop the Florida interstate highway system.

The study concludes that the primary sources of error associated with positional data can be found in the most applications that modify the data in some way, including acquisition or measurement, processing, transformation, and presentation or visualization, regardless of the measurement technique and referencing system. When the data is transformed between different reference systems and utilizing different reference methods, a degree of uncertainty is introduced. These uncertainties relate to the precision, accuracy, and issues of scale and resolution. The loss of positional accuracy in transformations from one-dimensional linear references to two-dimensional can be overcome with consistency in matching accurately measured anchor sections to the corresponding sections of any digital spatial representation. The same is true in conversions from two- to one-dimensional referencing (Fepke, Kovak, et al, 2003).

Exhibit 3.3.1 Table of applications of positional data in transportation.

Subject Area	Applications	Sensitivity		
		L	M	H
Safety	- Crash Reporting		*	
	- Black spot/crash prone location identification		*	
	- Traffic safety investigation		*	
	- Rail crossing safety analysis		*	
	- Pedestrian and bicycle safety analysis		*	
	- Incident management			*
	- 911 emergency planning and response			*
Transportation Planning, Impact Analysis, Policy Analysis	- Travel demand modeling	*		
	- Multi-modal freight modeling	*		
	- Hazardous materials routing		*	
	- Traffic impact analysis		*	
Transit and Public Transport Planning and Operations	- Transit planning	*		
	- Transit routing		*	
	- Handi-transit		*	
	- Real-time tracking and scheduling of buses		*	
Transportation Infrastructure Management and Operations	- Location of facilities (road, highway, airport, port) inventory	*		
	- Pavement management system		*	
	- Asset management		*	
	- Operation (congestion, service)		*	
	- Corridor analysis (rail, road, highway)	*		
	- Rail/highway information system management	*		

Transportation Design and Construction Planning	- Sources of construction materials	*		
	- Right of way			*
	- Road closure and detour		*	
	- Construction information	*		
	- Field crew scheduling	*		
	- Maintenance and operation		*	
	- snow plowing	*		
	- garbage collection	*		
	- street sweeping	*		
ITS Applications	- Traveler Information System		*	
	- Integrated Highway Information System (IHIS)		*	
	- Integrated Traffic Monitoring System (ITMS)		*	
	- Web-based road condition reporting system		*	
	- Vehicle Navigation System			*
	- Applications to commercial vehicle operations regulatory enforcement activities	*		
Freight Analysis and Commercial Vehicle Operations	- Fleet management	*		
	- Vehicle tracking, guidance, dispatching, and		*	
	other routing applications		*	
	- Permitting	*		
	- Freight movement	*		

Source: Fepke, Kovak, et al, 2003.

Real World Experiences with GIS/GPS Applications

The Environmental Systems Research Institute (ESRI) website (www.esri.com), contains an abundance of case studies. The next set of case studies describe different applications that used GIS and GPS in the development of transportation databases. Understanding the applications and procedures used was helpful in developing the Noise Barrier Geodatabase (Guo, Poling and Poppe,).

Roadway Inventory Data Collection—This case study described how GPS was used to collect existing roadway features for several design projects which did not have complete as-built roadway inventories. For a 17-mile long scenic route, information was needed about the location of different transportation related features including no-passing zones, turnouts and pullouts, mile-post markers, and other roadway features of interest. Two data collection personnel were employed. One collector drove the vehicle which was equipped with a GPS unit, while the other one recorded the feature by scanning the matching feature code using a bar code reader. Several runs were used to increase the accuracy. The GPS point data was processed using dynamic segmentation in ArcInfo. The resulting product was a mile-log report with all of the features collected.

White House/Washington Mall and Mount Rainier Projects—the goal of this project was to create a GIS-based sign inventory and management system that would allow a user to query a map and locate signs and related images. The Mount Rainier project was also set up to issue maintenance work orders. A user interface was created for maintaining and reporting data. Other functions of the system include: geographical editing, generating roadway feature maps, reporting data in user-defined formats as well as those required by the FHWA, and calculating vehicle-miles travel for various boundaries.

Applying GPS and ArcView GIS to Pollution Discharge Systems Data Collection. The GeoPlan Center at the University of Florida developed a GIS program to aid in maintenance and inspection activities related to FDOT Turnpike District's National Pollution Discharge Elimination System (NPDES) Municipal Separate Storm System (MS4). The application is used to manage the database development, inspections, data tracking, and reporting. The system is composed of a bar code data collection method, data logger and pen-tablet to collect data. Aerial photos were later used to check the soundness of the process and the accuracy of the collected data (Pfeilsticker, Renee, et al, 2003). Field crews were outfitted with Trimble GPS units, laptop computers, and two-way radios to maintain communications and download the data during each field visit. In this manner, the field crews were able to maintain real-time contact with a centralized office location where the data was being processed. It also allowed the data to be stored in case connections were unavailable and the data could then be post-processed. A pen-tablet application with a graphical user interface (GUI) form was also supplied to the field crews that allowed them to provide additional attribute information about the stormwater structures. The GUI listed attributes from which the surveyors could select by checking the appropriate boxes. In the end, two data collection methods were developed for future updates and inspections. The first involves the use of the Trimble FPS units that the Turnpike already owns. The second involves the use of a pen-tablet with DANS software that runs the graphically visual collection method and allows the user to manipulate the data in the field (Pfeilsticker, Renee, et al, 2003).

IV. ASSESSMENT SURVEYS AND INTERVIEWS

An assessment of the existing Noise Barrier Inventory was conducted as well as a review of processes and procedures related to this task. This was accomplished through surveys, interviews, and review of the existing district databases. In addition, the project team conducted two presentations at the state noise task team semi-annual meetings which were followed by a question and answer period and discussion, which provided additional information to the study.

Initial inquiries uncovered that the existing database was in spreadsheet format and appears in the June 2000 Noise Barrier status report. The entries in the database record noise barriers that were built between 1977 and 2000. Many noise walls that were in the planning or construction stages at the time were not included in the report. In addition to updating the existing inventory, two survey documents were created to determine other administrative and procedural elements including, persons with access to current inventory, potential users of the noise barrier database, as well as the GIS capabilities at each District within various departments. Survey participants included District noise specialists GIS coordinators, consultants, and other related staff.

The research team conducted face-to-face interviews with FDOT District staff to uncover additional information about how each district manages the data and differences in their

GIS capabilities and organizational structures, in addition to further understanding the need for the geodatabase at the district level. Districts 4 and 6 were chosen for the interview process due to the large number of noise walls, established contacts, and GIS capabilities. A phone interview was conducted with District 7, located in the Tampa region, pursuant to recommendations by District 4 FDOT staff. Lists of the different staff members interviewed and surveyed may be found in appendices C and D along with the tabulation of survey results and copies of the survey forms.

4.1 First Survey Results

Responses to the first survey were obtained from all seven FDOT districts and Turnpike. In each case either the principal consultant to the district on noise barriers responded or the district noise specialist, and sometimes both. Additionally, the maintenance manager form District 7 also responded as well as a GIS staffer from District 4. Below is a summary of the responses by question. A full tabulation of the responses can be found in Appendix C.

Exposure to noise barrier data—Five of the seven districts responded that they maintain and also collect the barrier data. In some of the districts the data is collected and maintained by a transportation consultant. However, the noise barrier coordinators access the data as needed.

Data format—Less than half of the districts work with data in spreadsheet format. Most of the districts also maintain data in textual document formats (namely Word). The GIS staffer maintains the data in database format and at the time of the survey, District 4 was looking into converting the information into a geodatabase. Data on built noise barriers is generally found on the construction plans and only referenced as needed.

Frequency of use of GIS—Only two of the districts use GIS during the course of their day-to-day activities. A total of four have access to GIS, but don't use it, and three staffers were not aware of having access to GIS within their district, including the maintenance staffer.

Current GIS platforms—The research team found a variety of ArcGIS platforms being used in the different districts and in some cases within the same districts, since the GIS operations are not centralized. The most current GIS platform being used was ArcView 8.x, and by only two of the Districts. Older versions are more common.

How GIS projects are handled within each department—Of seven districts who run GIS within their offices (including Turnpike), four handle their GIS internally within their own departments and two do not have access to GIS within their department. One district relies on outsourcing the GIS with a consultant and another district combines both in- and out-sourcing this process.

GIS databases: access and storage—Assessing how GIS is managed within the districts, the research team found that none of them have an Enterprise GIS in terms of utilizing ArcSDE allowing for simultaneous access and editing to geospatial information. Two of the noise barrier coordinators had access to standalone system and three are networked to a GIS that allows multiple users, but the information is downloaded for each use. Again, almost half of the specialists reported having no access to GIS and one of the districts uses a consultant to manage the database.

GIS linkage to other databases—Responses reflected earlier responses. Only two of the seven districts who maintain GIS databases link them to other databases.The responses seem to indicate that GIS and other databases are rarely coordinated internally within the Districts. When asked what the GIS was linked to, several districts referenced the Florida Geographic Data Library (FGDL) and in one case the Work Program. In one district ArcIMS is linked with their construction department.

Data sharing with other districts—Only three out of a possible eight noise barrier specialists share their noise barrier data with other Districts. Most data is shared directly with Central Office for reporting purposes. It was unclear in what format the data was shared and responses seemed to contradict earlier questions about use and access to GIS. The second survey addressed this issue.

Use of orthophotographs—All of the districts, except one, reported using ortho-photographs (aerial photos) which were supplied by either the District or FDOT Central Office, local government, or in a couple of cases from educational institutions. However, at the time of the survey, none of the district noise specialists reported using orthophotographs archived at FGDL. Orthophotographs are used by noise specialists primarily for site and land use verification and in a couple of cases for digitizing barriers. In one case the user reported looking for parks and contaminated sites. The orthophotographs are also being used at a variety of scales including: 1 in. = 400 ft., 1:200, and 1:01, among others.

Conclusions from the first survey

Data Sharing Issues—The predominance of standalone desktop systems implies that data is not being shared. This can create problems with database maintenance and compatibility because of separate instances of information updates, layer creation, and modification of underlying maps. The same compatibility issues may arise when the Districts try to share information between themselves or with Central Office. The data may be kept in different formats or the base information may differ. An Enterprise GIS is the most ideal implementation, however, a GIS System that is networked with the departments and maintained by a single database manager would lay a good foundation for future improvements.

4.2 Interviews

Interviews were conducted in person and separately with noise barrier coordinators and GIS staff from Districts 4 and 6. The District 4 interview was also attended by the Environmental Management Office head. The noise barrier consultant for District 6 joined the interview via conference call. A third interview was conducted with District 7 by phone.

Interviews revealed and clarified several issues pertaining to noise barrier planning and data management. Discussions included existing inventories, procedures, datasets, as well as GIS capabilities. In addition, FDOT staff often provided suggestions for converting the geodatabase, including additional attributes and methods for retrieving data.

Some common issues that resulted from the interviews conducted with FDOT staff include:

- Districts create, store and maintain much of their own data, and generally do not rely upon the RCI or Geoplan (FDGL) for datasets.
- Districts have unique partnerships with local government agencies to access GIS datasets including aerial photography.
- GIS capabilities differ from District to District and from department to department within a district.
- Districts feel that they should be responsible for maintaining their own databases. The Roadway Characteristics Inventory (RCI) and other data repositories are updated infrequently to include changes and modifications.
- The communications between District GIS staff and Central Office, RCI, and Geoplan are not coordinated.
- Maintenance department should have access to the geodatabase.
- Districts request that the geodatabase would be accurate to roadway level.
- Districts generally do not maintain a digital photo file.
- ‘As Builts’ should be included in the geodatabase.

4.3 Second Survey Results

The first survey and the interviews led to the development of a second survey to examine more specific issues. The survey included questions about existing and suggested fields for the noise barrier geodatabase, how GIS data is exchanged within and outside of each District, anticipated use of the database by different offices or sections within each District, and a set of questions about noise assessments and modeling.

For the second survey, replies were received from six of the eight noise specialists and from several GIS coordinators at different districts. The survey helped to obtain information that would be useful in developing the geodatabase format and the type of information that should be made available to future users. A more in depth summary of the survey questions and results can be found in Appendix D.

Barrier information—Those districts that possess noise mitigation structures maintain an updated list, but only the Turnpike maintains its list in a relational database. All others maintain their data in spreadsheet or Word format.

As Builts—is a term used for final construction plans showing all features of the project as constructed. Noise specialists use the As Builts to ascertain that PD&E study recommendations have been implemented. During the interviews the noise specialists voiced their desire to see the As Builts linked to the noise barrier data. This request was later supported by the second survey. In some districts, newer As Builts can be found in digital form (CADD), however, older plans would need to be digitally scanned.

Desired Data Fields—The noise specialists were asked to rank the importance of attributes in the database. All agreed that the current list of attributes are still needed (see list on page 10). Some respondents noted that projects have a new numbering system, so the Work Program Identification (WPI) number has become less relevant than the newer Financial Management (FM) number. However, older projects do not have new FM numbers and the WPI number is the only identification available for these barriers. Other fields that have lost importance over time include all project dimensions in metric scale. New fields were identified to be included in the geodatabase including:

- County
- City
- Adjacent Neighborhood
- Project Related Roadway
- Photo Image
- As Built Link
- Begin Mile Marker

Additional fields that were highly recommended for consideration include:

- FM Number (FM#)
- Nearest Cross Road
- Last Maintained
- Paint Code
- Begin and End x coordinates
- Begin and End y coordinates

The two latter fields were identified as most important by the GIS staffers.

Other fields of interest to individual respondents included:

- Imprint style for tracking
- Wall texture, instead of block style
- Begin & End Station Number, which could replace mile marker for accuracy or simply an additional field.
- Number of benefited receivers and cost/benefited receivers
- Road ID should require to be plotted using mileposts

- Barrier type

When are the fields most used?—In the survey, the respondents were asked to rank during what phases of construction of a noise barrier would information about the barriers (fields) be useful. Using different intensities of gray, the table below shows which fields will most likely be used during the different planning and construction stages. The likelihood of use is reflected in the intensity of the gray, darker with higher likelihood of use, decreasing in intensity with decreasing likelihood, and white indicates no response.

Exhibit 4.3.1 Table of likelihood that types of information may be used by the districts during a particular transportation planning/construction phase.

Field	PD&E	Design	Construction	Post-Construction
Barrier ID				
WPI				
Contractor				
Year Built				
Barrier Material				
District				
Length (m or ft)				
Height (m or ft)				
Area (m2 or ft2)				
Total Cost				
Cost/Area $/m2 or $/ft2				
IL Predicted				
IL Measured				
Comments				
FM#				
County				
*City				
Adjacent Neighborhood				
Project Related Roadway				
Nearest Crossroad				
Photo Image				
As-Built Link				
Last Maintained				
Paint Code				
Block Style				
Block Code				
Begin Mile Marker				

End Mile Marker				
Begin x coordinate				
Begin y coordinate				
End x coord				
End y coord				

Responses to this table led to the following conclusions:

- Generally, the fields are more likely to be reviewed after construction than in earlier planning stages.
- The variables that most likely to be used are:
  - Barrier ID
  - Length, height, and area measured in feet.
  - Total cost and cost/area in dollars and feet.
  - Comments
  - FM #
  - Location variables such as county, city, adjacent neighborhood and project related roadway
  - Begin and end mile markers
- At the front end of the project, the most important variables are:
  - Barrier ID
  - District
  - Length (m/ft)
  - Height (m/ft)
  - Area (m2/ft2)
  - Total Cost
  - Cost/Area $/m2: ft2
  - IL Predicted
  - FM#
  - County
  - City
  - Adjacent Neighborhood
  - Project Related Roadway
- After construction, most of the variables are important, with the exception of:
  - WPI #
  - Block style and code
  - Nearest cross road

Data Submission Protocols—the survey asked several questions about how updated information was submitted to other transportation database managers.

Roadway Characteristics Inventory (RCI)—is a database that contains information about all of the roadways' features within a district. The respondents were asked whether there was a protocol to submit updates about the noise barriers to the RCI, and only one person responded "yes" and that the information needs to be provided through the Planning Office; however they were unaware of the specific protocol requirements.

Geoplan—is a center at the University of Florida which currently archives GIS data from around the state. The Department of Transportation is using these archives to house statewide GIS databases and information on transportation projects in the Florida Geographical Data Library (FGDL). One important use of the FGDL involves the storage of project information that is used in the PD&E process that needs to be shared with other agencies. Through the environmental transportation decision-making or ETDM review, multiple agencies have access to information about the transportation project. Only one district recognized submitting information to Geoplan, but could not provide any details.

Database management systems currently used with GIS—The survey asked specifically about several management systems and received the following responses:

- **Access:** 5 responses, only 2 from NBS.
- **SQL Server:** one response from an NBS
- **IBM DB2, Informix:** no responses
- **Oracle:** one response
- **Other:** DBF, and SQL server is used on the Arc IMS application and is linked via a query URL that allows for searches by FM number only—no true connection.

Of the nine responses received, three came from District 6, and five others came from District 4. Three of the five responding districts did not mention what system they use.

Web-based mapping—the survey asked whether the respondents used web-based mapping. District 4 and 6 use it internally, and the Turnpike district uses it both internally and externally. The District 6 consultant will be implementing web-based mapping within the next 6-12 months after the survey.

4.4 Wall data updates

The existing noise barrier database that preceded the study had been last updated in 2000. Between 2000 and 2004, walls have been built in several districts. The research team worked with FDOT to update the list of all state owned noise barriers. Updates were requested from the noise specialists of the different districts. Additionally, the districts were asked to provide any relevant information available about their walls, such as mile marker posts, FM numbers, and (X,Y) coordinate information.

Responses from the districts were received in a variety of formats (See Appendix D). Some Districts replied with spreadsheets, others have replied with text project descriptions. The Turnpike District provided detailed descriptions of the location of the noise barrier as well as beginning and ending station numbers. However, in several cases, the same description applied to more than one barrier under one financial project number (See Appendix D). Exhibit 4.4.1 displays the increase in numbers of noise barriers constructed over a four year period. The 2000 total wall count is taken from the June

2000 Noise Barrier status report and the 2004 total count is based on information provided by the Districts between April and May of 2004.

Exhibit 4.4.1 Table of Noise Barrier Update Status.

FDOT District	2000 Total Walls	2000-2004 Additional Walls	2004 Total Walls	Comment
District 1	**1**	**3**	**4**	Update received with FM #'s and Mile Markers
District 2	**11**		**11**	No update received
District 3	**0**	**0**	**0**	New walls planned for 05
District 4	**49**		**49**	No update received, pending GPS Testing
District 5	**3**		**3**	No update received
District 6	**13**	**84**	**97**	Update received with X, Y coordinates. Dataset still requires FM #'s
District 7	**14**	**-1**	**13**	Temporary wall removed. Post 2000 update pending
Turnpike	**1**	**6**	**7**	Update received with detailed descriptions. Three new projects one with four noise barriers.
TOTAL	**92**	**92**	**184**	**Based on updates by FDOT Districts through 5-10-04*

Source: Michael Stamm, CUES, 2004.

V. CONCEPTUALIZING THE NOISE BARRIER GEODATABASE

5.1 Needs Statement

In June 2000, FDOT completed the Florida Noise Barrier Status Report, which included an inventory of Florida noise abatement barriers built as of June 2000. The purpose of the report was to document the noise abatement efforts of the FDOT completed at that time. This report contains information on the physical dimensions of each barrier; costs of each barrier; and the percentage of the total construction project cost; job number and general location; the contractor; existing background levels without the walls and predictions related to future noise levels with and without the wall; construction dates; and any general information of value (FDOT, 2000).

Although the inventory has been useful in providing the status of noise abatement barriers built as of June 2000, the format of how the information is stored is limited in terms of spatially locating these barriers and it does not include additional walls built since that time. The noise barrier inventory was formatted into a spreadsheet, and did not provide sufficient geographic information useful for locating a specific barrier on roadway during a new project's planning, development and design process.

A statewide inventory of noise abatement barriers was needed in a format that would allow users to identify the geographic location of walls, access attribute information associated with the wall, and identify the spatial relationship to other geographic features such as interstates, in/out shoulders, land use, and other features important when planning, designing, and maintaining these structures.

More importantly, the format should be compliant with the GIS format used by FDOT for updating purposes. The challenge in developing a statewide geographic database for noise wall barriers is to adhere to best practices that utilize a data structure which is an industry-standard, *scalable* for different types of uses, and based upon an *object-oriented data model*. Utilizing these best practices promote 'interoperability' allowing users to access this information based upon their current GIS as well as integrate this database to other related geographic information collected by FDOT

5.2 Purpose of the Noise Barrier Geodatabase

Tracking, documenting and reporting is an everyday reality for many organizations. Quality decision making relies upon accurate, timely data, and, equally important, geographic information about where structures such as noise barriers are located throughout the state of Florida. FDOT's EMO at Central Office identified the need for a noise barrier GIS inventory since a State-wide GIS database inventorying these structures was practically non-existent. Although a few Districts took the initiative to develop their own geodatabase, there was no Statewide Noise Abatement Barrier Geodatabase available to all District offices.

The benefits associated in developing a Statewide Noise Barrier Geodatabase are briefly highlighted below:

- Up-to-date, accessible data for decision making purposes
- Standard format for exchange of information
- Virtual elimination of duplicate data
- Centralized access to important data
- Centralized modifications and updates capabilities
- Improved data accuracy

Developing a Statewide Noise Barrier Geodatabase allows standards to be established. These standards can promote data consistency in terms of data updating and data sharing. For example, using standard unique identifiers such as the Roadway Characteristics Inventory (RCI) number, Work Program Index (WPI) and/or Financial Management (FM) identifiers, can link the geodatabase to other databases containing more detailed information about the walls. The noise barrier inventory could then integrate with these other FDOT inventories, particularly the RCI.

The standardized geodatabase can provide accurate information on barrier locations within the right-of-way and relative to other spatially referenced features and structures. More importantly, the Statewide Noise Barrier Geodatabase can be maintained by a central entity such as FDOT's Transportation Statistics Office or the FGDL. This Office is responsible for maintaining and updating FDOT's base map layers in GIS format. This Statewide Noise Barrier Geodatabase (NBGD) could be maintained centrally and accessible to authorized users at the Central Office and Districts through a query interface, which allows the user to query, map, and report information to an enterprise NBGD.

5.3 Why a Geodatabase Data Model?

The Environmental Systems Research Institute, Inc. (ESRI) ArcInfo coverage was introduced in 1981 along with ESRI's first commercial GIS software. Also known as a georelational data model, there are two core aspects of the coverage. The first core concept is that spatial data is combined with attribute data. Optimum display and access functions were achieved by storing the spatial data into indexed binary files. Attribute data is stored in tabular form with rows in the table representing the exact number of cases or objects included in the binary tables and most importantly, joined by a common unique field identifier. The second core concept of the coverage data model was that the topological relationships between vector features could be stored. In other words, the spatial data record for a line contains nodal, connectivity, and adjacent polygon information. An ArcInfo coverage can contain more than one class of geographic features (feature classes), with only one of these feature classes associated with a topological role. A coverage stores geographic features like points, lines, and polygons as primary features and stores tics, map extent, links, and annotation as secondary features.

There are some limitations associated with ESRI's ArcInfo coverage data model. One such shortcoming is that features within a coverage are aggregated into homogeneous groups of points, lines, and polygons with a uniform, generic behavior. Therefore, the behavior of a line representing a street is the same as the behavior of a line representing a canal. This behavior is important because GIS practitioners often have a need to depict the specific behaviors of streets, canals, and other objects represented by a line. An example of streets, is when they intersect it should be represented by a traffic intersection or an over-underpass. If a line feature representing a street is the same characteristically as the line that represents a canal, then one would not be able to properly show descriptive info about these features.

The ArcView shapefile stores geographic features and their attributes. It is stored in a set of related files and contains one feature class. Shapefiles are composed of three main files, which contain spatial and attribute data. The geographic data is stored in two of the files (.shp and .shx), which are compressed into binary for fast drawing of the data. The attribute data is stored in an embedded database file (.dbf). However, the attributes of other objects can be stored in another database table, which can be joined to the shapefile. The shapefile is a homogeneous collection of point, multipoint, polyline, or polygon shaped features.

Although the ArcView shapefile is the most commonly used GIS data model by FDOT and other government agencies throughout Florida, the feature classes are non-topological in nature.

A geodatabase is the "top-level unit of geographic data. It is a collection of datasets, feature classes, object classes, and relationship classes, it represents the next generation of GIS data models." (Zeiler, 1999). Simply put, the geodatabase is like a storage container holding spatial data. All the data in this container is organized based on relationships and commonalities.

Geodatabases are usually separated into broad categories of data like transportation, environment, and aspects of infrastructure. Feature classes within a geodatabase are either stand alone features or they can be topologically integrated like the coverage data model, allowing improved relationships among feature classes that the coverage model did not have. An important concept of the object-oriented geodatabase data model is that features within the geodatabase are represented as 'smart features'. According to Zeiler (1999), objects in the real-world have natural rules and relationships that they follow. Features in a geodatabase have a framework of attributes, geometry, spatial reference, relationships, validation rules, and topology. All aspects of this framework is built within the geodatabase itself, allowing considerable control in modeling real-world phenomena more naturally. Designing a geodatabase is essential since users can employ a progressive set of steps to add the intelligence framework within the geodatabase itself. Zeiler (1999) further states that the geodatabase data model brings the physical data model closer to its logical data model.

From a technical perspective, the geodatabase follows the fundamental relational data model in which each object and its attributes are stored as a row in a table. An object represents a feature or a real-world entity that the GIS is designed to emulate (e.g., a parcel, a street, a streetlight, a river, or a customer). A collection of similar features (objects), such as parcels, buildings, or rivers, stored in a database management systems (DBMS) table is called a feature class. Collections of related feature classes that share the same spatial reference can be organized into a larger structure called a feature data set.

Each feature in a geodatabase (e.g., an interstate, noise barriers, etc) contains its own shape (geometry) and can exist on its own, as opposed to the coverage data model that models a polygon as a collection of arcs and label points. The ability to store the complete geometry of a simple feature (such as noise barriers) is one of the advantages of the geodatabase model, as the feature is always available for display and analysis.

5.4 Why Adopt the Geodatabase Data Model for FDOT's Noise Barriers?

Choosing the appropriate GIS data model for this project was largely based upon the standard GIS platform utilized by FDOT. As stated in the first survey results, the most current GIS platform being used is ESRI. In addition, other entities within FDOT utilize the ESRI product as one of their standard GIS platforms. According to FDOT's Roadway Characteristics Inventory (RCI) Handbook (Chapter 7, July 2004), the RCI/GIS base map was developed in ESRI's ArcInfo coverage data model, comprised of arcs, nodes, and a route system that geographically represents the roadways maintained in the RCI.

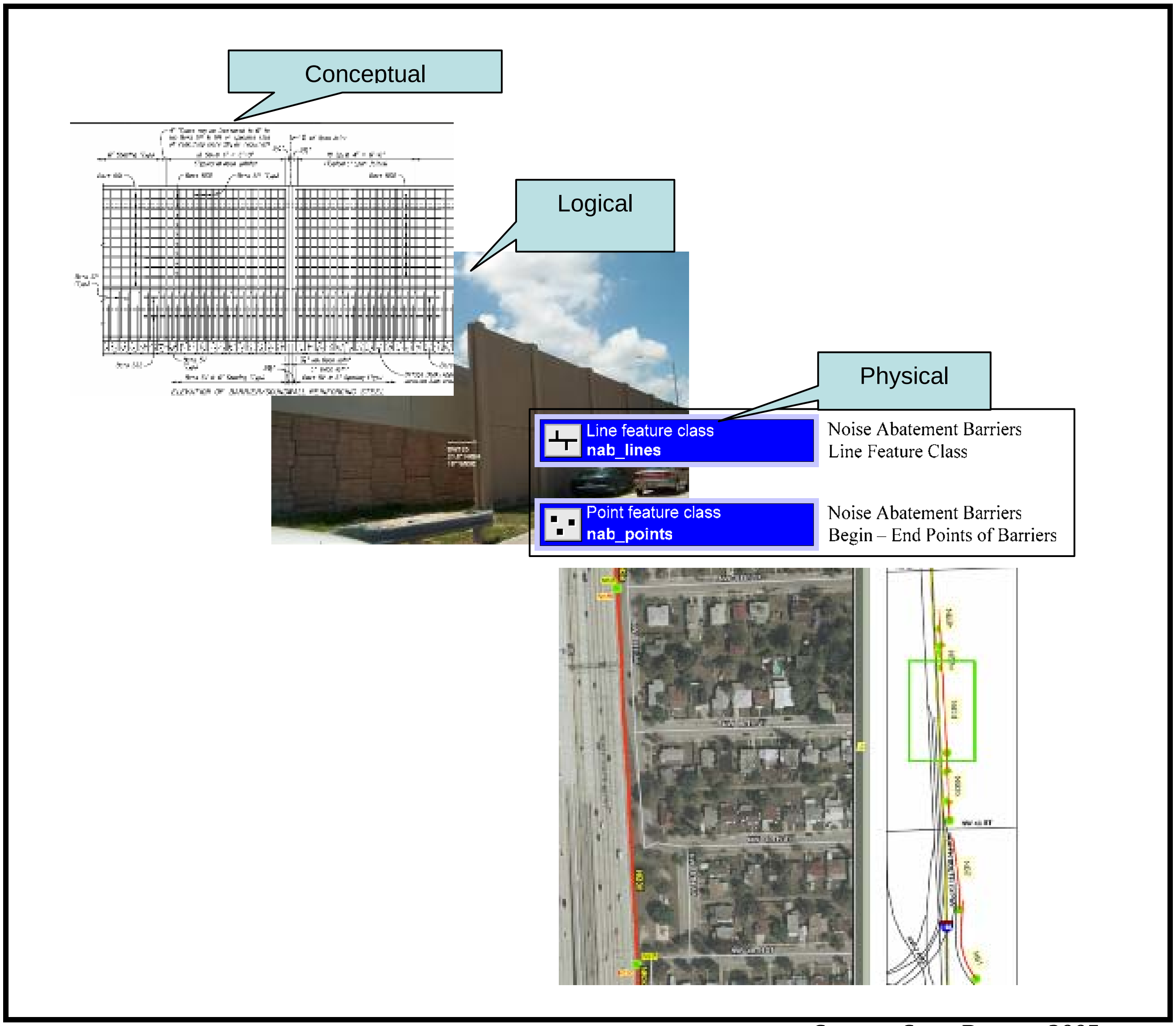
The Office of Transportation Statistics has a RCI/GIS Base Map Coordinator who works with appropriate staff from District offices to make corrections to the FDOT's base map layers and to ensure compatibility between the RCI and Basemap Roadway ID information. Recently, this office has exported the ArcInfo coverage into a personal geodatabase which can be found on FDOT's Office Transportation Statistic's GIS Data Dictionary web site (http://www.dot.state.fl.us/planning/statistics/gis/default.htm). It should also be noted that their geodatabase's spatial reference is based upon UTM 17 as opposed to the Albers projection which is used by GeoPlan's Florida Geographic Data Library (FGDL).

Although the Noise Barrier Geodatabase adheres to the FGDL standard, the geodatabase projection information can be transformed seamlessly if the situation arises to include the feature classes and feature data sets associated with the noise barriers with FDOT's Base Map Geodatabase.

Finally, ESRI is a standard GIS platform utilized by other Florida State Departments and other regional, county, and local government agencies. According to a 1999 survey conducted by the FDOT Model Task Force (MTF) GIS Subcommittee, ESRI's ArcView was being used by all 25 metropolitan planning organzations (MPOs) in Florida.

For several years, ESRI has been working with the GIS user community to develop a set of "best practices" in designing and implementing a geodatabase. The research team applied these best practices in developing the geodatabase for the noise barriers. The following sections document the methodology utilized in the geodatabase development stages from the conceptual phase to the logical and physical database implementation phases, as shown in Exhibit 5.4.1, below.

Exhibit 5.4.1   Diagram of the geodatabase design and implementation process.



Source: Scott Burton, 2005.

VI. Designing the Noise Barrier Geodatabase

6.1 Define the Database Schema (Structure)

The next step was to identify the logical design of the attributes that are included in the geodatabase. As stated earlier, a second interview was necessary to identify the types of information that should be made available to future users within the geodatabase. During this interview, various issues pertaining to noise barriers were revealed. Discussions included existing inventories, procedures, datasets, as well as GIS capabilities. In addition, FDOT staff often provided suggestions for converting the inventory into a geodatabase, including additional attributes and methods for retrieving support data

Some common logical design issues were identified by those interviewed:

1. Districts create, store and maintain much of their own data, and generally do not rely upon the RCI or Geoplan for datasets. Therefore, if the geodatabase is created, standard operating procedures and policies may need to be warranted which would allow Districts to maintain their own inventory yet establish standards and data sharing coordination to ensure accessibility to all Districts. For example, establishing a 'standardized key identifier' may be required to promote sharing among District offices regarding noise barriers.

2. Districts have unique partnerships with local government agencies for access to GIS datasets including aerial photography. The geodatabase should be spatially referenced to both an agency-wide perspective and the spatial referencing should be based upon those standards adopted at the local level. Perhaps, creating feature data sets representing a state-wide perspective as well as a district-office perspective.

3. GIS capabilities are different from District to District and from department to department within a district. Therefore, training may need to be required to assist those Districts in fully utilizing the geodatabase. In addition, some Districts may not have the staffing resources to maintain their information. Providing GIS capability and training to the District's maintenance departments should be considered as well.

4. Districts feel that they should be responsible to maintain the databases, RCI and other repositories are not frequently updated with changes and modifications. Therefore, the geodatabase should contain not only RCI, WPI or FM identifiers, but utilize identifiers established at the District level.

5. Maintenance office should have access to the geodatabase.

6. District desire that the geodatabase would be accurate to roadway level.

7. Districts generally do not maintain a digital photo file. District Four was the only District that had digital photographs associated with their noise abatement walls.

8. 'As Built' plans should be included in database. This was one of the reasons that each Maintenance departments be included in any training on how to update this Geodatabase.

Based upon these issues and/or concerns, the data structure was logically designed to support multiple feature data sets for both types of users (statewide vs. district office), the data structure should be designed to capture the attributes deemed by the users as essential within the line feature class of the Noise Barrier Geodatabase (NBGD). Finally, this geodatabase would maintain multiple identifiers that include: RCI, WPI, FM, Unique Identifier assigned by District, and a Key Identifier assigned by the research team.

During the logical design process, it was determined that information pertaining to attributes such as WPI#, RCI#, FM#, construction dates, materials or costs had not been updated since the 2000 Noise Barrier Inventory. In addition, this information was not readily available to be appended to the Noise Barrier Geodatabase being developed through this project.

However, the geodatabase schema (structure) developed for this project will support this information being collected and stored within the geodatabase itself. The field structure was logically designed to store information such as:

- Barrier ID
- District
- Length (m and/or ft)
- Height (m and/or ft)
- Area (m2 and/or ft2)
- Total Cost
- Cost/Area $/m2 and/or ft2

This will require a policy recommendation set forth by the sponsor of this project to mandate that each District office provide the attribute information required for the Noise Barrier Geodatabase. The attributes are based upon the second survey administered by the research team for this project.

The geodatabase schema structured to collect and store attributes will be part of the line feature class representing the barriers. The attributes are described in the table below:

Exhibit 6.1.1 NBID Attributes and Key Identifiers.

NBID	*Key Identifier*
ROADWAY	Roadway Characteristic Inventory Number
ROAD_DESCR	Roadway Characteristic Inventory Description
G_LENGTH	Length generated by ArcGIS
STATE_FIPS	State Federal Information Processing Standards (FIPs) code
FDOT_DISTR	FDOT District Office number
COUNTY_FIP	County FIPS
COUNTY_F_1	Secondary County FIPS
RCI	Roadway Characteristic Inventory
WALL_ID	Wall ID based upon 2000 inventory
SECTION_	Section ID based upon 2000 inventory
BARRIER_ID	Barrier ID based upon 2000 inventory
WPI_ID	WPI number
CONTRACTOR	Contractor

YR_BUILT	Year Built
MATERIAL	Materials used
LEN_METER	Length in Meters
LEN_FEET	Length in Feet
HGT_METER	Height in Meters
HGT_FEET	Height in Meters
AREA_METER	Area in Meters Squared
AREA_FT	Area in Feet Squared
OVERLAP	Overlapping walls
TOTAL_COST	Total Construction Cost
COST_MET	Cost per meter
COST_FT	Cost per feet
PREDICTED	Predicted
MEASUE	Measure
COMMENTS	Comments
FM_ID	FM Identifer
BEGIN_POST	Begin post mile marker
BEG_X	Begin X coordinate (State Plane, NAD83)
BEG_Y	Begin Y coordinate (State Plane, NAD83)
END_POST	End post mile marker
END_X	End X coordinate (State Plane, NAD83)
END_Y	End Y coordinate (State Plane, NAD83)
IMAGE_LINK	Hyperlink field

6.2 Identify Key Identifiers

Since there were numerous yet incomplete unique identifiers associated with noise barriers such as RCI, Job number, FM number, WPI number or unique identifier assigned by an individual District office, a Key Identifier was created by CUES. The Key Identifier developed for this project is a combination of FDOT's multiple unique identifiers including identifiers that distinguish each individual District office as well as the county where the wall is located. For example, a noise barrier in District 4 located in Palm Beach County would be assigned **'120409999004342017'** where [12] represents the State FIPS, [04] represents the District, and so forth, refer to table for further explanation.

Exhibit 6.2.1 Table describing the composition of the Key Identifier

Key Identifier		**120409999004342017**
Value	***Width***	***Description***
12	02	Statewide FIPS
04	02	FDOT District
099	03	County FIPS
99004	05	RCI / Job Number
3420	04	WPI
17	02	Sequence Unique ID Assigned by CUES

Some limitations with the unique identification number include those walls where no WPI and no FM numbers exist nor were available. For example, in District 6, the research team incorporated the key identifier along with the Statewide FIPS, FDOT District number, Countywide FIPS, and Roadway Characteristic Inventory number, including the new RCI number for south-bound Interstate 95. As for District 4's unique identifier, it is contained in the point feature class which can be linked to the line feature. Although, the WPI or FM numbers may not be included since it was not available for this geodatabase, it can be updated to it quite easily.

The importance of the Key Identifiers are to link together information derived from individual District offices and it should be considered by FDOT as a standard identifier for future data updates. The Key Identifiers provide users the ability to create relationships among multiple tables both within and outside the geodatabase. For example, if a District office maintains a database containing the WPI or FM numbers associated with the noise barriers, a relationship class can be generated.

The Key Identifier established by the research team permits a relationship between the point feature class and the line feature class to exist as well. The point feature class contains the GPS coordinates representing the begin point and end point of a wall, hyperlink to digital pictures for the barrier, and District 4's unique identifier. Therefore, if the user clicks on a line feature representing a wall within District 4, they can easily identify the unique identifier assigned to that wall by the District itself as well as any digital photos associated with the wall. One of the limitations with relating the line features to the point features is where a begin or end point overlap.

6.3 Define the spatial properties

To ensure that a high quality, well documented noise barrier geodatabase is fully integrated into FDOT's existing geodatabase(s) the spatial referencing standards utilized for FDOT layers within the Florida Geographic Data Library was applied. The map projection applied to the geodatabase is Albers Conical Equal Area. The mapping units for this projection are referenced in meters.

Detailed Projection Parameters:

Standard parallel: 24.000000
Standard parallel: 31.500000
Longitude of central meridian: -84.000000
Latitude of projection origin: 24.000000
False easting: 400000.000000
False northing: 0.000000
The horizontal datum used is D_North_American_1983_HARN.
The ellipsoid used is Geodetic Reference System 80.
The semi-major axis of the ellipsoid used is 6378137.000000.
The flattening of the ellipsoid used is 1/298.257222

It should be noted that FDOT's Office of Transportation Statistics utilizes a different map projection (UTM17, Meters) but the Noise Barrier Geodatabase can easily be transformed into the same projection if the data is to be included as part of FDOT's base map layers available from their web site at:
http://www.dot.state.fl.us/planning/statistics/gis/default.htm#geodatabases

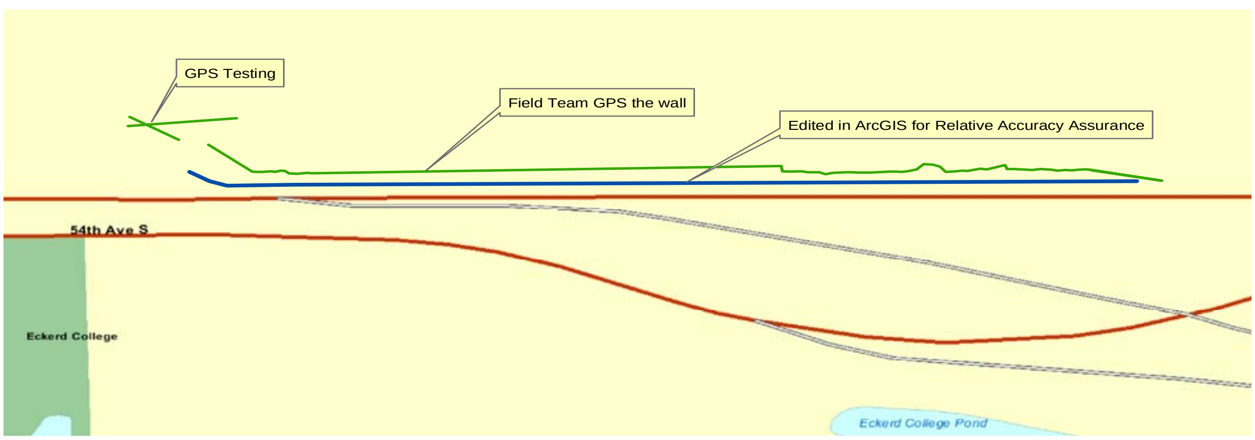
VII. PHYSICAL DESIGN OF THE NOISE BARRIER WALL

7.1 Data Acquisition Methods

Source of the data regarding positional accuracy played a major role in the quality aspect of "positionally" locating the noise abatement barriers. Specifically, the location of the barriers was based upon the relative scale(s) associated with FDOT's Florida Digital Geographic Library (FGDL) data set.

Relative scale was utilized as opposed to field measurements that define absolute scale. This is not to say GPS technology was excluded, in fact during this project, nearly every barrier was identified and/or verified using a Trimble GXT. However, if data was collected through GPS it was no longer positionally aligned relative to the scale used for

Exhibit 7.1.1 Illustration of spatial editing of noise barrier GPS data.



This figure shows how the research field team walked next to the barrier to capture the GPS coordinates associated with this wall (green line). Note the jagged line depicting the path the field team walked along. Using GIS and deploying on-screen digitizing, the

FDOT FGDL layers. Therefore, spatial editing was used to adjust the positional location of the barriers to align them based upon the relative accuracy of the existing GIS layers. Another limitation associated with collecting locational information using GPS was that the research field team could not stand directly on top of the wall to collect GPS readings.

Rather, the field team had to collect GPS readings near or offset from the wall location. The figure below depicts the differences between the location of where GPS information was collected and adjustments made using GIS to edit the features to align them relative to aerials and/or other FDOT GIS layers.

Global Positioning Systems

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these “man-made stars" as reference points to calculate positions accurate to a matter of meters. This spatial data technique was used to collect nearly 90% of all walls spatially converted into the geodatabase.

In late May 2004, the research team deployed a field team to conduct the GPS field work for the original 30 noise abatement walls in Districts 1, 2, 5, 6, and 7. Utilizing a Trimble GeoXT with GPS correct for real-time post-processing, the field team collected GPS information for these walls (see Appendix F).

During the GPS field work, three (3) new walls were identified in District 1 along the I-4 Corridor, the GPS information was collected for these walls as well. Once research staff confirmed these were owned by FDOT, they were included into the Noise Barrier Geodatabase (NBGD). GPS coordinates were collected by the research field team for 33 noise barriers. District 4 and District 6 indicated that they would be initiating their own GPS collection during the summer and fall of 2004. Rather then replicate this effort, CUES coordinated with these two districts to obtain the completed GPS information and import it into the NBGD. However, approximately seven walls were not included in these two Districts inventories. Therefore, CUES field team used GPS to collect wall information mainly for the Sawgrass Expressway and the Florida Turnpike. Overall GPS coordinates were collected for 40 walls by CUES.

The internal setting of the GeoXT’s GPS were set to ensure the highest possible accuracy. The settings utilized are as follows:

- PDOP: (Position Dilution of Precision) : 6 or less
- SNR (Signal To Noise Ratio): 4
- Elevation Mask: 15%
- Number of Satellites: 4 or Higher
- Differential Correction: WAAS

Each noise barrier wall in the region was surveyed to obtain both spatial, attribute and photographic information necessary for the project. Upon arrival to the particular barrier wall, the team would investigate the following conditions before undertaking the survey:

- Traffic volume & Safety conditions
- Survey Obstacles
- GPS Satellite Visibility
- GPS Availability

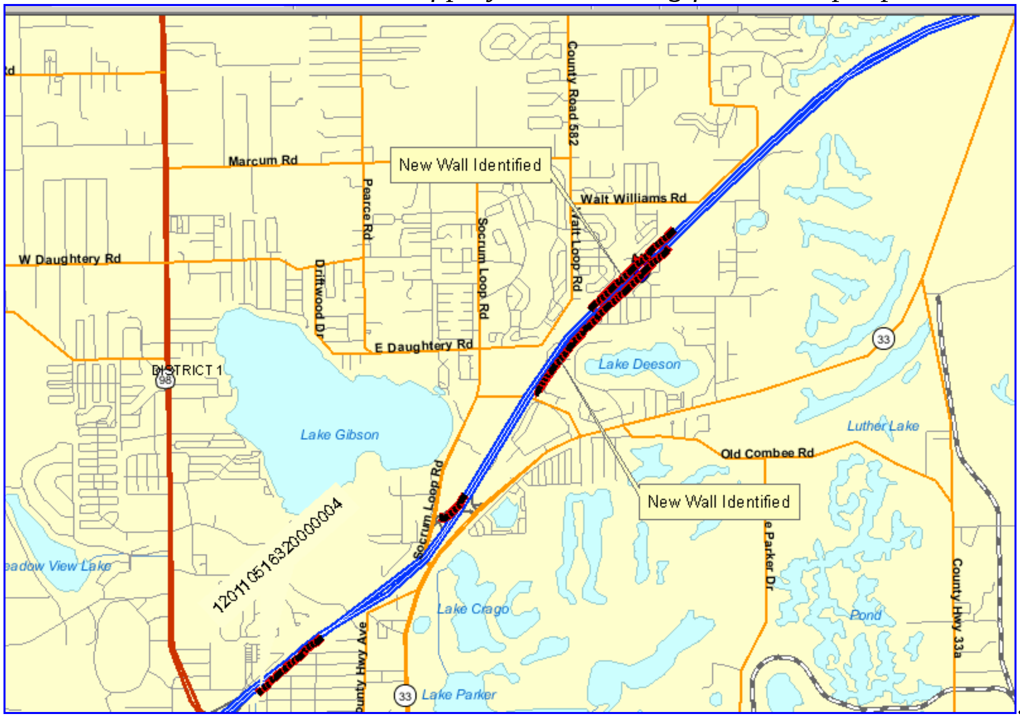
Upon arrival to the location, traffic volume was determined by the amount of traffic traveling adjacent to the wall of interest. The estimated volume determined whether it was judged safe for a foot survey or required use of a vehicle. Hard hats and florescent safety vests were worn at all times while conducting the surveys.

Numerous barrier walls surveyed had large swaths of vegetation planted next to them. Major types of vegetation included: Sable Palm trees, Sea Grape and various other bushes. These vegetation lines often followed the length of the given wall and ranged on average from 10-75 feet. Since many of the walls had some type of vegetation, an offset was incorporated into the survey. Generally all surveys were done on an average of 20 feet from the wall. Many of the walls not only had a vegetation line in front, but also a layer of standing water. This situation occurred in areas where the walls possessed a gully or depression directly in front of the vegetation line. In many situations, the accumulated water actually formed a small linear wetland including typical wetland flora and fauna which included unfortunately high concentrations of biting insects. If these water bodies existed, the offset was increased to account for the additional obstacle, so that the survey could continue. Other barriers to the survey included manmade structures such as tollbooths, embankments, bridges and narrow walks. If such obstacles were encountered, the situation was noted in the attribute table and the offset increased as needed.

GPS is a line of sight technology which relies on the ground based receiver the ability to have a clear and unobstructed line of sight to the GPS satellites. Noise barriers provide a unique problem in that they can obstruct half of the sky depending on how close the surveyor is conducted to them. Due to this fact, an offset was also needed to obtain the best possible satellite lock. GPS uses a measurement called PDOP (Position Dilution of Precision) to indicate accuracy. To ensure high accuracy GPS positioning, it is recommended that the PDOP value be less than 6. During all wall surveys, PDOP was monitored very closely and any measurement greater than 6 was resurveyed.

Once the Noise Barrier Wall was cleared to survey, the walking team member would activate the Mobile GIS/GPS unit and begin logging the polyline feature. At the beginning of the logging, an initial starting coordinate would be relayed to the vehicle team member for input into handwriting log. If a walking survey was done, the survey team member would walk the length of the wall with the vehicle team member following along to provide a look out for traffic. At the halfway point of the survey, the walking team member would again call out the coordinate of the middle of the wall to the vehicle team member. Once the entire length of the wall had been traversed, the walking team member would stop the logging and fill in the custom input form in the ArcPad software. Digital photos were also taken at each survey location. If safety conditions forced a vehicle survey, the same steps were performed in the vehicle at a slightly higher rate of speed. Exhibit 7.1.2, below, shows a sample of the resulting polylines.

Exhibit 7.1.2 Illustration of polylines resulting from the input process.



After each wall was surveyed, the team would back up the data on the GeoXT mobile device and then download the data onto a laptop computer. This procedure was completed at the location in case data was lost and the survey would have to be redone. Once back at the office, all data for that day was downloaded onto the project server to be used by the GIS section.

Acquisition from Individual Districts of Barriers in GIS format

At the time FDOT personnel were interviewed and surveyed for this project, it was determined that *no* District office maintained an inventory of their noise barriers in GIS. However, in the summer and fall of 2004, two District offices began using GPS technology to store information about their noise abatement walls in GIS format.

District 4 utilized GPS to store both the point (begin/end points) and line feature classes for **95** noise abatement walls. District 4 provided the research team with their personal geodatabase. The project team merged these point and line feature classes and spatially projected them into the statewide Noise Barrier Geodatabase (NBGD). District 4 also created a hyperlink to the photos collected during their GPS work. These hyperlinks have also been included as part of the NBGD.

District 6 utilized GPS technology to capture the begin node and end node for each wall. However, no line feature classes were created. Utilizing the GPS begin and end nodes, the research team digitized the line feature class representing the noise barriers for approximately 84 out of 96 total walls in District 6. A Trimble GeoXT was used to collect the points and linear features depicting the remaining 12 barriers.

On Screen (Heads-up) Digitizing

On Screen (Heads-up) Digitizing, a spatial data collection technique that utilizes high quality, rectified aerial photos and other georeferenced GIS layers, was used to primarily to edit the spatial data collected through GPS for relative positional accuracy purposes. The level of accuracy of the derived dataset is taken from the initial accuracy of the digital image along with georeferenced GIS layers.

One of the challenges was to utilize aerial photos in GIS at an acceptable resolution needed to create and edit spatial features for all District offices that have noise barriers. The central problem is that most orthophotos in GIS are collected by county governments, who collect this raster information at varying scales, different data formats (e.g. MrSID, TIF, JPEG, SDE), and/or capture them at different time frames. These challenges, as well as the degree of time investment involved in acquiring these raster features, led the research team to choose ESRI's ArcWeb Services instead.

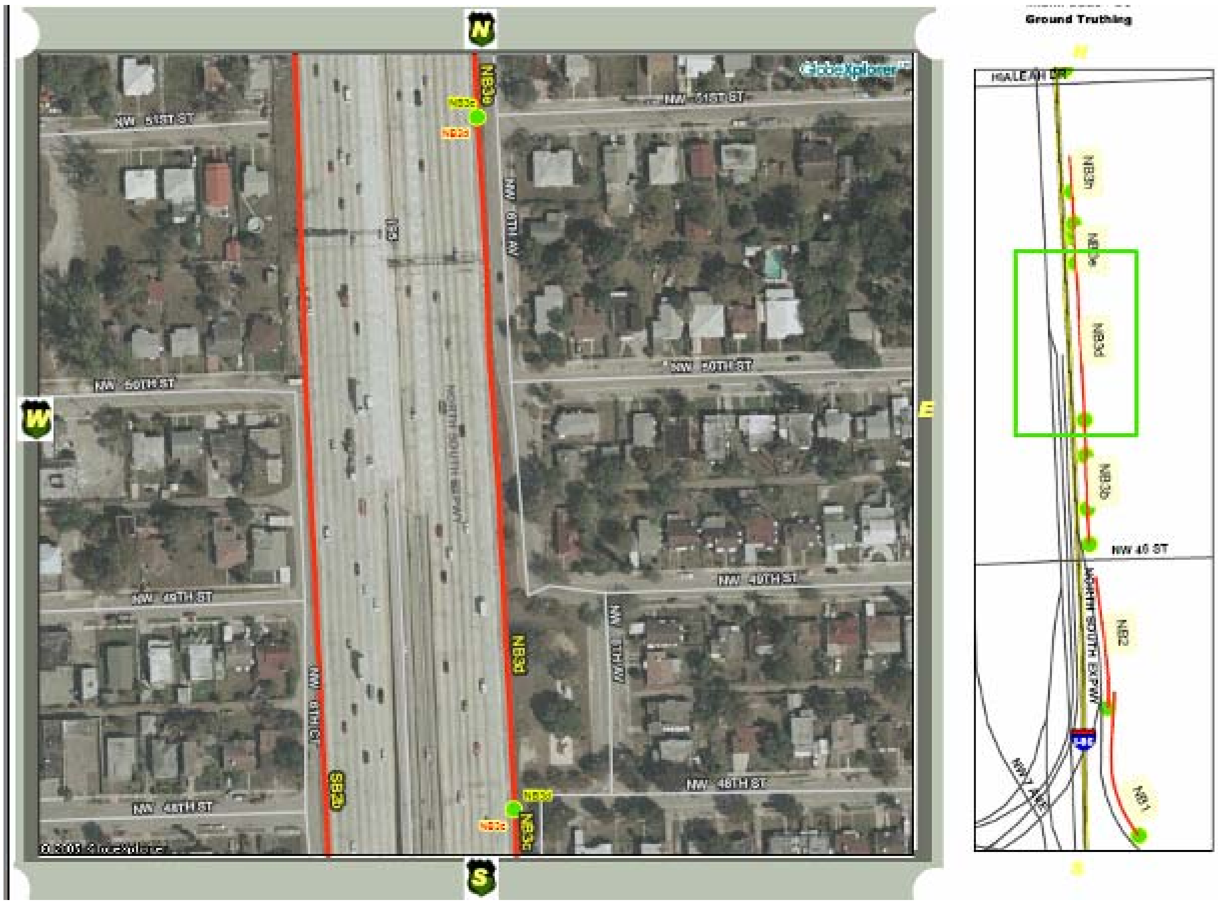
One of ArcWeb Services offered is access to GlobeXplorer's 'Citipix/Digital Ortho' which was used to perform the spatial edits required to verify and/or 're-align' the GPS collected data relative to scale of FDOT's GIS base map layers. Citipix is the largest high-resolution aerial imagery dataset available online through ArcWeb Services. Captured at six-inch resolution and in 24-bit color, Citipix is precision geo-referenced and ortho-rectified. It covers over 7,000 cities and towns in over 73 metropolitan areas in the United States, with a total area of over 90,000 square miles.

Citipix's high resolution provided the optimal background layer to digitize, edit, and verify the linear features representing the walls. Using GPS points collected by District 6 which represent the begin and end nodes for each wall along with GlobeXplorer's digital orthophotography, the line feature classes for these barriers were digitized. **Ninety six** out of the **217** barriers within the Statewide Geodatabase were digitized. District 6 accounts for approximately 44% of all noise barriers in the statewide Noise Barrier Geodatabase.

7.2 Data Verification / Quality Assurance

To verify the correctness of the georeferenced information collected (ground truthing), the research team validated in the field nearly 70% of all noise barriers maintained by FDOT utilizing GPS technology (150 of the 217 walls). The remaining 30% of the walls were validated utilizing GlobeXplorer's high resolution imagery, as shown below in Exhibit 7.2.1.

Exhibit 7.2.1 Sample result from groundtruthing.



7.3 Constructing the Physical Geodatabase

There are three distinct methods used to create the physical geodatabase. The first and most simple method is where the user creates the geodatabase from scratch using ArcCatalog. ArcCatalog is one of three core application components within the ArcGIS platform, it allows users to design and create a geodatabase. This method was used to design and create the Noise Barrier Geodatabase. Another method is migrating data into an existing Geodatabase. This method may be utilized if FDOT plans on exporting this Noise Barriers Geodatabase into another geodatabase. The final method which is often used for complex database design is utilizing Computer-Aided Software Engineering (CASE). CASE consists of tools and techniques that automate the process of developing software systems and database design.

7.4 Feature Datasets

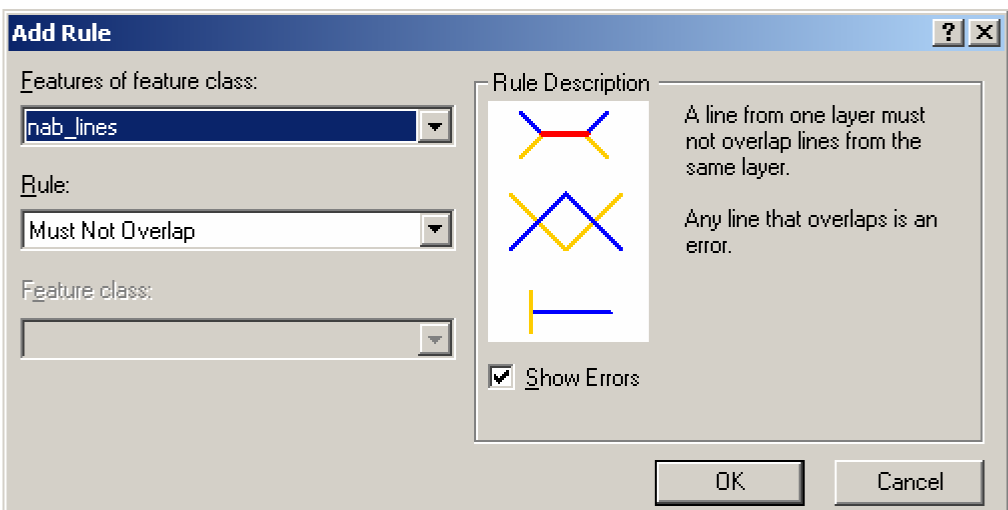
To maintain a topological association between ‘begin-and-end’ nodes with their respective linear feature class, the point and line features were stored as an integrated feature data set. A feature data set is a collection of feature classes that are grouped together based upon topological association among the features and/or they represent a homogeneous group of features.

The begin and end nodes for Districts 1, 2, 5, and 7 were generated in ArcInfo which was needed to build the node feature class derived from the linear features that were created in GIS. Once the nodes were created, the Unique Identifiers (i.e., noise barrier identification number (NBID)) were associated with begin and end nodes representing a single wall. This allows a relationship class to exist between the node or point feature class and the line feature showing discrete x,y coordinates depicting the beginning and ending points of a wall.

7.5 Validation Rules

By managing data in a geodatabase, the user can define rules about how the data can be edited. Since the NBGD only contains the line and point feature classes within a single feature dataset, the only topological rule that was added for demonstration purposes was that line features cannot overlap. This is to prevent users from inadvertently overlapping two line features that may share the same node which was commonplace for the wall data obtained from District 6.

Exhibit 7.5.1 Illustration of validation rules.



7.6 Use of Subtypes to Control Object Behavior

By managing data in the Noise Barriers Geodatabase (NBGD), the user can define the rules about how the data can be edited. Using the geodatabase, any user can set up subtypes and domains to ensure the attribute integrity of the database. For example, if a noise barrier wall needs to be identified by type of construction material (i.e., concrete blocks, precast-concrete, or wood), the user can establish a subtype for each type of constructed wall so that during data entry, users can easily associate or search by the appropriate attribute.

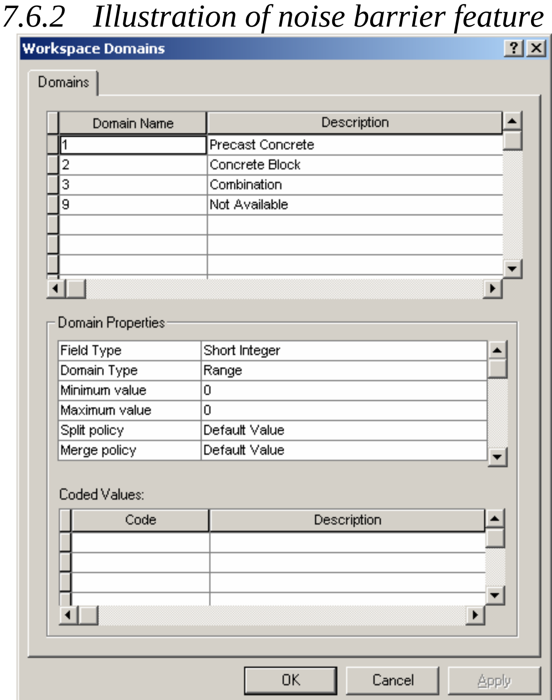
Domains control the allowable set of values that may be input for any field in a geodatabase table. For example, in the field designated to store construction materials (Material), there are variations in how the users entered ‘Precast Concrete’, 60 entries specified ‘Precast Concrete’ while 3 entries were input as ‘Pre-cast Concrete Pan’. Similar data entry errors occurred when identifying a combination of construction materials. A sample depicting the data entry variations for entering construction materials is shown in the table below.

Exhibit 7.6.1 Table of sample variations of data

Construction Material	Total Walls
Cast-in-place Concrete	14
Combination	**5**
Combination berm/wall	**1**
Concrete Block	8
No entry provided	126
Precast Concrete	**60**
Pre-cast Concrete Pan	**3**

Domains would limit the possibility of data entry errors because the choices for each data value are limited within defined parameters. As shown in the figure, a numeric value could be used for the construction material information within the noise barrier feature class.

Exhibit 7.6.2 Illustration of noise barrier feature class.

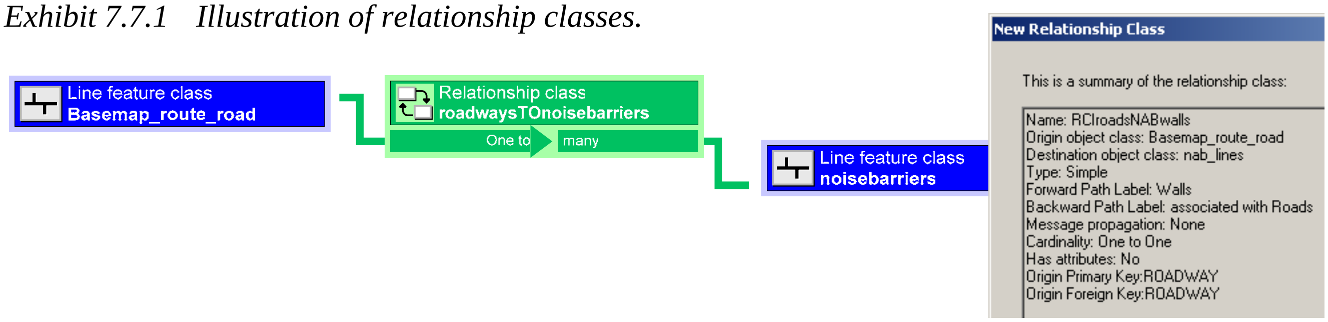


7.7 Use of Relationship classes

As stated earlier, the importance of the Key Identifiers provide users the ability to link together information derived from individual District offices. Unique Identifiers provide users the ability to create relationships among multiple tables within the geodatabase. Relationships are organized as relationship classes within the geodatabase. Each relationship class has the same origin class and destination class.

For example, if the user wants to see the relationship between the noise barriers and FDOT's roadway base map, the *origin object class* would be the *roadway* feature class while the *destination object class* would be the noise barriers. The relationship class between these two feature classes would be based upon a unique identifier common to both features, in this event, the 'Roadway' field which represents the Roadway Characteristics Inventory (RCI).

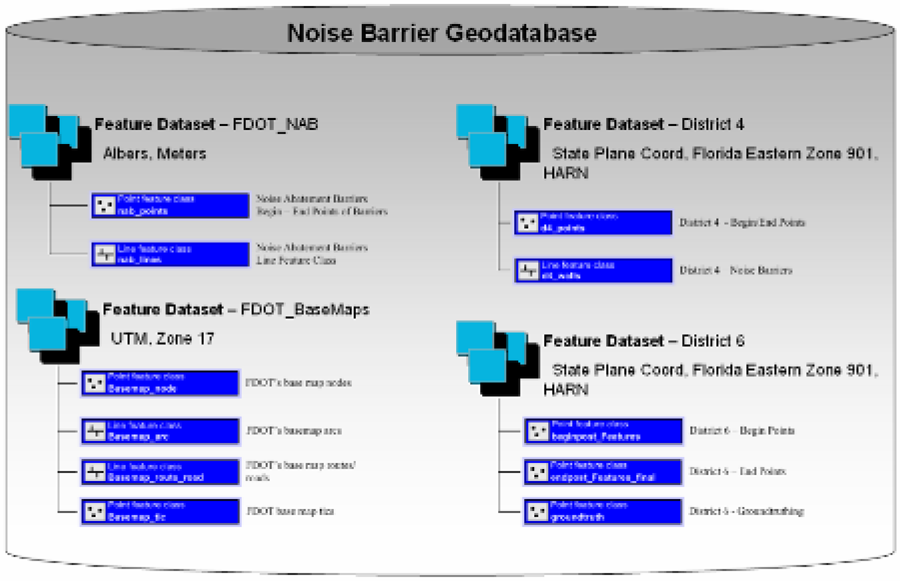
Exhibit 7.7.1 Illustration of relationship classes.



7.8 Geodatabase Diagrammer

The Geodatabase Diagrammer is an ESRI ArcScript which allows users to automatically generate the physical design of a geodatabase. Although the Geodatabase Diagrammer ArcScript is free and available online at www.esri.com, and requires the user have access to Microsoft, Microsoft Visio 5, or Visio 2000. Exhibit 7.8.1 below depicts the physical geodatabase designed for the Noise Barriers. The Feature Dataset called FDOT_NAB contains the point and line feature classes representing approximately 217 barrier structures throughout Florida. The other three feature data sets representing FDOT's base maps and noise barrier information collected independently by Districts 4 and 6. The complete Geodatabase Diagrammer is located in Appendix G.

Exhibit 7.8.1 Illustration of Noise Barrier Geodatabase.



VIII. APPLICATION INTERFACE

The application interface is a custom ArcGIS query tool to simplify access to specific data within the geodatabase.

The query tool is written in the native language of ArcGIS, that is, ArcObjects. ESRI created ArcObjects a 'flavor' of the Visual Basic language which is a Component Object Model (COM) based language. This language is also the basis for all Windows software and operating systems; therefore, the tool is also compatible and can be integrated with various Windows software products, such as Excel or Word. The code is written using the ArcGIS 9.0 Object Model, which is the most current version, so it may not be compatible with previous versions of the software since ESRI altered the Object Model in 9.0 from the previous version.

The query tool code is not encrypted, so FDOT will have access to the source code for expanding it, reducing it, or changing it as they see fit for their current and future needs. The code is integrated into the Map Document (mxd), so that to change the coding, the Visual Basic Editor tool would be utilized.

8.1 Functionality

Query – "to ask a question"; "a request for information".

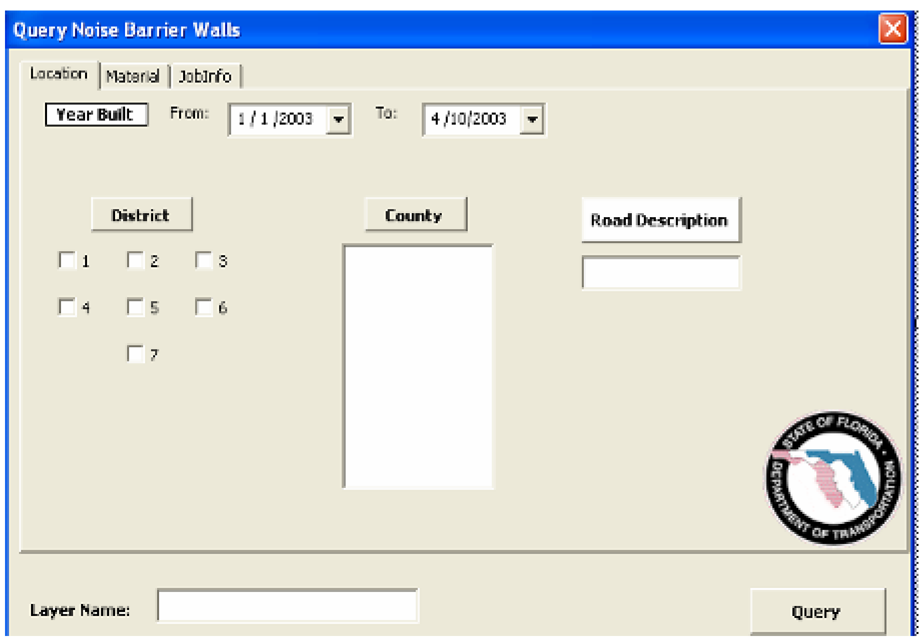
Current functionality within ArcGIS requires the end user to have some familiarity with Structured Query Language (SQL) to perform attribute or spatial queries. SQL is recognized as the Information Technology industry standard for requesting information from relational databases, and for certain classes of object oriented databases. The first SQL standard was adopted by American National Standards Institute (ANSI) in 1986. The current version ESRI supports and uses for both personal geodatabases (which utilize Microsoft Access) and ArcSDE supported Relational Database Management Systems (RDBMS) is the International Organization for Standardization (ISO) of 1992.

8.2 Design

The query tool design is based on the concept of a "wizard" tool. A wizard tool is a pop-up window that takes the user step-by-step through a process to allow them to ask a question of the geodatabase without writing a single line of SQL code.

The user initializes the query tool by selecting a button on the toolbar. Once selected, the wizard interface opens a new pop-up window on the screen. This query tool wizard has multiple items the user can choose, or not choose, to include in their question for the geodatabase. Once all items are chosen, the user gives the data selection a name and clicks OK. The tool then performs the query for the user and displays the results in the Table of Contents along with symbology representing the selection criteria. The user can then use any of the existing ArcGIS 9.0 standard tools to further view the data, such as opening the attribute table for the new layer symbolized.

Exhibit 8.2.1 Illustration of sample query for NBGD.



IX. RECOMMENDATIONS

The statewide Noise Barrier Geodatabase (NBGD) is the first and only comprehensive geodatabase designed to serve as an inventory for existing and future barriers. The geodatabase structure provides FDOT with the ability to store information on the job number and general location of the barrier as well as physical dimensions of each barrier; costs of each barrier; percentage of the total construction project cost; contractor; existing background levels without the walls and predictions related to future noise levels with and without the wall; construction dates; and any general information of value to FDOT.

It is recommended that the Environmental Management Office (EMO) located in the Central Office of FDOT, be the entity responsible for coordinating with other District offices in regards to acquiring any missing information needed to populate the geodatabase. Central Office EMO should also facilitate a standardized process where changes or additions can be submitted to the Central Office EMO from each District office so that the statewide geodatabase can be updated as part of the standard FDOT GIS base map layers, and make the NBGD available to all District offices. Specifically, the research team recommends that:

1. The statewide Noise Barriers Geodatabase (NBGD) be maintained and updated by the Central Office Environmental Management Office (EMO) and if possible shared with the Transportation Statistics Office, the current custodians of FDOT's GIS base map layers.

2. The EMO become the GIS data stewards where they would coordinate with the individual District offices regarding edits, updates, and additions to the NBGD, and be responsible for subsequent transfers to the Transportation Statistics Office.

3. The Noise Abatement Barriers be incorporated to FDOT's Base Map layers that are stored within their existing FDOT geodatabase representing these layers.

4. Standard operating policies and procedures be established where information pertaining to the walls will be transmitted directly from the District offices, including the District maintenance departments, to the Transportation Statistics Office for to geodatabase maintenance purposes. The Districts should use the Key Identifier (NBID) developed by CUES for the noise barriers when providing updated information about changes to existing walls as well information about new barrier construction.

5. The Noise Barrier Geodatabase (NBGD) should be enhanced by creating new validation rules such as using subtypes and domains for automatic attribute validation. For example, subtypes categorize attributes within a single field such as 'construction materials' in the geodatabase. This ensures data consistency by categorizing the data in the feature class without physically splitting the data into a separate layer.

6. Attached to the NGBD should be the acoustical data referenced for each of the noise barrier wall sites indicating both existing sound conditions and with the sound attenuating barrier in place in terms of sound data (dBA) expressed as the Level Equivalent (L_{eq}), and/ or L_{10} (Level exceeded ten percent of the time).

X. RECOMMENDATIONS FOR FUTURE RESEARCH

1. The NBGD represents a major first step in creating a meaningful relational data base of spatially referenced information geographically correlated to existing noise wall barrier systems to assist the Florida Department of Transportation. This represents a two-dimensional (2-D) data base.

2. Existing state-of-the-art technology in the area of computer based real-time virtual simulation (3D/4D) would increase the utility of NBGD relational data base by:

    a. Visually correlating the barrier and surrounding location in 3-D by incorporating the actual sound level data in order for FDOT and the community to see and hear the existing or proposed design solution(s)

    b. A virtual simulation of the noise wall barrier system site and barrier would allow the individual to utilize multiple eye points, or views (e.g., flyover, walkthrough) using a mouse to navigate. It provides a “magic carpet ride” allowing the user to fly anywhere in the scene (ground level, cross-section, aerial, plane view, any angle) to examine and validate options.

    c. Acoustical modeling would be correlated to the virtual visual navigation so the sound would change as of function of distance, vegetative cover and type and height of barrier.

    d. This virtual visual and sound tool (Geosonics) could be used in many applications including public hearings, scoping, infrastructure transportation design development and alternatives, community input, conflict-resolution and public participation, impact assessment and review, etc. When applied it has been shown to expedite time, enhance understanding, examine multiple options and assist in providing consensus and closure to the decision making process.

XI. References

Baldwin, Y.B. and Clark K.B., (1997). "Managing in an Age of Modularity," Harvard Business Review, September – October 1997. P84-93

Bragdon, Clifford. (2000). Chapter 3 "Simulation" in NCHRP Report, *Using Technology to Address Environmental Quality Issues in Transportation,* a National Cooperative Highway Research Project (NCHRP) for Pennsylvania Department of Transportation, in cooperation with CHM2Hill.

Clark, J., (2004). "Working with the Geodatabase using SQL Server," White Paper. Redlands, CA:ESRI Press.

Boyle, B., (2000). "Electronic government for New Zealand: Managing the Transition," Thesis, Boston, MA: Massachusetts Institute of Technology.

Daniels, Mitchell E., (2001). "Memorandum for the Heads of Executive Departments and Agencies," Office of Management and Budget, The Executive Office of the President (USA).

Dunn, S.E. and Smart, R.C., (1986). *Determination of Vehicle Noise Levels for Highway Noise Computer Model*, Boca Raton, FL: Florida Atlantic University.

Dunn, S.E, (1988). *Investigation of the Effectiveness of Noise Barriers Along I-275 and I-95,* Boca Raton, FL: Florida Atlantic University.

Fekpe, E.S., Novak, K., et al (2003). *Quality and Accuracy of Positional data in Transportation*, NCHRP Report 506. Washington, D.C.: Transportation Research Board.

Florida Department of Transportation (FDOT), (2000). *Noise Barrier Status Report,* prepared by Win Lindeman, Tallahassee, FL: Environmental Management Office (EMO), FDOT Central Office.

Glegg, S.A. and Yon, J.R., (1989). *Determination of Noise Source Height of Vehicles on Florida Roads and Highways,* Boca Raton, FL: Florida Atlantic University.

Goodchild, Michael, K. Curtin, S Grise, V. Noronha, (2004). *ArcGIS Transportation Data Model (UNETRANS) – ArcGIS 8.3.*, Redlands, CA: ESRI Press

Gronmo, R., Berre, A., Soldheim, I., Hoff, H. and Lantz, K., (2000). "DISGIS: An Interoperability Framework for GIS – Using the ISO/TC 211 Model-based Approach," The fourth Global Spatial Data Infrastructure Conference 2000, Cape Town, South Africa: ISO/TC 211 Scope , 2001

Guo, Bo, Poling, Allen, and Poppe Mark, (1995). “GIS/GPS in Transportation, Real World Experiences” ESRI 1995 Conference Proceedings at http://gis.esri.com/library/userconf/proc95/to250/p.249html.

Landgraf, G., (1999). “Evolution of EO/GIS Interoperability; Towards an Integrated Application Infrastructure,” paper presented at the Interop99, Zürich, Switzerland.

MacDonald, Andrew, (2000). *Building a Geodatabase*, Redlands, CA: ESRI Press

Mann, Cary and Daugherty, Kevin, (2003). “Bentley/ESRI: Architecture, Engineering, and Construction (AEC) and Geodatabase-Interoperability,” white paper, Redlands, CA: ESRI Press

Peters, D. (2002). System Design Strategies. *ESRI, 1-171*

Pfeilsticker, Renee, Doty, Suzanne, and Zwick, Paul, (2003). *Applying GPS and ArcView GIS to NPDES MS4 GIS Data Collection Application,* Gainesville, FL: for the Florida Department of Transportation by the University of Florida GeoPlan Center. [website: http://gis.esri.com/library/userconf/proc99/proceed/papers/pap516/p516.htm]

United Kingdom, Office of the Deputy Prime Minister, (2003). GLOSSARY. Retrieved February 1, 2004 from the World Wide Web: http://www.bvpi.gov.uk/pages/glossary.asp#e

Vckovski, A, (1998). *Interoperable and Distributed Processing in GIS,* London: Taylor & Francis.

Vckovski, A., Brassel, K. E., & Schek, H.-J, (1999). Proceedings of the 2nd International Conference, March, 1999.

Wayson, R.L, (1997). *A Method to Determine Reasonableness and Feasibility of Noise Abatement at Special Use Locations,* Orlando, FL: University of Central Florida.

Wayson, R.L., McDonald, J.M., El-Aassar, A., and Arner, W, (2002). *Continued Evaluation of Noise Barriers in Florida*, Orlando, FL: University of Central Florida.

Wayson, R.L., McDonald, J.M., El-Aassar, A., and Chua, C.B, (2003). *Continued Evaluation of Noise Barriers in Florida,* Orlando, FL: University of Central Florida.

Wiederhold, G., (1992). “Mediators in the Architecture of Future Information Systems”, *IEEE Computer*, 25(3), 38-49.

Zeiler, Michael, (1999). *Modeling our World,* Redlands, CA: ESRI Press

Appendix A: Glossary of Terms

***Acoustics* –** Of or relating to sound, the sense of hearing, or the science of sound.

Feature classes- Collections of points, lines, polygons, or annotation (map text managed as feature tables. Related feature classes are managed as collection in feature data sets.

***Geodatabase* –** A physical store of geographic information inside a database management system.

***GIS* –** Geographical Information System(s): An integration of software and hardware tools for the input, analysis, display, and output of spatial data and associated attributes.

***GPS* –** Global Positioning System: By use of 24 satellites, a worldwide radio-navigation system is able to determine the latitude and longitude of a receiver on Earth.

***Noise* –** Any sound which annoys or disturbs humans or which causes or tends to cause an adverse psychological or physiological effect on humans; unwanted sound devoid of informational content; unpleasant, unexpected, or undesired.

***Noise Barriers* –** Solid obstructions built between a transportation corridor (noise source) and the region adjacent to the transportation corridor (noise receiver). A barrier system constructed of manmade and/or natural materials is designed to mitigate the propagation of noise between the noise source and the receiver, thereby minimizing the impact of noise to the receiver (i.e. population, sensitive land use, etc.).

***Shapefile* –** Computer files that store non-topological geometry and attribute information for spatial features in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates (ESRI® Shapefile Technical Description).

***Sound* –** An oscillation in pressure in a medium capable of evoking the sensation of hearing for humans in the sonic frequency range of 20 to 20,000 Hertz (Hz). This description of sound can be characterized by intensity, frequency and duration.

***Tables*—**A collection of rows or records containing fields or columns used to represent nongraphic objects.

Appendix B: List of Acronyms

AVL	automatic vehicle location
CUES	Center for Urban and Environmental Solutions
DBMS	database management system
DMI	distance measuring instruments
EMO	Environmental Management Office
ESRI	Environmental Systems Research Institute, Inc.
FDOT	Florida Department of Transportation
FGDL	Florida Geographic Database Library
FIPS	Federal Information Processing Standard
FM#	Financial Management Number
GIS	geographic information system
GPS	global positioning system
GUI	graphical user interface
ISO	International Standard Organization
ITS	intelligent transportation system
NEPA	National Environmental Policy Act of 1969
NBGD	noise barrier geodatabase
PD&E	project development and environment
RCI	Roadway Characteristics Inventory
UTM	Universal Transverse Mercator
WPI	work program index

Appendix C: Results Survey No. 1

FDOT: BD-546
NBGD: SURVEY #1 ANALYSIS

Respondents:

Noise Barrier Specialists (NBS)

District 1	Mark Schultz
District 2	Donald Dankert
District 3	Natalie Kent
District 4	Gregor Senger
District 5	Bill Walsh, Project Manager
District 6	Marjorie Bixby, Environmental Administrator
District 7	Robin Rhinesmith
Turnpike	John M. Post, Jr.

GIS Coordinators

District 4	Michelle Chalfant
District 7	Tom Kelly

Other FDOT Staff

District 4	Scott McDermott, Transportation Specialist
District 4	Richard W. Miller, Environmental Specialist
District 6	Xavier Pagan, Environmental Specialist, GIS and Tim Ogle, Consultant
District 7	William Turner, Maintenance Management, System Manager

Question Responses:

Q#2 How would you describe your exposure to noise barrier data?

	Possess	Collect	Have Access to	Do not have access
NBS	**7**	**5**	**7**	**0**
GIS	**0**	**0**	**1**	**1**
Others	**0**	**1(M)**	**2**	**0**

Comments and Conclusions:

- All NBS responded that they possess and have access to the data, some of them also collect it. Others who collect the data may include maintenance personnel.
- NBS maintain noise barrier (NB) data, but others have access to and use it.

Q#3: In what format is this data maintained?

	Spreadsheet	Word Doc	Database	GIS	CADD	Other
NBS	3	6	0	0	2	2*
GIS	0	1	1	0	0	2✦
Others	1	1	1(M)	0	1	0

* Individual Environmental Document; hard copy files; georeferenced microstation drawings of walls in plain view

✦ Transitioning to geodatabase (D4)

Comments and Conclusions:

- It isn't apparent that NBS maintain NB data in database or GIS format. Only two responded that they maintain NB data in a database: one is a GIS coordinator and one isn't. No one is maintaining the information in GIS format.
- This means thatthe project team will be conducting most of the work as it relates to digitizing and converting the existing data into GIS format. However, D4 has indicated that it is transitioning into geodatabase. (See also interviews for more details). This means that the transition to a geodatabase with NB data will be easier for that district.

Q#4 Do you use GIS?

	Yes	No	Not implemented in my Dept
NBS	2	4	2
GIS	2		
Others	1	1	1 (M)

Comments and Conclusions:

- Most NBS did not indicate that they have any kind of access to GIS. The projec team can propose to redress the issue of establishing access for the NBS to GIS and the future geodatabase through protocol.
- Recommendations: provide NBS access to District GIS to enable them to update the NBGD.

Q#5 What is your current GIS platform?

	ArcView 3X	ArcInfo	ArcGIS	ArcView8 x	Intergrap h	MapInfo	Other
NBS	2	1	2	2	0	0	4*
GIS			1	1			
Others	1✦	1✦	1✦	1✦			✦

✦ Replies from District 4, Scott McDermott

* Replies:

- ArcGIS8 Spatial Analyst
- Don't Use
- ArcIMS
- Handled by others
- TransCADD

Comments and Conclusions:

- Some Districts have several platforms, while others have limited or older versions. Recommendation: If an Enterprise GIS is developed and it is maintained elsewhere, this could provide some assurance that it will be maintained in a more recent GIS format and also help resolve the access problem.
- Need to verify if TransCADD is compatible with ESRI products. However, since the NBID is not currently maintained in that format,the project team probably don't need to worry about it.

Q#6 How are GIS Projects handled in your department?

	Internally, by own GIS staff	Outsourced, contracted consultants	Combination of a and b	Other
NBS	**4**	**1**	**1**	**2 Handled in other Dept.**
GIS	**1**		**1**	
Others	**1 (M)**	**1**	**1**	

Comments and Conclusions:

- Probably all Districts maintain some sort of GIS system, the issue is that not all of them are using the most recent generations of software. In addition, not all NBS have direct access to GIS. This will have an effect on how the database is maintained and updated. In addition, it is also known that some of the NBS would like more direct access to the information, particularly when they need to handle complaints or provide more immediate information for reporting purposes.
- The problem with outsourcing is providing access to the Enterprise GIS or other form.

Q#7 Describe your GIS, is your GIS:

	Desktop Standalone	Network GIS Multiusers	Enterprise GIS	Other	Describe
NBS	**2**	**3**	**0**	**3**	**Don't use; handled by others**
GIS	**1**	**1**	**1**	**1**	**Under Development**
Others	**1**				

Comments and Conclusions:

- Standalone desktop formats imply that data is not being shared. This can create problems with compatibility because information updates, layer creation, and modification of underlying maps are being done separately. In the interviews, it also became apparent that communication is poor between GIS coordinators who are located in different department and between GIS coordinators from different districts. The latter type of communication may not even exist, in many cases.

- Ideallythe project team would want to see an Enterprise GIS, but a Network GIS that is being maintained and coordinated by a single manager with the different departments that use the information may also work. Unfortunately, however, the same compatibility issues may arise when the Districts try to share information between districts or with Central Office due to the risk of having different formats or different base information.

Q#8 How is your GIS data stored?

	Standalone	Network Internal to District	Network Shared by others	Consultant	Other	Describe
NBS	**3**	**2**	**1**	**1**	**2**	**Don't use; handled by others**
GIS	**0**	**2**	**1**	**0**	**1**	**Under development**
Others	**1**					

Comments and Conclusions:

- Again, the prevalence of a combination of standalone, internal, and consultant maintained databases points to the potential for incompatibility issues when there is a desire to share the information.

Q#9 Is your GIS linked to other databases?

	Yes	No	No response
NBS	**2**	**4**	**2**
GIS	**1**	**1**	
Others		**1**	**2**

Comments and Conclusions:

- These responses continue to highlight the fact that GIS doesn't seem to be coordinated internally within the Districts or very rarely.

Q# 10 Describe links:

- FGDL
- Linked to ArcIMS, with construction office as well as FGDL
- Handled by others
- Work program--many internal maintained by different departments and GIS maintained

Comments and Conclusions:

- FGDL is one of the few outside links between databases, however, the project team continues to question compatibility issues related to maintaining and updating an NBGD.

Q# 11 Do you share data with other districts?

	Yes	No
NBS	**3**	**5**
GIS	**1**	**1**
Others	**3 (M)**	

Comments and Conclusions:

- Only 3 out of a possible 8 NBS share their NB data with other Districts. Most data is shared directly with Central Office for reporting purposes. However, Central Office sees the benefit of being able to share information, reason for this project.

Q# 12 If yes, how is this data shared

	Spreadsheet	Word Doc	Database	GIS	CADD	Other
NBS	**0**	**1**	**0**	**2**	**0**	**3**
GIS				**1**		
Others	**1**	**0**	**1**	**1**		

Comments and Conclusions:

- Answers to his question conflict with an earlier question #3, which indicated that no one maintained the data in GIS format. Therefore, it is probable that they are referring to other types of data that is being shared.
- Should the project team ask what types of data is shared with other districts?

Q# 13 Do you maintain or update geodatabases?

	Yes	No
NBS	**3**	**5**
GIS	**2**	
Others	**2 (M) ***	**1**

Comments and Conclusions:

- Again, this question conflicts somewhat with earlier questions where they responded that they do not maintain a geodatabase. Unless, they are referring to FGDL. However, the majority responded as expected, that they do not maintain or update a geodatabase.

Q# 14 If no, who is responsible?

- **Lawrence Massey**
- **Consultants and staff**
- **Mapping Department**

Comments and Conclusions:

- Assume that Lawrence Massey is a consultant?

Q#15 Do you use orthophotographs?

	Yes	No

NBS	**7**	**1**
GIS	**2**	
Others	**2**	**1 (M)**

Comments and Conclusions:

- Most of the respondents use orthophotographs. Part of the reasoning behind this question had to do with identifying sources of orthos for digitizing the walls.

Q#16 What is your source for orthophotographs?

	Local FDOT District	**FDOT Headquarters**	**Local Gov't**	**Educational**	**Geoplan**	**Other**
NBS	**5**	**3**	**2**	**2**		
GIS	**2**	**1**	**2**	**1**		
Others	**2**		**1**			

Comments and Conclusions:

- Most Districts seem to have a library of orthophotographs, however, scale and age may need to be identified.
- Geoplan or FDGL was not identified as a source of orthophotographs, when it is.

Q#16 What do you use orthophotographs for?

	Digitizing	**Site/LU verification**	**Other: reasons**
NBS	**2**	**5**	**3:** **Mapping;** **Mapping coordinates by hand;** **Noise studies; Overlays for many purposes**
GIS	**1**	**2**	**1**
Others	**1**	**1**	**1: contamination, parks, land use**

Comments and Conclusions:

- As expected, the orthophotographs are being used to map and verify information. However, it is known that these maps are not in GIS format.

Q# 17 At what scale do you use the orthophotographs?

- 1”=400’
- 1:200
- 1:01
- Various, varies, depending on the scope of the project and the extent of the impact.

Comments and Conclusions:

- The scales mentioned are not useful for this project.

APPENDIX D: RESULTS SURVEY NO. 2

FDOT: BD-546
NBGD: SURVEY #2 ANALYSIS

Respondents:

<u>NB Specialists:</u>

2	Donald Dankert	Jacksonville
3	Natalie Kent	Tallahassee
4	Gregor Senger	Broward/PBC
6	Tim Ogle (consultant)	Miami/Monroe
6	Marjorie Bixby, Environmental Administrator	Miami/Monroe
TPK	John Post, Jr.	Turnpike District

<u>GIS Coordinators:</u>
4 Michelle Chalfant

<u>Others:</u>
4 Richard Estabrook, Principal Investigator
4 Ann Broadwell, Environmental Administrator, EMO
6 /Xavier Pagan, Environmental Specialist (GIS)

Responses:

Q# 1 Do you possess a current list of NBs in your district?
All Districts with NB responded that they had an updated list.

Q#1a Is the list kept in a relational database?
Only Turnpike keeps the list in a relational database.

Q#2 Do you have access to As Builts for NBs?
Four out of seven respondents have access to As Builts, and one does not. Two did not respond.

Q#3 What format are the As Builts kept in?
One district keeps them in PDF format and another in TIF, two have access to hard copies in or paper formats, of them one also keeps copies on a microstation.

Q#4 How important is it for your section to have the following information available in the NBGD?

From the existing list of fields, the most important for all respondents (Most answered “Important” with fewer than 2 answering “Somewhat Important”) included:

- Barrier ID
- Yr Built
- Barrier Material
- District
- Length (ft)
- Height (ft)
- Area (ft2)
- Total Cost
- Cost (ft2)
- IL predicted
- IL measured Comments

One existing field was less important, but still somewhat important (3 or fewer responding that they are “Important”):

- WPI#

The rest were not very important at all (fewer than one responding “important” and most responding “not important”):

- Contractor
- Dimensions in meters: length, height, area, cost/m2

From the new fields scoped we received the following responses:

The most important for all respondents (Most answered “Important” with fewer than 2 answering “Somewhat Important”) included:

- County
- City
- Adjacent Neighborhood
- Project Related Roadway
- Photo Image
- As Built Link
- Begin Mile Marker

Fields that were less important, but still somewhat important (3 or fewer responding that they are “Important”):

- FM#
- Nearest Cross Road
- Last Maintained
- Paint Code
- Begin and End x coordinates
- Begin and End y coordinates

For the last fields, several were not sure. However, given that the respondents were Noise Specialists and not GIS coordinators, that can be understood.

Additional fields that were not considered important include:

- FM#
- Block style and/or code

Q# 5 During what stage of the pre- and post-construction process do you foresee using the fields in the NBGD?

FIELD	PD&E	Design	Construction	Post-Construction	Row Totals
Barrier ID	**6**	**7**	**6**	**6**	**25**
WPI	3	4	2	4	13
Contractor	0	1	**5**	**5**	11
Year Built	0	1	1	**7**	9
Barrier Material	0	4	1	**5**	10
District	**5**	**6**	**5**	**5**	**21**
Length (m/ft)	0/**6**	0/**7**	2/**6**	4/**7**	6/**23**
Height (m/ft)	2/4	2/**5**	2/4	4/**5**	6/**18**
Area (m2/ft2)	1/4	1/**5**	¼	3/**5**	6/**18**
Total Cost	**6**	**5**	3	**7**	**21**
Cost/Area $/m2: ft2	2/**6**	2/4	¼	3/**7**	8/**21**
IL Predicted	**6**	**5**	2	3	16
IL Measured	4	3	2	**6**	15
Comments	4	5	5	**6**	**20**
FM#	**5**	4	4	**6**	**19**
County	**6**	5	4	**6**	**21**
*City	**5**	4	3	**7**	**19**
Adjacent Neighborhood	**6**	**5**	4	**6**	**21**
Project Related Roadway	**7**	**6**	**5**	**7**	**25**
Nearest Crossroad	2	3	2	3	10
Photo Image	3	2	2	**7**	14
As-Built Link	1	1	0	**6**	8
Last Maintained	0	0	0	**6**	6
Paint Code	1	0	1	**5**	7
Block Style	1	0	1	4	6
Block Code	0	0	1	4	5
Begin Mile Marker	4	6	4	**7**	**21**
End Mile Marker	4	6	4	**7**	**21**
Begin x coordinate	1	2	3	**6**	12
Begin y coordinate	2	3	3	**6**	14

End x coord	2	3	3	**6**	14
End y coord	2	3	3	**6**	14
Additional fields	Imprint: for tracking				
	Wall texture: instead of block style				
	Begin & End Station Number: could replace mile marker for accuracy or simply an addit'l field.				
	Number of benefited receivers				
	Road ID: require to plot using mileposting				
	Old State Project No. (WPI#?): associated with older documents				
	Barrier type				

* Only NBS responded to this question

NOTES:

- Metric measurements are no longer deemed very relevant
- Some activities are clearly front end in the planning through post construction process, while others are back ended. Front ended activities would naturally be related to the PD&E process, while the back ended activities would be related to post-construction activities, including reporting to Central Office and tracking NB related complaints.
- The most significant variables with 18 or more points included:
    - Barrier ID
    - Length, height, and area measured in ft/ft2
    - Total cost and cost/area in ft2
    - Comments
    - FM #
    - Location variables such as county, city, adjacent neighborhood and project related roadway
    - Begin and end mile markers
- Other significant variables at one or other point of the process included:
    - IL Predicted and IL Measured
    - Photo images
    - Begin and end x, y coordinates
- At the front end of the project the most important variables included:
    - Barrier ID
    - District
    - Length (m/ft)
    - Height (m/ft)
    - Area (m2/ft2)
    - Total Cost
    - Cost/Area $/m2: ft2
    - IL Predicted
    - FM#
    - County
    - City

    - Adjacent Neighborhood
    - Project Related Roadway
- After construction, the most of the variables are important, including:
    - Barrier ID
    - Contractor
    - Year Built
    - Barrier Material
    - District
    - Length (m/ft)
    - Height (m/ft)
    - Area (m2/ft2)
    - Total Cost
    - Cost/Area $/m2: ft2
    - IL Measured
    - Comments
    - FM#
    - County
    - City
    - Adjacent Neighborhood
    - Project Related Roadway
    - Photo Image
    - As-Built Link
    - Last Maintained
    - Paint Code
    - Begin Mile Marker
    - End Mile Marker
    - Begin x coordinate
    - Begin y coordinate
    - End x coord
    - End y coord

    - With the exception of:

        - WPI #
        - Block style and code
        - Nearest cross road

The latter list may be eliminated from the final list.

Q# 6 Is there a protocol for submitting data (GIS files) to Geoplan?

Only one person responded “yes”, but didn’t know the process.

Q# 7 Is there a protocol for submitting data (GIS files) to RCI?

Only one person responded "yes", who indicated that while they didn't know the protocol, they knew that the information had to be provided through the Planning Office.

Q#8 Are there specific fields required for submitting data to depositories such as RCI and FDGL/Geoplan?

No one responded.

Q#9 Please check all database management systems that you are currently using with your GIS.

- Access: 5 responses, only 2 from NBS.
- SQI Server: one response from an NBS
- IBM DB2, Informix: no responses
- Oracle: one response
- Other: DBF, and SQL server is used on the Arc IMS application and is linked via a query URL that allows for searches by FM number only—no true connection.

Observations:

- Three of the 9 responses came from D6, three others came from D4 GIS, and the other three came from different individual, two of which are from D4. Three of the five responding districts did not mention what system they use. We assume it is only Access.

Q#10 Does your agency use web-based mapping?

- Yes, internally only (D4)
- No, but we will be implanting it in the next 6-12 months (D6, consultant)
- Yes, internally only (D6)
- Yes, internal and external (TPK)

Appendix E: Data Acquisition Samples

Turnpike Noise Barrier Update

FINANCIAL PROJECT #: 232352-1

LOCAL NAME: State Road 869 (Sawgrass Expressway) Widening from South of Sunrise Boulevard to South of Atlantic Boulevard; Broward County.

DESCRIPTION: Four noise walls were built on the Sawgrass Expressway at a cost of $4,867,500. All walls are on the east side of the highway.
BARRIER DIMENSIONS:

(Noise Barrier #1)From south to north an 8-foot wall for 200 feet transitioning to a 12-foot wall for 2700 feet and then transitioning to a 10-foot wall for the last 200 feet. Begins at station 126+00 and terminates at station 157+00 for a total length of 2,900 feet.

(Noise Barrier #2) From south to north a 10-foot wall for 2900 feet transitioning to an 8-foot wall for the last 100 feet. . Begins at station 245+00 and terminates at station 275+00 for a total length of 3,000 feet.

(Noise Barrier #3) From south to north an 8-foot wall for 200 feet transitioning to a 10-foot wall for 1500 feet and then transitioning to an 8-foot wall for the last 100 feet. . Begins at station 289+00 and terminates at station 307+00 for a total length of 1,800 feet.

(Noise Barrier #4) From south to north a 10-foot wall for 100 feet, transitioning to a 12-foot wall for 100 feet transitioning to a14-foot wall for 200 feet, transitioning to a 12-foot wall for 400 feet and then transitioning to a 12-foot wall for the last 5,650 feet. . Begins at station 390+00 and terminates at station 466+50 for a total length of 7,650 feet.

BARRIER AREA:	(Noise Barrier #1)	38,150 square feet
	(Noise Barrier #2)	32,900 square feet
	(Noise Barrier #3)	19,500 square feet
	(Noise Barrier #4)	104,150 square feet
	TOTAL	**194,700** square feet

BARRIER COST:	(Noise Barrier #1)	$953,750.00
	(Noise Barrier #2)	$822,500.00
	(Noise Barrier #3)	$487,500.00
	(Noise Barrier #4)	$2,603,750.00
	TOTAL	**$4,867,500.00**

Turnpike Noise Barrier Update

FINANCIAL PROJECT #: 258927-1-52-01

STATE JOB #: 97103-3300 & 97103-3301

WPI#: 7153119

LOCAL NAME: Suncoast Parkway, Section 1B, Sound walls were constructed on both sides of the roadway from the north side of Ramblewood Boulevard to the south side of Lutz Lake Fern Road.

CONTRACTOR: Cone Constructors, Inc. (defaulted), PCL was the “Take-over” Contractor under the Surety, St. Paul Fire and Marine Insurance Co.

CONSTRUCTION BEGIN: September 8, 1998

CONSTRUCTION END: April 27, 2001

BARRIER TYPE: Most of the sound walls are a combination of precast post and panel section varying from 4’-6” (for the 8’ sound Barrier Wall) to 6’-6” (for the 10 sound Barrier Wall), placed on reinforced concrete barrier wall (either shoulder concrete barrier wall construction or traffic railing on MSE wall). Across the TPC Bridge, the sound wall was cast-in-place on top of the traffic railing at a height of 5’-4”. The pre-cast panels are a double vertical raised textured panels – 20’ in length. There are the alternating vertical raised textured 1’5” wide, 2” deep panels and progressive logo panel sections, which have up to 3 logos per panel (logo is a representation of *Andropogon* sp.). The barrier wall portion of the sound wall has a 3” wide x 2” deep reveal at 10” from the top and has a class V finish in a dark tan color. The top of the barrier wall is 14” wide to accommodate the panels. The precast panels have a class V finish in a light tan color, but the recessed logo is a dark tan.

BARRIER LENGTH: 10’ – 2,881 Ft.; 8’ – 4,445 Ft.; 9’ – 848.5 Ft. = 8,174.5 Ft. Total

BARRIER AREA: 42,904 SF (Total)
10’ - C3 1083+18.63 -1088+67.50 on MSE portion
- C4 1088+67.50 - 1107+00 on barrier wall (shldr.)
- D1 1107+00 -1112+ 00 on MSE portion
8’ - C5 1091+87.62 – 1094+00 on barrier wall (shldr.)
- C6 1094+00 – 1103+00 on MSE portion
- C7 1103+00 – 1112+73.79 on barrier wall (shldr.)
- TPC bridge ~ 129’
- F1 1114+04.46 – 1120+00 on barrier wall (shldr.)
- F2 1120+00 – 1136+33.04 on MSE portion

9’ - F3 1127+86.52- 1131+65 rt. on barrier wall (shldr.)
- LLF1 1131+65 – 1136+35.02 on MSE portion

BARRIER HEIGHT: 10’ – 2,881 Ft.; 8’ – 4,445 Ft.; 9’ – 848.5 Ft. (wt. average = 8.7 Ft.) (These heights are inclusive of barrier wall and traffic railing from top of asphalt surface to top of sound wall.)

BARRIER COST: $1,193,202.80.
The cost of the sound wall pre-cast panels and the portion cast in place at the bridge is $673,592.80 (42,904 SF @ $15.70/SF). The barrier wall (shoulder) utilized to support the panels was $559,580.00 (3,997 LF @ $140/LF); but guardrail would have been used if no sound wall treatment was designated in the area which would be a credit of $39,970 (3,997 LF @ $10.00/LF). There was approximately 4,052 LF of traffic railing for areas at the MSE wall which is paid for under pay item 528-70 Reinforced Earth Wall. No cost is calculated, because this would be in place with or without the sound wall; although the walls were thicker than normal so there may have been a slight increase.

BARRIER COST AS A % OF TOTAL CONSTRUCTION PROJECT: 3%

EXISTING NOISE LEVEL: 51 dBA (Leq)

PREDICTED NOISE LEVEL (without barrier): 69 dBA (Leq)

AVERAGE BARRIER INSERTION LOSS PREDICTED: 6 dBA

AVERAGE BARRIER INSERTION LOSS MEASURED: not measured

COMMENTS: There are three sound wall locations. The 8' sound wall starts on the left roadway at Sta. 1091 + 87.62 and ends at Sta. 1136+33.04. The 10' sound wall starts on the right roadway at Sta. 1083 + 25.12 and ends at 1112 + 00. The 9' sound wall starts on the right roadway at Sta. 1131 + 65 and ends at 1136 + 35.02.

Turnpike Noise Barrier Update

FINANCIAL PROJECT #: 409289-1

LOCAL NAME: Widen Four to Six Lanes, from Boca Raton to Delray;
Palm Beach County

DESCRIPTION: The noise barrier is constructed along the west side of the Turnpike between S.R. 808/Glades Road and S.R. 794/ Yamato Road. The project is located in Section 8, township 47 south, Range 42 east in unincorporated Palm Beach County. The 1.1 mile noise wall begins at milepost (MP) 76.662 and ends at MP 77.730. The noise barrier was built under a separated construction contract from the widening project.

BARRIER LENGTH: 5,640 feet

BARRIER HEIGHT: 19 feet

BARRIER AREA: 107,160 square feet

BARRIER COST: $3,607,477.00

District 6 Noise Barrier Update

	Begin			End							
Name	Mile Post^	North Coordinate	East Coordinate	Mile Post^	North Coordinate	East Coordinate	Length (feet)	Height (feet)	Approximate (area)	Approximate Overlap (feet)#	Notes
NB-1	4.934	538617.7576	917679.0279	5.094	539438.044	917538.9813	860	20	17,200	N/A	
NB-2	5.071	539341.3951	917501.5604	5.212	540088.8333	917430.5096	752	19	14,288	121	
NB-3a	5.249	540275.155	917402.186	5.288	540474.8501	917391.4208	200	20	4,000	N/A	
NB-3b	5.288	540474.8501	917391.4208	5.342	540774.6731	917381.1238	300	20	6,000	0	
NB-3c	5.342	540774.6731	917381.1238	5.382	540974.5111	917373.1344	200	20	4,000	0	
NB-3d	5.382	540974.5111	917373.1344	5.55	541868.0194	917325.327	892	19	16,948	0	
NB-3e	5.55	541868.0194	917325.327	5.577	542004.1488	917317.8773	138	17	2,346	0	
NB-3ee	5.577	542004.1488	917317.8773	5.583	542033.8555	917316.2751	29	17	493	0	
NB-3f	5.583	542033.8555	917316.2751	5.593	542090.1237	917313.2404	57	17	969	0	
NB-3g	5.593	542090.1237	917313.2404	5.627	542272.6384	917303.3968	183	17	3,111	0	
NB-3h	5.627	542272.6384	917303.3968	5.665	542475.6841	917291.9508	203	16	3,248	0	const.
NB-3j	5.78	542968.6312	917262.7762	6.112	544737.695	917485.2328	1,848	16	29,568	N/A	
NB-4	6.099	544728.7917	917437.2304	6.235	545457.8703	917460.5527	731	15	10,965	69	
NB-5	6.270	545658.8009	917449.9107	6.412	546391.4718	917417.5561	739	19	14,041	N/A	
NB-6	6.396	546308.1295	917461.6775	6.658	547628.0815	917412.5294	1,320	18	23,760	84	
NB-7a	6.644	547605.3936	917480.4794	6.659	547687.1228	917410.8059	111	17	1,887	74	
NB-7b	6.659	547687.1228	917410.8059	6.742	548134.5603	917391.089	450	17	7,650	0	
NB-9	7.079	549888.6244	917186.5624	7.202	550496.1505	916960.591	624	19	11,856	N/A	No NB-8 in project design plans.
NB-10	7.173	550337.5414	916965.1295	7.263	550808.3026	916848.732	485	18	8,730	153	
NB-11	7.306	551020.3717	916833.4813	7.383	551158.0858	916805.7836	439	18	7,902	N/A	
NB-12	7.429	551658.555	916793.5747	7.518	552140.1713	916754.1885	482	18	8,676	N/A	
NB-13a	7.491	551896.3397	916843.7798	7.583	552478.8424	916765.7284	489	19	9,481	143	
NB-13b	7.583	552480.5768	916766.4071	7.761	553418.848	916729.3827	940	20	18,800	0	
NB-14	7.793	553588.4583	916741.6698	8.117	555237.7044	916631.639	1,700	18	30,600	N/A	
NB-15	8.159	555513.2307	916631.5648	8.284	556175.8412	916609.6406	663	18	11,934	N/A	
NB-16	8.326	556403.3755	916602.2634	8.442	556993.694	916582.523	596	18	10,728	N/A	
NB-17	8.393	556754.701	916579.202	8.723	558501.132	916508.535	1,800	18	32,400	259	
NB-18	8.702	558312.056	916536.306	8.792	558857.56	916521.266	476	18	8,568	111	
NB-19	8.832	559064.3129	916514.716	8.934	559612.5100	916490.525	549	18	9,882	N/A	
NB-20a	8.977	559274.1088	916500.2411	8.994	559343.5252	916571.2407	70	14	980	330	
NB-20b	8.994	559343.5252	916571.2407	8.995	559926.3071	916473.9445	530	14	[illegible]	0	
NB-20c	8.995	559926.3071	916473.9445	9.298	561506.4005	916355.9053	1,586	14	22,204	0	
NB-21	9.334	561657.4856	916347.655	9.482	562477.9473	916312.0943	781	14	10,934	N/A	
NB-22	9.552	562834.1088	916309.1243	9.704	563707.0621	916377.8344	900	19	17,100	N/A	
NB-23	9.671	563467.7118	916298.4498	9.798	564141.9707	916373.4674	675	17	11,475	174	
NB-24	9.838	564351.001	916305.5779	9.928	564830.3901	916281.2292	480	17	8,160	N/A	

APPENDIX F: NBGD MOBILE GIS/GPS PROCEDURES REPORT

1. Project Hardware/Software

1.1 Trimble's GeoXT - Professional Grade GPS

The Trimble GeoXT is the "all in one" standard Professional Grade sub-meter Global Positioning System (GPS) receiver with EVEREST™ multi-path rejection technology. This handheld device from the GeoExplorer® CE series, combines sub-meter GPS with a Microsoft®Windows® CE .NET operating system in a rugged (dustproof, water resistant) case. The unit includes integrated Bluetooth® for wireless connectivity to other Bluetooth-enabled devices, including cell phones and PCs. The GeoXT runs multiple applications, connects to the Internet, and has a familiar user interface and an all day battery with an advanced TFT outdoor color touch screen with backlight integrated. The unit can be integrated with the User's Desktop for 2-way communication. This unit requires no additional hardware for data collection.

1.2 ArcPad Mobile GIS Software

ESRI's ArcPad is the standard for Mobile GIS/GPS data collection gathering software. ArcPad provides database access, mapping, GIS and GPS integration to users out in the field via handheld and mobile devices. Since it is an ESRI product, its interface is similar to other GIS standard software products. Data collection with ArcPad is fast, easy, and significantly improved with immediate data validation and availability.

1.3 ArcPad Studio (Application Builder)

ESRI's ArcPad Studio is the industry standard for mobile application development. Custom forms can be developed for specific task oriented Mobile GIS projects.

1.4 GPS Correct Software

Trimble's GPSCorrect software provides the added ability to perform post-processing on shapefiles created in ArcPad and conduct mission planning.

2. GPS/Mobile GIS Overview

2.1 GPS

The Global Positioning System (GPS) is a space based navigation system maintained and operated by the Department of Defense. It consists of a nominal constellation of 24 satellites in high altitude orbits. Its primary mission is to provide passive, real-time, 3-D positioning, navigation and velocity data for land, air and sea based applications (both military and civilian). GPS satellites orbit the earth every 12 hours at an altitude of 14,000 miles from the earth's centre. Each satellite is equipped with four atomic clocks, which keep the time to an extremely high degree of accuracy. They each broadcast their precisely timed radio signals through the atmosphere and onto the earth's surface at the speed of light. The signals from each satellite arrive at any particular point on or above the earth's surface at slightly different times. This timing is proportional to the distance between the satellite and that particular point.

A ground based receiver contains a sensitive antenna and a timetable (or almanac) for the satellites. It measures the time difference between the arrivals of the signals and compares it with the timetable. With the application of trigonometry, the longitude, latitude and altitude of the receiver can be calculated. Three satellites are needed to calculate the longitude and latitude, and a fourth satellite is needed to calculate the altitude. Additional satellites simply increase the accuracy.

The quest for greater and greater accuracy has created an assortment of variations on basic GPS technology. One technique, called "Differential GPS," involves the use of two ground-based receivers. One monitors variations in the GPS signal and communicates those variations to the other receiver. The second receiver can then correct its calculations for better accuracy. Another technique called "Carrier-phase GPS" takes advantage of the GPS signal's carrier signal to improve accuracy. The carrier frequency is much higher than the GPS signal which means it can be used for more precise timing measurements.

The aviation industry has also developed a type of enhancement for GPS called the "Wide Area Augmentation System" (WAAS). WAAS is based on a network of approximately 25 ground reference stations that covers a very large service area. Signals from GPS satellites are received by wide area ground reference stations (WRSs). Each of these precisely surveyed reference stations receive GPS signals and determine if any errors exist. These WRSs are linked to form the U.S. WAAS network. Each WRS in the network relays the data to the wide area master station (WMS) where correction information is computed. The WMS calculates correction algorithms and assesses the integrity of the system. A correction message is prepared and linked up to a geosynchronous satellite via a ground uplink system (GUS). The message is then broadcast from the satellite on the same frequency as GPS (L1, 1575.42MHz) to receivers on board aircraft (or hand-held receivers) that are within the broadcast coverage area of the WAAS. These communications satellites also act as additional navigation satellites for the aircraft, thus, providing additional navigation signals for position determination.

The WAAS will improve basic GPS accuracy to approximately 7 meters vertically and horizontally, improve system availability through the use of geostationary communication satellites (GEOs) carrying navigation payloads, and to provide important integrity information about the entire GPS constellation which involves the use of a geostationary satellite as a relay station for the transmission of differential corrections and GPS satellite status information. The geostationary satellite provides corrections across an entire continent.

GPS is used freely by the military and civilian public to support land, sea, and airborne navigation, surveying, GIS Mapping, geophysical exploration, geodesy, conservation research, habitat modeling, vehicle location systems, farming, transportation systems, archaeology, fishing and a wide variety of other additional applications. Mobile GIS incorporates GPS data in order to create real time GIS layers in the field. GPS was used to check verify the spatial position of the Noise Barrier Walls

GPS Accuracy

Sub-meter is the standard positional accuracy that is required for all GPS data created for the project. While the positional accuracy of resource grade (recreational) GPS receivers has increased nearly ten times since the government turned off selective availability (SA) in 2000, this type of receiver is still not accurate enough to gather spatial information for input into most Corporate Databases.

Professional grade systems are capable of sub-meter accuracy (Root Means Squared - RMS)* and 2 meter accuracy (2dRMS)* after differential correction and specified procedures are followed.

*Note: Root Means Squared is defined as approximately 68% of the positions are within the specified value. 2dRMS means that approximately 95% of the positions are within the specified value. It should be noted when RMS is moved to a higher confidence level (2dRMS), the procedures are at least as important as the measuring equipment.

2.2 Mobile GIS

Mobile GIS is a task oriented mobile mapping and geographic information system (GIS) technology which provides database access, mapping, GIS, and global positioning system (GPS) integration to users out in the field via handheld and mobile devices. Mobile GIS software works in conjunction with all professional and resource-grade GPS systems to capture real-time GPS data on a field computer. Mobile GIS integrates:

- GIS Software
- GIS Data
- Non-GIS Data
- Global Positioning System
- Mobile Hardware (Laptop, PDA, or Tablet PC)

Mobile GIS/GPS is utilized for numerous applications and projects requiring the gathering and dissemination of high quality spatially referenced field data. Mobile GIS enables the field personal to use the information from enterprise databases in the field, as well as gather data in the field for uploading to enterprise databases. Various Mobile GIS/GPS applications include:

- Vegetation Management
- Utility Mapping
- Hazard/Disaster Mapping
- Right-of-Way
- Regulation Permit Compliance

3. Project GIS Shapefile and Custom Form

An ESRI Polyline Shapefile and corresponding custom input form were created in ArcPad Application Builder to facilitate rapid data entry during a survey.

3.1 Shapefile Attributes

The following attributes make up the ***Noise Barrier*** shapefile attribute table and are populated during each survey.

- **WALL_ID**
- **USER**
- **DATE**
- **HEIGHT**
- **VEG_OFFSET**
- **LOCATION**
- **CHANGES**
- **BARRIER**
- **DISTRICT**
- **COUNTY**
- **MILEMARKER**
- **DFR**
- **WALL LENGTH**
- **PDOP**

3.2 GPS Settings

The internal setting of the GeoXT's GPS were set to ensure the highest possible accuracy. The settings are as follows:

- PDOP: (Position Dilution of Precision) : 6 or less
- SNR (Signal To Noise Ratio): 4
- Elevation Mask: 15%
- Number of Satellites: 4 or Higher
- Differential Correction: WAAS

4. Methodology

Each Noise Barrier Wall in the region was surveyed to obtain both spatial, attribute and photographic information necessary for the project. Upon arrival to the particular Wall, the team would investigate the following conditions before undertaking the survey.

- Traffic volume & Safety conditions
- Survey Obstacles
- GPS Satellite Visibility
- GPS Availability

4.1 Traffic Volume & Safety Conditions

Upon arrival to the location, traffic volume was determined by the amount of traffic traveling adjacent to the Wall of interest. The estimated volume determined whether it was judged safe for a foot survey or required use of a vehicle. Hard hats and florescent safety vests were worn at all times while conducting the surveys.

4.2 Survey Obstacles

Numerous Walls surveyed had large swaths of vegetation planted next to them. Major types of vegetation included: Sable Palm trees, Sea Grape and various other bushes. These vegetation lines often followed the length of the given Wall an ranged on an average from 10-75 feet. Since many of the Walls had some type of vegetation, an offset was incorporated into the survey. Generally all surveys were done on an average of 20 feet in front of the Wall. Many of the Walls not only had a vegetation line in front but also a layer of standing water. This situation occurred in areas where the Walls possessed a gully or depression directly in front of the vegetation line. In many situations, the accumulated water actually formed a small linear wetland including typical wetland flora and fauna which included unfortunately high concentrations of biting insects. If these water bodies existed, the offset was increased to account for the additional obstacle so that the survey could continue. Other barriers to the survey included manmade structures such as tollbooths, embankments, bridges and narrow walks. If such obstacles were encountered, the situation was noted in the attribute table and the offset increased as needed.

4.3 Satellite Visibility

GPS is a line of sight technology which relies on the ground based receiver the ability to have a clear and unobstructed line of sight to the GPS satellites. Noise Barrier Walls provide a unique problem in that they can obstruct half of the sky depending on how close the survey is conducted to them. Due to this fact, an offset was also needed to obtain the best possible satellite lock. GPS uses a measurement called PDOP (Position Dilution of Precision) to indicate accuracy. To ensure high accuracy GPS positioning, it is recommended that the PDOP value be less than 6. During all Wall surveys, PDOP was monitored very closely and any measurement greater than 6 was resurveyed.

5. Procedure

Once the Noise Barrier Wall was cleared to survey, the walking team member would activate the Mobile GIS/GPS unit and begin logging the polyine feature. At the beginning of the logging, a initial starting coordinate would be relayed to the vehicle team member for input into handwriting log. If a walking Survey was done, the survey team member would walk the length of the Wall with the vehicle team member following along to provide a look out for traffic. At the halfway point of the survey, the walking team member would again call out the coordinate of the middle of the Wall to the vehicle team member. Once the entire length of the Wall had been traversed, the walking team member would stop the logging and fill in the custom input form in the Arcpad software. Digital photos were also taken at each survey location. If safety conditions forced a vehicle survey, the same steps were performed in the vehicle at a slightly higher rate of speed.

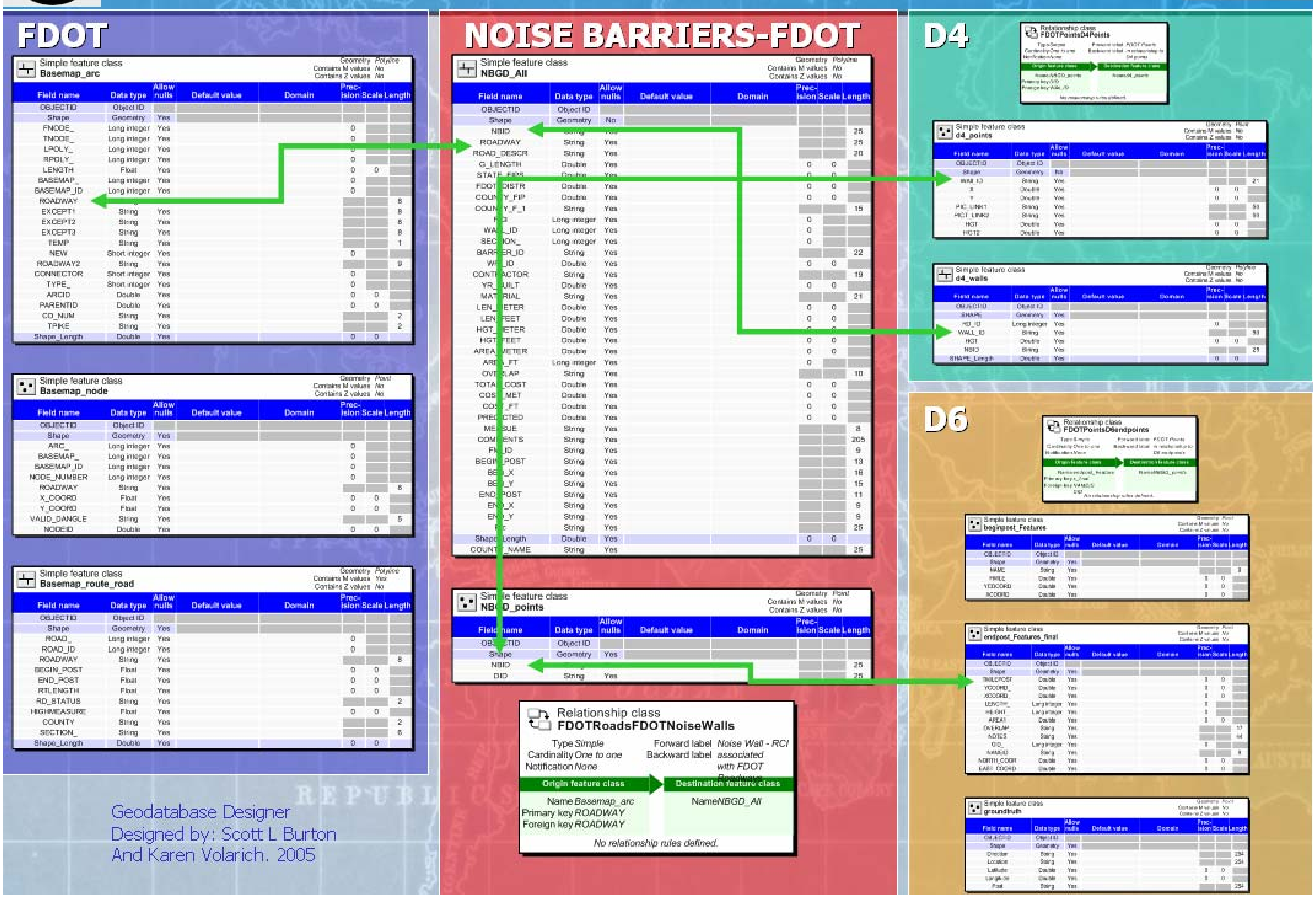
6. Data Backup and Downloading

After each Wall was surveyed, the team would back up the data on the GeoXT mobile device and then download the data onto a laptop computer. This procedure was completed at the location incase data was lost and the survey would have to be redone. Once back at the office, all data for that day was downloaded onto the project server to be used by the GIS section.

THIS PAGE LEFT INTENTIONALLY BLANK.

APPENDIX G: GEODATABASE DIAGRAMMER

NOISE BARRIER –GEODATABASE SCHEMA



THIS PAGE LEFT INTENTIONALLY BLANK.

Anthony James Catanese
CUES
CENTER FOR URBAN &
ENVIRONMENTAL SOLUTIONS
FLORIDA ATLANTIC UNIVERSITY