Transportation Asset Management Case Studies

Presented by

U.S. Department of Transportation
Federal Highway Administration

CULVERT MANAGEMENT SYSTEMS

Alabama, Maryland, Minnesota, and Shelby County

The need for better culvert management is apparent.

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Note From the Associate Administrator

With factors such as an aging and deteriorating national infrastructure, increasing congestion, highway safety challenges, and limited funds weighing heavily on transportation agencies, State departments of transportation are looking for innovative ways to manage their transportation dollars.

One tool that is providing great benefits is Transportation Asset Management (TAM), a strategic approach that strives to provide the best return for each dollar invested by maximizing system performance, improving customer satisfaction, and minimizing life-cycle costs.

TAM implementation varies from State to State and include the areas of bridge and pavement management, highway safety and operations, data integration, economics in asset management, life-cycle cost analysis, and network preservation, among others. TAM is also beginning to include often overlooked highway features such as sign structures, culverts, and retaining walls.

Because each State's experience is unique—and because the Federal Highway Administration believes that transportation agencies work more efficiently when information on one another's successes is shared—the Office of Asset Management is continuing its series of TAM case study reports begun in 2002.

On behalf of the Office of Asset Management, I am pleased to present this case study on culvert management systems (CMSs). Although sometimes included as part of bridge management systems, culverts are not always given the attention they require. This case study details the efforts and methods of three States and one local agency in implementing a CMS. I believe that this and other case studies generated by the Office of Asset Management will help transportation agencies meet the increasingly complex challenges facing them today.

King W. Gee
Associate Administrator for Infrastructure
May 2007

Note to the Reader

The Transportation Asset Management Case Study series is the result of a partnership between State departments of transportation (DOTs) and the Federal Highway Administration (FHWA) Office of Asset Management. FHWA provides the forum from which to share information, and the individual States provide the details of their experiences. For each case study report, FHWA interviewed State transportation staff, and the resulting material was approved by the State. As such, the reports rely on the agencies' own assessment of their experience. Readers should note that the reported results may or may not be reproducible in other organizations.

Executive Summary

State and local DOTs are responsible for a large number of highway assets. Many of these assets, such as bridges and pavements, are highly visible and have dedicated management systems. Highway agencies also have many less noticeable structures, such as culverts, that tend to go ignored until a catastrophic failure occurs. Unfortunately, several catastrophic failures have occurred across the United States, emphasizing the need for a culvert management system (CMS). Some States have utilized the CMS program developed by FHWA, while other States have created in-house programs to meet the specific needs of their area.

By taking a proactive role in managing culverts, States are preserving their investment in the transportation infrastructure and providing a safer roadway for the traveling public. Maryland, Minnesota, Alabama, and Shelby County (located in Alabama) use different methods to manage their culverts. This study explores their methods and offers information to agencies seeking new approaches to culvert management.

Maryland has divided the responsibility for its culverts based on size. Large culverts are the responsibility of Maryland's bridge unit, while small culverts are under the auspices of the State's roadway unit. Although Maryland no longer utilizes Pontis (a comprehensive bridge management system [BMS] tool), it applies the condition ratings from Pontis to its own in-house CMS for large culverts. Maryland has also developed a risk-based approach to selecting which structures receive priority for inspections, which helps to reduce inspection costs. For the smaller structures, the roadway unit uses a separate in-house inspection and rating system that incorporates geographic information system (GIS) tools.

Because of their potential for catastrophic failure, culverts require careful management.

Like Maryland, the Minnesota DOT divides the responsibility for its culverts between the bridge hydraulics unit and the roadway unit based on the size of the culverts. However, unlike Maryland, Minnesota uses Pontis along with element-level condition ratings to manage the larger culverts. The bridge hydraulics unit has developed an in-house GIS-based program called HYDINFRA, which is used for culverts and other types of drainage features, such as drop

inlets. The bridge hydraulics unit has also developed an inspection guide complete with condition rating language for use with HYDINFRA.

In Alabama, the DOT's maintenance bureau manages the State's culverts, and maintenance personnel inspect these structures on an as-needed basis. The current maintenance management system is scheduled to be updated in the near future, which could provide an excellent opportunity to develop an in-house system or commence use of a formal CMS.

Typically, Asset Management case studies focus on the activities of State DOTs rather than local agencies. However, the Shelby County Highway Department was found to have a very proactive approach to culvert management. While the county's inventory is not as large as that of a State DOT, Shelby County uses the FHWA CMS program. Shelby County has been a leader in the State of Alabama in promoting Asset Management on a county level and educating other counties using the program. Shelby County DOT has taken the initiative to partner with academia and industry and has utilized Asset Management principles to help determine budget and replacement priorities for highway structures in this fast-growing county.

This overview of the culvert management practices used by these DOTs is presented to show the importance of managing these drainage structures. It is also intended to help other State and local DOTs formulate and shape their Asset Management programs in ways that lead them to achieve their goals and performance measures efficiently and cost-effectively.

BACKGROUND

Asset Management is presently a key focus area for many transportation agencies in the United States and abroad. Asset Management merges quality asset data with well-defined objectives to help improve a transportation department's business process for resource allocation and utilization. In short, Asset Management is a strategic approach to managing transportation infrastructure.

The American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Asset Management defines Asset Management as *a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well-defined objectives.*[1]

Asset Management typically relies on data from the following management systems:

- Bridge management.
- Pavement management.
- Tunnel management.
- Ancillary structures management (i.e., sign structures, high-mast light poles, retaining walls, and roadway appurtenances).
- Information management.

This case study examines different types of CMSs used by State and county DOTs. The management systems include the Pontis BMS, the FHWA CMS, and a State-developed system.

In order to determine the characteristics of a well-functioning CMS, the study focuses on the following aspects:

- Inventory.
- Inspection.
- Management and documentation.
- Planning, budget, and decision-making methodology.

[1] http://www.transportation.org/sites/scoh/docs/Motion_Trans_Asset_Management.doc. Retrieved May 2, 2007.

Using a CMS assists a DOT not only in keeping track of its assets but also helps with prioritization of rehabilitation, repair, and replacement of structures. Prioritization in turn helps to optimize the use of the limited amount of funds a DOT may have available for culverts.

CASE STUDY

In reality, every DOT practices some form of Asset Management. However, the differences lie in the sophistication of data collection and management systems, and how they are employed in budgeting and decision-making processes.

Based on a questionnaire sent to FHWA division bridge engineers (see Figure 1), only 29 States have some sort of CMS, 8 report using Pontis, 13 are using an in-house program, and 8 are using some combination of systems for small structures and culverts under 20 ft in length. These combinations include using Pontis for some lengths and an in-house program for the remainder. Some in-house systems are quite sophisticated and include GIS capabilities, while some use simple spreadsheets and databases. Twenty-three of the States do not have a CMS. This case study highlights the use of different management systems in Maryland, Minnesota, Alabama, and Shelby County. The experiences of these transportation agencies are presented to encourage more States to implement culvert management.

FHWA CULVERT MANAGEMENT SYSTEM
(FROM THE USER'S MANUAL)

The FHWA CMS was developed in 2001 under the Local Technical Assistance Program to assist road agencies in managing their programs of culvert inventory and condition assessment and improvement. The purpose of this program is to provide a tool to facilitate the coordination of maintenance and repair or replacement operations on a system-wide basis.

The CMS formalizes and automates functions already performed by many agencies responsible for culverts. The program assists DOTs with:

- Recording the number and location of culverts for which the agency is responsible.

- Tracking the condition of the culverts.
- Determining what repairs are necessary to fix the culverts.
- Developing a long-term plan for repairs over the next 5 years.
- Formulating a schedule of work to be performed during the next year.

The CMS consists of five modules to aid the user in managing the inventory of culverts:

1. Inventory module.
2. Condition module.
3. Maintenance and Repair module.
4. Work Funding module.
5. Schedule module.

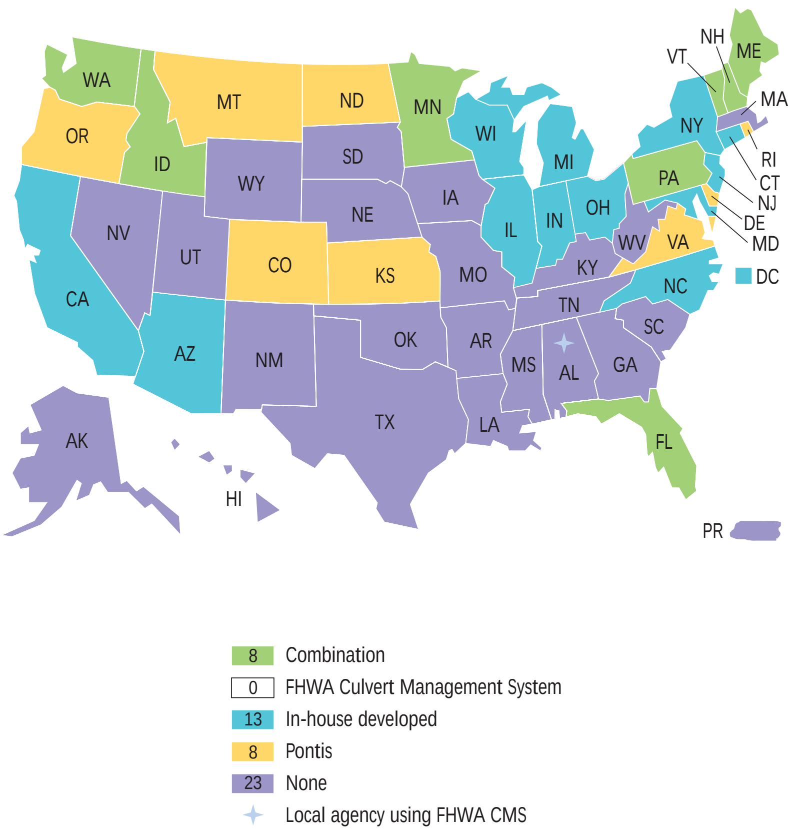

Figure 1. State usage of culvert management systems as of January 2007, based on a questionnaire sent to FHWA bridge engineers.

The Inventory module (see Figure 2) is a simple database storage and retrieval tool used primarily to supply information directly to users of the system and to other modules of the CMS. The inventory information is typically gathered from design and construction plans and from field verification and helps DOTs answer the question of "how many culverts do we have?" Information such as location, size, material type, and structure ID number is stored here. This module also allows users to enter new structures, delete structures that have been replaced, and obtain a detailed culvert description report. A search for culvert structure records can be performed in each module based on the culvert's unique structure ID.

The Condition module (see Figure 3) is used to enter and store information related to the condition of the culverts based on visual inspections. This information is used to develop work needs, costs, budgets, and schedules. The condition is rated on 17 different items, including inspection dates, overall condition rating, hydraulic adequacy, proposed repair types, and roadway condition. The inspection identifies the maintenance and rehabilitation activity to be performed to correct the condition in addition to the quantity of work required.

The Maintenance and Repair module (see Figure 4) develops the total work needs and costs for all work identified in the Condition module. This module has two parts:

1. Defining the work to be performed.
2. Developing the work needs and costs.

The work performed or maintenance and rehabilitation activities include items such as debris removal, scour hole repair, vegetation control, and joint sealing. The module then takes the work needs from the Condition module and applies unit costs to the work quantity.

The Work Funding module uses the work needs developed in the previous module to create a multi-year list of funded projects prioritized by repair type. The procedure uses a series of factors, defined by the user, that takes into account such items as priority, cost, remaining life, traffic, and hydraulic capacity to rank projects, and determines the projects that can be done that year using available funds. It also indicates the projects that cannot be undertaken due to lack of funding.

The Schedule module allows the user to schedule the programmed work for the year. The scheduling process takes the work programmed

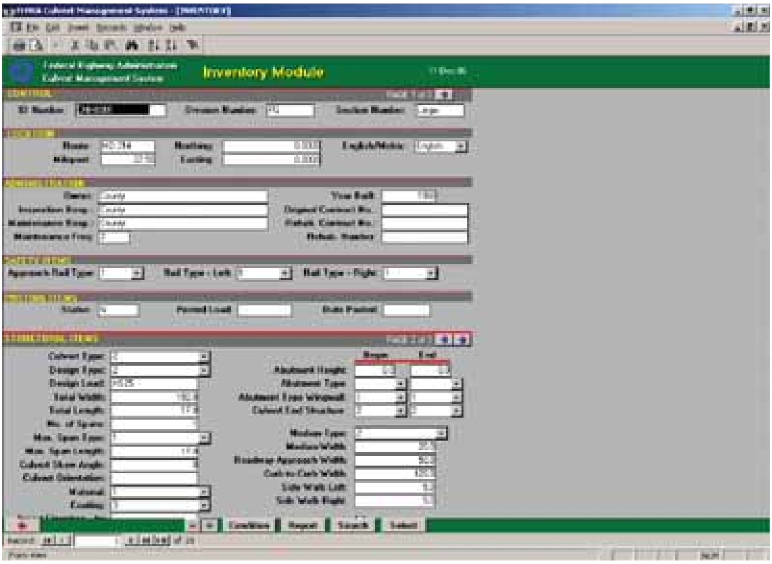

Figure 2. Inventory module.

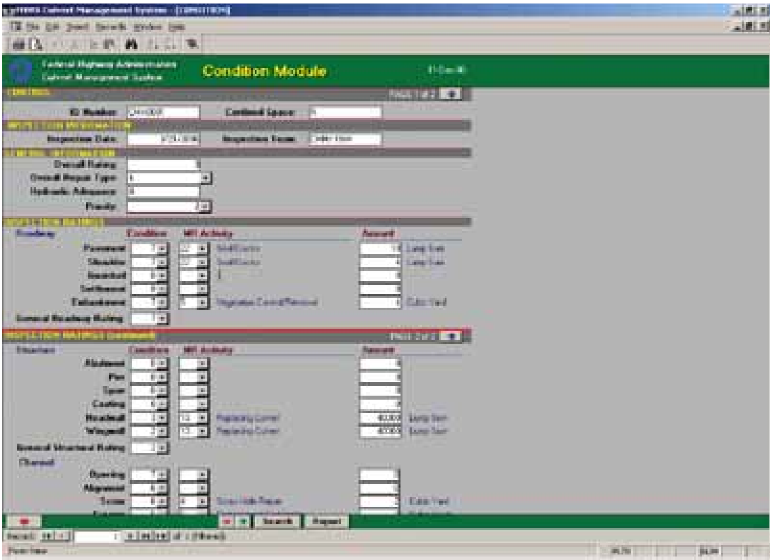

Figure 3. Condition module.

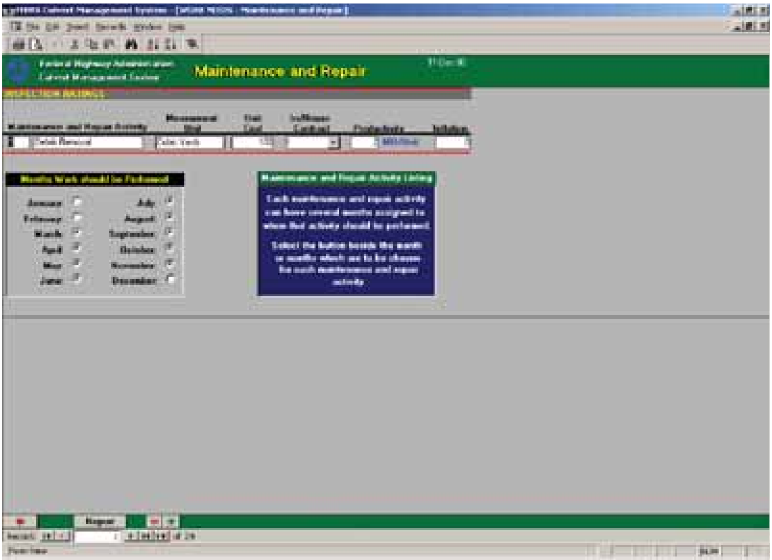

Figure 4. Maintenance and Repair module.

from the Work Funding module and, using the constraints of labor, dollars, and pre-scheduled projects input by the user, establishes when the various culvert projects can be performed. In the scheduling process, all of the activities within a project will be performed at the same time.

By using the FHWA CMS program to track culvert inventory, condition, and cost information, an agency can better manage its culvert program. This systematic process will help the agency to prioritize repair and replacement decisions and maximize the limited resources it has to expend on culverts.

MARYLAND

In Maryland the responsibilities for inspection and management of State-owned culverts belong to the State Highway Administration (SHA). The SHA has seven engineering districts, each encompassing several counties. Each district has a headquarters office, which is responsible for managing highway and bridge construction contracts, as well as all maintenance functions, including pavement and bridge repairs. Headquartered in

Baltimore, the SHA is responsible for more than 2,500 bridges and more than 16,000 lane-miles of interstate, primary, and secondary roads. In 1996, the agency assumed responsibility for the management and routine monitoring of small structures, including culverts, as a proactive measure. Although no collapse or other event prompted the routine monitoring, the SHA recognized that some smaller structures had structural problems that could lead to failure or other serious consequences.

Division of Responsibilities

Within the SHA, the responsibility for culvert management and inspection is divided between the Bridge Inspection and Remedial Engineering Division (BIRED) and the Highway Hydraulics Division (HHD). BIRED is part of the Office of Bridge Development, and HHD is part of the Office of Highway Development. Both offices operate under the deputy administrator/chief engineer for planning and engineering. Figure 5 illustrates the SHA hierarchy.

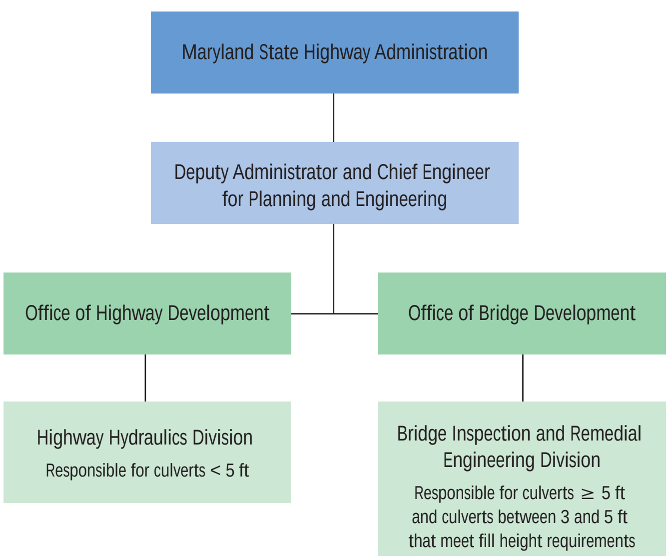

Figure 5. Maryland State Highway Administration hierarchy.

The division of inventory and inspection responsibilities is based on culvert size. BIRED typically inspects the larger structures, while HHD handles the smaller sizes. All culverts down to a 5-ft span are inventoried and inspected by BIRED, regardless of height of fill. Culverts from 3 to 5 ft in span are selected for inventory and inspection as follows:

- If the fill height is less than the span length, the culvert is inventoried and inspected at a regular frequency.
- If the fill height is greater than the span length, the culvert is not inventoried or inspected.

This selection process incorporates hazard levels, or consequences of failure, into the inventory and inspection policy. Based on experience, the SHA recognizes that the consequences of failure of a pipe under a small amount of fill are greater than one under a larger fill. A variation of this approach also applies to a battery of culvert pipes. Culverts in Maryland are primarily made of steel or concrete; however, some of the older culverts are made of stone or brick masonry. Although there are a few plastic pipes in the inventory, they are seldom used.

The district offices typically handle routine culvert repair and minor maintenance concerns, such as debris removal. Contract forces sometimes assist with maintenance. After the inspection crew notifies the district office of necessary repairs and maintenance, the district prioritizes the work. The central office is responsible for major repairs that may require an engineered fix. The central office prioritizes the work and creates a daily structure repair work list. Contractors assist the central office by undertaking substantial repairs, such as invert paving and shot-creting.

Most culvert replacements are handled as individual projects, but a few are done as part of corridor improvement projects. Although BIRED does not typically become involved in corridor improvement projects where a series of culverts is replaced, HHD sometimes considers drainage improvements to highway corridors where a series of culverts would be investigated for design (capacity) adequacy. Replacements of culverts with spans greater than 5 ft are typically performed by contractors. State maintenance crews occasionally perform smaller culvert pipe replacements.

The Maryland Department of the Environment (MDE) is concerned about fish passage and water quality and therefore requires permit approval for any in-water work, including repairs, replacements, scour counter-

measures, or culvert linings. HHD must follow the same MDE rules for permitting as BIRED does. However, fish passage is not as much of an issue for smaller structures.

Inventory and Inspection

When fully staffed, BIRED has 18 full-time in-house bridge inspectors who conduct culvert and small structure inspections in addition to performing bridge inspections in accordance with the National Bridge Inspection Standards (NBIS). The inspectors have taken the 2-week bridge inspection course sponsored by the National Highway Institute (NHI), and some have taken the bridge inspection refresher course. Local agency inspectors responsible for small structures typically do not have this training.

Although the SHA has a bridge inventory manual, Maryland does not have an inspection manual for bridges or culverts. The SHA is working to complete a policy and procedures manual, which will include formalized bridge inspection procedures. Culvert condition ratings are based on NBIS

Item 62 using a scale of 0 to 9. Also, Pontis element-level inspection ratings and condition-state language are used in inspection reports.

BIRED typically inspects culverts on a 4-year cycle, although inspection frequency can be increased to a 2-year cycle if the condition warrants. When possible (i.e., when the culvert is large enough, daylight is visible at the outlet, and access is not blocked by debris), culverts are manually inspected through the length of the barrel. BIRED has inventoried approximately 3,600 culverts since 1996.

HHD typically inspects culverts and pipes in the range of 36 to 60 in. and some up to 72 in. depending on the county and the highway classification, but does not inspect locally owned pipes. HHD also inventories drop inlets that are at the ends of the cross culverts and is inventorying these structures statewide. From the counties inventoried thus far, the SHA estimates that there are 10,000 culvert pipes in each rural county and 15,000 culvert pipes in each of the more urban counties—approximately 287,500 culvert pipes throughout the State's 23 counties.

HHD uses a different set of inspectors from BIRED. The inspectors are technicians but are not required to have any NBIS training. These inspectors receive in-house training from HHD based on HHD standard operating procedures. Inspectors generally inspect during dry weather and, in addition to looking for structural defects, use visual inspection techniques to detect latent discharge through the culverts. Inspectors can do basic pH tests on the water if a latent discharge is detected. Additional inspections may be conducted based on the reports or requests from district maintenance staff.

Prioritization

Culvert replacement is prioritized based on current condition, perceived consequences of failure, current use, and other factors. The "EPABCD" system is used as a tool to prioritize replacement, with an "E" code receiving the most consideration and a "D" code receiving the lowest priority.

“E” refers to an emergency situation requiring immediate action. “P” refers to a personal or political preference. Priority continues to decrease from “A” through “D.” Culvert repairs are conducted on an as-needed basis, typically by contractors, based on the EPABCD system, with items such as leaking joints typically receiving the highest priority.

Replacement of the smaller structures is prioritized based on the following criteria:

- Highway classification:
  - Interstate highways.
  - Higher classified State or U.S. routes.
  - Other State routes.
- Available resources (manpower and financial).
- Project complexity.
- Upcoming corridor improvements.
- Worst first.

The repair priority is based on a weighted system. Several of the weighted areas are highway safety, flooding, and drainage complaints. The culverts with the highest weighting are given first priority (i.e., worst first). Priority is also given to joint and erosion repairs. Some districts will make repairs based on their level of expertise and available manpower; otherwise, repairs are conducted by contractors.

HHD bases culvert condition ratings on a scale of 0 to 5. Zero signifies no rating, 1 means that no action is required, and 5 indicates that emergency repair is needed. The intent is to have these structures inspected on a 3-year cycle concurrent with their National Pollutant Discharge Elimination System (NPDES) cycle.

Databases

Rather than using the CMS developed by FHWA, BIRED tracks culverts that meet the size and fill requirements in an in-house Access database, referred to as a Structure Management System (SMS), which is also used for NBIS-length bridges. The SMS does not predict culvert service life as a function of existing or anticipated deterioration.

HHD developed an in-house, Access-based GIS for inventory (see Figure 6). Because of the large amount of data being stored in the

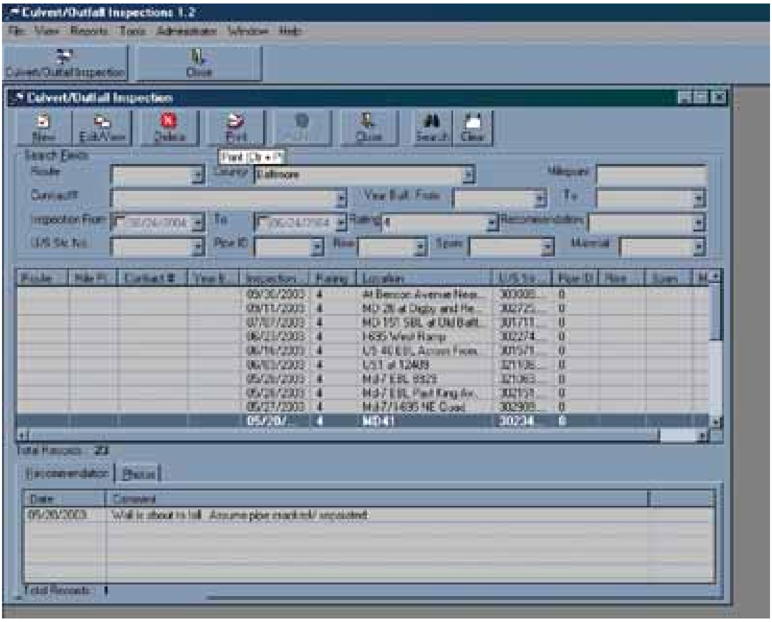

Figure 6. In-house, Access-based geographic information system used by the Maryland State Highway Administration's Hydraulics Unit.

inventory, HHD will eventually convert to an Oracle-based GIS. This database is separate from the BIRED bridge database, although there may be some small overlaps with culverts in the 60 to 72 in. range.

Funding

Although BIRED does not have funding dedicated specifically for culverts, financial support for the repair and replacement of culverts comes from the operating budget. On an annual basis, the SHA budgets $350,000 for its bridge inspection program, which includes NBIS bridges and small structures. For culvert repairs and replacements, BIRED spends approximately $500,000 per year; however, BIRED spent $1.7 million in 2005 and $2.4 million in 2006 on paving deteriorated steel pipe inverts.

HHD has a dedicated budget, established within the last 2 years, for addressing drainage improvements. The budget allocates system preservation dollars for the replacement of culverts. HHD anticipates that this budget will be in effect for at least the next 6 years.

Conclusion

The Maryland SHA has taken a proactive stance in creating its culvert inventory and inspection program. It has successfully balanced the time and cost of inspecting these numerous structures with a comprehensive risk-based approach. This allows the SHA to minimize potential hazards to the traveling public. Although the agency already has a well-established program, it may be receptive to the idea of national inspection standards for culverts and small structures with accompanying Federal funds. The SHA prefers an in-house database over the CMS software developed by FHWA, but is willing to consider an updated CMS in the future.

MINNESOTA

In Minnesota the responsibilities for inspection and management of State-owned culverts belong to the Minnesota DOT (MnDOT). MnDOT has eight engineering districts, each encompassing several counties; each district has a headquarters office. Most of MnDOT's day-to-day operations are managed at the district level, including highway construction projects and maintenance. MnDOT, headquartered in St. Paul, is responsible for more than 11,000 lane-miles of the State-owned trunk highway system and more than 3,800 bridges. With its additional 123,000 lane-miles of local highways and 9,800 local bridges, Minnesota has the fifth largest highway system in the Nation.

Division of Responsibilities

Within MnDOT the responsibility for culvert management and inspection is divided between the Bridge Inspection Unit and the Hydraulics Unit. Both units are part of the Bridge Office headed by the State bridge engineer. Figure 7 illustrates the MnDOT hierarchy.

The division of inventory and inspection responsibilities is based on the size of the culverts. The Bridge Inspection Unit is responsible for the inspection of structures that span more than 10 ft, while the Hydraulics Unit handles structures that span less than 10 ft. Culverts and pipes down to a 12-in. diameter are inventoried and inspected by MnDOT district personnel based on district priorities and resources.

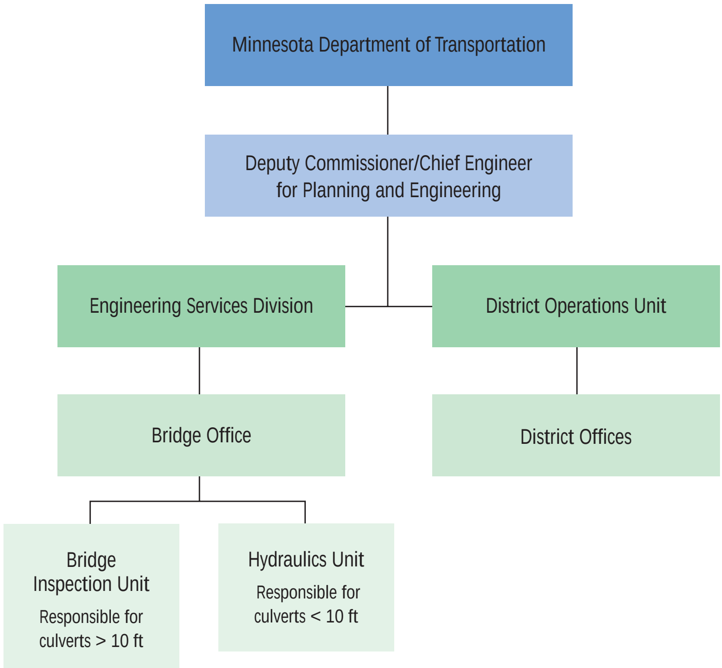

Figure 7. Minnesota Department of Transportation hierarchy.

Small culvert replacement, repair, and maintenance are done by both State forces and contractors. Most of the replacements and rehabilitations occur during corridor improvement projects. Slip lining and cured in-place liners are the most common rehabilitation methods. Replacement methods are most commonly open trench and occasional jacking, which is the horizontal placement of pipes by driving the pipe through an embankment.

Culvert replacements of all sizes on public waters require a Department of Natural Resources (DNR) permit. MnDOT has a general permit with the DNR for crossings of public waters. Fish passage is a concern for larger culverts on public waters.

Inventory and Inspection

The culverts on the State trunk highway system that span more than 10 ft are inspected on a 12- or 24-month frequency depending on the condition of the structure. Minnesota State law does not allow for inspection at intervals greater than 2 years; however, MnDOT is currently working to amend the law to allow a 4-year frequency on some structures, especially concrete box culverts. The Bridge Inspection Unit has been inventorying culverts longer than 10 ft since the early 1970s. Most of the approximately 10,500 culverts are made of steel and concrete, with some masonry, timber, and aluminum structures scattered throughout the State. These inspections are conducted by NBIS-certified inspectors.

Minnesota does not have a required inspection frequency for culverts less than 10 ft; therefore, each district can determine its own frequency. Most districts have chosen to inspect a number of these smaller structures on an as-needed basis. If the culverts are in an outfall in a Municipal Separated Storm Sewer Systems for Pollution Control area (MS-4), 20 percent of the culverts are required to be inspected each year.

Although the inspectors for these smaller structures are not required to have any NBIS training, most participate in a 1-day course focusing on condition, codes, problems, and data formatting. Inspections of smaller structures are conducted by district maintenance and hydraulic personnel, as well as contractors hired and supervised by the district. Individualized training is provided for district staff, while formal classes are held as needed for contractors. For a company to qualify for consultant work, two of its people must attend the formal training. Most culverts are inspected visually using flashlights. Video inspection is used on occasion.

Maintenance and repair of culverts, including extending culverts and placing pipes inside old box culverts, are carried out by both State forces and contractors.

Prioritization

The Bridge Inspection Unit prioritizes work on large culverts according to inspection condition ratings based on both Pontis and NBIS. The central Bridge Office is responsible for developing a needs assessment for the State-owned culverts spanning 10 ft or more in each district. The needs assessment covers short- to long-range budget needs in 7- to 9-year increments. The current needs assessment covers the following time frames:

- Short term: 7 years (2008–2014).
- Mid range: 9 years (2015–2023).
- Long term: 7 years (2024–2030).

Once the statewide needs are determined, the central Bridge Office prepares a list of recommended projects for each district. The districts must select which projects to fund and prioritize their selections.

The Hydraulics Unit has developed a culvert inspection guide that contains condition rating information and condition-state language. The ratings are based on a scale of 1 to 4, with 1 being the best condition and 4 meaning an immediate fix may be required. For the districts, pipes with a rating of 4 (emergency pipes) are top priority. Additionally, pipes with a condition rating of 3 will be fixed as time and resources permit. For corridor projects, pipes rated as 3 and 4 are reviewed and prioritized as part of the project scope.

Databases

In addition to the division in responsibilities, two different computerized management systems are used, Pontis and HYDINFRA.

Pontis

For inventory and management of the larger structures, the Bridge Inspection Unit uses Pontis. Although intended primarily for bridges, the software can be used by a DOT to manage its inventory of culverts. Pontis has the capability to predict deterioration and remaining service life and to make repair and rehabilitation recommendations.

HYDINFRA

The impetus for the development of HYDINFRA (HYDraulic INFRA-structure) came from the district hydraulics engineer's decision to create a management system for the hydraulic infrastructure on a statewide level. Development of HYDINFRA began in 1996 and was completed a year later. Prior to this, each district either did not collect data for small culverts or had its own way of inventorying and collecting data from paper records to simple databases. Fortunately, there was no catastrophic failure or event that prompted the MnDOT to manage these structures.

HYDINFRA catalogs several types of hydraulic features, as illustrated in Table 1. Although MnDOT does not differentiate culverts from storm drains, there are approximately 50,000 pipes in the inventory. MnDOT estimates that 75 percent of the State-owned pipes have been inventoried.

Other than steel and concrete, the inventory has some plastic and corrugated aluminum pipes.

HYDINFRA manages both inventory and inspection data for each hydraulic feature. Examples of inventory and inspection data are shown in Table 2.

HYDINFRA data is used primarily for construction project scoping and to plan maintenance and repairs. Survey crews have used HYDINFRA data to locate culverts for more detailed mapping work. Beginning in 2006, HYDINFRA was used to find features requiring maintenance under the new water quality requirements. Inspection and maintenance activities are logged by date so that the history of problems or repairs is available for each feature.

A field inspector uses a global positioning system receiver to collect data that will be recorded in HYDINFRA.

Table 1. Hydraulic Features Cataloged in HYDINFRA

Hydraulic Feature	Examples
Pipes	Culverts spanning between 12 in. and 10 ft
	Storm drains
Structures	Drop inlets
	Catch basins
	Manholes
Special structures	Aprons
	Headwalls
	End treatments
	Weirs
	Increasers/reducers
Water quality devices	Pond
	Ditch
	Structural pollution control device
Virtual features (added in 2006 to facilitate record keeping for National Pollutant Discharge Elimination System requirements)	Illicit discharge
	Outfalls

Table 2. Examples of Inventory and Inspection Data

Types of Data	Examples
Inventory data	Location
	Type
	Initial size
	Shape
	Material
Inspection data	Condition code
	Need for repair
	Need for cleaning
	Condition attribute flags
	Maintenance repairs accomplished and other changes over the life of the hydraulic feature
	Plan data for proposed features

Field inspectors collect data with global positioning system (GPS) receivers, and the data is then uploaded to an Oracle database. Geographic information tools allow users to query the database for specific information and create maps for use in various projects (see Figure 8). Users can query by condition, need for repair, or need for cleaning.

Users can access HYDINFRA reports to obtain detailed information about culverts in a specific geographic area. The Pipe Inventory and Inspection Report allows users to specify a highway and the beginning and ending milepost for the area of interest. The report lists information, line by line, about the set of pipes along that stretch of highway (see Figure 9). Data include size, shape, material, and location, plus condition ratings and detailed attribute flags that note problems in the pipes.

Oracle forms allow for data creation, editing, and access. Advanced users complete the Batch Review Form to view newly loaded data (see Figure 10). Forms also interact with the ArcGIS HYDINFRA tools, allowing data to be selected in GIS and viewed in forms and vice versa.

Funding

The cost of replacing large culverts is covered by the statewide general structures budget. There is no dedicated budget for small culverts. The

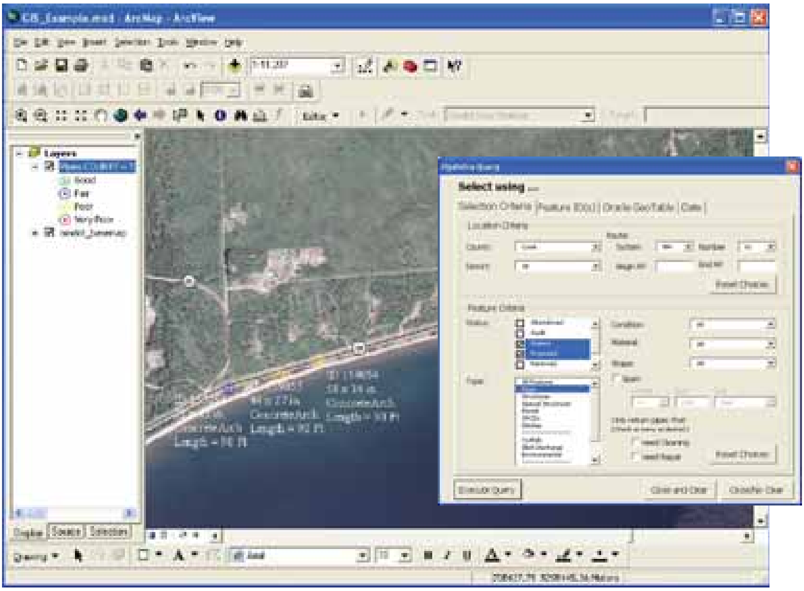

Figure 8. HYDINFRA geographic information system tools.

funds are allocated from the general roadway budget to the districts, who then prioritize projects and decide which to undertake.

For local structures, funding comes from the State gas tax, township bridge funds, and bonding. Counties and municipalities set their own budgets, select their own projects, and handle their own designs. On occasion, MnDOT offers assistance with large, complex, or unique structures.

Conclusion

In the absence of any Federal requirements, MnDOT has developed procedures and guidelines for inspection of its massive inventory of culverts and drainage structures. Although the management responsibilities are divided between two units within the Bridge Office that utilize two different management tools, MnDOT has a good handle on its small structure inventory. The use of Pontis is a practical application of an

Figure 9. MnDOT Hydraulic Infrastructure Pipe Inventory, Inspection, Maintenance
on MN210 from MP178.00 to 210.00
Status: In Place or Purposed

Pipe ID	MP	Cond	Pipe Shape	Material	Length	Span x Rise	Cover	Maint. Clean	Maint. Repair	Repair Under Road	Plugged	Deformed	Standing Water	Infiltration
588875	182.79	2	Box	Concrete	47.0 ft	72x48 in.	2–6 ft	Y	N	N	N	N	N	N
588876	183.82	2	Round	Concrete	72.0 ft	24x24 in.	2–6 ft	Y	N	N	N	N	Y	N
588877	185.05	2	Box	Concrete	57.0 ft	60x60 in.	2–6 ft	Y	N	N	N	N	Y	N
588878	185.58	4	Round	Concrete	84.0 ft	24x24 in.	6–10 ft	N	Y	N	Y	Y	Y	Y
588879	185.83	4	Round	Concrete	75.0 ft	24x24 in.	6–10 ft	N	Y	N	Y	Y	N	Y
588880	186.07	4	Round	Concrete	66.0 ft	24x24 in.	6–10 ft	N	Y	N	Y	Y	N	Y
588881	186.96	2	Round	Concrete	98.0 ft	30x30 in.	10–20 ft	Y	N	N	N	N	N	N

existing software package for CMS purposes. For the smaller structures, HYDINFRA can be used as a model for other States for managing their drainage systems. MnDOT has expressed a willingness to share information on their HYDINFRA with other DOTs. This evolving tool is consistently being enhanced to take advantage of the new developments in computer technology.

MnDOT sees no need for a Federal mandate to inspect culverts, especially since the State has already developed its own procedures. In fact, MnDOT maintains that a Federal mandate could be a burden to local governments. This view is consistent with the position already adopted in 2005 by the AASHTO Subcommittee on Bridges and Structures.

Figure 10. Oracle form used by MnDOT.

	Silt Present	Piping	Cracks	Spalling/Flaking	Pitting/Rusting	Misalignment	Joints Separation	Holes	Inslope Cavity	Road Void	Road Stress	Erosion	Inspection Date
	Y	N	N	N	N	N	N	N	N	N	N	N	6/29/2006
	Y	N	N	N	N	N	N	N	N	N	N	N	6/29/2006
	Y	N	N	N	N	N	N	N	Y	N	N	Y	6/29/2006
	Y	Y	Y		Y	Y	Y	Y	Y	N			6/30/2006
	Y	Y				Y	Y	Y	Y	N	N	Y	6/30/2006
	Y	Y	Y			Y	Y	Y	Y	N	N	Y	6/30/2006
	Y	N	N	N	N	N	N	N	N	N	N	N	6/30/2006

ALABAMA

In Alabama the responsibilities for inspection and management of State-owned culverts belong to the Alabama DOT (ALDOT). ALDOT has nine geographic divisions. Each encompasses several counties and has a headquarters office. Each division is responsible for managing highway and bridge construction contracts, as well as all maintenance functions, including pavement and bridge repairs. The divisions are further subdivided into districts with, typically, three to six districts within each division. ALDOT, headquartered in Montgomery, is responsible for more than 5,600 State-owned bridges.

Division of Responsibilities

The maintenance engineer in each of the ALDOT divisions is responsible for the inspections. Typically, these inspections are delegated to the districts. Figure 11 illustrates the ALDOT hierarchy.

Although culvert replacements and repairs can be part of a corridor improvement project, most are replaced individually. State forces primarily perform culvert maintenance and replace some minor drainage structures. ALDOT also handles culvert relining and filling with flowable fill, culvert

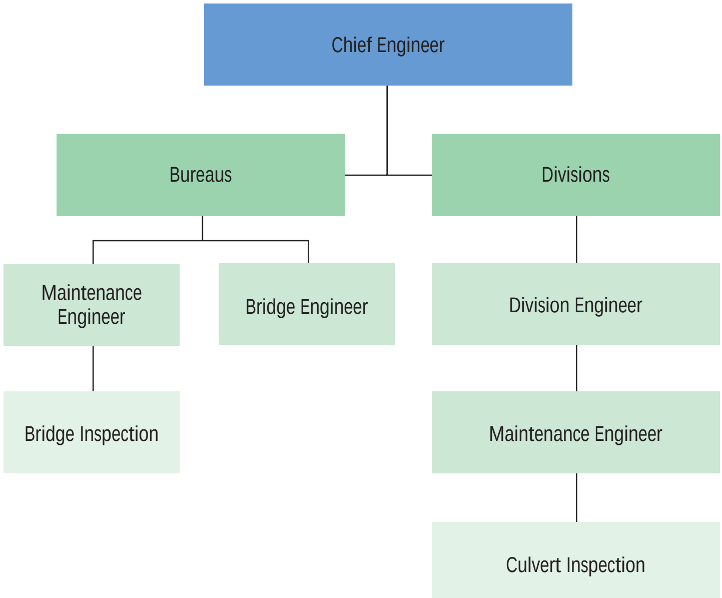

Figure 11. Alabama Department of Transportation hierarchy.

extensions, and some invert paving. The majority of the work—more than 90 percent—is completed by contractors.

Culverts are typically installed at least 1 ft below the flow line to allow siltation to occur and to provide a “natural” bottom for fish passage and other aquatic species. ALDOT has recently created a section that handles water quality and environmental issues for all maintenance activities. Permits are required from the Alabama Department of Environmental Management (ADEMS), U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and other environmental agencies.

Inventory and Inspection

All culverts and pipes ranging from 20 ft down to 15 in. are inventoried. The ALDOT Maintenance Bureau arranges this inventory of approximately 184,775 minor drainage structures by highway segment. Highway segments vary in length based on the type of roadway (i.e., rural or urban sections) or location (i.e., county or municipal sections). The count includes all of the minor drainage features along that roadway section and does not distinguish between different types or sizes of culverts. The vast majority of culverts in Alabama are made of steel or concrete. Some of the other structures are high-density polyethylene plastic.

Although ALDOT has not established a set frequency or cycle for inspections, the ALDOT Maintenance Manual recommends annual inspections if deemed necessary by the district engineer. After major rainfall or flooding, district roadway personnel conduct inspections by riding the highways and looking for any problems, such as ponding water, erosion, dips in the roadway, and other signs of distress. These inspections are for State-owned structures only and do not apply to local agencies.

The ALDOT employees who perform the culvert inspections are not required to have any formal bridge inspection training based on the NBIS. Inspections are not based on a formal rating or NBIS system, and formal inspection reports are not written. Since inspections are conducted as needed and do not adhere to a formal cycle, there is no database of inspection information or reports to share.

ALDOT uses a bridge inspection manual but not a separate culvert inspection manual. The field operations and maintenance manuals address but are not specifically geared toward culvert inspection. The inspections are conducted with flashlights, and on some occasions video equipment is used at the discretion of the district engineer. ALDOT is considering moving towards using video inspection for all of its small drainage structure inspections.

Prioritization

Instead of implementing a worst-first system for prioritizing culvert repairs and replacements, ALDOT fixes problems as they develop based on inspections.

Database

Instead of using the CMS software developed by FHWA, ALDOT has a computerized inventory system and a computerized maintenance management system. Developed in the 1970s, the maintenance management system can schedule future maintenance activities, but it cannot predict deterioration, estimate costs, or prioritize replacements. ALDOT has committed to changing and updating the system within the next few years and has expressed interest in a future version of the FHWA CMS software.

Funding

ALDOT has a dedicated budget for maintenance and inspection but does not have a dedicated budget for culvert replacements. The typical amount spent on culvert repairs and maintenance ranges from $1.5 to $2.5 million annually.

Conclusion

Although no failure of a small or minor drainage structure has occurred recently, ALDOT recognizes the importance of inventorying and inspecting these structures. The agency's program, however, is more reactive than

proactive. ALDOT's interest in a future version of the FHWA CMS may lead the agency to develop a more formal system with official inspection guidelines and frequencies. With a formal CMS, the agency could manage its facilities more proactively and efficiently, possibly lowering the costs of the inspection, repair, and replacement process.

ALDOT welcomes Federal guidance for culvert inspection, but does not support a mandate because the agency is already conducting inspections on its own terms. Adhering to the notion that States should have the freedom to establish individualized standards, ALDOT prefers Federal guidance rather than Federal standards.

SHELBY COUNTY

Shelby County, just south of Birmingham, is the fastest growing county in the State of Alabama. It encompasses approximately 800 mi^2 in central Alabama and is home to approximately 171,000 residents. Shelby County Highway Department (SCHD), located in Columbiana, is responsible for inspection and management of county-owned structures. SCHD is also responsible for maintenance and construction of county roads, bridges, guardrails, signs, and storm drains, and it provides engineering consulting services to other county departments. SCHD handles the inspection of 180 NBIS-length bridges throughout the county.

Division of Responsibilities

Approximately 11 years ago, the Shelby County engineer implemented and funded an in-house bridge design and construction team. As a result, most of the county's culvert replacements are performed in-house with specially trained and equipped county work crews. Less than 10 percent of the SCHD's LT20 Replacement Program has been performed by contract. Typically, replacement projects have been scheduled in conjunction with other rebuild elements such as widening, resurfacing, or intersection improvements that have used Federal-aid funding. Local county work crews under the supervision of a bridge inspector or bridge engineer typically perform culvert maintenance and repairs. Figure 12 illustrates the SCHD hierarchy.

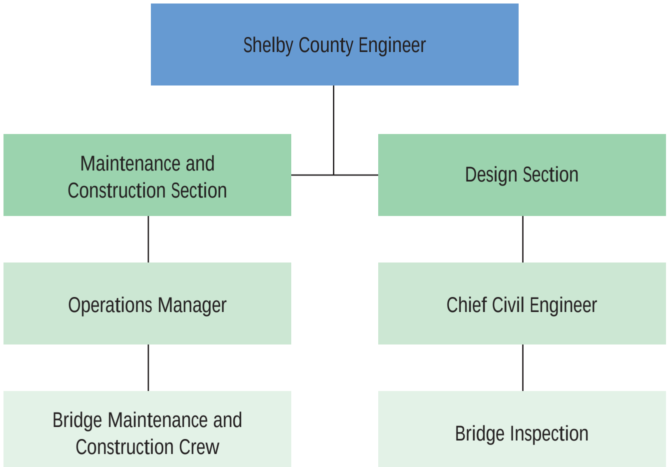

Figure 12. Shelby County Highway Department hierarchy.

Inventory and Inspection

The SCHD began inventory of its culverts in 1994 following receipt of a statewide memo from ALDOT directing all counties to provide a count of structures that are less that 20 ft (LT20) in length and have greater than 40 ft^2 of drainage opening. About a year and a half later, in the summer of 1995, the county initiated its LT20 Replacement Program based on recent inspections of structures less than 20 ft long. The 1995 inspections revealed 90 small structures and culverts requiring replacement or rehabilitation. This LT20 Replacement Program was part of a countywide infrastructure improvement philosophy that included paving dirt roads, widening paved roads, and rehabilitation and replacement of NBIS-length structures.

The county has 88 culverts and small bridges in its inventory. Most of the structures built in Shelby County in the 1960s through the early 1980s were made from treated timber. Almost all of these structures have been replaced with reinforced concrete boxes or reinforced concrete pipes. Steel and aluminum corrugated metal pipes (CMP) are only used for special applications, such as extensions of existing CMPs or for sliplining. The LT20s are routinely inspected on a 4-year cycle; however, interim inspections are performed after large storm events or reports of damage.

For the last 6 years, Shelby County has been participating in various culvert management research and development programs, allowing inspections to occur on a regular 2-year interval in conjunction with the NBIS inspection program. The condition rating system is based on NBIS Item 62, which utilizes a scale ranging from 0 to 9, with 9 meaning "no deficiencies" and 0 meaning "structure closed and needing replacement."

SCHD employs trained and certified NBIS bridge inspectors in its Engineering Department who perform inspections of all county-maintained NBIS and LT20 culvert structures in unincorporated Shelby County and on county-maintained roads within municipal limits. Municipalities within the county are responsible for both NBIS and culvert inspection programs on their city-maintained streets, although most municipalities contract their bridge inspections program to local consulting firms.

Shelby County inspectors have attended the NHI-sponsored 2-week training course for certification in bridge safety inspection, as well as the annual ALDOT 2-day bridge inspection refresher courses.

Although SCHD does not maintain a separate inspection manual, it uses the available FHWA and ALDOT culvert inspection manuals and other inspection resources. County inspectors are also encouraged to consult outside agency manuals available over the Internet such as the Ohio DOT culvert inspection manual and the Montana DOT maintenance manual.

Shelby County has led Alabama in the innovative use of fly ash flowable fill, structural lining, and other low-impact, environmentally sound culvert rehabilitation technologies. The county complies with the ADEMS NPDES permitting and testing system on culvert replacement projects. Generally, culvert replacements are below the reporting threshold for other environmental concerns. The Shelby County Best Management Practices Plan for reducing construction-related discharge in stormwater systems is used. Fish passage is not an issue that is addressed on county projects at this time.

Prioritization

SCHD utilizes both a modified worst-first replacement prioritization and a corridor-improvements-driven replacement prioritization. Specific budgetary consideration is given to LT20s that are in a deteriorated state or are

approaching the end of effective service life by a ranking of overall culvert condition. SCHD also includes replacement or rehabilitation of existing structures in all of its road-widening and corridor-enhancement projects. These projects may be as significant as Federal-aid projects sponsored by metropolitan planning organizations or may be as general as county-funded road widening and resurfacing projects. SCHD has found that an "as you go" small structure replacement protocol results in significant direct and user cost savings while enhancing the appearance and overall safety of the local roads network.

SCHD prioritizes its LT20 maintenance work in an increasing order of importance from routine repairs to preventative maintenance to major rehabilitation to replacement. In addition, bridge inspectors are empowered to categorize the maintenance activities requested as being "monitor, routine, priority, urgent, or emergency." Significant discussions are held between Shelby County's inspection and construction teams to ensure that specific maintenance or repair items are assigned appropriate levels of importance.

Database

SCHD's CMS consists of two parts:

1. The Inspection, Condition, and Maintenance and Repair modules of the FHWA CMS.
2. A prioritization module developed in-house.

SCHD is preparing to use the future deterioration and service life modules of the FHWA CMS. However, until this portion of the county's culvert database is operational, SCHD will continue to use its in-house-developed prioritization module, which is based on overall culvert condition with modifications to account for load posting, detour length, and average daily traffic. In 2001 the SCHD completed an in-house deterioration and service life module, known as the Local Roads Bridge Replacement Prioritization Database (BRPD) system, that was initially used to prioritize the Shelby County LT20 network of smaller structures and culverts. This system was found to be worthwhile, although it would require further development and enhancement before it could be easily utilized. The publication and implementation of the FHWA CMS in 2001 effectively postponed the further development of the Local Roads BRPD system.

SCHD has chosen to voluntarily collect and maintain its own LT20 inspection database. The benefits of this database have greatly outweighed the commitment of time and resources required to initiate and maintain the system. SCHD believes that its commitment to all facets of asset management have placed it in a position of national leadership among counties. SCHD recommends Federal guidance that will result in voluntary participation through a system of grant rewards that could fund additional innovative design and construction methods, composite materials research, and application of computer technology to management solutions. SCHD supports the establishment of national guidelines for culvert inspection, and would be willing to participate in the preparation and implementation of these standards.

Recently, SCHD personnel led a culvert management seminar that showcased the FHWA CMS to interested county and municipal engineers in Alabama (see “FHWA Culvert Management Seminar,” UTCA Project Number 05219, University of Alabama, 2006). Seminar participants requested updates and technical corrections. System updates would be beneficial to Shelby County and attractive to other potential users.

Funding

The Shelby County Commission permits the county engineer to designate projects for funding on an annual basis. The project-specific designations are subject to the ongoing prioritized needs as derived by the culvert management process. The net result is the dedication of a significant portion of the budget for culvert replacement and maintenance activities. This budget averages about $500,000 per year and includes funds for replacements, repair activities, and preventive maintenance (see Figure 13).

Conclusion

Following the initial inventory mandated by ALDOT, SCHD has taken a practical, hands-on approach to maintaining and improving its culvert inventory, inspection, and management system. It has taken the lead

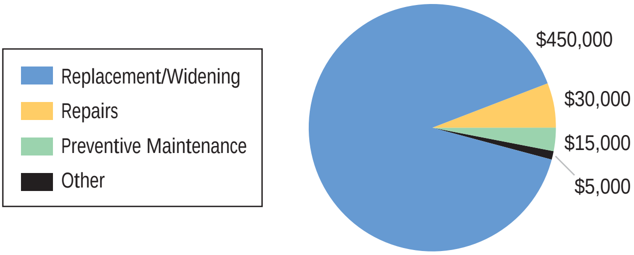

Figure 13. Shelby County Highway Department average annual culvert budget.

among Alabama counties in promoting CMS by using and teaching CMS principles. SCHD uses the FHWA CMS program and has identified areas of the program that need to be improved and updated. SCHD has expressed willingness to work with the FHWA in these efforts. Shelby County has extended great effort to become a leader in culvert management technology by partnering in research activities with academia and local corporate concerns.

CONCLUSION

Discussions with various DOTs around the country confirm a need to better manage all types of highway assets. Since culverts typically go unnoticed, there has not always been a sense of urgency to inspect or manage these structures. But as recent high-profile failures on Interstate and State highways around the Nation have occurred, the need to manage these structures has become apparent.

There are several keys to a high-quality, comprehensive management system applicable to culverts and drainage structures. Based on AASHTO guidelines, the purpose of a CMS is to use economic and engineering data to help determine the best actions to perform on the network of culverts over a period of time. An effective CMS includes these key components:

- Inventory.
- Inspection and condition appraisal.
- Cost data:
  - Agency costs (i.e., maintenance, repair, and replacement).
  - User costs.

- Deterioration models.
- Optimization models.
- Feasible actions and work needs.
- Scheduling.
- Reporting.

Although many DOTs have some form of CMS in place or under development, not all systems have all of the key components. FHWA has taken an initial step toward helping DOTs manage their culvert inventory. In October 2001, FHWA released CMS software along with a user's manual. The purpose of this program is to provide a tool to facilitate the coordination of maintenance and repair or replacement operations on a system-wide basis.

Many States have expressed interest in the FHWA CMS. The University Transportation Center of Alabama (UTCA) along with the SCHD has sponsored implementation seminars for the FHWA CMS software. The target audience of these seminars is county and city engineers, maintenance personnel, and contractors. In addition to discussing culvert inspection techniques and design philosophies, the seminar participants receive a copy of the FHWA CMS software and manual. Part of the seminar demonstrates how to build a culvert database using this software. Following the seminars, a written report documents the outcomes, participants' comments and questions, and recommendations. One recommendation was to update and enhance the existing software and to fix any errors that are discovered. Currently, FHWA is not actively supporting the maintenance of this program. The UTCA supports the concept that FHWA, through its Office of Asset Management, take ownership of the distribution, maintenance, and future enhancements of the CMS.

According to a survey of State DOT culvert management programs, many States are not using any type of formal management system for structures under 20 ft in length. DOTs who do use a system vary widely in the ways that they inspect, inventory, budget, and make decisions, not only from State to State but also within different divisions of the same agency.

Although many States recognize the importance of culverts and drainage structures, the lack of an actively promoted CMS and a current culvert inspection course could be a reason that more resources are not dedicated to culvert management. These facts have been taken into consideration by FHWA. As a result, FHWA will begin development of new culvert inspection training material and an updated and enhanced FHWA CMS.

An effective CMS helps highway agencies to enhance highway safety, use resources more efficiently, and preserve public assets:

- With the increased systematic attention to culvert inspection that accompanies use of a CMS, structures in need of repair or replacement can be identified before their condition is a risk for catastrophic failure.
- The prioritization of rehabilitation, repair, and replacement needs offered by a CMS helps agencies to optimize their use of the limited human and financial resources they have available.
- Finally, a CMS can help agency decision makers preserve the Nation's investment in highway infrastructure as they decide how best to spend resources to maintain culverts throughout the highway network.

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