University of California at Davis

California Department of Transportation

Inventory and Assessing Conditions of Roadside Features Statewide Final Report

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Report Number: CA09-0941
AHMCT Research Report: UCD-ARR-09-09-30-01
Final Report of Contract[*]: 65A0210 -Task Order 06-09
Date: September 30th, 2009

Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center

Division of Research and Innovation

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[*] This report has been prepared in cooperation with the State of California, Business Transportation and Housing Agency, Department of Transportation, and is based on work supported by Contract Number IA 65A0210 through the AHMCT Research Center at the University of California at Davis.

Technical Documentation Page

<table>
<tr><td>1. Report No.
CA09-0941</td><td colspan="2">2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="3" rowspan="2">4. Title and Subtitle
Inventory and Assessing Conditions of Roadside Features Statewide</td><td colspan="2">5. Report Date
September 30, 2009</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="3">7. Author(s):
Bahram Ravani</td><td colspan="2">8. Performing Organization Report No.
UCD-ARR-09-09-30-01</td></tr>
<tr><td colspan="3" rowspan="2">9. Performing Organization Name and Address
AHMCT Research Center
UCD Dept of Mechanical & Aeronautical Engineering
Davis, California 95616-5294</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant
65A0210</td></tr>
<tr><td colspan="3" rowspan="2">12. Sponsoring Agency Name and Address
California Department of Transportation
Division of Research and Innovation

P. o. Box 942873, MS#83
Sacramento, CA 94273-0001</td><td colspan="2">13. Type of Report and Period Covered
Final Report
12-01-2006 to 09-30-2009</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code
Caltrans</td></tr>
<tr><td colspan="5">15. Supplementary Notes</td></tr>
<tr><td colspan="5">16. Abstract
This report provides a summary of results obtained under a two phase project aimed at identifying the state of the arts in inventory and assessing condition of roadside features and developing the kernel of a software-based asset management tool that can be used for digitization of Roadside Inventory Data, its Assessment, and Visualization. The project has also involved experimentation on use of remote methods for gathering data and digitization of roadside features. The following research questions were addressed in this study:
What are the state of the art and best practices in inventory and assessing of roadside features?
What are the typical or generic costs associated with inventory of roadside assets?
How can GPS (Global Positioning System) be integrated into data gathering and Geo-Referencing in roadside asset management in Caltrans operations
What kind of databases and software tools can provide for an effective method for Caltrans to inventory and monitor conditions of roadside assets
Are there ways or methods that data gathering can be simplified or automated?</td></tr>
<tr><td colspan="2">17. Key Words
Roadside Features; Roadside Inventory, Asset Management, Google Earth, Visualization, Culverts, Mobile Data Collection</td><td colspan="3">18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.</td></tr>
<tr><td>20. Security Classif. (of this report)
Unclassified</td><td colspan="2">20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized
(PF V2.1, 6/30/92)

DISCLAIMER/DISCLOSURE

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

ACKNOWLEDGMENTS

The authors thank the California State Department of Transportation for their support of this research. This work would have not been possible without the input and help of several individuals from Caltrans: Mr. Larry Baumeister and Bob Meline of Division of Research and Innovation, Mr. Manuel Morales, Culvert Inspection Program Coordinator, Division of Maintenance, Mr. Wes Wilson, Division of Maintenance, Mr. Bruce Flaws, System/Program Coordinator, Division of Maintenance, Safety Roadside Rest Area System/Graffiti Removal Program, and Mr. Juan Sanchez, Division of Maintenance. The authors would also acknowledge the help and contributions of Mr. Kin Yen, and Somnath Roysarkar of AHMCT.

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1. INTRODUCTION

The main objective of this study was to develop a framework for integration of Advanced Technologies such as GPS (Global Positioning System), Information Technology (IT), and other Data Collection and Mobile Mapping methods for inventory and assessing roadside features in California. This effort is part of the main roadmaps of the AHMCT (Advanced Highway Maintenance and Construction Technology) Research center to develop a digital world model of transportation infrastructure for Caltrans in California for more effective and data driven planning, construction, maintenance, and operations. The following overall research questions were considered in this study:

- What are the state of the art and best practices in inventory and assessing of roadside features?
- What are the typical or generic costs associated with inventory of roadside assets?
- How can GPS be integrated into data gathering and Geo-Referencing in roadside asset management in Caltrans operations?
- What kind of databases and software tools can provide for an effective method for Caltrans to inventory and monitor conditions of roadside assets?
- Are there ways or methods that data gathering can be simplified or automated?

An important first step in this study was an identification of the type and nature of the roadside features that are part of the roadway assets in California. These are classified in 15 categories:

1. Lateral Roadway Support Features
2. Features Associated with Roadside Vegetation (e.g. Mowing Acreages, Tree Groupings, etc.)
3. Miscellaneous Roadside Items (e.g. Fences, Fire Hydrants etc.)
4. Features Associated with Drainage (e.g. Culverts, Ditches, Ponds, etc.)
5. Environmental Features (e.g. Wetlands, Fish Baffles, Regularity Outfalls, etc.)
6. Features Associated with Geological Aspects of Vegetation (e.g. fault lines)
7. Environmental Functional Groups (e.g. Landscape Area, Slopes and Slide Areas, etc.)

8. Safety (e.g. Guardrails, Impact Attenuators, Bridge Rails, etc.)
9. Utilities (e.g. Poles, Franchise Permits, Emergency Generators, etc.)
10. Electrical/ITS (e.g. Luminaries, Junction Boxes, License Plate Readers, etc.)
11. Roadside Facilities (e.g. Rest Areas, Border Stations, Toll Booths, etc.)
12. Roadway Features Affecting Roadsides (e.g. Trails, Sidewalks, Mile Post Paddles, etc.)
13. Signs
14. Structures (e.g. Bridges, Retaining/Noise Walls, Sidewalk Ramps, etc.)
15. Durable Markings/Stripping

The above features are enumerated in Table 1. It should be pointed out that some items are listed in more than one category. This redundancy may not be necessary but has been included here to be consistent with the manner in which features in California Highways are classified. Other items can also be added to the list specified in this table based on the special needs of different geographical areas or as new items are added into the highway infrastructure due to integration of ITS (Intelligent Transportation Systems) and other modern technologies.

Many Department of Transportation (DOT) agencies may have the need to perform road inventory, pavement inspection, and roadside features inventory on a regular basis. Present methods used for inventory of the roadside features seem to be too costly and require a large labor pool. In fact, it seems that there are no formal studies on cost benefit analysis of such a roadside monitoring system or all the cost savings from monitoring the conditions of different roadside features. There is clearly the need for at least a baseline evaluation of costs associated with such activities.

There is also a need for more research in the development of semi or fully automated methods or use of remote methods for inventory of all roadside features capturing the conditions of such features in an efficient and cost effective manner. Furthermore, any methods of data collection should allow for proper Geo-referencing for data driven planning and operation. In addition, very little data is collected in terms of monitoring the condition of the roadside features and only their existence is inventoried. In fact, in cases where data is collected on roadside features, such data is stored in different data bases or other media with minimal cross referencing and is not integrated with GIS or other software tools that would allow more effective management of such assets in planning, operation, and maintenance.

There is therefore a need for development of several technologies including a suite of methods for data collection with Geo-referencing based on manual, semi or fully automated, and remote methods. There is also a need for software systems and/or IT (Information Technology) solutions that can integrate such databases and possibly connecting them to GIS or other visualization tools to provide for a better management of the assets.

Caltrans Inventory/Asset Objects Manual	**7. Environmental Functional Role Groups**	**11. Facilities**
	Mitigation Sites	Right of Way
1. Lateral Supports	Fish Passage Facilities	Holding & Parking Areas/Park & Rides
	Fish Barrier Facilities	Restrooms (Ferries)
2. Roadside Vegetation	Stream Crossings	Toll Booths
Landscape Area	Storm Water Facilities	Safety Rest Areas
Slopes and Slide Areas (Clear Zone)	Wildlife Passage Facilities	Weigh Stations
Tree Groupings (Clear Zone)	**8. Safety**	Terminal Buildings (Ferries)
Tree (Individual) (4 in dia.+) (Clear Zone)	Guardrails	Flyer Stop
Rock Outcropping (Clear Zone)	Bridge Rails	Border Station
3. Miscellanous	Impact Attenuators	**12. Roadway**
Fences	Jersey Barriers (Concrete) (Clear Zone)	Intersections
Monuments (Survey)	Glare Screen (Clear Zone)	Road Approaches (legal)
Fire Hydrants (Clear Zone)		Driveways Crossing
Mailboxes (non-compliant) (Clear Zone)	**9. Utilities**	Rumble Strips (Clear Zone)
ADA Features (deficiencies)	Underground Utilities (DOT)	Bike Paths (Lanes?)
Misc. Fixed Objects	Utility Poles (Clear Zone)	Trails
4. Drainage	Franchise Permits	Sidewalks
Cross Culverts	Emergency Generators	Pavement
Culvert Ends (Clear Zone)	**10. Electrical/ITS**	Milepost Paddles (Clear Zone)
Catch basins	Luminaires (Illumination) (Clear Zone)	**13. Signs**
Approach Culverts	Junction Boxes (Clear Zone)	Signs
Ponds (Detention, Retention)	ITS Cabinet	Sign Support (Clear Zone)
Detention Vaults	Over height Detector	**14. Structures**
Dikes	CCTV	Noise Walls/Retaining Walls/Barriers
Ditches	Snapshot Cameras	Bridges
Oil/water Separators	Data Stations (Clear Zone)	Railroad Crossing
5. Environmental	Highway Advisory Radio Signs	Tunnels
Wetlands	Highway Advisory Radio Towers (Transmitters)	Sidewalk Ramps
Riparian Zones	Hubs	Dolphins
Fish Ladders	Signals (Clear Zone)	Wing walls
Fish Baffles	Ramp Meter Cabinets	Towers
Regulatory Outfalls	Variable Message Signs	Bridge Seat
Eelgrass	Variable Message Signs (Portable)	Transfer Span
Pipes (Pipe Ends - Clear Zone)	Changeable Message Sign	Apron
Water (depth 2 ft +) (Clear Zone)	Emergency Phone	Trestle
6. Vegetation/Geological	Under Bridge Deck Lighting	Bulkhead/Seawall
Landscape Area	Bridge Electrical Control	Overhead Loading
Slopes and Slide Areas (Clear Zone)	Sign Lighters	**15. Durable Marking/Stripping**
Tree Groupings (Clear Zone)	Navigation/Obstruction Lighting	Drainage Marking
Tree (Individual) (4 in dia.+) (Clear Zone)	Signs (Neon, Back Lit, Fiber)	Pavement Markings
Rock Outcropping (Clear Zone)	License Plate Reader	Durable Pavement Markers
	Temperature Signs	
	Crosswalk Flashers	
	Flashing Beacon	

Table 1: A List of Classes and Nature of Roadside Features for California Highways

These issues were considered in the present study. The next section deals with understanding the state of the art in the area of Inventory of Roadside Assets and identifying some of the best practices, section three deals with a baseline cost analysis that can be viewed as a first step that can be built upon for cost benefit analysis. Section four deals with methods for data collection that is Geo-referenced. Section five deals with the description of the software system "GVIZ" developed under this project that provides an IT solution with visualization capabilities for integration of collected data and the associated databases. Section six deals with a feasibility study of using remote methods based on integration of image processing algorithms for inventory of roadside feature data associated with vegetation.

2. STATE OF THE ART AND EXAMPLES OF BEST PRACTICES

Developing an understanding of the state of the art in the field was considered to be one of the first steps in this research study. The literature search was performed and assessment was made of available technologies.

2.1 Roadside Inventory Questionnaire

In order to identify the roadside features that are being inventoried and the methods used for inventory and condition monitoring within Caltrans and elsewhere nationwide a "Roadside Inventory Questionnaire" was prepared and was sent to State DOTs nationwide and some cities and counties. The questionnaire consisted of four different groups of questions. The first group of questions was modeled using the categories discussed in Table 1 and was intended for identification of the features being inventories and the method used for such a purpose. The second group of questions was intended to obtain data on costs associated with inventory data collection and repository. Finally, the third group of questions deals with identification of best practices, available technologies, and experienced people in the field. The questionnaire is shown in **Error! Reference source not found.**.

ROADSIDE INVENTORY QUESTIONNAIRE
1. Do you know of any successful program that collect and assess data for roadside inventory? If yes, please indicate the name of the program.
2. Do you have a cost estimate on a weekly or monthly or yearly basis for maintaining roadside inventory data in your organization?
3. What is the most desirable method for inventorying the roadside features?
4. Please supply the name, address, email and phone numbers of the contact persons involved in roadside inventory projects?
5. Please supply the name and contact information of any commercial vendor/system used for data collection of roadside inventory objects?

6. Do you have a cost estimate of per mile charges for data collection of roadside inventory objects?
7. Please supply the name of the commercial software that you use as the roadside inventory database?
8. Please enlist any project or program that failed to accomplish pre-determined tasks, as related to roadside inventory? Any possible causes?

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure
	GPS	Video Log	Photo Log	Field Inventory	Other	
Drainage						
Cross Culverts						
Culvert Ends (Clear Zone)						
Catch Basins						
Approach Culverts						
Ponds (Detention, Retention)*						
Detention Vaults*						
Dikes						
Ditches						
Oil/Water Separators						
Environmental						
Wetlands						
Riparian Zones						
Regulatory Outfalls						
Pipes (Pipe Ends - Clear Zone)*						
Mitigation Sites						
Fish Passage Facilities (e.g. Ladders)						
Fish Barrier Facilities (e.g. Baffles)						
Stream Crossings						
Wildlife Passage Facilities						

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure
	GPS	Video Log	Photo Log	Field Inventory	Other	
Environmental						

Storm Water Facilities						
Pipes*						
Ditches*						
Swales						
Filters						
Underground Tanks						
Vaults*						
Ponds						
Vegetation						
Landscape Area						
Shrubs						
Ground covers						
Irrigation facility						
Slopes and Slide Areas (Clear Zone)						
Tree Groupings (Clear Zone)						
Mulched Areas						
Rock Outcropping (Clear Zone)						
Safety						
Guardrails						
Bridge Rails						
Impact Attenuators						
Jersey Barriers (Concrete) (Clear Zone)						
Glare Screen (Clear Zone)						
Utilities						
Underground Utilities (DOT)						
Utility Poles (Clear Zone)						

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	**Method of Inventory**					**Unit of Measure**
	GPS	**Video Log**	**Photo Log**	**Field Inventory**	**Other**	
Utilities						
Franchise Permit Facilities						
Emergency Generators						
Electrical/ITS						
Luminaires (Illumination) (Clear Zone)						
Junction Boxes (Clear Zone)						
ITS Cabinet						
Over-Height Detector						
CCTV						
Data Stations (Clear Zone)						
Highway Advisory Radio Towers (Transmitters)						
Hubs						
Signals (Clear Zone)						
Ramp Meter Cabinets						

Variable/Changeable Message Signs (Portable)*						
Variable/Changeable Message Signs (Permanent)*						
Emergency Phone						
Under Bridge Deck Lighting						
Bridge Electrical Control						
Sign Lighters						
Navigation/Obstruction Lighting						
Signs (Neon, Back Lit, Fiber)						
License Plate Reader						
Temperature Signs						
Crosswalk Flashers						
Flashing Beacon						
Weather Stations (RWIS)						
Queue Detection						
Gate Controller						

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	**Method of Inventory**					**Unit of Measure**
	GPS	**Video Log**	**Photo Log**	**Field Inventory**	**Other**	
Electrical/ITS						
Gate						
Facilities						
Holding & Parking Areas/Park & Rides						
Maintenance Yards						
Landscape						
Pavement						
Trees						
Toll Booths						
Safety Rest Areas						
Weigh Stations						
Terminal Buildings (e.g. Ferries)						
Border Station						
Roadway						
Sidewalks*						
Road Approaches						
Driveway Crossings						
Rumble Strips (Clear Zone)						
Milepost Paddles/Signs (Clear Zone)						
Signs						
Signs*						
Sign Support (Clear Zone)						
Structures						
Noise/Sound Walls						
Retaining Walls						

Bridges						
Railroad Crossings						
Tunnels						
Sidewalk Ramps*						

Note: - '*'   Object appears in multiple categories

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	**Method of Inventory**					**Unit of Measure**
	GPS	**Video Log**	**Photo Log**	**Field Inventory**	**Other**	
Structures						
Dolphins						
Wing walls						
Towers						
Bridge Seat						
Transfer Span						
Apron						
Trestle						
Bulkhead/Seawall						
Overhead Loading						
Durable Marking/Striping						
Drainage Marking						
Pavement Markings						
Durable Pavement Markers						
Monuments (Survey)						
Fire Hydrants (Clear Zone)						
Fence (Clear Zone)						

Table 2: Roadside Inventory Questionnaire

The survey questionnaire in table 2 has provided much of the data needed to produce the results provided in this and the next section of this report. The rest of the data that provides the basis of this and the next section came from literature search and review of existing technologies.

2.2 Results of the Literature Search

The result of the literature survey identified some technologies that have evolved over the years and in one form or another can impact the process of data collection and inventory of roadside features. These are described in the remaining of this sub-section.

Roadside Feature Inventory Methods: Currently, several methods are used to collect inventory data. These methods vary in technique, equipment utilized, time requirements, as well as other details. Most agencies utilize manual or video-log/ photo-log methods as shown in Figure 1 [16].

States	Methods For Collecting Roadside Inventory					
	Yes/ No	GPS	**Video Log**	Photo Log	Field Inventory	Other
Alabama	Yes	√	√			
Alaska	Yes				√	
Arizona	Yes			√		
Colorado	Yes				√	
Connecticut	Yes				√	
Delaware	Yes			√		
Florida	No					
Georgia	Yes			√		
Hawaii	Yes			√	√	Straight Line Diagram
Idaho	Yes		√			
Illinois	No					
Indiana	Yes		√			Reference Post System
Kentucky	Yes				√	
Louisiana	Yes				√	
Maryland	Yes		√			
Massachusetts	Yes				√	
Michigan	Yes			√		
Minnesota	No					
Mississippi	No					
Nebraska	Yes		√			
New Hampshire	Yes	√				
New Jersey	Yes		√			
New York	Yes				√	
North Dakota	Yes				√	RIMS
Ohio	No					
Oklahoma	Yes		√		√	
Oregon	Yes				√	
Pennsylvania	Yes		√		√	
South Carolina	No					
South Dakota	Yes	√				
Texas	No					
Utah	Yes	√				
Washington	Yes	√				Linear Referencing System
West Virginia	No					
Wisconsin	No					

Figure 1: Methods Used for Collecting Roadside Inventory

Manual* Data *Collection: Manual data collection methods generally require one or more personnel go out into the field with measuring and recording devices to obtain the desired pieces of information. Measurement devices include distance measuring wheels for length and width data, and global positioning systems (GPS) receivers to obtain positional information. Data is recorded with a pencil and paper or a laptop computer [16].

The following is a list of the advantages and disadvantages of manual data collection:

Advantages

- Minimal training requirements for personnel
- Firsthand visual inspection
- Minimal equipment requirements

Disadvantages

- Data collection personnel exposed to dangerous roadway environment
- Time consuming
- Labor Intensive
- Data collection distracting to motorists

Video-log/Photo-log: Photo and video-logging methods utilize a vehicle, often a van, which drives along the roadway while recording devices gather data and produce a visual record which can be examined at a later date. The primary difference between the two methods is their recording mediums, video and pictures. In terms of labor, photo and video logging are a lot less labor intensive than manual collection methods. Generally, only one or two personnel are required to perform the data collection. Personnel are no longer directly exposed to traffic, as they ride inside the vehicle with the recording instruments. The vehicle serves as protection from the hazards of the roadway environment. Since the collection vehicle often travels at highway speeds, it is also less intrusive to motorists [16].

Soft* Photogrammetry*: The video-logging system basically provides the digital image and the X, Y, Z coordinates of the camera locations, using this information and soft photogrammetry it is possible to determine the location of any feature .Because digital camera used in video logging is a non-metric camera, therefore it must be calibrated frequently (See Figure 2 and Figure 3) [7].

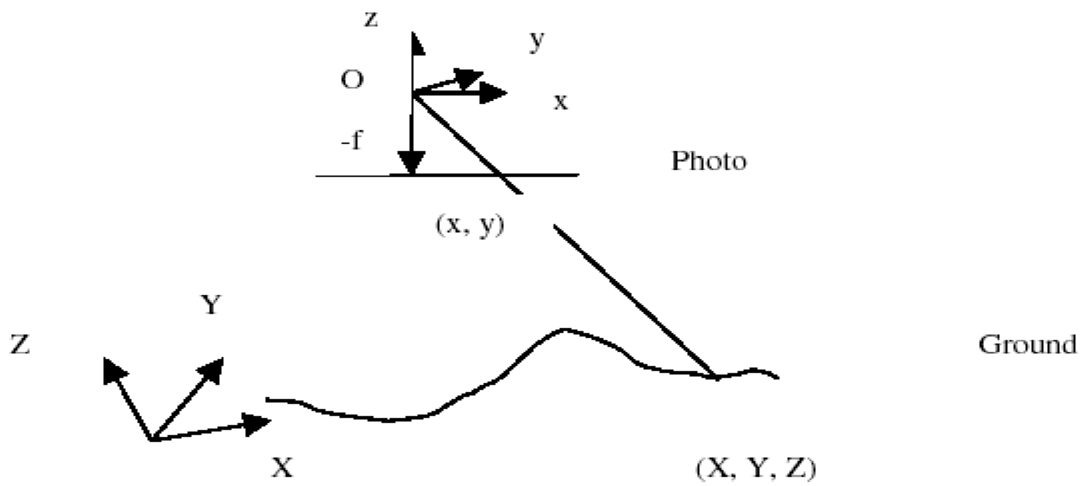


Figure 2: Collinearity

$$x - x_o + \delta_{xr} + \delta_{xd} = -f\,\frac{a_{11}(X - X_o) + a_{12}(Y - Y_o) + a_{13}(Z - Z_o)}{a_{31}(X - X_o) + a_{32}(Y - Y_o) + a_{33}(Z - Z_o)}$$

$$y - y_o + \delta_{yr} + \delta_{yd} = -f\,\frac{a_{21}(X - X_o) + a_{22}(Y - Y_o) + a_{23}(Z - Z_o)}{a_{31}(X - X_o) + a_{32}(Y - Y_o) + a_{33}(Z - Z_o)}$$

$$x_o, y_o, f = \text{interior orientation elements photo system}$$

$$X_o, Y_o, Z_o = \text{camera location in } X, Y, Z \text{ ground system}$$

$$a_{11} \ldots a_{33} = \text{parameters depending on rotation } \kappa, \phi, \omega$$

$$\delta_{xr}, \delta_{yr} = \text{radial distortion}$$

$$\delta_{xd}, \delta_{yd} = \text{decentering distortion}$$

Figure 3: Model Equation

The following is a list of the advantages and disadvantages of video-log/photo-log data collection:

Advantages

- Faster data collection
- Data collectors removed from direct contact with roadway environment
- Visual record of roadway features

Disadvantages

- Data collection vehicle may be obtrusive to motorists (at low speeds)
- Time consuming as segments must still be driven

Aerial Photography: Images taken from an aircraft provide a panoramic view not only of the road network as well as the location of structures and subsequently, land uses. Aerial photos have the advantage of displaying an entire area for analysis. However, the analysis and interpretation of images requires a great deal of skill. Additionally, good weather is required in order for a flight to take place and produce the required imagery. This limits the available window in which work can be completed. Some elements, such as signs, may not be visible at all. Image processing takes time, and it can also be quite expensive [16].

Integration of GIS and GPS/INS: Integration of GPS with a GIS is mostly used among the transportation agencies for roadside inventory. GIS allows the association of data statistics of any kind with a specific geographic location and the display of the data on an interactive map and GPS determines a location for each data point [3].

Most of the systems are also equipped with Inertial Navigation System (INS), which substitutes for GPS location whenever GPS loses lock due to signal obstruction. Therefore, continuous position determination will be provided to the system [7]. Integration of INS with GPS, it can provide both the track of the vehicle and position and orientation information of the mapping sensors (see Figure 4) [9].

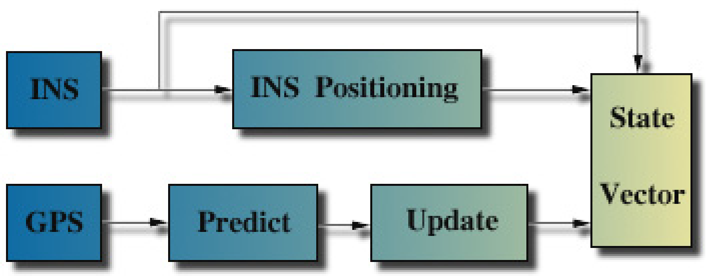


Figure 4: The GPS/INS Integration Procedure
(: http://www.lambdatech.com/gpstech html)

GPS [10]

- Image geo-positioning in 3D
- Time synchronization between GPS and INS
- Image time-tagging
- INS error control

INS [10]

- Image orientation in 3D
- Supports Image Geo-referencing

- Supports ambiguity resolution after losses of lock, and cycle slip detection and fixing

Direct Geo-referencing: The most important concept of mobile mapping is direct geo-referencing. The conceptual layout of direct geo-referencing is shown in Figure 5. Direct geo-referencing refers to the determination of the exterior orientation of the mapping sensor without using ground control points and the photogrammetric block triangulation. For example, if a camera sensor is used, any captured image can be "stamped" with the geo-referencing parameters, namely three positional parameters and three attitude (orientation) parameters. As a result, 3-D object measurements can be achieved directly by using a photogrammetric intersection [12].

There are three modes for direct geo-referencing, namely, stand-alone mode, integrated model and combined mode.

Stand alone mode has been used very often for video-logging applications where the accuracy requirement is not high [12].

It is the integrated use of external inertial positioning systems. Depending on the applications, different levels of integration and different ways of sensor combination can be developed, for example, GPS with INS, GPS with DR, etc [12].

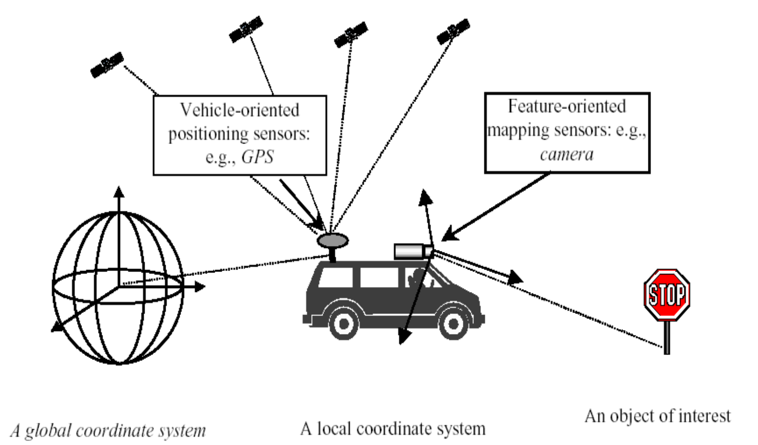


Figure 5: Concept of Direct Geo-referencing [12]

In the airborne photogrammetry, combined mode for geo-referencing is predominately used in practice due to its high performance, reliability and economic factors [12].

Positioning and Mapping Sensors: The development of mobile mapping systems is featured by the use of multiple sensors as well as integrated sensor processing methods (see Figure 6). In general, there are two primary types of sensors that are involved, namely, positioning sensors and mapping sensors [12].

Positioning sensors are:

a) Environment-dependent external positioning sensors: GPS, radio navigation system and cellular positioning devices, etc.

b) Self-contained inertial positioning sensors: INS or IMU (Inertial Measurement Unit), dead reckoning systems, gyroscopes, accelerators, compasses, odometers, and barometers, etc.

Mapping sensors are:

a) Passive imaging sensors: video or digital cameras, multi-spectrum or hyper-spectrum scanners, etc.

b) Active imaging sensors: Laser range finders or scanners, and synthetic aperture radar (SAR), etc.

Other sensors such as voice recording and speech recognition devices, touch-screens, temperature or air pressure meters, gravity gauges, etc. may be of use for integration. The positioning sensors are vehicle-oriented. They are used to determine the absolute locations of the mobile mapping platform with respect to a global coordinate system, e.g., WGS-84. While, the mapping sensors are feature-oriented. They provide the positional information of objects (features) relative to the vehicle in a local coordinate system. In addition, attributes of features can be obtained from the mapping sensors. Precise calibration is required to geometrically align the positioning sensors and mapping sensors together. Accurate synchronization (time referencing) of the sensors is also required [12].

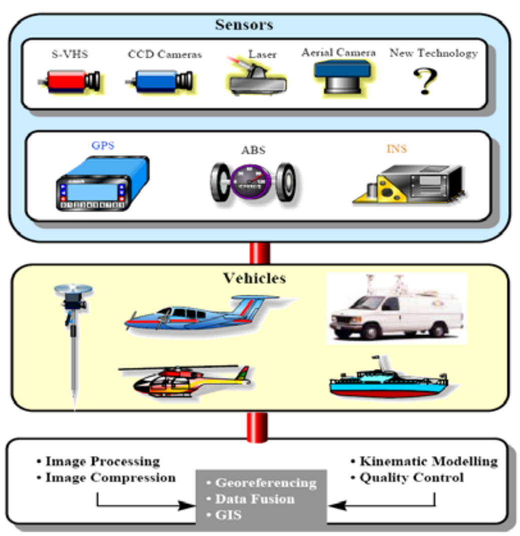


Figure 6: Multi-Sensor Integration for Mapping [14]

Mobile mapping systems are usually the data acquisition system used in digital mapping of highway features. These usually need to be integrated with some data base or software system that would keep track and would provide easy access to such information. The combination of the two systems is usually referred to as the "Automated Highway Inventory System (AHIS)". An AHIS system can therefore be considered as a combination of hardware and software system designed to collect inventory, condition, and location information for roadside features, and to store, access, and use this data for highway planning, managing, and maintenance. AHIS type technology can be an effective technology for sign inventory and are suitable for the extraction of many other types of roadway features and characteristics. It has also been applied in many fields, such as intelligent transport, precision agriculture, field surveying and environment engineering and so on. There are however some limitations of the existing and available AHIS technology limiting its broad application in Inventory and Assessment of Roadside Features. These include excessive cost and periodic subscription requirements, lack of effective visualization capabilities, proprietary nature of the software components limiting the ability for connectivity to existing legacy systems being used by some DOT's, and lack of flexibility for end user enhancement or adaptation.

Roadside Feature* Recognition *and Identification: Feature recognition is a measure of whether a particular feature can be identified at all and whether it can be identified consistently. The use of remote sensing for the extraction of data elements required by the statewide linear referencing system (LRS) is being developed by the Iowa Department of Transportation (DOT). One of the key elements of the LRS is creation of a datum that will provide structure to the LRS. Several methods are being considered for creation of datum including video-logging and remote sensing [5]. Images at 2-inch, 6-inch, 24- inch, and 1 meter resolutions were tested for positional accuracy, the number of inventory features that could consistently be identified, distance measurements, and variation among users in correctly positioning feature location.

A total of 21 features were tested in the 4 datasets (roadway feature inventory). The results are:

- 2-inch: 100% identified consistently
- 6-inch: > 80% identified consistently
- 24-inch: < 50% consistently identified, 6 features not identified at all
- 1 meter: < 25% consistently identified, 8 features not identified at all

where (%) = (Fg/Fa) * 100 and
Fa = number of features identified in photos
Fg = number features identified on the ground during field data collection.

Although the use of lower resolution images would be more cost-effective, they are limited by the ability to actually see and identify inventory features. A significant number of features could either not be identified or could not be regularly identified in the 1-meter (Figure 1) and 24-meter datasets. Because the ability to consistently identify features decreases with resolution, images with at least 6- inch resolution would be necessary for most inventorying purposes. For collection of data elements for the LRS datum 2-inch or 6-inch would be feasible if datum accuracy standards are relaxed slightly [5].

Figure 7: Meter resolution (Beijing, China)
(Source: http://www landinfo.com/GalSatIkonosBejing1 htm)

2.3 Commercially Available Mobile Mapping Systems

Currently, many commercial Mobile Mapping Systems (MMS) are available at the market place like TRANSMAP systems from Transmap Inc, GPSVision MMS by Lambda Tech International Inc., and VISAT MMS by the Sanborn Map Company, Inc. These are summarized in Table 3 with their hardware structures [10].

MM System	Development Institution	Navigation Sensors	Mapping Sensors
GPSVan™	Center for Mapping, OSU	GPS/Gyro/Wheel Counter GPS/INS (second generation of the system)	2CCD, voice recorder
VISAT	University of Calgary	GPS/INS/ABS	8 b/w CCD and 1 color SVHS
GeoVan	Geospan Corp., USA	GPS/DR	10 VHS, voice recorder
GPS Vision	Lambda Tech. Inc., USA	GPS/INS	2 color CCD
KISS	Univ. of Bundeswher Munich and GeoDigital, Germany	GPS/IMU/Inclination Odometer/Barometer	1 SVHS, 2 b/w CCD, voice recorder
ON-SIGHT	Transmap Corp., USA	GPS/INS	4 color CCD
RGIAS	Rowe Surveying and Eng., Inc., USA	GPS	video, laser range finder
TruckMap	John E. Chance Inc., USA	GPS/Gyro/WADGPS	Laser range finder, 1 video camera
WUMMS	Wuhan University, China	GPS	3 video cameras, laser range finder
ROMDAS	Highway and Traffic Consultants Ltd., New Zealand	GPS	digital video camera
DDTI	Digital Data Technologies, Inc., USA	GPS	touch-screen, voice recorder
POS/LV™ 420	Applanix Corporation, Canada	GPS/INS/ distance measuring instrument (DMI)/ GPS Azimuth Measurement Subsystem (GAMS)	CCD, video

Table 3: List of Some of the Existing Mobile Mapping Systems and Their Hardware Structure [10]

In addition to the systems listed in the table above, there are other systems developed for some specific application. For example, "Surveyor" (Figure 8) is a mobile right of way inventory/measurement system that can visually capture and accurately locate roadside features, while moving at highway speeds (1). It consists of a two part system: A fully automated mobile data collection vehicle, and a post processing workstation, where an operator scrolls through the video images, selects objects of interest with the click of a mouse, and classifies them [4].

Figure 8: Surveyor Mobile Vehicle and Work-station

Surveyor mobile data collection system is the continuous video imaging that takes place while the vehicle is moving at normal traffic speeds. The hardware for the mobile data collection system is an integrated system of video, hardware sensors and two data acquisition computers (Figure 9) [4].

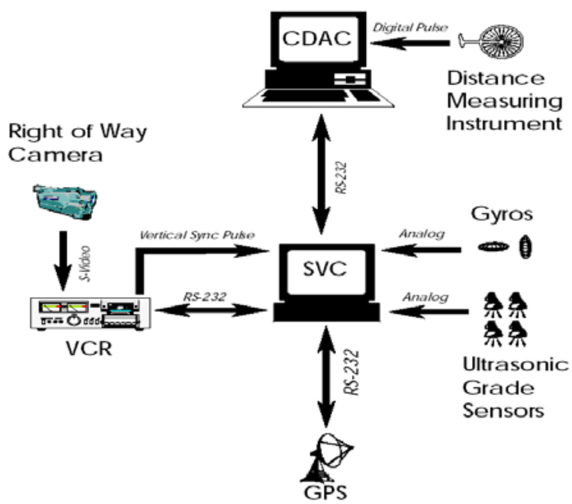


Figure 9: Hardware for the Surveyor Mobile

There are also custom utility vehicles that are equipped with photo loggers, sensors, and GPS/INS for geo-referencing and positioning. Some of these are described in the remainder of this sub-section.

VISAT *System:* VISAT System, a mobile highway survey system for road inventory and general GIS applications, is developed to test precise multi-sensor mobile mapping system. VISAT system consists of differential GPS, a strap-down INS, an ABS pick-up, and eight CCD cameras. Application of VISAT is as shown in Figure 10 [14].

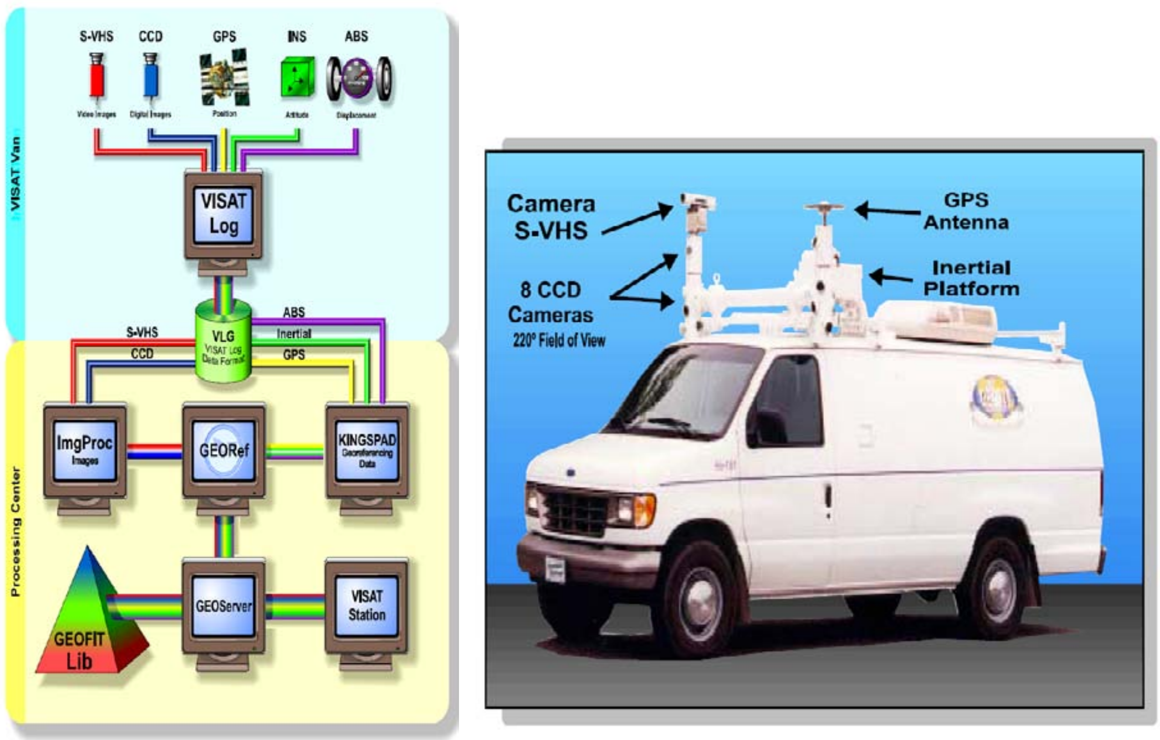


Figure 10: The Visat System and vehicle [14]

GeoVan: GeoSpan's Geovan (Data Collection Vehicles) have the capabilities with accurate GPS three-dimensional positioning, compensation for loss of satellite lock, video image recording, rapid entry of attribute information and integration with a GPS database. All this technology ensures the accuracy and completeness of the data collected [17].

Lambda (GPSVision) Technology: GPSVision utilizes Navstar GPS integrated with an INS (Figure 11) and two state-of-the-art progressive scan CCD (charge coupled device) cameras. The result is that any object that is "seen" by the sets of cameras can be precisely located using a stand-alone global coordinate system in conjunction with Lambda Tech's advanced soft-photogrammetric mathematical model [9].

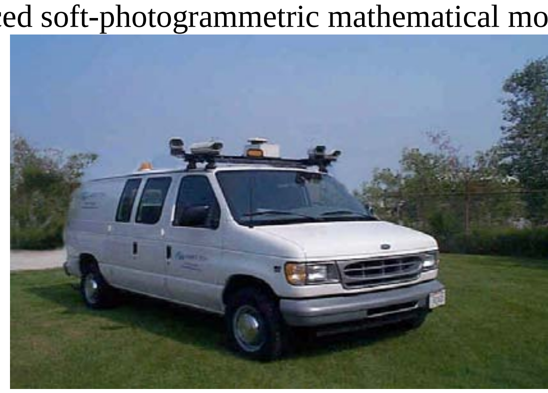


Figure 11: GPSVision Van

Roadware *(ARAN) Systems:* The Automatic Road Analyzer -system consists of a van equipped (Figure 12) with various measuring and data logging systems, and an office based unit for processing collected data and video frames.

ARAN appears to be an excellent data collecting tool, which identifies and quantifies various pavement characteristics at speeds of 40 to 90 km/h. After processing the data can directly be used as input for Pavement Management Systems [18].

Figure 12: ARAN Vehicle
(Source: http://www.koac-npc.nl/webbits/site/UK/Page.asp?PageID=4134)

Mandli* Systems*: Mandli uses "Digilog VX" which is a versatile integrated system for the collection of road data. Customized systems are built to collect high-resolution digital right-of-way images, real-time differential GPS, curve and grade, sign inventory and measurement, and sign reflectivity data[19].

Data is collected from a vehicle traveling at posted speeds by an operator in the passenger seat. Hardware components are installed on the vehicle and a master CPU controls the various functions delivered by the subsystems, as shown in Figure 13.

Figure 13: Video Workstation 2-Camera System (Mandli Video)
(Source: http://www.dynatest.com/gallery/rspgall/pages/07Inside6%20copy.htm)

2.4 Examples of the Best Practices

The result of the survey questionnaire, literature search, and contacts with some of the people involved in the field was used to identify examples of the best practices. The intention here is not to provide a complete list of the best practices but only examples of some. It is clear that there are probably some practices that can fit this category but were missed or not included for the sake of brevity. These examples include programs from:

- Washington DOT
- Iowa DOT and Nebraska Department of Roads
- Texas DOT
- Ohio DOT
- North Carolina DOT
- Michigan DOT
- Arizona DOT
- Idaho Transportation Department
- Minnesota DOT
- Hanshin Expressway Public Corporation (HEPC), Osaka, Japan
- New Zealand Transit – MWH Global Ltd., Auckland, NZ
- City of Hamilton, Ontario, Canada
- City of Redding, California
- Sacramento County, California
- Orange County, California

A more detailed description of the road feature inventory programs for each of the above organizations together with some snapshots of their activities is provided in Appendix A.

3. COST AND VALUATION ANALYSIS

In the United States, valuation of inventory for the road system is typically based on lane miles. Due to federal reporting requirements, DOT's maintain detailed records on the roads and bridges in their Highway Traffic Records Inventory System (HTRIS) [21].

3.1 Road Inventory Current Value Calculations

Average cost estimates for various roads can be calculated based on the baseline data available for the year 2000 [21] using the Consumer Price Index. This data for different categories of roadways are given in the following three tables. The detailed method of the calculation of the cost is provided after these tables.

Road Inventory – System

System	Average Cost to Construct One Lane Mile
Interstate	$ 1,874,055
Primary	$ 768,627
Secondary	$ 237,208
Urban	$ 779,775

Table 4: Cost Data from the Road Inventory-System

Road Inventory - Bridges, Culverts, and Tunnels

Type	Average Cost to Construct One Square Foot
Bridges	$ 75
Culverts	$ 100
Tunnels	$ 20

Table 5: Road Inventory- Bridges, Culverts, and Tunnels

Road Inventory - Right of Way

System	Average Cost per Acre	Right of Way Weighted Average Width in Feet per Mile of Road
Interstate	$ 13,608	265
Primary	$ 13,608	90
Secondary	$ 13,608	50
		90
Urban	$ 13,608	

Table 6: Road Inventory- Right of Way

Road Inventory - Interstate, Primary, Secondary, and Urban*

A. Determine lane miles by system, by year
B. Determine lane miles by system, by year related to bridges and tunnels
C. Determine current costs (FY00) to construct a lane mile of road by system
D. Determine a inflation/deflation factor by year, utilizing the Consumer Price Index

VALUE = ((A-B)*C)*D

Road Inventory - Bridges, Culverts, and Tunnels
Bridges

A. Identify bridges, <u>by year</u>
B. Calculate the area (by square feet) or each bridge (length times width)
C. Determine the current cost (FY00) to construct one square foot of a bridge
D. Determine a deflation factor <u>by year</u>, utilizing the Consumer Price Index

Value = (B*C)*D

Culverts

A. Identify culverts, <u>by year</u>
B. Calculate the area (by square feet) of each culvert (length * width)
C. Determine the current cost (FY00) to construct one square foot of culvert
D. Determine a deflation factor <u>by year</u>, utilizing the Consumer Price Index

VALUE = (B*C)*D

Tunnels

A. Identify Tunnels
B. Identify historical costs to build tunnels

Road Inventory - Right of Way

A. Determine miles, <u>by system</u>, <u>by year</u>
B. Determine average current cost (FY00) to purchase one acre of land
C. Determine acres per mile of road, by system as follows
    - Determine average right of way width and road width <u>by system</u>
    - Multiply the total average right of way width * the length of a mile (5,280 ft)
    - Divide the total square feet per mile by the number of square feet in an acre (43,560)
D. Determine a deflation factor <u>by year</u>, utilizing the Consumer Price Index

VALUE = ((A*B)*C)*D

3.2 Road Inventory – Depreciation

In order to depreciate the current value of a road system, one has to estimate the life through which a road system can be depreciated. In most applications, the useful life of a road is estimated to be 30 years whereas 50 years is usually used for bridges and structures (see Table 7). The typical depreciation method used by DOT's is simple straight line depreciation. Roadway assets are typically depreciated as though they are held the entire year. Data in Table 8 below is an example of how one of the DOTs June 30, 2000 road inventory assets were depreciated using this method.

Type	Depreciation Life [Year]	Depreciation Rate (Factor X)
Roads	30	0.0333
Structures	50	0.020
Bridges	50	0.020

Table 7: Life and Depreciation Factors for Roads

Column A Year	Column B Road Value	Column C One Year's Depreciation (Column B*Factor X)	Column D Years of Accumulated Depreciation	Column E Accumulated Depreciation (Column C*Column D)
1970	$181,538,570	$6,051,286	30	$181,538,570
1971	119,686,188	3,989,540	30	119,686,188
1972	109,210,085	3,640,336	29	105,569,749
1973	43,637,279	1,454,576	28	40,728,127
1996	67,530,148	2,251,005	5	11,255,025
1997	145,352,852	4,845,095	4	19,380,380
1998	141,892,196	4,729,740	3	14,189,220
1999	167,833,089	5,594,436	2	11,188,873
2000	352,988,389	11,766,280	1	11,766,280

Table 8: Straight Line Depreciation Method

3.3 Data Collection Time and Cost

The time and cost of inventory of roadside and roadway features have been performed in the literature [23]. Data collection times were calculated based on mean time for 100 elements inventoried for three types of roadway environments: two lane rural, rural interstate and urban areas and comparison was made between manual data collection and data collection using MMS (Mobile Mapping Systems). The data is summarized in Table 9 below. Data collection times are based on mean time for 100 inventory elements and include equipment set up and travel times. Processing times include data reduction times for 100 inventoried elements as data input, data base creation and interfacing with GIS systems. The total cost calculated also included the one time equipment purchase and installation costs. Server support costs however were not included.

Item	Manual method			MMS1-4		
	Two-lane rural	Rural interstate	Urban	Two-lane rural	Rural interstate	Urban
Mean collection time for 100 inventory elements in the field, including equipment setup and driving the roadway (person-minutes)	38	40	36	7	9	9
				8	7	10
				8	8	9
				6	7	8
Mean in-office processing time for 100 inventory elements (person-minutes)	—	—	—	5*	5*	5*
Mean inventory data extraction time for 100 inventory elements, inputting to computer, and creation of inventory database including transfer to GIS (person-minutes)	45	45	45	76	80	78
				82	77	80
				72	76	77
				84	82	75
Sum of mean collection, processing, and extraction times	83	85	81	87	92	92
One-time purchase of equipment (hardware, software, and peripherals, in dollars		30,000†			250,000 and above‡	

— = Not applicable
* = Approximately the same time for all four methods using vehicle systems
† = Manual method cost includes purchase of vehicle and a computer workstation
‡ = The cost of the methods employing vehicle systems depend on the number and type of sensors installed onboard and varies significantly

Table 9: Summary of Time and Cost of Data Collection by Different Methods

(http://www.bts.gov/publications/journal_of_transportation_and_statistics/volume_03_number_03/paper_02/table_03.html)

4. MANUAL GPS BASED DATA COLLECTION METHODLOGY FOR CALTRANS

This section describes the data collection methodology developed for manual data collection using GPS equipment which is recommended for CALTRANS use. This methodology is developed in collaboration with Caltrans and has been incorporated into the workflow for Caltrans for data collection associated with Assessment and Inventory of Culverts. The developments and workflow integration and deployment within Caltrans of the methodology described in this section has been one of the key results of this study. Experiments and research on methods for remote data collection are given in the next section.

4.1 Recommended Technologies and Equipment for Manual Roadside Inventory

The Recommended Equipment List for Roadside Feature Inventory Program manual data collection and data processing is given in the Table 10 table below:

Functional Characterization of Transportation Inventory Tasks	Recommended Technology	Recommended Equipment
Trip Planning	GIS, Digital Maps, Route Planning and Inertial Navigation System (INS)	County maps, Straight Line Diagrams, Manual Compass
Crew Protection and Safety	Passive/Active	Cones, Signs, Beacons, Balsi Beam, First Aid Kit
Sensing, Imaging and Measurement	GPS	Photo/Video Logger, Laser Rangefinder, GPS Zephyr Antenna, GPS Receiver and Data-logger combination – Trimble GeoXH
Data Analysis and Interpretation	GIS/Post-Processing Software	Pathfinder Office, Terrasync, ActiveSync
Database Inventory and Visualization	Semantic Data model, Relational Database	Semantic Data model on Google Earth or commercial GIS Platform, Hansen
Decision Support & Management Integration	Workflow management software	Workflow Operation Specific Interface

		Definition (OSID), Business Process Execution/Modeling Language (BPEL/BPML)
Miscellaneous		Communication tools e.g. cell phones, Digital camera with memory card, Carbon fiber range pole, hand tools, laptop etc.

Table 10: Recommended Equipment and Functional Classification of Inventory Tasks and Associated Technology

4.2 Generic Procedure for Manual Inventory Data Collection Using GPS

The generic procedure starting from the software installation, field survey, data collection and visualization in the database is outlined in a step-by-step format below:

1. Install Trimble Pathfinder Office software on all laptops and desktops
2. Install Microsoft ActiveSync software on all laptops and desktops
3. Install Trimble's TerraSync field collection software on the Geo-XH unit. This step entails placing the Geo-XH in the support cradle, connecting the USB cable to the laptop or desktop; then ActiveSync will launch from the laptop or desktop
4. Pre-installed software on the Geo-XH Handheld:

Software	Function
ActiveSync	Synchronize information between the handheld and a computer.
Calculator	Perform basic arithmetic functions.
Calendar	Keep track of appointments and arrange meetings.
Contacts	Keep track of your colleagues
File Explorer	View and manage files.
GPS	It allows you to configure the NMEA port (COM2) to be used with more than one application. GPS Connector Configure and view status information for the integrated GPS receiver.
GPS Controller	Configure communications between the handheld's integrated GPS receiver and external devices.
Internet Explorer	Browse the World Wide Web.
Notes	Create handwritten, typed, or recorded notes.
Pictures and Videos	Take, view, and edit pictures, as well as record and launch video clips.
PowerPoint	Mobile View slide show presentations.

Excel Mobile	Create and edit Excel spreadsheets.
Word Mobile	Create and edit Word documents.
Tasks	Keep track of your tasks.

5. *Preparatory Work*

The preparatory work involves the crew actually locating and marking these features in advance. All bridge seats, Culverts, GPS monuments and intersection points should be located and marked during this phase.

Bridge Seats (see Figure 14) are the transverse joints located at both ends of the bridge where the girders (or deck) tie into the abutment. In most cases, the first seam will be the beginning of the approach slab. The next seam (approximately 20 ft. from the beginning of the approach slab) will be the Bridge Seat (joint between the approach slab and the bridge deck).

Once located, the Bridge Seat is marked (with bright orange paint). This would make it easier to locate while collecting control run data on the fly. If the Crew Chief is unable to safely locate the Bridge Seats, it may be necessary to skip the bridge and not use it as control.

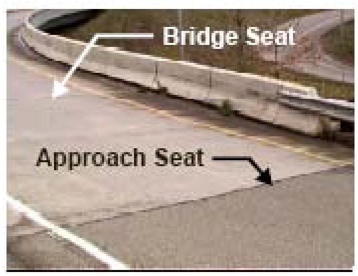


Figure 14: Bridge Seat Identification

6. *Mainline GPS Run*

At some point before and/or during the preparatory phase, the crew will establish a mainline GPS line feature that will be used to create a GIS theme. Coordinate values need to be collected on the fly, in both the increasing and decreasing milepost directions. In addition, a “quick mark” (a point manually inserted in a line feature) needs to be added at all major intersections. This will provide a way to tie the line feature to a physical point on the ground. The line feature will be run in the outside travel lane for the entire route. The vehicle will travel at approximately 30 MPH in order to collect coordinate values at 35 to 40 foot intervals. The GPS receiver must be placed in the “pause” mode at any stopping point along the way (e.g., signalized intersection) in order to eliminate the distances between the points being collected while in the stopped position. The vehicle should not deviate from the lane of travel and must not pull off to the side of the road unless the receiver is “paused” at a known point. Once the crew is ready to continue the survey, the receiver must “resume” collection of coordinate values from the point at which the survey was “paused”. Individual points (every 6 to 12 miles) will also be established wherever a previously established GPS monument is not within close proximity to the Edge of Pavement (EOP). These existing and newly established points, along with the line features, should be plotted using ArcView software. All other features should be plotted in relation to the Mainline GPS theme for validation purposes.

7. Satellite Availability

Prior to performing a survey, the crew should check for satellite availability. This can be done using quick plan in Pathfinder Office. Each time the data collection equipment is used; an almanac of the satellite information is gathered and stored in the data logger automatically.

The GPS Pathfinder Office software’s ‘Data Dictionary Editor’ utility creates custom lists of Asset features and attributes for data collection. This function will ensure that the data collected in the field will meet the program’s specific GIS needs.

The next step is to transfer to the TerraSync software on the data collector before field data collection starts.

To accurately log a 3D position at least four satellites with a well-spread geometrical configuration must be visible to the receiver. The Quick Plan utility in the GPS Pathfinder Office software uses an almanac file to give a view of satellite positions through the day and hence optimize the best time of the day to collect GPS data.

8. Field Data Collection

The use of the digital camera during the field data collection is a valuable tool that will accomplish a more through and complete mission of identifying features. A field calibration procedure is required for linking photos taken with the GPS collected for all features.

For Linear Features with event points the crew person will select the feature from the data dictionary, create the feature, fill in the appropriate attributes, and begin collecting the line feature using the basic mode of walking along the feature, or employing the “Vertex” option for linear feature collection. Using the linear feature ‘Guardrail’ as an example, guardrail has events (or attributes) that will be recorded as separate Point features.

Examples of events for the guardrail are:

A. GRPS- (guardrail post spacing) a- 6.3 b- 12.6
B. GRPM- (guardrail post material) a- wood b- metal c- composite
C. GRht- (guardrail height) this entry is a numeric value recorded in feet: a-2.0 (2 ft) b- (2.5) for 30 in. height

The recommended method of recording all the information for the 'Guardrail' and its events is to:

D. At the beginning of the guardrail, open the first event for the feature, collect it, and then close it.
E. Continue this procedure until all the event points are collected and stored for the beginning of the guardrail
F. Create the guardrail feature.
G. Begin to collect the feature by walking, or remain at the beginning of the guardrail and collect the 'VERTEX'.
H. When the crew encounters an event change along the guardrail, they will close the guardrail feature, then select the 'Event' point feature that has changed on the guardrail, open it and collect the point, then close the event point.
I. Re-open the guardrail feature and go to 'OPTIONS', hit the drop-down arrow, and click on the 'Continue' option, then you can choose the same linear feature and continue collecting the guardrail to the end if there are no more event changes along the feature, then close the guardrail.

The example above refers specifically to collecting the linear feature when collecting along the **Increasing** side of the state route and in the **Median** of a divided highway while collecting in the **Increasing (**post-mile) direction. The same procedure needs to be followed when collecting linear features traveling in the **Decreasing** direction along the state route.

For field collection of Linear Features that loop (or close) back to themselves, features that will include, but are not limited to, are a guardrail that mitigates another object, or a fence.

Example: Guardrail that forms a polygon

A. Collect all the event point features at the beginning of the guardrail.
B. Create the 'Guardrail' feature and begin collection.
C. Collect any event points that change along the guardrail
D. Finish GPS collection for the guardrail, except stop 10 Feet from the beginning of the guardrail, and then close the guardrail.
E. Collect all the event points again for the guardrail at the same position where the guardrail linear feature ended.

Additional field collection notes include:

F. Each feature in the data dictionary has a note field to utilize for recording additional information about the feature, when needed.
G. Crews also need to take pictures of features for additional data to assist in identification of odd or unusual features in the field to assist in feature identification and classification.

4.3 Example Process for Linear Asset Data Collection

Linear features form and important part of data for Culverts as well as some other road features such as certain aspects of roadside vegetation. A major emphasis of this study has been development and work flow integration of a data collection methodology for features associated with Culverts for Caltrans. This has been accomplished in terms of Manual GPS Data Collection, inventory, and visualization. The visualization part is discussed later in the sub-sequent sections. Error! Reference source not found., provides for a summary of the process chart for point and data collection on linear features.

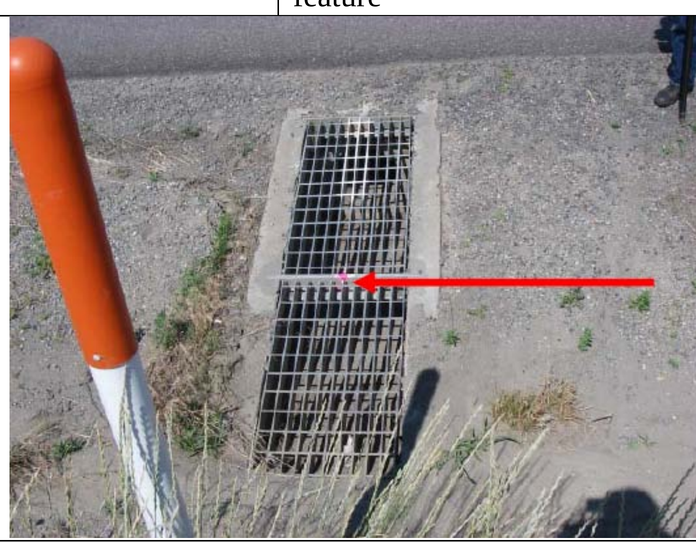
Feature Name: Culvert **Feature Type:** Linear	**Description:** A water conveyance under or alongside a traffic way with a clear opening 20 Feet that is designed to maintain flow from a natural channel or drainage ditch. Culverts are generally used to divert a stream or stormwater runoff to prevent erosion or flooding of highways	
Attribute	**Domains**	**Description**
GPS Location		Collect from the beginning to the end of the feature at the flow line.
Use	Water Crossing	The intended purpose for which the culvert was created
	Pedestrian Crossing	
Begin Shape	Round	The classification of the culvert based on the shape
	Box	
	Arch	
	Oval	
Begin Material Type	Concrete	The type of the material used to construct the Culvert
	Corrugated metal	
	Smooth metal	
	Polyethylene	
	PVC	
Begin End Type	Beveled	The type of the end treatment
	Headwall	
	Barred	
	Projecting	
	Other	
Primary water flow	N	The primary cardinal direction of the water flow through the culvert
	NE	
	E	
	S	
	SE	
	SW	
	W	
	NW	

	Unknown	
Orientation	Approach	The position of the culvert relative to the traveled way
	Cross	
Begin Diameter	User Defined	Inside diameter in inches
Begin Width	User Defined	Width of culvert opening in feet
Begin Height	User Defined	Height of culvert opening in feet

Attribute	Domains	Description
End Shape	Round	The classification of the culvert based on the shape
	Box	
	Arch	
	Oval	
End Material Type	Concrete	The type of the material used to construct the Culvert
	Corrugated metal	
	Smooth metal	
	Polyethylene	
	PVC	
End End Type	Beveled	The type of the end treatment
	Headwall	
	Barred	
	Projecting	
End Diameter	User Defined	Inside diameter in inches
End Width	User Defined	Width of culvert opening in feet an tenths of feet
End Height	User Defined	Height of culvert opening in feet and tenths of feet
Access Instructions	User Defined	Instructions on how to access the culvert
Note	User Defined	User defined text to further define the feature

Images	
	
	

Feature Name: Drainage Inlet	**Description:** A chamber for the admission of surface water to a subdrain having at it's base a sediment sump designed to retain debris below the point of overflow	
Feature Type: Point		
Attribute	**Domains**	**Description**
GPS Location		Collect in the center of the grate
Drainage inlet type	Catch Basin	
	Grate Inlet	
	Other	
Access Instructions	User Defined	Instructions on how to access the culvert
Note	User Defined	User defined text to further define the feature
Images		

Feature Name: Tree Group **Feature Type:** Point	**Description:** Any group of trees of various sizes greater than 4 inches in diameter. Trees are in a group when a automobile upon leaving the traveled way would run into multiple trees along it's path	
Attribute	**Domains**	**Description**
GPS Location		Collect GPS at the face of the tree closest to the edge of the roadway where the tree group feature starts and collect the end of the tree group
Note	User Defined	User defined text to further define the feature
Images		
		

Feature Name: Tree **Feature Type:** Point	**Description:** Any tree with a trunk thickness of 4 inches or greater occurring in the median area or in the maximum clear zone area adjacent to a State Route	
Attribute	**Domains**	**Description**
GPS Location		Collect GPS at the face of the tree closest to the edge of the roadway
Diameter		The distance along the tree through it's center
Note	User Defined	User defined text to further define the feature
Images		
		

Table 11: Example Process Charts for Point and Linear Asset Feature Collection.

5. TRANSPORTATION INFRASTRUCTURE ASSET VISUALIZATION SYSTEM - GVIZ

As part of this study a visualization tool was developed that would not have some of the short comings of other systems discussed in section 1 of this report. This tool referred to as "GVIZ" has been fully developed and integrated into Caltrans workflow for Culvert inspection and inventory but has also been developed in general form that can have a wide variety of applications in all kinds of transportation infrastructure asset management and visualization. The tool allows in-situ visualization of roadside (also roadway and transportation infrastructure) assets on Google Earth. The letter G in the name "GVIZ" is referring to Google Earth and the term "VIZ" as an acronym for visualization. As part of this study GVIZ has been fully integrated with GPS measurement and digital image and video capture for assessing the conditions of culverts in California. This section provides a brief introduction to the "GVIZ". The next several subsections provide a detailed description of GVIZ, the motivation used in its development and its different capabilities. A user guide for GVIZ is also developed and is discussed in Appendix B of this report. The user guide for the adaptation of GVIZ for culvert inventory and assessment is discussed in Appendix C. The development of GVIZ has been a major effort and one of the major contributions of this study.

5.1 System Description

The GVIZ visualization tool combines data from multiple sources and produces Keyhole Markup Language (KML) visualization files or "reports" that can be viewed in Google Earth. Google Maps also supports a limited subset of the KML standard. KML uses the eXtensible Markup Language (XML) schema, which has been standardized by the World Wide Web Consortium (W3C). The GVIZ application uses KML to represent three dimensional relationships between roadside inventory features that are presently stored in unrelated databases, spreadsheets and comma separated value (CSV) files. KML is a standard of the Open Geospatial Consortium (OGC).

5.2 Motivation for the Development of GVIZ

From early in the study it was clear that Caltrans engineers utilize multiple systems and file formats to store roadside inventory feature data. This includes databases such as Microsoft Access, spreadsheets, and CSV files. Files are stored on individual personal computers within districts and on networked systems that span districts. Files are typically shared using email and memory sticks. AHMCT saw a need for a software tool that could provide visualization relationships and display feature attributes between roadside inventory features stored in files with various file formats. Communication within Caltrans and between Caltrans and the public often involves exchanging information about spatial relationships between roadside features. For example, repairs to a failed culvert would involve maintenance crews and discussions about the existing culvert system, existing inlets, potential impacts on nearby lakes and streams, road closures, where to locate maintenance vehicles, etc. These all involve spatial relationships that can be clarified by a three dimensional visualization of existing and future roadside inventory assets. The validation of tabular data can realistically only be achieved through visualization. For example, a table of latitudes and longitudes in a spreadsheet are almost impossible to verify for accuracy. This same data transformed into a visual report with each point positioned in a three dimensional environment with aerial photos can be verified for accuracy within a short period of time.

5.3 The Goal in the Development of GVIZ

The goal was to provide a cost effective three dimensional visualization capability for existing and future Caltrans roadside inventory assets using data from existing sources and systems. Figure 15 shows a photographic image that Caltrans manually created using internal imagery and a bitmap editor program. In this image, lines represent culverts and various icons are used to indicate end treatment types. End treatments are numbered. The goal was to create an application that created similar visual reports, but for the entire Caltrans Culvert Database.

Figure 15: Desired Caltrans Culvert Visualization Capability (manually produced)

5.4 The Solution

Several approaches were considered. The first approach would have involved a centralized networked database that stored spatial roadside inventory information and provided integration capabilities. Access to the system would be through networked clients. There are many problems with this approach: expense, complexity, and rigidity to change. This approach would also require a Caltrans IT feasibility study.

After the 1st approach was rejected, a decentralized system design was considered. This approach would involve the design and implementation of an application (or applications) that have the ability to read and integrate data from multiple sources and provide visualization capabilities. This approach would require the ability to add new data formats, and visualization reports that 1) may are customized for specific Caltrans needs and 2) provide the user the ability to produce and tailor generalized visualization reports. The ability for users to generate and distribute visualization reports was also considered to be an important capability. This capability provides *data independence* from the original disparate sources. This is particularly crucial in systems that draw on network isolated data, such as spreadsheets stored on desktop computers.

The solution selected and developed during the course of the study uses the decentralized approach outlined above. The system architecture is shown in Figure 16.

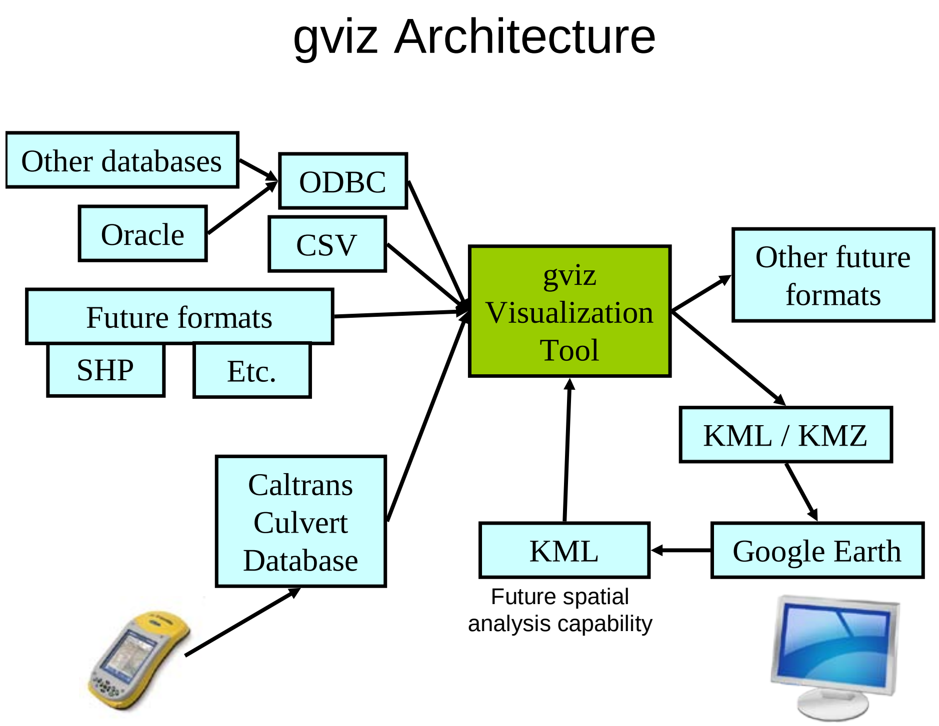


Figure 16: GVIZ Architecture

Google Earth was selected as a visualization client due to 1) the open nature of the KML standard, 2) the ability to visualize data through an application (Google Earth) and via the web (Google Maps), and 3) support of the KML standard by other vendors, such as ESRI. One of the advantages of this solution is the ability to layer data from many sources into a single visualization file. For example, Figure 17 shows culvert data layered with real-time Doppler radar.

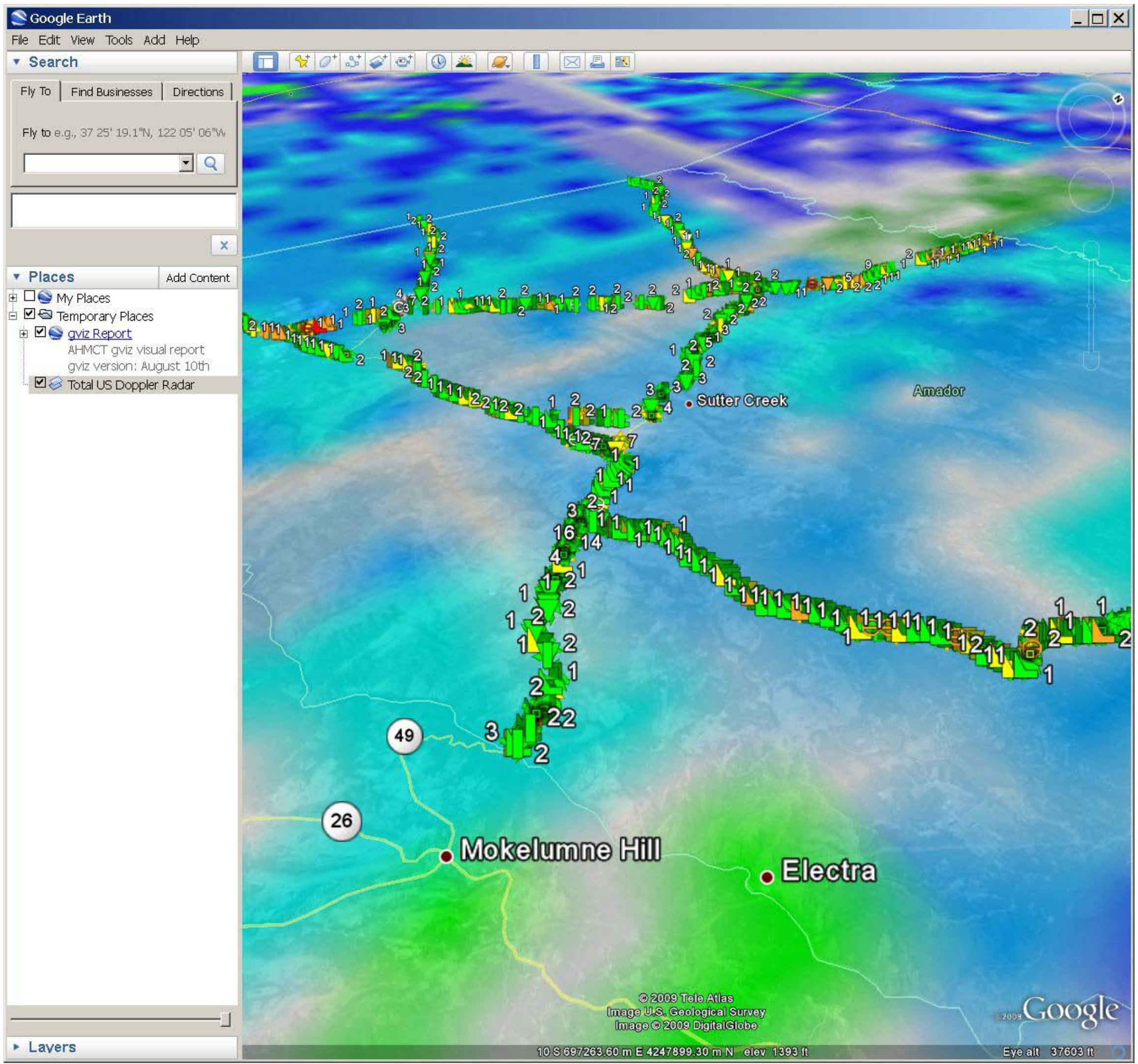


Figure 17: Culvert System Layered with Real-time Doppler Radar

5.5 Visualization Capabilities of GVIZ

The GVIZ visualization application was developed in collaboration with Caltrans engineers over the course of the project both to meet specific identified needs and to provide generalized visualization capabilities. These capabilities include:

- General features
    - Generate and distribute visualization reports independent of the source spatial data.
    - The ability to combine data from multiple sources into a single visual report. This enables discovery of relationships between different types of roadside assets that otherwise might be difficult to realize.
    - The ability to load and save configuration files.

- User friendly, providing quick turn around of spatial data in the form of visualization reports.
- Read spatial data in spreadsheet (xls) files directly.
  - Spatial data read as one point per row.
  - Spatial data read as one multi-segmented line per row.
  - Line and point attributes specified in adjacent columns.
- Read spatial data in comma separated value (CSV) files directly.
  - Spatial data read as one point per row.
  - Point attributes specified in adjacent columns.
- Read spatial data from Open DataBase Connectivity (ODBC) sources directly.
  - Spatial data read as one point per row.
  - Point attributes specified in adjacent columns.

- Culvert domain specific features
  - The ability to read the Caltrans Culvert database directly from GVIZ.
  - The use of the established Caltrans visualization format for depicting culverts, as shown in Figure 15. Figure 18 shows similar GVIZ output for a small portion of the Caltrans Culvert Database.

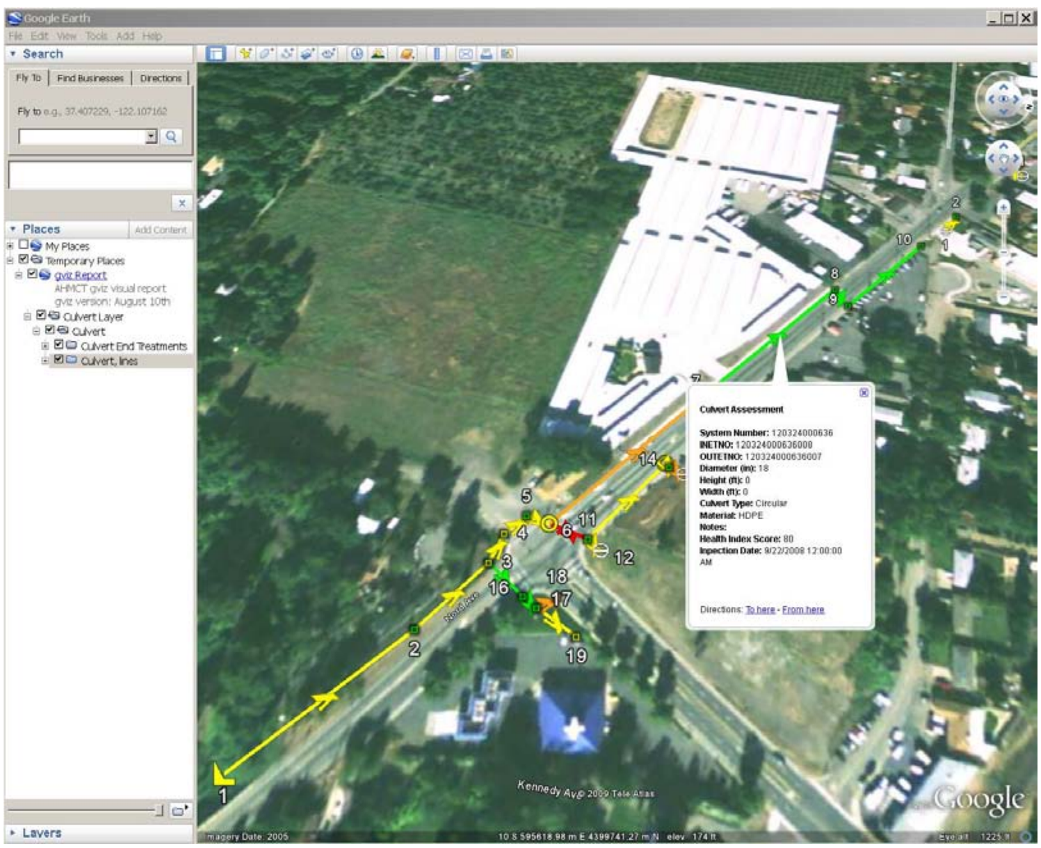


Figure 18: GVIZ Culvert Database Visualization

  - Diagnostic messages that indicate errors or omissions in the culvert database.
  - General culvert visualization report (see Figure 19 for an example), which depicts
    - Culvert condition using color codes.

- Inspection photos are embedded within attribute balloons, and stored in the local file system.
- Culvert attributes displayed on balloons, per culvert.
- End treatment attributes specified on balloons, per end treatment.
- End treatment condition using color codes.
- Flow direction is indicated with icon orientation.
- End treatment numbering.
- End treatments depicted using Caltrans specific icons.
- Clickable end treatments, providing a balloon that contains data on the conditions.

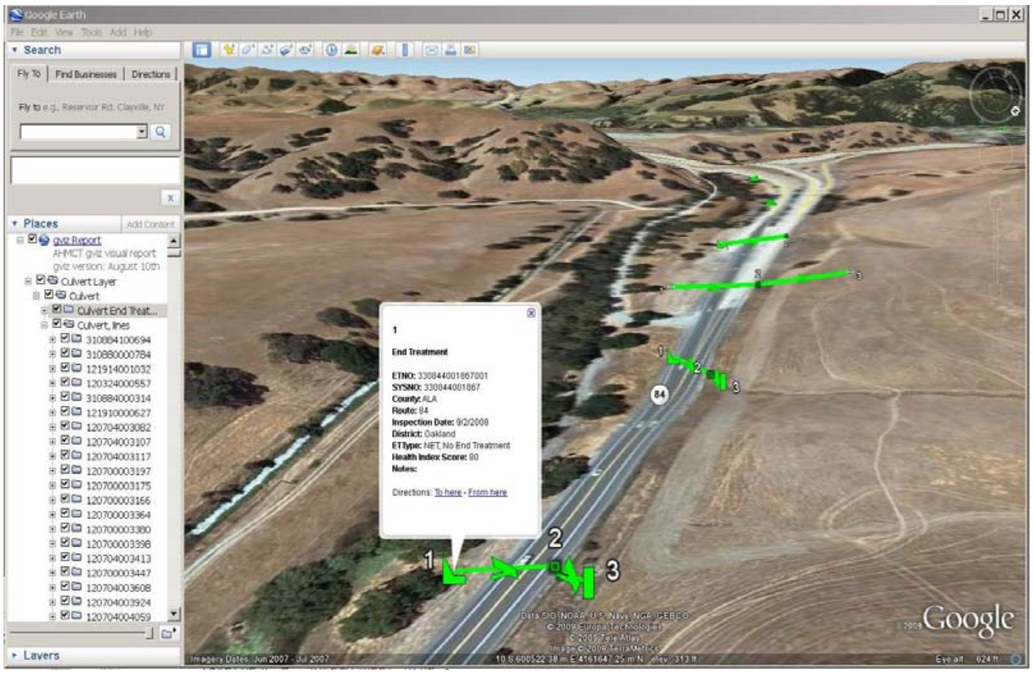


Figure 19: GVIZ Culvert Visualization Report

- Culvert end treatment timeline visualization report (see Figure 20), which depicts culvert end treatment inspections over time. This report uses the Google Earth timeline feature, which links a spatial end treatment location with an inspection date.
- Slotted drain visualization report.
- Ditch visualization report.
- CBMP visualization report.

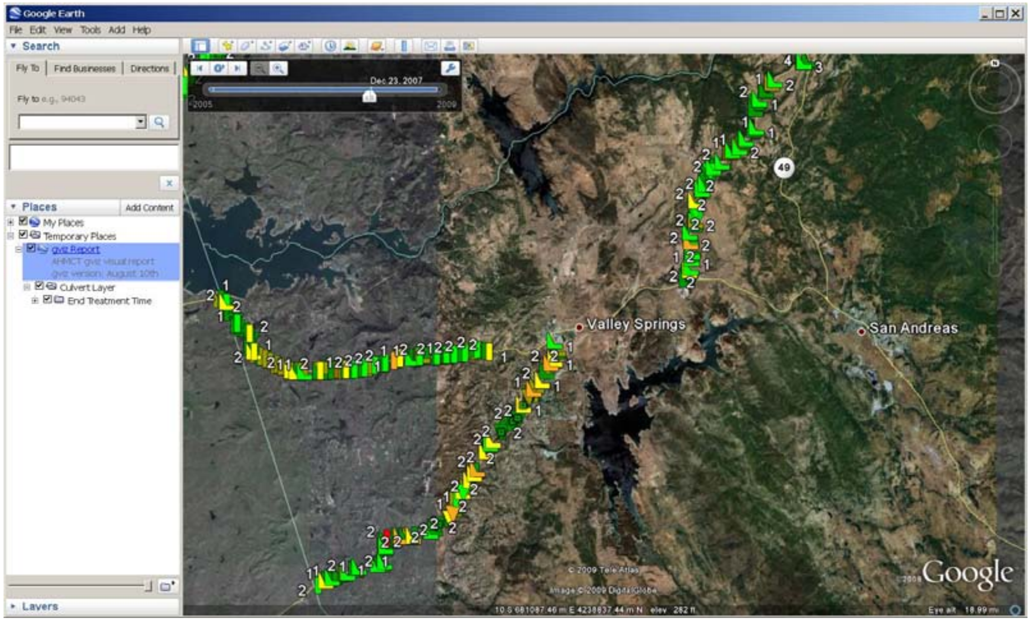


Figure 20: GVIZ Culvert Time Line Visualization Report

5.6 GVIZ System Benefits

The software system GVIZ provides for many benefits as follows:

- Rapid verification of tabular spatial data from multiple sources.
- Visualization and combination of tabular data from multiple sources into single visual reports.
- Enhanced collaboration with remote personnel who otherwise would have no access to the source data. For example, Caltrans engineers can now produce visual reports for maintenance personnel as needed. Figure 7 is one example of such a situation.
- In Figure 21, culvert conditions are photographically documented and geo-positioned using GPS measurements and visualized using GVIZ in situ on Google Earth. Figure 22 provides another example of the type of report that can be generated showing the Culverts in a special geographic area.
- Figure 23, shows the layout of the median guardrail for an overhead sign as measured and displayed on GVIZ as a layer on Google Earth.

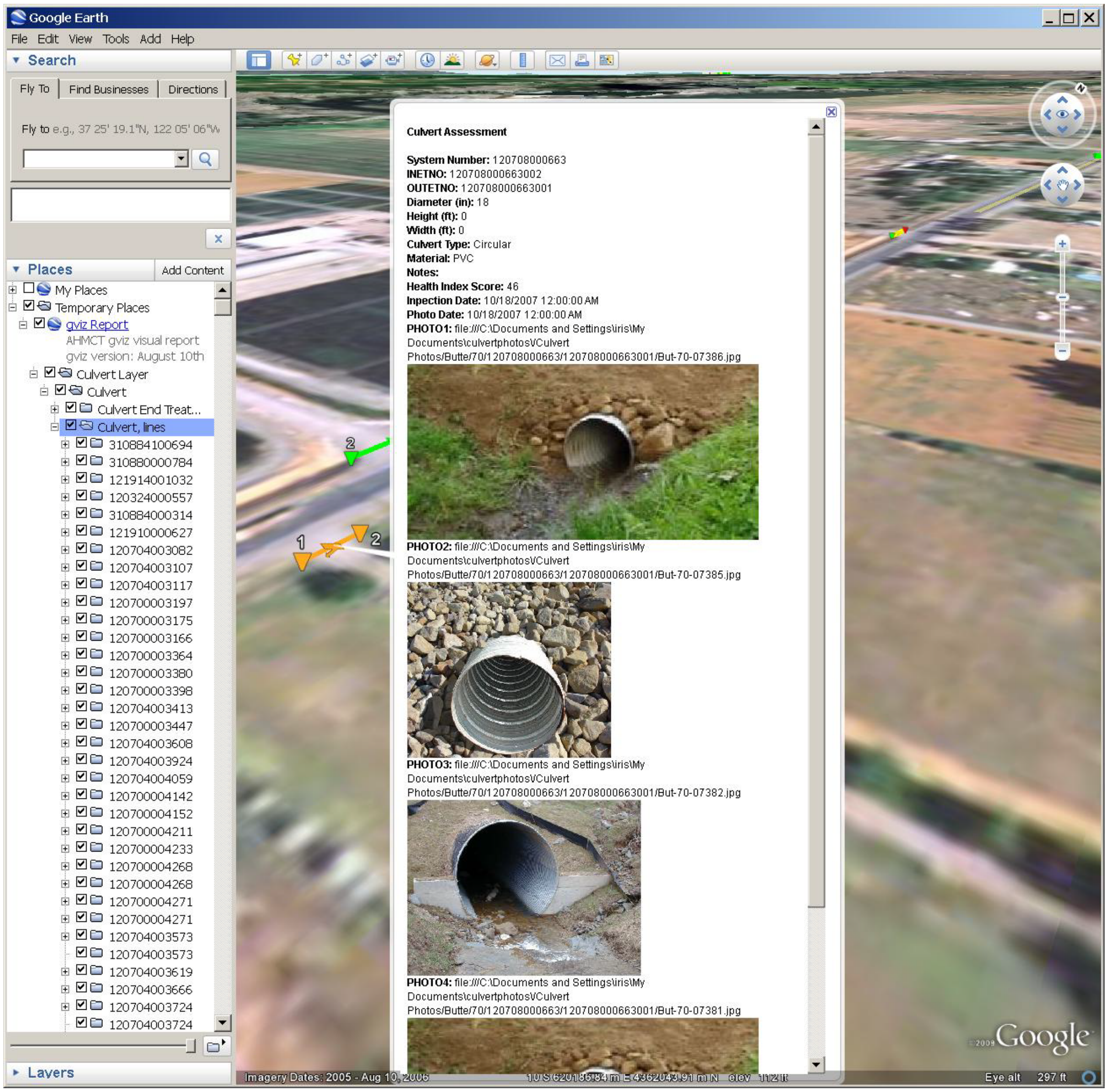


Figure 21: Geo-positioned Culvert Photos

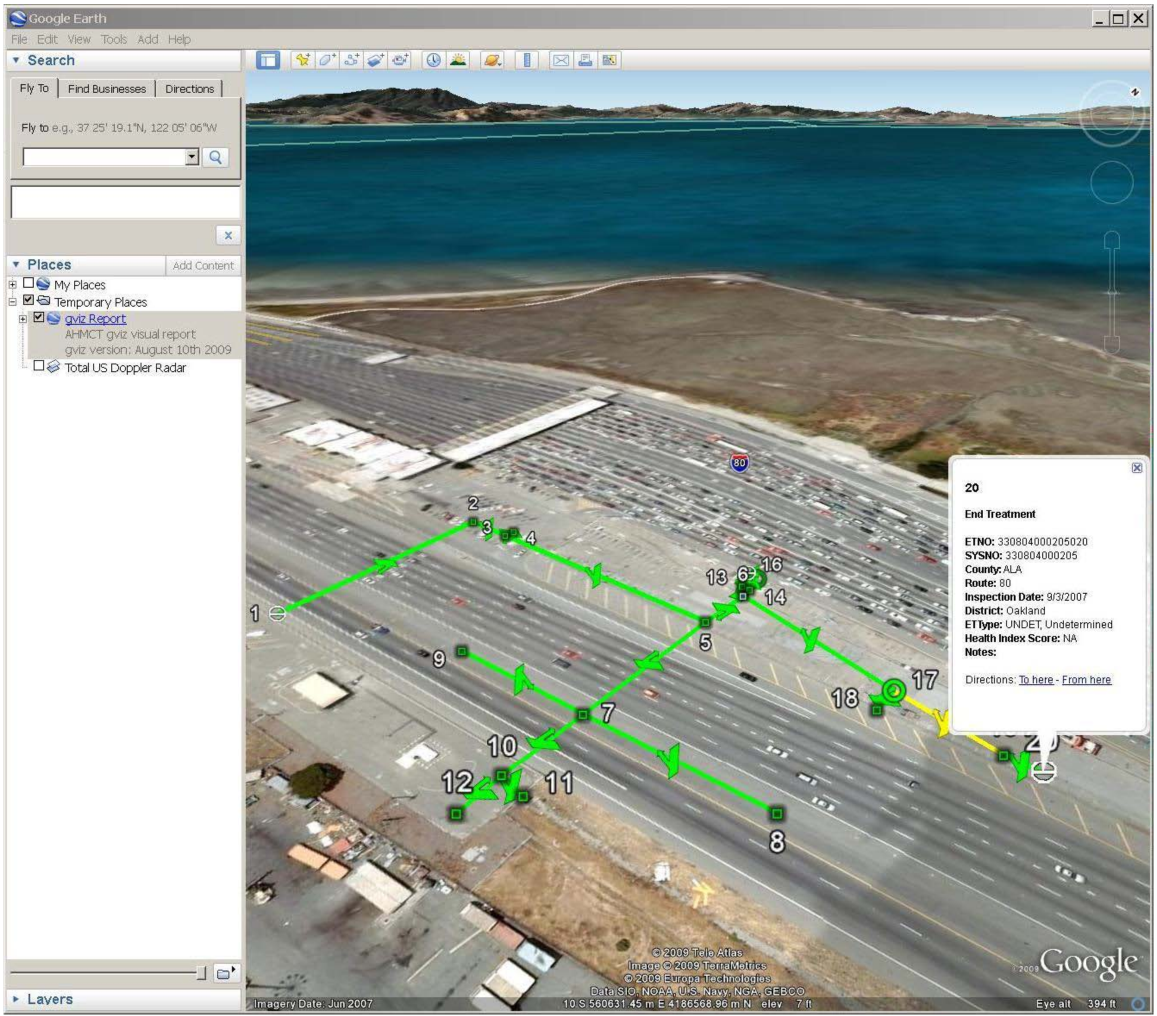


Figure 22: Bay Bridge Toll Area Culvert Inventory

Figure 23: Median Guardrail for Overhead Sign

6. FEASIBILITY EVALUATION OF TECHNIQUES FOR REMOTE INVENTORY OF ROADSIDE VEGETATION

The purpose of this part of the present study was to perform some evaluation of application of some image processing algorithms to see the feasibility of remote data collection related to inventory of roadside vegetation. The idea was to evaluate feasibility of using high-resolution aerial images such as DHIPP or existing Google Earth images to inventory roadside features with special emphasis on roadside vegetation. It was felt that such methods can drastically reduce the cost of manual inspection and inventory using GPS methodology discussed in section 4. Upon meeting with Caltrans personnel, it was decided that initial emphasis would be on determination and calculation of mowing acreages and perimeters, as well as number of trees associated with roadside vegetation. Mowing acreages are important in planning maintenance operations and developing cost estimates for maintenance budgets associated with roadsides. An example of the mowing area at a highway intersection is shown in Figure 24. It is clear from this Figure that the Google Earth Image can provide a basis for calculation of this area.

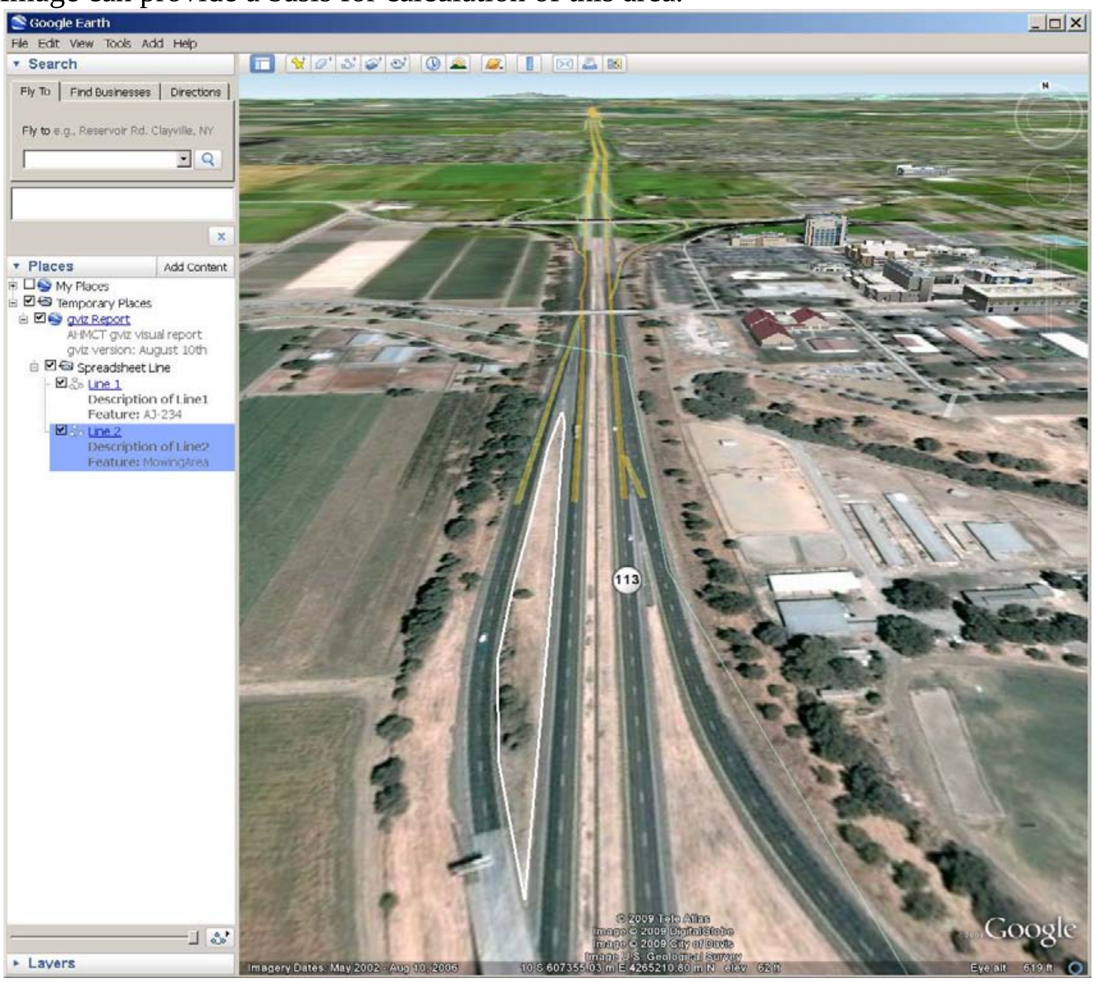


Figure 24: Intersection mowing area

In order to develop an understanding of the area of vegetation, the image has to be inspected visually and a polygonal approximation needs to be made of the area. This has to be performed on the satellite image in the Google Earth or on the aerial photographs image from DIHIPP files. The geo-referencing was performed using post markers that are identified in DIHIPP photo files. A flow chart was developed for the method used for the calculation. This is shown in Figure 25. The application of this technique and its feasibility is discussed in the sub-section below.

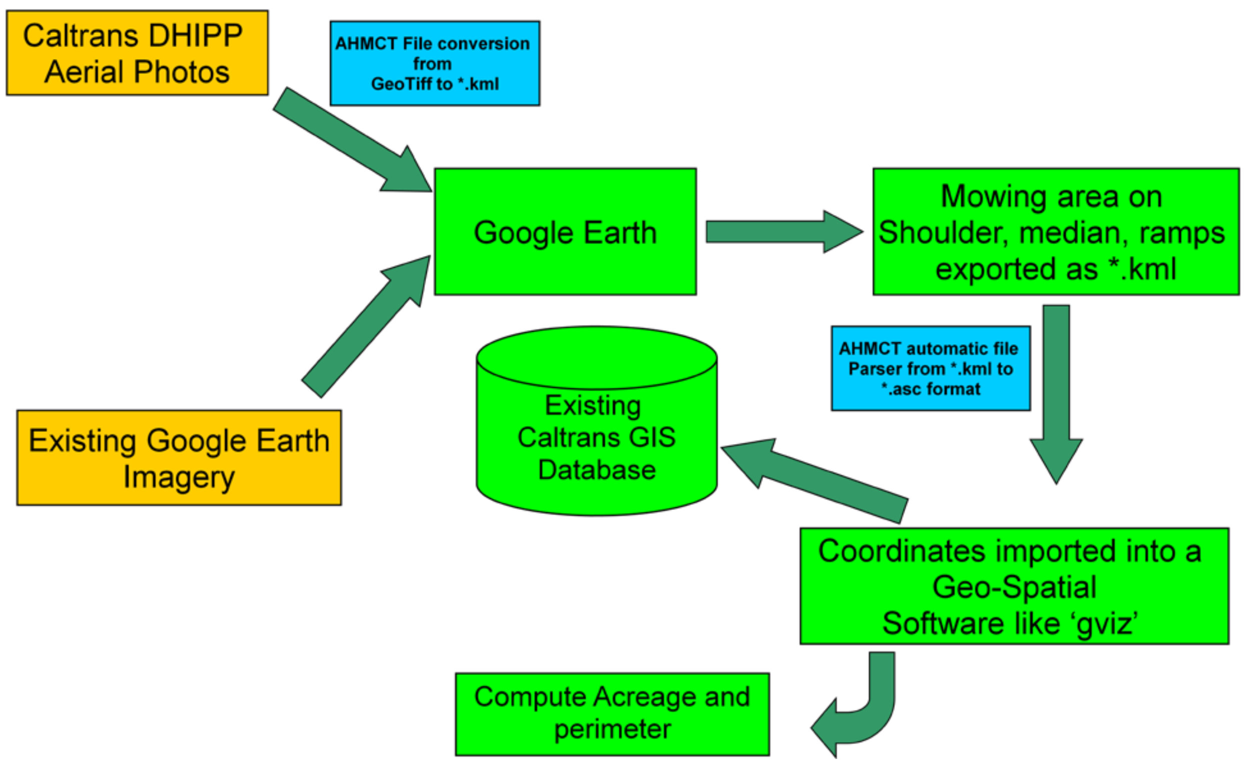


Figure 25: Flowchart of the process for Mowing Area and Perimeter Calculations

6.1 Mowing Acreage, Perimeter and Area Calculations

Since this was a feasibility study, the scope of the work was limited to only a small geographic area. The areas selected were a section of Interstate Highway 5 in Shasta area, a section of California Highway 1 near San Luis Obispo area, and a section of Interstate 405 in Los Angeles area. For individual sections of a highway in the above three corridors, a set of post-miles specifying start, end and various intermediate points were determined. These post-miles were found by comparing highway features with those listed in "California Log of Bridges" document. Some post-miles where interpolated by the Google Earth "Path" tool, using a known highway feature as a reference. A summary of the results are given in Table 12. It should be noted that in some cases due to lack of visual data and detail, the drawn polygons may be covering areas outside the highway fences and hence overestimate the mowing acreage. Another source of error is the lack of altitude data which causes the polygons areas to be flat projections and hence less than the true value, off by a factor equal to the inverse of the corresponding slope and the cosine of the angle. The most complicated section was the section on Interstate Highway 405 which involved drawing 152 polygons and took approximately 24 man-hours.

Highway	Begin	End	Len. (mi)	Acreage
02-SHA-005	SHA 19.31	SHA 9.64	9.67	248.95
05-SLO-001	SLO 47.82	SLO 43.67	4.15	71.58
05-SLO-001	SLO 36.15	SLO 35.15	1.00	29.59
05-SLO-001	SLO 29.00	SLO 23.55	5.45	92.25
07-LA-405	LA 24.67	LA 14.13	10.54	237.41

Table 12: Estimates of Mowing Acreages for the Three Selected Corridors

In making these calculations "GVIZ" was utilized which enhanced the processing and calculations associated with the data obtained from DIHIPP or Google Earth. This allowed storing individual vegetation areas as layers for easy access of information for further statistical analysis.

In order to determine whether or not data from Google Earth images would b accurate enough to avoid the need to use DIHIPP data, a comparative evaluation of the accuracy of mowing acreages calculated using the two inputs were conducted. This was performed for two of the three corridors and the results are shown in Table 13.

Area	Google Earth Acreage	DHIPP Acreage	% Difference
02-Shasta-005	248.9493 (Acres)	246.2749	1.08
07-LA-405	237.4093	233.2994	1.74

Table 13: Comparison of Mowing Area Computations

The results clearly indicate that Google earth images in the most parts and in areas where there are no obstructions can be used for developing a base line inventory of roadside features including mowing acreages. Inputting the polygonal approximations by looking at images was a time consuming process. A procedure for polygon manipulation, applicable to the estimation of the mowing acreage for the areas surrounding highways to reduce the time of manually calculating such information from the images was therefore developed in a program called KMLPOLY. This program would make polygonal approximation to the areas based on user input and saves much time. It is estimated that using this program, approximately a two human year time is needed to develop a baseline inventory for all California highways. This could involve four students at 50% time each for one year and can be accomplished in one year.

6.2 Creating and Manipulating Polygons in Google Earth

A procedure for polygon manipulation, applicable to the estimation of the mowing acreage for the areas surrounding highways, is outlined below. This procedure is developed to simplify the manual process of creating points as vertices of polygons needed for computation of the mowing acreages.

Figure 26: Polygon points for computing area for Cloverleaf Interchange with Google Earth snapshot for comparison.

The basic procedure is as follows:

1. Create a folder under "My Places" in Google Earth (see Figure 27).

2. While the new folder is selected (highlighted), create the polygons covering the areas of interest by the Google Earth Polygon tool[1]. The fastest way to create the polygons was found to be by specifying the least number of points on the perimeter, as needed to cover the curvature of the boundary of the area of interest.

3. There is no need to save the polygons individually. Instead, the whole folder containing the polygons is saved (see Figure 28). "Place-marks" and "Paths" may be added to show the name and/or other information about polygons in the folder. It is recommended that during the creation of polygons, the user save the folder often to avoid losing data in case of a power failure or other unforeseen events.

4. Once the user is done and the final version of the folder is saved, the areas of the polygons in the corresponding kml file may be extracted by the Kmlpolya program.

5. To install the Kmlpolya program, run "Kmlpolya Installer.exe". The installer extracts the program and copies it to the "Program Files" folder under "kmlpolya". It also

[1] The use of a pen tablet is highly recommended when creating polygons. It was found to be faster and more convenient than a mouse. The brand used was a Bamboo medium pen tablet by Wacom. The four buttons and the additional touchpad on the tablet where programmed for navigation, rotation of the field and zoom operations during the polygon creation process.

installs shortcuts on “Desktop” and in “Start Menu Programs” list and a release note is shown at the end of the installation. An additional shortcut is also provided for uninstalling the program.

6. After installation, the Kmlpolya program may be run through the “Extract Polygon Area” shortcut on “Desktop” or in “Start Menu Programs” under “kmlpolya”. Figure 29 shows the user interface. The user may specify a whole directory, a number of files in a directory or a single kml file to be scanned for polygons. If it is desired to scan a folder for kml files, a “ * ” has to be included in the file name box. Directory and file/s may be specified by clicking on the corresponding buttons which would open the appropriate menus, or alternatively by typing/pasting the path and file names directly in the respective boxes. Once the directory and file selection is done, pressing the “GO” button starts the scanning of file/s and the activity of the program is then displayed in the adjacent window. The above operation may be repeated once the program has finished the current area calculations.

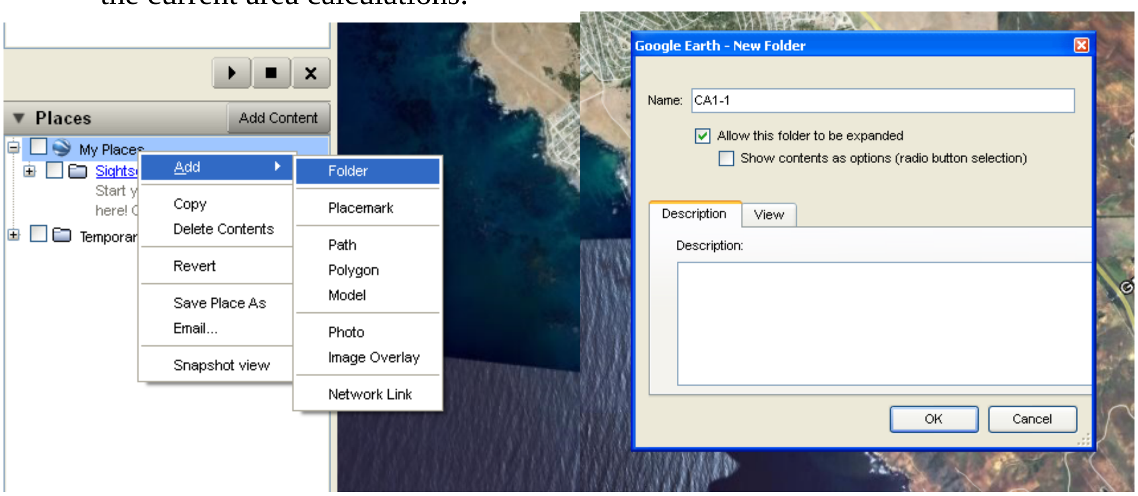


Figure 27: Add folder to “My Places”: Right click on “My Places”, select Add, Folder, type in name, OK.

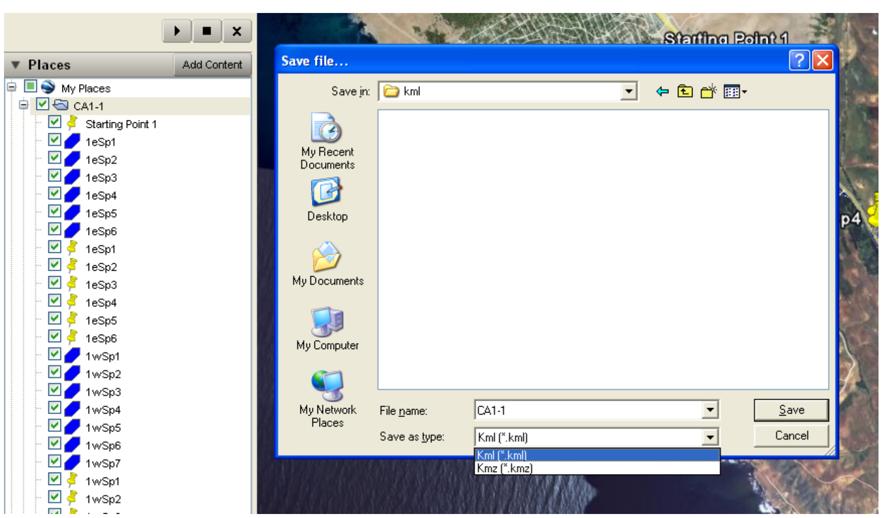


Figure 28: Save polygons folder: Right click on folder, select “Save Place As”, “Kml” type, Save.

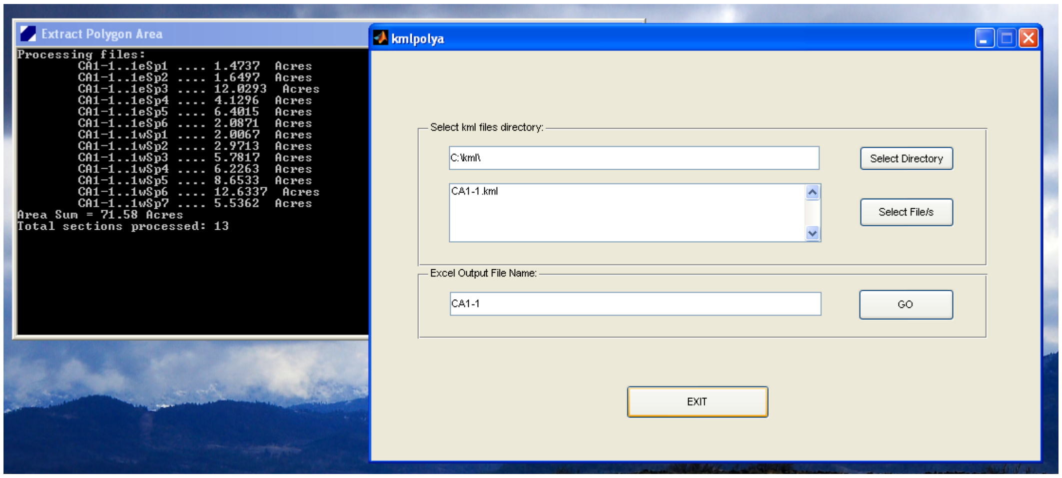


Figure 29: Kmlpolya program user interface.

7. The kml input files may contain any number of polygons in addition to other Google Earth objects such as place-marks and paths. All objects other than polygons are ignored by the program.

8. The file names, the names of the polygons in each file and the areas of individual polygons are inserted in columns in the output Excel file, whose name is supposed to be specified in the output file box by the user before pressing the GO button. The program automatically provides a name if the user chooses not to specify any output name; it also adds a "-" at the end of the output file name if that file exists, in order to avoid overwriting prior data. In addition to the Excel output file, the coordinates of individual polygons are gathered in text files whose names are a combination of the corresponding kml file name and the polygon section name.

Kmlpolya is a stand-alone program written in Matlab and is independent of any Matlab installation on the system. The Matlab environment was chosen because of its excellent string manipulation ability, diversity of file I/O and the simple compact form of specifying numerical computations. . Finally, it should be mentioned that the area calculations of this program was compared to that reported by the Google Earth Pro Area Measurement Tool and was found to be in agreement to better than 0.1%. The discrepancy is mostly believed to be due to lack of accuracy in matching the two polygons needed for the comparison.

7. CONCLUSIONS AND RECOMMENDATIONS

This research study has addressed five research questions as follows:

1. What are the state of the art and best practices in inventory and assessing of roadside features?

2. What are the typical or generic costs associated with inventory of roadside assets?

3. How GPS be integrated into data gathering and Geo-Referencing in roadside asset management in Caltrans operations

4. What data bases and software tools can provide for an effective method for Caltrans to inventory and monitor conditions of roadside assets

5. Are there ways or methods that data gathering can be simplified or automated?

7.1 Conclusions

This research has combined a review of the literature with a formal survey questionnaire to various state DOT's as well as counties and cities to answer the first question. The result of the survey has provided the data for understanding of the state of the art in roadside inventory, developing an understanding of the best practices, and identifying some of the commercially available systems for such a purpose. The data obtained in the survey has also shed some lights into the generic costs associated with data collection and inventory associated with Developing and Inventory of Roadside Features. Such data can be used in scoping and developing estimated budgets for undertaking inventory functions for an organization based on road miles of roadway assets. The survey and the analysis of the data obtained, has provided the answers to the first two research questions.

The analysis of the state of the art has indicated that as a minimum two types of technologies are needed for roadway assets inventory and management. One has to do with data acquisition and the second has to do with data storage, management, and presentation. In terms of data acquisition, a short term but practical method as well as a long term and more advanced methods were developed. It was found that the most practical method, in the short term is based on use of GPS equipment in manual operation of data collection. For this method, a detailed procedure was developed that was consistent with the existing Caltrans operations for use of GPS equipment for data collection. This procedure was implemented into the workflow at Caltrans for data collection associated with inventory of culverts and has provided the answer to the third research question.

In terms of a long term solution, example software algorithms were developed that would allow data collection in a remote fashion using satellite images available in Google Earth. More specifically, methods were developed for calculating mowing acreages for roadside vegetation using Google Earth images. These developments also provided some answers to the fifth question by showing that image processing algorithms together with satellite images can be used for a more simplified way of data collection for inventory purposes for at least some if not all roadside assets.

In dealing with data storage, management and display (answer to the fourth question) it was found that available technologies are proprietary and non-compatible with legacy systems within an existing organization. Furthermore they have limited direct visualization capabilities. In order to resolve some of these shortcomings, a major effort was undertaken in this study in the development of the "GVIZ" software system. This software system can work with any legacy database within the organization and provides visualization of the data over Google Earth images allowing for direct display of inventory data on roadway images.

7.2 Recommendations

In order to develop an effective program for assessment and inventory of roadside features and their conditions, it is recommended that a multi resolution approach be utilized. Such an approach is especially important in today's environment of shrinking budgets and limited resources as well as lack of available workforce due to work reduction programs. It is recommended that the first effort would be performed at the lowest resolution level and as more budgets become available then higher level of resolution or refinements be performed. At the lowest resolution level, the following steps are recommended:

1. Prioritize the items to be inventoried from Table 1 both in terms of their importance and separately in terms of estimated cost or difficulty of performing the data collection function for their inventory.
2. For the items selected perform a base line inventory costs analysis using the data in section 3.
3. Re prioritize the list based on cost estimates.
4. Develop baseline inventory data using the remote methods based on Google Earth images using GVIZ.
5. Use GPS manual data collection method for areas and items that remote methods prove to be not applicable.
6. Sample a few locations and check the remote calculation method against the GPS based manual methods to determine error rates.
7. As more budgets become available replace the remote data with new data that can be obtained by the GPS based manual method.

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APPENDIX A
EXAMPLES OF BEST PRACTICES

Washington DOT

Program Objectives (RFIP)

A statewide roadside feature inventory program where the data becomes a corporate asset by

- Consistent data definitions and values throughout the department.
- Methods and procedures that minimize cost of collection and maintenance of data.
- Allowing sharing of accurate and timely data

Program Budget

- **US$2 Million over two years (2005-2007)**

What has been accomplished so far?

Bridge Structures	Mailboxes
Underground Injection Well	Hydrants
Catch Basin	Pedestals
Guy Wire	Misc. Fixed Object
Cabinets	Tree (individual)
Rock Outcroppings	Culvert Ends
Water Hazard	Pipe Ends
Barriers	Tree Groups
Glare Screens	Supports
Impact Attenuators	Regulatory Outfalls
Re-directional Land Forms	Storm water Ponds (as a point)
Fence	Swale/Ditch
Curb	Roadway Slopes
Intersections	Walls (retaining)
Road Approaches	Storm water Vaults (as a point)

- GPS Equipment has been tested and selected for program use
- Front-end application designed in Arc GIS-XML and in sync with data collection devices
- GPS coordinate data associated with State Route location
- Feature class has been developed to present data in GIS workbench environment
- Procedures manual developed which has a training module associated with it

Washington DOT

<u>What has been accomplished so far?</u>

Culvert	Object Id
	Diameter
	Width
	Height
	Material
	Type
	Culvert Use

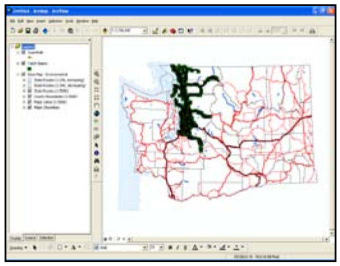
Culvert	Object Id
	Diameter
	Width
	Height
	Material
	Type
	Culvert Use

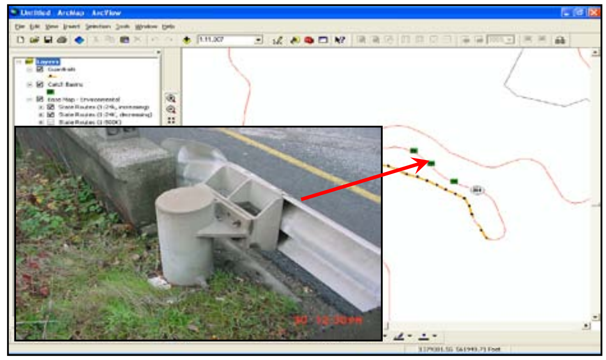
Examples of features and attributes collected

Washington DOT

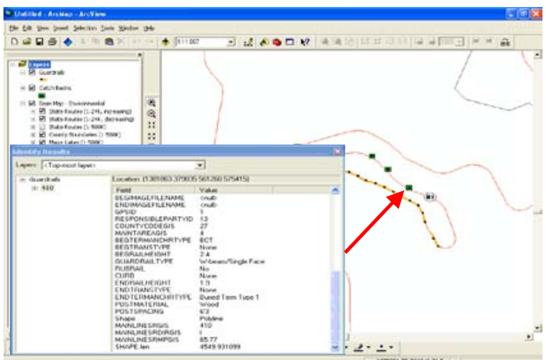
Snapshots of what an End-User sees…

Samples of Guardrails and Catch basins in the GIS workbench





Close-up of attribute data of a specific guardrail on SR 410



Close-up of attribute data of a specific guardrails and catch basins on SR 410

Iowa DOT & Nebraska Dept of Roads

Program Objectives

• Pilot highway stretch is 15 miles long divided into 200 ft increments

• Airborne laser mapping utilizing GPS systems, precision inertial navigation systems and high speed computing obtain elevation information on large tracts

• Typical accuracy is within 6 inches and frequency is 5000 pulses per second

• Data is used to create high-resolution Digital Elevation Models (DEMs)

What data is collected for further analysis?

• Landscape

• Sloped Areas

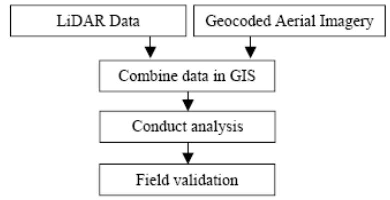
• Individual count of trees

• Side slope - measured at stations every 1000 ft intervals along both sides of highway

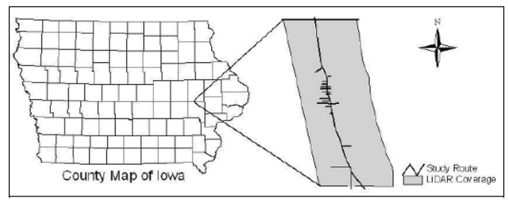
• Grade – 500 ft increment measured along the shoulder and elevation found at both ends of segment

• Contour – generated at 1.5 ft intervals using the TIN algorithm in ArcView

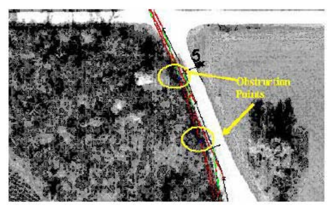
Methodology



Typical Result Snapshots



Study Corridor



Identifying Stopping Sight Distance (SSD) Obstructions

Texas DOT

Program Objectives

Texas Maintenance Assessment Program (TxMAP) developed by the Maintenance Division:

- **represents and evaluates 79000 miles of the state highway system**
- **provides documentation to districts on particular items of work they need to place additional emphasis**
- **visually inspects 21 elements of highway system in three different components – pavement, roadside and traffic operations**

Program Budget

- **US$200,000 per year to perform TxMAP evaluation**

What data is collected for further analysis?

- **Vegetation Management – Vegetation recently mowed or of uniform height, no noxious weeds, no grass in pavement**
- **Litter – ROW clean with no or minor litter, not visible at posted speed limit**
- **Sweeping – No dirt debris or ice rock along curbs, bridges, turn lanes or barriers**
- **Trees and Brush – Trees > 5 inches within clear zone, no sight restrictions or sign obstructions**
- **Drainage – Ditches, channels clear of silt/erosion, no high shoulders**

What data is collected for further analysis?

- **Encroachments Access Control – No illegal signs, buildings, vehicles etc. encroaching on highway ROW**
- **Guardrails – Functional, appropriately placed and installed to latest standards**
- **Mailboxes – Straight all on standard supports and hardware, with standard delineation**
- **Raised pavement markers**
- **Large Signs – installed on I or H beams or sign bridge**
- **Small Signs**
- **Striping Graphics**
- **Attenuator**
- **Delineators**

Texas DOT

TxMAP Sample Calculations					
Component	Element	Priority Multiplier	Inspection Score	Element Score	Component Score
Pavement	Rutting	6.5	5	100%	6.5
	Cracking	6.5	3	60%	3.9
	Failures	9	5	100%	9.0
	Ride	6	4	80%	4.8
	Edges	4.5	3	60%	2.7
	Shoulders	5	3	60%	3.0
Pavement Component Score		37.5 *			29.90 / 37.5 = 79.73%
Traffic Operations	Raised Reflective Markers	3	0	0%	0.0
	Large Signs	3	0	0%	0.0
	Small Signs	3	3	60%	1.8
	Striping	4	4	80%	3.2
	Attenuators	4	0	0%	0.0
	Delineators	3	4	80%	2.4
Traffic Operations Component Score		20 *			7.40 / 10.0 = 74.00%
Roadside	Vegetation Management	5.5	3	60%	3.3
	Litter	2.5	5	100%	2.5
	Sweeping	4.5	0	0%	0.0
	Trees and Brush	3.5	5	100%	3.5
	Drainage	5	5	100%	5.0
	Encroachments	3.5	5	100%	3.5
	Guard Rails	5	5	100%	5.0
	Mail Boxes	3	4	80%	2.4
	General Public Rating	10	5	100%	10.0
Roadside Component Score		37.5 *			35.20 / 38.0 = 92.63%
Overall Score					(79.73 * .50) + (74.00 * .20) + (92.63 * .30) = 82.35%

TxMAP Sample Calculations

Texas DOT

TxMAP Rank Comparison

FY2001 – 2005

District	Rank					Score				
	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
01-Paris	2	7	18	24	23	83.49	80.02	77.56	75.43	75.43
02-Fort Worth	15	11	23	23	24	78.14	78.72	74.53	76.20	74.07
03-Wichita Falls	25	25	21	13	7	72.96	74.63	76.52	79.86	79.98
04-Amarillo	6	10	6	5	12	80.63	79.00	80.85	81.60	78.71
05-Lubbock	16	8	13	4	18	78.07	79.64	78.51	81.97	77.12
06-Odessa	3	1	1	2	2	83.33	85.75	83.38	83.38	82.57
07-San Angelo	5	2	7	1	1	80.89	85.06	80.76	83.97	82.79
08-Abilene	10	4	12	17	15	79.57	82.90	79.19	77.84	78.07
09-Waco	9	13	10	3	14	80.28	78.49	80.22	82.03	78.18
10-Tyler	22	24	3	8	10	74.95	74.93	82.50	80.90	79.15
11-Lufkin	13	22	11	19	20	78.58	75.93	79.35	77.74	76.00
12-Houston	21	12	17	10	6	75.01	78.50	77.56	80.31	80.13
13-Yoakum	20	16	16	14	16	75.83	77.99	78.42	78.50	77.71
14-Austin	7	14	14	16	21	80.62	78.37	78.49	77.98	75.83
15-San Antonio	11	15	24	15	13	79.39	78.05	74.46	78.41	78.28
16-Corpus Christi	23	23	9	21	11	73.86	75.24	80.23	76.95	78.87
17-Bryan	17	18	19	6	17	77.97	77.93	77.41	81.23	77.54
18-Dallas	24	21	25	25	22	73.16	76.65	72.23	75.04	75.59
19-Atlanta	8	9	4	9	9	80.53	79.07	81.59	80.49	79.52
20-Beaumont	14	19	22	18	25	78.41	77.67	75.06	77.77	73.37
21-Pharr	12	5	2	12	4	78.99	81.06	82.88	79.86	81.04
22-Laredo	19	20	20	22	19	76.78	77.02	76.75	76.66	76.10
23-Brownwood	1	3	5	20	8	85.16	83.17	81.57	77.73	79.60
24-El Paso	4	6	8	7	3	82.60	80.14	80.31	81.11	81.15
25-Childress	18	17	15	11	5	77.33	77.96	78.47	80.26	80.62
Statewide						78.61	78.99	78.75	79.39	78.23

TxMAP Rank Comparison

Ohio DOT

Program Objectives

Data collection protocols:

• Office data collection – Assembling individual permit information, finding wetland mitigation plan, identifying precise site location

• Wetland delineation – Boundaries mapped using Trimble GeoExplorer and Trimble GeoXT GPS with real-time differential correction. Individual points recorded to sub-meter accuracy. Digital photographs of site stitched to form panoramic view.

• Vegetation classification – Wetlands as shown in Figures 1, 2 & 3

• Presence of a shallow literal zone – ban k slopes (less than 15:1) of replacement wetlands calculated along transects 15 m long and vegetation cover of over 50%

• Presence of predatory fish

• Landscape composition – Using ArcGIS different categories of land collapsed into open water, wetland, urban, pasture/grassland and row crop agriculture within a zone of 200m from wetland's edge

Program Budget

• Multiplying the amount of acres required by $15,000 (average price of acre of wetland credit) yields the incurred monetary shortfall between $2,676,000 and $3,174,000

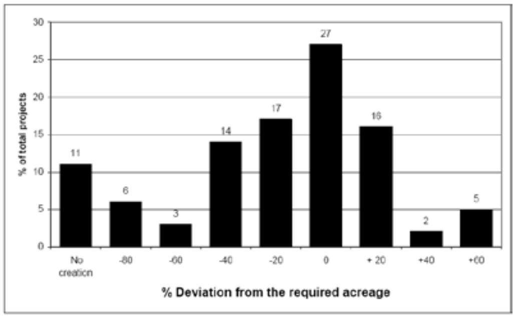
Perimeter wetland (<10% vegetation cover)

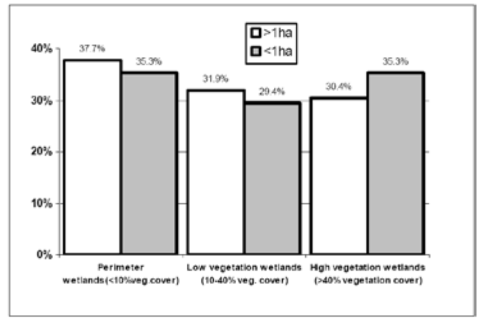
Low vegetation wetland (10-40% emergent vegetation cover)

Low vegetation wetland (40-80% emergent vegetation cover)

Ohio DOT (contd.)

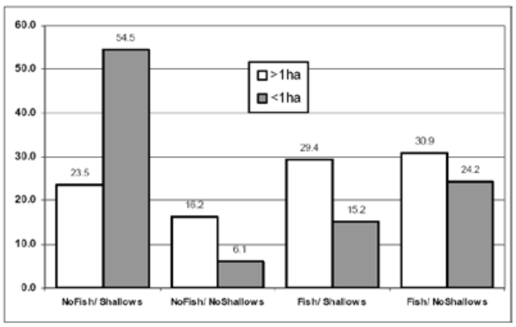
Results Summary





Distribution of wetland mitigation projects based on % deviation from required acreage

Distribution of replacement wetlands based on amount of emergent vegetation cover



Distribution of replacement wetlands based on presence of predatory fish and shallow littoral zones

North Carolina DOT

Program Objectives

- Determine, quantify and present alternative approaches for meeting the FHWA proposed minimum levels of retro reflectivity for signs
- Alternatives formulated for maintaining nighttime inspection with improvements
- Implement a sign inventory management system
- Spreadsheet to determine accuracy of nighttime sign inspection method to determine number of signs in compliance after visual inspection

Background

	Road Location	Background Sign Sheeting Colors								Totals
		Blue	Yellow	Green	White	Orange	Brown	Red	Stop	
Interstates	Rural	1928	1421	4844	2104	900	53	0	0	11,250
	Urban	1345	821	3240	1085	232	61	0	0	6784
	RA&WC	230	50	0	770	0	0	290	0	1340
	Interchanges	1997	694	897	3385	542	51	2370	694	10,630
	Weigh Stations	32	76	96	288	0	0	56	40	588
Interstate Total	-	**5533**	**3063**	**9077**	**7632**	**1674**	**165**	**2716**	**734**	**30,592**
US Routes	Rural	4995	22,296	9522	49,855	1915	639	10,979	0	100,200
	Urban	6165	8956	8311	51,261	1716	849	3159	31	80,448
	RA&VC	63	0	21	189	0	0	84	21	378
	Weigh Stations	0	0	0	4	0	0	2	0	6
	US TOTAL	*11,223*	*31,252*	*17,854*	*101,309*	*3631*	*1488*	*14,224*	*52*	*181,033*
NC Routes	Rural	2417	40,054	9108	60,787	3031	1304	1235	823	118,758
	Urban	7854	13,991	3324	40,020	2160	567	2003	0	69,919
	RA	1	0	0	11	0	0	4	2	18
	NC TOTAL	*10,272*	*54,045*	*12,432*	*100,818*	*5191*	*1871*	*3242*	*825*	*188,696*
Primary Total	-	**21,495**	**85,297**	**30,286**	**202,127**	**8802**	**3359**	**17,466**	**877**	**369,709**
Secondary	Type I Rural	3238	213,190	20,509	107,405	4318	1619	1619	43,717	395,615
	Type II Rural	1403	33,722	1143	30,709	935	104	883	5716	74,615
	Urban	7695	38,647	6233	82,410	4772	1204	3611	1634	146,206
Secondary Total		**12,336**	**285,559**	**27,885**	**220,524**	**10,025**	**2927**	**6113**	**51,067**	**616,436**
TOTAL		**39,364**	**373,919**	**67,248**	**430,283**	**20,501**	**6451**	**26,295**	**52,678**	**1,016,739**

Sign count Totals in NC

MANPOWER USED	HOURS ANNUALLY	TIME OF YEAR PERFORMED	DIVISON
7 sign trucks, 2 employees/truck, 6 hrs/wk for 20 weeks	1680 hours annually	November to March	4
40-60 hours per 2-person crew	640-960 hours annually	Late Fall into Winter	8
11 workers from December to February**	1056 hours annually	December to February	9
Six 2-person crews for 2-3 weeks*	480 – 720 hours annually	October or November	14
Not provided	1400 hours annually	November to February	3
Six 2- person crews for one week*	240 hours annually	January and February	13
12 people, 6 vehicles, 3-4 weeks*	720 - 960 hours annually	Fall	2
48 – 60 hours per county per year. 7 counties	336-420 hours annually	Fall	5
4 crews, 2 people each (plus 3 additional out of town crews) 60-80 hrs per person each season	840 – 1120 hours annually	November - February	11
Not provided	600 – 700 hours annually	January – March	6

*Assumed 4 hours per week/ 5 days week
*Assumed 4 hours per week/ 2 days week

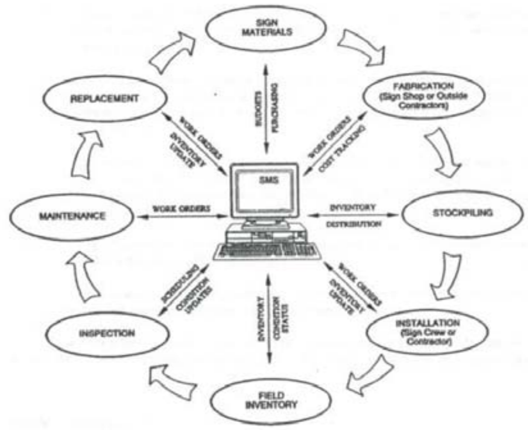
Manpower and timeframe committed to night ride inspection by NCDOT divisions

North Carolina DOT (contd.)

Background (contd.)

- Location
- Orientation
- MUTCD sign number
- Installation date
- Maintenance times
- Unique sign number
- Type of sheeting
- Predicted retroreflectivity
- Type of maintenance
- Substrate material
- Date of last inspection
- Post condition
- Mounting height
- Date of manufacture
- Measured retroreflectivity
- Digitized image of sign
- Sign condition

Sign attributes recorded in inventory



Integration of sign activities using a SIMS

Sign Inventory Management System (SIMS)

No.	Software Name	Company	Information Source
1	SIGN*view*	CarteGraph Systems, Inc.	http://www.cartegraph.com
3	VIMMS	Vulcan, Inc.	http://www.vulcaninc.com
4	Sign Inventory and Replacement	3M	http://www.3m.com/us/safety/tcm/solutions/prg_sms.jhtml
5	SIMS99	UNH T2 Center	http://www.t2.unh.edu/pwms/
6	SIGNMASTER™	MasterMind Systems, Inc.	http://www.mastermindsystems.com

SIMS Commercial Software

SIMS Software Evaluation Criteria

- **Data matrix**
- **Data Acquisition, Input and Exchange**
- **System Functionality**
- **System Requirements**
- **Cost and Technical Support**
- **Ease of use**

North Carolina DOT (contd.)

NCDOT Sign Function Codes and Cost Analysis

Function Code	Explanation
510	New Installation
511	Nighttime Surveillance (Labor & Vehicles)
512	(Field) Labor Only
513	Vandalism
514	Maintenance
515	Detours
516	Delineator Posts and Reflector Buttons
517	Logo Work on Primary Systems (installing logo panels)

Sign Expenditure Codes	Miles	510	511	512	513	514	515	516	517	Total
Division 6 -	-	$58,872	$13,023	$81,637	$278,414	$48,546	$60,051	$6,648	$3,405	$550,596
Division 11-	-	$68,365	$13,117	$161,762	$322,179	$315,487	$41,744	$11,783	$7,123	$941,560
Division 6 and 11 Total	-	$127,237	$26,140	$243,399	$600,593	$364,033	$101,795	$18,431	$10,528	**$1,492,156**
Miles in Division 6 and 11	-	12,231				12,231				
Cost per Mile	-	$10	$2	$20	$49	$30	$8	$2	$1	
Division 1	5050	$52,534	$10,793	$100,496	$247,976	$150,304	$42,030	$7,610	$4,347	**$616,089**
Division 2	4949	$51,484	$10,577	$98,486	$243,016	$147,298	$41,189	$7,458	$4,260	**$603,767**
Division 3	5445	$56,643	$11,637	$108,356	$267,372	$162,060	$45,317	$8,205	$4,687	**$664,278**
Division 4	6117	$63,634	$13,073	$121,729	$300,370	$182,061	$50,910	$9,218	$5,265	**$746,261**
Division 5	6256	$65,080	$13,370	$124,495	$307,196	$186,198	$52,067	$9,427	$5,385	**$763,219**
Division 7	5281	$54,937	$11,287	$105,093	$259,319	$157,179	$43,952	$7,958	$4,546	**$644,271**
Division 8	6721	$69,917	$14,364	$133,749	$330,029	$200,038	$55,937	$10,128	$5,785	**$819,948**
Division 9	5107	$53,127	$10,915	$101,630	$250,775	$152,000	$42,504	$7,696	$4,396	**$623,043**
Division 10	4935	$51,338	$10,547	$98,207	$242,329	$146,881	$41,073	$7,437	$4,248	**$602,060**
Division 12	5979	$62,199	$12,778	$118,983	$293,594	$177,954	$49,761	$9,010	$5,147	**$729,425**
Division 13	5095	$53,002	$10,889	$101,391	$250,186	$151,643	$42,404	$7,678	$4,386	**$621,579**
Division 14	4917	$51,151	$10,509	$97,849	$241,445	$146,345	$40,923	$7,409	$4,232	**$599,864**
Total (including 6 & 11)	65852	$812,284	$166,878	$1,553,865	$3,834,200	$2,323,995	$649,862	$117,664	$67,211	**$8,033,804**
Average Costs		$58,020	$11,920	$110,990	$273,871	$166,000	$46,419	$8,405	$4,801	**$573,843**
Cost per Sign ($/signs)		$0.81	$0.17	$1.55	$3.83	$2.32	$0.65	$0.12	$0.07	**$8.03**

North Carolina DOT (contd.)

Cost Estimates for data collection & Sign Inventory Management System (SIMS)

Cost per Roadway Mile for Various Inventory Methods			
Area Type	**Manual**	**Photologging**	**Videologging**
Urban area, high density	$134.41	$69.35	$68.88
Urban/suburban area, moderate sign density	$82.61	$46.70	$31.28
Rural/small urban area, low sign density	$43.83	$28.79	$22.11
Rural area, very low sign density	$15.27	$23.47	$16.04

Range of Cost to Create an Inventory based on Total Miles			
Area Type (NC miles)	**Manual**	**Photolog**	**Videolog**
Urban (6,976)	$558,000 - $942,000	$314,000 - $488,000	$209,000 - $488,000
Rural (71,106)	$1.067 M - $3.2 M	$1.778 M - $2.133	$1.067M - $1.778M
TOTAL (78,083)	$1.625 M - $4.142 M	$2.092M - $2.621M	$1.276M - $2.266M

Cost to Create an Inventory for Various Inventory Methods based on Total Miles*			
Area Type (NC miles)	**Manual**	**Photologging**	**Videologging**
Urban area, high density (3,488)	$469,000	$242,000	$240,000
Urban/suburban area, moderate sign density (3,488)	$288,000	$163,000	$109,000
Rural/small urban area, low sign density (35,553)	$1,558,000	$1,024,000	$786,000
Rural area, very low sign density (35,553)	$543,000	$834,000	$570,000
Total (78,083)	$2,858,000	$2,263,000	$1,705,000

Michigan DOT

Program

• Collection of physical feature inventory using handheld Trimble GeoXT or Trimble GeoXH units compatible with Terra Sync software on mobile units & Pathfinder Office in the desktop PC

• Each independent feature (e.g. guardrail, culvert) has an established data dictionary

• Includes stakeholders from Maintenance, Design, Traffic & Safety, Hydraulics, Environmental/Permits etc. so that everything related to a physical feature can be collected in a single visit

Program Budget

• Initial costs (data collection, creation of handbook, development of protocols and data dictionaries) estimated at US$ 260,007 per year. Data maintained up to 6 years

• Annualized cost of the inventory is US$ 42,110 per year

• Based on 9700 miles in the state of Michigan, annualized cost per mile is US$ 4.34 per mile per year with an initial investment of US$ 26 per mile per year

Lessons Learned from failed projects

• Standardizing conventions (right/left) and a common data dictionary across the state

• Collecting additional information on features and general trouble shooting on equipment

• Clear documentation

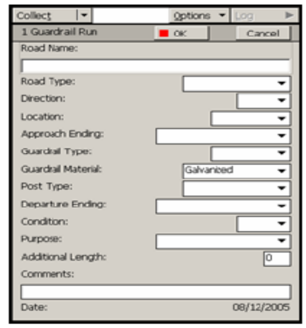
• Lessons learned from one physical feature has relevance to the other features collected

Michigan DOT (contd.)

GUI Snapshots

In-House Software Application for Guardrails

- **Inventory Limits:**
  - ➢ **Full limits of guardrail to be inventoried along highway including within freeway medians and ramps**
  - ➢ **On local roads the limit of guardrail inventory is limited to no more than 200 ft from the bridge railing end**
  - ➢ **On local roads the limit of guardrail inventory is limited to no more than 200 ft from the pier or abutment**
- **Data dictionary**
  - ➢ **Road name**
  - ➢ **Road type**
  - ➢ **Direction**
  - ➢ **Location**
  - ➢ **Approach ending**
  - ➢ **Guardrail type**
  - ➢ **Guardrail material**
  - ➢ **Post type**
  - ➢ **Departure ending**
  - ➢ **Condition**



GOOD Shiny Rail	FAIR Dull Rail	POOR Rust on Rail
6 or More of the Following	POOR	
3 or More of the Following	FAIR	
- Barrier is not in good repair (significant corrosion, accident damage or other misalignment). - Rust on connectors or transitions. - More than 25% of the splice bolts and post attachment bolts are missing. - Rails not attached to terminals and/or transitions. - Fixed objects (i.e. small trees, poles, or other objects) within three (3) feet of back of rail. - Rails not lapped in proper direction. - Missing or severely misaligned posts. - Offset blocks missing or rotated out of vertical positions. - Offset blocks in poor condition (concrete-cracked/deteriorated, wood- rotting) - Posts not firmly embedded - tilted and/or soil erosion around posts. - Anything in front of the barrier that can cause a vehicle to vault (i.e. rough ground, erosion, vegetation and debris). - Barrier face rough (not smooth). - Approach rail disconnected from the bridge rail.		

Michigan DOT (contd.)

Questionnaire Response

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory D=Detailed, P=Proposed, G=General Count					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Drainage										
Cross Culverts	D			D			X		X	
Culvert Ends (Clear Zone)	D			D			X		X	
Catch Basins	D			D			X		X	
Approach Culverts	D			D			X		X	
Ponds (Detention, Retention)*										
Detention Vaults*										
Dikes										
Ditches										
Oil/Water Separators										
Environmental										
Wetlands										
Riparian Zones										
Regulatory Outfalls										
Pipes (Pipe Ends - Clear Zone)*										
Mitigation Sites										
Fish Passage Facilities (e.g. Ladders)										
Fish Barrier Facilities (e.g. Baffles)										
Stream Crossings										
Wildlife Passage Facilities										
Note:- "*" Object appears in multiple categories										

Michigan DOT (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory D=Detailed, P=Proposed, G=General Count					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Environmental										
Storm Water Facilities										
Pipes*	D			D			X		X	
Ditches*										
Swales										
Filters										
Underground Tanks	P			P			P		P	
Vaults*										
Ponds										
Vegetation										
Landscape Area										
Shrubs										
Ground covers				G				X	X	
Irrigation facility										
Slopes and Slide Areas (Clear Zone)										
Tree Groupings (Clear Zone)										
Mulched Areas										
Rock Outcropping (Clear Zone)										
Safety										
Guardrails	D			D			X		X	
Bridge Rails										
Impact Attenuators	D			D			X		X	
Jersey Barriers (Concrete) (Clear Zone)	P			G			P	X	X	
Glare Screen (Clear Zone)	P			G			P	X	X	
Utilities										
Underground Utilities (DOT)										
Utility Poles (Clear Zone)										
Note:- "*" Object appears in multiple categories										

Michigan DOT (contd.)

Questionnaire Response (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory D=Detailed, P=Proposed, G=General Count					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Electrical/ITS										
Gate										
Facilities										
Holding & Parking Areas/Park & Rides	P			P			P		P	
Maintenance Yards										
Landscape										
Pavement										
Trees										
Toll Booths										
Safety Rest Areas	P			P			P		P	
Weigh Stations	P			P			P		P	
Terminal Buildings (e.g. Ferries)										
Border Station										
Roadway										
Sidewalks*										
Road Approaches										
Driveway Crossings										
Rumble Strips (Clear Zone)				G				X	X	
Milepost Paddles/Signs (Clear Zone)				G				X	X	
Signs										
Signs*	P			G			P	X	X	
Sign Support (Clear Zone)	P			G			P	X	X	
Structures										
Noise/Sound Walls				G				X	X	
Retaining Walls				G				X	X	
Bridges				G				X	X	
Railroad Crossings				G				X	X	
Tunnels										
Sidewalk Ramps*										
Note:- "*" Object appears in multiple categories										

Michigan DOT (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory D=Detailed, P=Proposed, G=General Count						Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other	Unit of Measure	Yes	No	Yes	No
Electrical/ITS										
Gate										
Facilities										
Holding & Parking Areas/Park & Rides	P			P			P		P	
Maintenance Yards										
Landscape										
Pavement										
Trees										
Toll Booths										
Safety Rest Areas	P			P			P		P	
Weigh Stations	P			P			P		P	
Terminal Buildings (e.g. Ferries)										
Border Station										
Roadway										
Sidewalks*										
Road Approaches										
Driveway Crossings										
Rumble Strips (Clear Zone)				G				X	X	
Milepost Paddles/Signs (Clear Zone)				G				X	X	
Signs										
Signs*	P			G			P	X	X	
Sign Support (Clear Zone)	P			G			P	X	X	
Structures										
Noise/Sound Walls				G				X	X	
Retaining Walls				G				X	X	
Bridges				G				X	X	
Railroad Crossings				G				X	X	
Tunnels										
Sidewalk Ramps*										
Structures										
Dolphins										
Wing walls										
Towers										
Bridge Seat										
Transfer Span										
Apron										
Trestle										
Bulkhead/Seawall										
Overhead Loading										
Durable Marking/Striping										
Drainage Marking										
Pavement Markings	P			G			P	X	X	
Durable Pavement Markers	P			G			P	X	X	
Monuments (Survey)	P			G			P	X	X	
Fire Hydrants (Clear Zone)										
Fence (Clear Zone)	P			G			P	X	X	

Arizona DOT

Program

• Developed and implemented a component of a Maintenance Management System (MMS) called Features Inventory System (FIS)

• Reports available from the system include Roadside feature inventory detail by milepost and feature summary

Objectives

• Robust functionality which will allow creation of new feature types

• Integration with other modules of MMS

- Interface from Phoenix Traffic Operations Inventory Database to FIS
- Interface from FIS to Performance Cost System (PeCoS)
- Interface from Sign Management System (SMS) to FIS

• Make the system Geographic Information Systems (GIS) ready. Future goal is to map these roadside features to a GIS map. Longitude, latitude and elevation will be attributes on every feature

• Intranet end-user interface, Active Server Page (ASP) with VB scripts and Active Reports. End users will access the system using Microsoft Internet Explorer. Data entry will be done at the Maintenance level. Data will be stored in a Central Database allowing for statewide reporting.

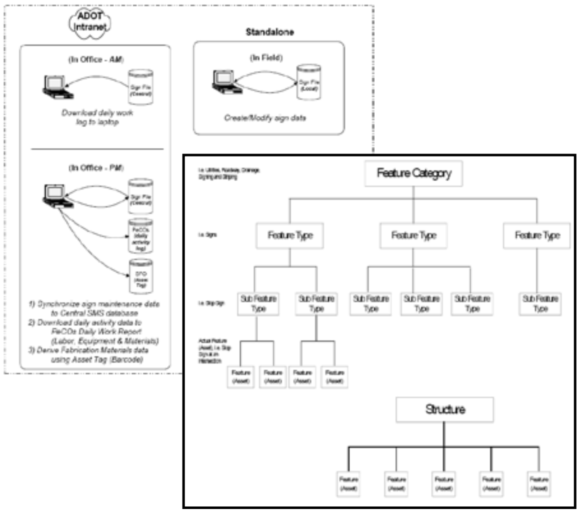
Objectives (contd.)

• The system will integrate with other modules of the Maintenance Management System, the ADOT Information Data Warehouse, and in the future with the ADOT GIS. This will reduce duplicate entry of data and provide users with visual/mapping reporting capacity.

• The system will comply with ADOT's current and planned IT Platform. This platform consists of Microsoft® Windows 2000 Server, MS SQL Server 2000 Relational Database Management System.

Arizona DOT (contd.)

Snapshots of Pilot MMS



Interface from SMS to FIS (Right) & SMS Data-Flow and Integration (Left)

Code	Sheeting Material Abbreviation	Description	Life Expectancy in Years
I	EG	Engineering Grade	7
II	SEG	Super Engineering Grade	10
III	HIG	High Intensity grade	15
IV	HIPR	High Intensity Prismatic	15
VII	SHPR	Super High Intensity Prismatic	15
VII	FGPR	Florescent Grade Prismatic	15

Maximum Sign Life/Sheeting Material (Above) & Sign Catalog Maintenance (Below)

Sign Catalog Number	Stock Number	Size	Color	MOAS	Name	Picture	Sign Type	Approval Required	Life Expectancy for EG Sheeting	Life Expectancy for SEG Sheeting
143	92D115	24 x 48	Orange	W1-6	Large Arrow (Single Arrowhead)		Standard	No	2 yrs	5 yrs
144	36A375	24 x 48	Yellow	W1-6	Large Arrow (Single Arrowhead)		Standard	No	7 yrs	10 yrs
145			Green	D2-2	Destination Mileage (2 Destination listed)		Standard	No	6 yrs	9 yrs
146	35D726	26 x 6	Brown		Ski Area		Special	Yes	5 yrs	7 yrs

Arizona DOT (contd.)

Questionnaire Response

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Drainage										
Cross Culverts										
Culvert Ends (Clear Zone)	x			x		feet		x	x	
Catch Basins	x			x		count		x	x	
Approach Culverts										
Ponds (Detention, Retention)*	x			x		count		x	x	
Detention Vaults*										
Dikes	x			x		feet		x	x	
Ditches	x			x		feet		x	x	
Oil/Water Separators										
Environmental										
Wetlands										
Riparian Zones										
Regulatory Outfalls										
Pipes (Pipe Ends - Clear Zone)*										
Mitigation Sites										
Fish Passage Facilities (e.g. Ladders)										
Fish Barrier Facilities (e.g. Baffles)										
Stream Crossings										
Wildlife Passage Facilities										
Environmental										
Storm Water Facilities										
Pipes*										
Ditches*										
Swales										
Filters										
Underground Tanks										
Vaults*										
Ponds										
Vegetation										
Landscape Area										
Shrubs	x			x		count	x		x	
Ground covers										
Irrigation facility	x			x		count		x	x	
Slopes and Slide Areas (Clear Zone)										
Tree Groupings (Clear Zone)	x			x		count	x		x	
Mulched Areas										
Rock Outcropping (Clear Zone)										
Safety										
Guardrails	x			x		feet		x	x	
Bridge Rails										
Impact Attenuators	x			x		count		x	x	
Jersey Barriers (Concrete) (Clear Zone)	x			x		count		x	x	
Glare Screen (Clear Zone)	x			x		count		x	x	
Utilities										
Underground Utilities (DOT)										
Utility Poles (Clear Zone)										
Note:- "*" Object appears in multiple categories										

Arizona DOT (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory: GPS	Method of Inventory: Video Log	Method of Inventory: Photo Log	Method of Inventory: Field Inventory	Method of Inventory: Other	Unit of Measure	Is feature condition assessed? Yes	Is feature condition assessed? No	Is the data entered into a database? Yes	Is the data entered into a database? No
Utilities										
Franchise Permit Facilities										
Emergency Generators										
Electrical/ITS										
Luminaires (Illumination) (Clear Zone)				x		count	x		x	
Junction Boxes (Clear Zone)				x		count	x		x	
ITS Cabinet				x		count	x		x	
Over-Height Detector										
CCTV				x		count	x		x	
Data Stations (Clear Zone)										
Highway Advisory Radio Towers (Transmitters)										
Hubs										
Signals (Clear Zone)										
Ramp Meter Cabinets				x		count	x		x	
Variable/Changeable Message Signs (Portable)*										
Variable/Changeable Message Signs (Permanent)*				x		count	x		x	
Emergency Phone	x			x		count	x		x	
Under Bridge Deck Lighting				x		count	x		x	
Bridge Electrical Control				x		count	x		x	
Sign Lighters				x		count	x		x	
Navigation/Obstruction Lighting										
Signs (Neon, Back Lit, Fiber)				x		count	x		x	
License Plate Reader										
Temperature Signs										
Crosswalk Flashers										
Flashing Beacon										
Weather Stations (RWIS)										
Queue Detection										
Gate Controller										
Facilities										
Holding & Parking Areas/Park & Rides										
Maintenance Yards	x			x		Bld Square Ft	x		x	
Landscape										
Pavement										
Trees										
Toll Booths										
Safety Rest Areas	x			x		count		x	x	
Weigh Stations	x			x		Bld Square Ft	x		x	
Terminal Buildings (e.g. Ferries)										
Border Station										

Arizona DOT (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Structures										
Dolphins										
Wing walls										
Towers										
Bridge Seat										
Transfer Span										
Apron										
Trestle										
Bulkhead/Seawall										
Overhead Loading										
Durable Marking/Striping										
Drainage Marking										
Pavement Markings				x		feet		x	x	
Durable Pavement Markers				x		feet		x	x	
Monuments (Survey)										
Fire Hydrants (Clear Zone)										
Fence (Clear Zone)	x			x		feet		x	x	
Signs										
Signs*				x		count	x		x	
Sign Support (Clear Zone)										
Structures										
Noise/Sound Walls	x			x		sq ft		x	x	
Retaining Walls	x			x		sq ft		x	x	
Bridges	x			x		count		x	x	
Railroad Crossings										
Tunnels	x			x		count		x	x	
Sidewalk Ramps*	x			x	ADA Ramps	feet		x	x	

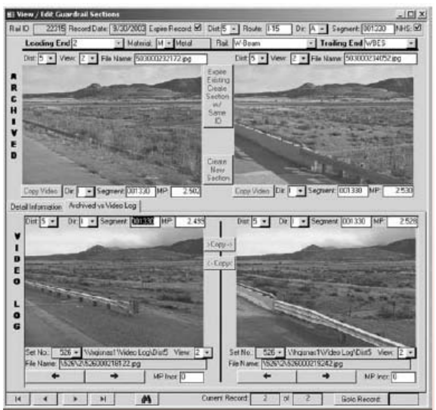
Idaho Transportation Dept (ITD)

Guardrail Inventory System

• Developed using MS Access and Visual Basic; serves as an interface between the photo log data sources and the guardrail inventory database

• ~5,400 guardrail sections in the inventory and process involves comparing the existing guardrail inventory to the latest photo log and updating information

• Application, tables and archived photos require ~500 MB of hard drive space to store database



GRail – Guardrail inventory photo-log entry

Work-flow

• Roadway video-logging survey system set-up on a vehicle with equipment capable of collecting high quality images, GPS data and distance traveled for use in GRail system

• Distance and sensor data fill in for milepost, distance & offset, direction, latitude and longitude information

• Digital images and curvature data are used for traffic applications and the GPS data is used for mapping & interfacing with ITD GIS systems

Video log software

GRail – Guardrail inventory detail

Minnesota DOT

Questionnaire Response & Program Highlights

• Mn/DOT does not have a statewide database system that collects and assesses data for roadside assets. Information is collected at a district level

• Workflow Management System keeps track of activity codes, labor spent and cost associated

• Maintenance activity (e.g. Litter collection, mowing sign maintenance etc.) is combined with data collection process

• In the process of developing a MS Access and SQL based database Sign TRACK/CAD for automating field sign inventory, maintenance, inspection and manufacturing

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Drainage										
Cross Culverts				x			x		x	
Culvert Ends (Clear Zone)				x			x		x	
Catch Basins				x			x		x	
Approach Culverts				x						
Ponds (Detention, Retention)*				x						
Detention Vaults*										
Dikes										
Ditches										
Oil/Water Separators										
Environmental										
Wetlands				x			x			
Riparian Zones				x			x			
Regulatory Outfalls										
Pipes (Pipe Ends - Clear Zone)*				x						

Minnesota DOT (contd.)

Questionnaire Response (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory: GPS	Method of Inventory: Video Log	Method of Inventory: Photo Log	Method of Inventory: Field Inventory	Method of Inventory: Other	Unit of Measure	Is feature condition assessed? Yes	Is feature condition assessed? No	Is the data entered into a database? Yes	Is the data entered into a database? No
Environmental										
Storm Water Facilities	x			x			x		x	
Pipes*				x						
Ditches*				x						
Swales										
Filters										
Underground Tanks				x						
Vaults*										
Ponds				x						
Vegetation										
Landscape Area				x			x			x
Shrubs				x			x			x
Ground covers				x			x			x
Irrigation facility				x			x			x
Slopes and Slide Areas (Clear Zone)				x			x			x
Tree Groupings (Clear Zone)				x			x			x
Mulched Areas				x			x			x
Rock Outcropping (Clear Zone)				x			x			x
Safety										
Guardrails				x						x
Bridge Rails				x						x
Impact Attenuators				x						x
Jersey Barriers (Concrete) (Clear Zone)				x						x
Glare Screen (Clear Zone)				x						x
Utilities										
Underground Utilities (DOT)				x						x
Utility Poles (Clear Zone)				x						x

Minnesota DOT (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Utilities										
Franchise Permit Facilities				x				x		x
Emergency Generators								x		x
Electrical/ITS										
Luminaires (Illumination) (Clear Zone)				x						x
Junction Boxes (Clear Zone)				x						x
ITS Cabinet				x						x
Over-Height Detector				x						x
CCTV										
Data Stations (Clear Zone)				x						x
Highway Advisory Radio Towers (Transmitters)				x						x
Hubs										
Signals (Clear Zone)				x						x
Ramp Meter Cabinets				x						x
Variable/Changeable Message Signs (Portable)*				x						x
Variable/Changeable Message Signs (Permanent)*				x						x
Emergency Phone										
Under Bridge Deck Lighting				x						x
Bridge Electrical Control				x						x
Sign Lighters										
Navigation/Obstruction Lighting				x						x
Signs (Neon, Back Lit, Fiber)										
License Plate Reader										
Temperature Signs										
Crosswalk Flashers				x						x
Flashing Beacon				x						x
Weather Stations (RWIS)				x						x
Queue Detection				x						x
Gate Controller				x						x

Minnesota DOT (contd.)

Questionnaire Response (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Electrical/ITS										
Gate										
Facilities										
Holding & Parking Areas/Park & Rides										
Maintenance Yards				x						x
Landscape				x						x
Pavement				x						x
Trees				x						
Toll Booths										
Safety Rest Areas				x						x
Weigh Stations				x						x
Terminal Buildings (e.g. Ferries)										
Border Station										
Roadway										
Sidewalks*				x						x
Road Approaches				x						x
Driveway Crossings										
Rumble Strips (Clear Zone)				x						x
Milepost Paddles/Signs (Clear Zone)				x						x
Signs										
Signs*				x						x
Sign Support (Clear Zone)				x						x
Structures										
Noise/Sound Walls				x						x
Retaining Walls				x						x
Bridges				x						x
Railroad Crossings				x						x
Tunnels				x						x
Sidewalk Ramps*				x						x

Note:- "*" Object appears in multiple categories

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Structures										
Dolphins										
Wing walls				x						x
Towers										
Bridge Seat										
Transfer Span										
Apron										
Trestle										
Bulkhead/Seawall										
Overhead Loading										
Durable Marking/Striping										
Drainage Marking				x						x
Pavement Markings				x						x
Durable Pavement Markers				x						x
Monuments (Survey)				x						x

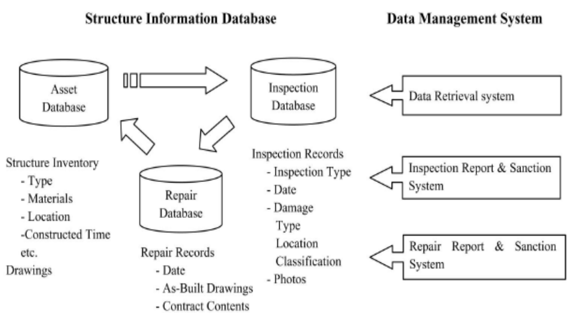
Hanshin Expressway Public Corporation (HEPC), Osaka, Japan

Maintenance Information Management System (MIMS)

- **Computerized database for processing and maintenance of bridge structure elements. Uses Life Cycle Cost (LCC) minimization rule for work prioritization**
- **Structure condition is expressed by a non-dimensional index value called Maintenance Control Index (MCI)**

$$\mathrm{MCI} = 10 - 1.51C^{0.3} - 0.3D^{0.7}$$

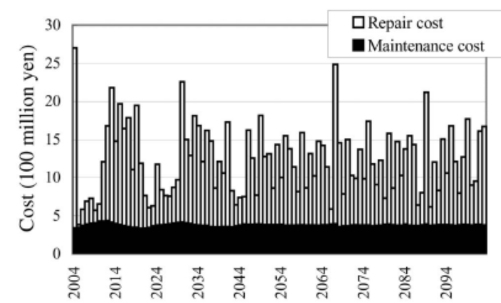
Where 'C' is the Cracking ratio (%) and 'D' is the rutting depth



MIMS Configuration

Cost

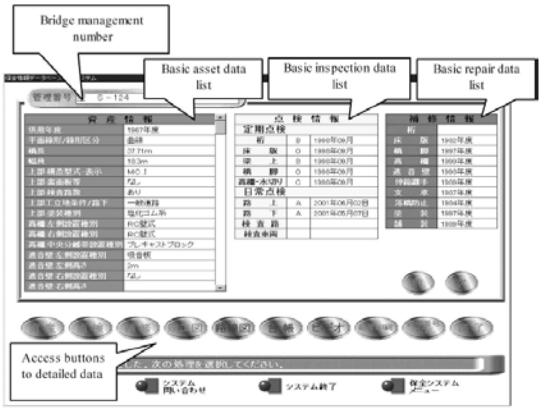
MCI	Maintenance unit price (yen/m^2)
10.0–9.0	31
8.9–8.0	50
7.9–7.0	71
6.9–6.0	90
5.9–5.0	109
4.9–4.0	129
3.9–3.0	148



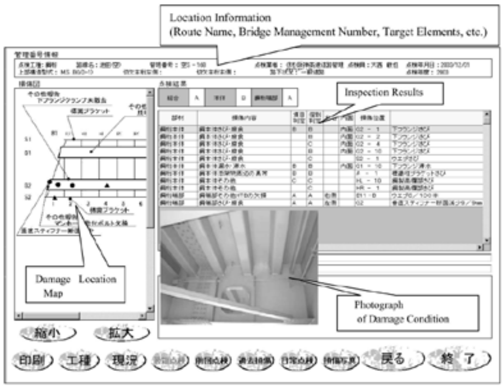
Current time value is 76.7 yen/vehicle-minute which is the typical cost –benefit assessment for highway projects in Japan

HEPC (Contd.)

Snapshots of MIMS Graphical User Interface



Example of Chart Information Retrieval



Example of Chart Information Retrieval

New Zealand Transit – MWH Global Ltd., Auckland, NZ

Roadside Asset Maintenance Management

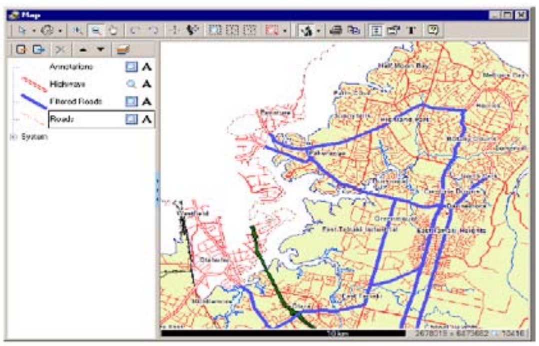
• Pocket RAMM is their jointly developed software program with MWH Global Ltd. & CJN Technologies. This program assigns all assets with GPS locations

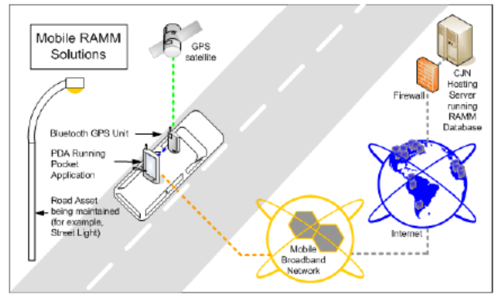
• Other forms of asset collection include a vehicle with calibrated terra trip meter locating route positions in meters from the start of the road to that position and offset side from center of that road

Cost

• For roadside data maintenance the yearly cost is about NZ$ 93,450. For data collection it is NZ$ 400 per road surveyed

• RAMM corporate license is available for initial cost of NZ$ 63,650 and an annual cost of NZ$ 13,570 + NZ$ 115 for every additional user





Software component of solution runs on PDA connected via mobile broadband connection (Telecom NZ, Vodafone NZ) and the internet to RAMM hosting server

Snapshot of Base Map layer of Pocket RAMM

New Zealand Transit (contd.)

Questionnaire Response

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Drainage										
Cross Culverts	✓			✓		No./Metres	Yes		Yes	
Culvert Ends (Clear Zone)					Included with culverts					
Catch Basins	✓			✓		number				
Approach Culverts					Included with culverts					
Ponds (Detention, Retention)*					Not collected in RAMM					
Detention Vaults*										
Dikes					Not collected in RAMM					
Ditches				✓		metres	Yes		Yes	
Oil/Water Separators					Not collected in RAMM					
Environmental										
Wetlands					Not collected in RAMM					
Riparian Zones					Unknown what Riparian zone is					
Regulatory Outfalls					Not collected in RAMM					
Pipes (Pipe Ends - Clear Zone)*					Not collected in RAMM					
Mitigation Sites					Not collected in RAMM					
Fish Passage Facilities (e.g. Ladders)					Not collected in RAMM					
Fish Barrier Facilities (e.g. Baffles)					Not collected in RAMM					
Stream Crossings				✓	Bridges Table	metres	Yes		Yes	
Wildlife Passage Facilities										
Environmental										
Storm Water Facilities				✓						
Pipes*				✓						
Ditches*				✓						
Swales				✓						
Filters										
Underground Tanks										
Vaults*										
Ponds										
Vegetation										
Landscape Area										
Shrubs										
Ground covers										
Irrigation facility										
Slopes and Slide Areas (Clear Zone)										
Tree Groupings (Clear Zone)										
Mulched Areas										
Rock Outcropping (Clear Zone)										
Safety										
Guardrails				✓						
Bridge Rails				✓						
Impact Attenuators				✓						
Jersey Barriers (Concrete) (Clear Zone)				✓						
Glare Screen (Clear Zone)										
Utilities										
Underground Utilities (DOT)										
Utility Poles (Clear Zone)				✓						

New Zealand Transit (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Utilities										
Franchise Permit Facilities										
Emergency Generators										
Electrical/ITS										
Luminaires (Illumination) (Clear Zone)										
Junction Boxes (Clear Zone)										
ITS Cabinet										
Over-Height Detector										
CCTV				✓						
Data Stations (Clear Zone)										
Highway Advisory Radio Towers (Transmitters)										
Hubs										
Signals (Clear Zone)										
Ramp Meter Cabinets										
Variable/Changeable Message Signs (Portable)*										
Variable/Changeable Message Signs (Permanent)*				✓						
Emergency Phone				✓						
Under Bridge Deck Lighting										
Bridge Electrical Control										
Sign Lighters										
Navigation/Obstruction Lighting										
Signs (Neon, Back Lit, Fiber)										
License Plate Reader										
Temperature Signs										
Crosswalk Flashers										
Flashing Beacon										
Weather Stations (RWIS)										
Queue Detection										
Gate Controller										
Roadway										
Sidewalks*				✓						
Road Approaches										
Driveway Crossings				✓						
Rumble Strips (Clear Zone)				✓						
Milepost Paddles/Signs (Clear Zone)										
Signs										
Signs*				✓						
Sign Support (Clear Zone)				✓						
Structures										
Noise/Sound Walls				✓						
Retaining Walls				✓						
Bridges				✓						
Railroad Crossings				✓						
Tunnels				✓	Part of Road section					
Sidewalk Ramps*										

New Zealand Transit (contd.)

Questionnaire Response (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Structures										
Dolphins										
Wing walls										
Towers										
Bridge Seat										
Transfer Span										
Apron										
Trestle										
Bulkhead/Seawall										
Overhead Loading										
Durable Marking/Striping										
Drainage Marking										
Pavement Markings				✓						
Durable Pavement Markers										
Monuments (Survey)										
Fire Hydrants (Clear Zone)				✓						
Fence (Clear Zone)				✓						

City of Hamilton, Ontario, Canada

Asset Management

• Features that are video/photo-logged include – concrete & granular pavement, trees (individual), signs, signposts, storm water drains etc.

• 6300 lane kilometers / 2700 center-lane kilometers

• Commercial vendors for data collection & post-processing include:

- Stantec Consulting
- Infrastructure Management Systems
- Roadware Corporation

• GPS data collected for every 30m intervals

Project Costs

• Cumulative quote for pavement data collection is C$ 226,000; 5 years back it used to be C$ 350,000. That comes up to US$ 50.50 per lane mile annually.

• Hansen Software – Pavement module costs about C$ 90,000 annually

Drawbacks - Hansen

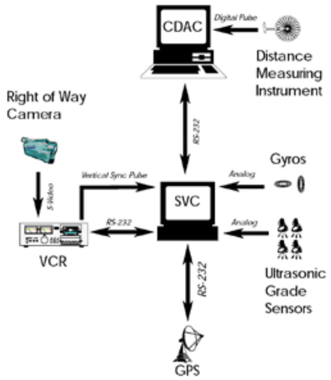
• It's based on block-by-block segmentation unlike dynamic segmentation that is needed for freeways

• The analytical module of the software does not meet maintenance standards

• Work-order based database and hence the automatic updating of maintenance data is not possible

• Poor technical support

City of Hamilton (contd.)



Schematic of information flow b/w Central Data Acquisition Computer (CDAC), Smart Video Controller (SVC) computer, Video Tape Recorder (VTR) and various sensors

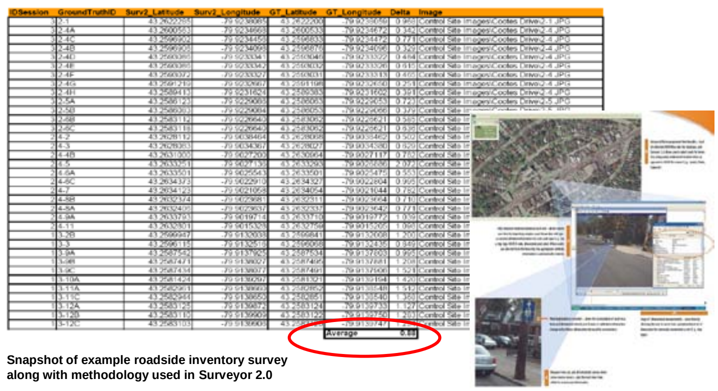
Mobile Highway Inventory and Measurement System

Surveyor 2.0 Features:

- Measures from any camera view
- Records pixel registration
- Cost Effective and Safe
- A GASB 34 inventory solution

ARAN (Automatic Road Analyzer) Data Item List

- **Digital Videolog**
  - o Single/Multi Camera
  - o Image capture interval - 1/500th of a mile
- **Mobile Mapping**
  - o Accuracy levels – Sub-Meter
- **Asset Management**
  - o Roadside asset inventories extracted from calibrated videolog images
  - o Inventories contain type, location (GPS & Linear), condition, measurement, unique identifiers etc.
  - o Data outputs can be formatted for subsequent import into a GIS/Asset Management Software
- **Road Geometry**
  - o Longitudinal Grade



Snapshot of example roadside inventory survey along with methodology used in Surveyor 2.0

City of Hamilton (contd.)

Applications

- Assess pipe conditions and trouble-shoot problematic culverts and storm lines
- View condition of bridges, tunnels and pole structures (initially scaffolding and bucket trucks being used)

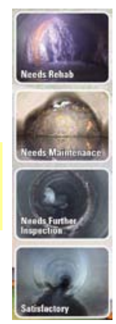
Advantages

- Eliminate cost and danger of personnel crawling into lines
- GIS/CAD compatible
- Looks 75-250’ down 6-60” diameter sewer and/or storm water lines
- Ideal for easements, remote areas
- 216:1 color zoom video camera
- Add-on to any concept utility vehicle

System

CCTV Camera

Sample Application Shots



Inventory Condition Deductions

City of Redding, California

Mobile GIS for Storm Water Infrastructure Inventory & Inspection

• Storm Drain Division (SSD) need for route maps and linking form-based data collection to inlet ID's for result-based maps started this pilot project

• 6250 inlets & 1480 outfalls

• Mobile GIS considered to reduce paper maps for field crew

Project Costs

• Total equipment cost came up to US$ 6,900 in first year which includes – 2 units of iPAQ's, ruggedized cases, ArcPad licenses & auto-chargers, 12 hours of consultant/training time, additional custom programming. This leads to US$ 0.75 per inlet/outfall/channel inspected.

• Considering labor (2-man crew with vehicle) the total savings over the first year was US$ 11,000 over manual methods.

Equipment

• iPAQ with ArcPad license in a ruggedized case

• GIS workstation running ArcPad on left and ArcGIS on right

City of Redding (contd.)

Ongoing/Completed Mobile GIS Projects

- **Street Tree Inventory**
- **Traffic Control Devices (Sign) Inventory (using GPS)**
- **Channel Inspection**
- **Outfall Inspection**
- **Roadside Ditch Inventory**
- **Backflow Prevention Device Collection**
- **Pavement Marking Collection**
- **Valve Turning/Inspection**
- **Hydrant Flushing/Inspection**
- **Commercial Meters Collection**

City of Redding (contd.)

Questionnaire Response

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory						Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other	Unit of Measure	Yes	No	Yes	No
Drainage										
Cross Culverts				X	X		X		X	
Culvert Ends (Clear Zone)	X		X	X	X		X		X	
Catch Basins				X	X		X		X	
Approach Culverts				X	X		X		X	
Ponds (Detention, Retention)*			X	X	X		X		X	
Detention Vaults*										
Dikes										
Ditches				X	X		X		X	
Oil/Water Separators										
Environmental										
Wetlands										
Riparian Zones										
Regulatory Outfalls				X	X		X		X	
Pipes (Pipe Ends - Clear Zone)*										
Mitigation Sites			X		X					
Fish Passage Facilities (e.g. Ladders)										
Fish Barrier Facilities (e.g. Baffles)										
Stream Crossings										
Wildlife Passage Facilities										

Note:- "*" Object appears in multiple categories

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory						Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other	Unit of Measure	Yes	No	Yes	No
Environmental										
Storm Water Facilities										
Pipes*				X	X		X		X	
Ditches*				X	X		X		X	
Swales				X	X		X		X	
Filters										
Underground Tanks										
Vaults*										
Ponds				X	X		X		X	

City of Redding (contd.)

<u>Questionnaire Response</u> (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory						Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other	Unit of Measure	Yes	No	Yes	No
Electrical/ITS										
Gate										
Facilities										
Holding & Parking Areas/Park & Rides										
Maintenance Yards										
Landscape										
Pavement										
Trees										
Toll Booths										
Safety Rest Areas										
Weigh Stations										
Terminal Buildings (e.g. Ferries)										
Border Station										
Roadway										
Sidewalks*										
Road Approaches										
Driveway Crossings										
Rumble Strips (Clear Zone)										
Milepost Paddles/Signs (Clear Zone)										
Signs										
Signs*	X			X	X		X		X	
Sign Support (Clear Zone)	X			X	X		X		X	
Structures										
Noise/Sound Walls										
Retaining Walls										
Bridges				X	X		X		X	
Railroad Crossings										
Tunnels										
Sidewalk Ramps*					X					
Structures										
Dolphins										
Wing walls										
Towers										
Bridge Seat										
Transfer Span										
Apron				X	X		X		X	
Trestle										
Bulkhead/Seawall										
Overhead Loading										
Durable Marking/Striping										
Drainage Marking										
Pavement Markings										
Durable Pavement Markers										
Monuments (Survey)										
Fire Hydrants (Clear Zone)				X	X		X		X	
Fence (Clear Zone)										

Sacramento County, California

Questionnaire Response & Program Highlights

- **Asset Inventory features consists of – culverts, signs, bridges, landscape, signals, sidewalks, streetlights and trees**
- **Commercial database being used is from Hansen Technologies and Oracle 8.x**

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory						Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other	Unit of Measure	Yes	No	Yes	No
Drainage										
Cross Culverts				X		lf	x		x	
Culvert Ends (Clear Zone)				x						
Catch Basins										
Approach Culverts										
Ponds (Detention, Retention)*										
Detention Vaults*										
Dikes										
Ditches				x		lf	x			x
Oil/Water Separators										
Environmental										
Wetlands										
Riparian Zones										
Regulatory Outfalls										
Pipes (Pipe Ends - Clear Zone)*										
Mitigation Sites										
Fish Passage Facilities (e.g. Ladders)										
Fish Barrier Facilities (e.g. Baffles)										
Stream Crossings										
Wildlife Passage Facilities										
Environmental										
Storm Water Facilities										
Pipes*				x		lf	x		x	
Ditches*										
Swales										
Filters										
Underground Tanks										
Vaults*										
Ponds										
Vegetation										
Landscape Area				x		sf		x		
Shrubs				x		sf		x		
Ground covers				x		sf		x		
Irrigation facility				x						
Slopes and Slide Areas (Clear Zone)										
Tree Groupings (Clear Zone)										
Mulched Areas										
Rock Outcropping (Clear Zone)										
Safety										
Guardrails										
Bridge Rails				x		lf	x		x	

Sacramento County (contd.)

Questionnaire Response (contd.)

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Utilities										
Franchise Permit Facilities										
Emergency Generators										
Electrical/ITS										
Luminaires (Illumination) (Clear Zone)				x		ea		x		
Junction Boxes (Clear Zone)										
ITS Cabinet				x		ea		x		
Over-Height Detector										
CCTV										
Data Stations (Clear Zone)										
Highway Advisory Radio Towers (Transmitters)										
Hubs										
Signals (Clear Zone)										
Ramp Meter Cabinets										
Variable/Changeable Message Signs (Portable)*										
Variable/Changeable Message Signs (Permanent)*				x		ea		x		
Emergency Phone										
Under Bridge Deck Lighting										
Bridge Electrical Control										
Sign Lighters										
Navigation/Obstruction Lighting										
Signs (Neon, Back Lit, Fiber)										
License Plate Reader										
Temperature Signs										
Crosswalk Flashers				x		ea	x		x	
Flashing Beacon				x		ea	x		x	
Weather Stations (RWIS)										
Queue Detection				x		ea	x		x	
Gate Controller										
Roadway										
Sidewalks*				x		sf	x		x	
Road Approaches										
Driveway Crossings										
Rumble Strips (Clear Zone)										
Milepost Paddles/Signs (Clear Zone)										
Signs										
Signs*				x		ea	x		x	
Sign Support (Clear Zone)										
Structures										
Noise/Sound Walls										
Retaining Walls										
Bridges				x		ea	x		x	
Railroad Crossings										
Tunnels										
Durable Marking/Striping										
Drainage Marking				x		ea	x		x	
Pavement Markings				x		lf	x		x	
Durable Pavement Markers				x		varies	x		x	
Monuments (Survey)										
Fire Hydrants (Clear Zone)										
Fence (Clear Zone)										

Orange County, California

Questionnaire Response & Program Highlights

• No county-wide established Asset Management program for inventories

• Commercial database used is MS Access 2000 on SQL Server

• Cost estimate for maintaining data varies between US$ 8,000 – 10,000 per month

9. Basic types of roadside variables/features/objects collected (Please check boxes in the row corresponding to each feature)	Method of Inventory					Unit of Measure	Is feature condition assessed?		Is the data entered into a database?	
	GPS	Video Log	Photo Log	Field Inventory	Other		Yes	No	Yes	No
Drainage										
Cross Culverts										
Culvert Ends (Clear Zone)										
Catch Basins				√		Each		√	√	
Electrical/ITS										
Crosswalk Flashers				√		Each	√		√	
Flashing Beacon				√		Each	√		√	
Roadway										
Sidewalks*				√		Linear Ft.		√	√	
Road Approaches										
Driveway Crossings										
Rumble Strips (Clear Zone)										
Milepost Paddles/Signs (Clear Zone)										
Signs										
Signs*				√		Each	√		√	
Sign Support (Clear Zone)										
Structures										
Noise/Sound Walls										
Retaining Walls										
Bridges				√		Each	√		√	
Railroad Crossings										
Tunnels										
Sidewalk Ramps*				√		Each	√		√	
Durable Marking/Striping										
Drainage Marking										
Pavement Markings				√						
Durable Pavement Markers				√						
Monuments (Survey)				√						

APPENDIX B
GVIZ USERS GUIDE

Introduction

This appendix discusses the general operation of the gviz application. Appendix B is tailored for users interested in visualizing the Caltrans Culvert Database.

Basic Concepts

The following terms and concepts are used below and in Appendix B.

- **Data layer**: is associated with a single data source. Creation of a new data layer is performed by pressing one of the buttons in Figure 30, labeled ‘Culvert Layer,’ ‘CSV,’ ‘ODBC’, etc. The listbox shown in Figure 30 contains data layers. Pressing the ‘Configure…’ button (see Figure 30) opens the data layer configuration dialog box (Figure 31), which is used to specify data layer attributes for the current data layer. The gviz application combines visual output from each data layer into a single visual report. In the generated visual report, a data layer is synonymous with a folder.
- **Data source**: may be a spreadsheet (e.g. guard_rails.xls), a culvert database (e.g. D4_backend.mdb), a CSV file, ODBC source, etc. A single data source is associated with a single data layer.
- **Visual report**: a single Google Earth KMZ file produced by gviz is a visual report. A visual report contains multiple data layers (folders), which can be seen in the pane on the left within Google Earth.
- **KMZ/KML**: By default, gviz produces KMZ files, which are compressed (zipped) KML files. KML files may be produced by manually naming the output file with a “kml” extension.

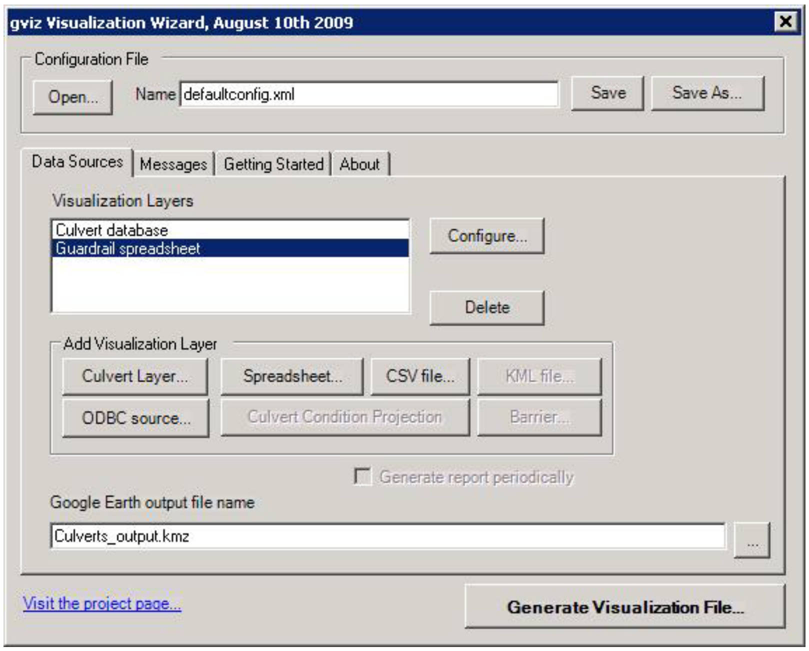


Figure 30: gviz Application Main Form

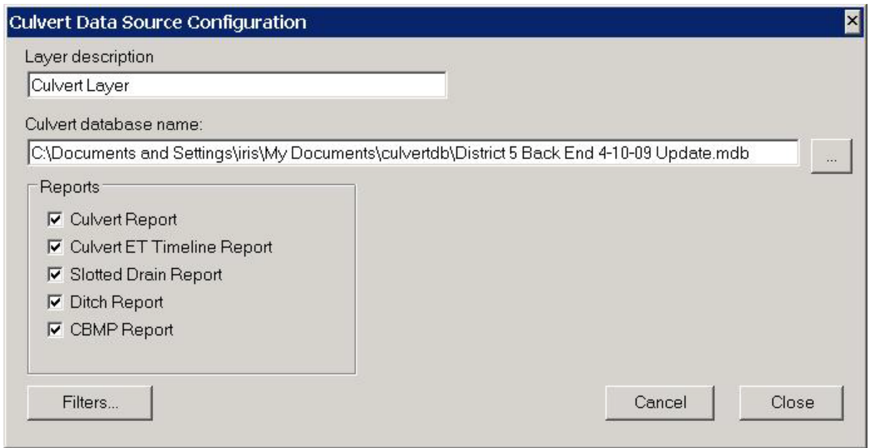


Figure 31: gviz Culvert Data Source Configuration Form

Distributing Visual Reports

Visual reports generated by the gviz application are in the form of KMZ files. These files may be emailed or copied to memory sticks for distribution. They are independent of the original data source (e.g. Culvert database, spreadsheets, etc.) and may be distributed freely (the exception to this are photos from the Culvert photo directory structure—see below). The only requirement for viewing visual reports is the installation of Google Earth on the user's computer. A web browser and Google Maps may also be used to view KMZ files (see Figure 34).

<u>Visualizing Spreadsheets</u>

The gviz application can directly read spreadsheet files (.xls). The spreadsheet must follow these conventions:

- There should be no blank columns.
- Column headers should be in a single row.
- Any number of columns can be read.
- Point locations must be specified with a latitude, longitude, and optional altitude. The longitude and latitude must be in decimal format, for example -123.747, 41.9667. Note that longitude is negative east of Greenwich, UK.
- Geometric data can be stored as a point per row, or a multi-segmented line per row. An entire spreadsheet must use either of these representations. Line and point data can not be mixed within a single spreadsheet. To combine line and point data, use separate layers—one for points, one for lines.

Point Data in Spreadsheets

A spreadsheet that contains point data is read assuming one point per row, in addition to the column title row. Dedicated columns for latitude and longitude are required. An altitude column is optional. In addition, gviz can perform rectangular coordinate conversion from UTM zones 10 and 11 into WGS84 latitude and longitude. The type of coordinate system is specified in the data layer configuration form. In addition, this same form is used to specify the column names of longitude (X), latitude (Y), and altitude columns.

Line Data in Spreadsheets

A spreadsheet that contains multi-segmented line data is read assuming one multi-segmented line per row, in addition to the column title row. A single cell is used to specify the multi-segmented line. The line is specified in the cell using multiple points, each separated with a space. The following format is used for each point: longitude, latitude, altitude. The altitude (and prefixed comma) is optional. At least 2 points must be specified.

Line and Point Attributes in Spreadsheets

All columns in the spreadsheets not used for geometric data are assumed to be line or point attributes. These attributes will show up in the KML balloon for each point and line when the user clicks them.

Getting Started Visualizing a Spreadsheet

1. Start the gviz application.
2. Click the 'Data Sources' tab (see Figure 30).
3. Click the 'Spreadsheet…' button to add new data layer.
4. Click the 'Configure…' button, which will open the 'Configure Spreadsheet Data Source' form, which is shown in Figure 32.
5. Specify the spreadsheet name, and the names of the column header in the spreadsheet that contain the longitude, latitude, and optional altitude.
6. Close the 'Configure Spreadsheet Data Source' form.
7. In the main gviz form on the 'Data Sources' tab, specify a visualization report output file name.
8. Click the 'Messages' tab and then the 'Generate Visualization File…' button on the main gviz form shown in Figure 30. Information messages will be displayed in the 'Messages' tab as the report is generated. Warning messages are also displayed in this same tab. See the section below for further information.
9. When report generation is complete, open the file in Google Earth. Figure 33 shows the Caltrans WiFi spreadsheet visualized in Google Earth. Figure 34 shows the same spreadsheet visualized within Google Maps.
10. Note that the generated report can be further customized—see the Customizing Visual Reports section.

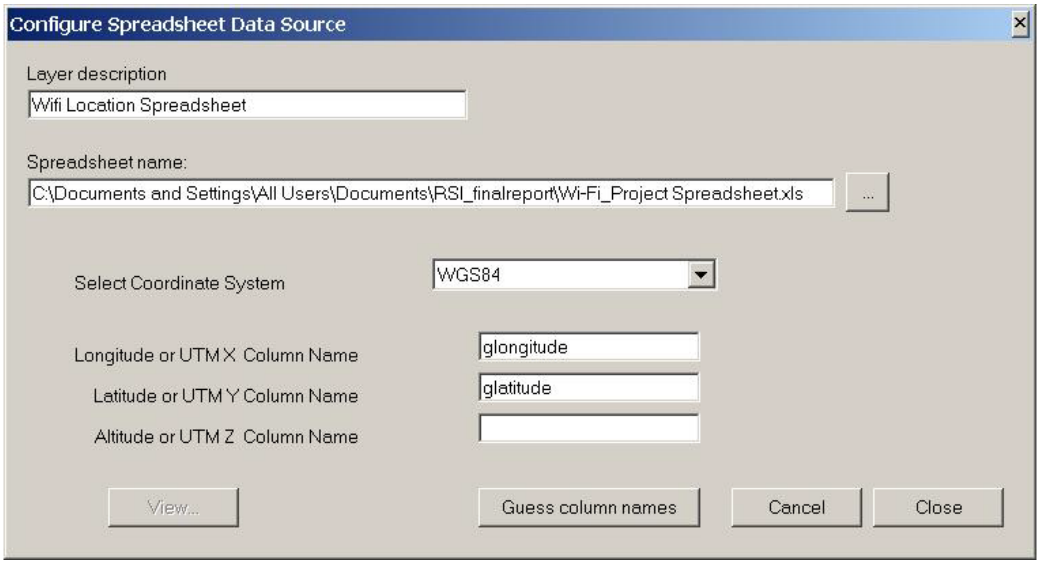


Figure 32: Spreadsheet Data Source Configuration Form

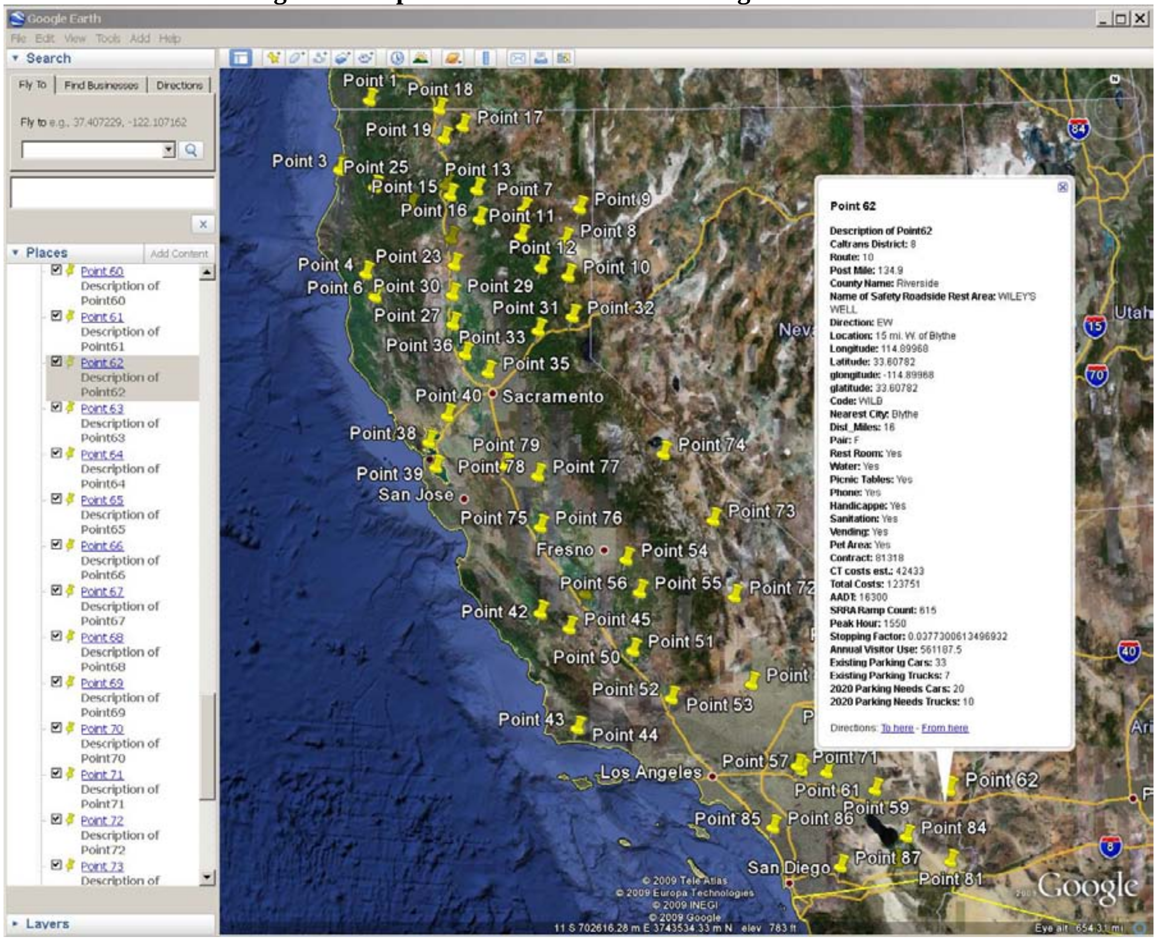


Figure 33: Caltrans WiFi Spreadsheet Visualized

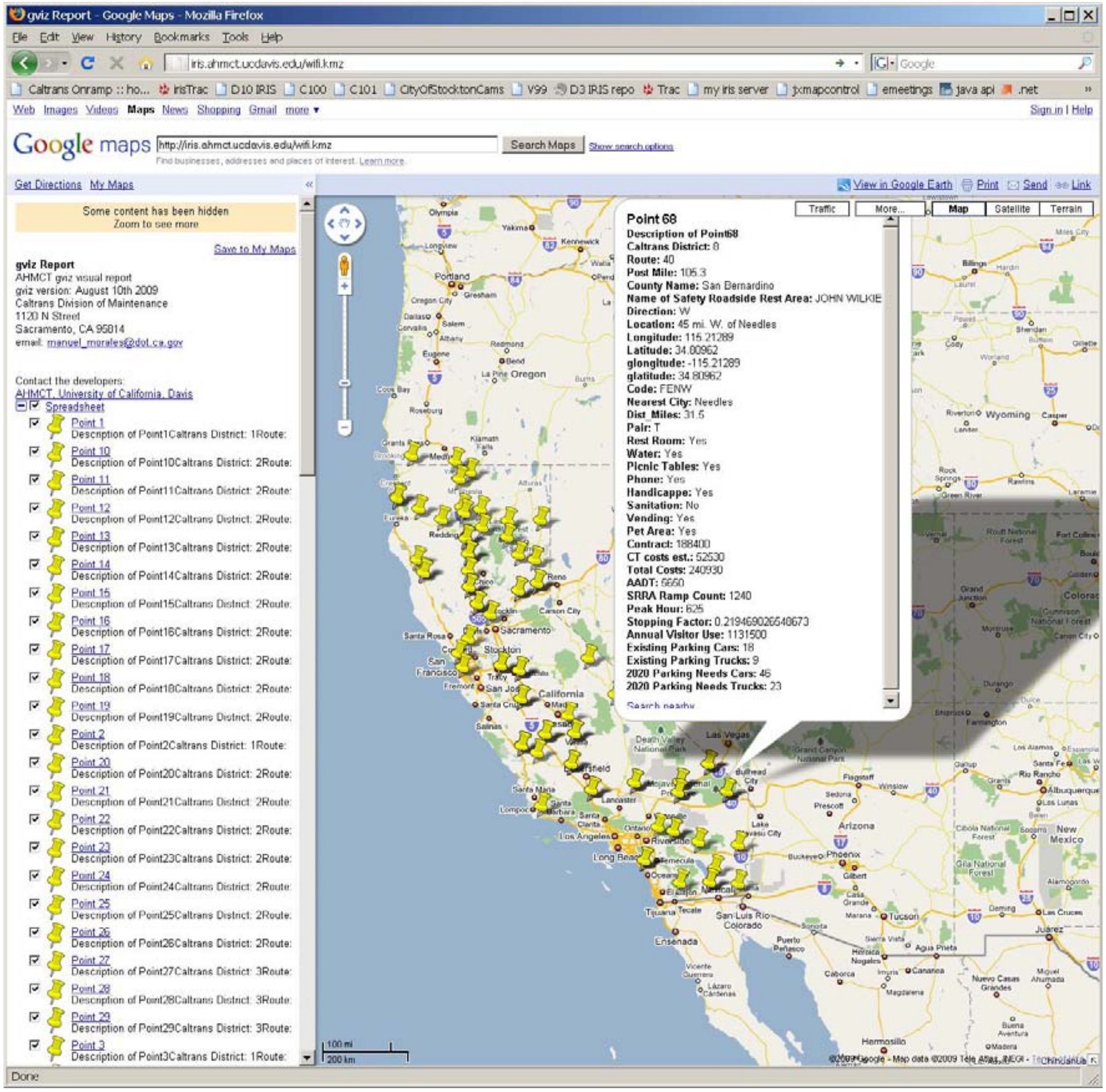


Figure 34: Caltrans WiFi Spreadsheet Visualized in Google Maps

Visualizing Data in CSV Files

A text file that contains comma separated values (CSV) can be read by gviz. Each row is assumed to contain a single point, specified in latitude, longitude, and optional altitude columns. Data in other columns are assumed to be point attributes and will be displayed within each placemark's balloon within the generated KML file.

Visualizing Data from ODBC Sources

The gviz application has the ability to read from data sources defined within the Windows 'ODBC Data Source Administrator' application. This application is bundled with Windows and enables users to define a data source by name. There are dozens of existing ODBC drivers that connect spreadsheets, databases, and other applications. A SQL statement is used to define a query which retrieves a data table which gviz then renders as a visualization table. Data in other columns are assumed to be point attributes and will be displayed within each placemark's balloon within the generated KML file.

Visualizing Data from the Caltrans Culvert Database

See Appendix C for the gviz Culvert Visualization Users Guide.

Notes and Tips

- There is a practical limit for the size of generated KMZ files. Typically, KMZ files larger than a megabyte cause problems with Google Earth, causing to perform very poorly. Use caution when creating large KMZ files. If a generated KMZ file is too large, break it down using the filter function into smaller files.
- The geospatial placemarks and lines within visual reports are turned off by default. When you load a gviz report into Google Earth, you must click each layer on to view the contents of that report or folder.

Customizing Visual Reports

Reports generated by the gviz application can be customized using:

1. Google Earth (see Figure 35),
2. Text editors to manually edit the generated KML files,
3. XML processing applications.

Customization of generated KMZ and KML files can include:

- Changing the default placemark or using a customized icon (see Figure 35).
- Changing the size, color, and label for a placemark.
- Changing the textual information in the balloon associated with a line or placemark.
- Adding photos or other images to balloons (see Figure 21 for an example of photos inside balloons).
- Adding new folders to the existing KML file to include additional information layers of spatial information.
- Adding a live data link to an existing KML server. This allows periodic refreshing of real-time data. For example, live traffic data. See **Error! Reference source not found.** for an example of linking real-time data (Doppler Radar).

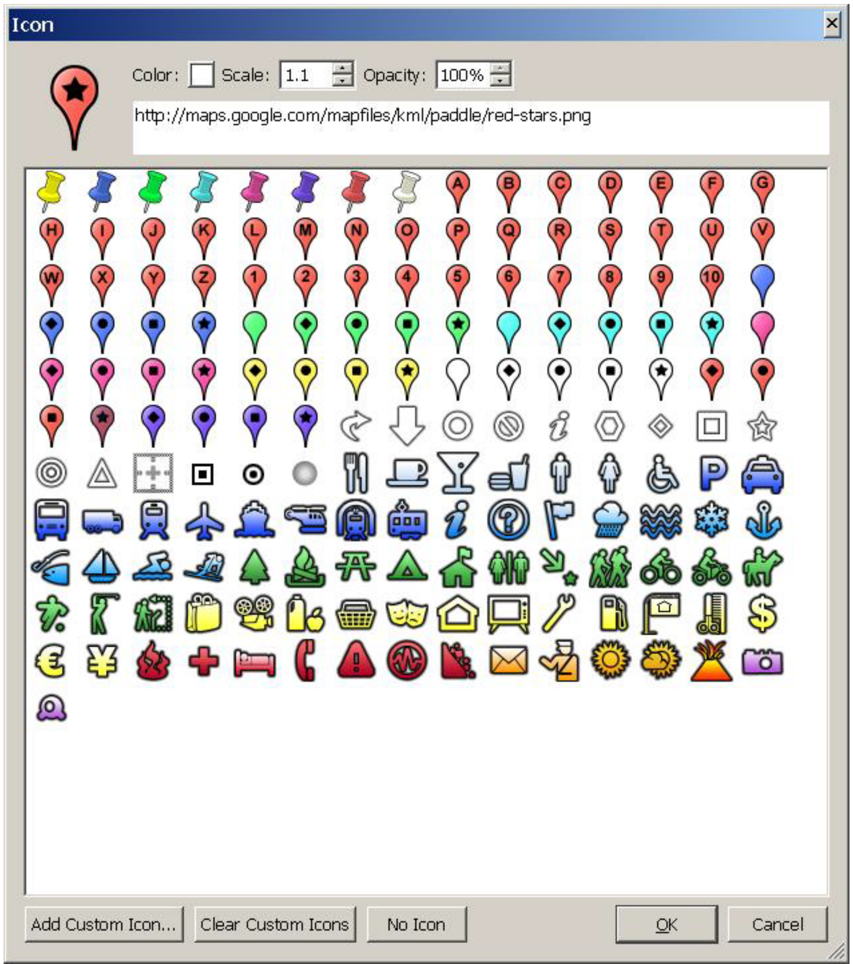


Figure 35: Customizing Visual Reports Using Google Earth

APPENDIX C

CULVERT DATABASE VISUALIZATION USERS GUIDE

Introduction

The gviz application can be used to visualize the contents of the Caltrans Culvert database. The following predefined reports are available and are activated on the layer configuration form:

- General culvert visualization report, which depicts
  - Culvert condition using color codes.
  - Inspection photos are embedded within attribute balloons, and stored in the local file system.
  - Culvert attributes displayed on balloons, per culvert.
  - End treatment attributes specified on balloons, per end treatment.
  - End treatment condition using color codes.
  - Flow direction is indicated with icon orientation.
  - End treatment numbering.
  - End treatments depicted using Caltrans specific icons.
  - Clickable end treatments, providing a balloon that contains.
- Culvert end treatment timeline visualization report, which depicts culvert end treatment inspections over time. This report uses the Google Earth timeline feature, which links a spatial end treatment location with an inspection date.
- Slotted drain visualization report.
- Ditch visualization report.
- CBMP visualization report.

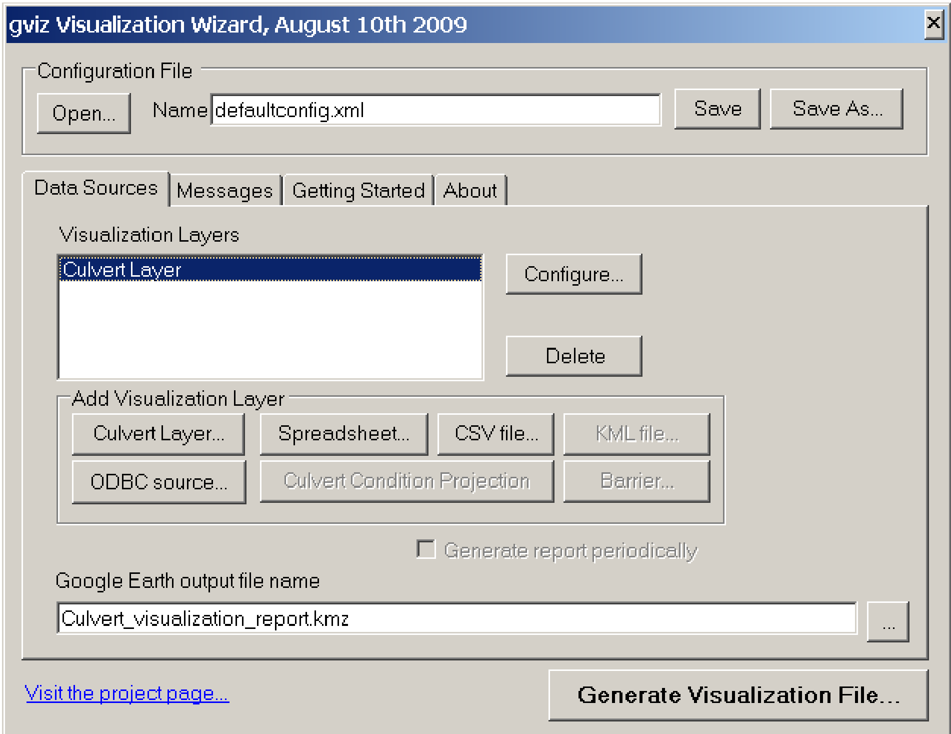


Figure 36: gviz Culvert Visualization Main Form

Getting Started

Figure 36 shows the main gviz form that appears when the application is started. Culvert database visual reports can contain any combination of 1) General culvert reports, end treatment timeline reports, slotted drain reports, ditch reports, and CBMP reports. These can be combined with other data layers, for example spreadsheets. There are several important controls to notice:

- Data Sources tab: the leftmost tab is labeled ‘Data Sources’ and is used to manage multiple data sources (layers) within a single visualization report.
- Visualization Layers listbox: within the ‘Data Sources’ tab, this listbox shows all data layers within the current report.

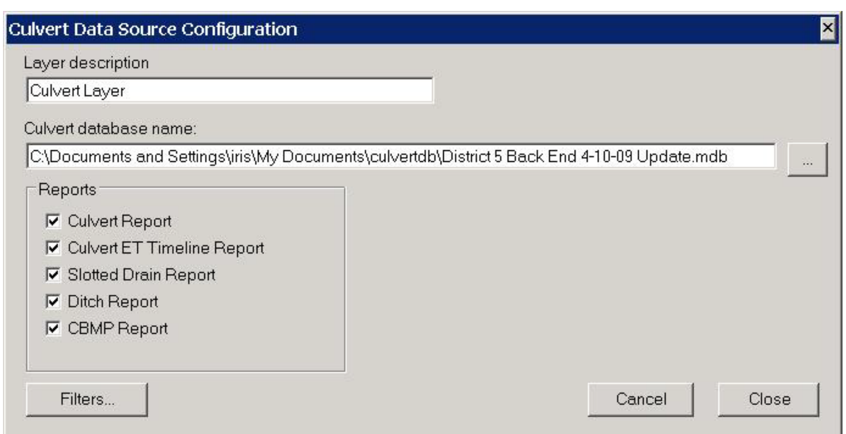


Figure 37: gviz Culvert Data Source Configuration Form

Creating a General Culvert Visual Report

To create a general culvert visual report, follow the steps below. Keep in mind that the layer that will be defined by the steps below can be combined with other visualization layers from spreadsheets, CSV files, and other culvert layers. Sample reports are shown in **Error! Reference source not found.**, Figure 19, **Error! Reference source not found.**, Figure 21, **Error! Reference source not found.**, and **Error! Reference source not found.**.

1. Start the gviz application.
2. Click the 'Data Sources' tab (see Figure 36).
3. Click the 'Culvert Layers…' button to add new data layer.
4. Click the 'Configure…' button, which will open the 'Culvert Data Source Configuration' form, which is shown in Figure 37.
5. Specify a culvert database name for the culvert backend database.
6. In the 'Reports' group box, select the desired report type. In this case, select 'Culvert Report checkbox.
7. Click the 'Filters…' button, which will open the 'Visualization Filter' form, which is shown in Figure 38.
8. Select the counties you would like to generate the report for. See the note below regarding KMZ file size in the 'Notes' section. The county list is queried from the database each time the form is opened.
9. Close the 'Visualization Filter' form.
10. Close the 'Culvert Data Source Configuration' form.
11. In the main gviz form on the 'Data Sources' tab, specify a visualization report output file name.
12. Click the 'Messages' tab and then the 'Generate Visualization File…' button on the main gviz form shown in Figure 36. Information messages will be displayed in the 'Messages' tab as the report is generated. Warning messages are also displayed in this same tab. See the section below for further information.
13. When report generation is complete, open the file in Google Earth.
14. Note that the generated report can be further customized—see the Customizing Visual Reports section.

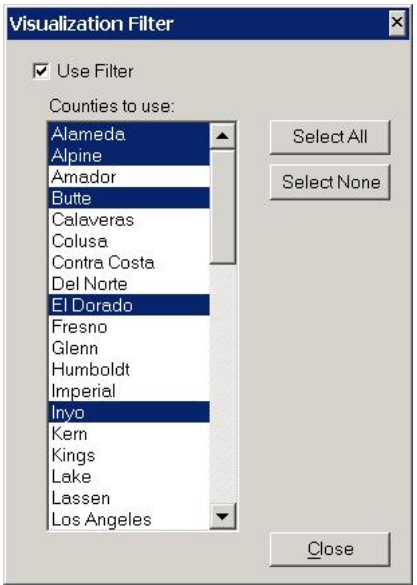


Figure 38: gviz Culvert Filter

Creating a Culvert End Treatment Timeline Report

The End Treatment Timeline report depicts end treatment inspections over time. A sample report is shown in **Error! Reference source not found.**. This report depicts the rate of end treatment inspection within a geographic area. To create the report, follow the steps in 'Creating a General Culvert Visual Report' and in step 6, click the 'Culvert ET Timeline Report' checkbox.

After the report is loaded into Google Earth, the time line control will appear in the upper left corner of the screen (See **Error! Reference source not found.**). This control contains a play button, and when pressed, Google Earth will incrementally step through time, turning on each end treatment placemark when its inspection date arrives. The report therefore visually shows inspections as the time control moves through time. The minimum and maximum time depicted on the time control is a function of the earliest and latest inspection date which was read from the database.

Creating a Slotted Drain Report

A culvert database slotted drain report is shown in Figure 39. To create the report, follow the steps in 'Creating a General Culvert Visual Report' and in step 6, click the 'Slotted Drain Report' checkbox.

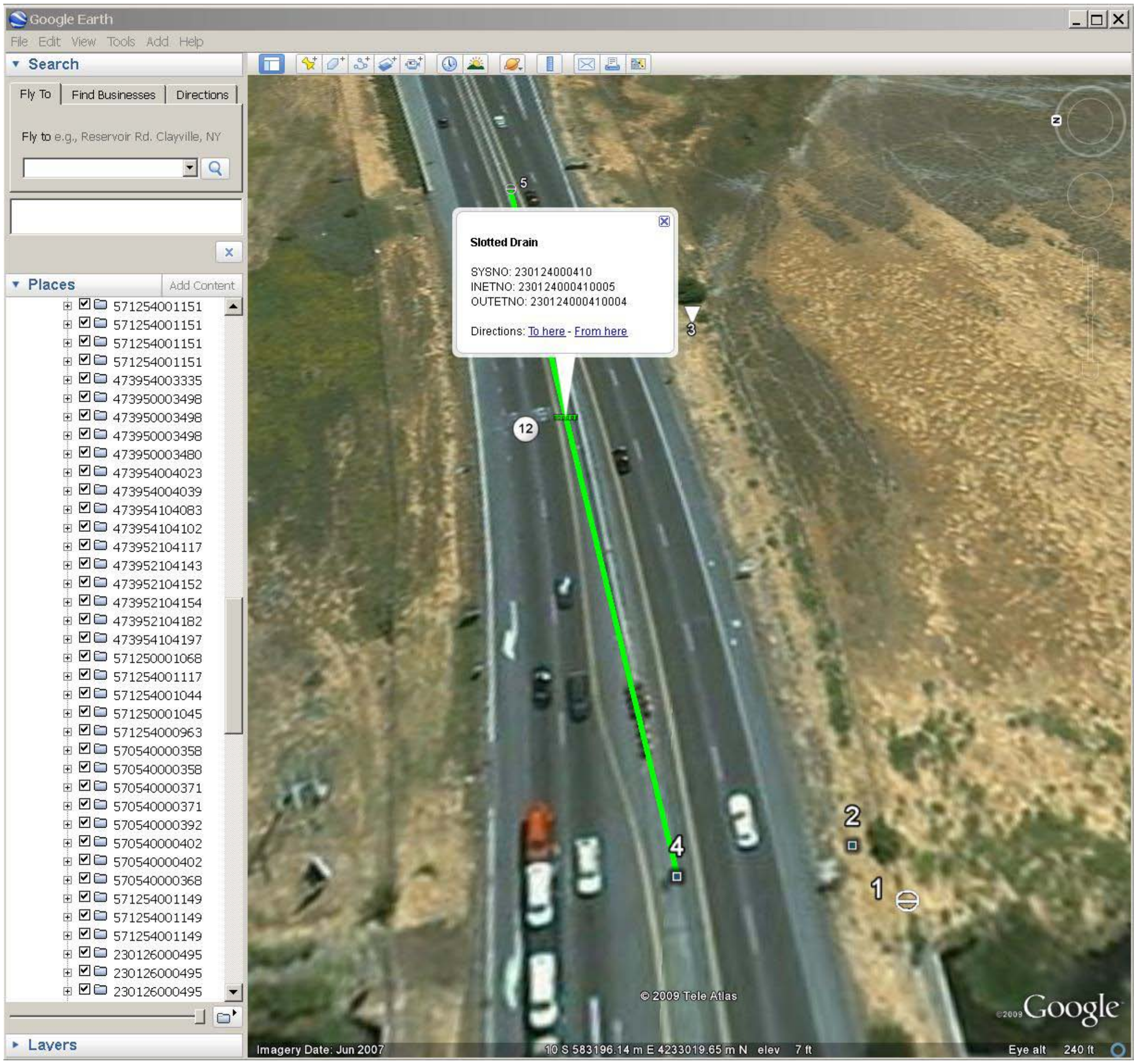


Figure 39: Culvert Slotted Drain Report

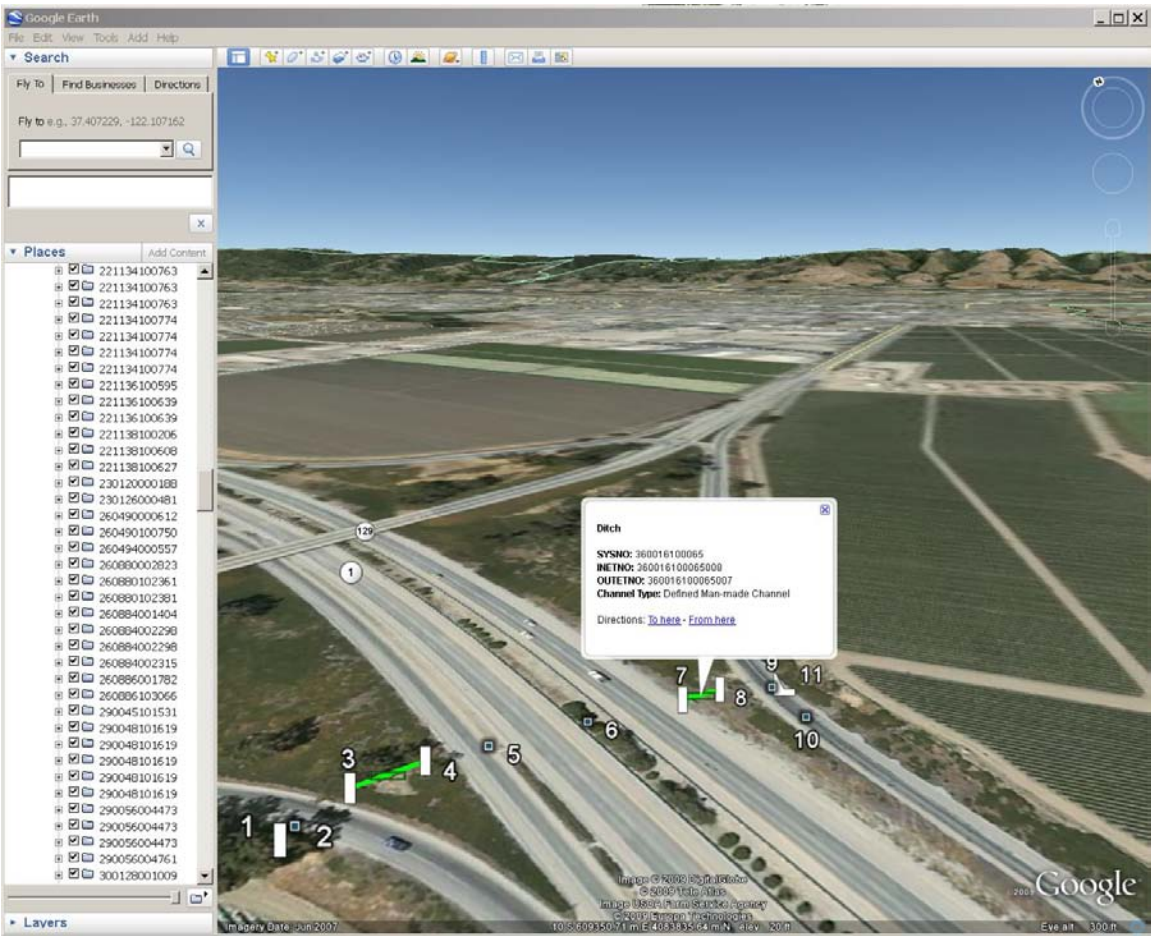


Figure 40: Ditch Visual Report

Creating a Ditch Report

A culvert database ditch report is shown in Figure 40. To create the report, follow the steps in 'Creating a General Culvert Visual Report' and in step 6, click the 'Ditch Report' checkbox.

Creating a CBMP Report

A culvert database ditch report is shown in Figure 41. To create the report, follow the steps in 'Creating a General Culvert Visual Report' and in step 6, click the 'CBMP Report' checkbox.

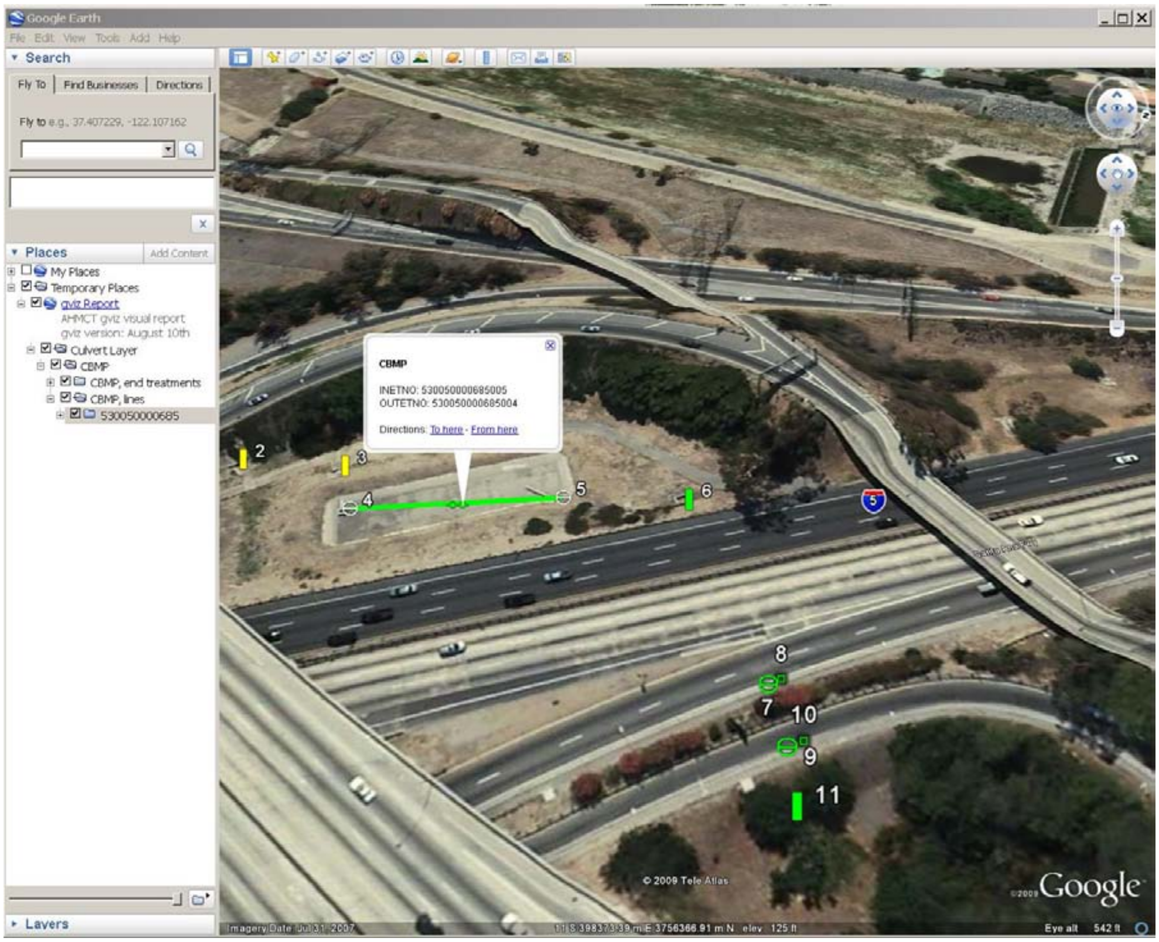


Figure 41: CBMP Visual Report

Information and Warning Messages Tab

The ‘Messages’ tab on the main gviz form (see Figure 30) displays information and warning messages during the generation of a visualization report. This may be useful for as a way of validating database fields. A sample is shown below in which 3 date/time fields contain invalid dates.

```
0: Starting to generate report.
0.11: Writing KML file.
0.11: Opening the database: C:\Documents and Settings\iris\My
Documents\culvertdb\State-Wide BE 3-20-09.mdb
0.11: Performing database query for photo root.
0.14: Warning: column 'ET Photos' does not exist in the table.
0.14: Generating reports.
0.14: Generating Culvert report.
0.14: Generating Culvert End Treatments report.
0.14: Performing database query.
5.44: Processing 77,554 database rows.
7.73: Error while processing row. Colname=CollectionDate. Expected DateTime, instead:
. Row ignored.
7.73: Error while processing row. Colname=CollectionDate. Expected DateTime, instead:
. Row ignored.
8.38: Error while processing row. Colname=CollectionDate. Expected DateTime, instead:
. Row ignored.
```

```
8.66: Rows rejected by filters: 0
8.66: Rows accepted by filters: 77554
8.66: Done generating Culvert report.
8.66: Generating culvert assessment lines report.
8.66: Performing database query.
81.28: Processing 45,362 database rows.
87.17: Rows rejected by filters: 0
87.17: Rows accepted by filters: 45362
87.17: Done generating culvert assessment lines report.
87.17: Done generating Culvert culvert report.
87.17: Done generating Culvert Layer report.
87.72: KML File size: 113,528,625 bytes.
87.72: Creating KMZ file.
92.28: KMZ file size: 9,647,375 bytes.
92.28: Successful completion.
```