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13. Abstract

This research advanced Geotechnical Asset Management (GAM) within DOTD. It describes the logic and software utilized to develop the DOTD retaining wall inventory and outlines a GAM path forward for the Department. The developed GAM GIS database provides geospatial locations, digital storage, digital rating applications, and visual interfaces for retaining walls including historical information. Inventory efforts utilized efficient and effective tools of aerial photography, mapping, and GIS software, web applications, and mobile applications. DOTD can replicate these efforts for other asset types. Researchers developed desk and mobile applications for efficient collection of condition and consequence assessment data into the GIS Database. Districts with their local knowledge should use these tools as part of the rating process. Full GAM development and implementation will provide the department a logical method to manage risk, address problematic locations, and effect a rationale to implement appropriate repairs in a timely manner.

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Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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Geotechnical Asset Management for Louisiana

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Abstract

This research advanced geotechnical asset management (GAM) within the Louisiana Department of Transportation and Development (DOTD). It describes the logic and software utilized to develop the retaining wall inventory for the DOTD and outlines a GAM path forward for the department. Full GAM development and implementation will provide the department a logical method to manage risk, address problematic locations, and effect a rationale to implement appropriate repairs in a timely manner.

The developed GAM Geographic Information System (GIS) database provides geospatial locations, digital storage, digital rating applications, and visual interfaces for retaining walls including historical information. Inventory efforts utilized efficient and effective tools of aerial photography, mapping, GIS software, web applications, and mobile applications. DOTD can replicate these efforts for other asset types.

Researchers developed desk and mobile applications for efficient collection of condition and consequence assessment data into the GIS Database. Districts with their local knowledge should use these tools as part of the rating process. Researchers await the DOTD Headquarters (HQ) Operation and Maintenance Section's issuance of direction to the districts regarding the next steps of the GAM implementation and segment ratings. HQ manages district workload, staffing, and funding priorities associated with the maintenance and asset management efforts. Awaiting HQ directives slowed implementation by affecting the timeliness of the risk calculations and the full implementation of GAM.

GAM is a proactive way to manage geotechnical assets, and future decisions regarding condition, performance, and consequences of risk improving upon the current reactive nature versus deteriorating conditions. GAM can assist DOTD with the logical allocation of limited financial resources to ensure safety and longevity of these assets. With the ever pressing "need to do more with less" and the knowledge drain of retiring workers, further implementation of the GAM system will help preserve the past so designers can plan for the future.

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Insight gained from Mark Vessely of BGC Engineering and Jerry DiMaggio, ARA Consultant) regarding their experience and work on the National Cooperative Highway Research Program (NCHRP) Report 930 [1] and the GeoComp Corporation & Federal Highway Administration (FHWA) Report [2], respectively, is much appreciated.

Implementation Statement

Findings from this project will result in tools that can be used to inventory Louisiana's geotechnical assets and information regarding their age, location, composition, and condition. The development and implementation of this geotechnical asset management system will result in a method to manage problematic locations and implement repairs in a timely manner. This data can be used for decisions regarding where and how to allocate limited financial resources. The system will also help preserve the past, so designers can plan for the future.

Table of Contents

Technical Report Standard Page 1
Project Review Committee 2
LTRC Administrator/Manager 2
Members 2
Directorate Implementation Sponsor 2
Geotechnical Asset Management for Louisiana 3
Abstract 4
Acknowledgments...5
Implementation Statement 6
Table of Contents 7
List of Tables..9
List of Figures 10
Introduction...12
Problem Statement 12
Introduction...12
Literature Review..18
Objective 21
Scope...22
Methodology 23
Task 1: Research existing state and federal efforts regarding GAM 23
Task 2: Determine the applicability and implementation of GAM within Louisiana...23
Task 3: Develop database parameters/schema for population into a Louisiana database...23
Task 4: Identify assessment criteria and management strategies...............24
Task 5: Recommend and implement strategies...25
Task 6: Document the research effort 25
Software 25
Discussion of Results..27
GIS Collection Methodology and Technology 28
Walls and Segments 31
Data Fields 33
Other Assets 35
Conclusions..80

DOTD Challenges 80
Recommendations 82
Acronyms, Abbreviations, and Symbols 83
References 86
Appendix A 89
NCHRP 24-46 Survey with Louisiana Responses 89
Appendix B 92

List of Tables

Table 1. Wall summary by DOTD district 52
Table 2. DOTD-approved wall systems 53

List of Figures

Figure 1. Failure examples affecting traffic corridors 13
Figure 2. Generalized geologic map of Louisiana 14
Figure 3. Normal Louisiana precipitation 15
Figure 4. Interstate 10 at Bluebonnet Boulevard slope failure, 2019 16
Figure 5. Interstate 10 at Bluebonnet Boulevard – historical aerial photos 17
Figure 6. NCHRP Research Report 903 18
Figure 7. Mechanically Stabilized Earth (MSE) walls, Shreveport, LA 27
Figure 8. Major Louisiana corridors 30
Figure 9. Example of multiple adjacent retaining wall facing types along I-20 31
Figure 10. Wall segments and continuous wall numbers 32
Figure 11. Mississippi River Bridge -- Vicksburg, MS 38
Figure 12. Generalized salt dome cross-section 39
Figure 13. Salt domes and sinkholes -- Bayou Corne 40
Figure 14. Louisiana salt domes and locations 40
Figure 15. Salt dome locations [18] 41
Figure 16. Blended calcium sulfate (BCS) locations ─ DOTD 1987-1991 43
Figure 17. DOTD District 02 retaining walls 44
Figure 18. DOTD District 03 retaining walls 45
Figure 19. DOTD District 05 retaining walls 46
Figure 20. DOTD District 07 retaining walls 47
Figure 21. DOTD Districts 08 retaining walls 48
Figure 22. DOTD District 62 retaining walls 49
Figure 23. DOTD District 61 retaining walls 50
Figure 24. DOTD District 04, Shreveport, LA 51
Figure 25. Wall facing types 54
Figure 26. Hudson St and I-20 55
Figure 27. I-49 & LA 3132, Shreveport, LA 56
Figure 28. Reinforced Earth Company (RECo) ─ Louisiana walls 58
Figure 29. Shreveport LA wall construction for I-49 59
Figure 30. Operation and Maintenance Condition (O&MC) tree 61
Figure 31. Safety Consequence (SC) tree 62
Figure 32. Mobility and Economic Consequence (MEC) tree 63
Figure 33. Enterprise Portal web application for rating the GAM attributes for retaining wall features 65

Figure 34. ArcMap interface displaying several retaining walls on I-20 WB in Shreveport, Louisiana 66
Figure 35. ArcGIS Field Maps ─ DOTD screenshots 67
Figure 36. Dashboard style ArcGIS Online web application 69
Figure 37. GAM Planner Model - Risk analysis (NCHRP Report 903) 71
Figure 38. Example rating and LOR, I-49 ramp to LA 3132 West, Shreveport, LA 72
Figure 39. Staged approach for data collection in asset management (NCHRP 903, Figure 4.3) 73
Figure 40. NCHRP Report 903 recommended technique for asset location 77

Introduction

Problem Statement

The Louisiana Department of Transportation and Development (DOTD) has many elements that compose its transportation system. Roads and bridges, old and new, are managed to provide proactive maintenance. Similar to the approach of bridge management, pavement management, and dam/levee safety, DOTD should adopt a methodology to evaluate bridge embankments, culverts, retaining walls and potentially problematic soil slopes to determine repair priorities. Knowing where and how many walls exist, and their age and condition will determine maintenance schedules, necessary funding, and potential risks of failure.

Problematic soil slopes have occurred on Louisiana roads over the years and failures could occur in the future. If slope failures and wall assets are not managed accordingly, future failures could affect the flow of goods, services, and people to market via our transportation corridors and system. DOTD should therefore manage and address slopes, retaining walls, and other geotechnical assets using an effective rationale to document assets and their properties that prioritizes and implements remediation alternatives and repairs.

For example, compare two roads with recent issues. First, LA 66 is a two lane rural highway roughly 20 miles long (Bains to Tunica). Secondly, US 84 stretches across LA roughly 25 miles (Clarence to Winfield). They sound similar, yet LA 66 is the lifeline of Angola Prison to the rest of the world. It must be maintained per the Warden as a two-lane highway 24/7, and there are no other paved routes for access. US 84 (Clarence to Winfield), though vital, is not the only paved route to either city. A recent series of slope failures on LA 66 required emergency action that cost millions of dollars to repair. The US 84 repair was not as critical, but progressively got worse, escalating its repair costs.

Introduction

A goal of a Geotechnical Asset Management (GAM) plan is to reinforce the Transportation Asset Management Plan (TAMP) and to keep transportation corridors open allowing the flow of commerce. If a geotechnical asset fails and blocks a road or disrupts traffic, the transportation corridor is affected along with economic growth (see Figure 1). Funds, labor, and time would be required to repair these failures in addition to the lost economic dollars, frustrated drivers, and businesses encountering more orange barrels.

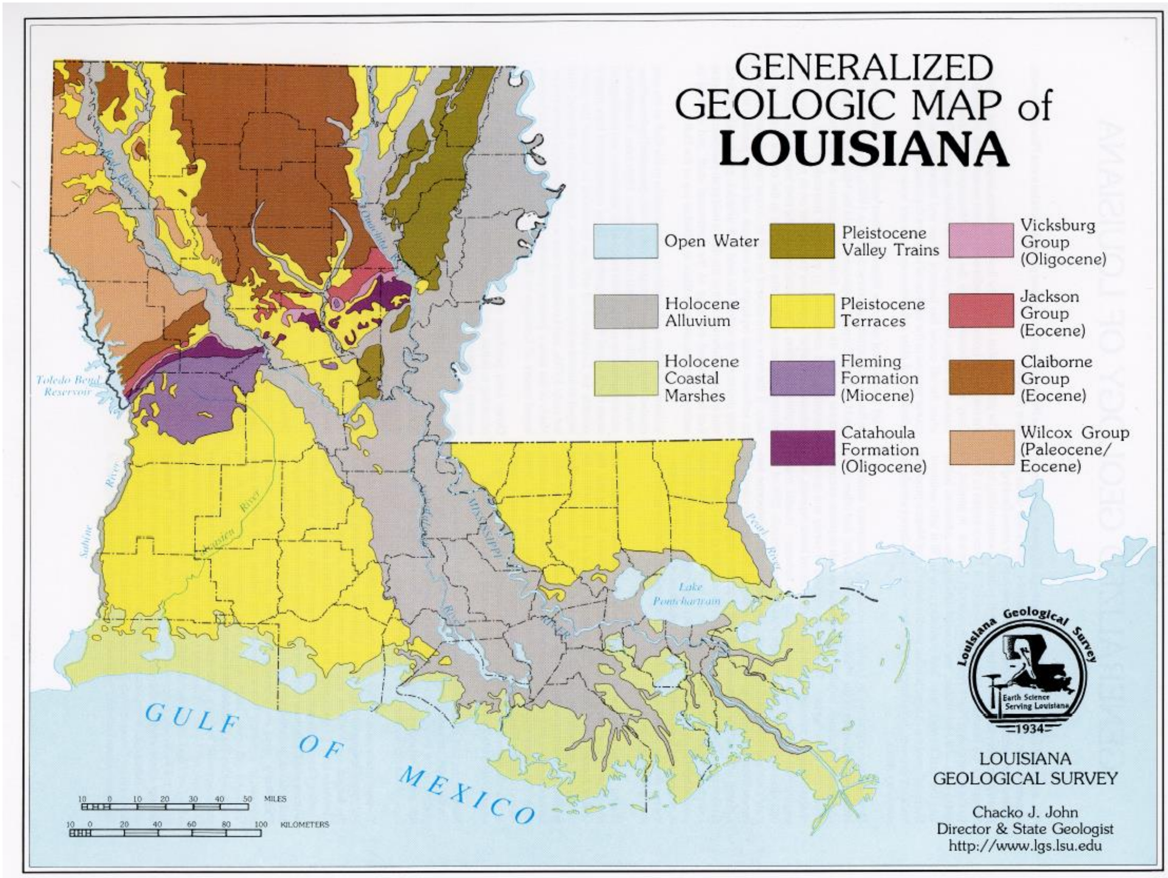
Figure 1. Failure examples affecting traffic corridors

Transportation Research Board (TRB) Section on Geology and Geotechnical Engineering, AKG00 (formerly AFP00), has a subcommittee, AKG00(1), for GAM. The following excerpt is from their website [3].

> Geotechnical Asset Management (GAM) applies these principles to geotechnical assets such as rock and soil slopes, embankments, retaining walls, rockfall mitigation installations, etc. TRB's Geotechnical Asset Management Subcommittee AFP10(2) was formed to "encourage research on GAM topics and to facilitate a free flow of information" related to GAM. The GAM Subcommittee provides a forum for sharing and developing research needs and providing information about GAM and its role in the broader aspects of TAM.
>
> "Virtually every structure is supported by soil or rock. Those that aren't either fly, float, or fall over." Richard L. Handy. ((AFP10), n.d.)

Louisiana differs from most states because it has little to no bedrock at or near the ground surface. Figure 2 shows a generalized geologic map of Louisiana. Some states must deal with the risk of falling rocks and boulders that can damage vehicles, create safety concerns, and block corridors. Luckily, Louisiana does not have any rock-fall worries.

Figure 2. Generalized geologic map of Louisiana

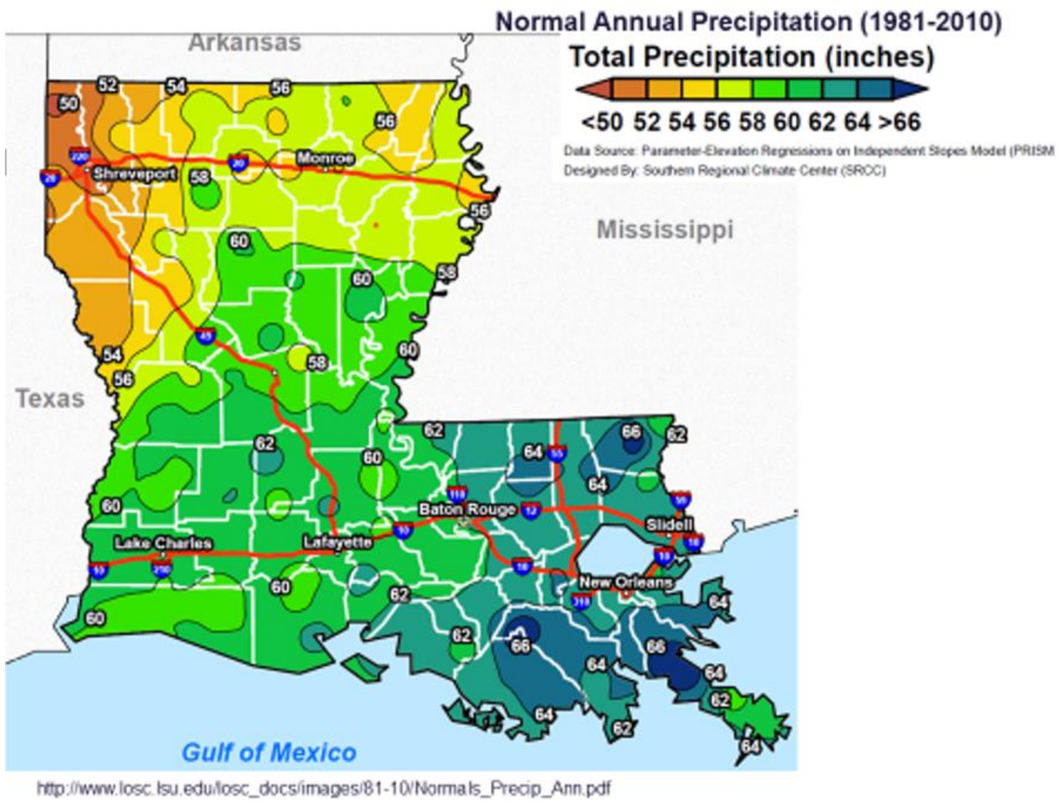


In contrast, Louisiana has lots of the opposite (soft wet clay). Louisiana has some rolling hills in the north, but most is relatively flat with alluvial flood plains from the Red and Mississippi rivers and coastal marsh areas along its southern coast. High river levels can cause concern [4], but Louisiana is fairly rural often allowing for flatter slopes with lower risks of slope failures. More often, walls and steeper slopes appear in and near congested urban areas where right of way (ROW) space is limited.

Louisiana's natural heavy/fat clays can hold moisture, have the potential to undergo large shrink and swell changes, and often have a propensity to incur slope failures. Unfortunately, historical embankment specifications were more liberal and allowed these heavy/fat clays in embankments and slopes. More recent DOTD material specifications are more stringent, but DOTD is responsible for the operation and maintenance of these historical (often problematic) existing slopes, bridge approach embankments, levees, mechanically stabilized earth (MSE) walls, culverts, and other assets that could affect our transportation system and corridors.

The Louisiana climate further exacerbates the issue with sixty-plus inches of rain each year. Rain softens the clayey soils by entering surface shrinkage cracks, providing lubrication to sensitive slopes, and reducing their slope stability. Poor drainage of these heavy fat clays also adds to the problems and instability of the slopes. Figure 3 shows typical precipitation for Louisiana, specifically during the period from 1981-2010.

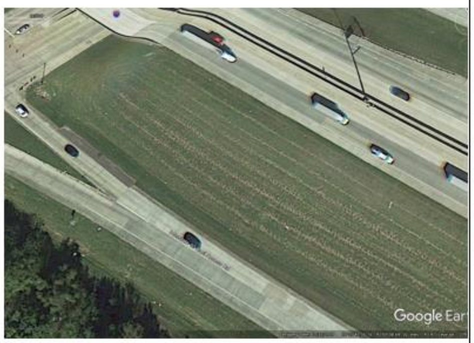
Figure 3. Normal Louisiana precipitation



LTRC project, 95-1GT [5], “Evaluation of the Effect of Synthetic Fibers and Nonwoven Geotextile Reinforcement on the Stability of Heavy Clay Embankments,” outlined a repair method for problematic, clayey slopes. In approximately 1995, a slope failure at Interstate 10 (I-10) and Bluebonnet Boulevard was used as a demo for the recommended reactionary repair. In 2019, another slope failure occurred along I-10 at a different corner of the same intersection. See Figure 4 and Figure 5. Both slope failures were near the active traffic of I-10. Two of the four slopes at this intersection have failed, and all were constructed during the same period with similar heavy clay soils. Relatively speaking, the slopes at this intersection are not incredibly steep, but due to the soils and moisture, failure occurred. The potential for slope failures at other corners of this intersection and similar intersections should be monitored and managed.

Figure 4. Interstate 10 at Bluebonnet Boulevard slope failure, 2019

Figure 5. Interstate 10 at Bluebonnet Boulevard – historical aerial photos



a. November 2017
– no apparent movement

b. January 2019
– scarp and toe visible

c. July 2019
- mowers avoiding scarp

d. March 2020
- repaired slope

A separate ongoing research study associated with LTRC project, 18-2GT, “DOTD Support for UTC Project: Prediction and Rehabilitation of Highway Embankment Slope Failures in a Changing Climate,” will help identify these slopes in a more proactive way. Jafari [6] offered up this recommendation to DOTD and others, “Develop a central online form for headquarters and local districts to document highway embankment failures, repairs, and new construction. This will assist in asset management, which is a key focus of the Federal Highway Administration.”

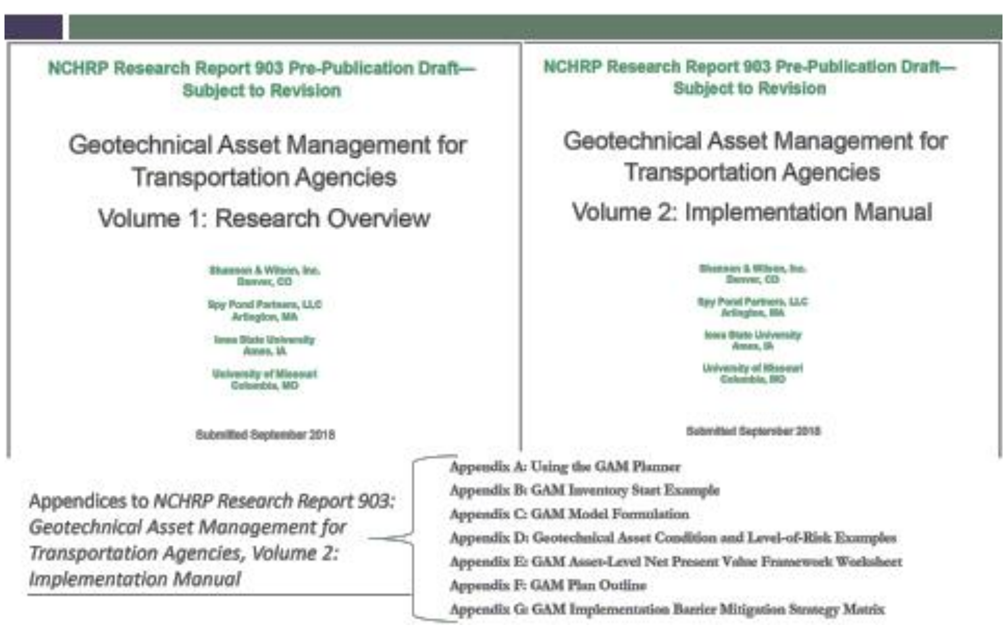
Additionally, LTRC project 18-1P [7], “Exploration of Drone and Remote Sensing Technology in Highway Embankment Monitoring and Management,” should help collect moisture and elevation data in hopes of identifying potential/developing slope failures. A GAM database would take this further by establishing a way to store this data, support geographic information system (GIS) visualizations, and document the data relative to construction and performance for future DOTD engineers.

Retaining walls have more components than a soil slope, which makes wall documentation effort more difficult. Wall component materials, ultimate design life, and remaining design life lead to the overall effectiveness of the retaining wall. By documenting these geotechnical assets, we can track and proactively plan to address these structures as they near their ultimate design life. For example, years ago, the author met a New York representative who was concerned with a large number of bridges constructed within the same few years, over 50 years ago. These New York bridges would all be reaching their end of life concurrently. A method to inventory and identify critical parameters would allow New York to prioritize modifications, repairs, and upgrades. A similar system for geotechnical structures and slopes would benefit DOTD.

Literature Review

National Cooperative Highway Research Program (NCHRP) study, NCHRP 24-46, entitled "Development of an Implementation Manual for Geotechnical Asset Management for Transportation Agencies," was underway at the start of this project and ultimately released as NCHRP Report 903 [1]. The report provided excellent guidance along with other references within. This manual was critical to this research and will be important in GAM implementation. Figure 6 presents the covers of Volume 1, Volume 2, and the appendices contents.

Figure 6. NCHRP Research Report 903



The NCHRP report provides valuable data, insight, and direction for state agencies regarding Geotechnical Asset Management. It recommends "starting lean," and researchers utilized this logic even prior to receiving the NCHRP report 903. There are thousands of geotechnical assets across the state, and potentially so much data that could be collected in a database. However, how much effort and energy is required to collect all this information, and what benefit would it provide on the microscopic detail level? Starting lean refers to getting a foothold in the data. Similar logic is that it might take 20% effort to collect 80% of the data, but the last 20% of data will take 80% effort. Starting lean ensures that the process is started and that existing data was utilized to speed the process.

Several years ago, DOTD was asked about Louisiana's wall inventory via survey, later published as part of NCHRP Synthesis 430 [8]. The responses were lacking and sparked a new initiative to get a handle on how many retaining walls DOTD had; their locations, age, and purpose; and an idea as to how they are performing. DOTD has a better handle on it now, but still has a way to go. There is still a need to incorporate techniques, documentation, and strategies to plan proactively for the future of our assets.

TRB AKG00(1) Committee Co-chair Darren Beckstrand provided a multitude of GAM resources for this research. Beckstrand's resources deal with many rock-fall prone states, and his "Jump-Starting a Geotechnical Asset Management Program with Existing Data" [9] was an especially valuable resource. Beckstrand's employer, Landslide Technology, conducted work for several states (Idaho, Alaska, Montana, etc.) to develop interactive GIS maps for asset inventory and condition assessments. [10] [11].

Alaska Department of Transportation and Public Facilities (AK DOT&PF) developed a *Retaining Wall Inventory Procedures Manual* spearheaded by Dave Stanley, chief engineering geologist (also former co-chair of TRB AFP10(2)). From the AK DOT&PF website [12]:

> "The Department's Geotechnical Asset Management (GAM) Program is under development in parallel with our Transportation Asset Management Program. GAM incorporates performance and risk management principles in managing assets such as material sites, rock and soil slopes, embankments and retaining walls. These assets have a vital role in providing raw materials to build our roads and airports, as well as physically supporting our transportation assets and structures. The Statewide Materials Geotechnical Services group is actively conducting research to guide development of GAM principles and practices."

Brutus et.al. [13] outlined a retaining wall inventory and inspection program noting the benefits as a reduction in potentially disastrous retaining wall failures, a valuable foundation element of an agency's asset management program, and through asset management a systematic way to optimize and allocate resources (budget, personnel, etc.).

Minnesota Department of Transportation (MnDOT) conducted a transportation research synthesis entitled "Asset Management for Retaining Walls" [14]. They stated, "While most transportation agency retaining wall asset management programs are in their beginning stages, we found a significant amount of useful guidance about developing such a program." Their research was broken into four sections: consultation with experts, state and local practices, national resources, and related issues.

An article from *GeoStrata* [15], "Sustainability and Resilience in Transportation Infrastructure Geotechnics," describes the need to plan for the future by integrating advanced technologies for better asset management. In their article, the researchers focus on environmental, economic, and social impacts from geotechnical assets and the need to assess sustainability and resilient alternatives, utilize alternate materials and methods, and harness new technologies. For DOTD to fully realize these benefits and opportunities, we must first inventory and assess our existing infrastructure.

Another key reference was insight from Jerry DiMaggio, former Federal Highway Administration (FHWA) principal bridge engineer/geotechnical engineer; and current senior principal civil engineer at Applied Research Associates, Inc. (ARA). DiMaggio spoke on an array of topics, including a statement he made at the TRB 2020 conference, "Walls are structures, and should demand a higher respect." The statement follows along with recent research from GeoComp Corporation (GeoComp)/ARA [2], other state departments of transportation (DOTs) [9], [10], and TRB AKG00(1) members and friends.

On April 15, 2020, FHWA and the American Association of State Highway Transportation Officials (AASHTO) sponsored Webinar 43 on GAM and Transportation Asset Management (TAM). There were three presenters. Mark Vessely of BGC Engineering presented a Summary of the NCHRP 903 report. Chris Merklin of the Ohio DOT presented their GAM efforts. Gavin Gautreau presented on progress towards GAM in Louisiana. Later in 2020, TRB accepted a paper by Gautreau and Adele Lee on the progress of GAM in Louisiana for presentation. This literature review provided abundant guidance for this research project and this LTRC report documents the full efforts toward GAM in Louisiana.

Objective

The objectives of the research were to:

- Research existing state and federal efforts regarding GAM.
- Determine the applicability and implementation of GAM within Louisiana.
- Develop database parameters for population.
- Identify the logical steps toward full implementation.
- Recommend and implement strategies.
- Document the research effort.

Scope

This project focused on geotechnical asset management (GAM) within DOTD, and established the basics and foundation on which to build a GAM system for DOTD. The project researched GAM systems and implementations within other state agencies and on the national level.

Methodology

This research project examined references to identify the logical and recommended path forward for DOTD regarding GAM.

Task 1: Research existing state and federal efforts regarding GAM

This task continued the literature review toward the formation and implementation of Geotechnical Asset Management within DOTD. This task includes, searching for other state agencies, DOTs, and national GAM programs, including FHWA, NCHRP, TRB, and Transport Research International Documentation (TRID).

Task 2: Determine the applicability and implementation of GAM within Louisiana

This task included researching DOTD policies and existing agency asset management programs including Agile Assets, Pontis, and other computer systems to see current applicability and potential locations for the resulting GAM database. Having reviewed other state and federal agency reports regarding GAM, researchers will confer with DOTD staff to determine how easily systems could be implemented. Some existing systems may benefit the implementation of a GAM database system. Other requirements may need to be created into hardware, software, and policy. DOTD staff experience with road and bridge asset management will likely play a large part in this task. This will include both technical details (geotechnical) and software (data management) staff. There may also be phased implementation to establish and setup the system with secondary phases developed at a later date. Best practices from the upcoming NCHRP 24-46 [1] will likely play a large part in reviewing potential compatibility with existing DOTD practices.

Task 3: Develop database parameters/schema for population into a Louisiana database

This task developed the database schema for implementation within DOTD. Best practices will indicate which parameters DOTD should include in their GAM system. The department may even have some of the data already. There are simple parameters like height, length, and current performance (functioning, or not). In contrast, a more complete database would likely include more detailed information such as year constructed, wall type, reinforcement type with measurements (length, diameter, corrosion rates, etc.), design life, etc. Some of these details may not be so easily revealed; however, DOTD has to start somewhere. The database will likely contain many fields with historical projects populating as many parameters as available to date (low hanging fruit). Collecting the data within DOTD will take time and could require district forces for historical and plan information. New projects would have the data more readily available to populate the fields. Database updates to historical projects could also be made by district investigation within best practice timeframe.

This task would also investigate geographic information systems (GIS) to display these geotechnical assets within DOTD. These location-based assets can be shown with links to metadata and the database information. Some states utilize this form of database as a hazards database to assist with future efforts. As experienced staff retire, their knowledge base leaves through the door with them. Problematic locations, like the US 84 and LA 66 described earlier, could be documented and stored in the database with information about their repair. With all the information in one place, future engineers can easily determine past efforts, unsuccessful repair attempts, and successful solutions. Should an area or an adjacent region have issues, a logical analysis with successful repair options would be available for design and repair decisions.

Task 4: Identify assessment criteria and management strategies

Physical inspection data and materials are but one side of the equation. How to rank and prioritize condition, performance risk, and maintenance strategies are the other side of the equation. Elements must be quantified and analyzed to determine the level of risk and repair priority associated with each. Certain elements and parameters will have more detailed and complex sensitivity levels based on available data and/or the collection method. The researcher will evaluate the sensitivity of each parameter to identify critical elements and methods for level analysis (e.g., Level 1 has no data, Level 2 has some data, Level 3 has good data, Level 4 recommended data level). These assessments will provide DOTD with a logical method to evaluate and rate the elements of their existing system and compare those ratings against associated risks as related to minimum safety standards.

When the threat analysis/management tool combines the socio-economic consequence of failure, the tool can be used to prioritize risks (red flags), support detailed engineering analysis, and allocate available funding to the most critical areas of the highway system in

Louisiana. The development and implementation of a GAM system will provide the department with a logical method to manage and address each problematic location and effect a rationale to implement each repair in a timely manner. This would be a proactive vs. reactive solution/system. With the ever-pressing need to do more with less and the knowledge drain of retiring workers, the system will help preserve the past so that designers can plan for the future.

Task 5: Recommend and implement strategies

This task developed an implementation plan for establishing a DOTD GAM program and policy. This task includes the actual steps within LTRC, information technology (IT), DOTD Bridge, Geotechnical, and District sections.

This action plan will guide the DOTD through a phased implementation of a comprehensive GAM system to analyze and manage elements/data. The analysis/management tool will be used to rate and evaluate elements as a highway network, and identify locations of risk (red flags) based on existing and collected information when compared against best practices and acceptable standards. The task will also provide recommendations on how and who should collect old and new data moving forward, and also how the GAM system should be maintained by the DOTD owner (recommended staff, hours, etc.).

Task 6: Document the research effort

This task prepared the final report to document the entire research effort. The research team will prepare a final report to document the entire research effort. The final report will include data, discussion of results, and recommendations generated by the study.

Software

ArcGIS ArcMap™ (Version 10.4.1) is a component of ArcGIS from Environmental Systems Research Institute (ESRI) used for collecting the geo-referenced data and the creation of maps in conjunction with other geographic information systems (GIS) and datasets available within DOTD.

DOTD has an internal official GIS road network available to the researchers, which contains various layers including centerlines and their corresponding linear referencing system identifications (LRS-IDs). The DOTD utilizes RouteID, specifically LRS-ID, to categorize road sections so that each road, ramp, direction, etc. has a unique identifier. This project will utilize as many software and protocols already existing within the department, as possible.

Google Earth and Google Maps are applications that have aerial and street view imagery that can be manipulated and viewed on the internet. The images and maps can provide relatively timely 2D and 3D perspectives for view of existing field and road conditions. DOTD also utilizes aerial imagery from the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP).

VisiWeb/iVision, is an internal DOTD computer application that has street-view roadway images to access information on field assets.

ArcGIS Collector is a mobile data collection application that is part of the ESRI suite. The application is designed to allow fieldworkers the ability to utilize web-maps to collect, edit and analyze geospatial data. Collector makes it easy to capture accurate data directly into centralized GIS databases. ArcGIS Collector works even when disconnected from the internet and integrates seamlessly into ArcGIS. ArcGIS FieldMaps is the newer version of this mobile application.

AgileAssets is a global provider of enterprise infrastructure management software for government and private organizations. [16] AgileAssets is currently utilized by DOTD as an asset management software.

Deighton Transportation Infrastructure Management System (DTIMS) is an asset management software utilized by the DOTD Pavement Management Section.

Microsoft Excel is a valuable spreadsheet software utilized to add and sort collected data in association with database efforts.

Discussion of Results

The LTRC GAM project started slightly earlier than the actual release of the NCHRP report 903. Without the NCHRP guidance, researchers focused on inventorying retaining walls. Walls are expensive to construct, and support or protect major roads in urban areas (Figure 7). These structures are primarily located on larger highways with high average daily traffic (ADT) counts, and were undertaken first as they were relatively easy to identify and limited in quantity compared to the numerous embankment slopes, culverts, etc. that exist. Walls would serve as a starting point/pilot program to develop criteria and methodology that could be adapted to other geotechnical assets like slopes, culverts, etc.

Figure 7. Mechanically Stabilized Earth (MSE) walls, Shreveport, LA

Researchers met with project review committee (PRC) members and key personnel within DOTD at the beginning of the research process. GAM logic was a new concept to some of the DOTD leadership. During an early PRC meeting, a member inquired if geotechnical assets included retaining walls. The member received an affirmative response as the project aims to inventory how many retaining walls are in Louisiana and proactively manage them. Unfortunately, these walls and other geotechnical assets were not fully on anyone's radar at the time.

At that initial PRC meeting, we discussed a broad overview of the goals of the project and where to possibly store the data. The department currently utilizes AgileAssets for maintenance operations for other transportation assets. However, the DOTD AgileAssets tables did not include DOTD GAM assets. DOTD staff familiar with the software retrieved some AgileAssets template GAM information with basic fields that one might expect to describe an asset, though not necessarily complex enough for robust GAM inventory or rating data.

GIS Collection Methodology and Technology

DOTD uses the ESRI suite of products for the agency-wide Enterprise GIS. For this research, a file geodatabase was created with Earth Retaining Structure as the primary line feature class for collected retaining walls. A feature class is the table structure in the geodatabase where rows and columns of spatial data is stored. In addition to the GAM suggested attributes, DOTD requires several attributes specific to the state and the ESRI *Roads and Highways* linear reference system (LRS). LRS is the GIS method for subcategorizing measured distances along a continuous line feature. In the geodatabase, domains were added for parishes and DOTD district offices to provide pull down choices in the map collection interface. This allowed researchers to populate many columns in the GAM with existing DOTD information.

An ESRI ArcMap (version 10.6.1) document was organized where the Earth Retaining Structure feature class, several other reference features classes, and aerial imagery were all added to the map interface with all layers set to DOTD standard horizontal datum UTM 1983 Zone 15 North Meters Project (EPSG 26915).

DOTD's Statewide Routes feature class was included as a reference layer in order to copy the unique RouteID roadway information into the Earth Retaining Structure feature class. This information is required to implement the retaining walls into the official DOTD *Roads and Highways* LRS. The RouteID attribute was automatically populated into each retaining walls feature using the ArcGIS Attribute Transfer geoprocessing tool.

Researchers used aerial imagery of the state to collect the retaining wall features. Imagery included the GOHSEP gathered imagery sources that range from the best ground resolution of 3 inches in some metropolitan areas to 39.37 in. (1 meter) National Agriculture Imagery Program (NAIP) data.

Researchers began collecting assets by digitizing the wall feature as a line vector in ArcMap. ArcMap allowed a research development platform without affecting the online production settings of AgileAssets. In addition, ArcMap allowed the walls to be drawn in their true location vs. along the road centerline. AgileAssets did not have linear offset assets in its GIS capability at the time. Walls are not always parallel to a road and may cross under a road, but most retaining walls are offset from the road edge. ArcMap allowed a platform for geospatial placement of the walls, and collection of other spatial attributes such as material, height, age data, and text information. GIS platforms are also the trending way to visualize multiple layers of data providing graphical data and links to metadata. As the GAM system matures, we should be able to link the GIS database to AgileAssets or other software as the need develops.

Walls and assets exist statewide and would take time to visit in person. Since wall locations are not easily found in the DOTD documentation for construction or inspections, researchers turned to online mapping sites and mapping software to collect initial information. This allowed researchers to optimize spatial collection efforts. Additionally, without easily located paper maps to inspect, researchers were starting from scratch and time was better spent in the office searching online maps rather than driving to each known or unknown location. For example, Shreveport is roughly four hours from Baton Rouge, but through Google Maps, Google Earth, and street view applications, researchers could conduct preliminary investigations to identify and locate walls statewide all from one office without travel.

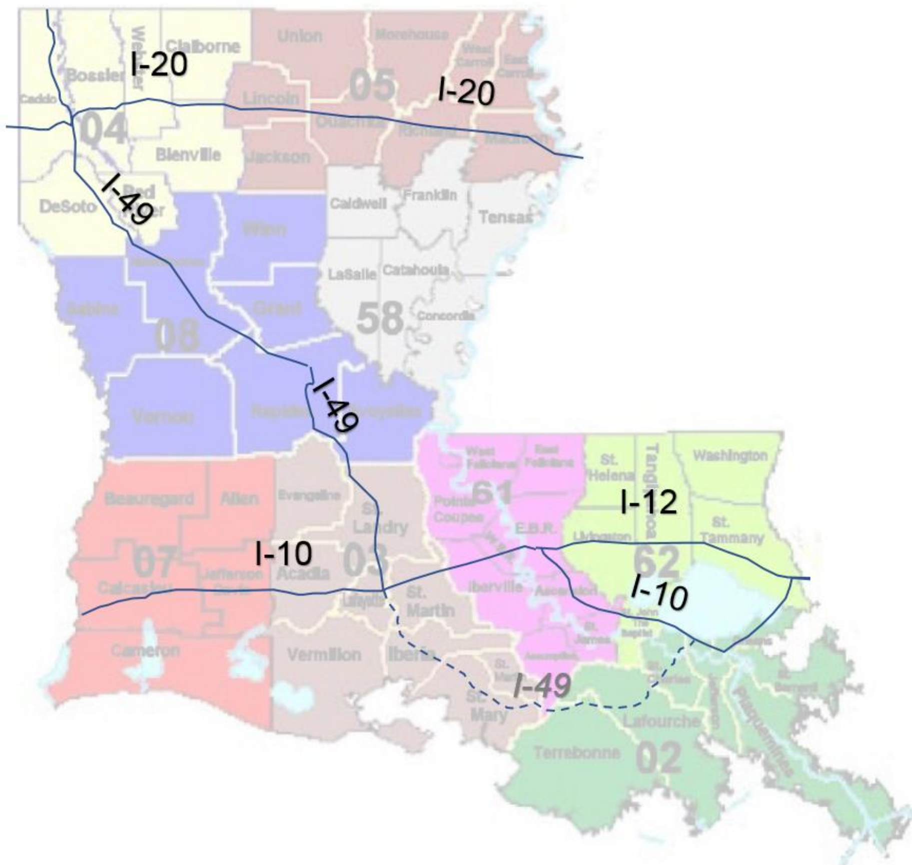
The software applications provided views (aerial 2D, aerial 3D, street) to quickly identify walls throughout Louisiana. These initial/virtual inventories collected from the office utilizing these platforms reduced field efforts necessary from district personnel, kept researchers off the streets, eliminated traffic issues, and eliminated any potential safety issues of distracted researchers or drivers during these initial inventories.

Congested, urban areas often have limited ROW and utilize walls with steeper slopes to address these geometric constraints. Retaining walls are also, more often than not, located at highway bridge crossings over other roadways, railways, and water bodies that are easy to spot in these online maps. Most retaining walls are located on our interstate corridors (Figure 8). This made collection of these walls easy and part of a low-hanging fruit logic since no database existed for these geotechnical assets. These inventories might not be perfect, but they are a good start to the database and certainly better than not starting at all.

Retaining walls were selected as a pilot dataset to begin building the DOTD GAM database. The collection of retaining walls later mirrored the recommendation of the NCHRP report

903 and other GAM contacts in addition to references to "start lean." Starting lean refers to collecting data that is easily and readily available as a starting point, rather than digging too deep and delaying the implementation of the GAM. This wall dataset could be expanded in the future, and other similar datasets initiated (slopes, culverts, etc.) following a similar model.

Figure 8. Major Louisiana corridors



Flyover capability in Google Earth and Google Maps allowed quick preliminary overview inspections of long stretches of highway. Researchers used ArcMap to collect walls statewide by utilizing the 3D views to see the wall facings, locate the walls on the DOTD roadway LRS, and differentiate them in the database. Initially, researchers started mapping walls in Baton Rouge at the Picardy interchange at the Mall of Louisiana because of the proximity to the LTRC researchers, but with the online tools, collection could have started anywhere in Louisiana.

Walls and Segments

New features were collected in ArcMap to reflect the existing walls, other assets, and hazards. The wall features were separated into two main categories. First, “segments,” represent a stretch of wall with a unique location, facing, slope, LRS-ID, route, purpose, and parameters. Secondly, adjacent segments were linked through a common field that identified that segment as part of a “continuous wall.” This way, a continuous wall could be composed of several different segments (faces, heights, purpose, etc.), that are physically next to each other, and may affect each other. For example, a stretch of I-20 in Shreveport (Figure 9) has several adjacent facings indicating different construction details, ages, and purposes, but were collected as adjacent segments in a continuous wall that protects I-20.

Figure 9. Example of multiple adjacent retaining wall facing types along I-20

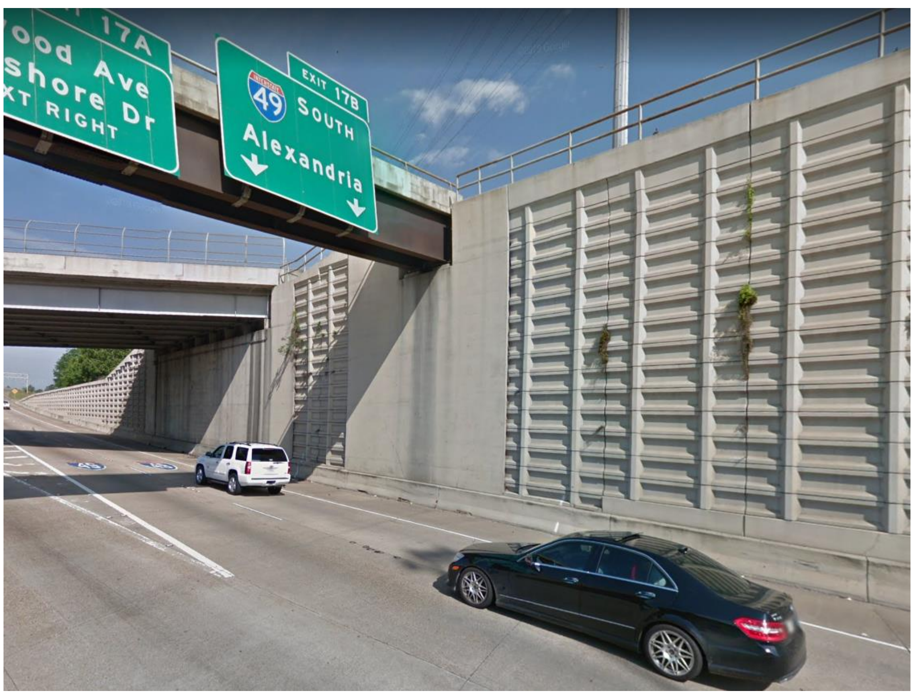
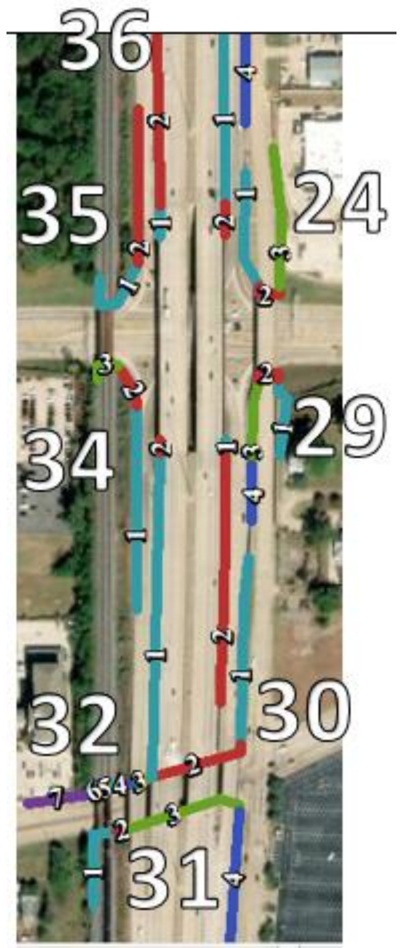


Figure 10 shows an intersection in Shreveport, LA with multiple walls labeled with large white numbers. Segments are in different colors with an associated smaller “segment number” on the line. Simple retaining structures might only have one segment in the continuous wall. In contrast, a long, complex wall like some shown below would have many segments in the continuous wall. Each different colored segment within a continuous wall gets a new segment number, starting with one (1). This repeats for the next continuous wall. Database structure records assign unique identifiers for each individual line segment drawn.

Again, some walls have multiple segments as it depends upon the particulars and differences of the wall segments.

Figure 10. Wall segments and continuous wall numbers



In Figure 10 the larger white numbers were added to represent continuous wall numbers in the database. The database record includes the wall and segment numbers along with other unique feature information; however, displays were kept simple with only segment numbers. The added wall numbers were written on printouts from ArcMap to easily identify a continuous wall's segment numbers and their location in relation to other streets, which helped when validating other mapping views and websites. These interim printouts allowed researchers to close ArcMap, which reduced computer memory requirements, and the potential for crashes with large datasets and graphically demanding map programs. These printed wall numbers helped researchers locate and group the segments into manageable datasets for further construction, and delegate associated properties data collection (historical

LRS-ID, height, wall facing, etc.) to engineering technicians without the need for extensive ArcGIS/ArcMap experience. Technicians utilized the printed maps in conjunction with Google Maps, Google Earth, and other DOTD information services to view and collect segment data. Technicians collected, then stored the segment's associated description and related data in an Excel template exported from the ArcGIS database. As each technician completed data collection for assigned walls, populated attributes were imported into the ArcGIS database.

Data Fields

The database contains many fields. This section describes each field contained in the database.

NAME	Description
• OBJECTID	Database structure unique identifier
• RetainingWallSegmentUniqueID	Wall segment unique ID
• RetainingWallSegmentNumber	Continuous wall number (can contain segments)
• RetainingWallSegmentCounter	Segment counter of continuous wall
• RetainingWallSegmentOrder	Total segment order
• RetainingWallSegmentName	Segment common road description name
• RouteID	Roads & Highways ID (Linear Referencing System (LRS))
• FromMeasure	Route ID start
• ToMeasure	Route ID end
• LRSID	Legacy Linear Referencing System (LRS) ID
• FromLogMile	DOTD Log mile measurement
• ToLogMile	DOTD Log mile measurement
• ControlSection	DOTD stretch of highway number
• Parish	Louisiana Parish Code
• District	DOTD District in which contained
• SegmentLength_Feet	Length converted to feet
• SegmentFaceMaterial	Wall face based on Google Earth, (Block, RECo, Panel, concrete, etc.)
• SegmentStartGroundElevation_Feet	Start ground elevation based on Google Earth
• SegmentStartRoadElevation_Feet	Start road elevation based on Google Earth
• SegmentStartHeight_Feet,Start Height	Start segment height (calculated)
• SegmentStartHeight_Blocks	Start blocks count height based on Google Earth
• SegmentEndGroundElevation	End ground elevation based on Google Earth

- SegmentEndRoadElevation — End road elevation based on Google Earth
- SegmentEndHeight_Feet — End segment height (calculated)
- SegmentEndHeight_Blocks — End blocks count height based on Google Earth
- SegmentHeightAverage_Feet — Average segment height (calculated)
- SegmentWallFaceArea_Feet — Segment face area (calculated)
- ConstructionDirectionFromGround — Construction (Up or Down)
- AssetOwner — Owner
- ProjectNumber — DOTD Project Number
- Construction_Year — Year Constructed
- AnchorType — Reinforcement Type
- PlanStampDate — Plan Stamp Date
- FromPlanStationNumber — Plan Station Number – From Start
- ToPlanStationNumber — Plan Station Number – To End
- PlanSheetsLink — Plan Sheet Link
- OperationConditionRating — Operation and Maintenance Condition Rating
- SafetyConsequenceRating — Safety Consequence Rating
- MobilityEconomicRating — Mobility and Economic Consequence Rating
- LevelOfRisk_Number — Level of risk (calculated from 3 rating fields)
- LevelOfRisk_Letter — Level of risk grade (calculated from 3 rating fields)
- SegmentRepairDate — Segment Repair Date
- RepairProjectNumber — Repair Project Number
- DecommissionDate — Decommission Date
- ReplacementWallID — Replacement Wall ID
- ReplacementWallProjectNumber — DOTD project number for wall replacement
- Comment
- FeatureCreated_User — User who first collected the spatial location
- FeatureCreated_Date — Date the spatial location was collected
- Shape_Length — Database structure length of segment in meters

Additional inventory information/ highway traffic characteristics to consider adding fields in the database as it grows over time.

- Highway classification
- Speed
- Wall purpose (support /ramp, retain, back-slope, both, etc.)

- Emergency route information
- Detour time
- Detour distance
- Slopes / Failure history
- Frequency of inspection
- Failure information
    - Type/description
    - Deformation rate
    - Scarp dimensions/volume
    - Damage
    - Repair history
- Condition consequences
- Injuries/fatalities
- Vehicle risk
- Road impact
- Annual cost
- Cost/benefit
- Future impact
- Specific inspection form details (higher risk walls)

Other Assets

Levees near Highways

Louisiana has several large rivers (Mississippi, Red, Atchafalaya, etc.) that cross through the state. These rivers can overtop their banks and cause damage to property or result in casualties. Louisiana is also subject to storm surges from the Gulf of Mexico, and has strengthened coastal and inland barriers since Hurricane Katrina. Though primarily the responsibility of the United States Army Corps of Engineers (USACE), these levees could affect adjacent roads.

Tunnels with Retaining Walls

There are three major tunnels in Louisiana, all south of Interstate 10. Tunnels were a historical solution to cross the Gulf Inter-Coastal Waterway and other large roadways. State Senator Reggie Dupre of Houma said the idea of replacing the tunnel has been around since the late 1990s. He indicated the three tunnels existing in the state – Houma, Harvey, and Belle Chasse – “are maintenance nightmares.” [17].

- The Belle Chase tunnel opened on February 15, 1956, and there are plans to replace this tunnel with a new bridge as part of Louisiana's first Public Private Partnership (PPP) project.
- The Harvey Tunnel opened on September 5, 1957. The tunnel is still in use; however, US 90 Business was built as an elevated section over the Harvey Canal that will eventually become part of Interstate 49 as the infrastructure to replace the aging tunnel.
- The Houma Tunnel was built in 1961 and its replacement is also in the early planning phases.

The DOTD Bridge Maintenance section manages each tunnel. The cast-in-place retaining walls that lead to tunnels should have a more formal review/inspection process. The department plans to retire all these tunnels, but the lead-in retaining walls should receive appropriate maintenance attention while the tunnels are still in service.

Geotechnical Boring Data

DOTD has made great strides with its geotechnical database efforts in recent years. Geotechnical data is an asset with value, and should not only be preserved, but stored as digital data in a readily accessible format. We are currently in transition from Bentley software, gINT, to Keynetix: HoleBASE and their cloud-based Open Ground, which was recently acquired by Bentley. HoleBASE/Open Ground is a newer, robust software platform that supports GIS visualization, and will benefit the department by providing a single resource to DOTD geotechnical designers for soil borings, Cone Penetrometer Tests (CPT), and pile load test data simultaneously. Adding walls to Open Ground will consolidate information and efforts. The DOTD Geotechnical Design section is also working toward the standard data transfer protocol of Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS). This transfer protocol will ease the transmission of data from our consultant geotechnical partners, and other regional state DOTs (Texas, Arkansas, and Mississippi). DIGGS will be a key toward digital data moving forward. The cloud version of HoleBASE, Open Ground, will also provide continual access to geotechnical data within the department. Linking geotechnical borehole data to assets using LRS-ID identifiers will facilitate interoperability with all other DOTD GIS features. Open Ground may also be an alternative place for information that is not necessarily a hard asset, but metadata linked to a hard asset (photos, load tests, etc.).

Emergency Data, Staff Knowledge

Not all geotechnical repairs are equal. The example stated earlier regarding LA 66, the highway leading to the Louisiana State Penitentiary informally Angola, illustrates that there can be many factors affecting the repair such as location, average daily traffic (ADT), slope contours, soil type, political considerations (warden need), etc. As experienced staff retire, their geotechnical repair knowledge leaves through the door with them. Therefore, problematic GAM locations should be documented and stored in the database with information about their repair so that future engineers can easily determine past efforts, unsuccessful repair attempts, and successful solutions. Should an area or an adjacent region have issues, a logical analysis with successful repair options would be available for design and repair decisions. Having this GAM database readily accessible to visualize via GIS maps will benefit the department in its scope of knowledge, efficiency, and planning. The following repairs are extensive and should be documented in a single source with a GIS map to link their location and repair information.

LA 66, West Feliciana Parish. The repair of LA 66 was part of a Highway Priority Program repair and estimated to cost the following for various stations along this short stretch of highway:

- The 0.1-mile project from Sta. 7+36 to Sta. 12+64 estimated $378,494, but totaled $427,606 for sheet piling at slide areas in loess soil area.
- 251-02-0037 Added Sheet Piles estimated cost $500,000
    - Log mile 7.1 to 7.6
- 251-02-0046 Repair Embankment Failures estimated cost $427,606
    - Log mile 6.61 to 6.71
- 251-02-0038 Repair Embankment Failures estimated cost $509,000
    - Log mile 6.5 to 6.5
- 251-02-0039 Repair Embankment Failures estimated Scarp to Scarp 5-12-2003
    - Proposed H.970395, Second slide area incorporating consultant plans w/ Geotechnical Staff (Sheet pile wall analysis 6/2010 and Preliminary plan review 8/2010)

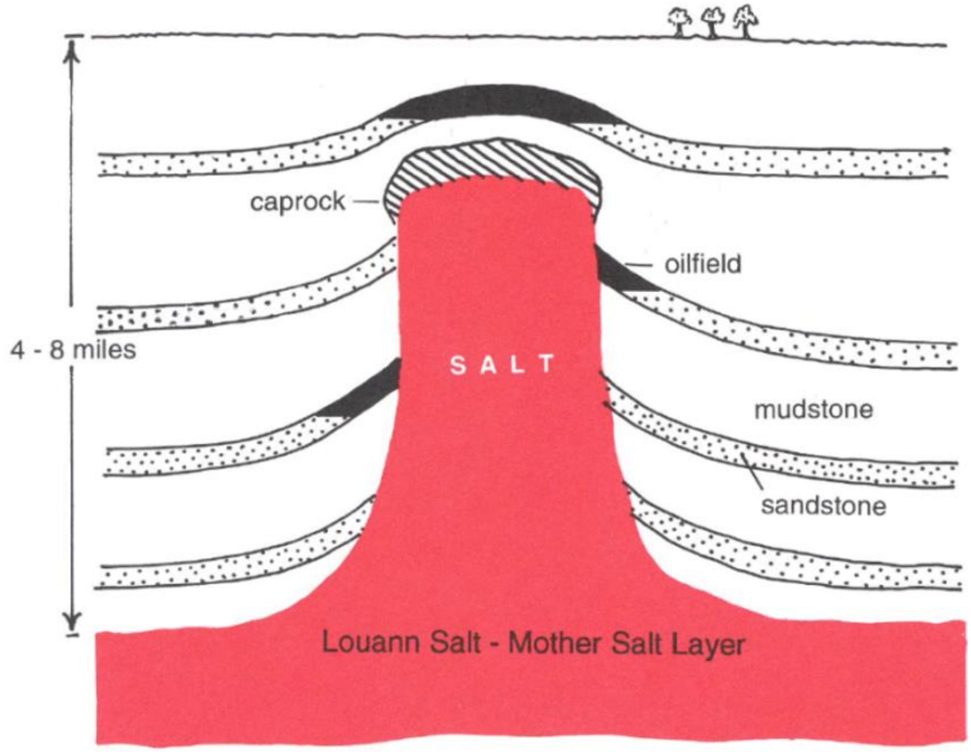
I-20, Vicksburg Bridge. There are two Mississippi River bridges connecting Louisiana and Mississippi, the Natchez Bridge on US 425 and the Vicksburg Bridge on I-20. These two states have a maintenance agreement that each is responsible for one of these major river crossings. Louisiana is responsible for the Vicksburg Bridge, and Mississippi is responsible for the Natchez Bridge. Unfortunately, the Vicksburg Bridge has experienced some movement due to slope stability issues over the years. DOTD hired consultants have documented the movement, which appears to be based on an ancient slope failure/slide that can be aggravated by fluctuations of the river, primarily drawdown. Additionally, there are slickensided clays exacerbating the movements (Figure 11). Current and historic major bridge monitoring efforts should be documented appropriately for future engineers, tasking and planning.

Figure 11. Mississippi River Bridge—Vicksburg, MS

Salt Domes

Louisiana is a petrochemical state with many natural resources. Salt deposits left from historic high sea-levels exist below the current ground surface layers in parts of the state. This low-density salt works its way to the surface over time due to heat, pressure, and a density inversion, like a lava lamp. These salt domes are a valuable natural resource that are mined for table salt, chemical process, and adjacent hydrocarbon deposits. A generalized sketch of salt dome basics is presented as Figure 12.

Figure 12. Generalized salt dome cross-section



Cross section of a salt dome. The horizontal scale is exaggerated; salt domes are normally much taller and narrower than shown. D, Spearing, 2007

In 2012, a sinkhole developed near Bayou Corne, LA in conjunction with salt mining operations on the Napoleonville Salt Dome. The sinkhole threatened the integrity and connectivity of LA 70 and the community in general. The Bayou Corne community was displaced, and the future of LA 70 was uncertain as the situation progressed. Emergency efforts to monitor the expansion of the sinkhole commenced, and bypass planning efforts began as an alternative to the 1.5-hour detour around the area. Five continuously operating reference stations (CORS) were installed in the area to monitor movements with both local and global reference points. Figure 13 shows the extent of the Napoleonville salt dome and the Bayou Corne sinkhole at its west edge.

This incident brings to light the need to document and cross-reference these salt dome assets with our highway system. The Louisiana Geological Survey (LGS) has compiled a map of salt domes across the state (Figure 14 and Figure 15). Digital versions of this map have been added to the GAM database as a GIS layer so that DOTD designers and managers can be aware of these sites and their associated risks.

Figure 13. Salt domes and sinkholes—Bayou Corne

Figure 14. Louisiana salt domes and locations

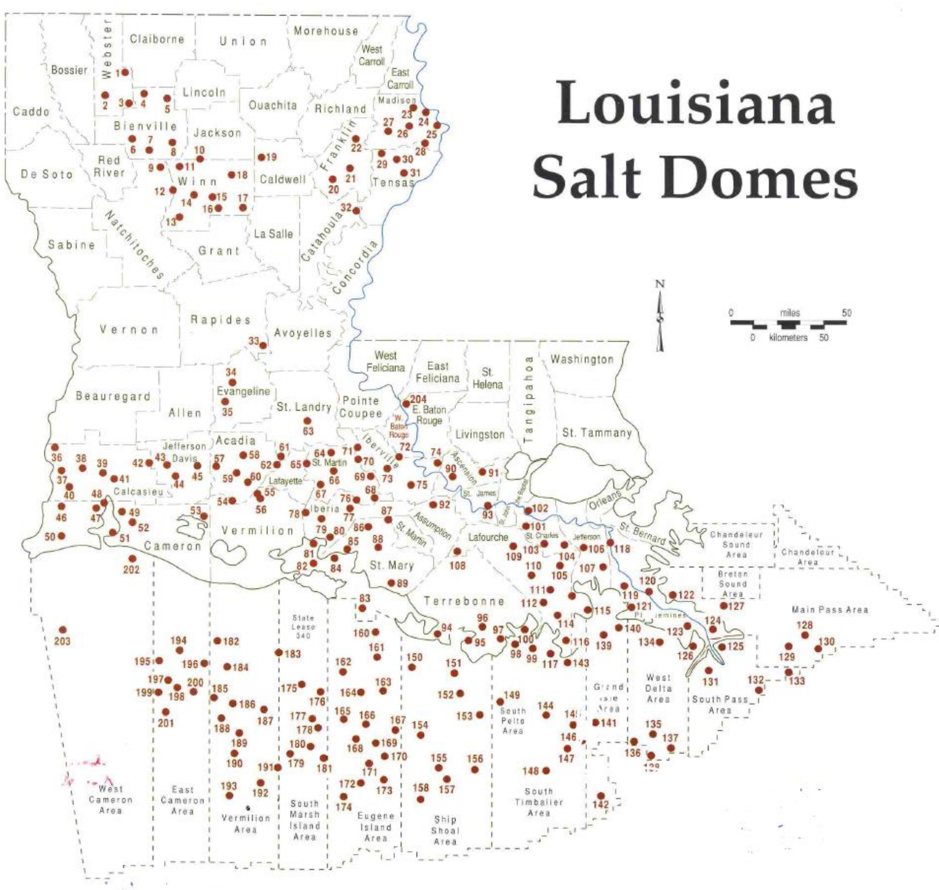


Figure 15. Salt dome locations [18]

Webster Parish

1. Minden ... 19N - 8W
*2. Bistineau ... 18N -10W

Bienville Parish

*3. Vacherie ... 17N - 8W
*4. Gibsland ... 18N - 7W
5. Arcadia ... 18N - 5W
*6. Kings ... 15N - 8W
*7. Prothro ... 14N - 6W
*8. Rayburns ... 15N - 5W

Natchitoches Parish

*9. Chestnut ... 13N - 6W

Winn Parish

*10. Milams ... 13N - 3W
*11. Prices ... 13N - 4W
*12. Drakes ... 12N - 5W
*13. Coochie Brake ... 10N - 4W
*14. Winnfield ... 11N - 3W
*15. Cedar Creek ... 11N - 2W
*16. Packton ... 10N - 2W
*17. Castor Creek ... 10N - 1E
*18. Sikes ... 12N - 1W

Caldwell Parish

*19. Chester ... 13N - 2E

Franklin Parish

*20. Fort Necessity ... 12N - 7E
*21. Gilbert ... 13N - 8E
*22. Crowville ... 15N - 8E

Madison Parish

*23. North Tallulah ... 17N - 13E
*24. Walnut Bayou ... 17N - 13E
*25. Duck Port ... 16N - 14E
*26. Tallulah ... 16N - 12E
*27. Singer ... 15N - 11E
*28. South Coleman ... 15N - 13E

Tensas Parish

*29. Snake Bayou ... 14N - 10E
*30. Somerset ... 14N - 11E
*31. Newellton ... 13N - 12E

Catahoula Parish

*32. Foules ... 10N - 8E

Rapides Parish

33. Cheneyville ... 1S - 2E

Evangeline Parish

34. Pine Prarie ... 3S - 1W
35. Reddell ... 4S - 1W

Calcasieu Parish

36. North Starks ... 8S - 13W
37. Starks ... 9S - 12W
38. Edgerly ... 9S - 11W
39. Sulphur Mines ... 9S - 10W
40. Vinton ... 10S - 12W
41. Lockport ... 10S - 9W

Jefferson Davis Parish

42. Iowa ... 9S - 6W
43. Woodlawn ... 9S - 6W
44. Welsh ... 9S - 5W
45. Roanoke ... 9S - 4W

Cameron Parish

46. Black Bayou ... 12S - 12W
47. Hackberry, West ... 12S - 10W
48. Hackberry, East ... 12S - 9W
49. Big Lake ... 12S - 8W
50. Cameron Meadows ... 14S - 13W
51. Calcasieu Lake ... 13S - 9W
52. Sweet Lake ... 13S - 8W
53. Mallard Bay ... 12S - 3W

Vermilion Parish

54. Gueydan ... 11S - 1W
55. Perry Point ... 11S - 1E
56. Leleux ... 11S - 2E

Acadia Parish

57. Jennings ... 9S - 2W
58. North Crowley ... 9S - 1E
59. Lawson ... 9S - 1E
60. Crowley ... 10S - 1E
61. Bosco ... 8S - 3E
62. Bosco, South ... 9S - 3E

St. Landry Parish

63. Port Barre ... 6S - 5E

St. Martin Parish

64. Plumb Bob ... 8S - 7E
65. Anse la Butte ... 9S - 5E
66. Section "28" ... 9S - 7E
67. St. Martinville ... 10S - 6E
68. Lake Chico ... 11S - 10E
69. Lake Mongoulois ... 10S - 9E
70. Bayou Bouillon ... 9S - 8E

Iberville Parish

71. Bayou des Glaises ... 8S - 8E
72. Bayou Choctaw ... 9S - 11E
73. Bayou Bleu ... 9S - 10E
++74 St. Gabriel ... 9S - 2E
75. White Castle ... 11S - 12E

Iberia Parish

76. Fausse Pointe ... 11S - 8E
77. Iberia ... 12S - 7E
78. Jefferson Island ... 12S - 5E
79. Avery Island ... 13S - 5E
80. Weeks Island ... 14S - 6E
81. South Tigre Lagoon ... 14S - 5E
82. Vermilion Bay ... 16S - 5E
83. Rabbit Island ... Gulf

St. Mary Parish

84. West Cote Blanche Bay ... 16S - 7E
85. Cote Blanche Island ... 15S - 7E
86. Jeanerette ... 13S - 9E
87. Charenton ... 13S - 9E
88. Franklin ... 14S - 9E
89. Belle Isle ... 17S - 10E

Ascension Parish

++90. Darrow ... 10S - 2E
++91. Sorrento ... 10S - 4E

Assumption Parish

92. Napoleonville ... 12S - 13E

St. James Parish

++93. Hester-Vacherie ... 12S - 5E

Terrebonne Parish

94. Bay Junop ... 21S - 14E
95. Dog Lake ... 21S - 16E
96. Four Isle Dome ... 21S - 16E
97. Bay St. Elaine ... 22S - 18E
98. Lake Pelto ... 23S - 18E
99. Caillou Island ... 23S - 20E
100. Lake Barre ... 21S - 20E

St. Charles Parish

101. Paradis ... 14S - 20E
102. Good Hope ... 12S - 8E
103. Bayou des Allemands ... 15S - 20E
104. Bayou Couba ... 15S - 21E
105. Lake Salvador ... 16S - 22E

Jefferson Parish

106. Barataria ... 16S - 23E
107. Lafitte ... 17S - 24E

Lafourche Parish

108. Chacahoula ... 15S - 15E
109. Raceland ... 15S - 19E
110. Valentine ... 17S - 20E
111. Cut Off ... 18S - 21E
112. Bully Camp ... 18S - 20E
113. Clovelly ... 18S - 22E
114. Golden Meadow ... 19S - 22E
115. Bay de Chene ... 19S - 24E
116. Leeville ... 21S - 22E
117. Timbalier Bay ... 23S - 21E

Plaquemines Parish

118. Stella ... 14S - 24E
119. Lake Hermitage ... 18S - 25E
++120. Potash ... 18S - 15E
121. Lake Washington ... 20S - 26E
++122. Quarantine Bay ... 19S - 17E
123. Venice ... 22S - 30E
++124. Delta Duck Club ... 21S - 20E
125. Garden Island Bay. ... 23S - 32E
126. West Bay ... 23S - 30E

Offshore

Main Pass Area

127. BL. 46
128. BL. 144
129. BL. 299
130. BL. 306

South Pass Area

131. BL. 27
132. BL. 61
133. BL. 62

West Delta Area

134. BL. 30
135. BL. 133
*136. BL. 138
*137. BL. 148
138. BL. 152

Grand Isle Area

139. BL. 16
140. BL. 18
141. BL. 72
142. BL. 106

Bay Marchand Area

143. BL. 2

South Timbalier Area

144. BL. 54
145. BL. 86
146. BL. 131
147. BL. 135
148. BL. 176

South Pelto Area

149. BL. 20

Ship Shoal Area

150. BL. 32
151. Coon Point (Blk. 39)
152. BL. 72
153. BL. 113
154. BL. 154
155. BL. 204
156. BL. 208
157. BL. 230
158. BL. 274
159. BL. 323

Eugene Island Area

160. BL. 32
161. BL. 77
162. BL. 110
163. BL. 126
164. BL. 128
165. BL. 175
166. BL. 184
167. BL. 188
168. BL. 205
169. BL. 208
170. BL. 231
171. BL. 238
172. BL. 273
173. BL. 276
174. BL. 292

South Marsh Island Area

175. BL. 6
176. BL. 8
177. BL. 38
178. BL. 48
179. BL. 66
180. BL. 73
181. BL. 79

Vermilion Area

182. BL. 102
183. BL. 111
184. BL. 120
185. BL. 162
186. BL. 164
187. BL. 193
188. BL. 200
189. BL. 218
190. BL. 245
191. BL. 271
192. BL. 289
193. BL. 304

East Cameron Area

*194. BL. 115
195. BL. 118
196. BL. 126
197. BL. 139
*198. BL. 151
*199. BL. 155
200. BL. 160
201. BL. 189

West Cameron Area

202. BL. 2
*203. BL. 306

East Baton Rouge Parish

204. Port Hudson ... 4S - 2W++

* Nonproducing salt domes
++ St. Helena Meridian

Calcium Sulfate

The DOTD Materials Laboratory has a new product evaluation (NPE) process for specialty products. The NPE process reviews non-standard materials that may offer the department economic benefit. One particular product that the department has utilized for its availability and cost features is blended calcium sulfate (BCS). BCS is often the residual bed-ash from chemical plant sulfur air-scrubbing operations. BCS is stockpiled, milled, graded, and utilized as a base course material alternate for crushed stone in DOTD roadway construction specifications. The product works well when high and dry, but can have moisture sensitivity issues and behave like a pumping silt when near the groundwater table.

Additionally, the product does not react well with cement. This creates potentially long-term issues with the utilization of BCS and its future maintenance by DOTD. When most roads are rehabilitated, cement is often mixed into the base course to create a stiff, bound "recycled soil-cement" layer. However, when cement is mixed with BCS, an expansive crystal (ettringite) can form, heave, and disrupt the pavement's surface layers. This heave can occur shortly after reconstruction and affects surface paving ride quality. This does not bode well with the perception of taxpayers, since additional rehab is often necessary. Tracking the use of BCS as a potential hazard will benefit the department.

BCS has been sold under other names such as Florolite, Fluorolite, Bearlite, bedash, etc. Early projects that possibly used BCS from 1987 to 1991 are shown below in Figure 16. This information will be confirmed with the districts and added to the GAM database. Figure 16, as a GIS layer, will benefit the department and its future design engineers and planners.

Figure 16. Blended calcium sulfate (BCS) locations ─ DOTD 1987-1991

Project #	Route	Description	Layer Type	Date Tested	Struct. #	Layer Coefficient
007-07-0039	US 61	Bayou Manchac to Gonzales	Shoulders	10/88	0.2	NA
713-53-0080	LA 42	US 61 to LA 73	Shoulders	NA	NA	NA
948-01-0002	Access Road	St. John Parish Airport	Base	4/88	3.4	0.31
948-01-0002	Runway	St. John Parish Airport	Base	4/88	1.3	0.17
077-05-0039	LA 73	Old Hammond to Brentwood Dr.	Base	5/89	-0.1	0.17
424-05-0073	US 90 Relocated	Morgan City to Gibson	Haul road to Embankment	3/93	6.5	NA
424-05-0073	US 90 Relocated	Morgan City to Gibson	Embankment	3/93	>6.5	NA
266-01-0009	LA 22 Relocated	I-10 to Sorrento	Working Table	1/90	2.7	0.34--
389-02-0013	LA 95	Jct LA 365 to Church Pt.	Shoulder	NA	NA	NA
213-03-0007	LA 92	Jct LA 700 to Jct US 167	Shoulder	NA	NA	NA
801-30-0010	LA 1111	Jct LA 13 to Jct LA 98	Shoulder	NA	NA	NA
266-02-0023*	LA 22	Jct US 61 to Jct LA 429	Shoulder	7/91	0.2	0.32
256-01-0023*	LA 427	Jct LA 42 to Jct LA 3064	Shoulder	NA	NA	NA
434-03-0001	LA 641 Gramercy	Relocation to LA 3213	Base	3/93	4.8	NA
434-03-0001	LA 641	Relocation to LA 3213	Base	3/93	1.4	NA
832-32-0005	LA 3002	Range Ave Denham Springs	Base	10/93	0.2	0.05

Notes:

1. Sites constructed from 1987 to 1991
2. * Blended with limestone (possibly for pH neutralization).

District Wall Collection/Inventory

Initial collection efforts categorized by district are presented in the following sections. Walls in each district are highlighted in blue to show the location and length.

District 02

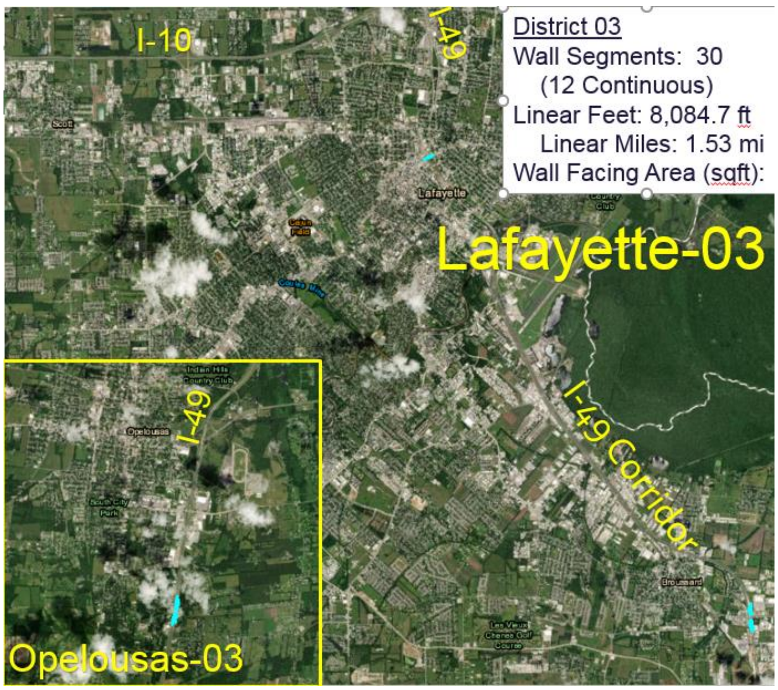
As discussed earlier, three major tunnels exist in Louisiana. Specifically, all three tunnels are located in the New Orleans District 02. The soil in this district is, generally, so soft that there are no large embankments. Settlement values in south Louisiana can exceed 11 inches for a foot of added fill. Rather than a large mass for an approach ramp, most bridge abutments are pile supported down to/near natural ground. There are some apparent walls in the district, but these are likely to prevent public access under/in these spaces. Figure 17 shows the locations in cyan color on the map. On initial inspection, there are 50 wall segments in 20 continuous walls totaling to roughly 1.89 miles.

Figure 17. DOTD District 02 retaining walls

District 03

The Lafayette District 03 has portions of Pleistocene terraces at the surface, but also coastal marshes. Interstate 10 traverses the district and intersects with the existing I-49, which is completely north of I-10, and the I-49 planned route south of I-10. Some of the newest MSE walls in Louisiana are part of this expansion/planning construction of I-49 South. I-49 will eventually continue south from I-10 to New Orleans, via US 90. Because there are existing roadways in the area and ROW space is limited, these new intersections include overpasses and retaining walls (Figure 18).

Figure 18. DOTD District 03 retaining walls



District 05

District 05 is fairly rural, but Interstate 20 runs through the district. There are some crossings in Monroe and Ruston in association with Interstate 20 (see Figure 19). These wall assets are smaller tunnels for allowing access via frontage roads.

Figure 19. DOTD District 05 retaining walls

District 05
Wall Segments: 22 (10 continuous)
Linear Feet: 1103.7 ft. Linear Miles: 0.21 mi

District 58

District 58 is very rural and without interstate highways. It is also very flat due to historical scouring and movement of the Mississippi River valley and channel. During our review, no retaining walls were located in District 58. Should any be discovered or built through new construction, they can be added to the database in the future.

District 07

District 07 has Lake Charles as its major city. Interstate 10 passes through Lake Charles, and there is an I-210 bypass on the south side of Lake Charles. This area has grown over the last few years, and has seen a growth in casino resorts. Specifically, the L'Auberge Casino addition sparked the need for improvements around Cove Lane (Figure 20).

Figure 20. DOTD District 07 retaining walls

District 07
Wall Segments: 64 (18 Continuous Walls)
Linear Feet: 13,035.9 ft. Linear Miles: 2.47 mi.

District 08

District 08 is centered on Alexandria, LA, its largest city. Interstate 49 passes through Alexandria along with older northwest routes of US 71 and LA 1. US 71 crosses the Red River, under I-49, and other roads (Figure 21).

Figure 21. DOTD Districts 08 retaining walls

District 08
Wall Segments: 23 (9 Continuous Walls)
Linear Feet: 6,865.9 ft. Linear Miles: 1.30 mi

District 62

District 62 is centered on Hammond, LA. This district is fairly rural but does have some larger interstate crossings. With plenty of room for slopes, there are only a few walls around the intersection of I-10, I-12, and I-59. Initial reconnaissance only identified three segments in this district (Figure 22).

Figure 22. DOTD District 62 retaining walls

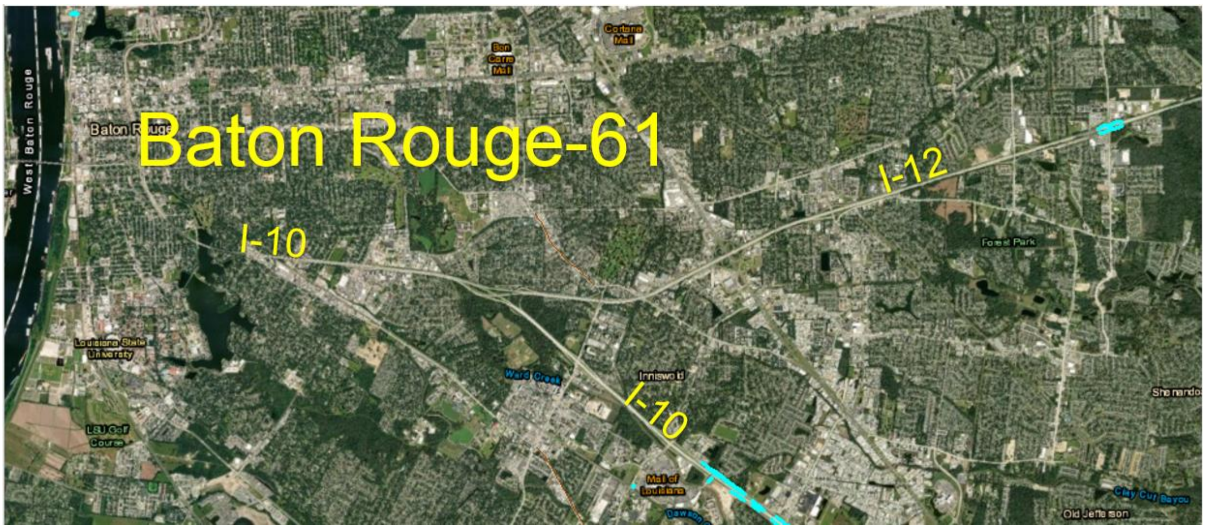
<u>District 62</u>
Walls Segments: 3 (3 Continuous)
Linear Feet: 115.7 ft. Linear Miles: 0.02 mi

District 61

Baton Rouge, LA, is home to both the DOTD HQ and District 61. Interstate 10 and Interstate 12 have walls associated with expansions of the interstate system. The Mall of Louisiana ramps and exits supported by retaining walls are some of the largest in the state. There are also walls in Baton Rouge related to the expansion of Bluebonnet Boulevard and the downtown casinos (Figure 23).

Figure 23. DOTD District 61 retaining walls

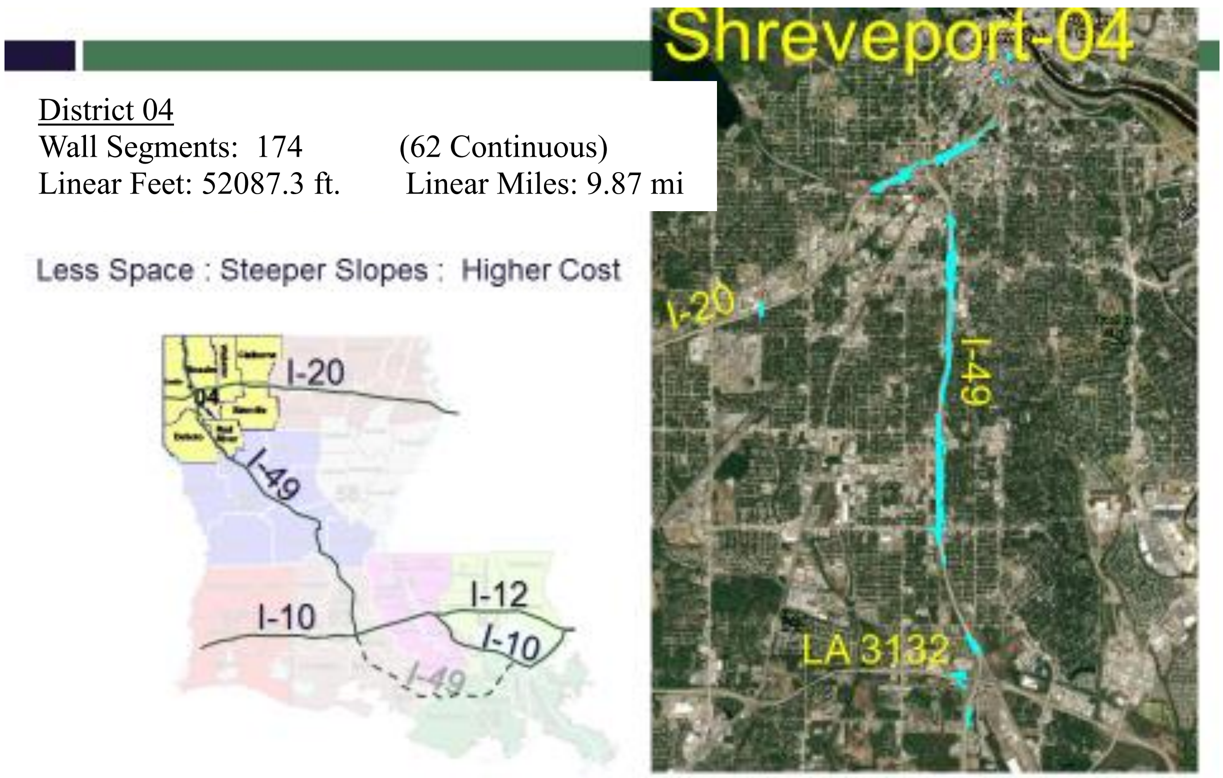
<u>District 61</u>	
Wall Segments: 44	(19 Continuous)
Linear Feet: 18,706.8 ft.	Linear Miles: 3.54 mi



District 04

District 04 is focused around Shreveport, LA with Interstate 20 running east-west, and the relatively new Interstate 49 intersecting with I-20. As discussed, I-49 runs through the city and construction required many walls to squeeze it in the limited right of way. This district contains the most walls of all DOTD districts. As I-49 North is connected, more walls are being added to join all of I-49 (Figure 24).

Figure 24. DOTD District 04, Shreveport, LA



Wall Lengths and Facing Area

Since the walls are drawn to scale in ArcMap, the length of each wall is known. These lengths are estimates based on the points placed on the map images from start to stop of a segment. Totals for each district, parish, and/or the whole state can be tabulated using the database. Sorting can isolate the walls by other attributes (facing type, RouteID, etc.) as data is available. Table 1 shows an early summary of walls collected and sorted by DOTD district using Excel. The total miles are shown, and percent of the total indicates that Shreveport has most of Louisiana's retaining walls. Ideally, the project numbers would be identified for each wall, however, this is often difficult to determine as most walls are subcontracted. Project numbers with DOTD Control Section are easier than the newer H.XXXXX format as the control section identified a stretch of road. "H." numbers do not have that inherent location link. Some projects in Shreveport were able to be connected to the RECo project list.

Table 1. Wall summary by DOTD district

District	Segments (of 3/3/2022)	# Walls	Linear, ft	Linear, mi	Linear % of Total
2	50	20	9964.8	1.9	9.1%
3	30	12	8084.7	1.5	7.4%
4	174	62	52087.3	9.9	47.4%
5	22	10	1103.7	0.2	1.0%
58	0	0	0.0	0.0	0.0%
61	44	19	18706.8	3.5	17.0%
62	3	3	115.7	0.0	0.1%
7	64	18	13035.9	2.5	11.9%
8	23	9	6865.9	1.3	6.2%
Total	410	153	109964.8	20.8	100%

Construction Details and Visible Parameters.

Walls, when needed, are part of a construction process and must be from a DOTD approved list of wall manufacturers/systems. Wall type/manufacturer is normally not specified at the time of construction letting, so contractors work with wall vendors to meet specifications. The contractor's wall supplier and wall plans are utilized for construction, but unfortunately, this information generally does not make it into the final "as-built" plan set.

Since the walls are a specialized service, there are not many suppliers on the DOTD approved list. Additionally, the wall manufacturers' products have different appearances and properties that make present day identification slightly easier. We can, luckily, see from physical (or virtual) inspections what wall type/facing exists at these sites, and then infer with relative confidence what type of reinforcement, construction, etc. was utilized to construct these walls. This information is not totally “as-built” information, but it leads us in the right direction.

Wall Manufacturers – Louisiana Approved List

The DOTD Geotechnical Section has a process of approving wall systems. The Retaining Wall System Approval Procedure and the DOTD Approved Retaining Wall Systems List can be found on the DOTD Pavement and Geotechnical website [19]. Table 2 presents the DOTD approved wall systems.

Table 2. DOTD-approved wall systems

Name of System	Manufacturer	Phone
Reinforced Earth Walls	The Reinforced Earth Company 1331 Airport Freeway, Suite 302 Euless, TX 76040-4150	(817) 283-5503
Keysystem I / Highway Wall System (Modular Block/Steel Reinforcement)	Keystone Retaining Wall Systems, Inc. 4444 W 78th Street Minneapolis, MN 55435	(952) 987-1040
Keysystem II/ Highway Wall System (Modular Block/Steel Reinforcement)	Keystone Retaining Wall Systems, Inc. 4444 W 78th Street Minneapolis, MN 55435	(952) 987-1040
Mesa™ Retaining Wall System (Modular Block/Geosynthetic Reinforcement)	Tensar Earth Technologies, Inc. 5883 Glenridge Drive Suite 200 Atlanta, GA 30328	(404) 250-1290
Pre-Approved Status	Manufacturer	Phone
TriWeb Retained Soil Wall System	Tricon Precast, Ltd. 15055 Henry Road Houston, TX 77060	(281) 931-9832

Note 1: Systems with pre-approved status have been reviewed and approved by DOTD, but have not yet constructed walls on DOTD projects. These systems are expected to perform acceptably and should be considered for inclusion on any non-interstate route projects, which includes ramps leading to and from the interstate. Final approval will be based upon the successful completion of the first wall constructed, which shall also perform successfully for a period of one year.

Note 2: All Wall systems utilizing Geosynthetic strips are required to be designed using the AASHTO default values for Geogrid materials Ci = 0.67 and alpha = 0.80.

The earliest highway retaining walls constructed in Louisiana are cast-in-place concrete walls. MSE walls are newer to the state and were first utilized in Shreveport, LA. These MSE walls were primarily Reinforced Earth Company (RECo) walls and have their recognizable cruciform shape. Other walls in the state include some historical Hilfiker (previously Johnson

Brothers) walls constructed from 1989-1995 with a horizontal panel face; and Keystone block facing, common in Baton Rouge and Lake Charles. Figure 25 presents three common MSE walls in Louisiana.

Figure 25. Wall facing types

Hilfiker "Panel"	RECo "Cruciform"	Keystone "Block"

DOTD First MSE Walls—Shreveport

Shreveport is located in the northwest corner of the state and has a relatively new interstate, I-49. Construction on I-49 started in the late 1980s/early 1990s. This interstate was constructed through the city of Shreveport rather than as an outside loop. It runs roughly north to south and connects to I-20 in downtown Shreveport. ROW was likely too expensive for wide flatter slopes (i.e., a low-cost, rural option). Therefore, retaining walls were utilized to save space, but ultimately resulted in higher costs.

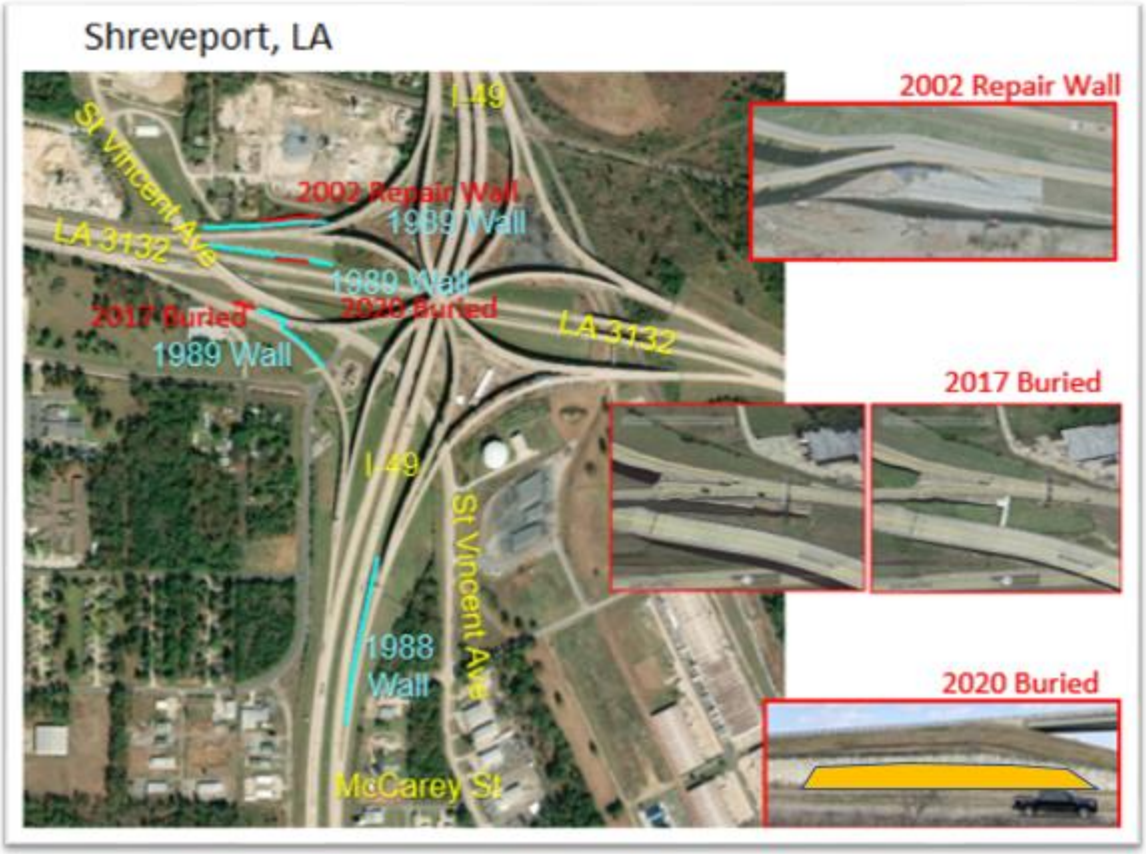
I-49 designers chose to connect pile-supported bridges with retaining walls to support traffic through Shreveport rather than ramps up and down between these adjacent intersections. This appears to have satisfied the space, settlement, and foundation requirements of the area and project. In some areas of the state, alluvial soils can dictate extensive foundation support (e.g., piles, ground improvement, etc.) at likely higher costs due to settlement concerns. Even in the northwest corner of the state where we have some weak sandstone, soil conditions and settlement can be a concern due to the alluvial plains of the Mississippi and Red rivers. In this case, walls were an effective solution over wide ramp embankments and pile supported bridge construction.

Walls along the older I-20 in Shreveport are often precast like that of Hudson Street. shown in Figure 26. Precast walls with pile support were a common Department design prior to the construction of I-49 in Shreveport. I-49 walls were originally designed to be pile-supported, cast-in-place concrete walls. However, now retired DOTD designers noted that the change to MSE walls happened rather quickly, markedly “almost overnight.” The technology and construction of MSE walls, new to DOTD at the time, were encouraged by FHWA for their advantages. Inexperience may have, unfortunately, led to some eventual problems on these earliest of DOTD walls (Figure 27). Walls on piles would experience little settlement; however, the newer MSE walls were not pile-supported and likely settled more than anticipated. Problems like global settlement with/without wall collapse, and poor/improperly planned drainage lead to DOTD maintenance issues and repairs.

Figure 26. Hudson St and I-20

Louisiana Department of Transportation and Development (DOTD)
#TBT - Aerial - Hudson St. and I-20. Caddo Parish 1964.

Figure 27. I-49 & LA 3132, Shreveport, LA



Design Life

DOTD Mechanically Stabilized Earth Wall (MSEW) policy [20] provides design life requirements for both permanent and temporary walls.

a. Permanent MSEW structures are generally designed for a 75-year design life. Permanent MSEW structures that support bridge abutments (without deep foundation support) should be designed for a 100-year design life.
b. Temporary MSEW structures shall have a design life of not less than the contract time of the project or three years, whichever is greater. Structures remaining in service for more than 5 years shall be designed as permanent MSEW structures.

Most DOTD permanent MSEWs fit into the 75-year design life, yet there are two fairly new Geosynthetic Reinforced Soil-Integrated Bridge Systems (GRS-IBS) designed and constructed as part of the "Every Day Counts" (EDC) initiative and implementation technology. To date, none of Louisiana's MSEWs have reached their design lives. With an appropriate asset management program, assets can reach and likely exceed their design life with appropriate monitoring, inspections, maintenance, and management.

Researchers contacted wall vendors to cross-check their constructed lists Louisiana against LTRC gathered data. Hilfiker was unable to produce/share data due to company mergers/transfers and lack of projects within recent years (only active from 1989-1995). Keystone provided a short list that matched most of our records. These block walls are relatively new compared to some other wall systems. Reinforced Earth Company (RECo) was very helpful in providing a summary list of their walls in Louisiana (Figure 28). Their list proved to be concise with dates and wall facing areas. RECo MSE walls were common in the construction of I-49 in Shreveport. Figure 29 shows the increase in wall facing area for the RECo walls in the creation of I-49 through Shreveport. These walls were constructed within a few years of each other, starting in 1985. That was about 35 years ago, nearly halfway to the 75-year design life. Like the New York bridges referenced earlier, the I-49 walls will reach their design life concurrently. DOTD will need to monitor these walls as they age, and be prepared to plan for the maintenance, rehabilitation, or replacement as the 75-year design life approaches in 2060 to 2070. Maintenance, inspections, and monitoring may allow these structures to function beyond their design life with confidence, but we should begin planning those activities and reserve funding appropriately.

Researchers added the wall surface areas together, just for these RECo walls, and determined a total wall surface area of 834,000 sq.ft. Recent DOTD retaining wall bid history indicated an average cost of $24 per sq.ft.; yielding a total replacement cost of over $20 million to construct new walls. FHWA officials indicated to researchers that this value is a low estimate, and that repairs/replacing existing walls would likely cost more per sq.ft. Removal and repair of structures would also likely cost more than starting with a clean slate. DOTD also has other walls (block, panel, cast-concrete) and geotechnical assets across the state to inventory and consider maintenance/repair/replacement costs in the future.

Figure 28. Reinforced Earth Company (RECo) ─ Louisiana walls

REINFORCED EARTH WALLS

I-49 SHREVEPORT

SECTION	LIMITS	WALL AREA	# OF WALLS	COMPLETE	RE#
2	McCarey to St Vincent Ave	19,000 SF	1 EA	5/1988	2007
4A	LA 3132 (Inner Loop) Inchg	38,000 SF	8 EA	4/1989	2050
6	LA 3132 (Inner Loop) Inchg	21,000 SF	4 EA	3/1989	2008
7	MOPAC RR to 85th St	21,000 SF	2 EA	1/1989	1975
10	79th St to 75th St	3,000 SF	1 EA	3/1988	2558
11	75th St to 63rd St	86,000 SF	10 EA	2/1994	2126
14	63rd to Indiana Ave	101,000 SF	8 EA	3/1994	2009
16 & 18	Indiana Ave to St Vincent Ave	104,000 SF	3 EA	2/1994	2040
20	St Vincent Ave to Dalzell St	100,000 SF	14 EA	6/1993	3126
21	Dalzell St to T & P RR	12,000 SF	2 EA	10/1990	2290
22 & 25	I-20 Interchange	75,000 SF	9 EA	6/1993	3349
24	Lakeshore Dr Modification	1,000 SF	1 EA	6/1993	3755
K	I-49 N, Phase 2	81,000 SF	5 EA	9/2018	17068
	13 Projects TOTALING	662,000 SF	68 EA		

ALEXANDRIA

SECTION	LIMITS	WALL AREA	# OF WALLS	COMPLETE	RE#
5	I-49 / Broadway Interchange	15,000 SF	3 EA	8/1990	2596
9	I-49 Meeker to Boyce Hwy	6,000 SF	2 EA	6/1990	2791
23	I-49 Horseshoe to Broadway	47,000 SF	5 EA	1/1994	4219
N/A	Sugarhouse Rd over I-49	1,000 SF	2 EA	5/1992	3359
N/A	Mac Arthur Dr @ Bolton Ave	5,000 SF	1 EA	10/1993	4214
N/A	US 165 / US 71 Pineville	4,000 SF	1 EA	6/1996	3601
	6 Projects TOTALING	78,000 SF	14 EA		

LAKE CHARLES

SECTION	LIMITS	WALL AREA	# OF WALLS	COMPLETE	RE#
N/A	I-210 / I-10 Interchange	9,000 SF	2 EA	4/1985	1089
N/A	Shattuck St	3,000 SF	2 EA	5/1990	2239
	2 Projects TOTALING	12,000 SF	4 EA		

LAFAYETTE

SECTION	LIMITS	WALL AREA	# OF WALLS	COMPLETE	RE#
N/A	I-49/Albertsons Pkwy Design-Build	82,000 SF	8 EA	2019 (est)	16850

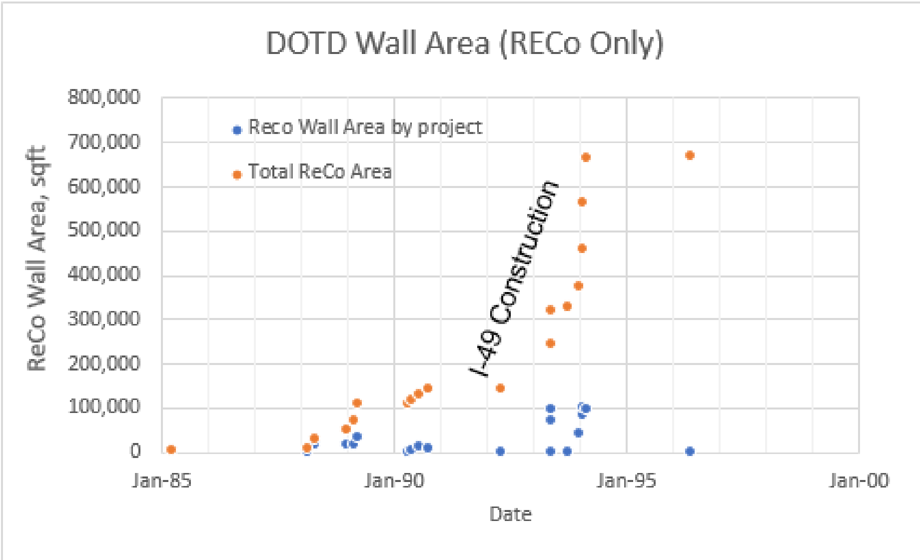
REINFORCED EARTH WALLS

LADOTD SUMMARY

AREA		WALL AREA	# OF WALLS
Shreveport		662,000 SF	68 EA
Alexandria		78,000 SF	14 EA
Lake Charles		12,000 SF	4 EA
Lafayette		82,000 SF	8 EA
	22 Projects TOTALING	834,000 SF	94 EA

NOTE: WALLS ERECTED FROM 1985 THRU 2019

Figure 29. Shreveport LA wall construction for I-49



Corrosion

Several wall types utilize metal reinforcement. DOTD early RECo walls are located in the northern portion of the state where roads freeze often, and district forces salt these roads. Metal corrosion rates vary based on soil conditions, galvanization, de-icing salts, and other factors. Metal reinforcement, culverts, and other metallic items associated with geotechnical assets, like bridge items, should be monitored to verify corrosion rates and the performance of those items. Corrosion testing on some of the earliest walls may help verify rates. Some newer walls are utilizing geosynthetics for reinforcement, which will not rust, but has other design factors.

Erosion and Drainage

As with most civil engineering projects, controlling surface water is an important element. Swales, joints, catch-basins and drainage pipes must be protected and sealed properly. Wall wick drains are not intended to carry surface water, and protecting walls from surface water and erosion will often extend the life of a retaining wall. Unfortunately, some early walls have issues resulting from water seepage behind the wall face. At the intersection of I-49 and LA 3132, two of the earliest walls were covered/buried with soil to stabilize the wall/slope because in this case ROW allowed this solution. Another wall at the same intersection with less ROW was mitigated by installing a temporary wall in front of the original wall.

Obviously, ROW varies from site to site. Wall aesthetics will also play a role in the repair decisions, design life, and costs.

Condition Assessments

The NCHRP report 903 provides comprehensive valuable guidance for state agencies regarding geotechnical asset management (GAM). It recommends three criteria to assess inventoried assets based on condition and consequences. With a good inventory set for walls, researchers requested the DOTD Maintenance & Operation group to collect condition and consequence rating data for walls in each district. The districts would evaluate each segment on a scale of 1 to 5 for each of the criteria based on the decision trees outlined in NCHRP Report 903.

Figure 30 shows the Operation and Maintenance Condition tree. Assets in good condition would receive a low or smaller number indicating that the asset is not a critical or expensive asset to maintain. Assets requiring more attention due to their poor, critical, or failed condition would receive larger numbers. To reassert, in this rating system, smaller numbers indicate good condition, while larger numbers (5 as max) indicate an asset needs more attention. When these condition assessment numbers are combined with other consequence ratings (discussed in later paragraphs), we can calculate risk and a relative determination of whether an asset is functioning or not. These initial ratings will help filter out assets that are not performing and potential maintenance/safety/mobility issues for the Department.

Figure 30. Operation and Maintenance Condition (O&MC) tree

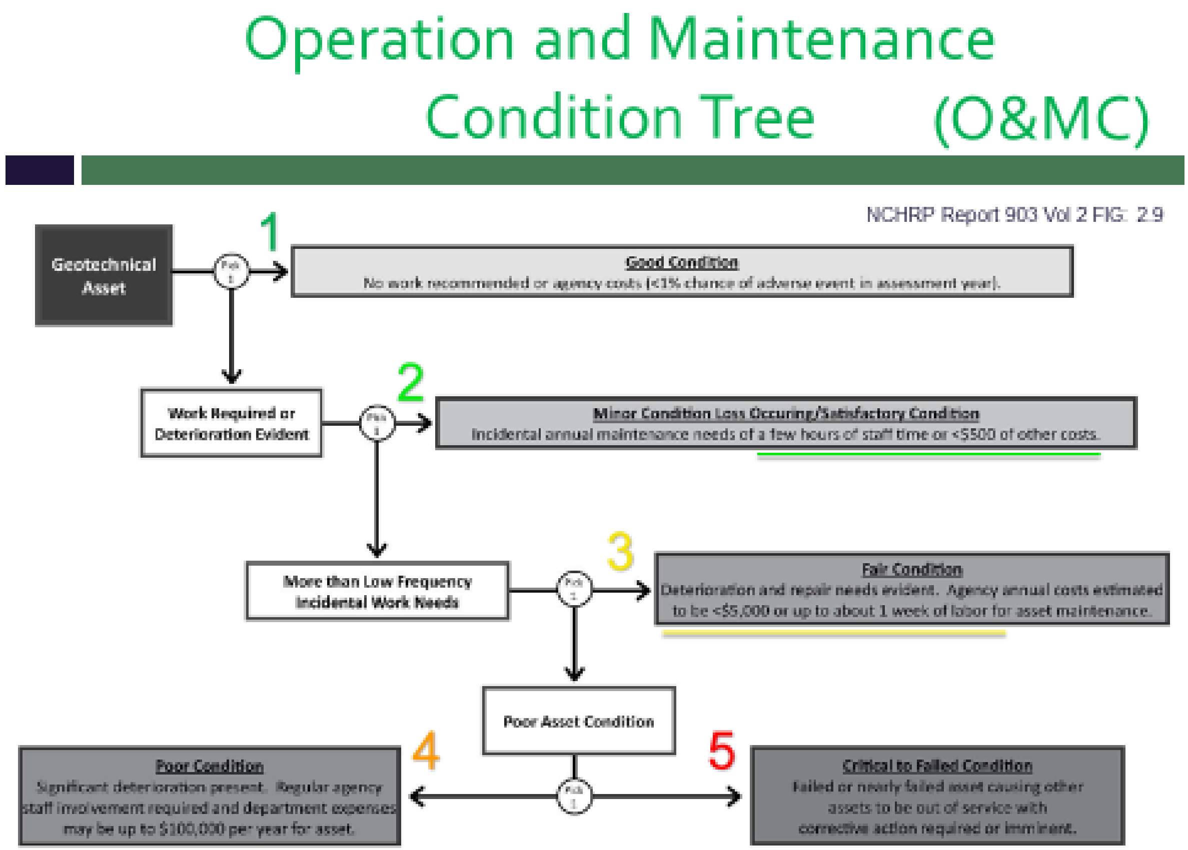


Figure 31 shows the Safety Consequence tree. Assets with no known crash history or low potential for crashes would receive a low or smaller number indicating that the asset is of low criticality/danger. Assets having the potential to damage vehicles or cause injury/fatality would receive larger rating numbers. Larger numbers again indicate that more attention is needed on that asset in relation to GAM.

Figure 31. Safety Consequence (SC) tree

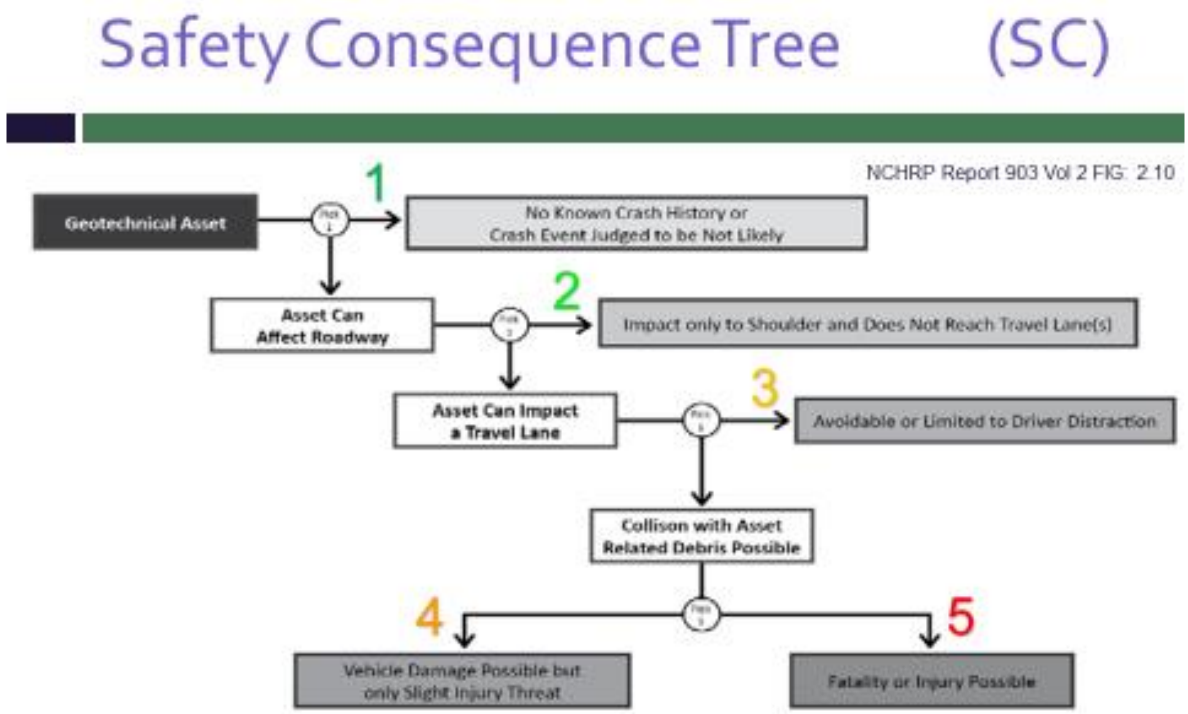
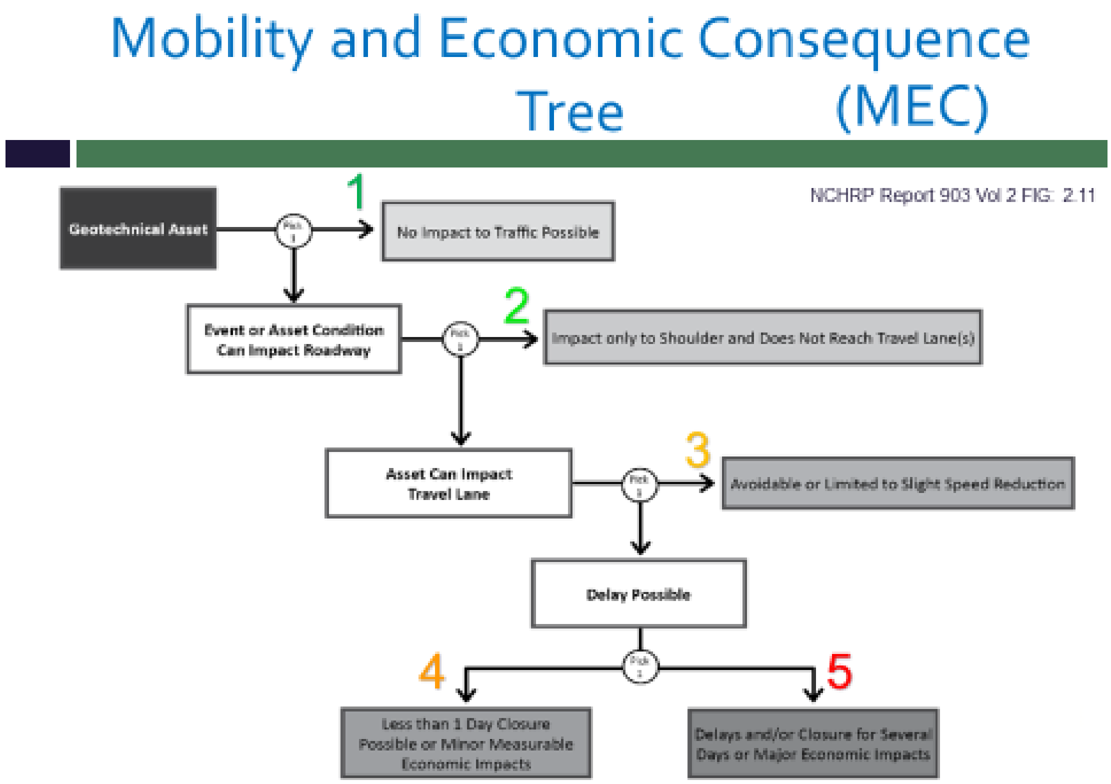


Figure 32 shows the Mobility and Economic Consequence (MEC) tree. Assets with no impact to traffic would receive a smaller number rating. As the possibility of needing orange barrels increases to control or reroute traffic, so would the MEC rating increase. Long traffic delays and/or closures would result in a max rating of 5. This rating helps address the cost of public perceptions and frustrations.

Figure 32. Mobility and Economic Consequence (MEC) tree



DOTD district offices hold the specialized regional knowledge about the roadways and assets in their area. They would know if an old or new wall was missing from the inventory and should be added to the database. This project was designed to additionally tap into their knowledge to help populate these condition and consequence ratings for each asset in their district.

Webmaps and feature layers were configured in DOTD's Enterprise Portal to facilitate district personnel rating each wall segment for the three GAM attributes. To access the webmaps and feature layers, district personnel logins are assigned the editing role and added to the GAM editors group. Figure 33 presents a screen shot of the online portal web application. An additional mobile solution was developed where the webmap and feature layer can be edited using ArcGIS Field Maps or Collector for ArcGIS mobile app. Figure 34 shows an intersection in Shreveport, and a portion of the Earth Retaining Structure feature class attribute table from the Geotechnical assets geodatabase.

Researchers created a user manual (an appendix) for each collection solution to guide the districts in the condition assessments. Using either the traditional web or mobile solution, personnel enter the predefined domain choice of 1 (lowest risk) to 5 (highest risk) for each attribute. Differing colors in the solutions denote each district's retaining wall features that need to be rated. The black retaining wall features indicate that the three GAM attributes contain values and are considered rated. Webmap filters and the webmap search by feature layer options provide an assignment-based list by district.

Online Portal Application Collection Solution

The traditional web application has each district's list already prepopulated, and is intended for use on non-mobile devices. The editing workflow is: choose a feature to rate, choose the appropriate ratings (1-5) for the three GAM decision-tree attributes, add additional comments (optional), and save the edits. The district count will decrease as features are completed, but clicking on the list updates the count as well.

Mobile Device Collection Solution

A mobile device option was developed to simplify rating operations and allow District forces to collect data from the field. The ArcGIS Field Maps or Collector for ArcGIS app can be downloaded from either the Apple AppStore or the Google Store. Collector is still available but will be unsupported as of December 2021. Field Maps is the replacement. A user opens either one of these apps and logins in with their DOTD login to the Enterprise Portal located at https://maps.dotd.la.gov/portal. As an identified editor for this data, the District field personnel would then see webmaps available to be edited through the ArcGIS Field Maps or Collector for ArcGIS app.

The mobile apps have multiple options, which allow the user to work from the office or the field. Each DOTD District's area was preconfigured as a download, in case the user wishes to collect in an offline mode. The field ratings can sync upon return to the office/internet. Figure 35 shows screen shots of the ArcGIS Field Maps for DOTD. The visual utilities of the app ensure that the correct wall is being evaluated.

Figure 33. Enterprise Portal web application for rating the GAM attributes for retaining wall features

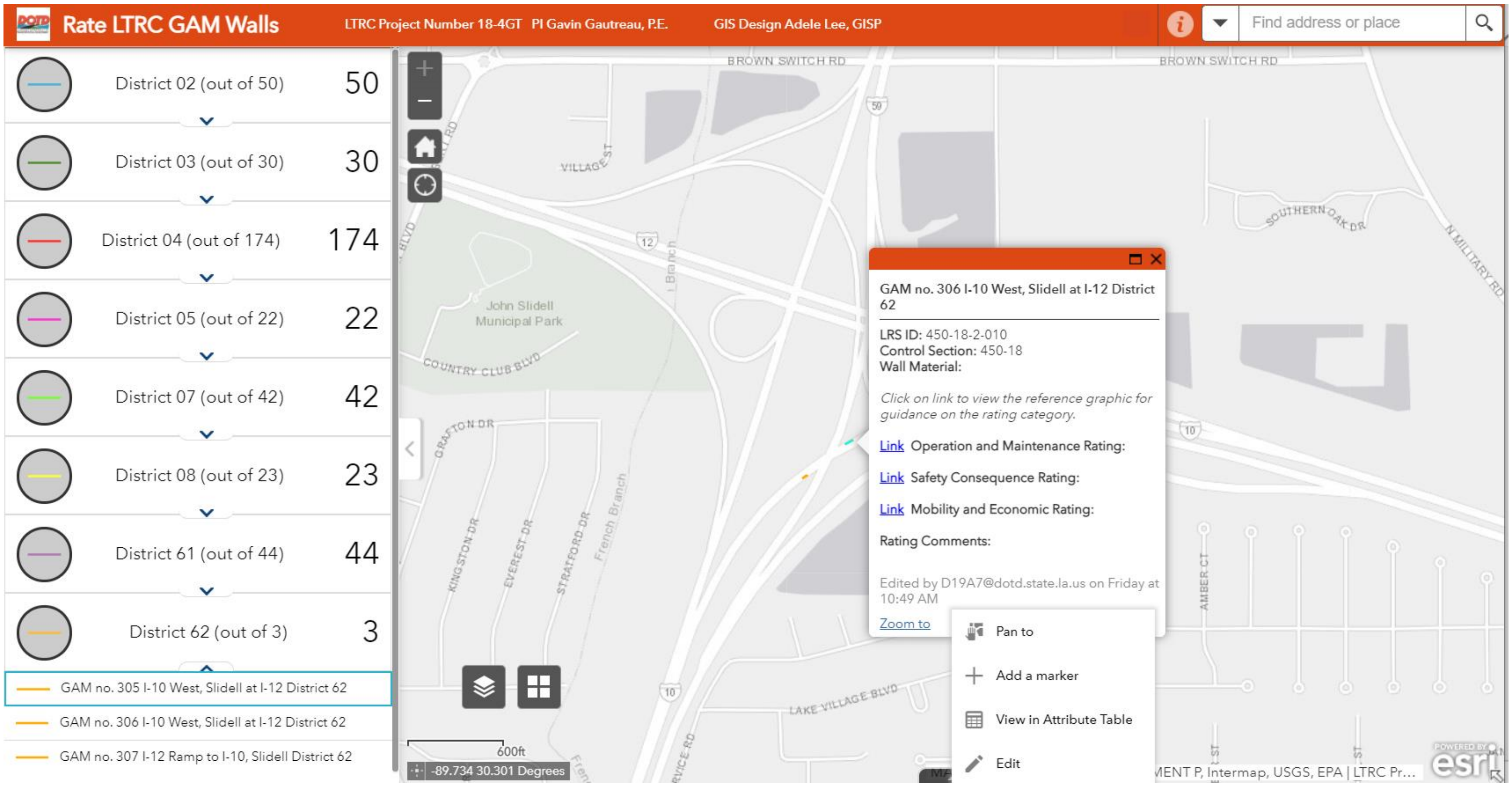


Figure 34. ArcMap interface displaying several retaining walls on I-20 WB in Shreveport, Louisiana

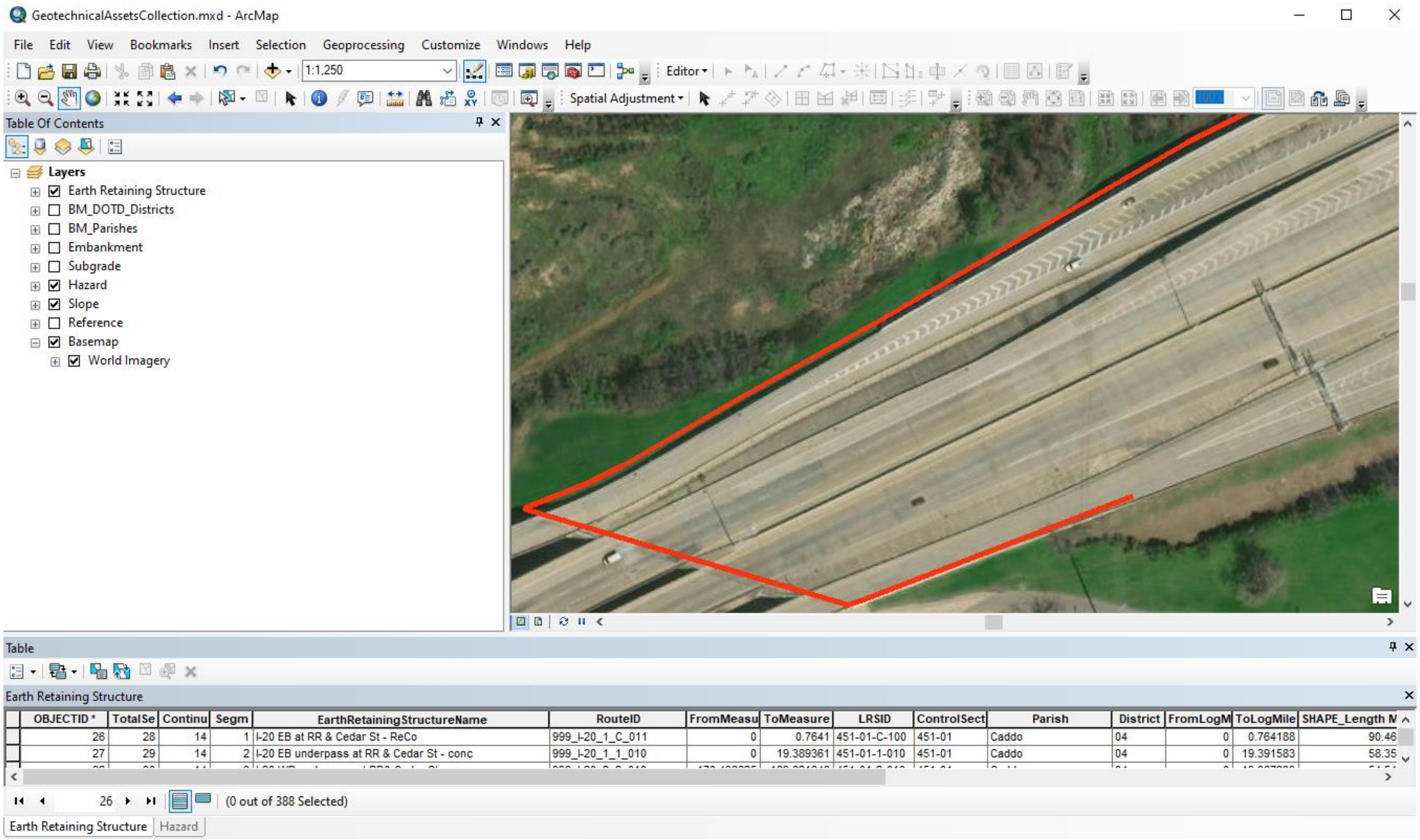
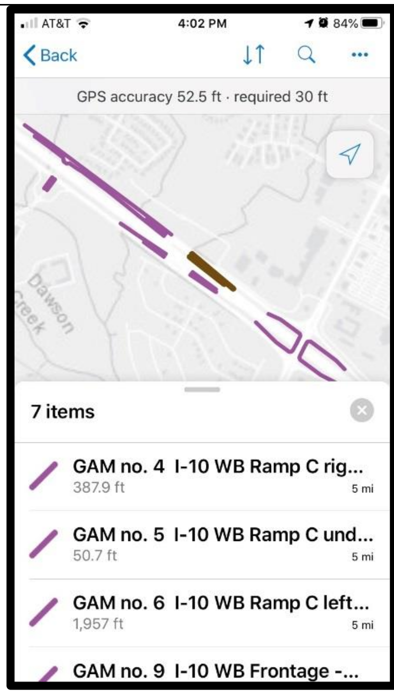
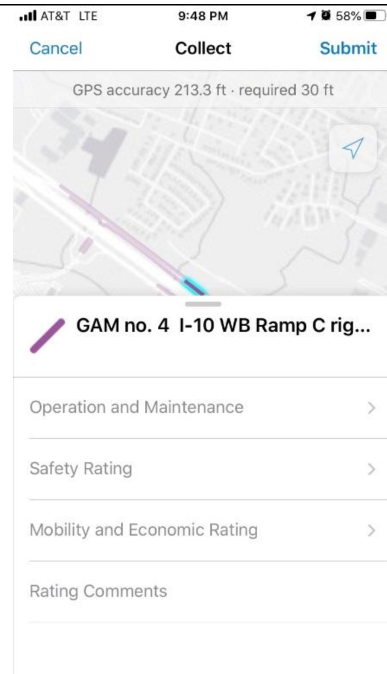


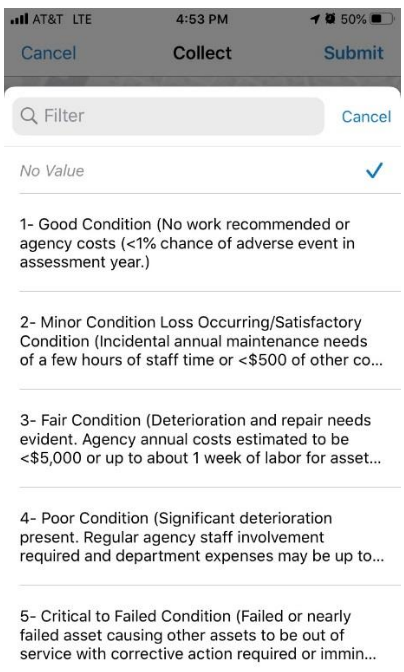
Figure 35. ArcGIS field maps─DOTD screenshots



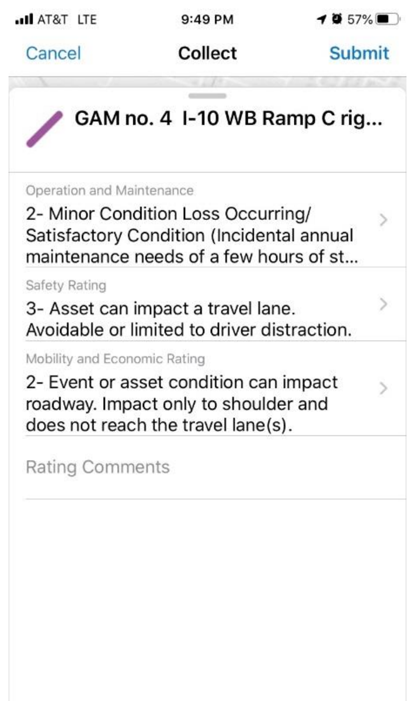
Multiple Walls Shown



Wall Selected for Ratings



Rating options



Completed ratings – Submit

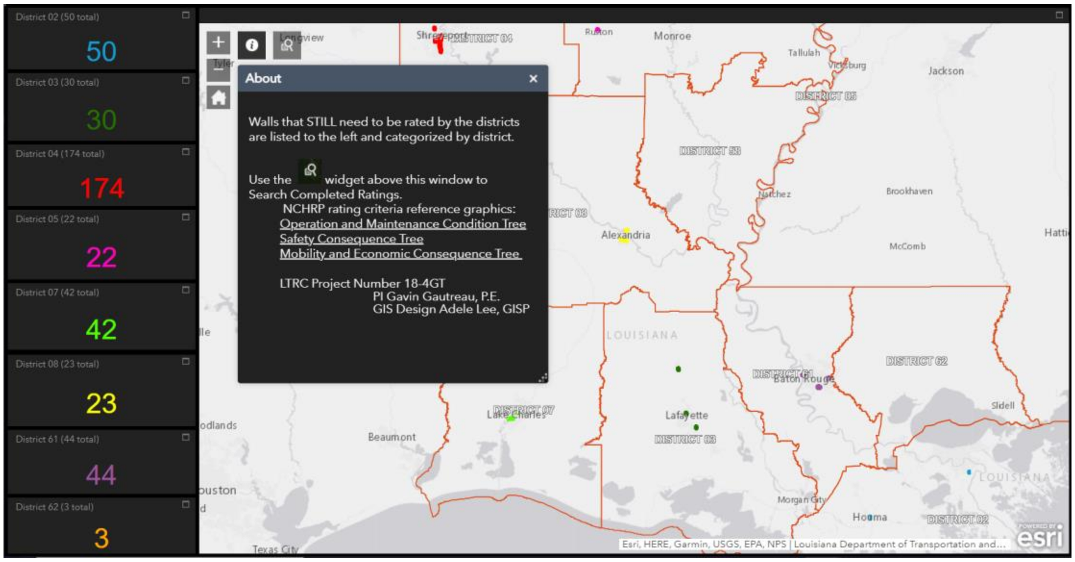
Mobile app users utilize the same workflow as the traditional online version. Users can open a map and use the search tool to filter the retaining walls feature by district. Users select a feature to edit its rating attributes. Using the interactive pull-downs, the user chooses the appropriate ratings and adds additional comments (optional). The user then submits the edit, or if offline syncs the edits back to the data layer when back online. This workflow continues until the user rates all the retaining walls features for the District. The field data updates the full GIS database for further analysis and risk calculations based on those attribute ratings.

Survey 123 for ArcGIS was evaluated but not chosen as a mobile collection solution. Survey 123 does not support visualization of adjoining features while editing a singular wall segment. Field Maps may provide a useful tool in the future collection of culvert data in the field. Culverts are more difficult to locate from aerial photos and a simple field app, like Field Maps (or Headlight) may aid in their collection.

Dashboard Solution for Rating Overview (Non-Editing)

An additional Enterprise Portal web app was created as a dashboard to allow management and LTRC research personnel to evaluate the progress of rating retaining wall features (Figure 36). This app is not used to edit the features but instead provides situational awareness on the project. The web app displays a count of the remaining walls to be assessed by each DOTD district. There is also a search utility to investigate specific wall information. These features will aid in project rating and monitoring efforts. Apps like these can be modified to assist with other GAM future monitoring, planning, and/or management needs.

Figure 36. Dashboard style ArcGIS online web application



District Involvement via HQ

Researchers coordinated with DOTD Operation and Maintenance (O&M) staff to coordinate district rating efforts. O&M administrators asked researchers to direct all requests to districts through them. Unfortunately, researchers encountered some delays and a bit of pushback from administrators regarding Condition and Consequence ratings by district forces via the GIS mobile app. Additionally, the author was invited to speak at a maintenance conference directly to the districts, when the topic was fresh near the start of the project. However, the invite was rescinded and another topic was selected for the slot. Some likely logic and reasons are outlined below.

- District forces are stressed with collecting other asset and project information.
    - Staff, funding, and time are limited in these busy areas.
    - Researchers developed a field application (ESRI Field Maps) to ease collection efforts.
- GAM is not currently mandated like bridge or pavement management operations.
    - Other priorities appeared to come first, and funding is limited.
    - A user manual was developed to assist with ratings. Already issued user Id's were added to the GIS permissions.
- Internal changes were in development to expand the asset management staff.
    - Researchers described GAM process and logic at internal meetings.

  - A district representative is being assigned by O&M that will be responsible for all assets.
  - A pilot district, District 62, was identified and approved by O&M to test the application by conducting initial ratings and consequences; this is in progress.
- Questions about who would own the data arose.
  - Researchers developed a working GIS database with plans to add information to the DOTD Enterprise GIS framework authoritative data.
  - Bentley geotechnical software, HoleBASE, and the cloudbased version, Open Ground (currently being implemented within DOTD HQ Geotechnical), would also allow links and visualization of the GAM data, combining wall/asset locations with the associated soil borings and pile load tests (PLT) regardless of where the data is stored within DOTD/Cloud.

The initial inventory collected by researchers utilizing online maps and tools, may have overlooked some obscure, hidden, or new walls. This was part of the “start lean” logic to get the ball rolling. As part of the district ratings, a review of the assets in the database was also requested. District review would assist with populating the database by notifying researchers of edits or additions to the database. Edits and new walls could be added by researchers, and ultimately by O&M administrators. This would protect the database from possible errors with the many local staff utilizing the mobile or online collection solutions.

Risk Calculations

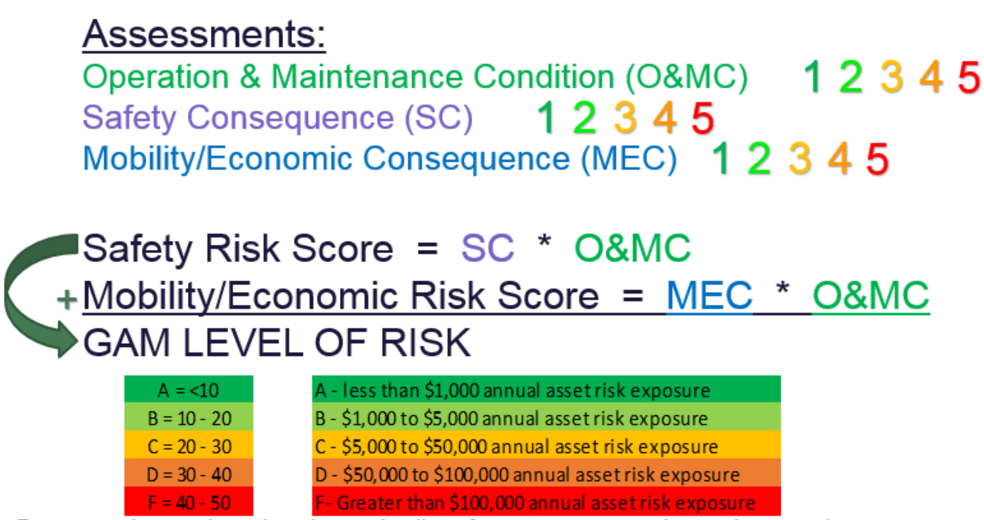
Physical inventory data and decision trees assessments are but one side of the coin, which help determine if assets are functioning or not. How to rank and prioritize condition, performance risk, and maintenance strategies hereafter fall on the other side of the coin.

> *Currently, most agencies manage geotechnical features on the basis of "worstfirst" conditions, reacting to failures and incurring significant safety, mobility, environmental, and intangible costs. The goal of geotechnical asset management is to implement project planning and selection on the basis of "most-at-risk" for the asset class with consideration of collective and site specific risks throughout the life cycle* [21].

Once inventoried in the GIS database and rated by the districts for condition, safety, and consequences, the database can be utilized to determine a level of risk (LOR). The assessments from the districts must be quantified and analyzed to determine the level of risk and repair priority associated with each asset.

The NCHRP GAM Risk Analysis model is outlined in Figure 37, and combines the assessments to create a GAM Level of Risk (LOR). In the model, each asset's Safety Consequences (SC) rating is multiplied by its Operation & Maintenance Condition (O&MC) to determine a Safety Risk Score. Secondly, for each asset its Mobility/Economic Consequences (MEC) rating is multiplied by its O&MC to determine its Mobility/Economic Risk Score. These two risk scores are then added together to create a GAM Level of Risk. The best score would be calculated as two (1 x 1 + 1 x 1 =2); and the worst possible score would be calculated as fifty (5 x 5 + 5 x 5 =50). This range of scores is divided into five categories defined by school grades "A" – "F". These scores, when sorted by size/grade, can help determine inspection frequency, treatment, repair priorities, and a plan for funding both necessary and future needs.

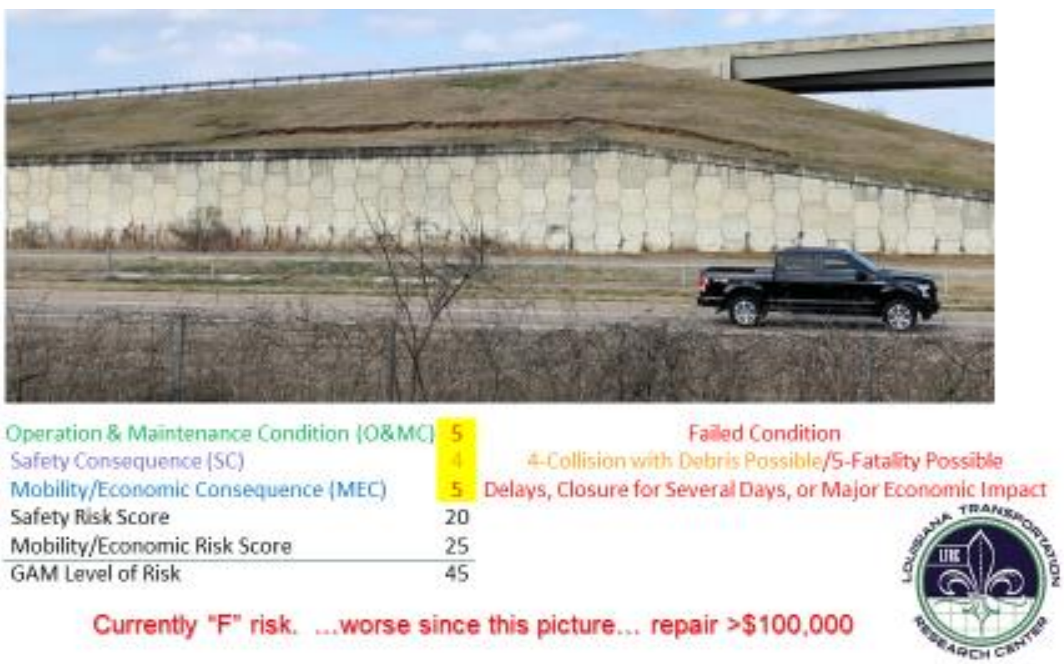
Figure 37. GAM Planner Model—risk analysis (NCHRP Report 903)



When the threat analysis/management tool combines the socio-economic consequence of failure, the tool can be used to prioritize risks (red flags) on assets that need extra attention, including more frequent and detailed inspections by engineers and inspectors. The calculations for the LOR will be done within the database.

An example of the assessment tool calculating LOR is shown in Figure 38. The wall was showing movement indicating a failure condition. The wall could cause a traffic safety issue, should it fail/fall into the road (vehicle damage/driver injury), and could cause traffic delays should it fall and block the road. These high assessment numbers brought the wall LOR near the max at 45/50. As discussed earlier, district forces addressed the problem by adding soil (partially burying) the toe of the wall. This method counterbalances the active slide by providing more resistance against the driving force of the wall stability problem. This wall maintenance reduced the overall risk to the public at this site, but this solution is not available at all sites and may not be the most aesthetic of repairs.

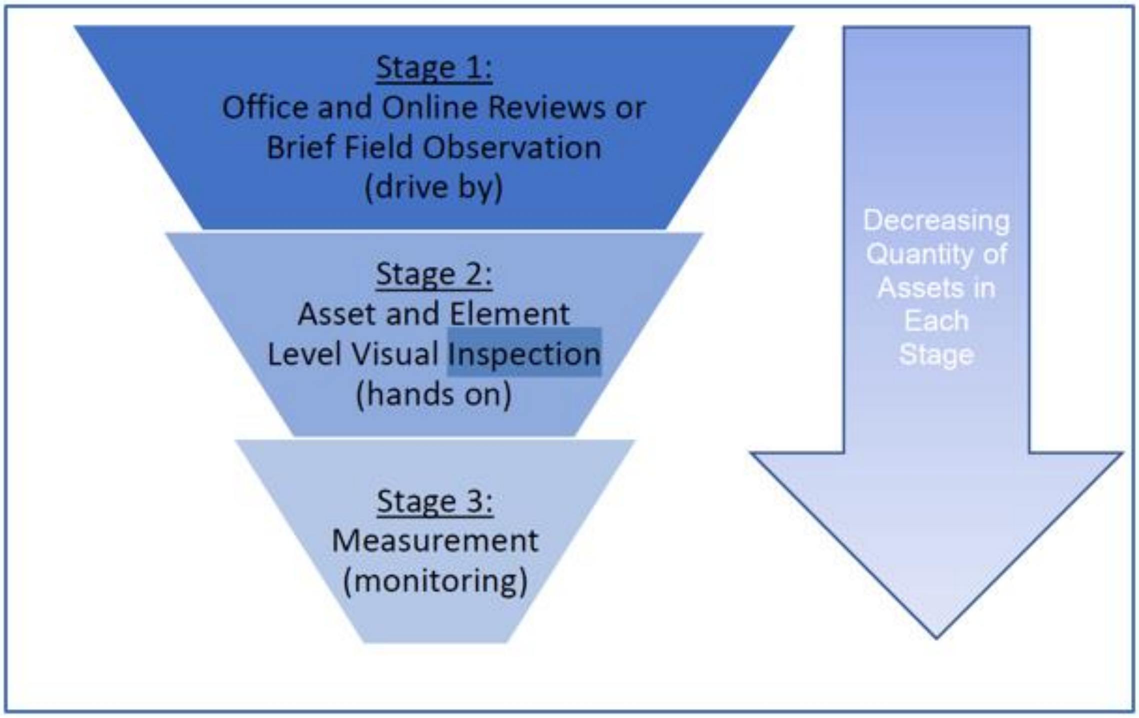
Figure 38. Example rating and LOR, I-49 ramp to LA 3132 West, Shreveport, LA



Inspections

The initial condition and consequence assessments give an overview of our existing structures, Stage 1. NCHRP Report 903 presented here as Figure 39 outlines this stage concept. Stage 1 efforts get the ball rolling with the initial implementation of the GIS system to help populate the GAM database, and breakout the differences between performing and non-performing assets. These first level efforts help identify those assets that need more detailed (hands on) inspections. Most assets are likely functioning versus those that need extra attention, including more detailed inspections described in Stage 2 and Stage 3.

Figure 39. Staged approach for data collection in asset management (NCHRP 903, Figure 4.3)



The calculated level of risk (LOR) will help determine priorities. For poorly performing walls and geotechnical assets, more detailed inspection checklists will provide insights to the HQ Geotechnical Section and Operation and Maintenance Section personnel. These insights will help address these challenged assets appropriately by allocating available funding and engineering analysis to critical assets.

Stage 2 inspections should be more hands on, and would likely require more technical staff. For example, there may be an issue with an asset that requires a detailed inspection and recommendations from staff engineers. Documentation in the database to describe these potential issues and any remedial actions will be utilized to perform more detailed analysis and assessments to share with HQ Geotechnical and other DOTD Sections.

Stage 3 inspections, however, involve measuring and monitoring. An example of this case would be the Vicksburg Bridge and its associated active slope movements. This bridge will be monitored long into the future, in contrast to other assets addressed more easily with a return to functioning properly. Depending upon the asset's condition, consequences, and risk, the DOTD HQ Geotechnical staff may work separately or in conjunction with consultant engineers or contractors.

Researchers examined existing DOTD policy for bridge inspection. DOTD retains documents for Tunnel Inspection Policies [22] and Procedures as well as Inventory & Inspection Manual for Ancillary Structures [23]. The bridge inspection requirements are extensive and do not directly apply to geotechnical assets. Criteria and frequencies vary from bridge structures, but the manuals have similar elements. Since the GAM process is not currently mandated by the FHWA, there is some flexibility with the process. These DOTD inspection manuals aid in the logical formation of a GAM inspection procedure to meet current needs and the potential implementation if/when mandated by FHWA. As GAM is further developed on the national stage, mandated inspection frequencies may require changes in the implementation such as the inspection schedule reporting procedures, etc.

Researchers have drafted a document, "Louisiana DOTD Geotechnical Asset Management (GAM) Design, Construction, and Long-Term Inspection Guidance", aka "GAM Guide." The GAM Guide is attached as an appendix to this report in draft form that can be refined with time as a living document.

Treatment Actions/ Repair Options

NCHRP Report 903 provides guidance on treatment actions/options for geotechnical assets. Like most asset management programs, a variety of treatment options exist ranging from the simplest option of "Do Nothing" to "Maintenance and Rehabilitation", on to more complicated options like "Reconstruction and Restoration."

The "Do Nothing" is simple, but not necessarily the cheapest. In the long run, this option likely only applies to assets that are performing well and only need periodic inspections. "Do Nothing" if not applied correctly could lead to more problems in the future by requiring higher repair costs, longer shutdowns, more risk, etc. Similar logic applies to district reshaping and maintenance of slopes. Short-term fixes can provide relief that may last for a while, but if not addressed appropriately, issues can reoccur. For example, slope failures of old, heavy clay embankments can be reshaped with the soil pushed back in to place by district personnel. However, a more appropriate and extensive repair may be necessary still within the district forces ability. LTRC Report 95-1GT [5] outlines research and a repair to such slopes that promotes drainage and resistance to potential failure planes.

Unfortunately, with the need to “do more with less,” it is difficult to be proactive with repairs when the highway funds are limited or not available. Therefore, reactive repairs often are the path for geotechnical assets. GAM would help establish a more proactive method to evaluate the different treatment options. Ultimately, full reconstruction may be required based on current condition, previous or lack of maintenance, and the age of the asset within its design life. GAM could help direct appropriate repairs with available/appropriate funding.

As stated earlier, DOTD walls averaged about $24/sq.ft. at the beginning of the research project. Walls constructed along I-49 as part of DOTD project (H.013579.6) in Broussard, LA, were estimated at $40/sq.ft. by DOTD. However, the four bids came in at $48.79/sq.ft., $45.40/sq.ft., $48.00/sq.ft., and $48.00/sq.ft. averaging to $47.55/sq.ft. An even more recent March 2021 DOTD bid item search revealed that the 3-year period average cost increased to $56/sq.ft. This is 2.3 times higher than the $24/sq.ft. estimate obtained at the beginning of this research and more closely matches discussions with FHWA officials. This price point increases an estimated new wall cost from $20 million to $47 million using the Shreveport RECo example. Just like home construction, new retaining wall construction is less expensive than renovations/repairs due to the unknowns, cleanup, and repairs. Again, this estimate only applies to one specific example (data presented earlier regarding walls constructed by Reinforced Earth Co.).

Another example relates to an early wall on LA 3132 (Figure 27) that had issues and in 2002 a “temporary” wall was built in front of the original wall. This is a fix, but is it the most appropriate fix? The “temporary” wall has a design life and depends upon the lumber in the soldier-pile, lag wall. Again, this type of emergency repairs works as a “temporary/permanent” repair in a location unseen by the general public, but would not necessarily be acceptable in a more highly visible location such as along I-49. Management would need to choose an appropriate path.

Each geotechnical asset will have specific circumstances that dictate treatment actions. The goal is to manage each asset effectively by balancing performance, failure consequences, risk, and funding issues. There is a cost/benefit breakpoint where the repair would require more effort with the need to hire a contractor and/or design engineer. For example, DOTD has contracted companies to provide deep mixing efforts, install sheet piles, etc. to repair slope failures. Some minor repairs can be fixed with internal staff; however, contracted options can be faster, provide more options that ease traffic congestion, and may provide a more stable, long-term solution. Yet, these benefits often come at higher costs. Without a proper management strategy and life-cycle planning, emergency response is often the only effective method to address these unmanaged assets. NCHRP Report 903 developed a GAM Planner tool/Excel spreadsheet to evaluate and administer an asset model that includes simulating risk calculations. An additional spreadsheet is available to help evaluate the Net Present Value (NPV), Life-Cycle-Costs, and treatment options.

Data Collection of Culverts, Slopes, and other Geotechnical Assets

The DOTD Operation and Maintenance Staff is concerned about the efforts to inventory, assess, and manage additional assets like GAM items. Other concerns include weighing the cost benefit ratio of repairs versus failure event frequency. This project collected asset information for retaining walls, however other data sets exist. LTRC Project 21-5SS [24] "Determining the True Cost and Benefit for Collecting and Maintaining Non-road and Non-bridge Asset Data" is ongoing, and an additional LTRC study [25] investigated the "Cost and Time Benefits for Using Subsurface Utility Engineering in Louisiana."

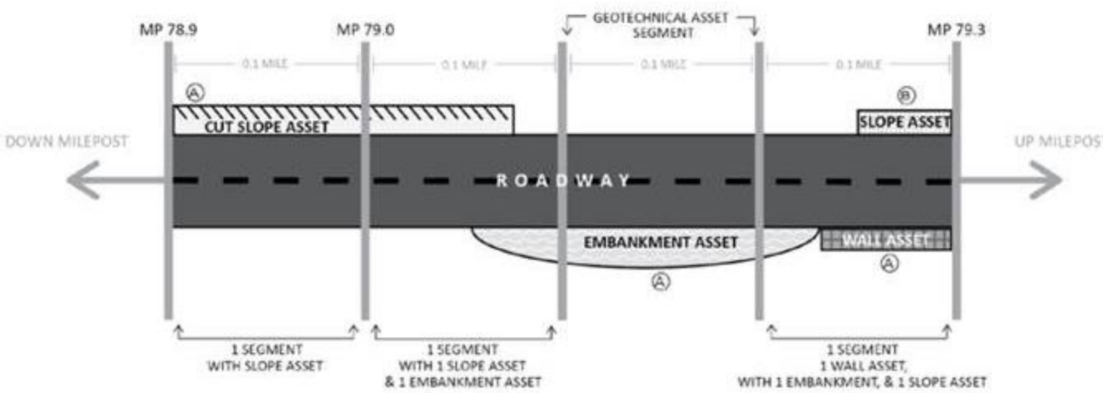
Depending upon how HQ decides to manage assets, there are assets across the state. Some are within DOTD, some are not. Some could affect DOTD transportation corridors more than others. Inventorying these sets would get them on the radar, and help with their management. Other major geotechnical assets include:

Culverts. Late into this research, DOTD Operation and Maintenance staff indicated that culverts could be more of a problem than walls due to the numerous culvert sites across the state. Staff indicated the culverts were a "higher priority than walls because they have a funding source." Though this research focused more on walls to start lean, the same logic applies to other assets such as culverts. DOTD should inventory and manage these assets appropriately. Data collection of culverts especially will be a more extensive operation since Google Map imagery is not as useful for underground assets. In addition, there may be other cross drain structures (bridge types) that do not meet the federal definition of a bridge (by opening or construction/placement method) that exist and are not part of the existing bridge inventory. These assets are not currently inventoried or inspected, and could cause a safety concern or disruption to traffic. The department should decide criteria (size, ADT, etc.) of these cross-drain assets to set limits on which should be included within GAM.

Slopes. Slopes of various types (earthen: side, embankment, fore, back) fit into a similar scenario as culverts, in that, there are many across the state even in our relatively flat state of Louisiana. Due to our soft soils, some slopes are more stable than others. Unfortunately, due to the extensive collection efforts required, subtle slope change data was not collected as part of this study.

NCHRP Report 903 offers guidance for documenting geotechnical assets along a highway corridor (Figure 40). The logic breaks highways into GAM segments that represent a consistent length of highway. Within these lengths, a methodology to identify, name, and group assets is identified. Datasets inventorying and ratings would be needed along with the associated efforts to collect and manage the data. The introduction of ESRI Field Maps collection and the Headlight (Pavia) systems applications may prove to be an easier and more efficiently entry method that is direct-to-digital inclusion in a GAM database.

Figure 40. NCHRP Report 903 recommended technique for asset location



GAM Inventory Example

ASSET ID	ASSET TYPE	TOTAL LENGTH IN SEGMENT
Highway MP 78.9	Cut Slope A	400 feet
Highway MP 79.0	Cut Slope A	400 feet
	Embankment A	250 feet
Highway MP 79.1	Embankment A	500 feet
Highway MP 79.2	Embankment A	200 feet
	Wall A	300 feet
	Slope B	100 feet

Figure 2-7. Geotechnical Asset Segment and Location Process

In addition to Field Maps as a collection tool, DOTD has explored and implemented another tool within the districts. The "Evaluation of Headlight: An E-Construction

Inspection Technology" report [26] showed "…substantial, quantifiable gains when Headlight was used in place of traditional inspection processes. Researchers anticipate that these gains will be more considerable when the technology is further leveraged using big data analytics." These mobile interaction tools that exist within the districts could be utilized to collect GAM data in the field.

Why Include in the TAM?

The Alaska DOT&PF was one of the first state agencies adopting GAM. They summarized their logic behind the inclusion of the GAM within the TAM Plan [27] very succinctly in the technical report. A portion of that report is included below and their decision logic still holds true today. From the 2017 Alaska DOT&PF Geotechnical Asset Management Plan: Technical Report *15 1.3* [27]

> *Why Include Geotechnical Assets in a TAM Plan? The National Highway Performance Program (NHPP) was established in MAP-21 and subsequent legislation as the primary federal means of paying for infrastructure replacement and preservation. Funding can be used for "a project or part of a program of projects supporting progress toward the achievement of national performance goals for improving infrastructure condition, safety, mobility, or freight movement on the National Highway System" (23 USC 119(d)(1)(A)). Inclusion of geotechnical assets within the Transportation Asset Management Plan ties the construction and preservation of these assets to the national goals and ensures the eligible use of these funds under 23 USC 119(d)(2)(A), "Construction, reconstruction, resurfacing, restoration, rehabilitation, preservation, or operational improvement of segments of the National Highway System." In addition, 23 USC 119(d)(2)(K) allows the use of NHPP funds for "Development and implementation of a State asset management plan for the National Highway System in accordance with this section, including data collection, maintenance, and integration and the cost associated with obtaining, updating, and licensing software and equipment required for risk-based asset management and performance-based management." It is clear from the MAP-21 legislation and subsequent rules that the TAM Plan is intended to become a strategic document that guides and justifies a large portion of the STIP. By providing an objective, data driven justification for the funding and selection of geotechnical investments, and by including these investments in the STIP process, incorporation of geotechnical assets within the TAM Plan gives this asset class a seat at the table in preservation strategy, funding allocation, and investment programming decisions*

(Stanley 2011). The purpose of a GAM Plan is very similar to a TAM Plan. Therefore, it would promote the eventual usefulness and understandability of the GAM Plan if it is written to be consistent with the requirements of a TAM Plan. It is also important that the GAM Plan satisfy a set of Department objectives which may or may not be the same as the federal objectives.

Parallel DOTD Activities

Two new projects are slated for LTRC researchers that will align with this project's GAM activities. The two projects are Geotechnical Database Phase IV and light detection and ranging (LIDAR) for Geotechnical Applications. These two projects went through our research problem solicitation process and were determined as DOTD priority needs.

The Geotechnical Database Phase IV project, LTRC 21-2GT [28], will focus on gathering information to transition data from existing systems to the more robust database and cloud based platforms of HoleBASE/Open Ground. Refining assets data into a more organized structure will help with access, visualizations, calculations, and design decisions. The project will also work to refine geotechnical digital data to ensure DIGGS compatibility.

An objective in the LTRC LIDAR project is to proactively collect slope inventories without field sites utilizing existing DOTD datasets. LIDAR aviation-based scans are an existing data source within DOTD that the researchers will attempt to tap into for other assets. This strategy will be similar to the computer based inventory efforts of this GAM research. It will also ideally provide a method to determine accurate geotechnical asset, soil boring and cone penetration test elevations, as well as develop an interface for geotechnical engineers to locate slope stability issues possibly using machine learning. The study will investigate not only traditional fixed-wing passenger-aircraft collection by other DOTD sections, but also drone based LIDAR for more detailed quick response activities related to emergency repair and other issues.

Conclusions

This research advanced Geotechnical Asset Management (GAM) within the DOTD. Full GAM development and implementation will provide the department a logical method to manage risk, address problematic locations, and effect a rationale to implement appropriate repairs in a timely manner.

The developed GAM GIS database provides geospatial locations, digital storage, digital rating applications, and visual interfaces for retaining walls including historical information. Inventory efforts utilized efficient and effective tools of aerial photography, mapping, GIS software, web applications, and mobile applications. DOTD can replicate these efforts for other asset types.

DOTD Challenges

- Walls are built, but fall off the radar after construction, until problems occur. Unfortunately, wall maintenance is most often a reactionary process.

- Walls are subcontracted, so as-built plans containing final wall info, type, and details are not normally included in DOTD retention records and digital software (files/Falcon/Content Manager, FileNET, etc.).

- Large Shreveport area (I-49) walls inventoried will reach maturity, simultaneously.
  - Earliest walls (~1985) are roughly 35 years old nearly halfway through design life.
  - Salt application rates are higher in North Louisiana due to its colder climate. These higher corrosion rates likely reduce actual-life span versus design life.

Researchers developed desk and mobile applications for efficient collection of condition and consequence assessment data into the GIS Database. Districts with their local knowledge should use these tools as part of the rating process.

Researchers await DOTD HQ Operation and Maintenance issuance of direction to the districts regarding the next steps of the GAM implementation and segment ratings. HQ manages district workload, staffing, and funding priorities associated with the maintenance and asset management efforts. Awaiting HQ directives slowed implementation by affecting the timeliness of the risk calculations and the full implementation of GAM.

Culverts and slopes are tougher to locate/inventory via aerial photos, and would benefit from a mobile application like Field Maps or Headlight. These could allow district personnel to spatially locate the start and end of assets, while in the field, and populate directly to the database.

GAM is a proactive way to manage geotechnical assets and provide insight to help future decisions regarding condition, performance, and consequences of risk improving upon the current reactive nature versus deteriorating conditions. GAM can assist DOTD with the logical allocation of limited financial resources to ensure safety and longevity of these assets. With the ever pressing "need to do more with less" and the knowledge drain of retiring workers, further implementation of the GAM system will help preserve the past so designers can plan for the future.

Recommendations

Coordination between the Bridge Maintenance, Districts, and Geotechnical Sections at DOTD is essential regarding the operation and maintenance of geotechnical assets across the state, currently and hereafter. The following bullets outline some recommendations on how DOTD can incorporate GAM into normal operations (HQ Maintenance and Operations, Geotechnical, and Bridge Maintenance sections) and ultimately into the TAMP.

- Add wall construction details (subcontractor designs/as-builts) to project files earlier (Falcon/FileNet, etc.)
- Continue to inventory assets (350+ segments so far)
    - Include additional information on wall age, ADT of roadway, project numbers
    - Verify with districts for accuracy and missing assets
- Conduct condition assessments (HQ-District forces) with FieldMaps Application
    - Operation & Maintenance Condition (1-5)
    - Safety Consequences (1-5)
    - Mobility/Economic Consequences (1-5)
- Calculate risk scores (A to F) to set priorities
- Review treatment options
- Communicate results and manage assets
    - Utilize the GIS database, mobile application, and the GAM guide as part of the GAM implementation within DOTD. A user guide was developed for the FieldMaps application and is attached as an Appendix.
    - Inspection recommendations (Checklist & Inspection Frequency)
- Conduct recurring inspections/re-rating of wall assets collected in this research.
- Include walls, culverts, and slopes in the GAM and ultimately in the TAMP. Other assets like salt domes, boring logs, should be part of the Geotechnical Section records for reference.
- Grow the asset database through follow-up efforts to collect other datasets (culverts, slopes, etc.). Consider FieldMaps and Headlight applications moving forward.

Acronyms, Abbreviations, and Symbols

Term	Description
AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
AFP10	TRB Committee: Design & Construction Group, Geological & Geoenvironmental Engineering Section, Standing Committee on Engineering Geology
AFP10(2)	TRB Committee: AFP10 Geotechnical Asset Management Subcommittee
AKG70	TRB Committee: AKG00(1) Geotechnical Asset Management Subcommittee
AKDOT&PF	Alaska DOT & Public Facilities
BCS	Blended Calcium Sulfate
cm	centimeter(s)
CORS	Continuously Operating Reference Station
CPT	Cone Penetration Test
DIGGS	Data Interchange for Geotechnical and Geoenvironmental Specialists
DOT	Department of Transportation
DOTs	Departments of Transportation
DOTD	Louisiana Department of Transportation and Development
DTIMS	Deighton Total Infrastructure Management System
EDC	Every Day Counts
ESRI	Environmental Systems Research Institute
FHWA	Federal Highway Administration
ft.	foot (feet)
GAM	Geotechnical Asset Management
gINT	Bentley Geotechnical Database Software
GIS	Geographic Information System
GOHSEP	Governor’s Office of Homeland Security and Emergency Preparedness

Term	Description
GRS	Geosynthetic Reinforced Soil
GRS-IBS	Geosynthetic Reinforced Soil – Integrated Bridge System
HoleBASE	Keynetix Geotechnical Database Software (now Bentley)
ID	Identification
in.	inch(es)
IT	Information Technology
DOTD	Louisiana Department of Transportation and Development
lb.	pound(s)
LGS	Louisiana Geological Survey
LIDAR	Light Detection and Ranging
LOR	Level of Risk
LRS	Linear Reference System
LTRC	Louisiana Transportation Research Center
m	meter(s)
MEC	Mobility & Economic Consequence
MnDOT	Minnesota Department of Transportation
MSE	Mechanically Stabilized Earth
MSEW	Mechanically Stabilized Earth Wall
NCHRP	National Cooperative Highway Research Program
NPE	New Product Evaluation
NPV	Net Present Value
O&M	Operation & Maintenance
O&MC	Operation & Maintenance Condition
PLT	Pile Load Test
PPP	Public Private Partnership
PRC	Project Review Committee
RECo	Reinforced Earth Company
ROW	Right of Way
RouteID	DOTD LRS-ID system
SC	Safety Consequences

Term	Description
SoE	System of Engagement within DOTD utilizing ESRI
sq.ft.	Square Foot
TAM	Transportation Asset Management
TAMP	Transportation Asset Management Plan
TRB	Transportation Research Board
TRID	Transport Research International Documentation
TRIS	TRB’s Transportation Research Information Services (TRIS) Database
USACE	United States Army Corps of Engineers

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Appendix A

NCHRP 24-46 Survey with Louisiana Responses

NCHRP 24-46 Implementation Manual for Geotechnical Asset Management Case Study Interview Outline

SME Specific Introduction:

The National Cooperative Highway Research Program is developing an Implementation Manual for Geotechnical Asset Management for Transportation Agencies (NCHRP 24-46) in partnership with geotechnical firm Shannon & Wilson, transportation management consultants Spy Pond Partners, the University of Missouri, and Iowa State University. The study calls for state DOT participants to share their experiences, barriers to implementation, and best practices in GAM. For this study, geotechnical assets consist of features such as unstable soil and rock slopes (landslides, rockfall), embankments, or subgrades.

1. Executive Action Area
    a. Does the DOT/agency dedicate resources to geotechnical asset management (e.g., retaining walls, slopes, embankments, drainage basins, etc.)? Not at this time.
    b. Does it have the capability to fund geotechnical asset management if not supported by FHWA or another external source? Not at this time, Department is currently prioritizing collection of assets in the future with utilizing a combination of consultant and in-house efforts.
    c. Does your agency experience impacts from adverse events or deterioration associated with geotechnical assets?
        i. Type of impact: Cost/safety/mobility/other? All of these, plus aesthetic.
        ii. Degree of impact: Embankment impact is probably moderate to severe, MSE wall impacts have been less serious to date.
        iii. Frequency of impact: Embankment impacts are becoming very frequent, MSE wall impacts are only a handful of cases.
    d. Can maintenance and engineering program expenses be reported based on asset groups? Yes, for capital projects. For operating expenses, the Department utilizes a Maintenance Management System (Agile Assets) to

capture maintenance costs on assets. At this time only roads, bridges, state parks, dams are inventoried.

   e. How are impacts from off-ROW assets addressed? E.g., An adjacent retaining wall impacting the ROW or a rock/debris that originates off-ROW. This hasn't been an issue to my knowledge.

2. Planning Action Area
   a. Does the TAM plan consider geotechnical assets? No.
   b. How is the risk across asset groups evaluated? N/A
   c. Does the agency measure direct impacts from events related to geotechnical assets (e.g., damage to highway, clean-up costs, damage to personal property, injuries, etc.)? No.
   d. Does the agency measure indirect impacts from these events (e.g., economic loss, vehicle delays, etc.)? No.
   e. How does source of funding factor into the trade-off analysis? (e.g., FHWA or FEMA emergency funds, agency contingencies, programed design budgets) N/A.
3. Geotechnical Action Area
   a. Are there inventory or condition data for any of the geotechnical assets? If so, what percentage? What are the tools used for data collection? No, embankments or walls only make it onto the radar once they have become a maintenance problem.
   b. Is the geotechnical program required to report on the performance of any geotechnical assets? If so, what are the performance metrics and how are they assessed? No.
   c. Does your agency differentiate the management of geotechnical assets based on whether the source area is on or off ROW? No.
   d. Have you been trained in the concepts and implementation of any type of transportation asset management? Are you familiar with the performance measures for your agency? No. DOTD maintenance and planning areas have experience in this area.
   e. How does the geotechnical program assess risk? Subjectively/qualitatively/quantitatively? N/A
   f. Does the agency conduct proactive geotechnical measures or are activities related to rockslides and other geotechnical events mostly reactive? To this point, all efforts are reactive.
   g. Are the geotechnical staff trained and able to perform risk assessment? No.
   h. Do you consider transportation asset management concepts in design?

    i. E.g., Life-cycle cost, design features to support inspection, different design standards based on performance/risk (even if it would be below AASHTO guidance)? Yes.

i. Are maintenance/repair costs tracked? Currently may be captured to the roadway associated with the maintenance/repair, but not specifically to the geotechnical asset at this time (except for bridges, which are directly captured).

j. What are the impacts geotechnical assets have outside of the department geotechnical group? Are they measured? Bridges are inventoried based on federal requirements.
    i. Type of impact: Cost/safety/mobility/other?
    ii. Degree of impact
    iii. Frequency of impact

k. Are there examples of successful proactive project work on a geotechnical asset, such as repair or rehabilitation, that you believe prevented a future adverse event? Usually this is taken care of during the design or repair process, but it is rare that we take measures to upgrade/enhance an asset that is already in service and performing well to prevent any future events. We often repair slopes with geofabric, which we believe will help to prevent similar failures in the future, but this is after an initial failure is already observed.

General:

1. What can/would enable GAM implementation? Funding for data collection, as well as prioritization of collecting these assets with respect to other assets to be collected.
2. What are the barriers to GAM implementation? Funding for data collection, as well as prioritization of collecting these assets with respect to other assets to be collected.

Appendix B

http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Pavement_Geotechnical/MSE%20Walls/LA%20DOTD%20Approved%20Retaining%20Wall%20Systems%20List.pdf

The following Mechanically Stabilized Earth Wall (MSEW) systems are approved for use on LADOTD projects:

Name of System	Manufacturer	Phone
Reinforced Earth Walls	The Reinforced Earth Company 1331 Airport Freeway, Suite 302 Euless, TX 76040-4150	(817) 283-5503
Keysystem I Highway Wall System (Modular Block/Steel Reinforcement)	Keystone Retaining Wall Systems, Inc. 4444 W 78th Street Minneapolis, MN 55435	(952) 897-1040
Keysystem II Highway Wall System (Modular Block/Geosynthetic Reinforcement)	Keystone Retaining Wall Systems, Inc. 4444 W 78th Street Minneapolis, MN 55435	(952) 897-1040
Mesa™ Retaining Wall System (Modular Block/Geosynthetic Reinforcement)	Tensar Earth Technologies, Inc. 5883 Glenridge Drive Suite 200 Atlanta, GA 30328	(404) 250-1290

Pre-Approved Status

The following systems are pre-approved:

Name of System	Manufacturer	Phone
TriWeb Retained Soil Wall System	Tricon Precast, Ltd. 15055 Henry Road Houston, TX 77060	(281) 931-9832

Systems on pre-approved status have been reviewed and approved by LADOTD, but have not yet constructed walls on LADOTD projects. These systems are expected to perform acceptably and should be considered for inclusion on any non-interstate route projects, which includes ramps leading to and from the interstate. Final approval will be based upon the successful completion of the first wall constructed, which shall also perform successfully for a period of one year.

All Wall systems utilizing Geosythetic strips are required to be designed using the AASHTO default values for Geogrid materials Ci = 0.67 and alpha = 0.80.

Contact Us

Questions regarding the use of pre-approved systems may be directed to:

LADOTD Geotechnical Section
(225) 379-1937