FINAL REPORT

GPS/GIS Inspection and Analysis Tools for Highway Construction

Contract No. BD-543-8

By

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And

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Prepared for

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16. Abstract

This study investigated the application of modern technologies to highway construction inspection. A pilot roadway construction project was utilized to demonstrate some of the methodologies developed during the study. A review and brief analysis of contract documents indicated that the GPS could be used to locate and measure over 90% of the FDOT's approximately 4,500 standard pay items (English Units) during the construction process. For the pilot project, a few items were measured in the direct pay item units.

During the study, three types of GPS receivers were evaluated: low cost or recreational GPS ($150 - $400 price range); mapping grade GPS ($3000 - $4000 price range); and the Real Time Kinematic (RTK) GPS receivers (typically more than $45,000 plus subscription costs). The mapping grade GPS would be recommended based on cost and two additional criteria: spatial modeling of the inspected pay item; and the accuracy of quantity estimated from the spatial data captured. Based on a comparison with the quantities measured using the construction inspector's traditional manual methods during the pilot project study, the mapping grade GPS receiver estimated same quantities with less than 3% error. The GPS receiver also reduced the time of quantity measure by over 80%.

The ESRI's ArcGIS was utilized as well as custom written computer programs to develop the GPS/GIS tools. A computer interface was developed between the GPS/GIS tools and the AASHTO's SiteManager, allowing data transfer between the GPS and the SiteManager's Daily Work Report Module. The Bentley's Construction Inspector program was also successfully demonstrated on the pilot project, using asphalt pay items, with the development of various Microsoft VB.Net application extension programs (dlls), along with a daily work report of construction.

It was observed during the study that the current project development procedures at FDOT would enhance the application of modern technologies as demonstrated in this study, particularly the following attributes: GIS-ready drawings generated from the Microstation; use of the project survey control points as base stations for differential GPS corrections; and the availability of the GEOPAK's Quantity Manager.

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METRIC CONVERSIONS

ft x 0.3048 = m

ft^2 x 0.09290 = m^2

yd^2 x 0.000008361 = m^2

yd^3 x 0.7646 = m^3

DISCLAIMER

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Florida Department of Transportation (FDOT) or the U.S. Department of Transportation (USDOT), and Federal Highway Administration (FHWA).

ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to the Florida Department of Transportation (FDOT) for funding this research. Special thanks are also extended to Dr. Sastry Putcha and Mr. James Johnson of the FDOT Construction Office, Ms. Esther Barwick of the FDOT CADD Office, and the FDOT District 4 Survey Office.

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EXECUTIVE SUMMARY

Considering the several millions of dollars of funds allocated by the Florida Department of Transportation (FDOT) every year for roadway and bridge construction every year, it would be beneficial to utilize modern technologies to enhance the construction inspection program, particularly for measuring quantities of constructed pay items. This study investigated the application of modern technologies such as the Global Positioning Systems (GPS), the Geographic Information System (GIS), and CADD-Data Integration, specifically using the Bentley's Construction Inspector program and also creating interface between inspectors' tolls and the AASHTO's SiteManager. A pilot roadway construction project was utilized to demonstrate some of the methodologies developed during the study. An extensive literature review indicated that the limited direct application of GPS/GIS in construction inspection for measuring quantities; commercial GPS programs exist for construction stakeout but they are very expensive. A short analysis of the FDOT 's several contract administration documents and procedure, including the list of standard pay items, revealed the potential benefits of applying GPS for construction inspection. It was observed that the GPS could be used to locate and measure over 90% of the FDOT's approximately 4,500 pay items (English Units). For the pilot project also, over 90% pay items can be measured using the GPS.

The GIS environment was used as a medium to display the planned work, using the original engineering drawing. Subsequent inspections are then transferred to the GIS to display the progress of work in a spatial manner. In other words, new work done by date can be displayed or queried in the GIS. This study evaluated the use of three types of GPS receivers: a low cost or recreational GPS ($150 - $400 price range); mapping grade GPS ($3000 - $4000 price range); and the Real Time Kinematic (RTK) GPS receivers (typically more than $45,000 plus subscription costs). In addition to cost, two other criteria were evaluated: spatial modeling of the inspected pay item; and the accuracy of quantity estimated from the spatial data captured. The first criterion is related to being able to display the inspected work relative to the original engineering plan. The estimated quantities are simply based on the geometry of the constructed pay item, i.e. length, area, or volume.

Using both the commercial ESRI's ArcGIS software and customized computer programs, methodologies were developed utilizing the CAD-GIS Interoperability to import original CAD documents into the GIS environment as a reference layer. Procedures were established for collection of GPS data for construction inspection, including the development of customized entry forms, unique for each pay item; differential GPS correction method; and GPS data transfer for analysis, display, and quantity computation. Customized computer program were developed for display and computation of inspected pay items. The evaluation of the GPS/GIS tools on the pilot project indicated that based on the limited (few) pay items, the GPS-measured quantities during inspection took only 5 to 8 minutes to conduct while the manual inspection by the inspector took 40 to 90 minutes for the same set of pay items. The latter includes time taken to locate the pay item's exact stationing on the plans, on site, to walk and measure on site, and do office computations and reporting. Also, the GPS-calculated quantities were less than 3% different from the inspector's quantities obtained using the traditional methods. The benefits are very obvious in terms of the time efficiency. It should be noted that survey requirements of a project establish some features that would enhance the applications of GPS on the project, including use of the control points as base stations for differential GPS corrections, and also the use of survey-grade GPS receivers for developing final as-built CAD documents for the project.

The interface between the GPS/GIS tools and AASHTO's Sitemanager was developed and successfully demonstrated. A link was established between the GPS/GIS tools using the Contract ID, Data, and Pay Item Number fields, before populating the quantity field of the Sitemanager's Daily Work Report (DWR) Module. The Bentley's Construction Inspector program was also demonstrated on the pilot project, including the use of an RTK GPS receiver system, with the real-time CAD display and pertinent data of the inspected pay item and automatic computation of the quantities; the asphalt tack coat inspection was demonstrated, with deliverables including various Microsoft VB.Net application extension programs (dlls), along with the development of a daily work report of construction,

It was observed during the study that the current project development procedures at FDOT would enhance the application of modern technologies as demonstrated in this study, particularly the following attributes: GIS-ready drawings generated from the Microstation; use of the project survey control points as base stations for differential GPS corrections; and the availability of the GEOPAK's Quantity Manager.

User Manual for GPS/GIS Construction Inspection Tools

Based on the completed FDOT study on the use of GPS/GIS methodology for quantity inspection during highway construction, the following sections are presented as a brief user manual for the inspector in the field. The basic steps are described using a mapping grade GPS receiver. The initial activity involves gathering the relevant contract documents: Microstation drawings, specifications, etc. The drawings are converted into GIS basemaps. The GPS receiver is configured to the project's local coordinate system and custom forms are developed for the project's specific pay items to be monitored on the construction site. Periodic inspections are carried out as required using the GPS receiver. GPS data are downloaded into an archival database, displayed (spatially) on the GIS maps and/or transferred to the AASHTO SiteManager.

Step 1. CAD/GIS Map Conversion

The original CAD data can be used directly or converted into an accepted format of GIS basemap in various shapefiles. As shown in Figure 1, the original CAD data in Microstation comes with an already-established referenced coordinate system. Figure 2 shows an ESRI shapefile converted from a CAD data (same project area as the Figure 1), with the orientation on the shapefile now in the North-south direction.

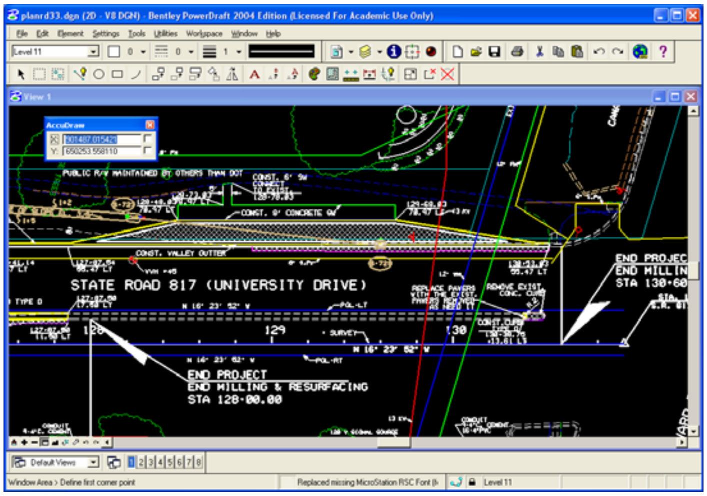


Figure 1. Microstation CAD Data with Established Coordinate System

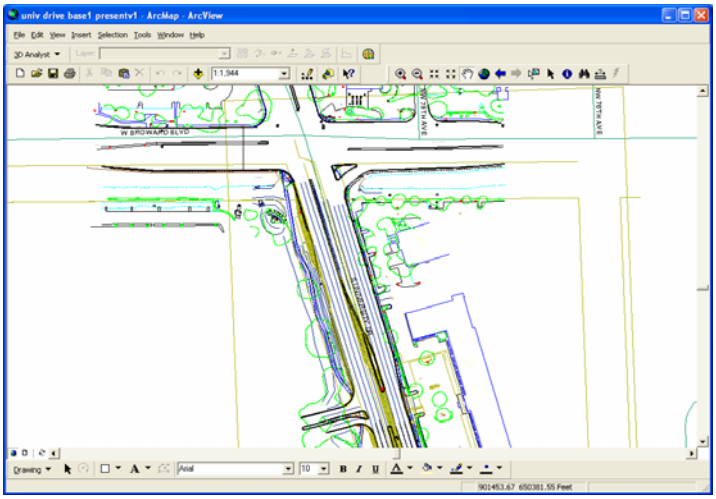


Figure 2. Microstation CAD Data Converted to ESRI Shapefile

In addition to direct conversion from CAD to ESRI shapefiles in the ArcGIS environment, a custom computer program is also available to view shapefiles or the original design drawings (Figure 3).

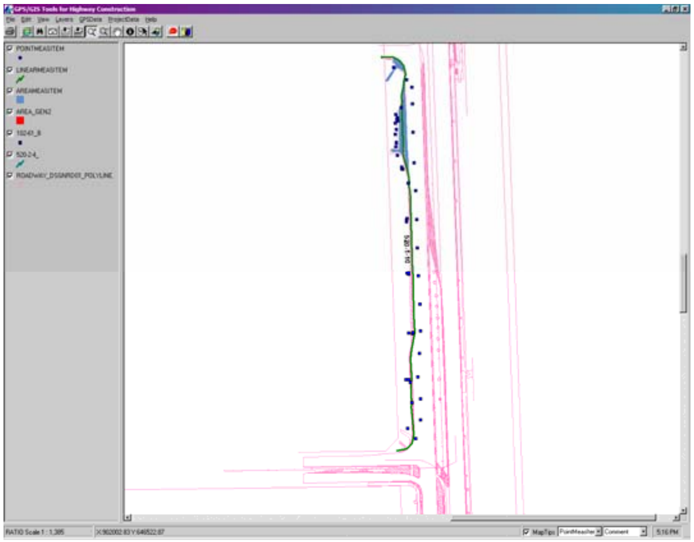


Figure 3. Spatial Data of Inspected Pay Items on Custom Computer Program

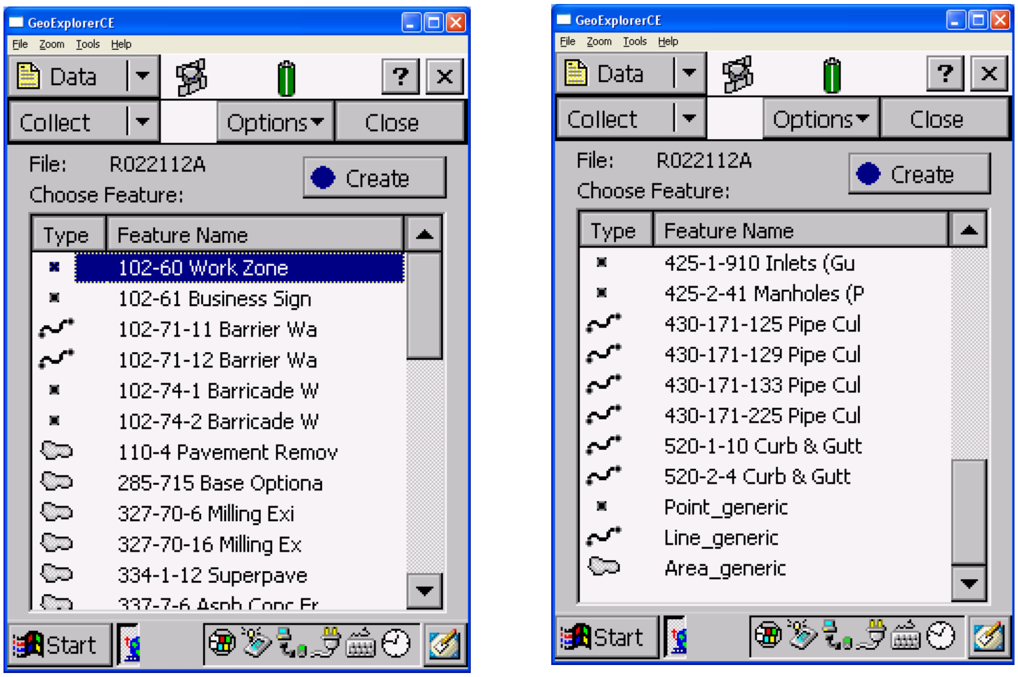
Step 2. GPS Data Collection

The mapping grade GPS receiver used for illustration here is Trimble’s GeoXT with the TerraSync data collection software, and Pathfinder Office Software for data processing. The data collection comprises two stages: office preparation and field data collection.

2.1 Office Preparation

The first task is to use the Trimble Pathfinder Office to create a project, including a data dictionary. The latter is a data entry form that is established and pulled up on the construction site when GPS readings are being taken. While the GPS receiver is recording the position data, the dictionary forms elicit and stores predefined attributes desired for the feature being inspected. Figures 3 and 4 show sample forms created for collecting various features. Based on geometry, GPS position data are recorded for three types of features– point, linear, or area feature. For construction inspection, point features represent pay items where only one (X, Y) coordinate is enough to locate the constructed item, e.g., traffic signal poles, signs, etc., typically with measuring units of EA or each. Linear items will include pay items such as curb and gutter, traffic stripes, drainage pipes, etc., while pay items based on area will include asphalt concrete work, concrete sidewalk, landscaping, etc. Combination of X, Y coordinates are required for linear and area items, with the latter requiring a closure of the points. The pay items measured by volume will be computed based on a combination of the area measure and the depth obtained from the GPS elevation readings.

Also the GPS receiver has to be checked and set up in terms of the error levels permitted (filter criteria) in the field, the data correction methods, the coordinate system of the proposed data, etc. The battery level of the GPS receiver should be fully charged. At this stage, an existing GIS layer such as the pertinent project drawing or aerial image can be uploaded into the receiver, for viewing as background during data collection in the field.



File: R022112A
Choose Feature:

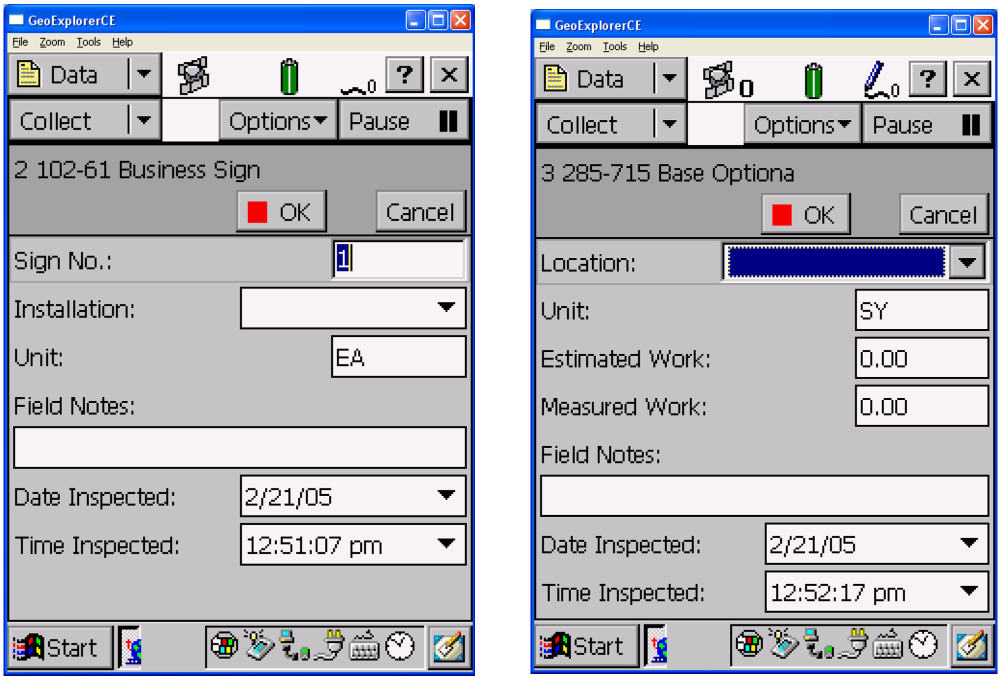
Type	Feature Name
✱	102-60 Work Zone
✱	102-61 Business Sign
〰	102-71-11 Barrier Wa
〰	102-71-12 Barrier Wa
✱	102-74-1 Barricade W
✱	102-74-2 Barricade W
⬭	110-4 Pavement Remov
⬭	285-715 Base Optiona
⬭	327-70-6 Milling Exi
⬭	327-70-16 Milling Ex
⬭	334-1-12 Superpave
⬭	337-7-6 Asph Conc Fr

File: R022112A
Choose Feature:

Type	Feature Name
✱	425-1-910 Inlets (Gu
✱	425-2-41 Manholes (P
〰	430-171-125 Pipe Cul
〰	430-171-129 Pipe Cul
〰	430-171-133 Pipe Cul
〰	430-171-225 Pipe Cul
〰	520-1-10 Curb & Gutt
〰	520-2-4 Curb & Gutt
✱	Point_generic
〰	Line_generic
⬭	Area_generic

a. Top of Pay Item Listing b. Bottom of Pay Item Listing

Figure 4. Predefined Inspection Forms on GPS Receiver Listing Pay Items



2 102-61 Business Sign

Sign No.: 1
Installation:
Unit: EA
Field Notes:
Date Inspected: 2/21/05
Time Inspected: 12:51:07 pm

3 285-715 Base Optiona

Location:
Unit: SY
Estimated Work: 0.00
Measured Work: 0.00
Field Notes:
Date Inspected: 2/21/05
Time Inspected: 12:52:17 pm

a. Pay Item No. 102-61 Business Signs b. Pay Item No. 285-715 Base Optional

Figure 5. Predefined Inspection Forms on GPS Receiver for Specific Pay Items

2. 2. Field Data Collection

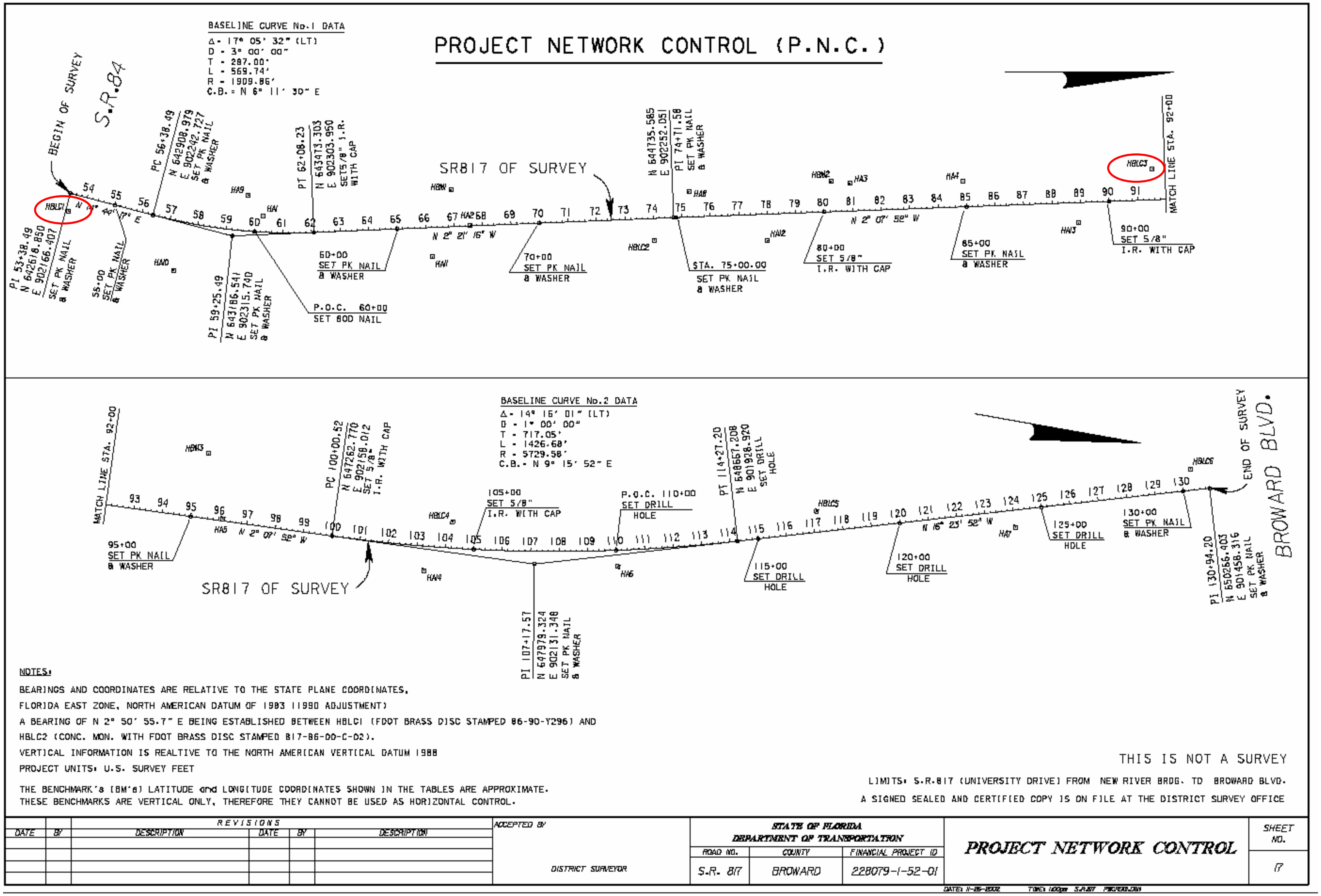
Once out in the field, it is necessary to have the GPS receiver at a location with a clear view of the sky. Depending on the sophistication of the receivers, blocking or weakening of the GPS satellite signals may be caused by tall buildings, heavy tree cover, very large vehicles, or powerful electromagnetic fields. First check the GPS to see the satellites being tracked by the receiver, and those identified as being used to calculate the position. On the Terrasync's Skyplot screen, the satellites' geometry is shown as well as the computed position coordinates, including each satellite's elevation above the horizon, and the Position Dilution of Precision (PDOP) value. A minimum of four satellites is needed to compute 3D GPS positions, as well as a good geometry (relative location) of the satellites.

The quality of the GPS data can be described in terms of two compromising factors: productivity and precision. The productivity means collecting data fast, with less accuracy while precision implies collected very accurate data but setting GPS to wait for more time to ensure appropriate satellite signal and configuration. A low PDOP value implies wide separation between the satellites in view, which translates to better position information. The default PDOP is 6 on the Trimble receiver but it can set using a slider control. The low PDOP set means fewer but more precise location positions. In construction inspection, the particular pay item will suggest level of precision or productivity to use. For example, recording positions of signs, poles, etc, may not require precision but sidewalk dimensions, volume measures of excavation, and length of curb and gutter, may require less productivity but more precision. But again, if the spatial location of the pay item is important, i.e., when plotted on the original drawing, then precision should be a priority. The Signal to Noise Ratio (SNR) is a measure of the satellite signal, its value can be set to a minimum; for the Trimble receiver, and the default is 4., i.e., below this value, the receiver will not use that particular satellite to calculate position. The minimum elevation, with default of 15 degrees in the Trimble receiver, also indicates the quality of satellite signal; satellites with low elevation from the horizon can indicate poor quality of data transmitted.

The GPS data is recorded for point features by collecting and averaging positions as you remain at the point. For linear features, GPS positions are recorded at various points on the line as you move with the receiver. It is advised that you remain stationary at pertinent points, such as vertices, to ensure accurate capture of the point. The GPS positions for area features are collected in a similar fashion to the linear features, and the points are connected to from the area boundary, with the last point connected to the first point.

By default, the GPS receiver will use latitude – longitude measure (along earth spherical surface) to record the positions in degrees, minutes, and seconds. The coordinate system should be set on the GPS receiver to the appropriate projection; a projection means "flattening" the earth spherical surface such that the (X, Y, Z) coordinates can be measured and used for arithmetic computations. There are various projection systems for different areas of the earth. The common projected coordinate systems in Florida are the UTM (statewide) and the State Plane systems (regional). A review of the project plans will show the appropriate coordinate system, as indicated on the survey work done for the project. Even the electronic CAD file should indicate the projected coordinate system. This is very important for the transfer of the recorded GPS positions to the original project plans.

The GPS position recorded is subject to various errors, thereby lowering the accuracy. The major types of GPS errors include orbit errors, effect of earth atmosphere, and difference in timing in the satellites and the receivers. A suitable way of removing these errors is the differential correction method, leading to the term Differential GPS or DGPS. For the DGPS, the data collected simultaneously by a GPS receiver at a known location (known X, Y, Z values) or base, can be used to correct the data collected by a GPS receiver or rover, at another location, with the father the distance between the points, the lesser the correction efficiency. The DGPS correction can be done real-time, as the data is collected, or done in a post-processing manner, after the data is downloaded. To implement the differential correction, the base is typically located among various reference stations available to the public in the United States, including the FDOT Reference Stations, the Continuously Operating Reference Stations (CORS) and several other community reference stations. For highway construction projects, the survey efforts will produce a survey control network, consisting of several points with the known (X, Y, Z) coordinates; these points will serve as excellent base stations. The survey control network for a sample project is shown in Figures 6 and 7.



NOTES:

BEARINGS AND COORDINATES ARE RELATIVE TO THE STATE PLANE COORDINATES, FLORIDA EAST ZONE, NORTH AMERICAN DATUM OF 1983 (1990 ADJUSTMENT)

A BEARING OF N 2° 50' 55.7" E BEING ESTABLISHED BETWEEN HBLC1 (FDOT BRASS DISC STAMPED 86-90-Y296) AND HBLC2 (CONC. MON. WITH FDOT BRASS DISC STAMPED 817-86-00-C-02).

VERTICAL INFORMATION IS REALTIVE TO THE NORTH AMERICAN VERTICAL DATUM 1988

PROJECT UNITS: U.S. SURVEY FEET

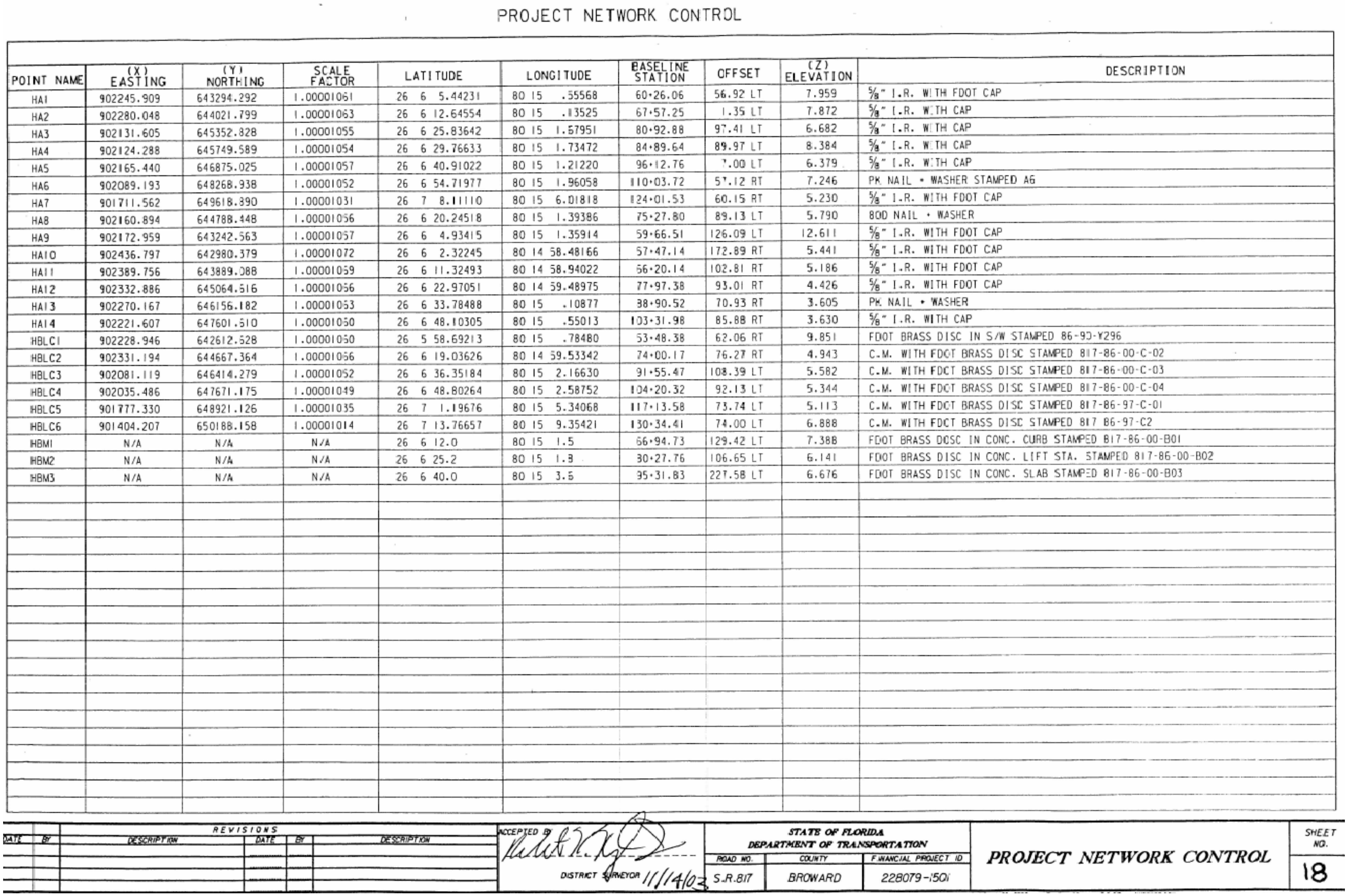
THE BENCHMARK'S (BM'S) LATITUDE and LONGITUDE COORDINATES SHOWN IN THE TABLES ARE APPROXIMATE.
THESE BENCHMARKS ARE VERTICAL ONLY, THEREFORE THEY CANNOT BE USED AS HORIZONTAL CONTROL.

THIS IS NOT A SURVEY

LIMITS: S.R.817 (UNIVERSITY DRIVE) FROM NEW RIVER BRDG. TO BROWARD BLVD.
A SIGNED SEALED AND CERTIFIED COPY IS ON FILE AT THE DISTRICT SURVEY OFFICE

REVISIONS						ACCEPTED BY	STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION			PROJECT NETWORK CONTROL	SHEET NO.
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION		ROAD NO.	COUNTY	FINANCIAL PROJECT ID		
						DISTRICT SURVEYOR	S.R. 817	BROWARD	228079-1-52-01		17

Figure 6. Project Network Control Locations as Shown on Engineering Plans (HBLC1 And HBLC3 Identified)



PROJECT NETWORK CONTROL

POINT NAME	(X) EASTING	(Y) NORTHING	SCALE FACTOR	LATITUDE	LONGITUDE	BASELINE STATION	OFFSET	(Z) ELEVATION	DESCRIPTION
HA1	902245.909	643294.292	1.00001061	26 6 5.44231	80 15 .55568	60+26.06	56.92 LT	7.959	⅝" I.R. WITH FDOT CAP
HA2	902280.048	644021.799	1.00001063	26 6 12.64554	80 15 .13525	67+57.25	1.35 LT	7.872	⅝" I.R. WITH CAP
HA3	902131.605	645352.828	1.00001055	26 6 25.83642	80 15 1.57951	80+92.88	97.41 LT	6.682	⅝" I.R. WITH CAP
HA4	902124.288	645749.589	1.00001054	26 6 29.76633	80 15 1.73472	84+89.64	89.97 LT	8.384	⅝" I.R. WITH CAP
HA5	902165.440	646875.025	1.00001057	26 6 40.91022	80 15 1.21220	96+12.76	7.00 LT	6.379	⅝" I.R. WITH CAP
HA6	902089.193	648268.938	1.00001052	26 6 54.71977	80 15 1.96058	110+03.72	57.12 RT	7.246	PK NAIL • WASHER STAMPED AG
HA7	901711.562	649618.390	1.00001031	26 7 8.11110	80 15 6.01818	124+01.53	60.15 RT	5.230	⅝" I.R. WITH FDOT CAP
HA8	902160.894	644788.448	1.00001056	26 6 20.24518	80 15 1.39386	75+27.80	89.13 LT	5.790	80D NAIL • WASHER
HA9	902172.959	643242.563	1.00001057	26 6 4.93415	80 15 1.35914	59+66.51	126.09 LT	12.611	⅝" I.R. WITH FDOT CAP
HA10	902436.797	642980.379	1.00001072	26 6 2.32245	80 14 58.48166	57+47.14	172.89 RT	5.441	⅝" I.R. WITH FDOT CAP
HA11	902389.756	643889.088	1.00001059	26 6 11.32493	80 14 58.94022	56+20.14	102.81 RT	5.186	⅝" I.R. WITH FDOT CAP
HA12	902332.886	645064.516	1.00001056	26 6 22.97051	80 14 59.48975	77+97.38	93.01 RT	4.426	⅝" I.R. WITH FDOT CAP
HA13	902270.167	646156.182	1.00001053	26 6 33.78488	80 15 .10877	38+90.52	70.93 RT	3.605	PK NAIL • WASHER
HA14	902221.607	647601.510	1.00001050	26 6 48.10305	80 15 .55013	103+31.98	85.88 RT	3.630	⅝" I.R. WITH CAP
HBLC1	902228.946	642612.528	1.00001050	26 5 58.69213	80 15 .78480	53+48.38	62.06 RT	9.851	FDOT BRASS DISC IN S/W STAMPED 86-90-Y296
HBLC2	902331.194	644667.364	1.00001056	26 6 19.03626	80 14 59.53342	74+00.17	76.27 RT	4.943	C.M. WITH FDOT BRASS DISC STAMPED 817-86-00-C-02
HBLC3	902081.119	646414.279	1.00001052	26 6 36.35184	80 15 2.16630	91+55.47	108.39 LT	5.582	C.M. WITH FDOT BRASS DISC STAMPED 817-86-00-C-03
HBLC4	902035.486	647671.175	1.00001049	26 6 48.80264	80 15 2.58752	104+20.32	92.13 LT	5.344	C.M. WITH FDOT BRASS DISC STAMPED 817-86-00-C-04
HBLC5	901777.330	648921.126	1.00001035	26 7 1.19676	80 15 5.34068	117+13.58	73.74 LT	5.113	C.M. WITH FDOT BRASS DISC STAMPED 817-86-97-C-01
HBLC6	901404.207	650188.158	1.00001014	26 7 13.76657	80 15 9.35421	130+34.41	74.00 LT	6.888	C.M. WITH FDOT BRASS DISC STAMPED 817 86-97-C2
HBM1	N/A	N/A	N/A	26 6 12.0	80 15 1.5	66+94.73	129.42 LT	7.388	FDOT BRASS DOSC IN CONC. CURB STAMPED 817-86-00-B01
HBM2	N/A	N/A	N/A	26 6 25.2	80 15 1.3	30+27.76	106.65 LT	6.141	FDOT BRASS DISC IN CONC. LIFT STA. STAMPED 817-86-00-B02
HBM3	N/A	N/A	N/A	26 6 40.0	80 15 3.5	95+31.83	227.58 LT	6.676	FDOT BRASS DISC IN CONC. SLAB STAMPED 817-86-00-B03

REVISIONS

DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

ACCEPTED BY

DISTRICT SURVEYOR 11/14/03

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID
S.R.817	BROWARD	228079-1501

PROJECT NETWORK CONTROL

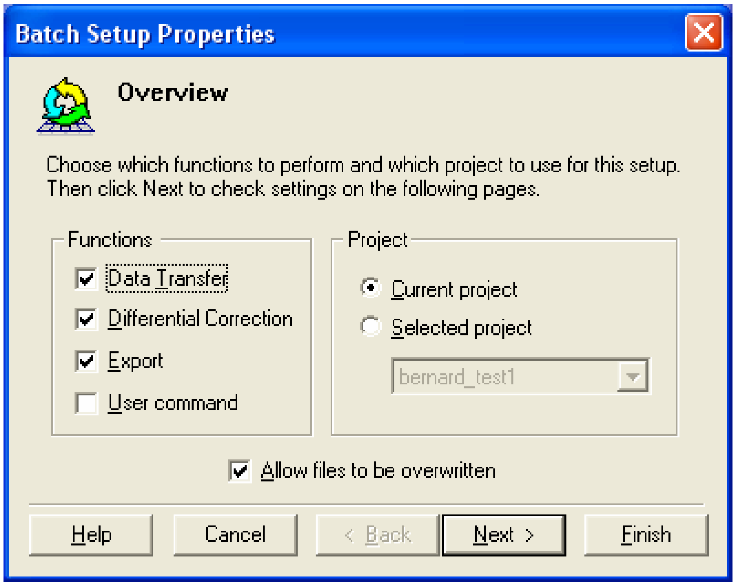
SHEET NO. 18

Figure 7. Project Network Control Data as Shown on Engineering Plans

Step 3. GPS Data Processing and SiteManager Interface

The collected GPS data, including some estimated quantities, can be differentially corrected and download into a desktop or laptop computer through a single-step batch process in the GeoXT and Pathfinder software (Figure 8). Alternatively, the receiver can collect the pertinent geometry points, and the quantities calculated in the Custom Computer Program. The data are stored in Microsoft Access tables and called into the computer programs, where some analyses are done, including calculation of the quantities. The project's local coordinate system is also important as shown in Figure 9.

Figure 8. Trimble-Enabled GPS Correction and Data Download (Single-Step Data Processing)



Batch Setup Properties

Overview

Choose which functions to perform and which project to use for this setup.
Then click Next to check settings on the following pages.

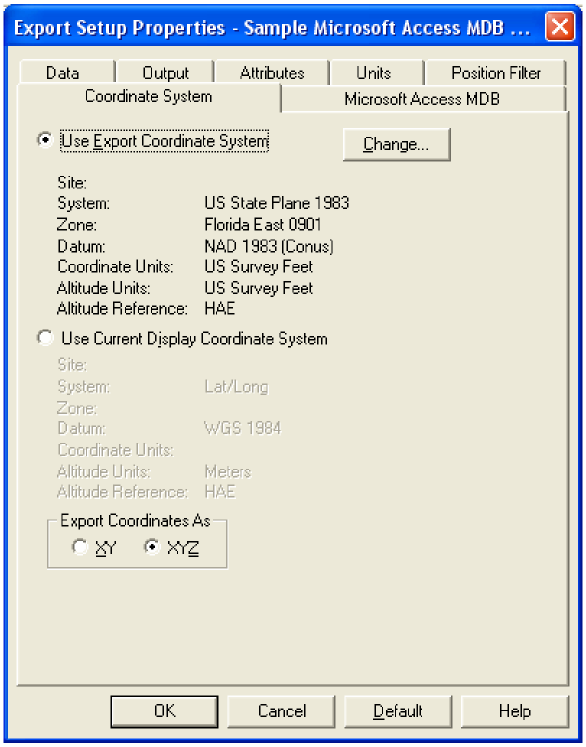
Functions
- ☑ Data Transfer
- ☑ Differential Correction
- ☑ Export
- ☐ User command

Project
- ● Current project
- ○ Selected project

bernard_test1

☑ Allow files to be overwritten

Figure 9. Data Download at Project's Local Projected Coordinate System



Export Setup Properties - Sample Microsoft Access MDB ...

● Use Export Coordinate System

Site:	
System:	US State Plane 1983
Zone:	Florida East 0901
Datum:	NAD 1983 (Conus)
Coordinate Units:	US Survey Feet
Altitude Units:	US Survey Feet
Altitude Reference:	HAE

○ Use Current Display Coordinate System

Site:	
System:	Lat/Long
Zone:	
Datum:	WGS 1984
Coordinate Units:	
Altitude Units:	Meters
Altitude Reference:	HAE

Export Coordinates As
○ XY ● XYZ

Also an interface can be made between the GPS/GIS computer programs and the AASHTO's SiteManager. As shown in Figures 10 and 11, the primary fields are the Contract ID, Date of inspection, and the Pay item number. These three attributes are utilized from the GPS/GIS tools to link the SiteManager's Daily Work Report (DWR) module. Once contact is made, then the quantity filed of the DWR is populated with the data (calculated quantity) sent from the GPS/GIS tools program.

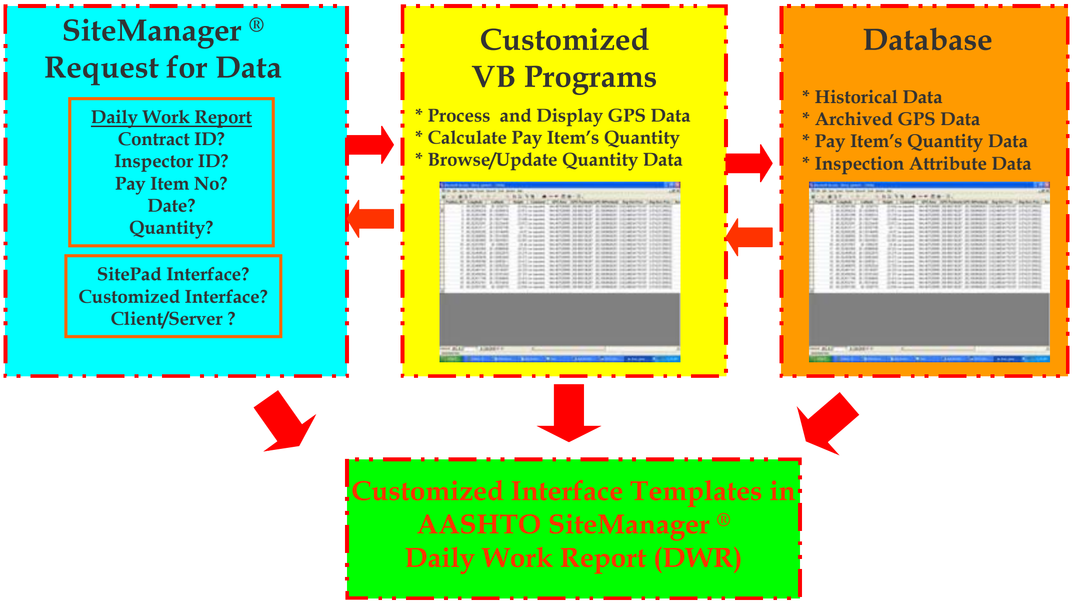
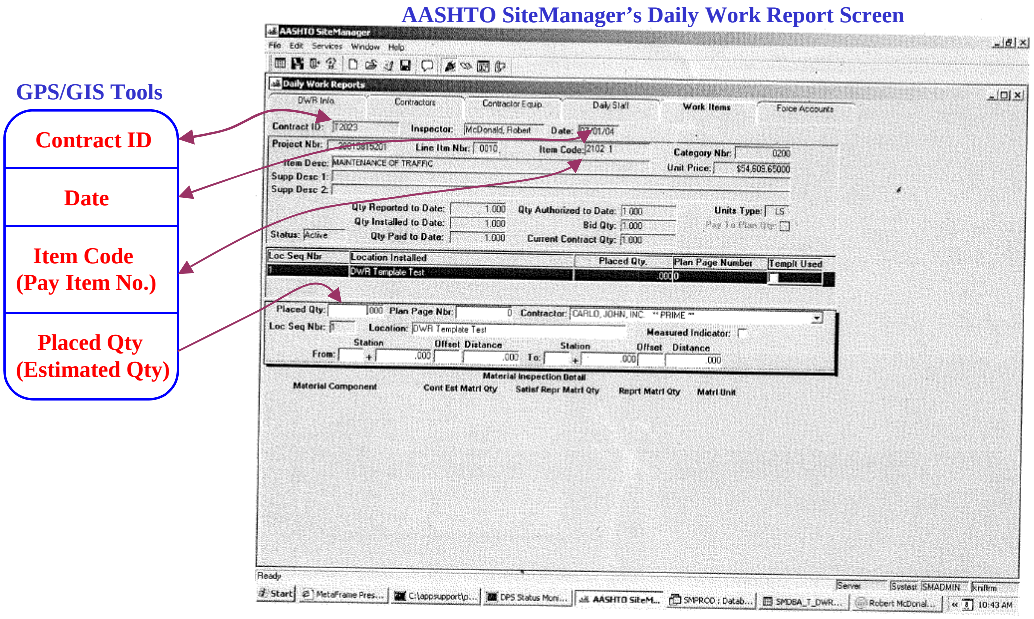


Figure 10. Trimble-Enabled GPS – SiteManager Interface Data Flow



Contract ID: T2023
Inspector: McDonald, Robert
Date: 07/01/04
Project Nbr: 20015815201
Line Itm Nbr: 0010
Item Code: 2102 1
Category Nbr: 0200
Item Desc: MAINTENANCE OF TRAFFIC
Unit Price: $54,609.65000
Supp Desc 1:
Supp Desc 2:
Qty Reported to Date: 1.000
Qty Authorized to Date: 1.000
Units Type: LS
Qty Installed to Date: 1.000
Bid Qty: 1.000
Pay To Plan Qty: ☐
Status: Active
Qty Paid to Date: 1.000
Current Contract Qty: 1.000

Loc Seq Nbr	Location Installed	Placed Qty.	Plan Page Number	Templt Used
1	DWR Template Test	.000	0	☐

Placed Qty: .000
Plan Page Nbr: 0
Contractor: CARLO, JOHN, INC. ** PRIME **
Loc Seq Nbr: 1
Location: DWR Template Test
Measured Indicator: ☐

	Station		Offset	Distance
From:	+	.000		.000
To:	+	.000		.000

Material Inspection Detail

Material Component	Cont Est Matrl Qty	Satisf Repr Matrl Qty	Reprt Matrl Qty	Matrl Unit

Figure 11. Interaction Between the GPS/GIS Tools and the AASHTO SiteManager Program

Step 4. Project Query and Analyses

Using both the ESRI's ArcGIS and the Custom Computer Program, some basic queries and analyses can be performed on the collected data. As illustrated in Figures 12 and 13, inspected GPS data can be displayed on the original drawings to see extent of work done so far. Though the Trimble GeoXT will compute the quantities for linear and area features, the inspected quantities can also be estimated from the raw GPS readings. Historical project data can be stored and queried as shown in Figures

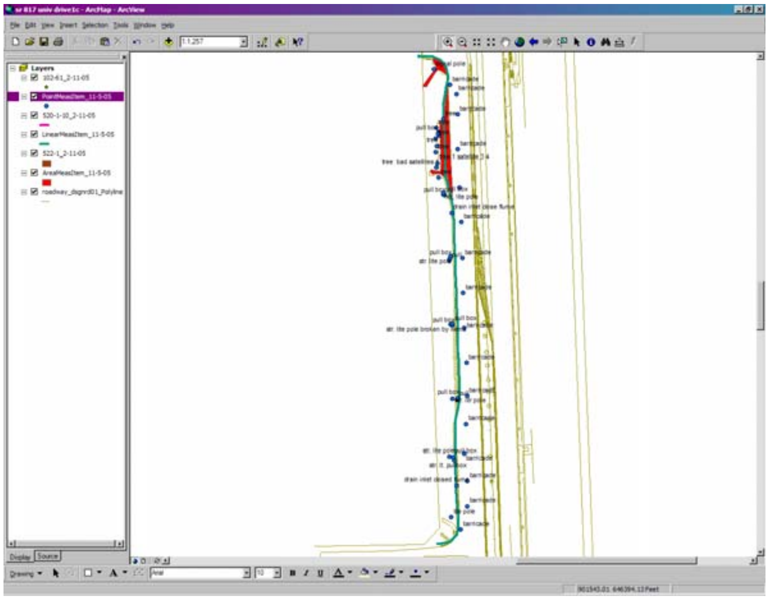
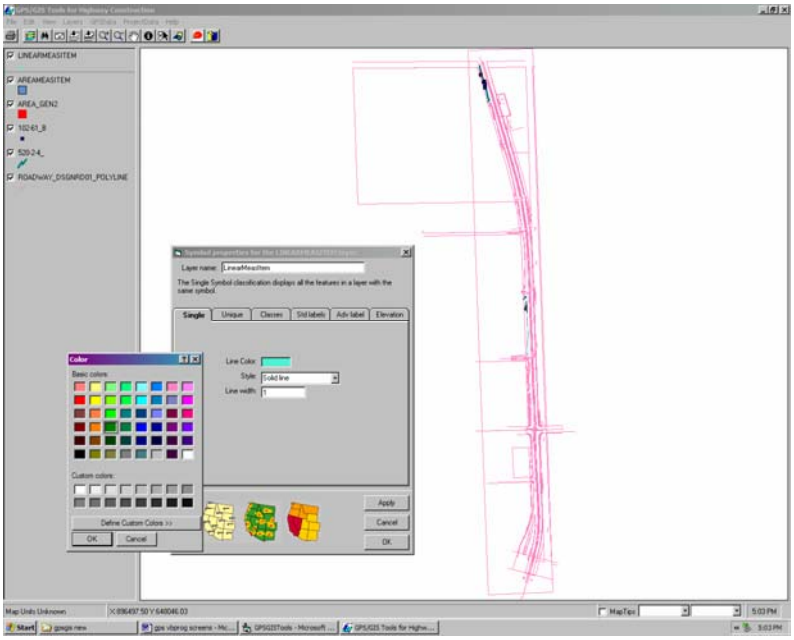


Figure 12. ArcGIS: Spatial Data of Inspected Pay Items Relative to the Original Drawing Locations



Layer name: LinearMeasItem

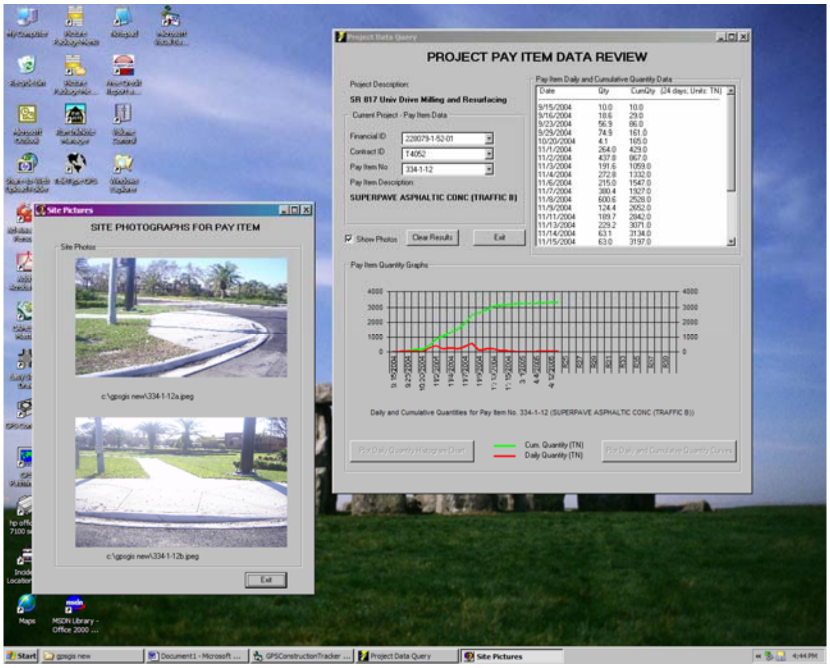
The Single Symbol classification displays all the features in a layer with the same symbol.

Line Color:

Style: Solid line

Line width: 1

Figure 13. Custom Program: Spatial Data of Inspected Pay Items) Relative to the Original Drawing Locations



PROJECT PAY ITEM DATA REVIEW

Project Description:

SR 817 Univ Drive Milling and Resurfacing

Current Project - Pay Item Data

Financial ID: 220079-1-52-01

Contract ID: T4052

Pay Item No: 334-1-12

Pay Item Description:

SUPERPAVE ASPHALTIC CONC (TRAFFIC B)

☑ Show Photos

Pay Item Daily and Cumulative Quantity Data

Date	Qty	CumQty (24 days; Units: TN)
9/15/2004	10.0	10.0
9/16/2004	18.6	29.0
9/23/2004	56.9	86.0
9/29/2004	74.9	161.0
10/20/2004	4.1	165.0
11/1/2004	264.0	429.0
11/2/2004	437.8	867.0
11/3/2004	191.6	1059.0
11/4/2004	272.8	1332.0
11/6/2004	215.0	1547.0
11/7/2004	380.4	1927.0
11/8/2004	600.6	2528.0
11/9/2004	124.4	2652.0
11/11/2004	189.7	2842.0
11/13/2004	229.2	3071.0
11/14/2004	63.1	3134.0
11/15/2004	63.0	3197.0

Pay Item Quantity Graphs

Daily and Cumulative Quantities for Pay Item No. 334-1-12 (SUPERPAVE ASPHALTIC CONC (TRAFFIC B))

SITE PHOTOGRAPHS FOR PAY ITEM

Site Photos

c:\gpsgis new\334-1-12a.jpeg

c:\gpsgis new\334-1-12b.jpeg

Figure 14. Custom Programs for Review of Project Historical Data for Pay Item's Quantity Including Site Photographs

TABLE OF CONTENTS

1. Research Background and Project Kickoff

Periodic inspection of constructed facilities during the construction process, constitute a vital component of the project management, particularly, the quantity measure for estimating contractor's payment. With the current rapid development and availability of advanced technologies, the highway construction process was studied for the feasibility of improvement using these modern technologies, specifically, the Global Positioning Systems (GPS), Geographic Information Systems (GIS), and Computer Aided Design (CAD)-Data integration. This section of the report presents the current status of the pertinent knowledge both in terms of a literature review, research activities, and industry practice in the construction inspection using GPS/GIS and electronic entry software.

1.1 Introduction and Research Objectives

The Florida Department of Transportation (FDOT) allocates funding for and supervises several millions dollars of roadway and bridge construction every year. The inspection procedure is currently based on traditional methods where tests are conducted and the quantities are taken, to enable progress payment to the contractor. Most of the current methods are manual. It will be beneficial for the FDOT to utilize modern technologies such as GPS and the GIS, to enhance its inspection program on ongoing roadway and bridge construction projects, as well as project analysis during construction.

The FDOT generates its engineering drawings, typically using Bentley's MicroStation® and GEOPAK® software programs. The graphical output of these programs can now be easily converted into GIS basemaps, with the appropriate establishment of geographical coordinates. Many roadway construction work items can be modeled as spatial data (x, y, z coordinates), which can be collected using GPS receivers in the field, and mapped in a GIS environment into the basemap. The updated GIS basemap can then be analyzed to obtain quantities and costs of pay items, as well as enabling a comparison of the GPS field data with the original construction plans. Areas, lengths or number counts and correct positioning can be checked for installed pipes, pavement stripping, reflective markers, manholes, etc. Bridge construction could also be monitored through collection of appropriate spatial data to capture position data and information on deck area, slab thickness, pile length, etc. With the current availability and affordability of submeter and subcentimeter accuracy in GPS receivers, coupled with the current effort by the FDOT Mapping Office towards GPS enhancement, the application of the tools proposed for the study will be very beneficial to FDOT.

FDOT is also interested in computerizing its construction inspection process through use of portable computer handheld devices for Computer-Aided-Drawing (CAD)-Data integration. These devices would allow users to do the following: graphically compose a selection set of elements for inspection; input inspection results for each, linear and area pay item instances; review inspection history by graphically selecting elements; perform specialized inspection activities using customized forms; and review customized inspection reports.

The FDOT currently uses an AASHTO Software SiteManager®, for progress monitoring on their construction projects. This study will review the operations of the SiteManager®, in order to develop an interface between the proposed GPS/GIS tools and the SiteManager®.

The objective of the research is therefore to develop some tools, based on modern technologies that can be used by the FDOT for inspection of ongoing roadway and bridge construction projects. Specifically, three goals of the research are described as follows:

1. Use GPS and GIS to capture spatial data on the construction site, generating an attribute database to capture the inspection results. An as-built documentation of the construction project can also be effectively and accurately accomplished using the proposed tools.
2. Conduct a pilot study using the Bentley Construction Inspector software to perform certain specialty inspections such as bituminous materials, concrete placement and pile driving information. The Bentley Construction Inspector automates data gathering, engineering calculations and input into electronic databases for subsequent review and reporting.
3. Develop an interface program for exchange of data between the inspection tools and the AASHTO's Sitemanager computer program.

1.2. Literature Review

First, a brief overview is presented on the technologies employed on this research, i.e. the GPS, GIS and CAD-Data Integration (using the Bentley Construction Inspector). Then the pertinent applications as found documented through literature review, are discussed, for the construction inspection process. In the presentation of the methodology utilized on this research, shown in other sections of the report, more details are further discussed on some of the technologies.

1.2.1 The Global Positioning System (GPS)

The Global Positioning System (GPS) is a navigation system based on 24 operational NAVSTAR (NAVigation Satellite Timing and Ranging) satellites orbiting the earth every 12 hours at an altitude of about 20200 kilometers or 12600 nautical miles and operated by the United States Department of Defense (USDoD) providing all-weather worldwide 24-hour position and time information. Basically there are three segments to GPS: space segment consisting of the 24 satellites with each satellite containing several high-precisioned atomic clocks and constantly transmitting radio signals; control segment involving the USDoD's four ground-based monitor stations three upload stations and one master control station; and the user segment, i.e. the GPS receiver. The satellites are continuously tracked by the monitor stations, which provide the data to the master control station. The master control station calculates satellite paths and clock corrections before forwarding the data to upload stations, which in turn transmit the data to each satellite daily.

GPS operation consists of five basic steps: satellite trilateration in which a point is located based on its calculated distances from four satellites; satellite ranging i.e. establishing the distance from a single satellite by measuring the travel time of the radio signal from the satellite to the receiver; accurate timing – since the calculations depends on highly accurate clocks and the satellites have accurate atomic clock but the receivers which do not receiver uses data from the fourth satellite to correct any clock errors; satellite positioning – identifying the exact locations of the 24 satellites; and error corrections including atomic clock errors satellite orbit errors multipath interference errors and errors due to the non-constant speed of GPS signals through the earth's ionosphere and troposphere layers.

Satellite trilateration is the basis of the GPS. With satellites acting as precise reference points distances are calculated from a number of satellites to a particular position on the earth surface. With one satellite, a possible location of the position is reduced to the surface of a sphere. Adding the distance from another satellite reduce the possible locations to the intersection of two spheres which is a circle. A third satellite measurement reduces the position to possible two points while adding the fourth satellite distance measurement narrows the position to one point. With the initial three satellites the coordinates of the location can actually be calculated usually by disregarding one of the two possible points due to it being far out in space. The fourth satellite measurement is needed to obtain the needed coordinate parameters and time. Satellite ranging involves the GPS receiver and satellite generating same pseudorandom noise code at the same time in order to establish when a signal was transmitted from the satellite.

The receiver examines the incoming signal from the satellite to check the time lapse from when the receiver generated the same code. The time difference is multiplied by the speed of light (186000 m/s) to calculate the distance. Since the noise code has to generated from both the receiver and the satellite at the exactly the same time the receiver which does not have an atomic clock may not have the same time stamp as the satellite's clock. In this case the use of three satellites would result in a series of measurements that do not intersect at a single point. It would then be necessary to use four satellites to cancel out time errors. Satellite positioning is enhanced by the USDoD stations with four satellites in each of six evenly distributed orbits inclined at 55 degrees to the equator. GPS errors primarily depend on the fact that the signals do not travel at a constant speed of light as assumed thus resulting in incorrect distance calculations. These errors can be corrected by GPS receivers to account for these delays in signal reception. Also the atomic clock and satellite orbit errors are minor and are adjusted by the USDoD at the monitor stations. Multipath interference errors are due to signals being reflected off other objects at or near the earth surface e.g. mountains trees buildings etc. Advanced signal processing and good antennas can help minimize the multipath effect.

The DGPS or Differential GPS is same as the GPS but with a correction done to the GPS collected data to improve the location accuracy. It involves a GPS receiver at an unknown location (rover) collecting data and comparing its data to the GPS data from another GPS receiver at a known location (base station). The base stations which are continuously monitored with strong antennas and receivers, produce the data that is used to determine errors contained in the satellite data. The base station data is then applied to the data collected by the rover GPS receiver to remove errors. Accuracy of differential corrections depends very much on the knowledge of the exact location of the base station. There are two types of differential correction: real-time and post processed. In real-time differential GPS the base station calculates and broadcasts correction data through radio signals for each satellite data that it receives. The rover GPS receiver applies this correction immediately to its position calculation. In post-processing differential GPS the base station records the correction for satellite to a file. The rover GPS records its own data also in a file. After data collection by the rover the two files are processed to remove the position errors. More precise techniques have been developed by surveyors as extensions of DGPS to improve accuracy of locations to within one centimeter.

1.2.2 The Geographic Information System (GIS)

As defined in several literatures the Geographic Information System (GIS) is simply

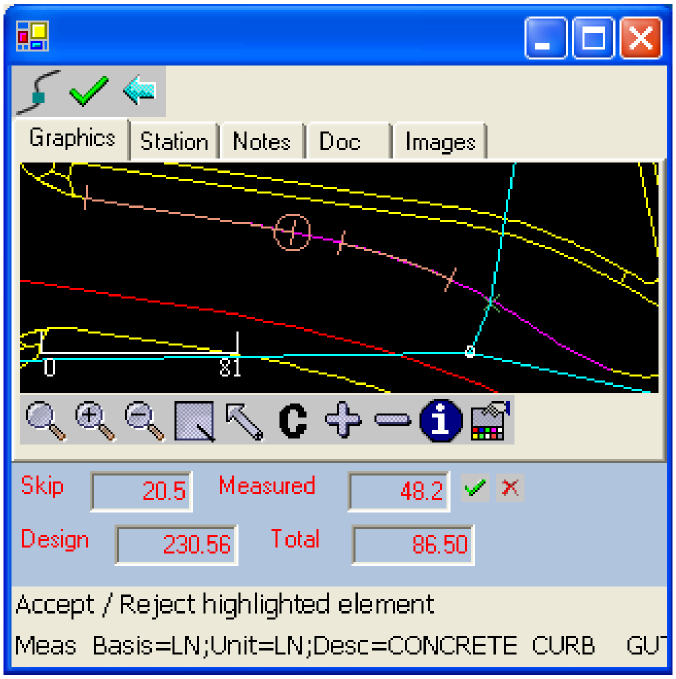
> *"A system of hardware software data people organizations and institutional arrangements for collecting storing analyzing and disseminating information about areas of the earth."*

The GIS consists of two data types – spatial data and attribute data. Spatial data in GIS can be either vector data in which geometric elements are shown on a Cartesian plane (point line and polygons) or raster data in which information is provided in the form of grid cells. Spatial data or topology contains information on geographic entities with orientation and relationship in a two or three-dimensional space. Attribute data usually in the form of a database system is pertinent information attached to the geographic entities. For example a roadway section may be a linear feature with attribute data such as the road condition on a linear segment or accident information at a point location.

The basic data needed for a GIS is the base map. It is a map containing the geographic features and necessary location reference information. Base maps can be generated from local regular maps aerial photographs CAD (Computer Aided Drawings) or as in many cases from TIGER (Topographically Integrated Geographic Encoding and Referencing) files. The major attractive aspect of a GIS is its ability to integrate data from several sources and spatially presenting results of queries and other analyses in the forms of maps and reports. The core of this integration is the location referencing system. GIS can utilize many location referencing systems but the predominant systems are linear referencing or Cartesian coordinates (absolute or relative including three dimensional).

1.2.3 Bentley Construction Inspector (CAD-Quantity Integration)

The most relevant literature found related to CAD-Data integration is Roe (2004), explaining the recent developments in data exchange between civil engineering CAD software and other applications. Roe (2004) described intelligent design software that maintains the continuous data chain, including the object-based software such as the Civil 3D from Autodesk. In earthwork grading, for instance Civil 3D allows dynamic updating of contours, earthwork volumes, section views, and annotation, enabling the development of "what-if" scenarios in land development projects. Also discussed in Roe (2004) were three products from Bentley Systems. First, working with the FDOT, Bentley developed the Quantity Manager, a stand-alone tool that manages quantities generated by the GEOPAK, another Bentley product. The Quantity manager streamlines the management of pay items during construction. Secondly, Bentley developed, working with the Minnesota DOT, handheld applications for construction staking and inspection quantities. With this tool, users can import design data from GEOPAK, and display drawings on the handheld device (Figure 1.1). Linked to a GPS receiver, items such as drainage structures can be staked during construction, calculating pipe slopes, etc. Also developed by Bentley was Handheld Inspection module for automating data gathering, calculations, and input processes during construction. Using the design data imported from GEOPAK, the user can use the Construction Inspector, to display and select a desired plan item, view its estimated quantity, and then enter a field –measured quantity. The historical inspection data is also available in a database. The Bentley Inspector was demonstrated in a Minnesota DOT pilot study in 2003.



Skip 20.5 Measured 48.2

Design 230.56 Total 86.50

Accept / Reject highlighted element

Meas Basis=LN;Unit=LN;Desc=CONCRETE CURB GU

Figure 1.1. Sample Screen from the Bentley Construction Inspector (Source: Bentley 2004)

According to the Bentley's GEOPAK's Help File, Quantity Manager is an application for managing design quantities, through the Design and Computation Manager. The features include the following: organization of quantities by pay items, by stations, by units of measure etc.; special treatment for rounding and lump sum items; support of CAD file quantities as well as non-graphic quantities; manual input and modifications; interface with estimating systems for pay items and funding sources; custom report capabilities; funding computations; cost estimates; and cost comparison. The program supports several Database Management Systems, including: Microsoft Access 2000, Oracle and SQL Server. Quantity Manager supports importing and exporting of data via XML, specifically, the aecXML. Figures 1.2 and 1.3 show the data link between pay items' quantities and design elements.

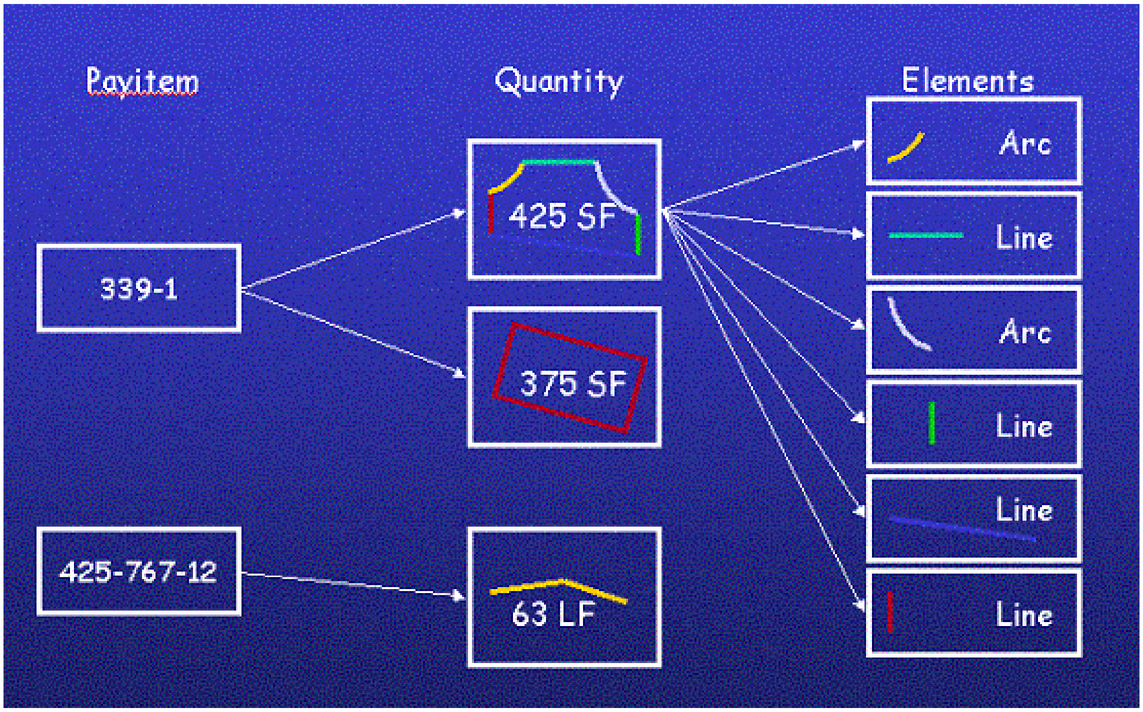


Figure 1.2. GEOPAK's Quantity manager's Graphical Link of Quantity to Pay Item and Design Elements

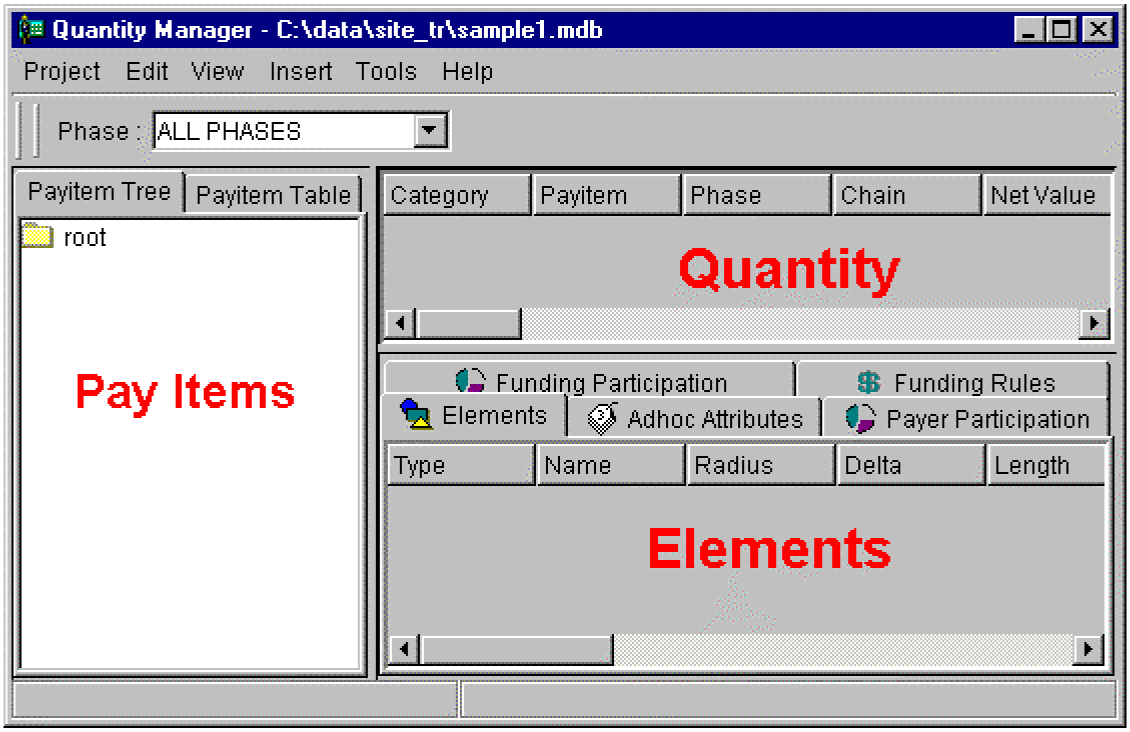


Figure 1.3 GEOPAK's Quantity manager's Tabular Link of Quantity to Pay Item and Design Elements

1.2.4 Applications of GPS/GIS in Highway Construction

Highway-related applications of GPS and GIS have primarily been in the areas of planning, traffic safety analysis, and infrastructure management. Few studies have been reported for specific application to the construction process, including the use of GPS for machine control, construction stakeout, and overall surveying operations. Navon and Shpatnitsky (2005) demonstrated the use of GPS to measure the performance of earthmoving operations, while Cable et al. (2004) evaluated the feasibility "stringless" paving for concrete using a machine guidance system based on a combination of GPS and laser technologies. White et al. (2004) performed a preliminary evaluation of a new GPS-based compaction monitoring system developed by Caterpillar, Inc. (CAT), for use as a quality control and quality assurance (QC/QA) tool during earthwork construction operations. Peyret et al. 2004 developed a GPS-based computer-integrated construction system for asphalt pavers and compactors, providing operators with real-time information regarding the number of passes, speed, and location of asphalt rollers or pavers; the accurate and continuous information on the location of the machine enhances machine control and optimal compaction. Zeyher (2002) discussed various machine control systems on earthwork operations, involving guidance by sonar, lasers, radio signals and the GPS, and. Oloufa (2002) presented the use of GPS in quality control of compaction of asphalt pavements.

1.2.5 AAASHTO SiteManager Interface

According to AASHTOware (2005), the development of a computer package, Trns•port, was financed by AAASHTO. Trns•port consists of 14 components designed to meet most highway/transportation agency pre-construction and construction contract information and management needs. Used by many state transportation agencies nationwide (Figure 1.2), one of the Trns•port components, the SiteManager, is a comprehensive client/server based construction management tool. It provides for data entry, tracking, reporting, and analysis of contract data from contract award through finalization. SiteManager is built on the same multi-tier architecture as the rest of the Trns•port suite, allowing for easy integration and data transfer. It can be used by all levels of construction personnel such as field inspectors, technicians, project managers, clerks, auditors, lab personnel, management, producer/suppliers, contractors, and the FHWA.

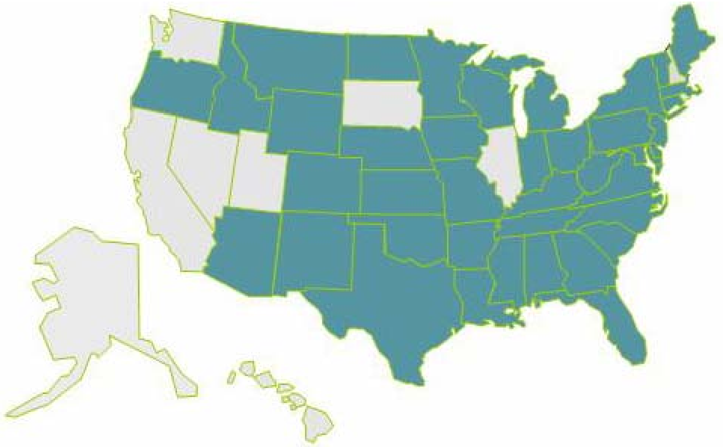


Figure 1.2 States using the AASHTO Trns*port Software (Source: AASHTOware 2005)

1.3. Project Kickoff Meeting

In order to obtain a familiarity with the pilot project, a kickoff meeting was held on February 11, 2005, at the FDOT (CEI) Resident Engineer's site office located on the University Drive in Fort Lauderdale, Florida. The research team met with the Resident Engineer in charge of inspecting the project, to determine the extent and expectations of the proposed inspection pilot. Topics discussed and actions performed at the meeting included the following: overview of the project and overall progress update; a review of the Resident Engineer's Diaries, with particular emphasis on measurement of Pay Item Quantities; elicitation of the Resident Engineer's opinions and needs regarding then proposed research, with a detailed review of pertinent Pay Items; a site tour with Resident Engineer; and the collection of preliminary GPS Data at Broward Blvd. end of the project, including FDOT Survey Control Points, a Point Feature Pay Item, a Line Feature Pay Item, and an Area Feature Pay Item.

The overall information about the pilot project is as follows:

Project Name:	University Drive (SR 817)
Limits:	North of SR-84 to just South of Broward Blvd (SR 842)
Description:	Milling and Resurfacing
County/Section:	Broward / 86220
Financial Project ID:	228079-1-52-01
Federal Aid Project ID:	4731034P
Contract Number:	T10452
Original Contract Amount (Contractor):	$6,843,164.73
Original Contract Amount (CEI):	$567,915.08
Original Contract Time:	340
First Contract Day:	June 15, 2004

Some site pictures taken during the project kickoff meeting are shown in Figures 1.3 and 1.4.

Figure 1. 3. Preliminary GPS Data Collection for Light Pole Location

Figure 1. 4. Southbound View at Broward Mall Area of the Project

1.4. Evaluation of the Spatial Relevance of FDOT Pay Items

One of the initial activities on this study was to review the FDOT's current construction administration process and evaluate the relevance of spatial location (GPS-usefulness) in construction monitoring of the pay items. The standard pay item structure, i.e., a comprehensive list of the pay items for FDOT construction work is indicated on the "Basis of Estimate" document available for download on the FDOT's Office of Estimate's website. Downloading an early 2005 version of this document (Microsoft Excel format), an evaluation was conducted to determine the usefulness of GPS for inspecting the construction of each pay item. The basis of evaluation was primarily by the indicated unit of measure. It is assumed that point measure items, defined by an X, Y coordinate in a plane, can be measured with GPS. Likewise, linear, area, and volume measure items can be identified and GPS measured using either or a combination of X, Y, and Z coordinates. Considering the English Unit version of the pay item structure with 4,523 listed pay items, point measure units would include Each (EA), Location (LO), Per Building (PB), Per Intersection (PI), etc. Linear measure units include Linear Feet (LF) and Net Mile (MI), while Square Feet (SF) and Square Yard (SY) are examples of the area measure units. The volume measure units include Cubic Foot (CF) and Cubic Yard (CY).

The relevance of spatial location is demonstrated in the results of this evaluation as shown in Table 1.1 and Figure 1.5. Of the 4,523-listed pay items, over 90% are GPS-measurable. This is a considerable portion of the FDOT's comprehensive list of construction pay items, implying that it is significantly useful to employ GPS in project monitoring. Among these GPS-measurable items, work items measured with Each (EA) and Linear Feet (LF), constitute the majority with over 70% of all pay items.

Now with emphasis on the pilot project for this study, a similar evaluation on spatial relevance of pay items was conducted, but with a little bit more detail. The first question was "Is spatial location relevant for this pay item?" in terms of construction inspection, i.e. based on the pay item description, is the physical location important to the inspector, particularly, to show it on the drwaing. For instance a pay item such as 101-1 Mobilization with unit of measure Lump sum (LS) has no need for spatial location to monitor the pay item as described, whereas a pay item such as 510-1-10 Curb & Gutter Conc (Type F) measured as Linear Feet (LF) will need the spatial location. Secondly, among the pay items that can be located spatially, it was determined if the basic X, Y coordinates are adequate to locate them. Another question similar to the first question, inquires if the spatial data (coordinates) are needed to estimate the quantities. This is important because some pay items such 590-70 Irrigation system, measured as Lump sum, may need to be located by the inspector, but need not be measured because of the required units.

It was also ascertained if pay items need just the X, Y coordinates to estimate the quantities or the elevation is needed in addition, i.e. the complete X, Y, Z coordinate. Another question also relates to if the GPS-measured quantities, i.e. using X, Y, Z coordinates, are in direct pay item units. For example, pay item 334-1-12 Superpave Asphalt Conc (Type B) can be measured with the X, Y, Z coordinates for the volume but the required or direct units are Tons (TN). The answers to these questions are indicated in Tables 1.2 to 1.6 and also illustrated in Figures 1.6 and 1.7.

Table 1.1 Summary Evaluation of Standard FDOT Pay Item Structure (4,523 Items English Units) for Relevance of Spatial Data

UNIT	UNIT DESCRIPTION	IS PAY ITEM GPS-MEASURABLE? (YES = 1, NO = 0)	TOTAL NO. OF PAY ITEMS WITH UNIT	NO. OF GPS-MEASURABLE PAY ITEMS IN UNIT	GPS-MEASURABLE ITEMS FOR UNIT AS % OF ALL PAY ITEMS
AC	ACRE	1	2	2	0.044
AS	ASSEMBLY	1	417	417	**9.220**
CF	CUBIC FOOT	1	15	15	0.332
CO	CLEANOUT	1	1	1	0.022
CY	CUBIC YARD	1	102	102	2.255
DA	DAY	0	9	0	0.000
DD	DOLLARS PER DAY	0	2	0	0.000
EA	EACH	1	2133	2133	**47.159**
ED	EACH DAY	1	13	13	0.287
GA	GALLON	0	9	0	0.000
GM	GROSS MILE	1	8	8	0.177
LB	POUND	0	40	0	0.000
LF	LINEAR FEET	1	1156	1156	**25.558**
LO	LOCATION	1	8	8	0.177
LS	LUMP SUM	0	227	0	0.000
LU	LUMINAIRE	1	3	3	0.066
MB	BOARD MEASURE/THOUSAND FEET	0	5	0	0.000
MG	THOUSAND GALLONS	0	2	0	0.000
MH	MAN-HOUR	0	5	0	0.000
NM	NET MILE	1	12	12	0.265
PA	PER ANALYSIS	0	20	0	0.000
PB	PER BUILDING	1	3	3	0.066
PI	PER INTERSECTION	1	21	21	0.464
PL	PLANT	1	24	24	0.531
PM	PER MILE	1	2	2	0.044
PS	PER SET	0	2	0	0.000
PW	PER WELL	1	5	5	0.111
SF	SQUARE FEET	1	53	53	1.172
SY	SQUARE YARD	1	186	186	**4.112**
TN	TONS	0	38	0	0.000
	TOTALS		**4523**	**4164**	**92.063**

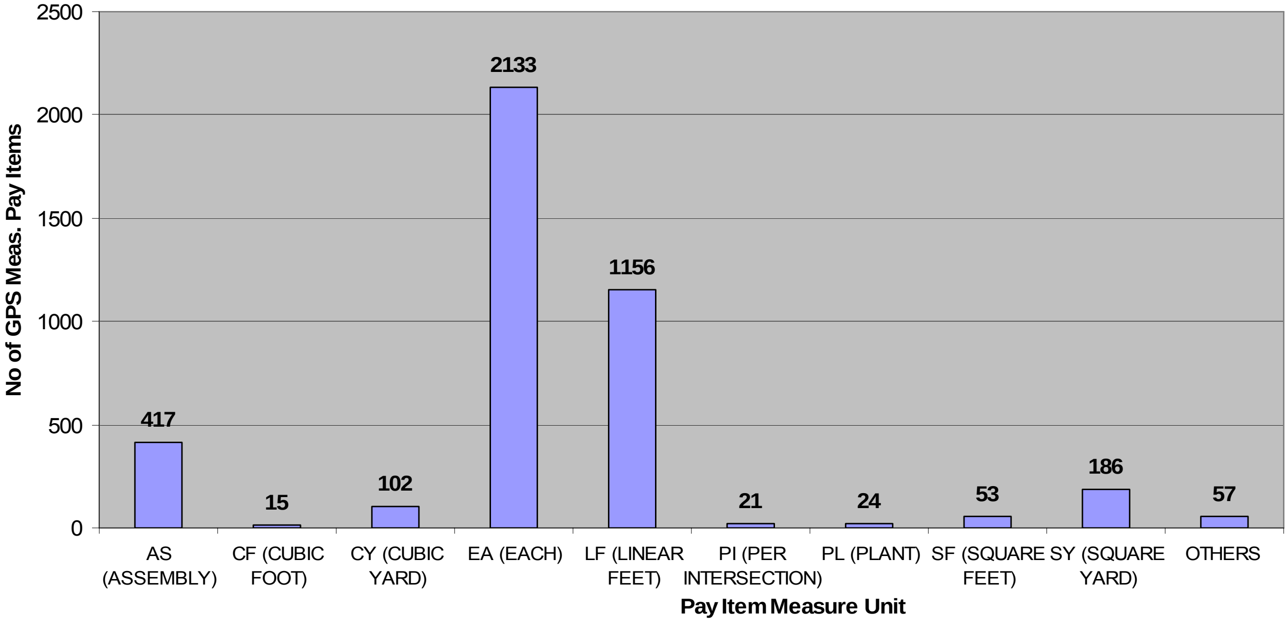


Figure 1.5 Summary Evaluation of Standard FDOT Pay Item Structure (4,523 Items English Units) for Relevance of Spatial Data

According to the contract documents, the pilot project has 180 pay items; these pay items were evaluated by the following pay item categories for the project: roadway (83 items), signings (14 items), lightings (19 items), signalization (50 items), landscaping and peripherals (14 items). It can be observed that spatial location is both relevant and needed for inspected quantities on over 90% of the roadway pay items. All signing, lighting, and signalization items have spatial location relevance. Almost 80% of the landscape/peripheral items also do, with over 90% of pay items in these categories indicating the spatial data as being useful in estimating quantities (Figure 1.6). As shown in Figure 1.7, among the GPS-measurable pay items, 100% of the categories can be measured in direct units, except roadway items where almost 80% can be measured directly, and in signing, where over 90% can be measured in direct pay item units. Looking at the same Figure 1.7, no elevation data is needed for the signalization category, while less than 10% of each of the other categories will need the elevation data, i.e. the complete X, Y, Z coordinates.

1.5. FDOT's Computation Methods for Pay Items

Several FDOT's documents were reviewed for pertinent information on measure of pay items as the construction progresses. Starting with the Standard Specifications (FDOT 2004a), the Sections 9 (Measure and Payment), 101 to 996 (work items), were reviewed in details, to ascertain the methods used at FDOT for measuring and payment of contractor's work on the construction site. The various forms used by FDOT for construction quantities, as listed and available on the FDOT's construction web site, were reviewed and recreated for possible use on the study. The document Topic No. 700-050-001c (FDOT 2004b) on computation methods indicated the three concepts for the method of measurement: final measure concept; lump sum concept; and the plan quantity concept. Final measure implies payment based on the field measurement on the calculations of quantities. The Lump sum is a fixed designated amount but may have secondary units of measure. The plan quantity concept is now being applied on a large percentage of FDOT pay items. Under this concept, the final pay quantity is based on the design plan quantity This is of great interest given that the resident engineer do not have to physically measure these related pay items. The plan quantities are generated from design files, typically, for FDOT projects, using the Bentley's GEOPAK Quantity Manager.

1.5. Summary

The current state of knowledge in the application of modern technologies such as GPS, GIS and CAD Integration, has been presented in this section of the report, including the summary of a short kickoff meeting conducted at the pilot project site. Pertinent literature and documented studies were also discussed. A preliminary review of the FDOT pay items structure and the pay items for the pilot project indicated the relevance of the spatial location of the pay items and also the significant importance of using the GPS to measure the construction quantities. Most of FDOT pay items are measured as Each (EA) and Linear Feet (LF); this observation as well as the use of other measure units such as area and volume measures, show the potential benefits on applying the GPS technology in project monitoring of construction pay items on FDOT projects.

Table 1.2 Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Data (Roadway Items)

ITEM NUMBER			ITEM DESCRIPTION	UNITS	QUANTITY	IS SPATIAL LOCATION DATA RELEVANT FOR PAY ITEM? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR LOCATION	IS SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR QUANTITIES	CAN SPATIAL DATA BE USED DIRECTLY FOR QUANTITY UNITS
101	1		MOBILIZATION	LS	1.000	N		N		
102	1		MAINTENANCE OF TRAFFIC	LS	1.000	N		N		
102	14		TRAFFIC CONTROL OFFICER	MH	86.000	N		N		
102	60		WORK ZONE SIGNS	ED	20184.000	Y	(X,Y)	Y	(X,Y)	N
102	61		BUSINESS SIGNS	EA	11.000	Y	(X,Y)	Y	(X,Y)	Y
102	71	11	BARRIER WALL (TEMPORARY) (F&I) (CONCRETE)	LF	400.000	Y	(X,Y)	Y	(X,Y)	Y
102	71	21	BARRIER WALL (TEMPORARY) (RELOCATE) (CONCRETE)	LF	400.000	Y	(X,Y)	Y	(X,Y)	Y
102	74	1	BARRICADE (TEMPORARY) (TYPES I, II, VP & DRUM)	ED	28092.000	Y	(X,Y)	Y	(X,Y)	N
102	74	2	BARRICADE (TEMPORARY) (TYPE III) (6')	ED	1546.000	Y	(X,Y)	Y	(X,Y)	N
102	76		PANELS ARROW ADVANCE WARNING	ED	960.000	Y	(X,Y)	Y	(X,Y)	N
102	77		HIGH INTENSITY FLASHING LIGHTS (TEMP - TYPE B)	ED	4892.000	Y	(X,Y)	Y	(X,Y)	N
102	78		MARKER PAVT REFLECTIVE (TEMPORARY)	EA	1186.000	Y	(X,Y)	Y	(X,Y)	N
102	79		LIGHTS (TEMP-BARR. WALL MOUNT) (TYPE C STEADY BURN)	ED	100.000	Y	(X,Y)	Y	(X,Y)	N
102	89	7	IMPACT ATTENUATOR (REDIRECTIVE OPTION) (TEMPORARY)	LO	2.000	Y	(X,Y)	Y	(X,Y)	N
102	99		CHANGEABLE-VARIABLE MESSAGE SIGN (TEMPORARY)	ED	878.000	Y	(X,Y)	Y	(X,Y)	N
104	4		MOWING	AC	77.300	Y	(X,Y)	Y	(X,Y)	Y
104	10	1	HAY OR STRAW BALE (18" X 18" X 36")	EA	540.000	Y	(X,Y)	Y	(X,Y)	Y
104	11		TURBIDITY BARRIER FLOATING	LF	375.000	Y	(X,Y)	Y	(X,Y)	Y
104	13	1	SILT FENCE STAKED (TYPE III)	LF	5769.000	Y	(X,Y)	Y	(X,Y)	Y
104	16		ROCK BAGS	EA	770.000	Y	(X,Y)	Y	(X,Y)	Y
109	71	3	FIELD OFFICE (900 SQ FT)	DA	380.000	Y	(X,Y)	Y	(X,Y)	N
110	1	1	CLEARING & GRUBBING	LS	1.000	Y	(X,Y)	Y	(X,Y)	N
110	4		PAVEMENT REMOVAL OF EXISTING CONCRETE	SY	7426.000	Y	(X,Y)	Y	(X,Y)	Y
120	1		EXCAVATION REGULAR	CY	3641.000	Y	(X,Y)	Y	(X,Y,Z)	Y
120	6		EMBANKMENT	CY	5158.000	Y	(X,Y)	Y	(X,Y,Z)	Y
285	715		BASE OPTIONAL (BASE GROUP 15)	SY	5606.000	Y	(X,Y)	Y	(X,Y)	Y
327	70	6	MILLING EXIST ASPH PVT (1 1/2" AVG DEPTH)	SY	81400.000	Y	(X,Y)	Y	(X,Y)	Y
327	70	16	MILLING EXIST ASPH PVT (1/2" AVG DEPTH)	SY	1606.000	Y	(X,Y)	Y	(X,Y)	Y
334	1	12	SUPERPAVE ASPHALTIC CONC (TRAFFIC B)	TN	13863.700	Y	(X,Y)	Y	(X,Y,Z)	N
337	7	6	ASPH CONC FRICTION COURSE (INC BIT/RUBBER) FC 12.5	TN	7456.300	Y	(X,Y)	Y	(X,Y,Z)	N
339	1		ASPHALT PAVEMENT MISCELLANEOUS	TN	40.400	Y	(X,Y)	Y	(X,Y,Z)	N
400	1	11	CONC CLASS I (RETAINING WALLS)	CY	134.300	Y	(X,Y)	Y	(X,Y,Z)	Y
400	2	15	CONC CLASS II (MISCELLANEOUS)	CY	67.300	Y	(X,Y)	Y	(X,Y,Z)	Y
415	1	6	REINF STEEL (MISCELLANEOUS)	LB	4188.000	N				
425	1	311	INLETS (CURB) (TYPE P-1) (<10')	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	321	INLETS (CURB) (TYPE P-2) (<10')	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	351	INLETS (CURB) (TYPE P-5) (<10')	EA	11.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	355	INLETS (CURB) (TYPE P-5) (PARTIAL)	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	361	INLETS (CURB) (TYPE P-6) (<10')	EA	10.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	365	INLETS (CURB) (TYPE P-6) (PARTIAL)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	471	INLETS (CURB) (TYPE 7) (<10')	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	505	INLETS (DT BOT) (TYPE A) (PARTIAL)	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	521	INLETS (DT BOT) (TYPE C) (<10')	EA	6.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	711	INLETS (GUTTER) (TYPE V) (<10')	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
425	1	910	INLETS (CLOSED FLUME) (N/A)	EA	15.000	Y	(X,Y)	Y	(X,Y)	Y
425	2	41	MANHOLES (P-7) (<10')	EA	14.000	Y	(X,Y)	Y	(X,Y)	Y
425	3	43	MANHOLES (P-7) (PARTIAL)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
425	2	73	MANHOLES (J-7) (PARTIAL)	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
425	5		MANHOLE (ADJUST)	EA	11.000	Y	(X,Y)	Y	(X,Y)	Y
430	171	125	PIPE CULV (OPT MATL) (ROUND) (18" SS)	LF	2656.000	Y	(X,Y)	Y	(X,Y)	Y
430	171	129	PIPE CULV (OPT MATL) (ROUND) (24" SS)	LF	1379.000	Y	(X,Y)	Y	(X,Y)	Y
430	171	133	PIPE CULV (OPT MATL) (ROUND) (30" SS)	LF	728.000	Y	(X,Y)	Y	(X,Y)	Y
430	171	225	PIPE CULV (OPT MATL) (OTHER) (18" SS)	LF	420.000	Y	(X,Y)	Y	(X,Y)	Y
430	941	29	PIPE DESILTING (24" SS)	LF	340.000	Y	(X,Y)	Y	(X,Y)	Y
430	941	33	PIPE DESILTING (30" SS)	LF	206.000	Y	(X,Y)	Y	(X,Y)	Y
430	941	40	PIPE DESILTING (42" SS)	LF	55.000	Y	(X,Y)	Y	(X,Y)	Y
430	941	41	PIPE DESILTING (48" SS)	LF	122.000	Y	(X,Y)	Y	(X,Y)	Y
430	984	125	MITERED END SECTION (OPTIONAL ROUND) (18" SD)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
430	984	625	MITERED END SECT (OPT/ELLIP/ARCH) (18" SD)	EA	6.000	Y	(X,Y)	Y	(X,Y)	Y
515	2	201	PEDESTRIAN/BICYCLE RAILING (STEEL ONLY) (42" PICKE	LF	1438.000	Y	(X,Y)	Y	(X,Y)	Y
520	1	10	CURB & GUTTER CONC (TYPE F)	LF	25273.000	Y	(X,Y)	Y	(X,Y)	Y
520	2	4	CURB CONC (TYPE D)	LF	5244.000	Y	(X,Y)	Y	(X,Y)	Y
520	3		GUTTER VALLEY CONC	LF	257.000	Y	(X,Y)	Y	(X,Y)	Y
522	1		SIDEWALK CONC (4" THICK)	SY	5032.000	Y	(X,Y)	Y	(X,Y)	Y
522	2		SIDEWALK CONC (6" THICK)	SY	303.000	Y	(X,Y)	Y	(X,Y)	Y
536	1	1	GUARDRAIL (ROADWAY)	LF	900.000	Y	(X,Y)	Y	(X,Y)	Y
536	8		GUARDRAIL BRIDGE ANCHORAGE ASSEM	EA	3.000	Y	(X,Y)	Y	(X,Y)	Y
536	73		GUARDRAIL REMOVAL	LF	900.000	Y	(X,Y)	Y	(X,Y)	Y
536	85	22	GUARDRAIL END ANCHORAGE ASSEMBLY FLARED	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
536	85	24	GUARDRAIL END ANCHORAGE ASSEMBLY PARALLEL	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
550	6	1	FENCE END POST ASSEMBLY (TYPE B) (STANDARD)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
710	5	1	GUIDE LINES (PAINT) (WHITE)	LF	360.000	Y	(X,Y)	Y	(X,Y)	Y
710	6		DIRECTIONAL ARROWS, PAINTED	EA	140.000	Y	(X,Y)	Y	(X,Y)	Y

Table 1.3 Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Data (Signing Items)

ITEM NUMBER			ITEM DESCRIPTION	UNITS	QUANTITY	IS SPATIAL LOCATION DATA RELEVANT FOR PAY ITEM? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR LOCATION	IS SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR QUANTITIES	CAN SPATIAL DATA BE USED DIRECTLY FOR QUANTITY UNITS
700	40	1	SIGN SINGLE POST (LESS THAN 12)	AS	84.000	Y	(X,Y)	Y	(X,Y)	Y
700	40	2	SIGN SINGLE POST (12 - 25)	AS	11.000	Y	(X,Y)	Y	(X,Y)	Y
700	41	10	SIGN MULTI POST (50 OR LESS)	AS	7.000	Y	(X,Y)	Y	(X,Y)	Y
700	45	22	SIGN LT'D OVHD CTLVR (C 21 OR 30, S 51 TO 100)	AS	2.000	Y	(X,Y)	Y	(X,Y)	Y
700	45	34	SIGN LT'D OVHD CTLVR (C 31 TO 40, S 151 TO 200)	AS	1.000	Y	(X,Y)	Y	(X,Y)	Y
700	46	11	SIGN EXISTING (REMOVAL) (SINGLE POST)	AS	52.000	Y	(X,Y)	Y	(X,Y)	Y
700	46	12	SIGN EXISTING (REMOVAL) (MULTI - POST)	AS	2.000	Y	(X,Y)	Y	(X,Y)	Y
700	46	13	SIGN EXISTING (REMOVAL) (OVERHEAD TRUSS)	AS	1.000	Y	(X,Y)	Y	(X,Y)	Y
700	46	14	SIGN EXISTING (REMOVAL) (OVERHEAD CANTILEVER)	AS	1.000	Y	(X,Y)	Y	(X,Y)	Y
700	46	21	SIGN EXISTING (RELOCATE) (SINGLE POST)	AS	3.000	Y	(X,Y)	Y	(X,Y)	Y
705	10	11	MARKER OBJECT (POST MOUNT) (TYPE 1)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
710	30		REFLECTIVE PAINT (ISLAND NOSE) (YELLOW)	SY	80.000	Y	(X,Y)	Y	(X,Y)	Y
710	90		PAINTED PAVEMENT MARKINGS (FINAL SURFACE)	LS	1.000	Y	(X,Y)	N		
711	3		PAVT MESSAGES THERMOPLASTIC	EA	29.000	Y	(X,Y)	Y	(X,Y)	Y

Table 1.4 Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Data (Lighting Items)

ITEM NUMBER			ITEM DESCRIPTION	UNITS	QUANTITY	IS SPATIAL LOCATION DATA RELEVANT FOR PAY ITEM? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR LOCATION	IS SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR QUANTITIES	CAN SPATIAL DATA BE USED DIRECTLY FOR QUANTITY UNITS
400	1	15	CONC CLASS I (MISCELLANEOUS)	CY	21.500	Y	(X,Y)	Y	(X,Y,Z)	Y
715	1	113	CONDUCTORS (F&I) (INSULATED) (NO 6)	LF	31787.980	Y	(X,Y)	Y	(X,Y)	Y
715	1	115	CONDUCTORS (F&I) (INSULATED) (NO 2)	LF	13278.960	Y	(X,Y)	Y	(X,Y)	Y
715	2	114	CONDUIT (F&I UNDERGROUND) (PVC SCH 40) (1 1/2")	LF	6509.200	Y	(X,Y)	Y	(X,Y)	Y
715	2	115	CONDUIT (F&I UNDERGROUND) (PVC SCH 40) (2")	LF	6509.200	Y	(X,Y)	Y	(X,Y)	Y
715	2	214	CONDUIT (F&I UNDERPAVEMENT) (PVC SCH 40) (1 1/2")	LF	897.100	Y	(X,Y)	Y	(X,Y)	Y
715	2	215	CONDUIT (F&I UNDERPAVEMENT) (PVC SCH 40) (2")	LF	897.100	Y	(X,Y)	Y	(X,Y)	Y
715	2	235	CONDUIT (F&I UNDERPAVEMENT) (RIGID GALV) (2")	LF	2070.000	Y	(X,Y)	Y	(X,Y)	Y
715	2	344	CONDUIT (F&I SURFACE MOUNT) (PVC SCH 80) (1 1/2")	LF	314.600	Y	(X,Y)	Y	(X,Y)	Y
715	2	345	CONDUIT (F&I SURFACE MOUNT) (PVC SCH 80) (2")	LF	314.600	Y	(X,Y)	Y	(X,Y)	Y
715	2	438	CONDUIT (F&I JACKED UNDERPVT) (RIGID GALV) (6")	LF	887.000	Y	(X,Y)	Y	(X,Y)	Y
715	7	11	LOAD CENTER (F&I) (SECONDARY VOLTAGE)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
715	14	11	PULL BOX (F&I) (ROADSIDE)	EA	145.000	Y	(X,Y)	Y	(X,Y)	Y
715	14	14	PULL BOX (F&I) (SURFACE MOUNT)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
715	500	1	POLE CABLE DISTRIBUTION SYSTEM (CONVENTIONAL)	EA	63.000	Y	(X,Y)	Y	(X,Y)	Y
715	511	150	LIGHT POLE COMP (F&I) (SGL ARM SHLDR MNT-ALUM) (50')	EA	59.000	Y	(X,Y)	Y	(X,Y)	Y
715	512	150	LIGHT POLE COMP (F&I) (DBL ARM SHLDR MNT-ALUM) (50')	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
715	521	150	LIGHT POLE COMP (FURNISH) (SGL ARM SHLDR MNT-ALUM) (	EA	5.000	Y	(X,Y)	Y	(X,Y)	Y
715	550	000	LIGHT POLE COMP (REMOVE)	EA	9.000	Y	(X,Y)	Y	(X,Y)	Y

Table 1.5 Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Data (Signalization Items)

ITEM NUMBER			ITEM DESCRIPTION	UNITS	QUANTITY	IS SPATIAL LOCATION DATA RELEVANT FOR PAY ITEM? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR LOCATION	IS SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR QUANTITIES	CAN SPATIAL DATA BE USED DIRECTLY FOR QUANTITY UNITS
555	1	2	DIRECTIONAL BORE (6" TO < 12")	LF	764.000	Y	(X,Y)	Y	(X,Y)	Y
630	1	12	CONDUIT (FURNISH & INSTALL) (UNDERGROUND)	LF	4086.000	Y	(X,Y)	Y	(X,Y)	Y
630	1	13	CONDUIT (FURNISH & INSTALL) (UNDER PAVEMENT)	LF	9820.000	Y	(X,Y)	Y	(X,Y)	Y
632	7	1	CABLE (SIGNAL) (FURNISH & INSTALL)	PI	3.000	Y	(X,Y)	Y	(X,Y)	Y
632	8	212	CABLE (INTERCONNECT) (F&I) (1 - 25 PR) (UNDER-GRND)	LF	8100.000	Y	(X,Y)	Y	(X,Y)	Y
635	1	11	PULL & JUNCTION BOXES (F&I) (PULL BOX	EA	49.000	Y	(X,Y)	Y	(X,Y)	Y
635	1	15	PULL & JUNCTION BOXES (F&I) (FIBER OPTICS)	EA	17.000	Y	(X,Y)	Y	(X,Y)	Y
639	1	23	ELECTRICAL POWER SERVICE (UNDERGROUND)	AS	3.000	Y	(X,Y)	Y	(X,Y)	Y
639	2	1	ELECTRIAL SERVICE WIRE	LF	465.000	Y	(X,Y)	Y	(X,Y)	Y
649	411	001	M/ARM (F&I/HL) (SGL ARM W/O LUM (1ST ARM TYPE BI (2N	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
649	413	002	M/ARM (F&I/HL) (SGL ARM W/O LUM) (1ST ARM (B3)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
649	415	003	M/ARM (F&I/HL) (SGL ARM W/O LUM) (1ST ARM (B5)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
649	416	004	M/ARM (F&I/HL) (SGL ARM W/O LUM) (1ST ARM (B6) 2ND (0)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
649	417	006	M/ARM (F&I/HL) (SGL ARM W/O LUM) 1ST ARM (B7)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
649	426	504	M/ARM (F&I/HL) (DBL ARM W/O LUM) (1ST ARM (B6)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
650	51	311	SIGNAL TRAFFIC (F&I) (3 SECT 1 WAY) (STD)	AS	37.000	Y	(X,Y)	Y	(X,Y)	Y
650	51	411	SIGNAL TRAFFIC (F&I) (4 SECT 1 WAY) (STD)	AS	2.000	Y	(X,Y)	Y	(X,Y)	Y
650	51	511	SIGNAL TRAFFIC (F&I) (5 SECT 1 WAY) (STD)	AS	1.000	Y	(X,Y)	Y	(X,Y)	Y
653	181		SIGNAL PEDESTRIAN (F&I) (LED) (1 DIRECTION)	AS	20.000	Y	(X,Y)	Y	(X,Y)	Y
659	101		SIGNAL HEAD AUXILIARIES (BACK PLATES 3 SECT)	EA	13.000	Y	(X,Y)	Y	(X,Y)	Y
659	102		SIGNAL HEAD AUXILIARIES (BACK PLATES 4 SECT)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
659	106		SIGNAL HEAD AUXILIARIES (TUNNEL VISOR)	EA	126.000	Y	(X,Y)	Y	(X,Y)	Y
659	107		SIGNAL HEAD AUXILIARIES (ALUMINUM PEDESTAL)	EA	4.000	Y	(X,Y)	Y	(X,Y)	Y
659	118		SIGNAL HEAD AUXILIARIES (BACK PLATES 5 SECT CLU)	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
663	74	11	VEHICLE DETECTOR ASSEM (F&I) (OPTICAL TYPE)	EA	11.000	Y	(X,Y)	Y	(X,Y)	Y
665	11		DETECTOR PEDEST (F&I) (DET STA POLE OR CABINET MTD)	EA	20.000	Y	(X,Y)	Y	(X,Y)	Y
670	5	130	CNTL ASSEM ACT SS (F&I) (SPECIAL)	AS	3.000	Y	(X,Y)	Y	(X,Y)	Y
678	1	110	CNTRL ACCESS (F&I) (TYPE 4 TIME SWITCH)	EA	3.000	Y	(X,Y)	Y	(X,Y)	Y
685	106		SYSTEM AUXILIARIES (UNINTERRUPTIBLE POWER SOURCE)	EA	3.000	Y	(X,Y)	Y	(X,Y)	Y
685	120		SYSTEM AUXILIARIES (TELEMETRY TRANSCEIVER)	EA	3.000	Y	(X,Y)	Y	(X,Y)	Y
685	128		SYSTEM AUXILIARIES (INTERFACE PANEL)	EA	3.000	Y	(X,Y)	Y	(X,Y)	Y
690	10		SIGNAL HEAD TRAFFIC ASSEMBLY REMOVAL	EA	32.000	Y	(X,Y)	Y	(X,Y)	Y
690	20		SIGNAL PEDESTRIAN ASSEMBLY REMOVAL	EA	12.000	Y	(X,Y)	Y	(X,Y)	Y
690	31		SIGNAL PEDESTRIAN REMOVAL	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
690	33	1	POLE REMOVAL (DEEP DIRECT BURIAL)	LF	220.000	Y	(X,Y)	Y	(X,Y)	Y
690	50		CNTRL ASSEM REMOVE	EA	5.000	Y	(X,Y)	Y	(X,Y)	Y
690	60		DETECTOR VEHICLE ASSEMBLY REMOVE	EA	12.000	Y	(X,Y)	Y	(X,Y)	Y
690	70		DETECTOR PEDESTRIAN ASSEMBLY REMOVE	EA	13.000	Y	(X,Y)	Y	(X,Y)	Y
690	80		SPAN WIRE ASSEMBLY REMOVE	EA	10.000	Y	(X,Y)	Y	(X,Y)	Y
690	90		CONDUIT & CABLING REMOVE	PI	3.000	Y	(X,Y)	Y	(X,Y)	Y
690	91		SIGNAL INTERCONNECT CABLE REMOVE	LF	8490.000	Y	(X,Y)	Y	(X,Y)	Y
690	100		SIGNAL EQUIPMENT MISCELLANEOUS REMOVE	PI	3.000	Y	(X,Y)	Y	(X,Y)	Y
699	1	1	SIGN, INTERNAL ILLUM (ST NAME)	EA	11.000	Y	(X,Y)	Y	(X,Y)	Y
700	48	18	SIGN PANELS (F&I) (15 OR <)	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
700	48	60	SIGN PANELS (REMOVE)	EA	12.000	Y	(X,Y)	Y	(X,Y)	Y
741	70	111	TMS VEHICLE SENSOR (CLASS II) (F&I) (TYP I) (1/2 LN)	EA	13.000	Y	(X,Y)	Y	(X,Y)	Y
744	70	32	TMS SOLAR POWER UNIT (INSTALL) (EXISTING POLE)	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y
745	70	12	TMS INDUCTIVE LOOP ASSEM (F&I) (2 LOOPS/LN)	AS	13.000	Y	(X,Y)	Y	(X,Y)	Y
746	71	132	TMS CABINET (F&I) (TYPE III) (PEDESTAL) (2 BACKPLANE)	EA	2.000	Y	(X,Y)	Y	(X,Y)	Y
746	73	111	TMS CABINET (INSTALL) (TYPE III) (BASE MOUNT) (1 BACK	EA	1.000	Y	(X,Y)	Y	(X,Y)	Y

Table 1.6 Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Data (Landscape/Peripheral Items)

ITEM NUMBER			ITEM DESCRIPTION	UNITS	QUANTITY	IS SPATIAL LOCATION DATA RELEVANT FOR PAY ITEM? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR LOCATION	IS SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? (Y/N)	TYPE OF SPATIAL DATA NEEDED FOR QUANTITIES	CAN SPATIAL DATA BE USED DIRECTLY FOR QUANTITY UNITS
526	1	1	PAVERS, ARCHITECTURAL (ROADWAY)	SY	552.000	Y	(X,Y)	Y	(X,Y)	Y
570	3		SEED GRASS (PERMANENT TYPE)	LB	6.210	N		N		
570	9		WATER FOR GRASS	MG	2.320	N		N		
570	12		SEED WILDFLOWER	LB	0.015	N		N		
571	1	13	PLASTIC EROSION MAT (TRM) (TYPE 3)	SY	3214.000	Y	(X,Y)	Y	(X,Y)	Y
580	327	1	TREE RELOCATION (PALM)	EA	20.000	Y	(X,Y)	Y	(X,Y)	Y
580	327	2	SMALL TREE, SHRUBS, GROUND COVER RELOCATION	EA	8.000	Y	(X,Y)	Y	(X,Y)	Y
580	340	1	TREE PROTECTION (BATTERBOARD)	LF	984.000	Y	(X,Y)	Y	(X,Y)	Y
582	2		SHRUBS (10" TO 18" HEIGHT OR SPREAD)	PL	8431.000	Y	(X,Y)	Y	(X,Y)	Y
582	3		SHRUBS (19" TO 7' HEIGHT OR SPREAD)	PL	90.000	Y	(X,Y)	Y	(X,Y)	Y
583	4		TREE (8' TO 20' HEIGHT OR CLEAR TRUNK)	PL	191.000	Y	(X,Y)	Y	(X,Y)	Y
584	4		PALMS SINGLE TRUNK (8' TO 20' HEIGHT OR CLEAR TRUNK)	PL	108.000	Y	(X,Y)	Y	(X,Y)	Y
590	70		IRRIGATION SYSTEM	LS	1.000	Y	(X,Y)	N	(X,Y)	Y
902	576	2	PERFORMANCE SODDING	SY	9670.000	Y	(X,Y)	Y	(X,Y,Z)	Y

Table 1.7 Summary Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Data (By Pay Item Categories)

PAY ITEM CATEGORY (NO. OF ITEMS)	IS SPATIAL LOCATION DATA RELEVANT FOR PAY ITEM? %(YES)	NEED LOCATION FOR PAY ITEM? %(NO)	GPS MEAS. ITEMS -- (X,Y) DATA ADEQUATE FOR LOCATION? %(YES)	DATA NEEDED FOR LOCATION %(X,Y,Z)	SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? %(YES)	SPATIAL DATA RELEVANT FOR QUANTITIES (GPS MEASURABLE)? %(NO)	GPS MEAS. ITEMS -- (X,Y) DATA ADEQUATE FOR QUANTITY? %(YES)	GPS MEAS. ITEMS -- (X,Y,Z) DATA NEEDED FOR QUANTITY? %(YES)
ROADWAY (83)	92.8	7.2	100.0	0.0	92.8	7.2	90.9	9.1
SIGNING (14)	100.0	0.0	100.0	0.0	92.9	7.1	92.9	7.1
LIGHTINGS (19)	100.0	0.0	100.0	0.0	100.0	0.0	94.7	5.3
SIGNALIZATION (50)	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
LANDSCAPE / PERIPHERAL (14)	78.6	21.4	100.0	0.0	90.9	9.1	90.9	9.1

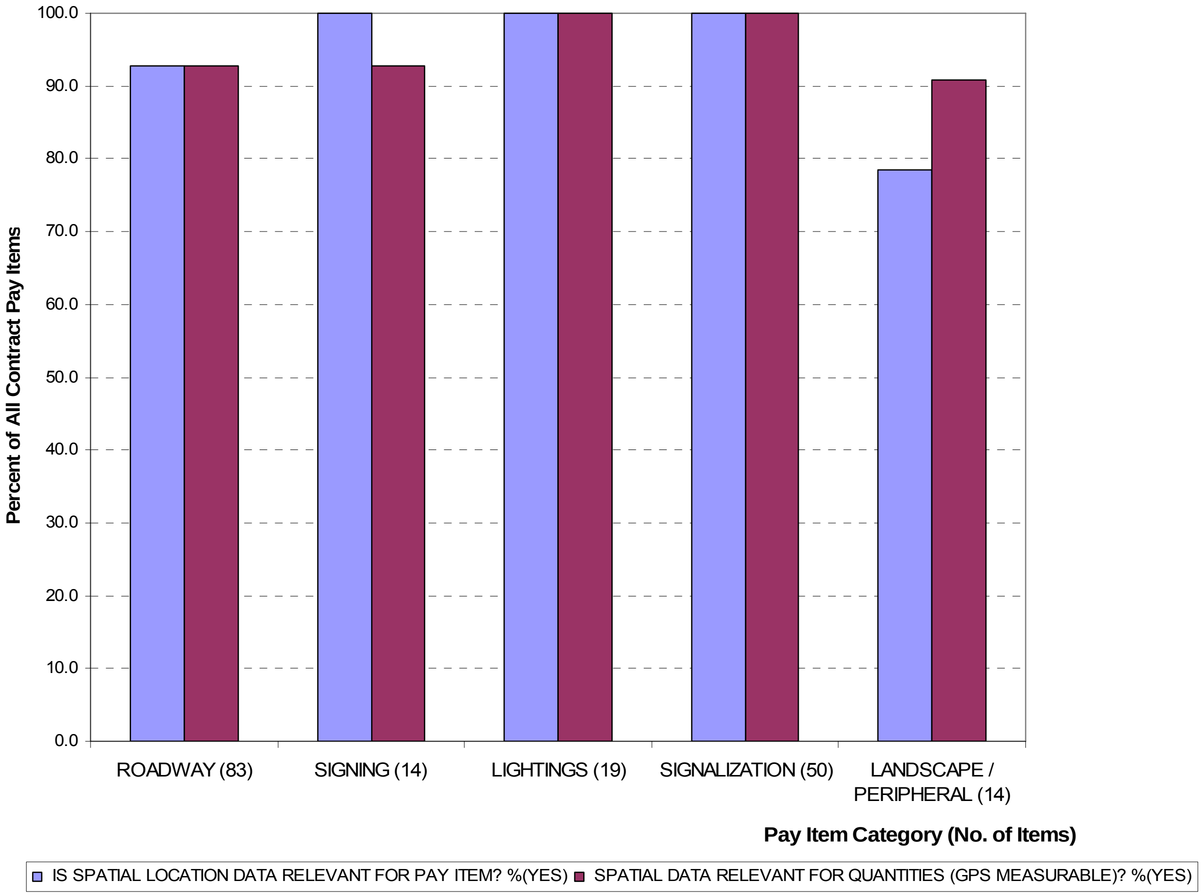


Figure 1.6 Overall Evaluation of SR 817 Contract Pay Items for Relevance of Spatial Location Data

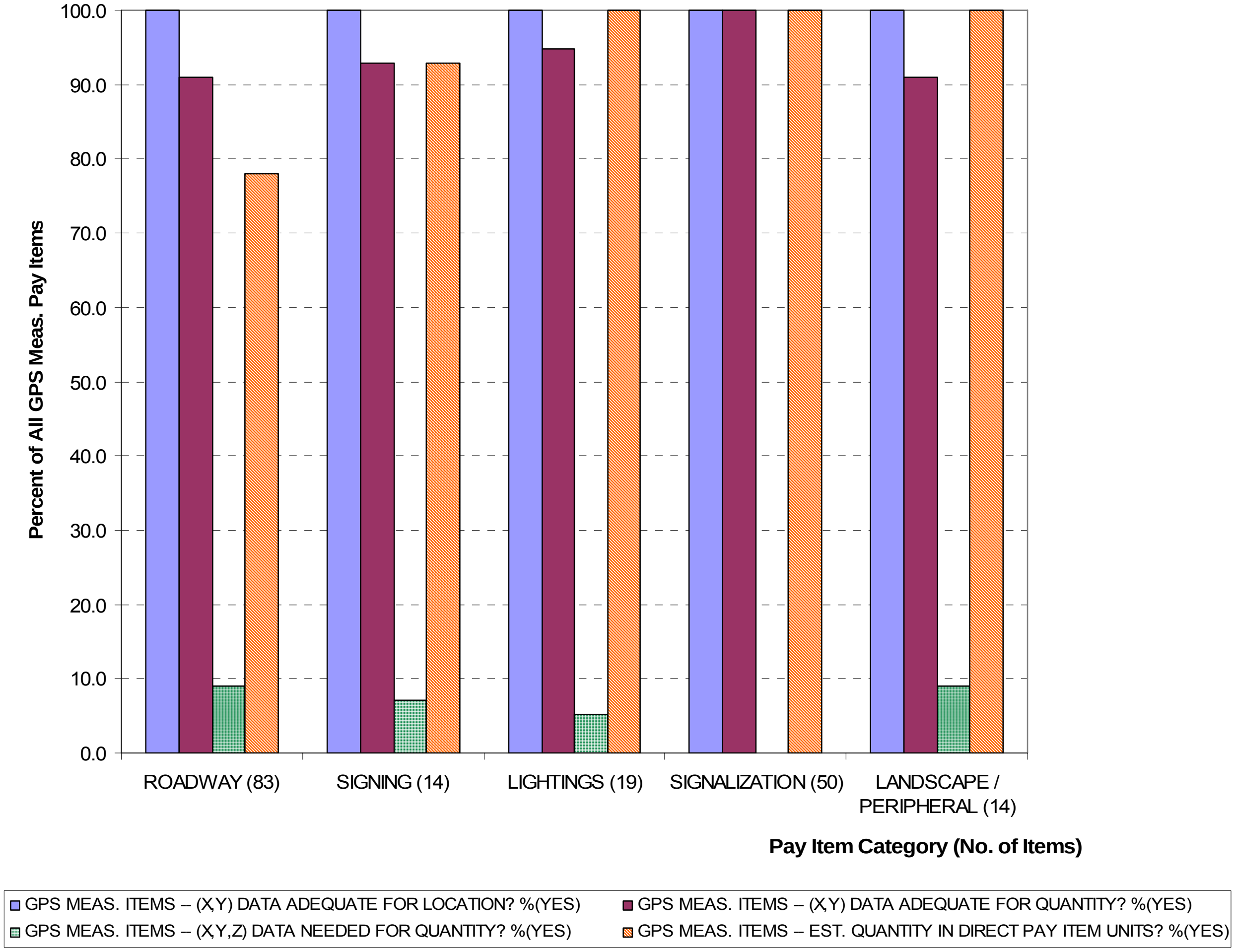


Figure 1.7 Evaluation of SR 817 Contract Pay Items (GPS Measurable Items) for Relevance of Spatial Location Data

2. Methodology and Development of GPS/GIS Tools

The overall data flowchart, the concepts employed, and utilization of modern devices are described in this section of the report. Starting with the choice of GPS receiver, accuracy issues are very relevant to the proposed methodology. It was necessary to establish the GPS configuration for the acquisition of spatial data, including hardware specifications and data error correction methods. The compatibility of CAD documents with GIS basemaps is also important for comparison of field data with the original design, including the establishment of the geo-referencing methods for FDOT engineering plans; and creating a relational database structure for both spatial and construction attribute data.

2.1 Overall Framework

Based on the original plans and specifications, along with the engineer's estimate of quantities and bid data, a baseline database can be generated both spatially and in attribute form. FDOT's Microstation (GEOPAK) drawings can be converted into GIS basemaps, with correction to the proper projections. As the project progresses, GPS receivers with sub meter accuracy can be used to capture location data (x, y, z coordinates), at each point or linear sections on the site, as well as the construction data. Differential correction through real-time and post-processing of the GPS data will improve the accuracy of the location points. The GPS receiver is capable of creating dictionaries to capture this data and also doing the differential correction. Database can be developed to store both the spatial and attribute data, as well as digital photographs of the various inspected locations. In addition to being able to capture the updated data of the construction process, spatial analyses can be done to compute pay item quantities and costs for the contractor, e.g., earthwork quantities, length of pipe, length of stripping, etc. An as-built documentation of the construction project can also be effectively and accurately accomplished using the proposed tools.

The efficiency of the proposed system depends to a great extent, on the accuracy of the GPS receiver, ranging from the recreational or low-cost receivers (less than $500), to medium-price mapping grade GPS (about $4,000), to the high-end survey-grade GPS receivers ($over $45,000). The three types were utilized in this study, with the first type low-cost GPS evaluated rigorously for its accuracy. The mapping grade GPS was used extensively for collecting most of the data while the expensive grade was utilized for the pilot study with the Bentley's Construction Inspector. The choice of the mapping grade GPS was based on a preliminary analysis of data collected early in the study; it has many enhancements in terms of custom data collection forms, ease of data correction for errors, and the flexibility of exporting data collected in various formats. Figure 2.1 shows the three types of GPS receivers.

As shown in Figure 2.2 the proposed flow of data is indicated, where a generic or low-cost GPS data can be used to collect data (Option 1) but has to be corrected for large errors. The second option involves using a more accurate GPS receiver, capable of generating corrected data in flexible formats such as Microsoft Access database tables. Either option will have the GPS position data processed in a set of computer programs written in the Microsoft Visual Basic language. This component also includes the GIS programs. These computer programs will both generate reports for the user and create an interface with the AASHTO SiteManager. The report will be in the forms of spatial (maps), tabular, and graphs. The Interface will be through provision of basic Microsoft

Access tables, development of XML or application extension or dynamic link libraries (dll) files for the SiteManager software.

a. Low-cost GPS Receiver b. Mapping Grade GPS Receiver

c. High-end Survey Grade GPS Receiver

Figure 2.1 Illustrations of GPS Receivers

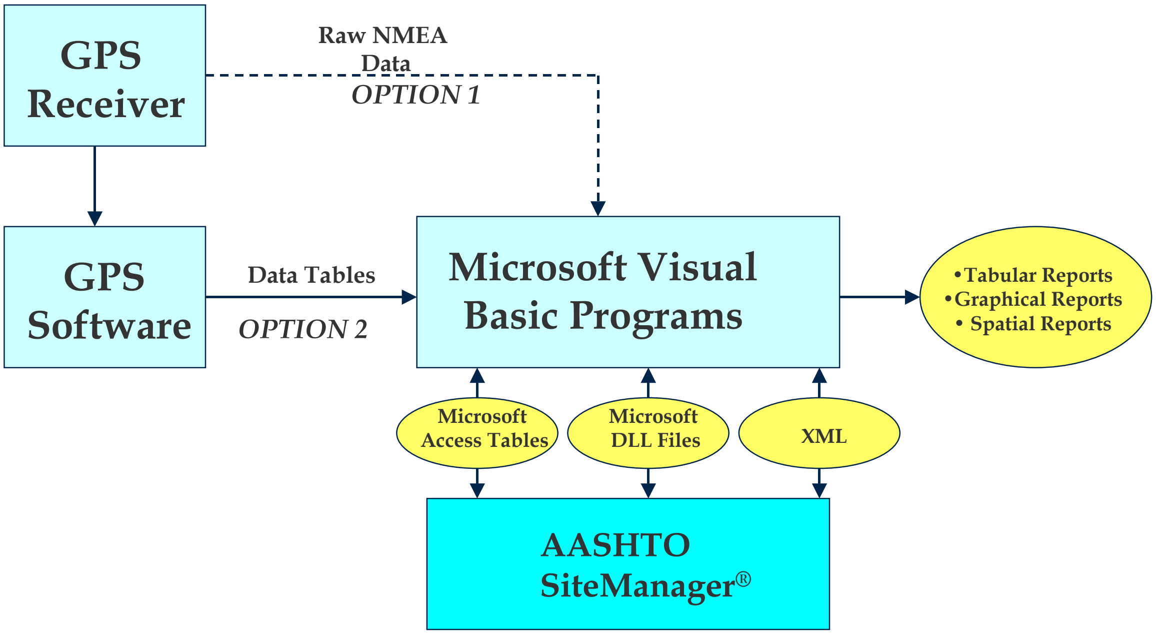
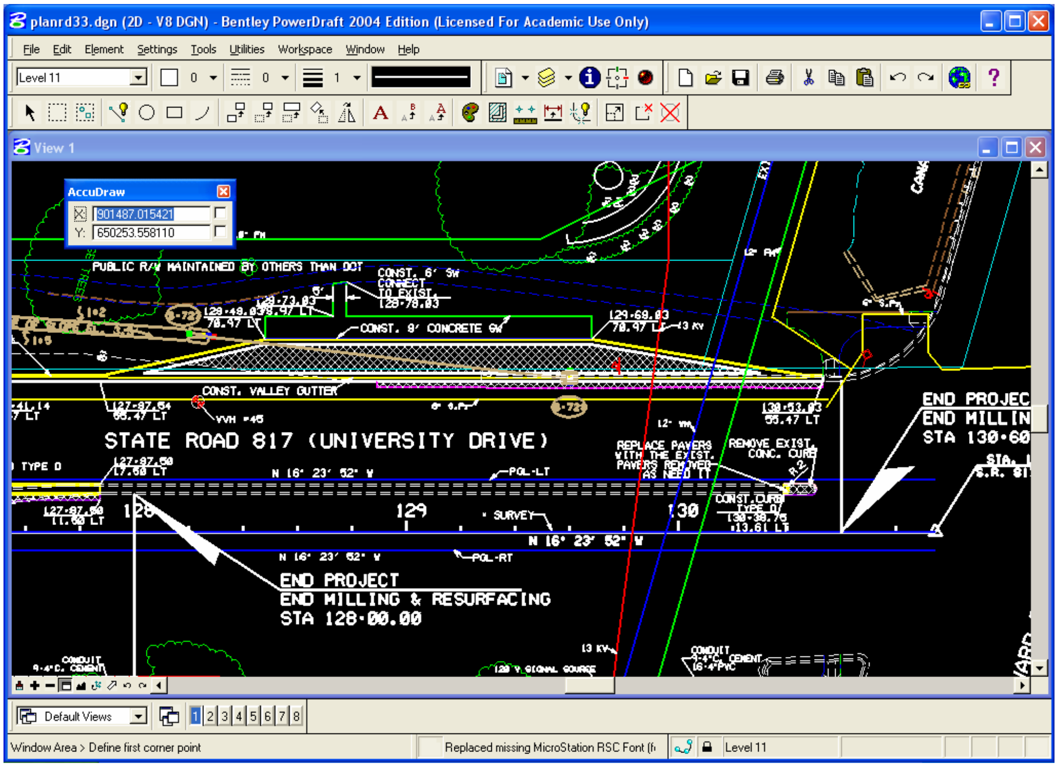


Figure 2.2 Overall Flowchart of Data in the Proposed GPS/GIS Tools

2.2 CAD/GIS Interoperability

As mentioned earlier, the GIS basemaps will serve as a background for the GPS-collected field data. The GPS and GIS work together so well, with the latter providing the medium to show the former. The original CAD data can be used directly or converted into an accepted format of GIS basemap in various shapefiles. The ESRI ArcGIS shapefile format was adapted for this study based primarily on its FDOT-wide use and the industry-wide acceptance. As shown in Figure 2.3, the original CAD data in Microstation comes with an already-established referenced coordinate system; this makes it very convenient to use the CAD data for geospatial purposes. Figure 2.4 shows an ESRI shapefile converted from a CAD data (around the same area as the Figure 2.3 features), with the orientation on the shapefile being now in the North-south direction.

In addition to direct conversion from CAD to ESRI shapefiles in the ArcGIS environment, custom computer programs were also developed in the Microsoft Visual Basic 6 Language, to open and view shapefiles or the original design drawings. In both cases, an inspected pay item's spatial data can be superimposed on the on the original location of the pay item on the engineering plans. This is demonstrated later in this report.



planrd33.dgn (2D - V8 DGN) - Bentley PowerDraft 2004 Edition (Licensed For Academic Use Only)

AccuDraw

X: 901487.015421

Y: 650253.558110

Level 11

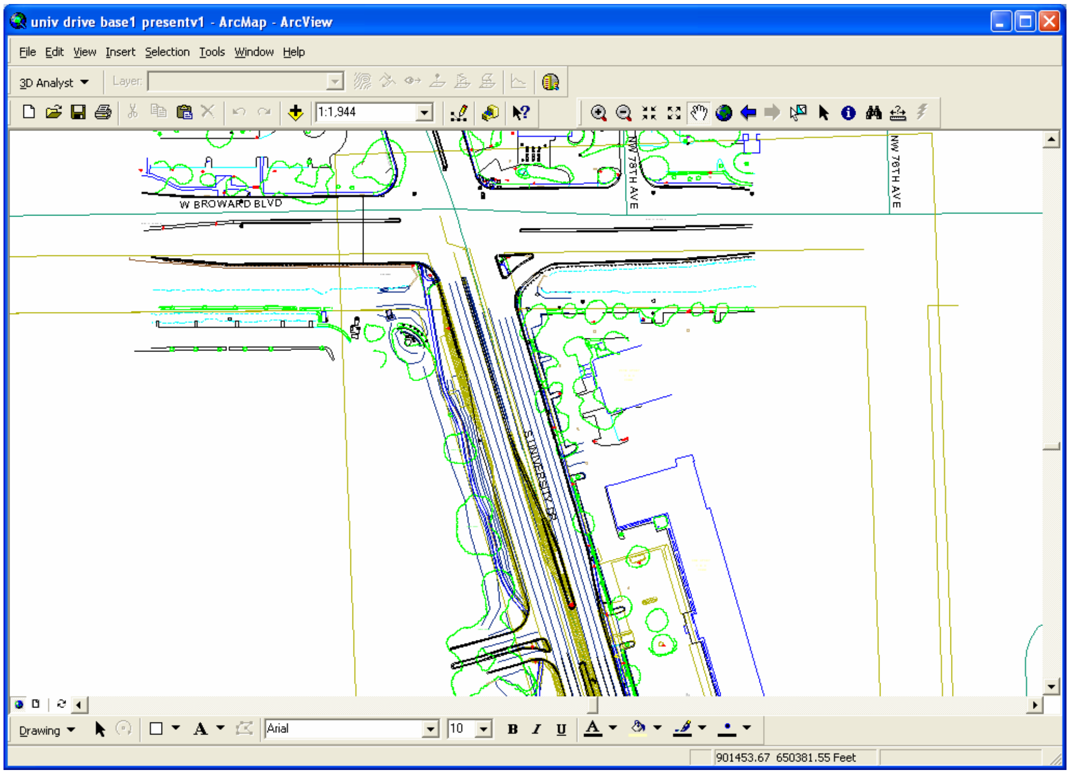
Default Views

Window Area > Define first corner point

Replaced missing MicroStation RSC Font (f

Level 11

Figure 2.3 Microstation CAD Data with Established Coordinate System



univ drive base1 presentv1 - ArcMap - ArcView

1:1,944

Arial

10

901453.67 650381.55 Feet

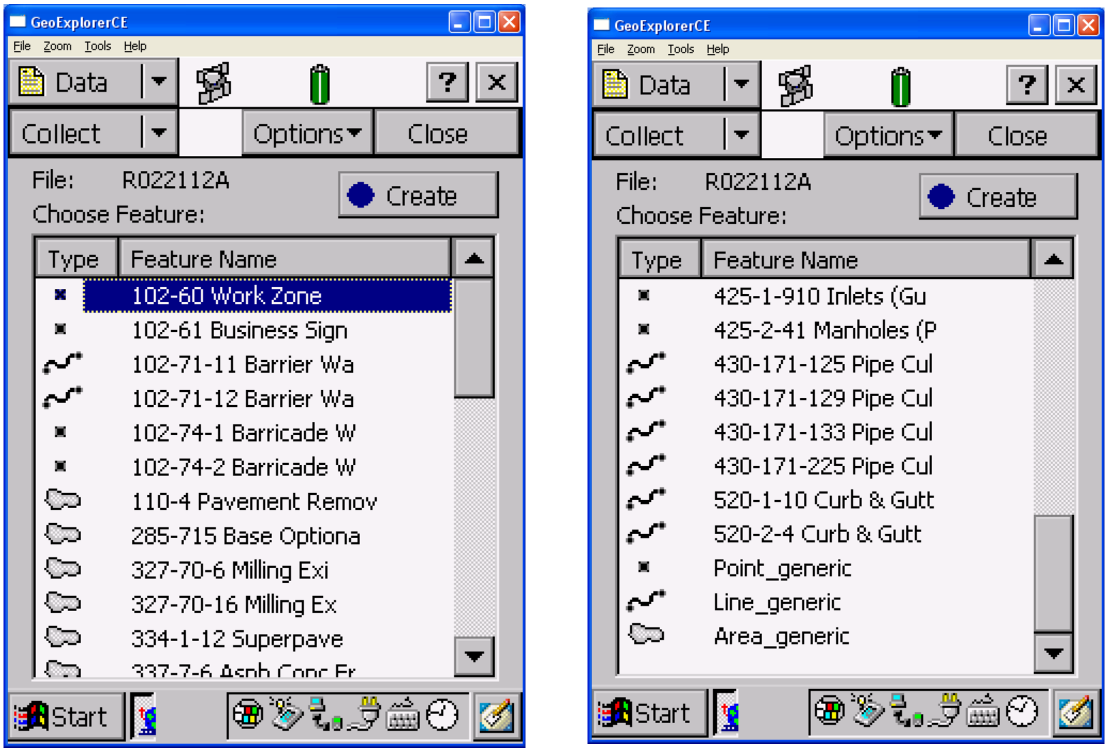
Figure 2.4 Microstation CAD Data Converted to ESRI Shapefile

2.3. GPS Data Requirements

The mapping grade GPS receiver used was the Trimble's GeoXT with the TerraSync data collection software, and Pathfinder Office Software for data processing. The data collection comprises two stages: office preparation; field data collection and data processing.

2.3.1 Office preparation

The first task is to use the Trimble Pathfinder Office to create a GPS project, including a data dictionary. The latter is a data entry form that is established and can be viewed on the construction site when GPS readings are being taken. While the GPS receiver is recording the position data, the dictionary forms elicit and stores predefined attributes desired for the feature being inspected. Figures 2.5 and 2.6 show sample forms created for collecting various features (for construction pay items) on the SR 817 construction project. Based on geometry, GPS position data are recorded for three types of features – point, linear, or area feature. For construction inspection, point features represent pay items where only one (X, Y) coordinate is enough to locate the constructed item, e.g., traffic signal poles, signs, etc., typically with measuring units of EA or each. Linear items will include pay items such as curb and gutter, traffic stripes, drainage pipes, etc., while pay items based on area will include asphalt concrete work, concrete sidewalk, landscaping, etc. Combination of X, Y coordinates are required for linear and area items, with the latter requiring a closure of the points. The pay items measured by volume will be computed based on a combination of the area measure and the depth obtained from the GPS elevation readings.



File: R022112A
Choose Feature:

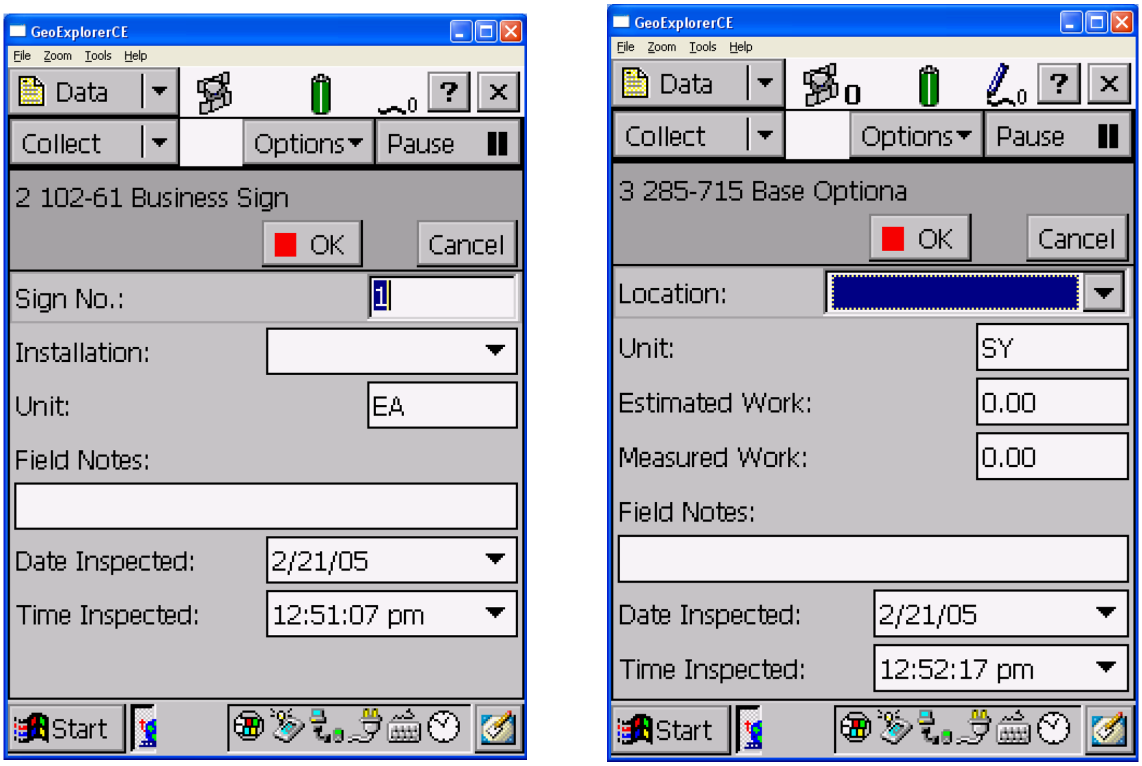
Type	Feature Name
✱	102-60 Work Zone
✱	102-61 Business Sign
∿	102-71-11 Barrier Wa
∿	102-71-12 Barrier Wa
✱	102-74-1 Barricade W
✱	102-74-2 Barricade W
⬭	110-4 Pavement Remov
⬭	285-715 Base Optiona
⬭	327-70-6 Milling Exi
⬭	327-70-16 Milling Ex
⬭	334-1-12 Superpave
⬭	337-7-6 Asph Conc Fr

File: R022112A
Choose Feature:

Type	Feature Name
✱	425-1-910 Inlets (Gu
✱	425-2-41 Manholes (P
∿	430-171-125 Pipe Cul
∿	430-171-129 Pipe Cul
∿	430-171-133 Pipe Cul
∿	430-171-225 Pipe Cul
∿	520-1-10 Curb & Gutt
∿	520-2-4 Curb & Gutt
✱	Point_generic
∿	Line_generic
⬭	Area_generic

a. Top of Pay Item Listing b. Bottom of Pay Item Listing

Figure 2.5. Predefined Inspection Forms on GPS Receiver Listing Pay Items



2 102-61 Business Sign

Sign No.: 1
Installation:
Unit: EA
Field Notes:
Date Inspected: 2/21/05
Time Inspected: 12:51:07 pm

3 285-715 Base Optiona

Location:
Unit: SY
Estimated Work: 0.00
Measured Work: 0.00
Field Notes:
Date Inspected: 2/21/05
Time Inspected: 12:52:17 pm

a. Pay Item No. 102-61 Business Signs b. Pay Item No. 285-715 Base Optional

Figure 2.6. Predefined Inspection Forms on GPS Receiver for Specific Pay Items

Also, the GPS receiver has to be checked and set up in terms of the error levels permitted (filter criteria) in the field, the data correction methods, the coordinate system of the proposed data, etc. The battery level of the GPS receiver should be fully charged. At this stage, an existing GIS layer such as the pertinent project drawing or aerial image can be uploaded into the receiver, for viewing as background during data collection in the field.

2.3.2. Field Data Collection and Data Processing

Once out in the field, it is necessary to have the GPS receiver at a location with a clear view of the sky. Depending on the sophistication of the receivers, blocking or weakening of the GPS satellite signals may be caused by tall buildings, heavy tree cover, very large vehicles, or powerful electromagnetic fields. First check the GPS to see the satellites being tracked by the receiver, and those identified as being used to calculate the position. On the Terrasync's Skyplot screen, the satellites' geometry is shown as well as the computed position coordinates, including each satellite's elevation above the horizon, and the Position Dilution of Precision (PDOP) value. A minimum of four satellites is needed to compute 3D GPS positions, as well as a good geometry (relative location) of the satellites.

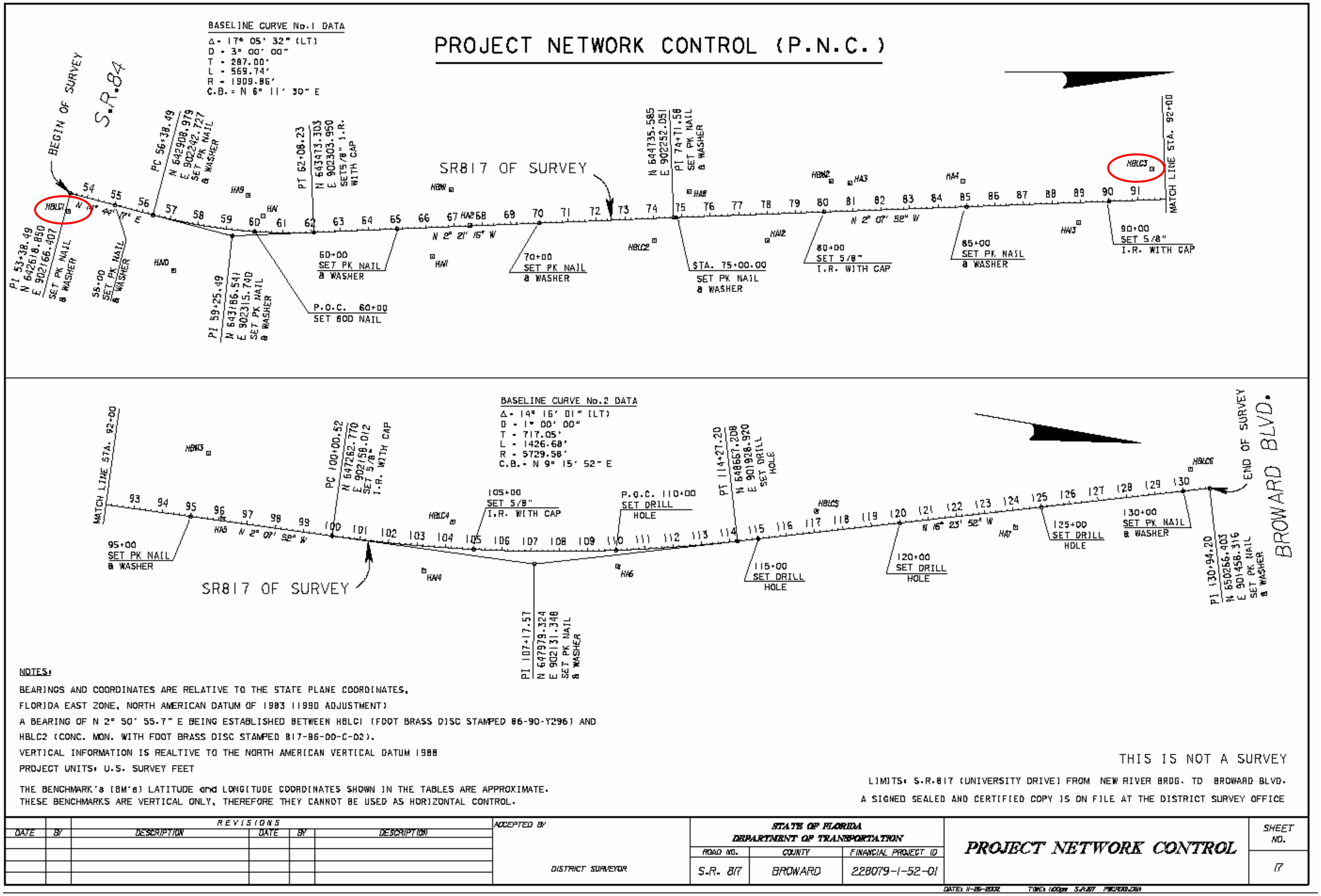
The quality of the GPS data can be described in terms of two compromising factors: productivity and precision. The productivity means collecting data fast, with less accuracy while precision implies collected very accurate data but setting GPS to wait for more time to ensure appropriate satellite signal and configuration. A low PDOP value implies wide separation between the satellites in view, which translates to better position information. The default PDOP is 6 on the

Trimble receiver but it can set using a slider control. The low PDOP set means fewer but more precise location positions. In construction inspection, the particular pay item will suggest level of precision or productivity to use. For example, recording positions of signs, poles, etc, may not require precision but sidewalk dimensions, volume measures of excavation, and length of curb and gutter, may require less productivity but more precision. But again, if the spatial location of the pay item is important, i.e., when plotted on the original drawing, then precision should be a priority. The Signal to Noise Ratio (SNR) is a measure of the satellite signal, its value can be set to a minimum; for the Trimble receiver, and the default is 4., i.e., below this value, the receiver will not use that particular satellite to calculate position. The minimum elevation, with default of 15 degrees in the Trimble receiver, also indicates the quality of satellite signal; satellites with low elevation from the horizon can indicate poor quality of data transmitted.

The GPS data is recorded for point features by collecting and averaging positions as you remain at the point. For linear features, GPS positions are recorded at various points on the line as you move with the receiver. It is advised that you remain stationary at pertinent points, such as vertices, to ensure accurate capture of the point. The GPS positions for area features are collected in a similar fashion to the linear features, and the points are connected to from the area boundary, with the last point connected to the first point.

By default, the GPS receiver will use latitude – longitude measure (along earth spherical surface) to record the positions in degrees, minutes, and seconds. The coordinate system should be set on the GPS receiver to the appropriate projection; a projection means “flattening” the earth spherical surface such that the (X, Y, Z) coordinates can be measured and used for arithmetic computations. There are various projection systems for different areas of the earth. The common projected coordinate systems in Florida are the UTM (statewide) and the State Plane systems (regional). A review of the project plans will show the appropriate coordinate system, as indicated on the survey work done for the project. Even the electronic CAD file should indicate the projected coordinate system. This is very important for the transfer of the recorded GPS positions to the original project plans.

The GPS position recorded is subject to various errors, thereby lowering the accuracy. The major types of GPS errors include orbit errors, effect of earth atmosphere, and difference in timing in the satellites and the receivers. A suitable way of removing these errors is the differential correction method, leading to the term Differential GPS or DGPS. This is discussed later in this report. For the DGPS, the data collected simultaneously by a GPS receiver at a known location (known X, Y, Z values) or base, can be used to correct the data collected by a GPS receiver or rover, at another location, with the father the distance between the points, the lesser the correction efficiency. The DGPS correction can be done real-time, as the data is collected, or done in a post-processing manner, after the data is downloaded. To implement the differential correction, the base is typically located among various reference stations available to the public in the United States, including the FDOT Reference Stations, the Continuously Operating Reference Stations (CORS) and several other community reference stations. For highway construction projects, the survey efforts will produce a survey control network, consisting of several points with the known (X, Y, Z) coordinates; these points will serve as excellent base stations. For the SR 817 project, the survey control network is shown in Figure 2.7. With significant assistance from FDOT District 4 Survey Office, two of these survey control points (labeled HBLC1 And HBLC3 In Figure 2.7) were located on the construction site.



NOTES:

BEARINGS AND COORDINATES ARE RELATIVE TO THE STATE PLANE COORDINATES, FLORIDA EAST ZONE, NORTH AMERICAN DATUM OF 1983 (1990 ADJUSTMENT)

A BEARING OF N 2° 50' 55.7" E BEING ESTABLISHED BETWEEN HBLC1 (FDOT BRASS DISC STAMPED 86-90-Y296) AND HBLC2 (CONC. MON. WITH FDOT BRASS DISC STAMPED 817-86-00-C-02).

VERTICAL INFORMATION IS REALTIVE TO THE NORTH AMERICAN VERTICAL DATUM 1988

PROJECT UNITS: U.S. SURVEY FEET

THE BENCHMARK'S (BM'S) LATITUDE and LONGITUDE COORDINATES SHOWN IN THE TABLES ARE APPROXIMATE. THESE BENCHMARKS ARE VERTICAL ONLY, THEREFORE THEY CANNOT BE USED AS HORIZONTAL CONTROL.

THIS IS NOT A SURVEY

LIMITS: S.R.817 (UNIVERSITY DRIVE) FROM NEW RIVER BRDG. TO BROWARD BLVD.

A SIGNED SEALED AND CERTIFIED COPY IS ON FILE AT THE DISTRICT SURVEY OFFICE

REVISIONS					
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

ACCEPTED BY

DISTRICT SURVEYOR

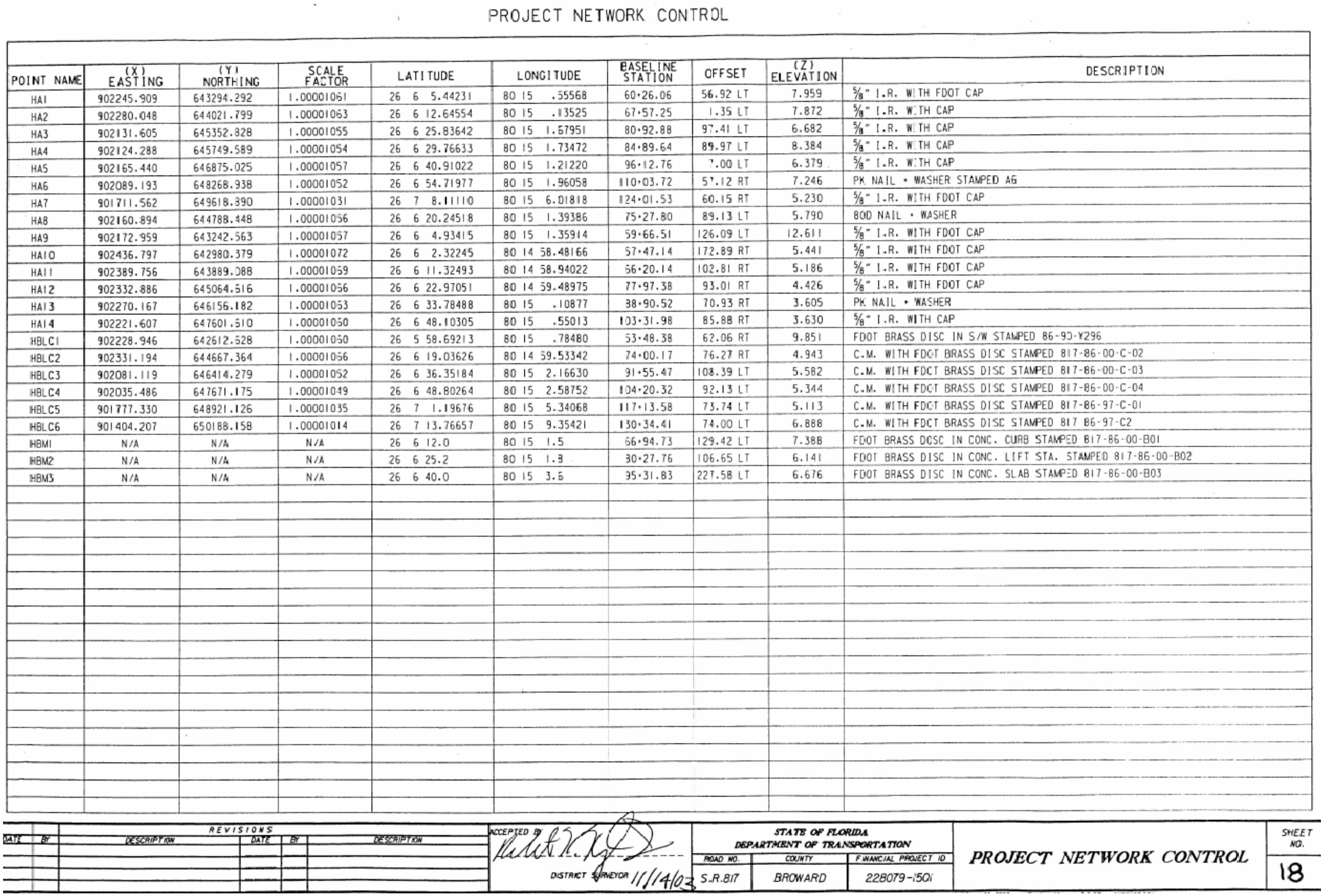
STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID
S.R. 817	BROWARD	228079-1-52-01

PROJECT NETWORK CONTROL

SHEET NO. 17

Figure 2.7. Project Network Control Locations as Shown on Engineering Plans (HBLC1 And HBLC3 Identified)



PROJECT NETWORK CONTROL

POINT NAME	(X) EASTING	(Y) NORTHING	SCALE FACTOR	LATITUDE	LONGITUDE	BASELINE STATION	OFFSET	(Z) ELEVATION	DESCRIPTION
HA1	902245.909	643294.292	1.00001061	26 6 5.44231	80 15 .55568	60+26.06	56.92 LT	7.959	5/8" I.R. WITH FDOT CAP
HA2	902280.048	644021.799	1.00001063	26 6 12.64554	80 15 .13525	67+57.25	1.35 LT	7.872	5/8" I.R. WITH CAP
HA3	902131.605	645352.828	1.00001055	26 6 25.83642	80 15 1.57951	80+92.88	97.41 LT	6.682	5/8" I.R. WITH CAP
HA4	902124.288	645749.589	1.00001054	26 6 29.76633	80 15 1.73472	84+89.64	89.97 LT	8.384	5/8" I.R. WITH CAP
HA5	902165.440	646875.025	1.00001057	26 6 40.91022	80 15 1.21220	96+12.76	7.00 LT	6.379	5/8" I.R. WITH CAP
HA6	902089.193	648268.938	1.00001052	26 6 54.71977	80 15 1.96058	110+03.72	57.12 RT	7.246	PK NAIL + WASHER STAMPED AG
HA7	901711.562	649618.390	1.00001031	26 7 8.11110	80 15 6.01818	124+01.53	60.15 RT	5.230	5/8" I.R. WITH FDOT CAP
HA8	902160.894	644788.448	1.00001056	26 6 20.24518	80 15 1.39386	75+27.80	89.13 LT	5.790	80D NAIL + WASHER
HA9	902172.959	643242.563	1.00001057	26 6 4.93415	80 15 1.35914	59+66.51	126.09 LT	12.611	5/8" I.R. WITH FDOT CAP
HA10	902436.797	642980.379	1.00001072	26 6 2.32245	80 14 58.48166	57+47.14	172.89 RT	5.441	5/8" I.R. WITH FDOT CAP
HA11	902389.756	643889.088	1.00001059	26 6 11.32493	80 14 58.94022	56+20.14	102.81 RT	5.186	5/8" I.R. WITH FDOT CAP
HA12	902332.886	645064.516	1.00001056	26 6 22.97051	80 14 59.48975	77+97.38	93.01 RT	4.426	5/8" I.R. WITH FDOT CAP
HA13	902270.167	646156.182	1.00001053	26 6 33.78488	80 15 .10877	38+90.52	70.93 RT	3.605	PK NAIL + WASHER
HA14	902221.607	647601.510	1.00001050	26 6 48.10305	80 15 .55013	103+31.98	85.88 RT	3.630	5/8" I.R. WITH CAP
HBLC1	902228.946	642612.528	1.00001050	26 5 58.69213	80 15 .78480	53+48.38	62.06 RT	9.851	FDOT BRASS DISC IN S/W STAMPED 86-90-Y296
HBLC2	902331.194	644667.364	1.00001056	26 6 19.03626	80 14 59.53342	74+00.17	76.27 RT	4.943	C.M. WITH FDOT BRASS DISC STAMPED 817-86-00-C-02
HBLC3	902081.119	646414.279	1.00001052	26 6 36.35184	80 15 2.16630	91+55.47	108.39 LT	5.582	C.M. WITH FDOT BRASS DISC STAMPED 817-86-00-C-03
HBLC4	902035.486	647671.175	1.00001049	26 6 48.80264	80 15 2.58752	104+20.32	92.13 LT	5.344	C.M. WITH FDOT BRASS DISC STAMPED 817-86-00-C-04
HBLC5	901777.330	648921.126	1.00001035	26 7 1.19676	80 15 5.34068	117+13.58	73.74 LT	5.113	C.M. WITH FDOT BRASS DISC STAMPED 817-86-97-C-01
HBLC6	901404.207	650188.158	1.00001014	26 7 13.76657	80 15 9.35421	130+34.41	74.00 LT	6.888	C.M. WITH FDOT BRASS DISC STAMPED 817 86-97-C2
HBM1	N/A	N/A	N/A	26 6 12.0	80 15 1.5	66+94.73	129.42 LT	7.388	FDOT BRASS DOSC IN CONC. CURB STAMPED 817-86-00-B01
HBM2	N/A	N/A	N/A	26 6 25.2	80 15 1.8	30+27.76	106.65 LT	6.141	FDOT BRASS DISC IN CONC. LIFT STA. STAMPED 817-86-00-B02
HBM3	N/A	N/A	N/A	26 6 40.0	80 15 3.5	95+31.83	227.58 LT	6.676	FDOT BRASS DISC IN CONC. SLAB STAMPED 817-86-00-B03

REVISIONS

DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

ACCEPTED BY

DISTRICT SURVEYOR 11/14/03

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID
S.R.817	BROWARD	228079-1501

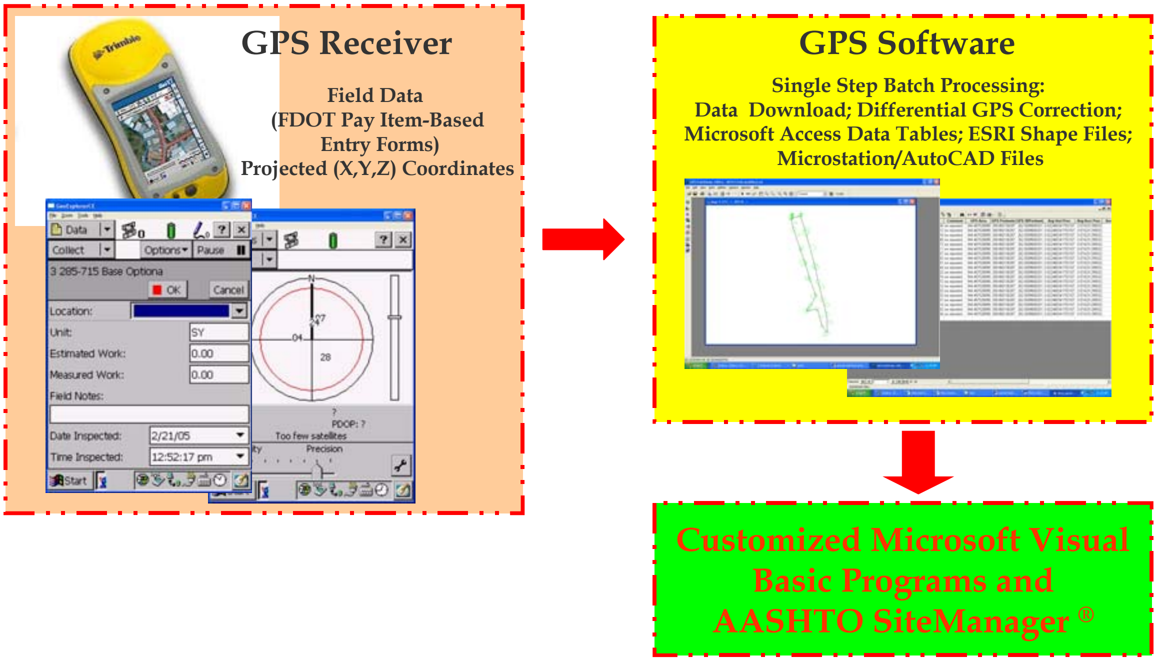
PROJECT NETWORK CONTROL

SHEET NO. 18

Figure 2.8. Project Network Control Data as Shown on Engineering Plans

2.4. GPS/GIS Data Processing and SiteManager Interface

As shown in Figure 2.1, two of the GPS receivers employed in the GPS/GIS study included the "low cost" and mapping grade receivers. The data inputs and processing are summarized in the following Figures 2.9 to 2.14.

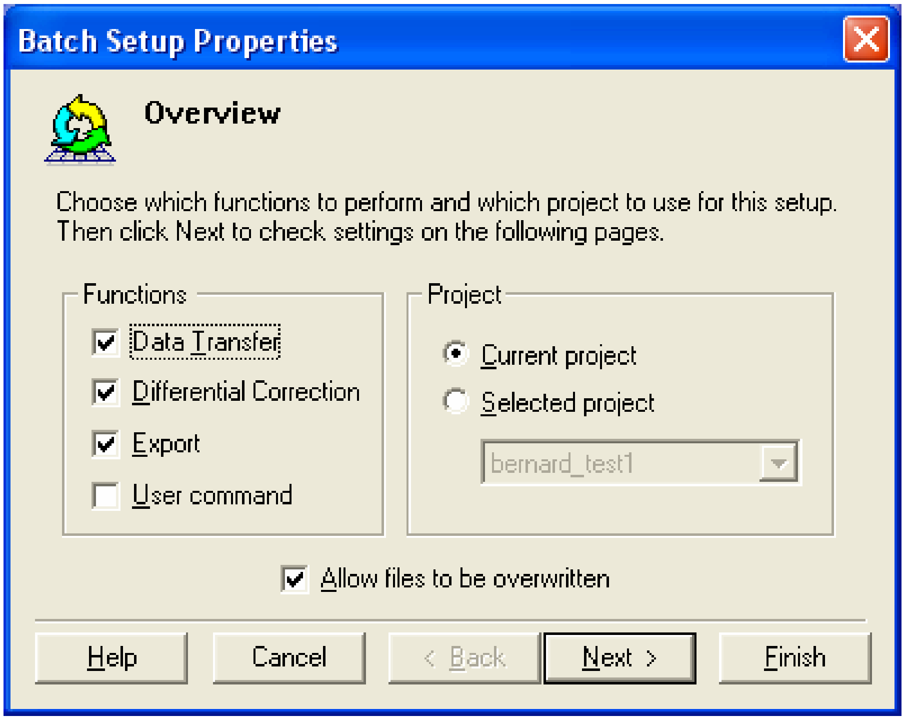


3 285-715 Base Optiona
Location:
Unit: SY
Estimated Work: 0.00
Measured Work: 0.00
Field Notes:
Date Inspected: 2/21/05
Time Inspected: 12:52:17 pm

Figure 2.9. Trimble-Enabled GPS Data Processing/Transfer

The GPS data, including some quantities, can be collected through a single-step batch process in the GeoXT and Pathfinder software (Figures 2.10 and 2.11). Alternatively, the receiver can collect the pertinent geometry points, and the quantities calculated in a custom Computer Program as described later in this report. The data were stored in Microsoft Access tables and called into the computer programs, where some analyses are done, including calculation of the quantities.

Also an interface was developed between the GPS/GIS computer programs and the AASHTO's Sitemanager. As shown in Figures 2.13 and 2.14, the primary fields are the Contract ID, Date of inspection, and the Pay item number. These three attributes are utilized from the GPS/GIS tools to link the Sitemanager's Daily Work Report (DWR) module. Once contact is made, then the quantity filed of the DWR is populated with the data (calculated quantity) sent from the GPS/GIS tools program. The process described above was done for the mapping grade GPS receiver. The equivalent process for a low-cost GPS receiver is shown in Figure 2.14.



Overview

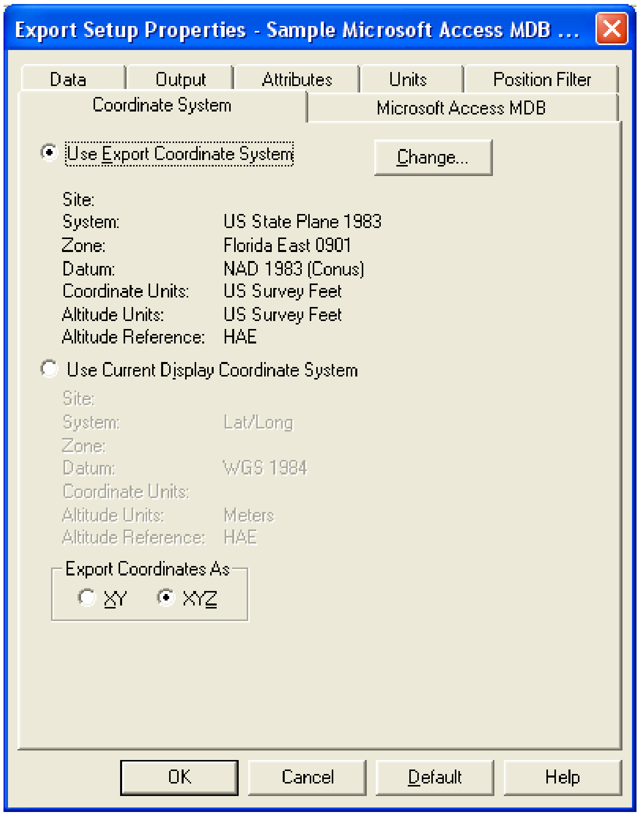
Choose which functions to perform and which project to use for this setup. Then click Next to check settings on the following pages.

Functions
- ☑ Data Transfer
- ☑ Differential Correction
- ☑ Export
- ☐ User command

Project
- ● Current project
- ○ Selected project
- bernard_test1

☑ Allow files to be overwritten

Figure 2.10. Trimble-Enabled GPS Correction (Single-Step Data Processing)



● Use Export Coordinate System

Site:	
System:	US State Plane 1983
Zone:	Florida East 0901
Datum:	NAD 1983 (Conus)
Coordinate Units:	US Survey Feet
Altitude Units:	US Survey Feet
Altitude Reference:	HAE

○ Use Current Display Coordinate System

Site:	
System:	Lat/Long
Zone:	
Datum:	WGS 1984
Coordinate Units:	
Altitude Units:	Meters
Altitude Reference:	HAE

Export Coordinates As
○ XY ● XYZ

Figure 2.11. Trimble-Enabled GPS Correction (Projected Coordinate System)

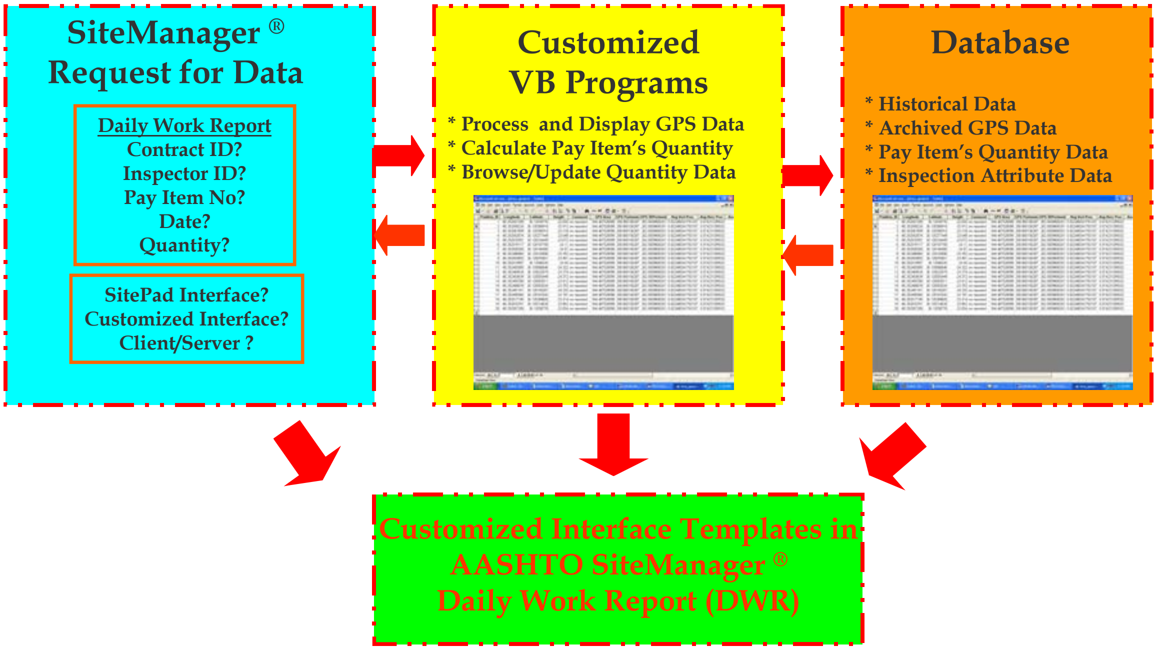
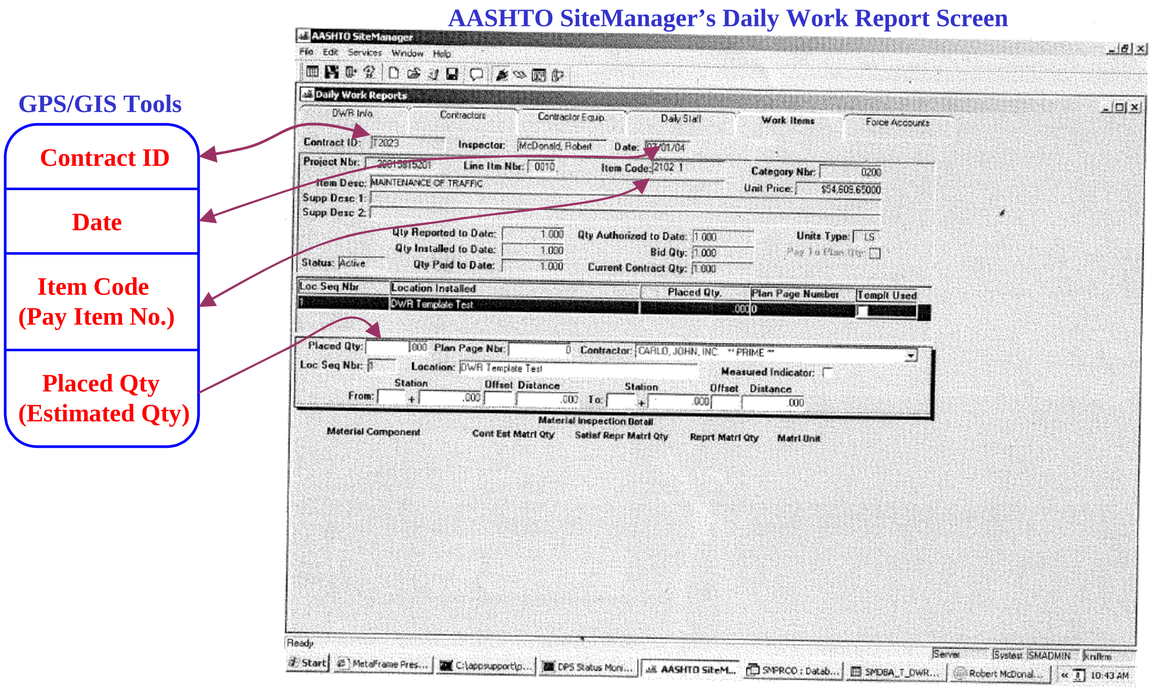


Figure 2.12. Trimble-Enabled GPS – SiteManager Interface Data Flow



Contract ID: T2023 Inspector: McDonald, Robert Date: 07/01/04

Project Nbr: 20015815201 Line Itm Nbr: 0010 Item Code: 2102 1 Category Nbr: 0200

Item Desc: MAINTENANCE OF TRAFFIC Unit Price: $54,609.65000

Supp Desc 1:

Supp Desc 2:

Qty Reported to Date: 1.000 Qty Authorized to Date: 1.000 Units Type: LS

Qty Installed to Date: 1.000 Bid Qty: 1.000 Pay To Plan Qty: ☐

Status: Active Qty Paid to Date: 1.000 Current Contract Qty: 1.000

Loc Seq Nbr	Location Installed	Placed Qty.	Plan Page Number	Templt Used
1	DWR Template Test	.000	0	☐

Placed Qty: .000 Plan Page Nbr: 0 Contractor: CARLO, JOHN, INC. ** PRIME **

Loc Seq Nbr: 1 Location: DWR Template Test Measured Indicator: ☐

From: Station + .000 Offset Distance .000 To: Station + .000 Offset Distance .000

Material Inspection Detail

Material Component Cont Est Matrl Qty Satisf Repr Matrl Qty Reprt Matrl Qty Matrl Unit

Server System SMADMIN knifkm

Figure 2.13. Interaction Between the GPS/GIS Tools and the AASHTO SiteManager Program

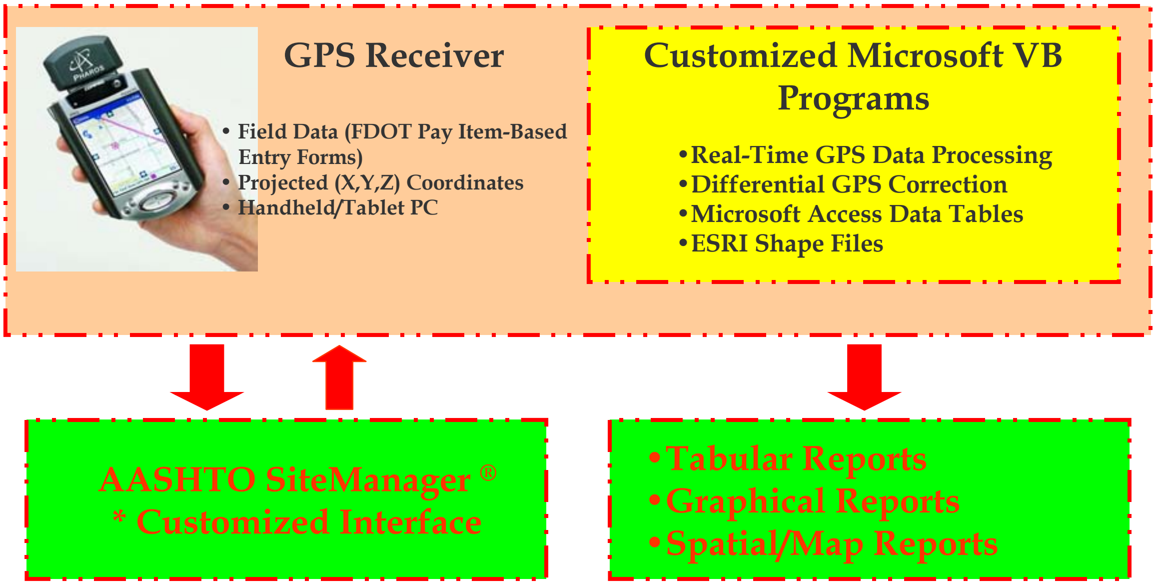


Figure 2.14. “Low Cost” GPS Data Processing and Interface with SiteManager

2.5. Summary

The overall data flow among components of the proposed GPS/GIS tools has been described in this section, as well as the interface with the AASHTO SiteManager. Three types of GPS receivers are presented as options for data collection, with the major differences being the prices of the receivers, and also their capabilities. It is noteworthy to mention that each construction project has a set of survey control points. These points are extremely valuable for differential GPS, i.e., using getting very accurate GPS readings for applications on the project. The following section presents the data collection efforts with the receivers and the results.

3. Data Collection and Analyses

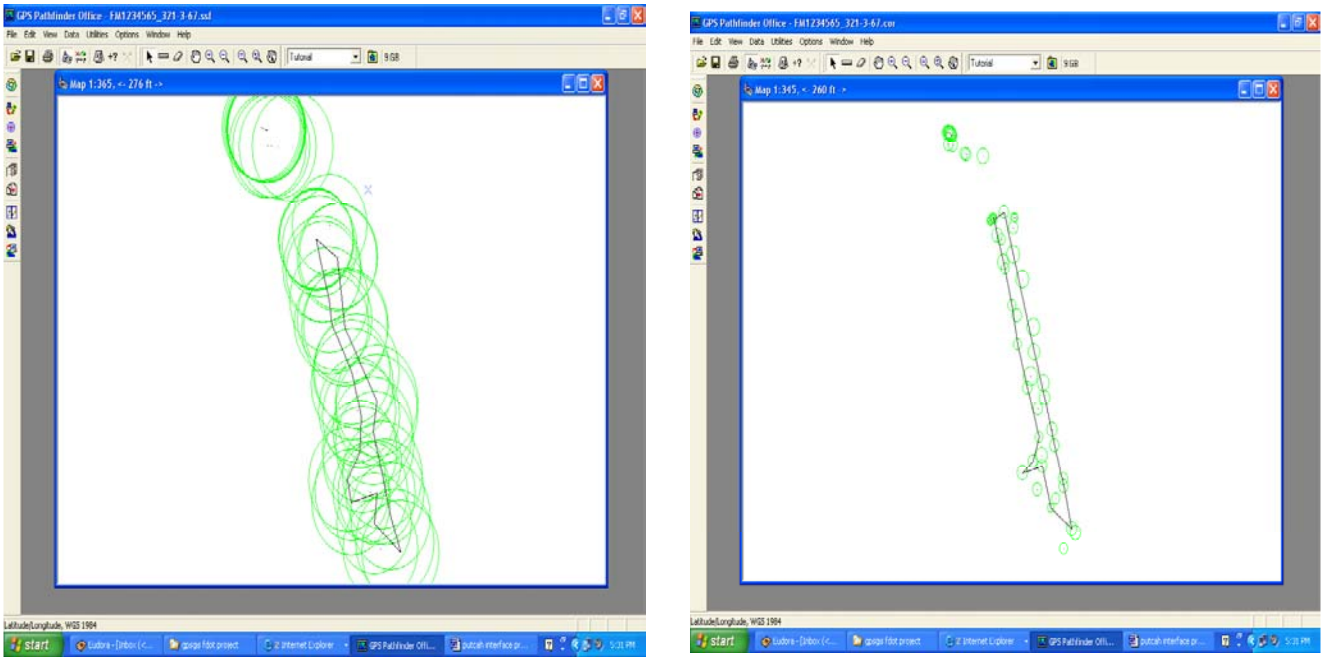
Based on the methodology described earlier, some procedures and computer programs were developed for the GPS/GIS tools. It was also necessary to collect field data from the pilot project. The data collection efforts, the challenges and the overall results are discussed in this section. Also presented is the demonstration of the developed tools and commercial software in the display of the collected data.

3.1 GPS Data Collection

Several attempts were made for site visits to take GPS measurements during the active project duration, but due to many interruptions by weather (heavy rains and hurricanes), only three of such visits will be discussed here. Actually, only two of the visits were productive in terms of data collection. First on February 11, 2005, as discussed earlier in section 1 of the report, during the project kickoff, some data were collected at the north end of the project, near Broward Mall, from approximately station 124+50 to station 131+00. Also on August 18, 2005, an attempt was made on a differential GPS data collection, involving the use of a rover GPS receiver and the setup of a reference GPS base station at the project control point HBLC3. The process was going fine for a few minutes until a heavy rainfall ended it. The last site visit on November 10, 2005 was used to collect data near the south end of the project, approximately between station 85+50 and station 96+00.

The collected data will be presented to include the following: background data as retrieved from the contract documents, mostly the plans and inspector's diaries; site pictures; and the GPS data for both cases of the Trimble GeoXT receiver and the Teletype GPS receiver, including some analyses. The GIS basemap projection of these field data will also be shown, relative to the original basemap (plans) for the project.

The uncorrected and corrected GPS data are shown in Figure 3.1 and Table 3.1 for Pay Item No. 522-1 "Sidewalk Conc. 4 in." measured during the first site visit, on Feb. 11, 2005, near the Broward Mall (north end of the project). The relevant portions of the original drawings are shown in Figure 3.2 with the sidewalk circled out here for identification. Only the GeoXT receiver was used here to collect data on three pay items: the sidewalk; signs; and the Curb and Gutter Conc. Type F. Figures 3.3 to 3.6 show some site pictures for the pay items. For comparison purposes, the construction inspector's diary daily (hard copy) entries were also reviewed and shown in Figures 3.7 and 3.8 for some of the GPS-measured pay items. The data collected during the site visit of November 10, 2005 are similarly demonstrated in Figures 3.9 to 3.18 and Tables 3.3 to 3.6.



a. Raw GPS Data: Conc. Sidewalk b. Corrected GPS Data: Conc. Sidewalk

Figure 3.1. Trimble-Enabled GPS Correction (Reduced Errors)

Table 3.1 GeoXT GPS Corrected Positions for Sidewalk Near Broward Mall (Feb. 11, 2005)

Position_ID	Easting	Northing	GPS Area	GPS Perimeter
1	901418.1	650121.735	944.4675281	258.8601363
2	901417.8	650121.427	944.4675281	258.8601363
3	901416.5	650121.928	944.4675281	258.8601363
4	901419.7	650110.727	944.4675281	258.8601363
5	901426.1	650091.498	944.4675281	258.8601363
6	901430.9	650078.189	944.4675281	258.8601363
7	901435.5	650063.217	944.4675281	258.8601363
8	901441.6	650047.626	944.4675281	258.8601363
9	901436.2	650037.779	944.4675281	258.8601363
10	901432.1	650032.939	944.4675281	258.8601363
11	901442.8	650034.307	944.4675281	258.8601363
12	901447.5	650018.06	944.4675281	258.8601363
13	901452.7	650011.32	944.4675281	258.8601363
14	901451.9	650029.33	944.4675281	258.8601363
15	901447.8	650043.669	944.4675281	258.8601363
16	901443.4	650060.976	944.4675281	258.8601363
17	901440.3	650075.802	944.4675281	258.8601363
18	901431.3	650107.579	944.4675281	258.8601363
19	901426.1	650124.28	944.4675281	258.8601363
20	901418.1	650121.735	944.4675281	258.8601363

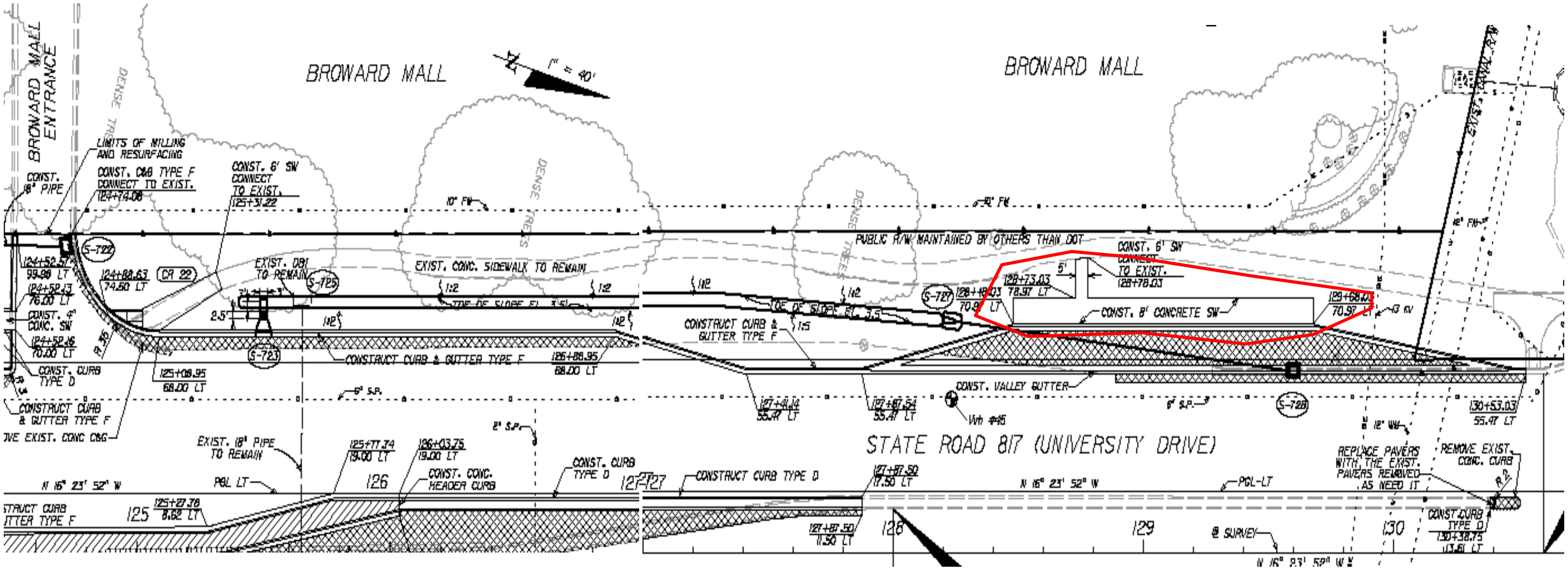


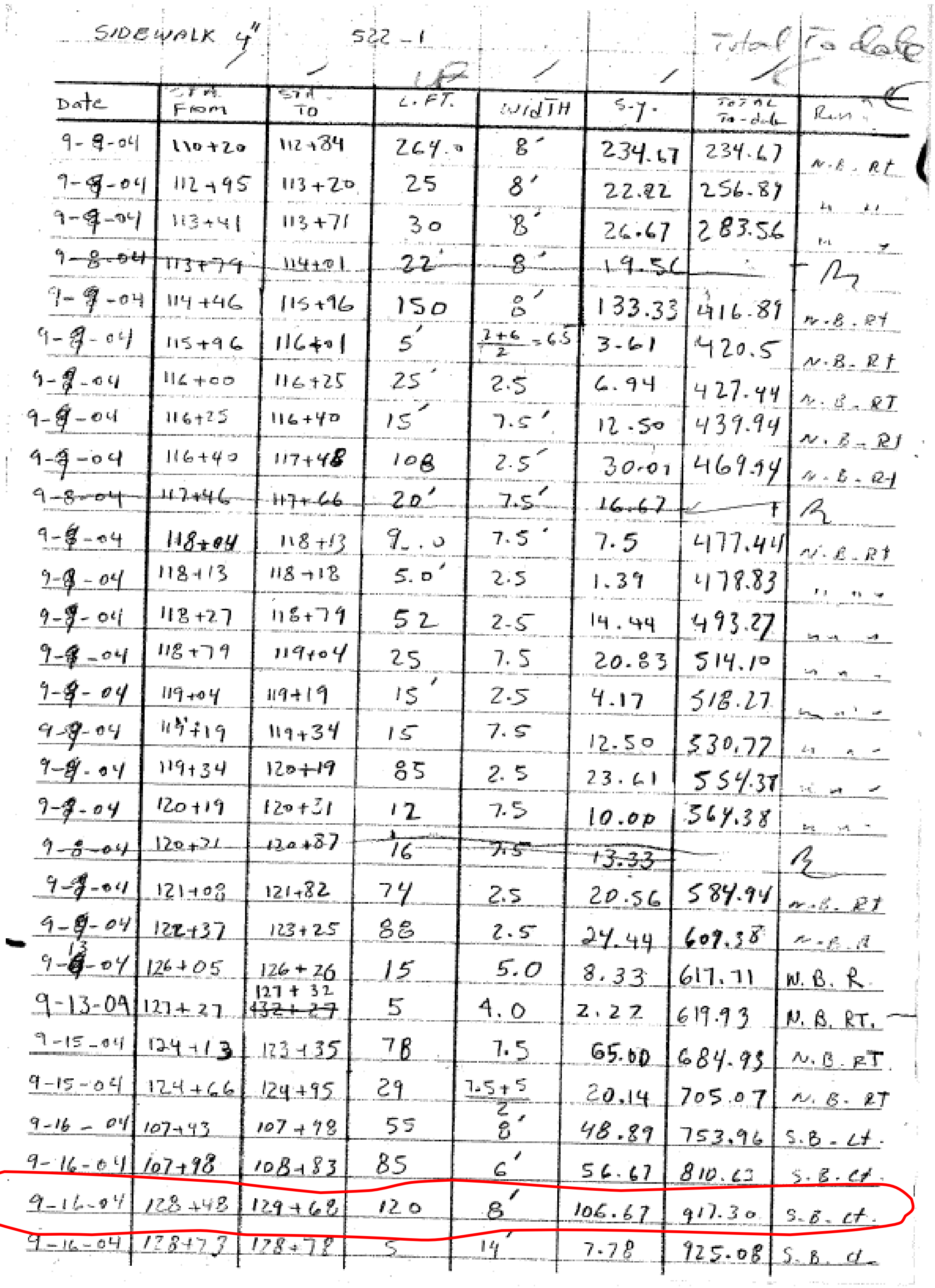
Figure 3.2. Engineering Plans Portions showing Inspected Pay Items (Feb. 11, 2005 - Approx. STA 124+50 to STA 131+00 End of Project)

Figure 3.3 Pay Item No. 522-1 "Sidewalk 4in." (Near Broward Mall) GPS-Measured on Feb. 11, 2005: Southbound View, Showing part of Pay items 520-1-10 "Curb & Gutter Conc. Type F"

Figure 3.4 Pay item 520-1-10 "Curb & Gutter Conc. Type F with Signs and Light Poles GPS-Measured on Feb. 11, 2005: Southbound View

Figure 3.5 Light Pole and Part of Pay Item No. 522-1 “Sidewalk conc. 4in.” GPS-Measured on Feb. 11, 2005: Southbound View

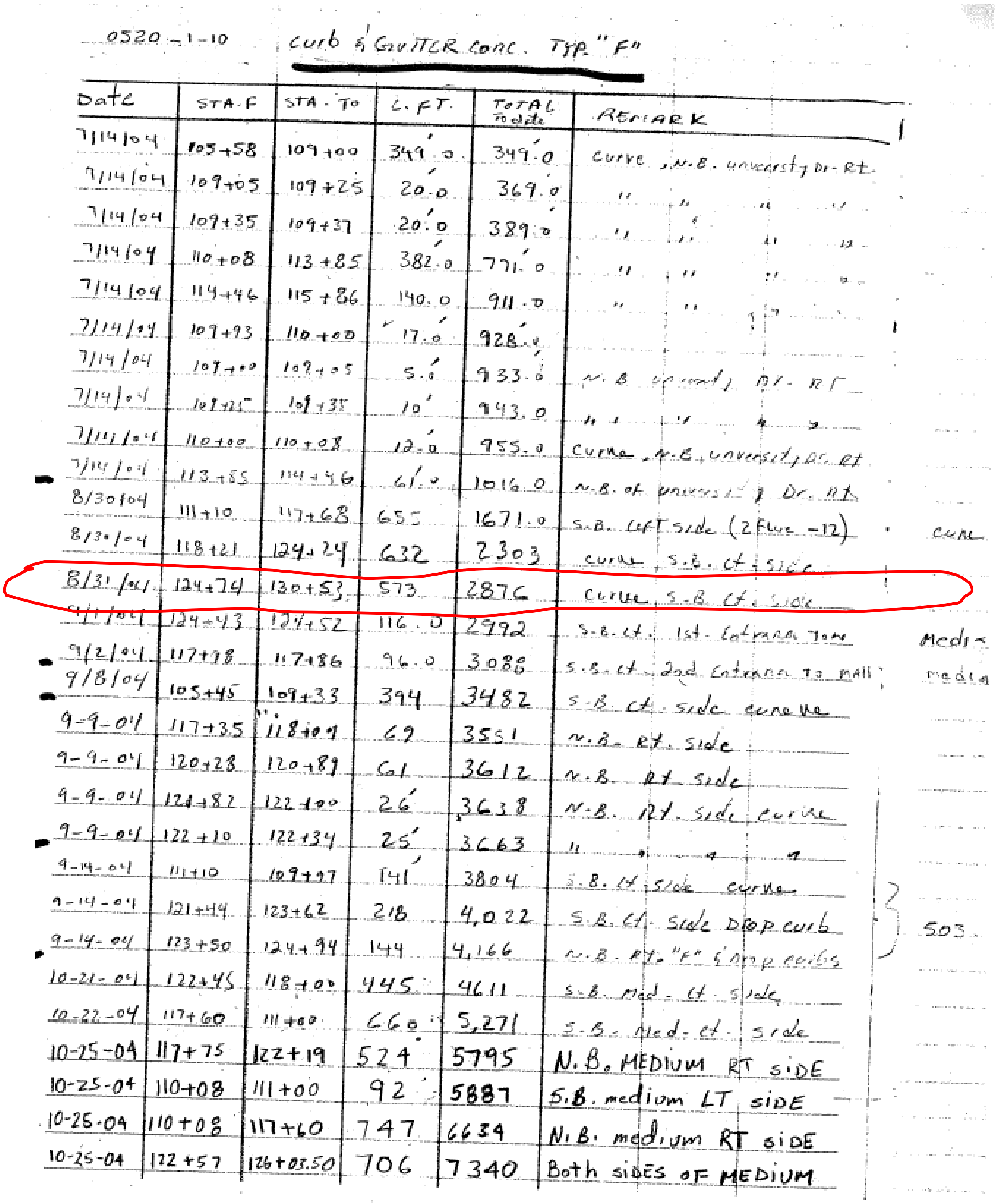
Figure 3.6. Pay Item No. 520-1-10 “Curb & Gutter Conc. Type F with Signs and Light Poles GPS-Measured on Feb. 11, 2005: Northbound View



SIDEWALK 4" 522-1 Total To date

Date	STA. From	STA. To	L. FT.	WIDTH	S.Y.	TOTAL To-date	Rem.
9-9-04	110+20	112+84	264.0	8'	234.67	234.67	N.B. Rt
9-9-04	112+95	113+20	25	8'	22.22	256.89	" "
9-9-04	113+41	113+71	30	8'	26.67	283.56	" "
~~9-8-04~~	~~113+79~~	~~114+01~~	~~22'~~	~~8'~~	~~19.56~~		
9-9-04	114+46	115+96	150	8'	133.33	416.89	N.B. Rt
9-9-04	115+96	116+01	5'	$\frac{2+6}{2}=6.5$	3.61	420.5	N.B. Rt
9-9-04	116+00	116+25	25'	2.5	6.94	427.44	N.B. RT
9-9-04	116+25	116+40	15'	7.5'	12.50	439.94	N.B. Rt
9-9-04	116+40	117+48	108	2.5'	30.01	469.94	N.B. Rt
~~9-8-04~~	~~117+46~~	~~117+66~~	~~20'~~	~~7.5'~~	~~16.67~~		
9-9-04	118+04	118+13	9.0	7.5'	7.5	477.44	N.B. Rt
9-9-04	118+13	118+18	5.0'	2.5	1.39	478.83	" "
9-9-04	118+27	118+79	52	2.5	14.44	493.27	" "
9-9-04	118+79	119+04	25	7.5	20.83	514.10	" "
9-9-04	119+04	119+19	15'	2.5	4.17	518.27	" "
9-9-04	119+19	119+34	15	7.5	12.50	530.77	" "
9-9-04	119+34	120+19	85	2.5	23.61	554.38	" "
9-9-04	120+19	120+31	12	7.5	10.00	564.38	" "
~~9-8-04~~	~~120+71~~	~~120+87~~	~~16~~	~~7.5~~	~~13.33~~		
9-9-04	121+08	121+82	74	2.5	20.56	584.94	N.B. RT
9-9-04	122+37	123+25	88	2.5	24.44	609.38	N.B. R
9-13-04	126+05	126+26	15	5.0	8.33	617.71	N.B. R
9-13-04	127+27	127+32 ~~132+27~~	5	4.0	2.22	619.93	N.B. RT.
9-15-04	124+13	123+35	78	7.5	65.00	684.93	N.B. RT
9-15-04	124+66	124+95	29	$\frac{7.5+5}{2}$	20.14	705.07	N.B. RT
9-16-04	107+43	107+98	55	8'	48.89	753.96	S.B. Lt.
9-16-04	107+98	108+83	85	6'	56.67	810.63	S.B. Lt.
9-16-04	128+48	129+68	120	8'	106.67	917.30	S.B. Lt.
9-16-04	128+73	128+78	5	14'	7.78	925.08	S.B. Lt.

Figure 3.7 Inspector's Recorded Quantity (522-1 "Sidewalk 4in.") Showing Work GPS-Measured on Feb. 11, 2005.



0520-1-10 curb & GUTTER Conc. Typ. "F"

Date	STA. F	STA. To	L. FT.	TOTAL To date	REMARK	
7/14/04	105+58	109+00	349.0	349.0	curve, N.B. university Dr. Rt.	
7/14/04	109+05	109+25	20.0	369.0	" " " "	
7/14/04	109+35	109+37	20.0	389.0	" " " "	
7/14/04	110+08	113+85	382.0	771.0	" " " "	
7/14/04	114+46	115+86	140.0	911.0	" "	
7/14/04	109+93	110+00	17.0	928.0		
7/14/04	109+00	109+05	5.0	933.0	N.B university Dr. Rt	
7/14/04	109+25	109+35	10'	943.0	" " " " "	
7/14/04	110+00	110+08	12.0	955.0	curve, N.B. university Dr. Rt	
7/14/04	113+85	114+46	61.0	1016.0	N.B. of university Dr. Rt	
8/30/04	111+10	117+68	655	1671.0	S.B. Left side (2 Flue -12)	curve
8/30/04	118+21	124+24	632	2303	curve, S.B. Lt. side	
8/31/04	124+74	130+53	573	2876	curve, S.B. Lt. side	
9/1/04	124+43	124+52	116.0	2992	S.B. Lt. 1st Entrance [illegible]	media
9/2/04	117+78	117+86	96.0	3088	S.B. Lt. 2nd Entrance to mall	media
9/8/04	105+45	109+33	394	3482	S.B. Lt. side curve	
9-9-04	117+35	118+04	69	3551	N.B. Rt. side	
9-9-04	120+28	120+89	61	3612	N.B. Rt side	
9-9-04	121+82	122+00	26'	3638	N.B. Rt. side curve	
9-9-04	122+10	122+34	25'	3663	" " " "	
9-14-04	111+10	109+97	141'	3804	S.B. Lt. side curve	
9-14-04	121+44	123+62	218	4,022	S.B. Lt. side Drop curb	503
9-14-04	123+50	124+94	144	4,166	N.B. Rt. "F" & ramp curbs	
10-21-04	122+45	118+00	445	4611	S.B. Med. Lt. side	
10-22-04	117+60	111+00	660	5,271	S.B. Med. Lt. side	
10-25-04	117+75	122+19	524	5795	N.B. MEDIUM RT SIDE	
10-25-04	110+08	111+00	92	5887	S.B. medium LT SIDE	
10-25-04	110+08	117+60	747	6634	N.B. medium RT SIDE	
10-25-04	122+57	126+03.50	706	7340	Both SIDES OF MEDIUM	

Figure 3.8. Inspector's recorded quantity (520-1-10 "Curb & Gutter Conc. Type F.") showing Work GPS-Measured on Feb. 11, 2005.

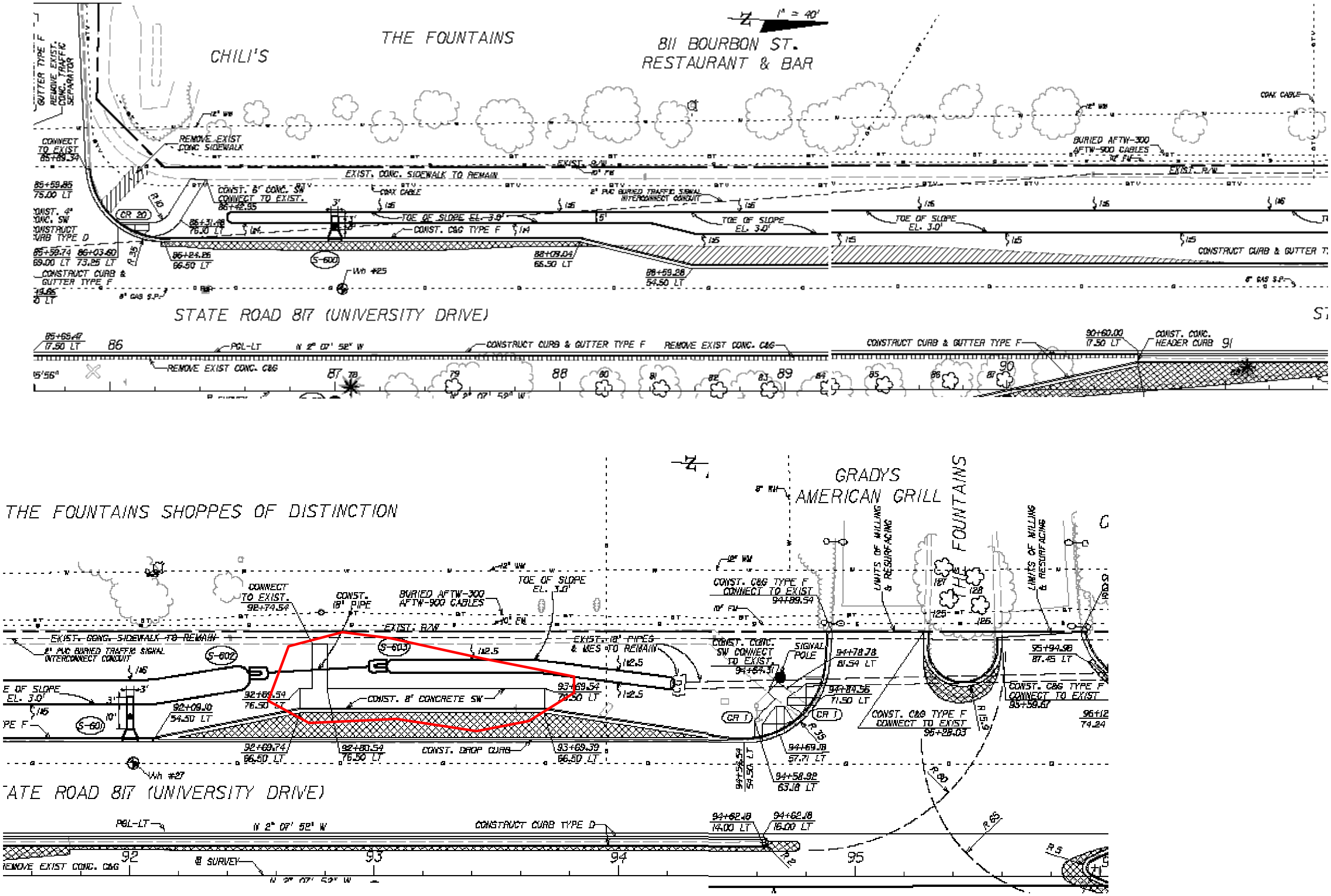


Figure 3.9. Engineering Plans Portions showing Inspected Pay Items (Nov. 10, 2005 - Approx. STA 85+50 to STA 96+00)

Table 3.2 Plans Estimated Quantities by Location for Selected Curb and Gutter pay items

No.	Pay Item No.	Item Description	StaFrom	StaFromOffset	StaFromOffSetSide	StaTo	StaToOffset	StaToOffSetSide	EstPlanQuantity
1	520-1-10	Curb & Gutter Conc (Type F)	52+11.61	49.59	LT	52+39.40	73.92	LT	60
2	520-1-10	Curb & Gutter Conc (Type F)	52+89.51	68.57	LT	53+09.52	54.72	LT	30
3	520-1-10	Curb & Gutter Conc (Type F)	52+11.35	52.7	LT	52+32.35	52.71	LT	25
4	520-1-10	Curb & Gutter Conc (Type F)	54+99.37	51.96	LT	56+56.92	48.66	LT	180
5	520-1-10	Curb & Gutter Conc (Type F)	54+99.37	19	RT	56+90.52			180
6	520-1-10	Curb & Gutter Conc (Type F)	55+38.51	56.77	RT	62+50.5			690
7	520-1-10	Curb & Gutter Conc (Type F)	54+99.46	57.42	RT	55+02.51	57.37	RT	10
8	520-1-10	Curb & Gutter Conc (Type F)	56+83.62	48.65	LT	60+53.88	48.51	LT	360
9	520-1-10	Curb & Gutter Conc (Type F)	57+94.23	0.41	RT	62+10.00			420
10	520-1-10	Curb & Gutter Conc (Type F)	62+82.99	72.86	LT	67+15.07	107.6	LT	470
11	520-1-10	Curb & Gutter Conc (Type F)	62+21.12			66+95.79	12.77	LT	470
12	520-1-10	Curb & Gutter Conc (Type F)	62+62.17			65+57.84	47.22	RT	300
13	520-1-10	Curb & Gutter Conc (Type F)	67+79.83			67+49.23	106.5	LT	70
14	520-1-10	Curb & Gutter Conc (Type F)	69+44.13	99.27	LT	67+79.58	68.74	LT	190
15	520-1-10	Curb & Gutter Conc (Type F)	69+88.68	99.27	LT	70+18.68	70	LT	45
16	520-1-10	Curb & Gutter Conc (Type F)	67+85.22			68+59.93	19.6	LT	80
17	520-1-10	Curb & Gutter Conc (Type F)	71+55.02			74+26.03			310
18	520-1-10	Curb & Gutter Conc (Type F)	73+1.00			74+19.77			170
19	520-1-10	Curb & Gutter Conc (Type F)	75+19.47			78+11.96	66.5	LT	340
20	520-1-10	Curb & Gutter Conc (Type F)	75+15.92			77+89.27	49	RT	350
21	520-1-10	Curb & Gutter Conc (Type F)	78+61.96	54.5	LT	80+14.92	82.91	LT	200
22	520-1-10	Curb & Gutter Conc (Type F)	78+80.00	3.5	RT	85+25.74	14.5	.5	630
23	520-1-10	Curb & Gutter Conc (Type F)	83+82.50	62.5	LT	85+25.23			270
24	520-1-10	Curb & Gutter Conc (Type F)	85+49.66	54.5	LT	26+84.18			260
25	520-1-10	Curb & Gutter Conc (Type F)	85+89.34			94+89.54			930
26	520-1-10	Curb & Gutter Conc (Type F)	85+34.85	7.5	LT	90+60.00	17.5	LT	500
27	520-1-10	Curb & Gutter Conc (Type F)	95+28.03			95+59.67			126
28	520-1-10	Curb & Gutter Conc (Type F)	95+92.00			104+32.02	102.42	LT	966
29	520-1-10	Curb & Gutter Conc (Type F)	95+97.68	3.5	LT	104+26.60	14.51	LT	810
30	520-1-10	Curb & Gutter Conc (Type F)	104+98.84	101.57	LT	109+33.22	100	LT	590
31	520-1-10	Curb & Gutter Conc (Type F)	104+40.64	7.5	RT	105+90.34	17.52	LT	150
32	520-1-10	Curb & Gutter Conc (Type F)	106+42.00	59.5	RT	109+40.91	65	RT	330
33	520-1-10	Curb & Gutter Conc (Type F)	109+97.01	100	LT	117+68.64			818
34	520-1-10	Curb & Gutter Conc (Type F)	110+07.93	2.06	RT	117+60.00	14.5	LT	750
35	520-1-10	Curb & Gutter Conc (Type F)	109+84.88	73.22	RT	110+61.24			100
36	520-1-10	Curb & Gutter Conc (Type F)	118+21.05			124+22.81			684
37	520-1-10	Curb & Gutter Conc (Type F)	117+75.08	7.5	RT	122+18.78	8.07	RT	470
38	520-1-10	Curb & Gutter Conc (Type F)	122+56.89	7.76	RT	126+0.375	19	LT	340
39	520-1-10	Curb & Gutter Conc (Type F)	124+43.65	100	LT	124+87.29	70	LT	120
40	520-1-10	Curb & Gutter Conc (Type F)	124+74.08			130+53.03	55.47	LT	580

*Item No. 25 Measured with GPS on Site visit Nov. 10, 2005

Table 3.3 Plans Estimated Quantities by Location for Selected Sidewalk pay items

No.	Pay Item No.	Item Description	StaFrom	StaFromOffset	StaFromOffSetSide	StaTo	StaToOffset	StaToOffSetSide	EstPlanQuantity	Remarks
1	522-2	Sidewalk Conc 6"	55+13.95	238.21	LT	66+96.47	62.23	LT	823.3	
2	522-2	Sidewalk Conc 6"	54+99.60			55+17.60			26.7	
3	522-2	Sidewalk Conc 6"	66+00.00			67+40.00			94.7	
4	522-2	Sidewalk Conc 6"	67+58.09			67+92.66			40.0	
5	522-2	Sidewalk Conc 6"	69+00.39			69+14.84	69.89	LT	21.3	
6	522-2	Sidewalk Conc 6"	70+01.06	75.86	LT	72+14.72	75	LT	141.3	
7	522-2	Sidewalk Conc 6"	74+11.42			74+10.88	106.95	LT	13.3	
8	522-2	Sidewalk Conc 6"	73+77.04			74+18.41			80.0	
9	522-2	Sidewalk Conc 6"	75+26.93			78+12.67	74.5	LT	246.7	
10	522-2	Sidewalk Conc 6"	75+23.92			77+54.98			200.0	
11	522-2	Sidewalk Conc 6"	78+61.96	54.5	LT	80+15.31	54.5	LT	100.0	
12	522-2	Sidewalk Conc 6"	83+82.50			85+34.80	70	LT	120.0	
13	522-2	Sidewalk Conc 8"	85+34.80	66.5	LT	85+23.22	70	LT	81.8	
14	522-2	Sidewalk Conc 6"	86+03.60	73.25	LT	86+42.95			33.3	
15	522-1	Sidewalk Conc 4"	87+20.00	49.5	LT	87+70.00	49.5	LT	26.7	
16	522-1	Sidewalk Conc 4"	92+69.54	76.5	LT	93+69.54	76.5	LT	106.7	
17	522-1	Sidewalk Conc 4"	94+64.31			94+84.56			0.3	
18	522-1	Sidewalk Conc 4"	94+41.00			95+76.64			62.2	
19	522-2	Sidewalk Conc 6"	96+35.49	66.5	LT	96+46.51			32.0	
20	522-2	Sidewalk Conc 6"	103+89.36			104+30.64	88.19	LT	29.3	
21	522-2	Sidewalk Conc 8"	107+44.08			107+50.34	76.5	LT	13.3	
22	522-2	Sidewalk Conc 6"	107+50.34	76.5	LT	108+00.00	76.5	LT	53.3	
23	522-2	Sidewalk Conc 6"	108+00.00	76.5	LT	108+82.49	62.5	LT	53.3	
24	522-2	Sidewalk Conc 6"	108+89.62			109+26.59	80.33	LT	80.0	
25	522-2	Sidewalk Conc 6"	106+01.18			109+30.84	64.79	RT	242.2	
26	522-1	Sidewalk Conc 6" & 8"	109+93.55	55.5	RT	115+90.00			400.0	
27	522-2	Sidewalk Conc 6"	110+27.43	66.5	LT	110+62.00			45.3	
28	522-2	Sidewalk Conc 6"	117+28.00			117+63.58	71.37	LT	24.0	
29	522-1	Sidewalk Conc 4"	117+86.65	74.55	LT	117+98.05	68.5	LT	3.6	
30	522-2	Sidewalk Conc 6"	118+32.40	73	LT	118+69.89			26.7	
31	522-4	Sidewalk Conc 8"	122+04.56	69.49	LT	123+04.54	73.57	LT	94.2	
32	522-2	Sidewalk Conc 6"	124+36.00	70	LT	124+52.16	70	LT	3.6	
33	522-2	Sidewalk Conc 6"	125+08.95	68	LT	125+31.22			26.7	
34	522-2	Sidewalk Conc 8"	128+48.03	70.97	LT	129+68.03	70.97	LT	112.0	
35	522-2	Sidewalk Conc 5"	128+73.03	78.97	LT	128+78.03	78.97	LT	183.1	

*Item No. 16 and 17 Measured with GPS on Site visit Nov. 10, 2005

Figure 3.10 Southbound View of GPS-measured Pay items on Nov. 10, 2005:

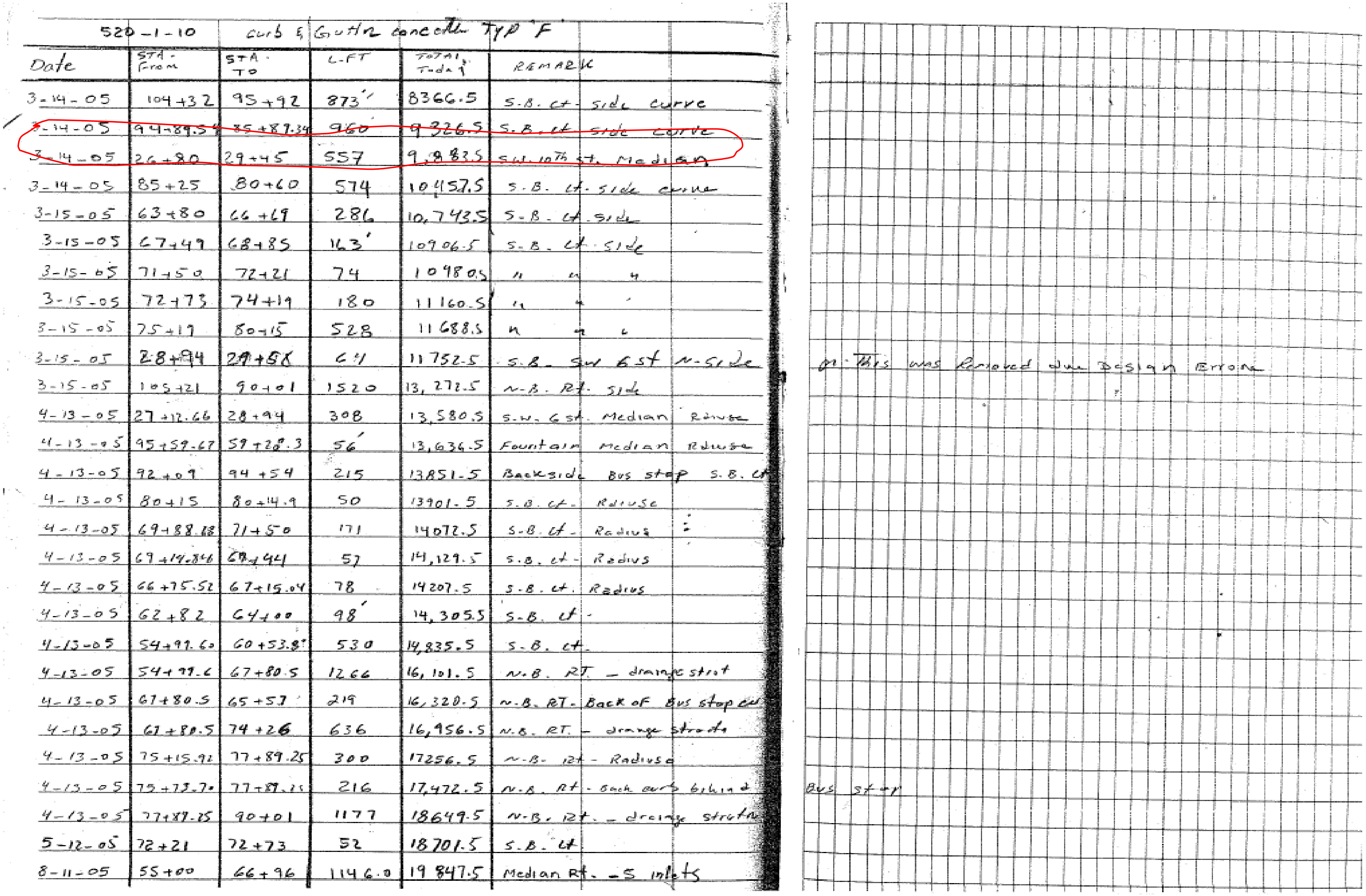
Figure 3.11 Northbound View of GPS-measured Pay items on Nov. 10, 2005:

Figure 3.12. Pay Item No. 522-1 “Sidewalk Conc. 4 in” near the Pay Item 334-1-12 “SuperPave rebuild” GPS-measured on Nov. 10, 2005: Southbound View

Figure 3.13. Pay Item No. 334-1-12 “SuperPave rebuild” GPS-measured on Nov. 10, 2005: Northbound View

Figure 3.14 Pay item No. 520-1-10 “Curb & Gutter Conc. Type F” GPS-measured on Nov. 10, 2005: Southbound View

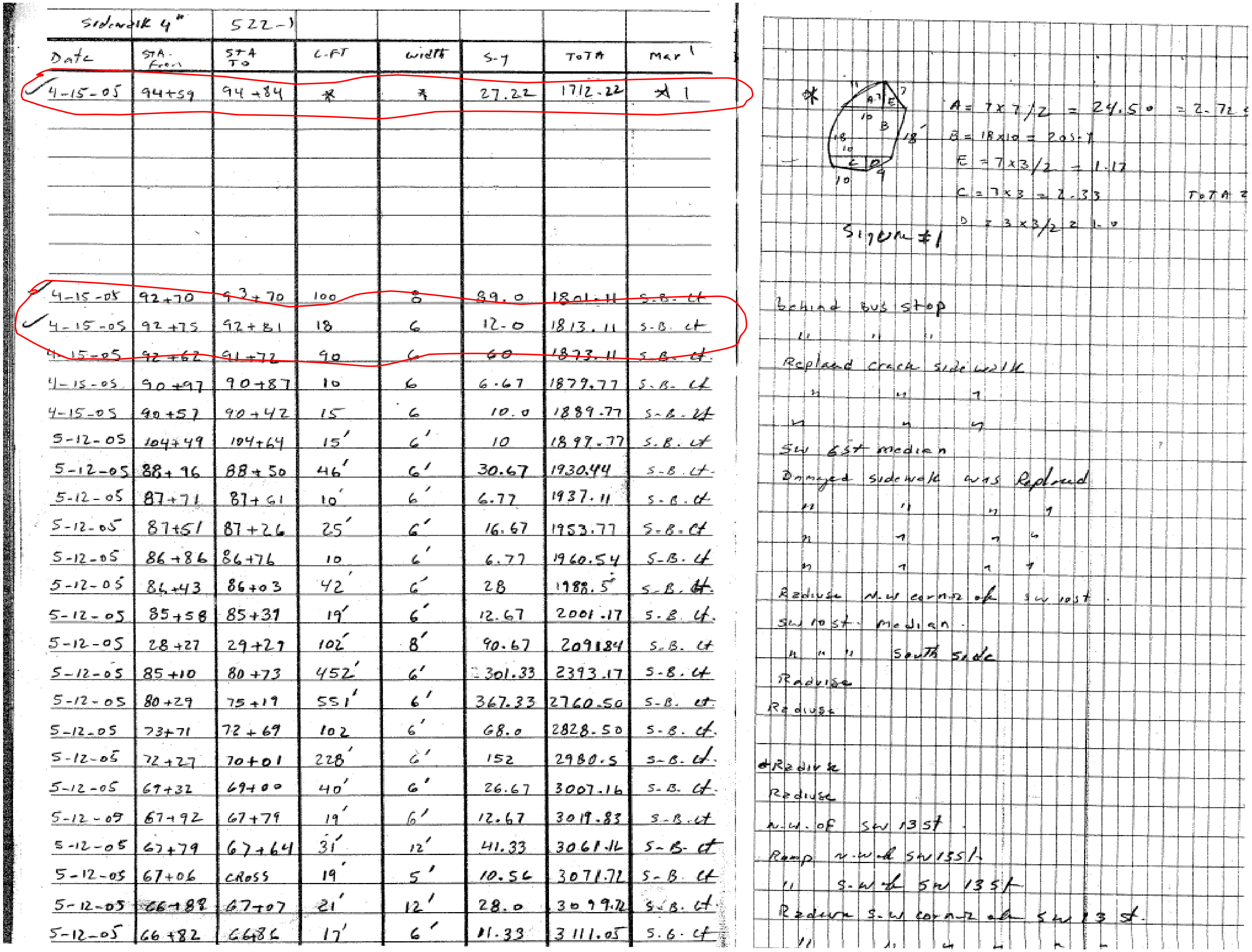
Figure 3.15 Pay Item No. 522-1 “Sidewalk Conc. 4 in.”” GPS-measured on Nov. 10, 2005: Northbound View



520-1-10	Curb & Gutter concrete Typ 'F'				
Date	STA. From	STA. To	L-FT	Total To-day	Remark
3-14-05	104+32	95+92	873'	8366.5	S.B. ct - side curve
3-14-05	94+89.59	85+87.34	960	9,326.5	S.B. ct side curve
3-14-05	26+80	29+45	557	9,883.5	S.W. 10th St. Median
3-14-05	85+25	80+60	574	10,457.5	S.B. ct. side curve
3-15-05	63+80	66+69	286	10,743.5	S.B. ct. side
3-15-05	67+49	68+85	163'	10906.5	S.B. ct. side
3-15-05	71+50	72+21	74	10980.5	" " "
3-15-05	72+73	74+19	180	11160.5	" " "
3-15-05	75+19	80+15	528	11688.5	" " "
3-15-05	28+94	29+58	64	11752.5	S.B. SW 6 St N-side
3-15-05	105+21	90+01	1520	13,272.5	N.B. Rt. side
4-13-05	27+12.66	28+94	308	13,580.5	S.W. 6 St. Median Raduse
4-13-05	95+59.67	59+28.3	56'	13,636.5	Fountain Median Raduse
4-13-05	92+09	94+54	215	13851.5	Backside Bus stop S.B. ct
4-13-05	80+15	80+14.9	50	13901.5	S.B. ct - Raduse
4-13-05	69+88.18	71+50	171	14072.5	S.B. ct - Radius
4-13-05	69+14.846	69+44	57	14,129.5	S.B. ct - Radius
4-13-05	66+75.52	67+15.04	78	14207.5	S.B. ct. Radius
4-13-05	62+82	64+00	98'	14,305.5	S.B. ct -
4-13-05	54+99.60	60+53.8	530	14,835.5	S.B. ct.
4-13-05	54+99.6	67+80.5	1266	16,101.5	N.B. RT. - drainage struct
4-13-05	67+80.5	65+57	219	16,320.5	N.B. RT. Back of Bus stop cu
4-13-05	67+80.5	74+26	636	16,956.5	N.B. RT. - drainage structure
4-13-05	75+15.92	77+89.25	300	17256.5	N.B. Rt - Raduse
4-13-05	75+73.70	77+89.25	216	17,472.5	N.B. Rt - Back curb behind Bus stop
4-13-05	77+89.25	90+01	1177	18649.5	N.B. Rt. - drainage structure
5-12-05	72+21	72+73	52	18701.5	S.B. ct
8-11-05	55+00	66+96	1146.0	19 847.5	Median Rt. - 5 inlets

This was Removed due Design Error

Figure 3.16. Inspector's recorded quantity (520-1-10 "Curb & Gutter Conc. Type F.") showing Work GPS-Measured on Nov. 10, 2005.



Sidewalk 4"	522-1						
Date	STA. From	STA To	L.FT	width	S.Y	TOTA	Mar'
4-15-05	94+59	94+84	*	*	27.22	1712.22	* 1
4-15-05	92+70	93+70	100	8	89.0	1801.11	S.B. ct
4-15-05	92+75	92+81	18	6	12.0	1813.11	S.B. ct
4-15-05	92+62	91+72	90	6	60	1873.11	S.B. ct
4-15-05	90+97	90+87	10	6	6.67	1879.77	S.B. ct
4-15-05	90+57	90+42	15	6	10.0	1889.77	S.B. ct
5-12-05	104+49	104+64	15'	6'	10	1897.77	S.B. ct
5-12-05	88+96	88+50	46'	6'	30.67	1930.44	S.B. ct.
5-12-05	87+71	87+61	10'	6'	6.77	1937.11	S.B. ct
5-12-05	87+51	87+26	25'	6'	16.67	1953.77	S.B. ct
5-12-05	86+86	86+76	10	6'	6.77	1960.54	S.B. ct
5-12-05	86+43	86+03	42'	6'	28	1988.5	S.B. ct.
5-12-05	85+58	85+31	19'	6'	12.67	2001.17	S.B. ct.
5-12-05	28+27	29+29	102'	8'	90.67	2091.84	S.B. ct
5-12-05	85+10	80+73	452'	6'	301.33	2393.17	S.B. ct
5-12-05	80+29	75+19	551'	6'	367.33	2760.50	S.B. ct.
5-12-05	73+71	72+69	102	6'	68.0	2828.50	S.B. ct.
5-12-05	72+27	70+01	228'	6'	152	2980.5	S.B. ct.
5-12-05	69+32	69+00	40'	6'	26.67	3007.16	S.B. ct.
5-12-05	67+92	67+79	19'	6'	12.67	3019.83	S.B. ct
5-12-05	67+79	67+64	31'	12'	41.33	3061.16	S.B. ct
5-12-05	67+06	CROSS	19'	5'	10.56	3071.72	S.B. ct
5-12-05	66+88	67+07	21'	12'	28.0	3099.72	S.B. ct.
5-12-05	66+82	66+86	17'	6'	11.33	3111.05	S.B. ct

*

A = 7x7/2 = 24.50 = 2.72

B = 18x10 = 20S.Y

E = 7x3/2 = 1.17

C = 7x3 = 2.33 TOTA

D = 3x3/2 = 1.0

Sigurn #1

Behind bus stop

" " "

Replaced crack sidewalk

" " "

" " "

SW 65st median

Damaged sidewalk was Replaced

" " " "

" " " "

" " " "

Rediuse N.W corner of SW 10st.

SW 10 st. Median.

" " " South side

Raduise

Rediuse

Rediuse

Rediuse

N.W. of SW 13 st.

Ramp N.W of SW 13 st

" S.W of SW 13 st

Raduse S.W corner of SW 13 st.

" " " " " "

Figure 3.17. Inspector’s recorded quantity (522-1 “Sidewalk 4 in.”) showing Work GPS-Measured on Nov. 10, 2005.

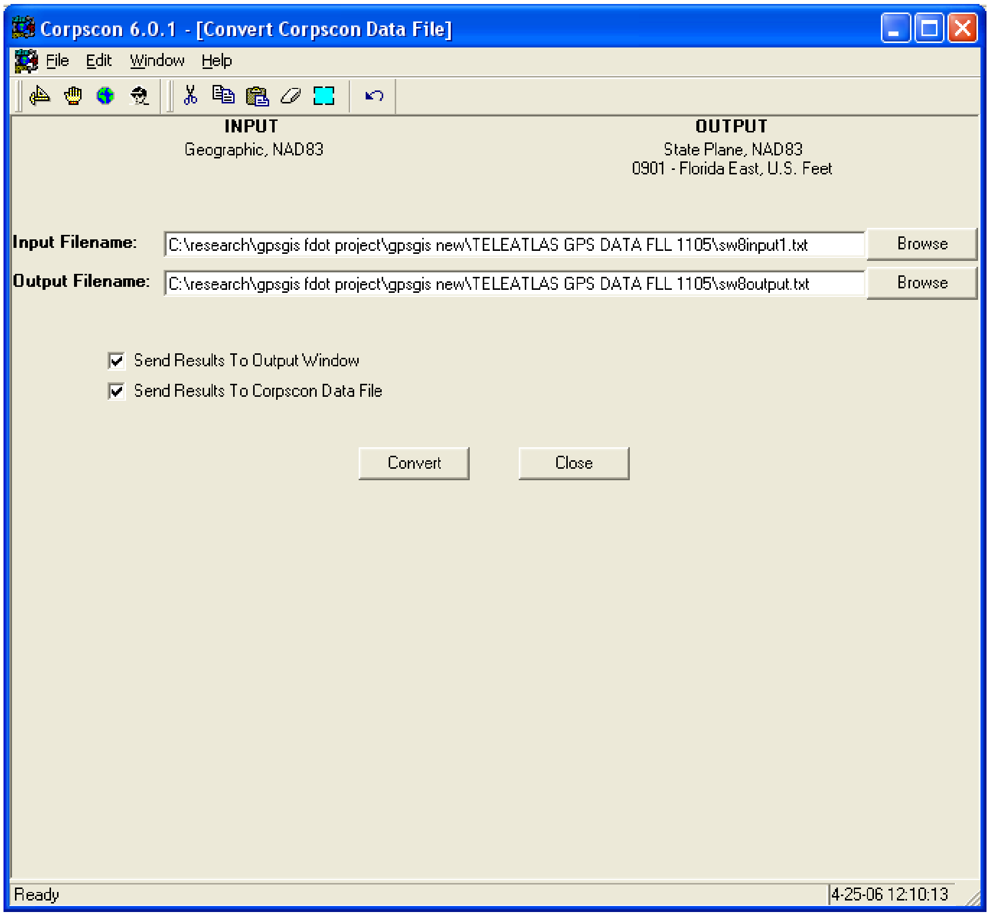
Table 3.4 State Plane Coordinates SR 817 Sidewalk GPS Data with GeoXT GPS Receiver

Position_ID	Easting	Northing	Elevation	Latitude	Longitude
1	902113.10	646629.17	3.11	26.110694000	-80.250515000
2	902113.01	646629.11	3.43	26.110694000	-80.250515000
3	902111.75	646629.78	5.46	26.110695000	-80.250517000
4	902112.97	646631.54	5.60	26.110702000	-80.250508000
5	902112.22	646630.66	6.23	26.110699000	-80.250510000
6	902111.91	646630.47	5.82	26.110698000	-80.250512000
7	902111.83	646630.59	6.57	26.110697000	-80.250512000
8	902111.13	646630.83	7.23	26.110697000	-80.250512000
9	902110.74	646630.86	7.81	26.110697000	-80.250512000
10	902115.97	646629.46	8.21	26.110694000	-80.250500000
11	902115.92	646629.96	6.18	26.110694000	-80.250501000
12	902115.54	646630.22	5.16	26.110694000	-80.250504000
13	902116.61	646630.68	1.86	26.110694000	-80.250503000
14	902117.45	646631.13	-0.86	26.110695000	-80.250502000
15	902117.20	646626.56	-0.18	26.110685000	-80.250501000
16	902119.28	646615.45	-3.09	26.110648000	-80.250498000
17	902118.62	646601.42	0.76	26.110612000	-80.250496000
18	902118.84	646589.58	-2.44	26.110583000	-80.250496000
19	902118.25	646577.13	-4.42	26.110547000	-80.250496000
20	902118.36	646563.96	-3.90	26.110511000	-80.250494000
21	902118.41	646551.67	-3.45	26.110476000	-80.250494000
22	902119.57	646538.57	-4.22	26.110442000	-80.250493000
23	902116.52	646531.36	-3.67	26.110424000	-80.250494000
24	902113.72	646533.37	-4.73	26.110425000	-80.250513000
25	902111.53	646536.15	1.62	26.110436000	-80.250519000
26	902112.95	646535.49	5.73	26.110438000	-80.250521000
27	902102.75	646537.12	11.67	26.110437000	-80.250548000
28	902095.67	646535.92	7.82	26.110437000	-80.250573000
29	902091.78	646541.70	19.04	26.110450000	-80.250576000
30	902094.22	646544.44	13.67	26.110453000	-80.250572000
31	902101.64	646542.51	7.29	26.110453000	-80.250546000
32	902110.87	646541.92	2.18	26.110455000	-80.250522000
33	902111.64	646548.06	-1.33	26.110470000	-80.250519000
34	902111.65	646562.74	-1.87	26.110510000	-80.250520000
35	902110.97	646572.88	-5.47	26.110539000	-80.250521000
36	902110.62	646589.45	-2.43	26.110578000	-80.250526000
37	902110.26	646606.15	0.81	26.110620000	-80.250528000
38	902109.50	646617.00	8.69	26.110655000	-80.250528000
39	902110.32	646632.37	10.01	26.110683000	-80.250529000
40	902111.37	646635.63	10.69	26.110700000	-80.250527000
41	902115.04	646629.65	7.72	26.110696000	-80.250508000
42	902117.34	646630.34	-1.87	26.110695000	-80.250508000
43	902113.10	646629.17	3.11	26.110695000	-80.250508000

It was necessary to convert the Teletype GPS data from its recorded format of latitude/longitude (deg/min), to a projected coordinate system, i.e. the Florida East State Plane coordinate system. The latter system will show projected Eastings (X) and Northings (Y) in feet units (Figure 3.6). This was done using the US army Corp of Engineer's free software, the Corpscons (screen shot shown in Figure 3.7).

Table 3.5 State Plane Coordinates SR 817 Sidewalk Vertices GPS Data with TeleType GPS Receiver

Position_ID	Easting	Northing	Latitude	Longitude	No. of Readings
sw pt1	902296.486	642808.241	26.1001737793	-80.2500087793	127
sw pt2	902296.456	642808.256	26.1001738216	-80.2500088707	26
sw pt3	902296.116	642808.252	26.1001738167	-80.2500099071	35
sw pt4	902296.164	642808.375	26.1001741548	-80.2500097579	28
sw pt5	902296.326	642808.258	26.1001738310	-80.2500092651	35
sw pt6	902296.322	642809.993	26.1001786025	-80.2500092487	42
sw pt7	902296.708	642809.940	26.1001784511	-80.2500080721	42
sw pt8	902296.658	642808.271	26.1001738600	-80.2500082544	51



INPUT
Geographic, NAD83

OUTPUT
State Plane, NAD83
0901 - Florida East, U.S. Feet

Input Filename: C:\research\gpsgis fdot project\gpsgis new\TELEATLAS GPS DATA FLL 1105\sw8input1.txt

Output Filename: C:\research\gpsgis fdot project\gpsgis new\TELEATLAS GPS DATA FLL 1105\sw8output.txt

☑ Send Results To Output Window
☑ Send Results To Corpscon Data File

Ready 4-25-06 12:10:13

Figure 3.18. Screen Shot of US Army Corps' Corpscan Software used for Coordinate Conversion

In order to evaluate accuracy and efficiency, a comparison was made between the procedures of the GPS measure of quantities, and that of the inspector's traditional manual process. Table 3.6 indicates a comparison of the time required in both processes, based on the three pay items inspected on November 10, 2005. Though this was based on a limited data, it could be seen that the time taken to measure the quantities are significantly reduced, up to 80% reduction, when GPS receivers are used.

Table 3.6 Comparison of GPS-Measured Times with Traditional Manual Methods for Field Quantities (Site Visit on Nov. 10, 2005).

Pay Item No.	Pay Item Description	Time for Traditional Measurement* (min.)	Time for GPS-Measurement (min.)	
			Trimble GeoXT	"Low-cost" TeleType
520-1-10	Curb and Gutter Conc. Type F	40	5	N/A
522-1	Sidewalk Conc (4" Thick)	60	5	15
334-1-12	Superpave Asphaltic Conc (Traffic B)	90	8	N/A

* Based on interview of the Resident Engineer's Inspector who actually did the inspection and quantity measurement. Includes time taken to do the following: locate the pay item's exact location (station) on the plan, locate on the site, walk and measure on site, and do office computations and reporting.

It was also of interest in this study to evaluate the relative GPS-performance of the two receivers used – the low cost Teletype and the mapping grade GeoXT. First, the study wanted to find out if the spatial location or attributes can be effectively collected and displayed relative to the original drawing. Second, it was also desired to know if the quantities could be accurately estimated. The second criterion was evaluated by a comparison of the GPS-estimated quantity to the manually collected data by the inspector in the field during construction (Table 3.7).

The Teletype GPS receiver used to collect data at vertices of the sidewalk pay item, GPS-measured during the site visit of Nov. 10, 2005. The raw data have been shown earlier in Table 3.5. It was necessary to use the vertices because of the relatively long time required, using such low cost receivers to get reasonably accurate readings from the satellites. The GeoXT GPS receiver was also used, but continuously along the perimeter of the sidewalk, to collect the data as an area feature. As shown in Figures 3.19 to 3.23, the results were plotted for both receivers. The low cost receiver did not produce accurate results. While it approximately retains the shape of the sidewalk (Figure 3.20), the dimensions indicated for the feature were not reasonable; the teletype GPS estimates the sidewalk width as about 0.6 ft. or six inches, compared with the 8 ft. shown on the engineering plans. Observing the Eastings (X) values for the vertices reveals this. On the other hand, the GeoXT showed a reasonable accuracy of the spatial location of the sidewalk, especially when displayed on an existing shapefile of the engineering drawing, which is demonstrated later in this report. As shown in Figure 3.23, the incredible gap between the two sets of data (over one mile length) indicates the serious error on the spatial location using the low cost GPS receiver.

Also, the accuracy of the quantities estimated using the GeoXT was very impressive, when compared to both the inspector's estimates and the approximate plan quantity of the described location of work. The comparison is shown in Table 3.7 for the pay items GPS-measured during the visit of Nov. 10, 2005.

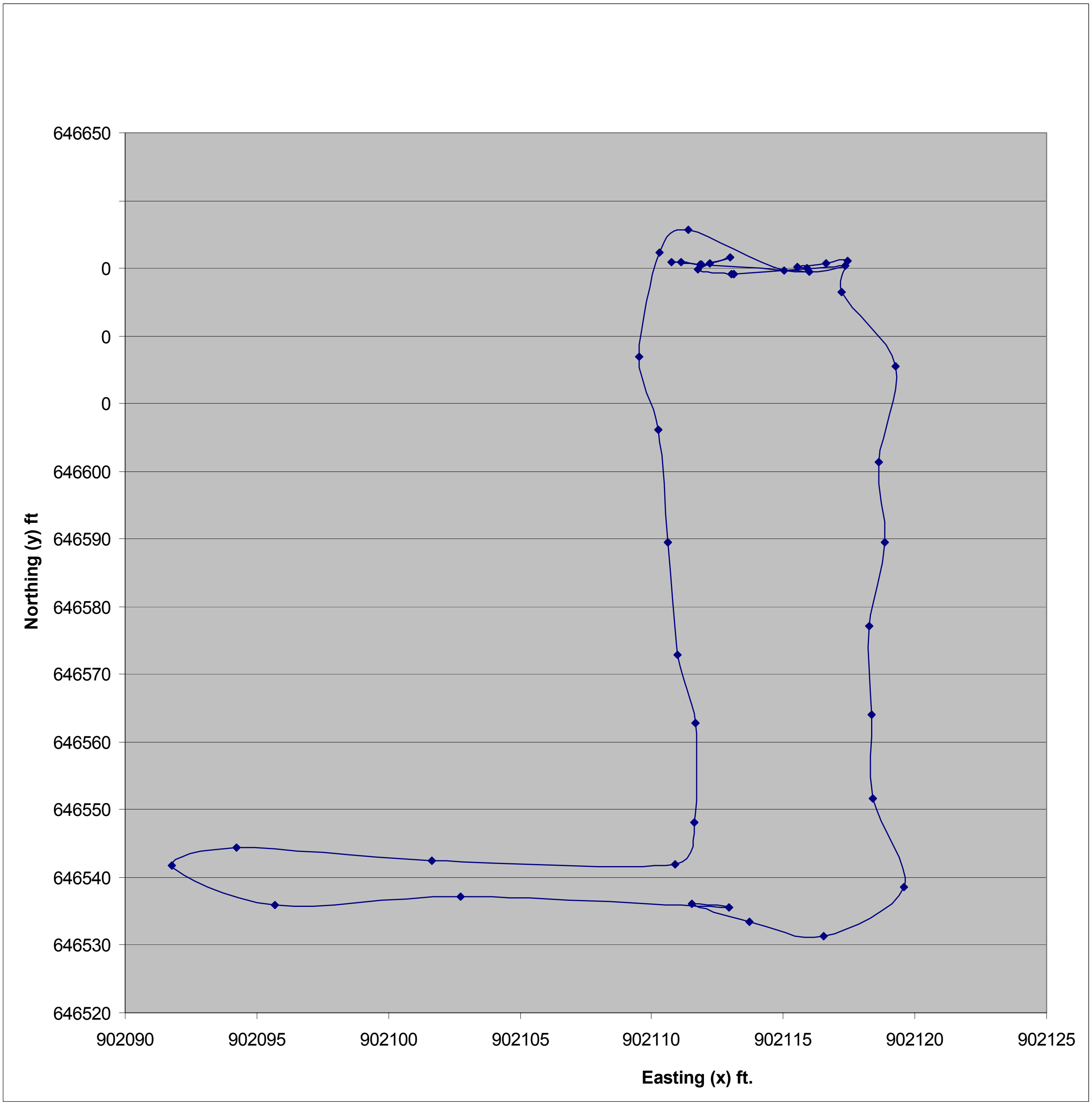


Figure 3.19. State Plane Coordinates Plot of SR 817 Sidewalk GPS Data Using GeoXT GPS Receiver

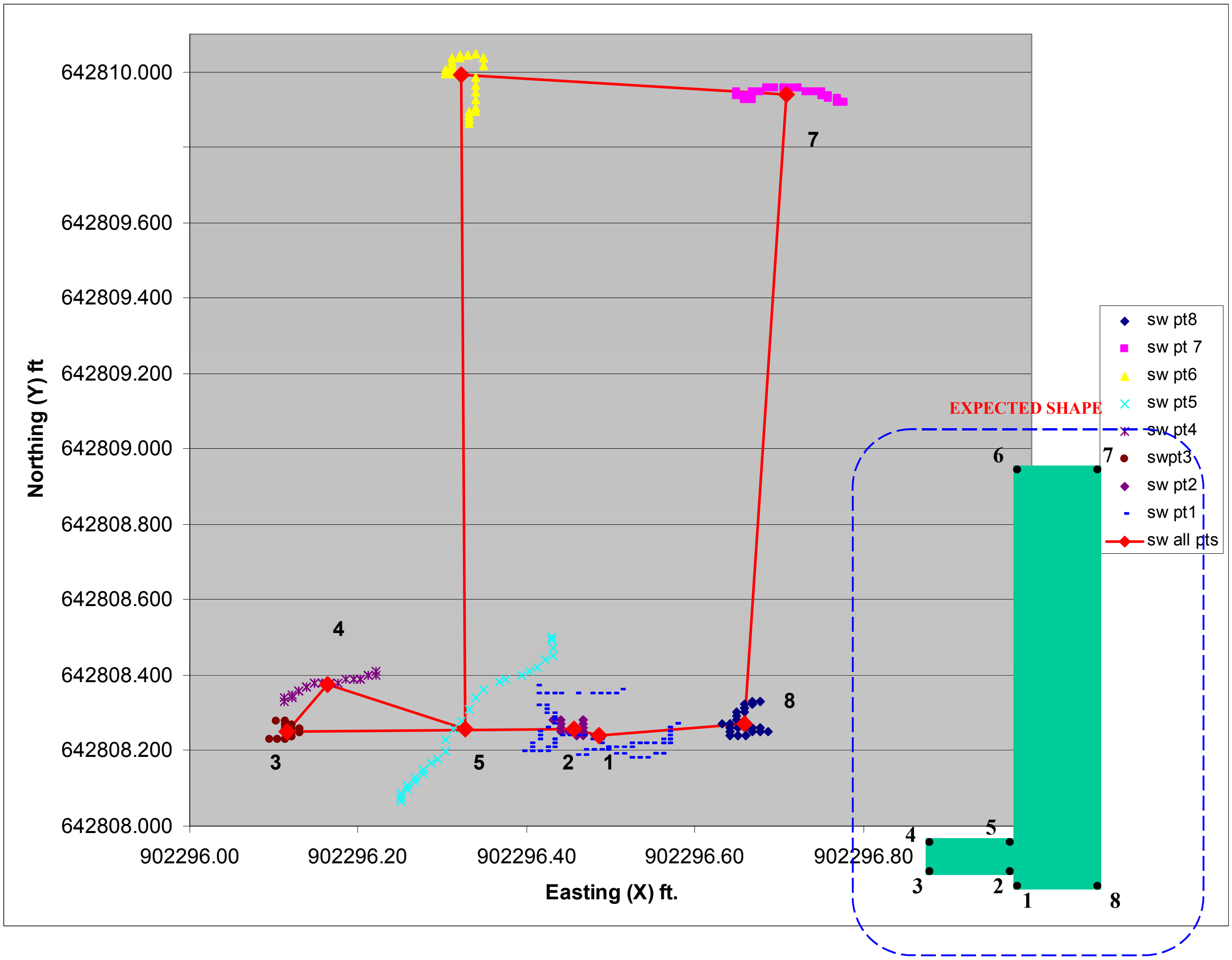


Figure 3.20. State Plane Coordinates Plot of SR 817 Sidewalk GPS Data Using TeleType GPS Receiver

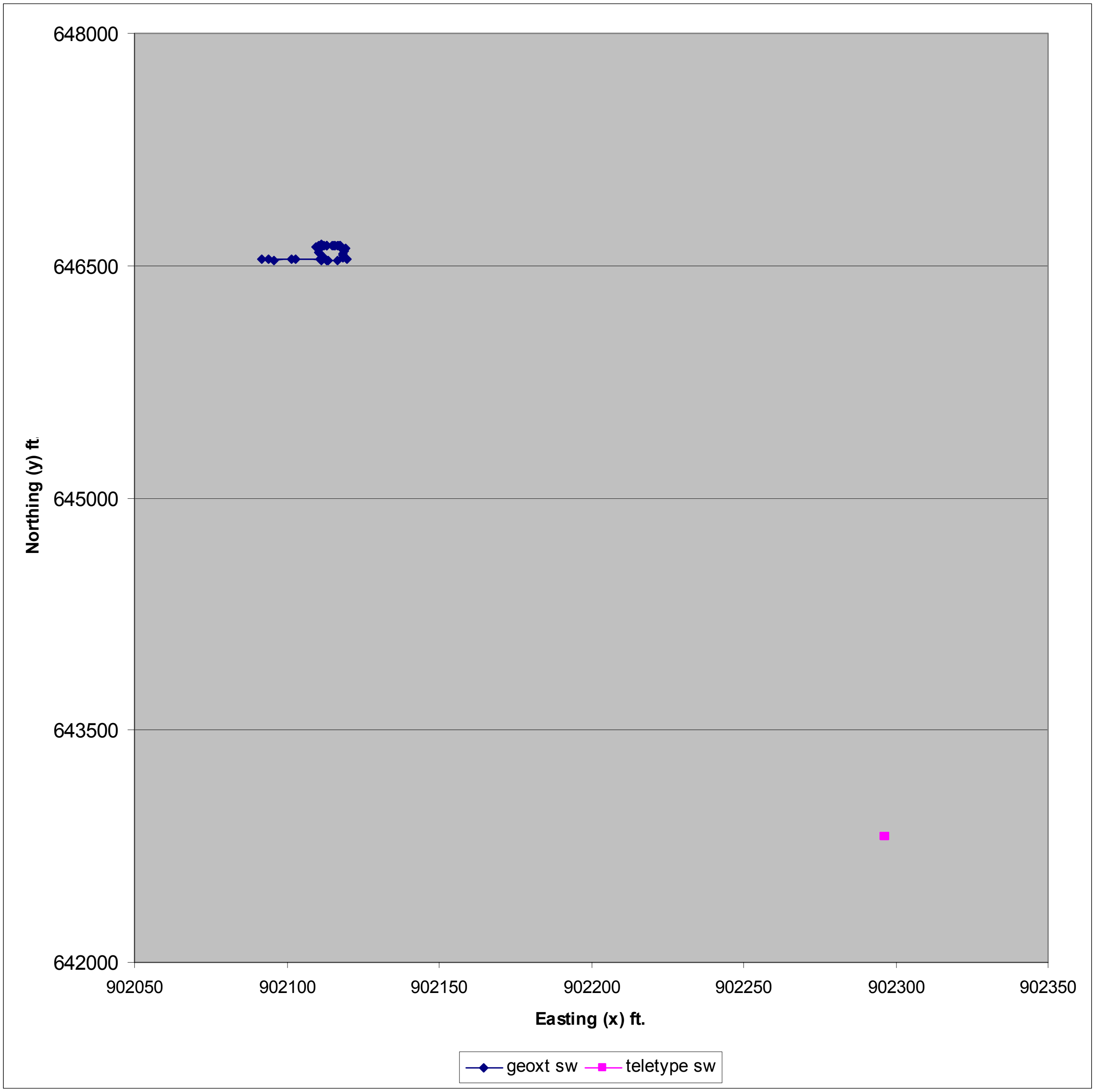


Figure 3.21. State Plane Coordinates Plot of SR 817 Sidewalk GPS Data with TeleType and GeoXT GPS Receivers

TABLE 3.7 Comparisons of GPS-measured Quantities with Inspector's and Plan Quantities

GPS Inspection Date	**Pay Item No.**	**Pay Item Description**	**Plan Location**	**Unit of Measure**	**Approx. Plan Qty**	**Trimble GeoXT GPS Qty**	**Inspector's Qty**	**% Difference (Geoxt *minus* Plan Qty)**	**% Difference (GeoXT *minus* Inspector Qty)**
Feb. 11, 2005	520-1-10	Curb & Gutter Conc (Type F)	124+74.08 - 130+53.03	LF	568	566.92	573	-0.2%	**-1.1%**
Feb. 11, 2005	522-1	Sidewalk Conc (4" Thick)	128+48.03 - 129+68.03	SF	997	944.47	960	-5.3%	**-1.6%**
Nov. 10, 2005	520-1-10	Curb & Gutter Conc (Type F)	85+89.34 - 94+89.54	LF	957	975.29	960	1.9%	**1.6%**
Nov. 10, 2005	522-1	Sidewalk Conc (4" Thick)	92+69.54 - 93+69.54	SF	888	883.95	909	-0.5%	**-2.8%**
Nov. 10, 2005	334-1-12	Superpave Asph. Conc (Traffic B)	92+09.10 - 94+54.54	SF	1401	1405.88	N/A	0.3%	**N/A**

3.2. Computations from GPS Geometry Points

Basic computation tools were developed in Microsoft Excel Spreadsheets based on GPS coordinates, for calculations of the lengths, areas, and volumes of inspected quantities of pay items. The formulas were eventually implemented in custom computer programs.

The length d between two points is given as follows

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

And the area A can be computed as

$$A = \frac{1}{2}\sum_{i=0}^{N-1}(x_i y_{i+1} - x_{i+1} y_i)$$

These simple formulas were applied to GPS data collected for a sidewalk near the Broward mall end of the project. First the GPS data points for the linear item were shown earlier in Table 3.2, including the software-computed perimeter and area. The same data points were plotted as shown in Figure 3.22 and used to compute the perimeter and area in the Excel spreadsheet as shown in Table 3.10. The elevations are simulated here to illustrate the volume computations. For simplicity, the thickness can be assumed to be 4 in. to estimate the volume also, as shown. It could be observed that the computed area and perimeter are practically the same values as those from the Trimble's Commercial Software (Pathfinder)'s computations.

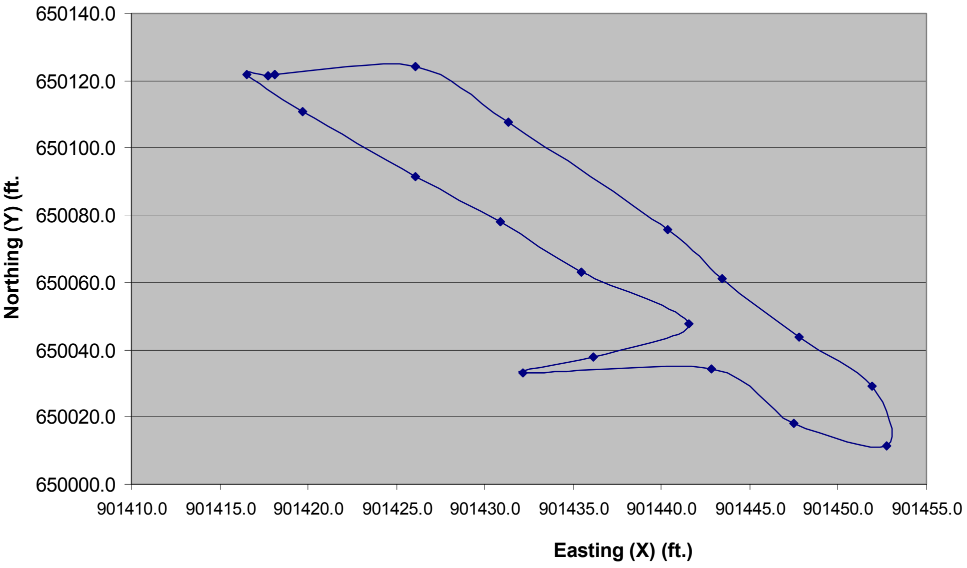


Figure 3.22 Sidewalk Layout Plotted from GeoXT GPS Positions

Table 3.8 GeoXT GPS Positions for Sidewalk Near Broward Mall

Position_ID	Easting	Northing	GPS Area	GPS Perimeter
1	901418.1	650121.735	944.4675281	258.8601363
2	901417.8	650121.427	944.4675281	258.8601363
3	901416.5	650121.928	944.4675281	258.8601363
4	901419.7	650110.727	944.4675281	258.8601363
5	901426.1	650091.498	944.4675281	258.8601363
6	901430.9	650078.189	944.4675281	258.8601363
7	901435.5	650063.217	944.4675281	258.8601363
8	901441.6	650047.626	944.4675281	258.8601363
9	901436.2	650037.779	944.4675281	258.8601363
10	901432.1	650032.939	944.4675281	258.8601363
11	901442.8	650034.307	944.4675281	258.8601363
12	901447.5	650018.06	944.4675281	258.8601363
13	901452.7	650011.32	944.4675281	258.8601363
14	901451.9	650029.33	944.4675281	258.8601363
15	901447.8	650043.669	944.4675281	258.8601363
16	901443.4	650060.976	944.4675281	258.8601363
17	901440.3	650075.802	944.4675281	258.8601363
18	901431.3	650107.579	944.4675281	258.8601363
19	901426.1	650124.28	944.4675281	258.8601363
20	901418.1	650121.735	944.4675281	258.8601363

Table 3.9. Computation of length, area, and volume based on GeoXT GPS Data in Excel Spreadsheet.

X (FT)	Y (FT)	Z1	Z2	Delta Z	SEG.. L (FT)	CUM. L (FT)	AREA (SF)
901418.086	650121.735	-75.291	-74.916	0.375			
901417.771	650121.427	-75.520	-75.170	0.350	0.441	0.441	-72848.424
901416.529	650121.928	-76.583	-76.175	0.408	1.339	1.780	1259061.115
901419.654	650110.727	-77.951	-77.584	0.367	11.629	13.409	-12128397.566
901426.092	650091.498	-78.038	-77.663	0.375	20.278	33.687	-21518811.387
901430.852	650078.189	-79.425	-79.100	0.325	14.135	47.821	-15091515.389
901435.503	650063.217	-80.986	-80.611	0.375	15.678	63.499	-16519736.373
901441.578	650047.626	-78.369	-78.027	0.342	16.733	80.232	-18003414.970
901436.181	650037.779	-78.831	-78.414	0.417	11.229	91.461	-5368188.181
901432.149	650032.939	-80.582	-80.182	0.400	6.299	97.760	-1741998.791
901442.836	650034.307	-80.178	-79.795	0.383	10.774	108.534	-5713742.839
901447.471	650018.060	-76.708	-76.358	0.350	16.895	125.430	-17658650.770
901452.722	650011.320	-80.302	-79.960	0.342	8.544	133.974	-9489000.788
901451.920	650029.330	-77.127	-76.810	0.317	18.028	152.002	16756472.602
901447.799	650043.669	-78.092	-77.767	0.325	14.919	166.921	15604689.950
901443.406	650060.976	-79.862	-79.504	0.358	17.856	184.777	18456998.895
901440.321	650075.802	-76.132	-75.790	0.342	15.144	199.920	15370238.048
901431.314	650107.579	-77.191	-76.816	0.375	33.029	232.949	34500301.829
901426.110	650124.280	-78.456	-78.089	0.367	17.493	250.442	18437964.216
901418.086	650121.735	-75.299	-74.916	0.383	8.418	258.860	2922467.773
					LENGTH	**258.860**	
					TOTAL AREA		**944.475**
					VOLUME (CY)	**12.72**	**11.66**
							(4 in. thick)

3.3. Resident Engineer's Comments

The CEI Resident Engineer indicated that the construction inspectors use survey crews to establish control or stakeout on project (contract already allows this); it may therefore be beneficial to recommend that the crew use RTK GPS for both the survey and the quantity documentation, in order to generate as-built CAD documents. Also some pay items such as erosion control mat or sodding may be on a sloping plane; the measurement could be enhanced with GPS because of the elevation issues, i.e. plan area compared with the actual area along the surface plane.

Other features identified by the Resident Engineer as being important and could benefit from GPS measures include the following: Signalization and Lighting; Conduit length measurement between pull boxes elevation after excavation, before pavement base is placed, thickness of asphalt surfacing layer; and as mentioned earlier, sloped area measurements, e.g. Sod pay items. Some pay items such as Curb and Gutter are plan quantity items, i.e. FDOT does not measure them, and Contractor is assumed to do them correctly. Currently measured pay items include traffic striping but Contractor just certifies them (no FDOT measure). The Contractor also certifies maintenance of Traffic (MOT) and signs. In short, many FDOT pay items are now plan quantity or certified by Contractor but that does not diminish the use of GPS for quantity measurement of these pay items, especially for verifying the quantities at inspection.

3.4. GPS Error Correction Methods

Due to the various constraints and eventual completion of the pilot SR 817 project by the Contractor, the development of GPS error correction methods could not be done using the project data. The issues were revisited and studied on a small scale using data from the Tallahassee area. Primarily, some Leon county survey control points were identified, and their coordinate data retrieved from the appropriate agencies. First, the low cost GPS receiver was again tested for accuracy, using the known X, Y coordinates of some control points. The GPS latitude/longitude data were collected, using minimum 100 positions at each point, and averaging the positions into a single point. The data was then converted using another software the Franscoord, into the Florida North State Plane projection. The results are shown in Table 3.8.

The concept of differential correction was also attempted. As mentioned earlier, a site visit to the SR 817 project site on August 2005 was designed to carry out a differential GPS using the HBLC3 as the GPS based station and rover GPS to collect the pay item features (Figures 3.23 and 3.24). This visit to the project site visit was not effective because of the weather at the site. Another attempt was therefore made in Tallahassee, using the DGPS to ascertain the accuracy of the rover GPS receivers through a simple differential correction of the GPS receivers at these control points. The Trimble ProXR, also mapping grade GPS receivers, were used as both the base GPS and Rover GPS, with the former mounted on a stationary tripod while the latter was mounted on a survey range bipod pole. The results in terms of errors along the X, Y, and Z coordinates are shown in Table 3.9. The values are also demonstrated in Figures 3.20 to 3.26.

Figure 3.23. Base station GPS receiver at FDOT Control Point HBLC3 (August 2005)

Figure 3.24. Setting up a Rover GPS receiver near Sidewalk Pay Item (August 2005)

TABLE 3.10 Evaluation of Low Cost GPS Receiver's Accuracy Based on Leon County Survey Control points

Date	Time	Survey Control Point Number	Latitude (Deg.min)	Longitude (Deg.min)	GPS X-Coordinate* (ft.)	GPS Y-Coordinate* (ft.)	Known X-Coordinate* (ft.)	Known Y-Coordinate* (ft.)	GPS Error X-Coord (ft)	GPS Error Y-Coord (ft)	Error Length (ft.)
2/24/2006	11:25 AM	TLC141S1W	30.419877	-84.340755	2018698.22	516408.97	2018693.87	516408.81	4.351	0.160	4.354
2/24/2006	11:45 AM	TLC151S1W	30.434173	-84.353273	2014745.73	521603.34	2014734.24	521591.72	11.495	11.624	16.348
2/24/2006	11:59 AM	TLC2291N1W	30.452933	-84.345425	2017209.93	528429.60	2017201.95	528424.88	7.977	4.719	9.268

* Florida North State Plane Coordinate Projection System

TABLE 3.11 Evaluation of Trimble ProXR GPS Receiver's Accuracy Based on Leon County Survey Control points

	Date	Time	Survey Control Point Number	GPS X-Coordinate* (ft.)	GPS Y-Coordinate* (ft.)	GPS Z-Elevation* (ft.)	Known X-Coordinate* (ft.)	Known Y-Coordinate* (ft.)	Known Z-Elevation* (ft.)
BASE	17-Feb-06	14:38:26	TLC231S1W	2029250.40	516933.72	85.06	2029250.57	516927.81	96.10
ROVER	17-Feb-06	15:01:26	TLC151S1W	2014734.48	521598.10	69.80	2014734.24	521591.72	80.85
ROVER	17-Feb-06	15:21:20	TLC2291N1W	2017202.10	528429.38	83.11	2017201.95	528424.88	88.70
BASE	24-Feb-06	10:52:00	TLC231S1W	2029253.71	516932.00	92.81	2029250.57	516927.81	96.10
ROVER	24-Feb-06	11:16:16	TLC141S1W	2018695.52	516412.80	106.32	2018693.87	516408.81	109.45
ROVER	24-Feb-06	11:39:00	TLC151S1W	2014737.79	521587.52	71.63	2014734.24	521591.72	80.85
ROVER	24-Feb-06	11:55:21	TLC2291N1W	2017205.65	528431.06	87.02	2017201.95	528424.88	88.70

* Florida North State Plane Coordinate Projection System

TABLE 3.12 Evaluation of Trimble ProXR GPS Receiver's Accuracy Based on Leon County Survey Control points (Continued)

	Date	Time	Survey Control Point Number	GPS Raw Data Error X-Coord (ft)	GPS Raw Data Error Y-Coord (ft)	GPS Raw Data Error Z-Elev (ft)	GPS Raw Data Error Length (ft.)	GPS Base Corr. Error X-Coord (ft)	GPS Base Corr. Error Y-Coord (ft)	GPS Base Corr. Error Z-Elev (ft)	GPS Base Corr. Error Length (ft.)
BASE	17-Feb-06	14:38:26	TLC231S1W	-0.17	5.92	-11.05	5.92				
ROVER	17-Feb-06	15:01:26	TLC151S1W	0.24	6.39	-11.05	6.39	0.42	0.47	0.00	0.63
ROVER	17-Feb-06	15:21:20	TLC2291N1W	0.14	4.50	-5.60	4.50	0.32	-1.42	5.45	1.45
BASE	24-Feb-06	10:52:00	TLC231S1W	3.13	4.19	-3.29	5.23				
ROVER	24-Feb-06	11:16:16	TLC141S1W	1.65	3.99	-3.12	4.32	-1.48	-0.20	0.16	1.49
ROVER	24-Feb-06	11:39:00	TLC151S1W	3.55	-4.20	-9.22	5.50	0.42	-8.39	-5.93	8.40
ROVER	24-Feb-06	11:55:21	TLC2291N1W	3.70	6.18	-1.69	7.20	0.57	1.99	1.60	2.07

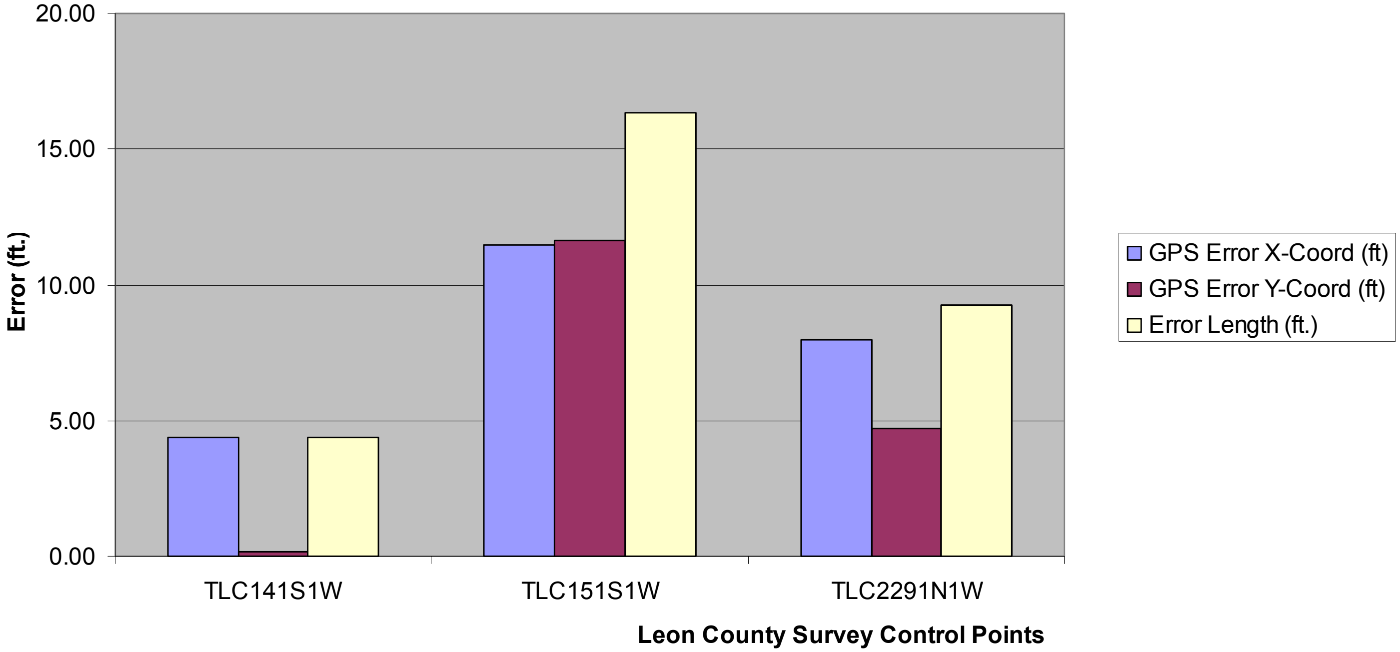


Figure 3.25. Evaluation of Low Cost GPS Receiver’s Accuracy Based on Leon County Survey Control points

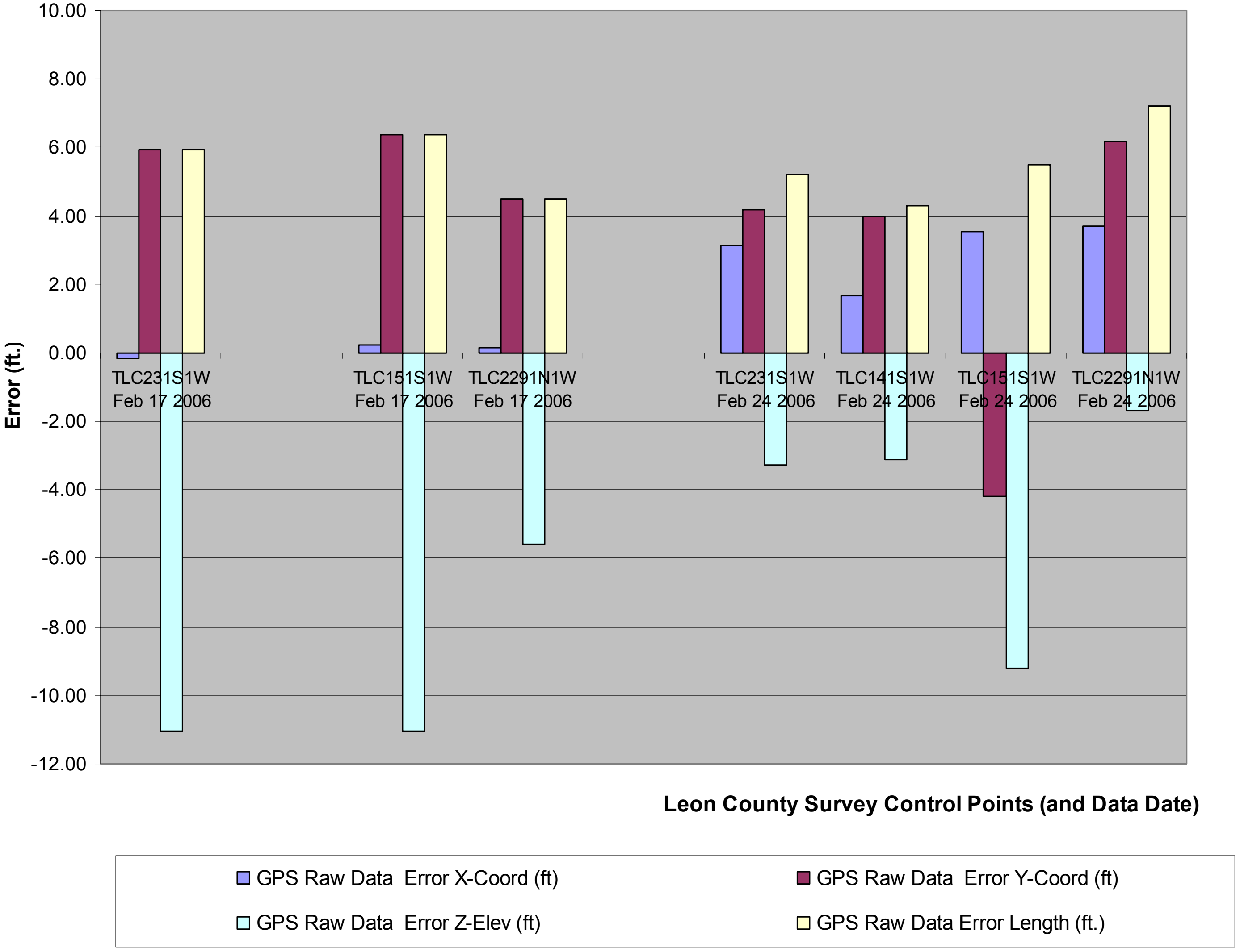


Figure 3.26. Evaluation of Trimble ProXR GPS Receiver's Accuracy Based on Leon County Survey Control points

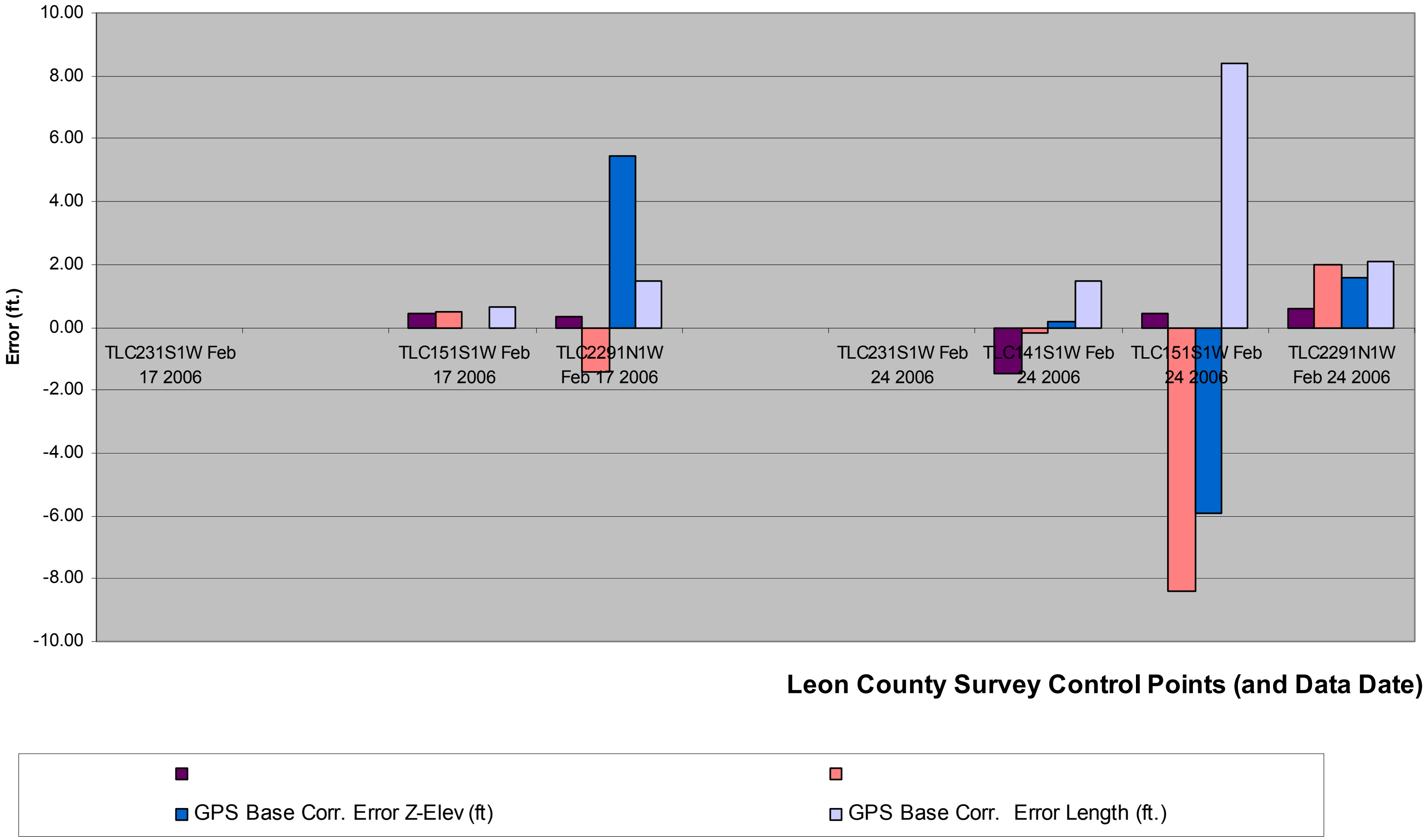


Figure 3.27. Evaluation of Trimble ProXR GPS Receiver's Accuracy Based on Leon County Survey Control points

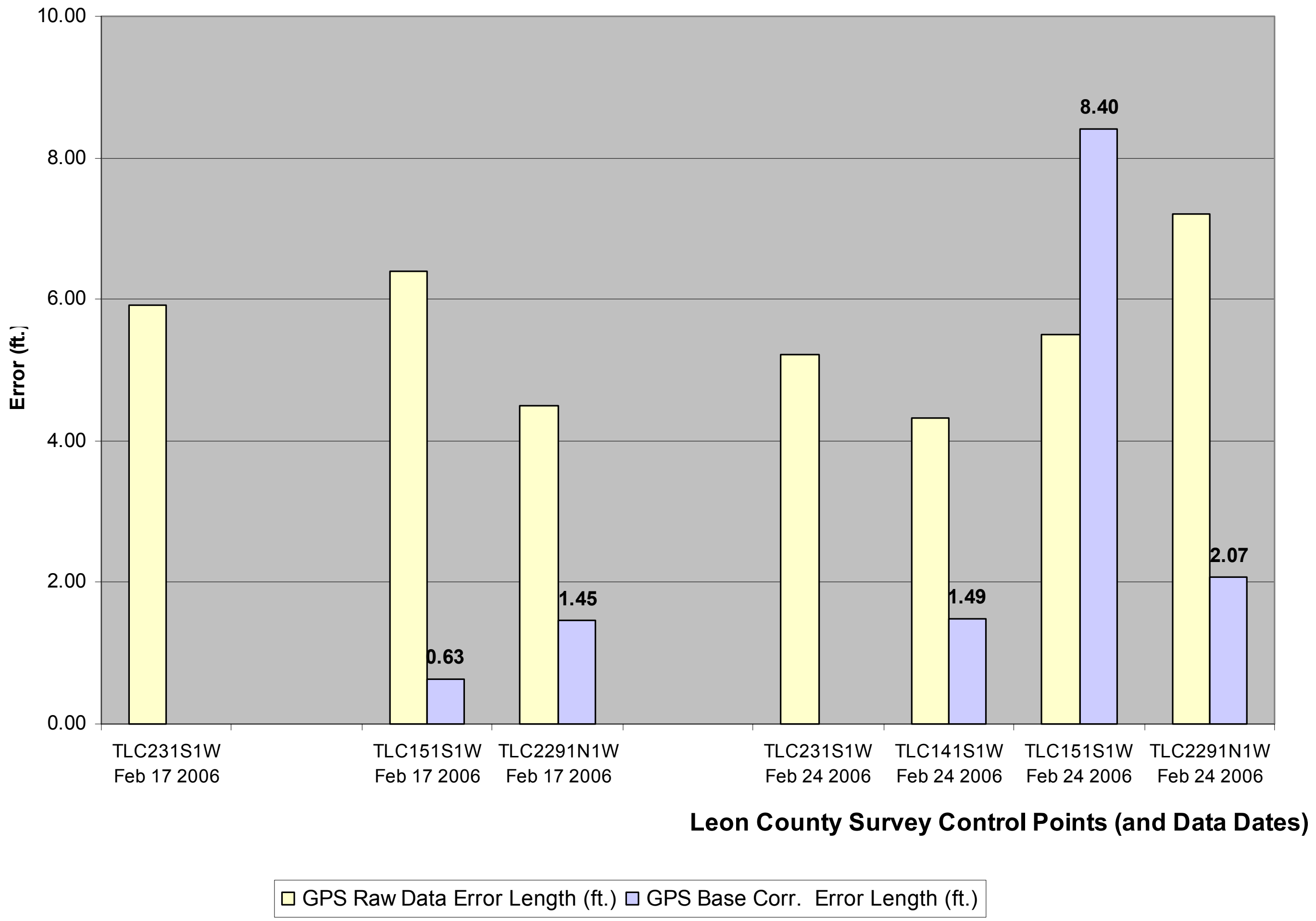


Figure 3.28. Evaluation of Trimble ProXR GPS Receiver's Differential Corrected Accuracy Based on Leon County Survey Control points

3.5. Demonstration of GPS/GIS Tools using Field-Collected Data

Using the ESRI software ArcGIS, and custom computer programs written in the Microsoft Visual Basic 6 Language, the GPS/GIS tools for construction inspection of highway projects were developed, based on the methodology described so far in this report..

With use of only screen shots from the various software and computer programs, the use of the GPS/GIS tools are shown in the following figures, and explained to some extent, by the captions.

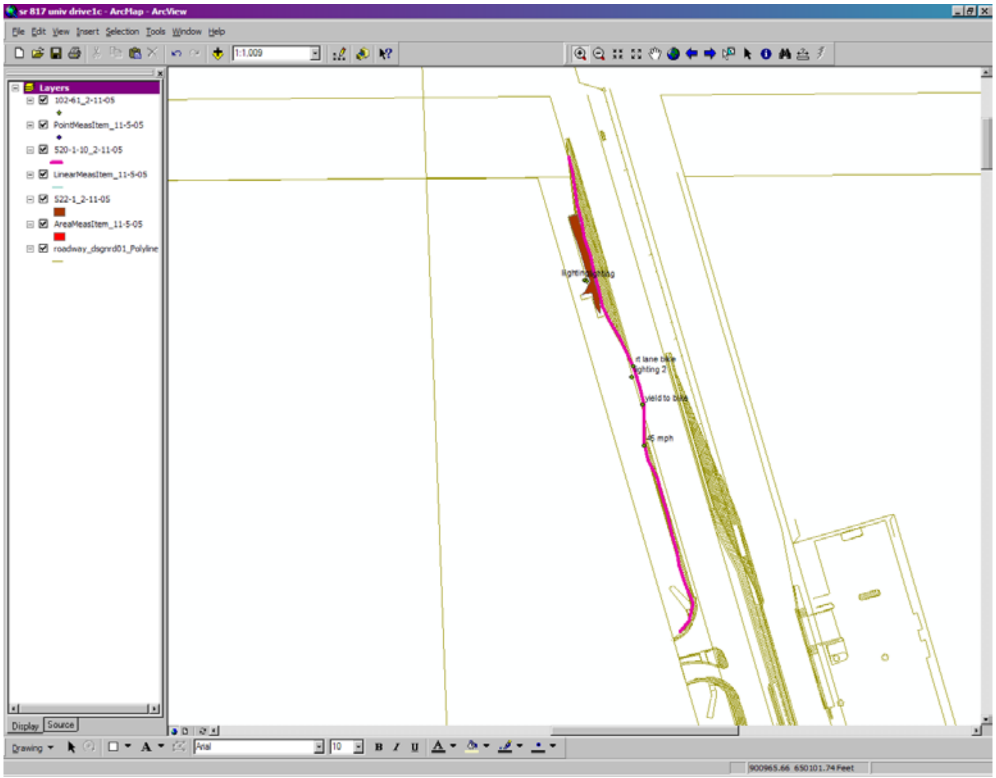


Figure 3.29. ArcGIS: Spatial Data of Inspected Pay Items (Feb. 11, 2005) Relative to the Original Drawing Locations

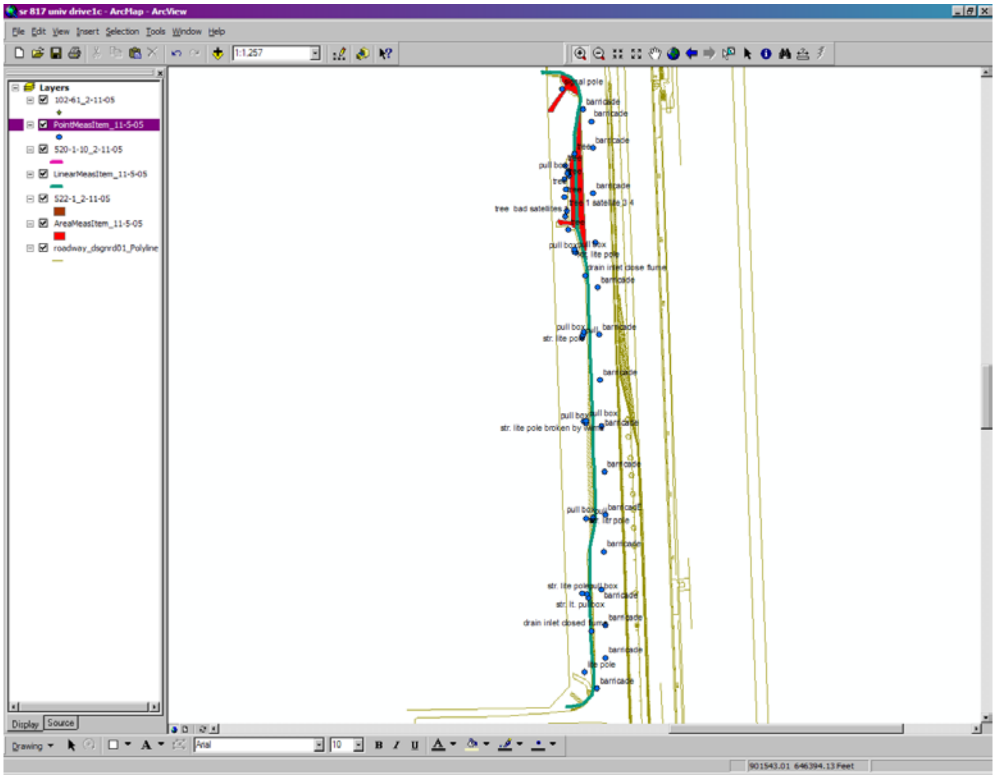
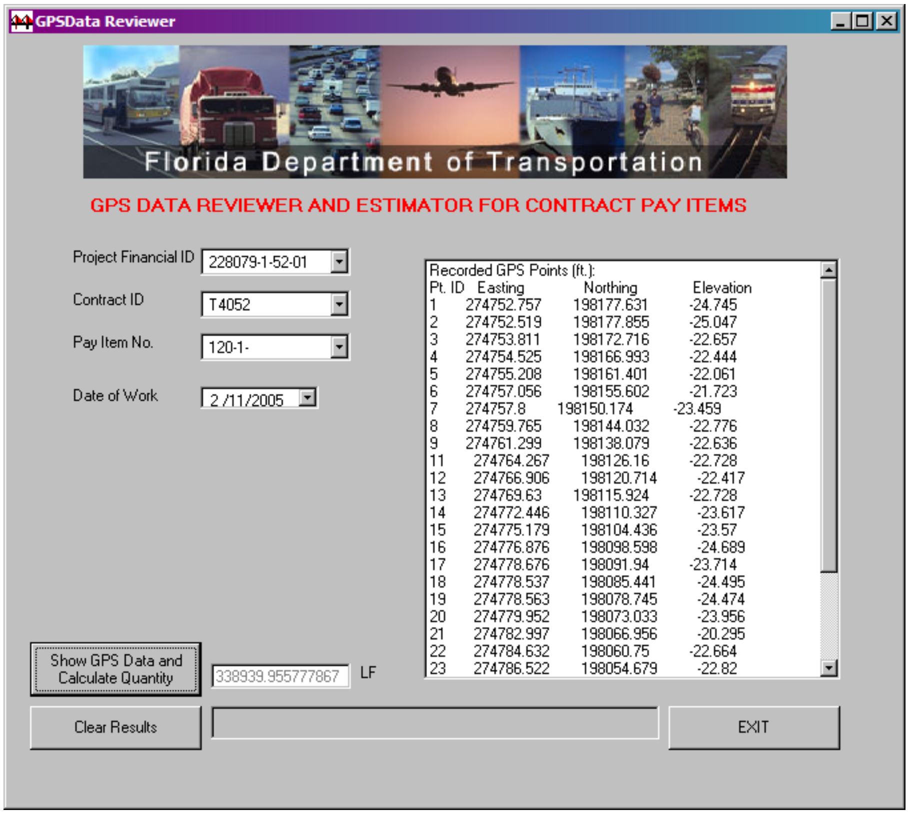


Figure 3.30. ArcGIS: Spatial Data of Inspected Pay Items (Nov. 10, 2005, with Point Items Labeled) Relative to the Original Drawing Locations



Project Financial ID: 228079-1-52-01

Contract ID: T4052

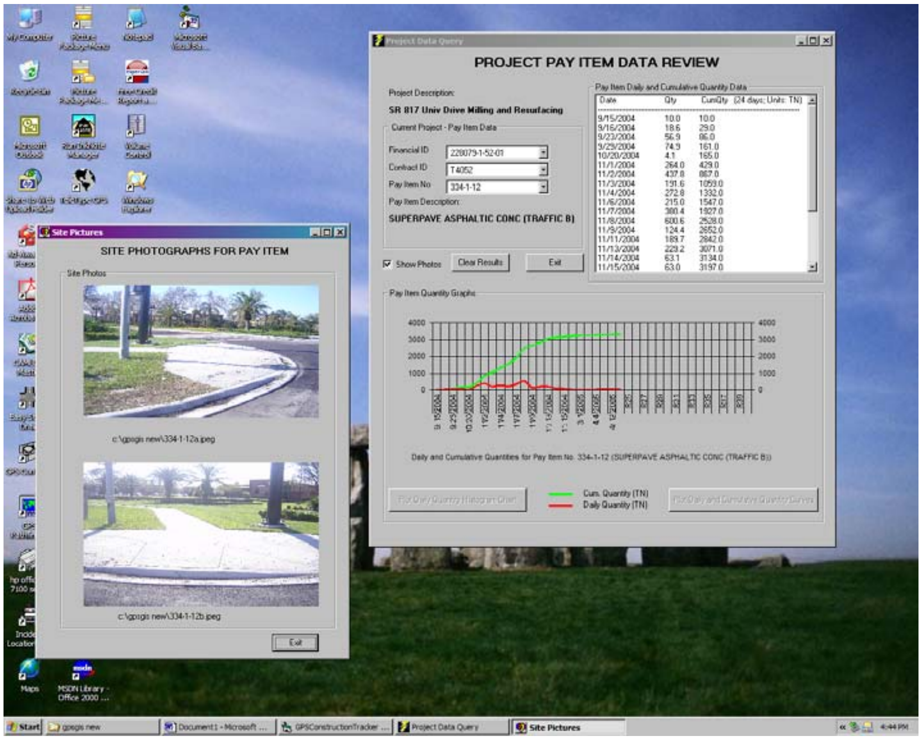
Pay Item No.: 120-1-

Date of Work: 2 /11/2005

338939.955777867 LF

```
Recorded GPS Points (ft.):
Pt. ID  Easting        Northing       Elevation
1       274752.757     198177.631     -24.745
2       274752.519     198177.855     -25.047
3       274753.811     198172.716     -22.657
4       274754.525     198166.993     -22.444
5       274755.208     198161.401     -22.061
6       274757.056     198155.602     -21.723
7       274757.8     198150.174     -23.459
8       274759.765     198144.032     -22.776
9       274761.299     198138.079     -22.636
11       274764.267     198126.16     -22.728
12       274766.906     198120.714     -22.417
13       274769.63     198115.924     -22.728
14       274772.446     198110.327     -23.617
15       274775.179     198104.436     -23.57
16       274776.876     198098.598     -24.689
17       274778.676     198091.94     -23.714
18       274778.537     198085.441     -24.495
19       274778.563     198078.745     -24.474
20       274779.952     198073.033     -23.956
21       274782.997     198066.956     -20.295
22       274784.632     198060.75     -22.664
23       274786.522     198054.679     -22.82
```

Figure 3.31. VB Program for Review and Calculation of Inspected Pay Item's Quantity based on GPS Data



PROJECT PAY ITEM DATA REVIEW

Project Description:
SR 817 Univ Drive Milling and Resurfacing

Current Project - Pay Item Data

Financial ID: 228079-1-52-01
Contract ID: T4052
Pay Item No: 334-1-12
Pay Item Description:
SUPERPAVE ASPHALTIC CONC (TRAFFIC B)

☑ Show Photos

Pay Item Daily and Cumulative Quantity Data

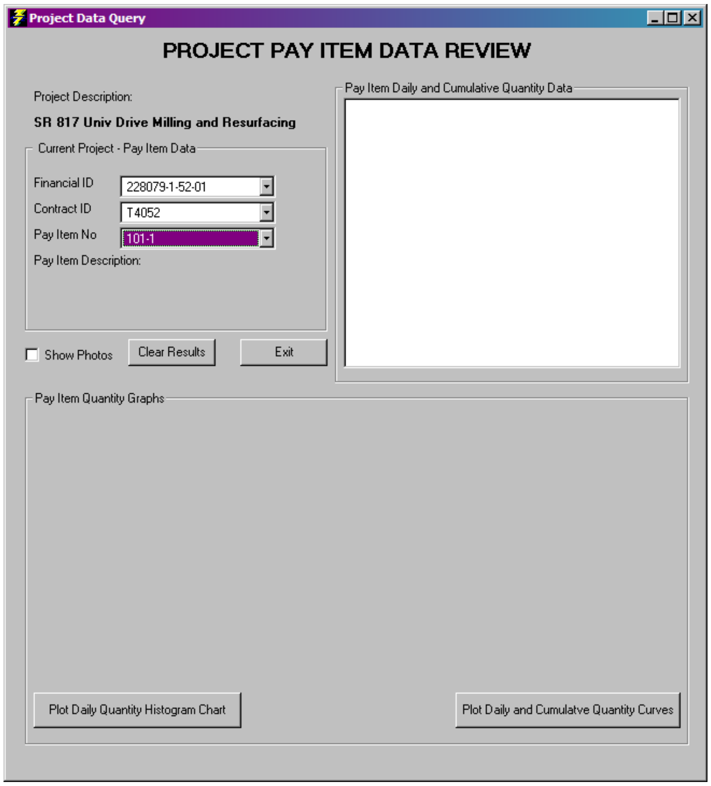
```
Date          Qty     CumQty  (24 days; Units: TN)
--------------------------------------------------
9/15/2004     10.0    10.0
9/16/2004     18.6    29.0
9/23/2004     56.9    86.0
9/29/2004     74.9    161.0
10/20/2004    4.1     165.0
11/1/2004     264.0   429.0
11/2/2004     437.8   867.0
11/3/2004     191.6   1059.0
11/4/2004     272.8   1332.0
11/6/2004     215.0   1547.0
11/7/2004     380.4   1927.0
11/8/2004     600.6   2528.0
11/9/2004     124.4   2652.0
11/11/2004    189.7   2842.0
11/13/2004    229.2   3071.0
11/14/2004    63.1    3134.0
11/15/2004    63.0    3197.0
```

Daily and Cumulative Quantities for Pay Item No. 334-1-12 (SUPERPAVE ASPHALTIC CONC (TRAFFIC B))

c:\gpsgis new\334-1-12a.jpeg

c:\gpsgis new\334-1-12b.jpeg

Figure 3.32. VB Program for Review of Project Recorded Data for Pay Item's Quantity Including Site Photographs



PROJECT PAY ITEM DATA REVIEW

Project Description:
SR 817 Univ Drive Milling and Resurfacing

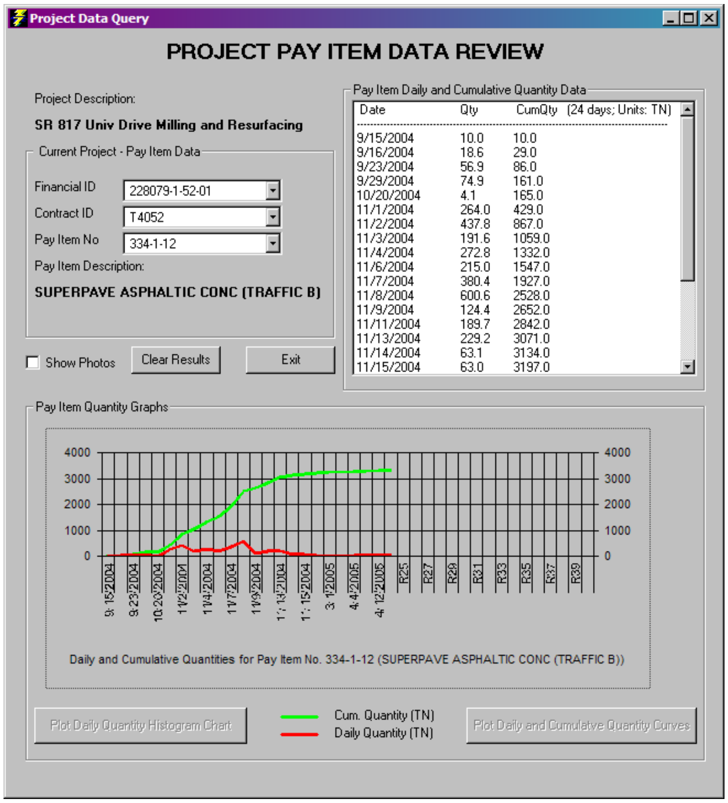
Current Project - Pay Item Data

Financial ID: 228079-1-52-01
Contract ID: T4052
Pay Item No: 101-1
Pay Item Description:

☐ Show Photos

Pay Item Daily and Cumulative Quantity Data

Figure 3.33. VB Program for Review of Project Recorded Data for Pay Item's Quantity (No Entries)



Project Description:

SR 817 Univ Drive Milling and Resurfacing

Financial ID: 228079-1-52-01

Contract ID: T4052

Pay Item No: 334-1-12

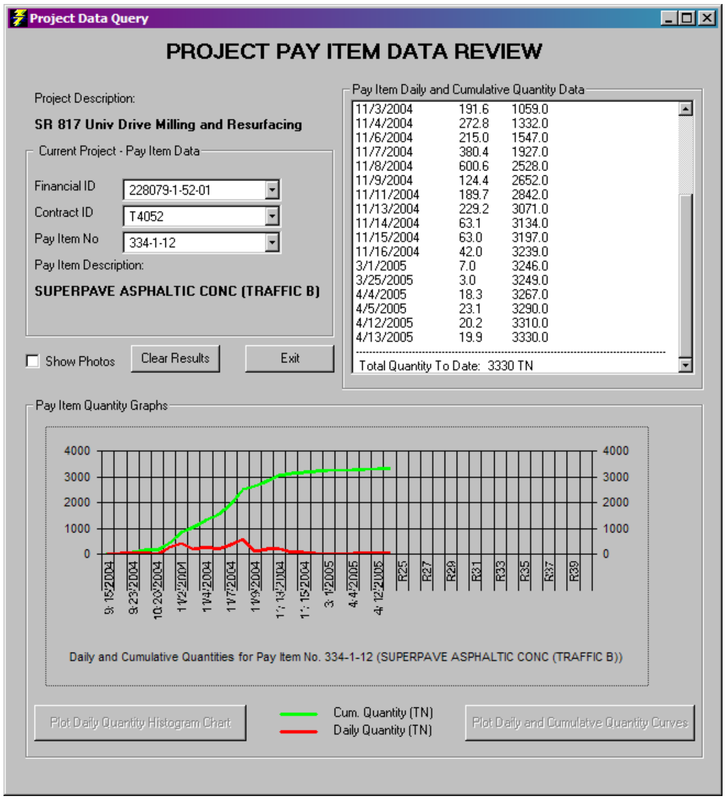
Pay Item Description:

SUPERPAVE ASPHALTIC CONC (TRAFFIC B)

Pay Item Daily and Cumulative Quantity Data

```
 Date          Qty      CumQty  (24 days; Units: TN)
--------------------------------------------------------
9/15/2004      10.0     10.0
9/16/2004      18.6     29.0
9/23/2004      56.9     86.0
9/29/2004      74.9     161.0
10/20/2004     4.1      165.0
11/1/2004      264.0    429.0
11/2/2004      437.8    867.0
11/3/2004      191.6    1059.0
11/4/2004      272.8    1332.0
11/6/2004      215.0    1547.0
11/7/2004      380.4    1927.0
11/8/2004      600.6    2528.0
11/9/2004      124.4    2652.0
11/11/2004     189.7    2842.0
11/13/2004     229.2    3071.0
11/14/2004     63.1     3134.0
11/15/2004     63.0     3197.0
```

Figure 3.34. VB Program for Review of Project Recorded Data for Pay Item's Quantity (With Results After Entries)



Project Description:

SR 817 Univ Drive Milling and Resurfacing

Financial ID: 228079-1-52-01

Contract ID: T4052

Pay Item No: 334-1-12

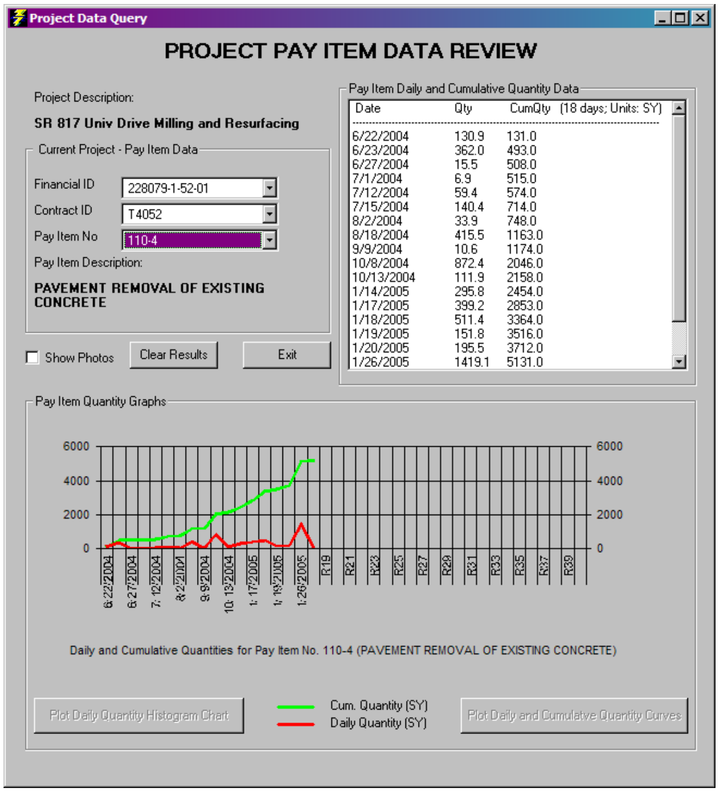
Pay Item Description:

SUPERPAVE ASPHALTIC CONC (TRAFFIC B)

Pay Item Daily and Cumulative Quantity Data

```
11/3/2004      191.6    1059.0
11/4/2004      272.8    1332.0
11/6/2004      215.0    1547.0
11/7/2004      380.4    1927.0
11/8/2004      600.6    2528.0
11/9/2004      124.4    2652.0
11/11/2004     189.7    2842.0
11/13/2004     229.2    3071.0
11/14/2004     63.1     3134.0
11/15/2004     63.0     3197.0
11/16/2004     42.0     3239.0
3/1/2005       7.0      3246.0
3/25/2005      3.0      3249.0
4/4/2005       18.3     3267.0
4/5/2005       23.1     3290.0
4/12/2005      20.2     3310.0
4/13/2005      19.9     3330.0
--------------------------------------------------------
 Total Quantity To Date:  3330 TN
```

Figure 3.35. VB Program for Review of Project Recorded Data for Pay Item's Quantity (With Results After Entries Pay Item No. 334-1-12)



PROJECT PAY ITEM DATA REVIEW

Project Description:

SR 817 Univ Drive Milling and Resurfacing

Current Project - Pay Item Data

Financial ID: 228079-1-52-01

Contract ID: T4052

Pay Item No: 110-4

Pay Item Description:

PAVEMENT REMOVAL OF EXISTING CONCRETE

Pay Item Daily and Cumulative Quantity Data

```
 Date          Qty       CumQty   (18 days; Units: SY)
------------------------------------------------------
6/22/2004      130.9     131.0
6/23/2004      362.0     493.0
6/27/2004      15.5      508.0
7/1/2004       6.9       515.0
7/12/2004      59.4      574.0
7/15/2004      140.4     714.0
8/2/2004       33.9      748.0
8/18/2004      415.5     1163.0
9/9/2004       10.6      1174.0
10/8/2004      872.4     2046.0
10/13/2004     111.9     2158.0
1/14/2005      295.8     2454.0
1/17/2005      399.2     2853.0
1/18/2005      511.4     3364.0
1/19/2005      151.8     3516.0
1/20/2005      195.5     3712.0
1/26/2005      1419.1    5131.0
```

Daily and Cumulative Quantities for Pay Item No. 110-4 (PAVEMENT REMOVAL OF EXISTING CONCRETE)

Figure 3.36. VB Program for Review of Project Recorded Data for Pay Item's Quantity (With Results After Entries Pay Item No. 110-4)

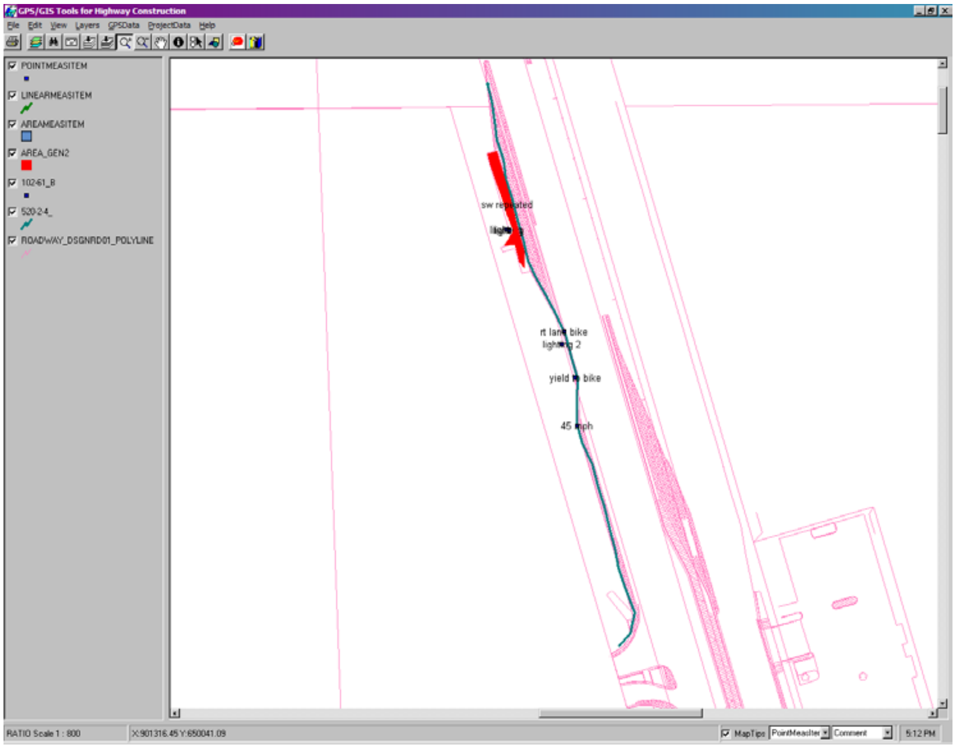


Figure 3.37. Custom VB Program: Spatial Data of Inspected Pay Items (Feb. 11, 2005, with Labels for Signs and Light Posts) Relative to the Original Drawing Locations

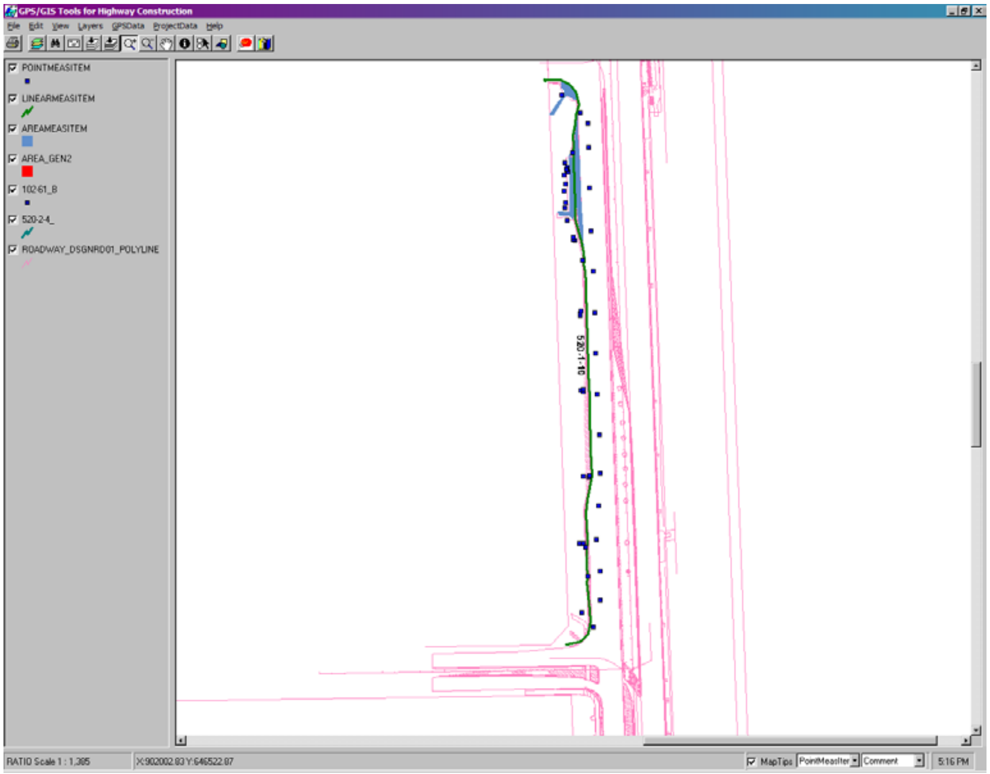


Figure 3.38. Custom VB Program: Spatial Data of Inspected Pay Items (Nov. 10, 2005, with label for Curb and Gutter) Relative to the Original Drawing Locations

3.6. Summary

The data collection efforts have been demonstrated in this section, along with the results of some brief analyses. Custom computer programs were developed with the capability to display the inspected quantity data, as well as perform some basic quantity computations.

4. Pilot Study with Bentley's Construction Inspector

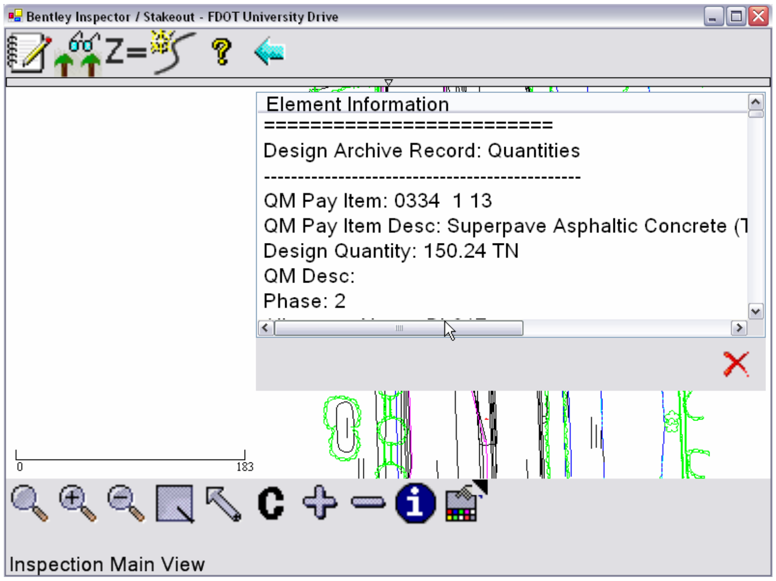
The purpose of this document is to outline the deliverables for the Bentley Inspector/Stakeout Pilot Study. These include a collection of screen shots, digital pictures and software DLLs categorized as follows:

- Digital pictures of the October 14, 2005 field review where Bentley personnel demonstrated the capabilities of the Bentley Inspector/Stakeout tool by performing inspection activities to construction on University Drive in Plantation. See ftp://ftp.bentley.com/pub/outgoing/pix.zip.

- Tack Coat Report screen shots and DLLs representing a VB.NET based specialty inspection. See TackCoat.zip.
- Daily Report of Construction screen shots and DLLs reflecting a single, standardized FDOT report. See EstimatedWorkPerformed.zip

Tack Coat Report

The contract specified that Bentley would deliver a "FDOT specific VB.NET application for defined specialty inspections" (Task 4b). The Tack Coat Report satisfies this requirement. This report operates in the context of the Bentley Inspector/Stakeout tool. Hence, it is automatically made available for optional application when the appropriate pay item is selected for inspection. For example, consider selection of Superpave Asphaltic Concrete (Pay Item 0334-1-13).

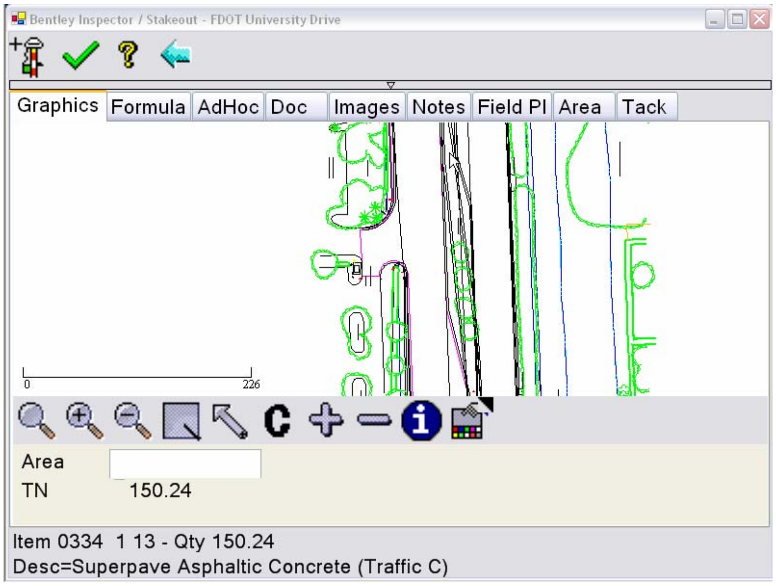


Element Information
========================
Design Archive Record: Quantities

QM Pay Item: 0334 1 13
QM Pay Item Desc: Superpave Asphaltic Concrete (T
Design Quantity: 150.24 TN
QM Desc:
Phase: 2

Inspection Main View

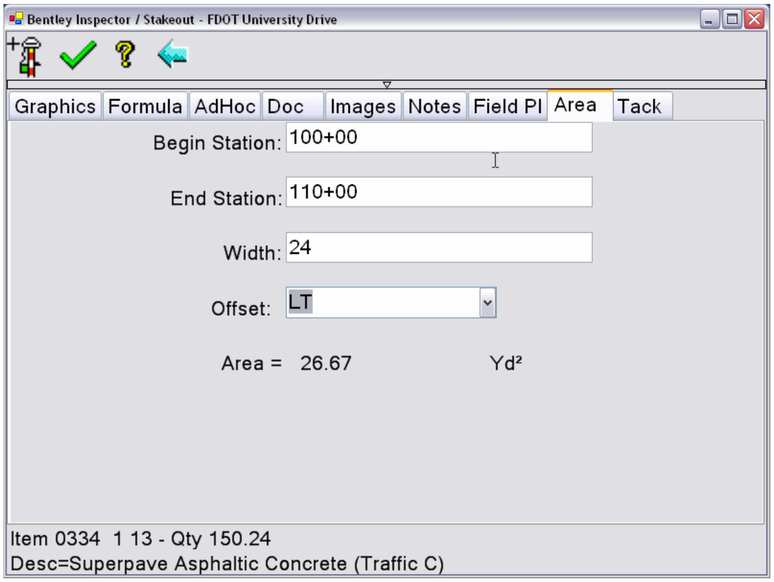
If the user subsequently presses the Inspection icon, the VB.NET Tack Coat application adds two additional tabs - Area and Tack tabs – to the typical collection of Bentley Inspector/Stakeout tabs that include Graphics, Formula, AdHoc, Doc, Images, Notes and Field PI.



Area
TN 150.24

Item 0334 1 13 - Qty 150.24
Desc=Superpave Asphaltic Concrete (Traffic C)

On the Area tab, the user can specify the area whereupon the tack coat is being applied in terms of stations and widths. The Area is then computed.



Begin Station: 100+00

End Station: 110+00

Width: 24

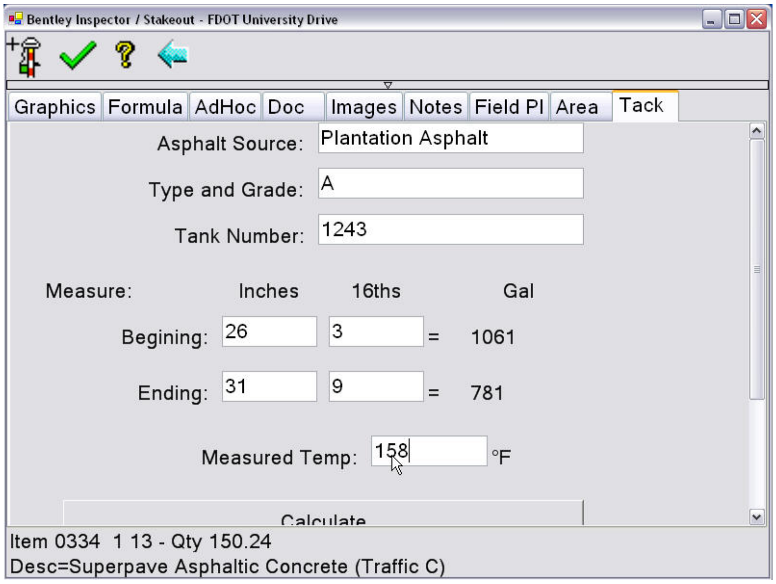
Offset: LT

Area = 26.67 Yd²

Item 0334 1 13 - Qty 150.24
Desc=Superpave Asphaltic Concrete (Traffic C)

Optionally, precise station offset and area shapes could be supported in the manner customary for Bentley Inspector/Stakeout. Hence, the purpose of the Area tab is an alternative, less precise method that corresponds with legacy procedures.

On the Tack tab, the user inputs the Tank Number, Measured Temperature along with Beginning and Ending dip stick measurements. For each dip stick measurement, the software immediately returns the gallons contained in the tanker for each measurement.



Asphalt Source: Plantation Asphalt

Type and Grade: A

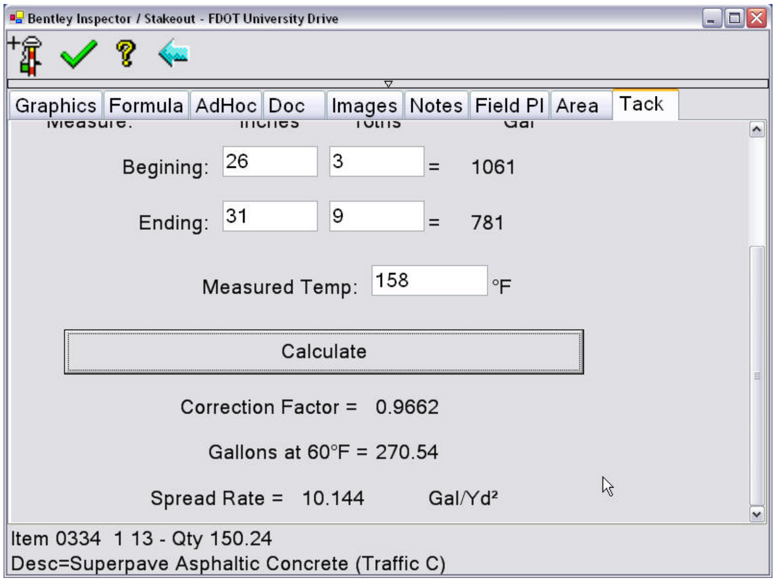
Tank Number: 1243

Measure:	Inches	16ths		Gal
Begining:	26	3	=	1061
Ending:	31	9	=	781

Measured Temp: 158 °F

Item 0334 1 13 - Qty 150.24
Desc=Superpave Asphaltic Concrete (Traffic C)

Upon pressing the Calculate push button, the Tack Coat Report tool calculates and displays the Correction Factor for temperature, the gallon difference between before/after measurements adjusted for temperature and the resultant Spread Rate.



Begining: 26 3 = 1061

Ending: 31 9 = 781

Measured Temp: 158 °F

Correction Factor = 0.9662

Gallons at 60°F = 270.54

Spread Rate = 10.144 Gal/Yd²

Item 0334 1 13 - Qty 150.24

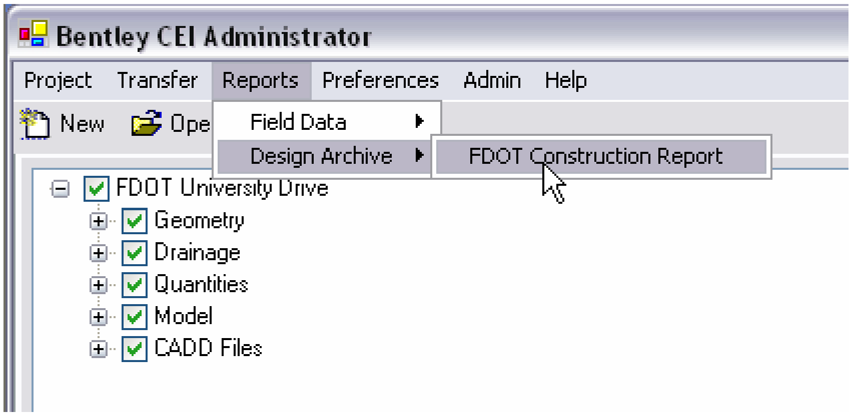
Desc=Superpave Asphaltic Concrete (Traffic C)

Deliverables for this tool include:

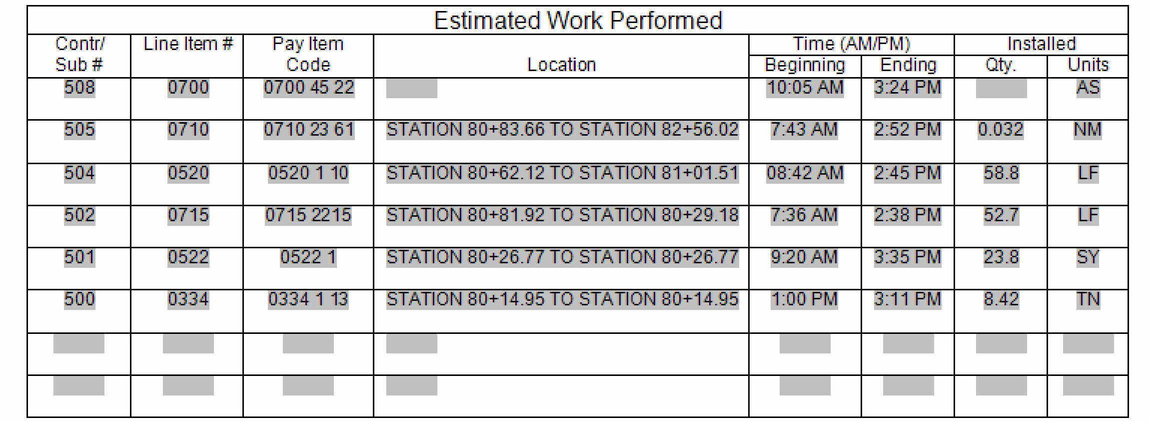
- CustomAddon.dll
- TankCapacity.dat
- TempCorrection.dat

Daily Report of Construction

The contract specified that Bentley would deliver a "FDOT specific VB.NET application for generating a single, standardized FDOT report" (Task 4a). The Daily Report of Construction satisfies this requirement. This report is invoked from the CEI Administrator tool of the Bentley Inspector/Stakeout system.



For a given date, the report tool collects the assembled inspection activities of all inspectors and completes the Estimated Work Performed section of the standard FDOT Daily Report of Construction to a high level of detail that now includes specific station to station ranges.



Estimated Work Performed

Contr/ Sub #	Line Item #	Pay Item Code	Location	Time (AM/PM)		Installed	
				Beginning	Ending	Qty.	Units
508	0700	0700 45 22		10:05 AM	3:24 PM		AS
505	0710	0710 23 61	STATION 80+83.66 TO STATION 82+56.02	7:43 AM	2:52 PM	0.032	NM
504	0520	0520 1 10	STATION 80+62.12 TO STATION 81+01.51	08:42 AM	2:45 PM	58.8	LF
502	0715	0715 2215	STATION 80+81.92 TO STATION 80+29.18	7:36 AM	2:38 PM	52.7	LF
501	0522	0522 1	STATION 80+26.77 TO STATION 80+26.77	9:20 AM	3:35 PM	23.8	SY
500	0334	0334 1 13	STATION 80+14.95 TO STATION 80+14.95	1:00 PM	3:11 PM	8.42	TN

Deliverables for this tool include:

- Bentley.Civil.Base.dll
- Bentley.Civil.Geometry.dll
- GEOPAK.DataModel.dll
- GEOPAK.DesignArchive.dll
- GEOPAK.FPDB.dll
- GEOPAK.System.dll
- Interop.Word.dll

APPENDIX A. References

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