TRANSPORTATION RESEARCH SYNTHESIS

Minnesota Department of Transportation
Office of Policy Analysis, Research & Innovation
Research Services
(651) 366-3780
www.dot.state.mn.us/research

TRS 1305
Published May 2013

Asset Management for Retaining Walls

The purpose of this TRS is to serve as a synthesis of pertinent completed research to be used for further study and evaluation by MnDOT. This TRS does not represent the conclusions of either CTC & Associates or MnDOT.

Introduction

MnDOT would like to create an asset management plan for retaining walls and develop a proposal for a project to obtain inventory and condition information about metro retaining walls. To support these efforts, MnDOT is interested in the best practices and lessons learned from other transportation agencies with such programs.

Questions of particular interest include:

- What methods (e.g., LiDAR) are used to find and inventory retaining walls (which are often concealed by foliage)?
- What attributes should be collected for each asset?
- What inspection guidelines, criteria and time frames should be used?
- What are the criteria for the useful life of assets of various types and field circumstances?
- What performance measures and indicators are used for management of these assets?
- What risk management strategies are used (including the risks of certain inspection intervals)?

To meet this need, CTC & Associates conducted a literature search and interviews with practitioners concerning their retaining wall asset management programs.

Summary

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. Particularly important is the Federal Highway Administration's (FHWA's) recent inventory of 3,500 walls for the National Park Service (NPS) (and the related guidance, Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**). Of the agencies that we interviewed for this Transportation Research Synthesis (TRS), FHWA, Alaska Department of Transportation & Public Facilities (DOT&PF) and Oregon Department of

Transportation (DOT) have substantial programs and offered guidance about most of MnDOT's questions of interest. We also found a number of reports related to establishing retaining wall asset management programs in particular and geotechnical asset management programs in general, as well as an active Transportation Research Board (TRB) Geotechnical Asset Management Subcommittee (https://sites.google.com/site/trbcommitteeafp10/Welcome/geotechnical-asset-management-subcommittee). A webinar sponsored by the American Association of State Highway and Transportation Officials (AASHTO) and FHWA on June 24 will include an overview of Oregon and Utah DOTs' retaining wall programs.

The information in this TRS is divided into the following sections:

- Consultation with Experts
- State and Local Practices
- National Resources
- Related Research

Consultation with Experts

We contacted experts at FHWA and the Alaska, Colorado, New York State, Oregon, Vermont and Washington State transportation agencies. Interviews confirmed the findings of our literature review that most agencies are in the early stages of establishing asset management programs for retaining walls and other geotechnical assets:

- Colorado DOT has a draft Request for Proposal (RFP) (Appendix B) to solicit a consultant to start a retaining wall asset management program.
- New York State DOT has a limited database of mechanically stabilized earth (MSE) walls only.
- Vermont Agency of Transportation has a nascent program but could provide no guidance.
- Washington State DOT developed a plan for a geotechnical asset management program but abandoned it for lack of funding.

However, FHWA, Alaska DOT&PF and Oregon DOT have substantial programs about which they were able to provide a significant amount of information. FHWA's inventory of 3,500 walls for the NPS constitutes the most extensive retaining wall asset management program in the United States to date, and this effort is well-documented. (See Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**.)

Findings can generally be characterized as follows:

- **Inventory Methods:** FHWA relied on maintenance staff guidance to conduct its inventory of retaining walls. Alaska DOT&PF thus far has used only internal records, but in its next phase will recruit technicians to collect data in the field. These techs will target critical routes systematically and interview district maintenance personnel to find concealed walls. Alaska DOT&PF hopes eventually to use such technologies as Light Detection and Ranging (LiDAR). Oregon DOT uses Google Maps and Bing Maps for visible walls and field visits for others.
- **Attributes:** Height, length, location, condition and wall type are typical attributes. FHWA suggests keeping data collection simple initially, although it collected data for an extensive number of attributes for its program (documented in Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**). For the list of attributes used by Alaska DOT&PF, see Retaining Wall Inventory Procedures Manual (Appendix A), and for Oregon DOT, see the access screenshot of its database (page 8 of this TRS).
- **Inspection:** FHWA has extensive inspection guidance. (See the chapter about criteria in Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**.) Interviewees agreed on five years as an appropriate interval for routine inspection (which our literature review confirmed).
- **Useful Life:** This is a difficult area that even FHWA is unsure how to manage in its database. Alaska DOT&PF and Oregon DOT have not yet addressed this area.
- **Performance Measures:** See the data collection forms and libraries in Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**. Oregon DOT and Alaska DOT&PF have not yet developed performance measures.
- **Risk Management:** None of the interviewees had conducted an extensive risk analysis.

State and Local Practices

We found several documents related to state DOT retaining wall asset management programs. These include an early feasibility study by Colorado DOT, a pilot project by North Carolina DOT and limited overviews of Ohio and Oregon DOTs' programs. Also of interest is an upcoming webinar about Oregon and Utah DOTs' programs.

National Resources

- Retaining Wall Inventory and Condition Assessment Program (WIP) contains the most thorough guidance we could find on establishing a retaining wall asset management program. Chapter 2 includes detailed data collection processes and procedures, and Chapter 4 provides an overview of collected attributes, including data related to wall location, description and condition. The manual also includes guidance about rating the condition of wall elements. See also our interview with the author of this report, Matt DeMarco, in **Consultation with Experts**.
- The NCHRP's Guide to Asset Management of Earth Retaining Structures also contains extensive information about current retaining wall asset management programs at U.S. transportation agencies, based in part on a survey of highway agencies in late 2008 and early 2009. Thirteen of 40 respondents reported having programs, but most are in their early stages. The guide covers inventory procedures and condition assessment, and recommends an inspection cycle of five years.
- For the complex topic of assessing the condition of retaining walls, there may be relevant information in documents on the performance of MSE walls, including the NCHRP synthesis, Assessing the Long-Term Performance of Mechanically Stabilized Earth Walls.
- We also found several reports about geotechnical asset management in general. FHWA's Geotechnical Asset Management: Implementation Concepts and Strategies covers establishing performance measures, defining geotechnical features to incorporate into a single asset, performing assessments, completing a risk screening and using assessment data to support the transportation asset management program.
- We also include links to several documents about transportation asset management in general.

Related Research

- We found several reports about establishing an inventory program for retaining walls, including Inventory System for Retaining Walls and Sound Barriers with inventory items adapted from the National Bridge Inventory Record. (Unfortunately we could not find the full text of this document.)
- We also found several reports about assessing the condition of MSE walls that may be applicable to retaining walls in general. Critical to this task is the assessment of corrosion rates for steel reinforcements. (See also NCHRP documents Assessing the Long-Term Performance of Mechanically Stabilized Earth Walls, and LRFD Metal Loss and Service-Life Strength Reduction Factors for Metal-Reinforced Systems in **National Resources**.)
- A few studies discuss geotechnical asset management in general, including risk-based methods (see Risk Based Methods for Management of Geotechnical Features in Transportation Infrastructure) and a *TR News* overview of several state DOT programs (Asset Management in a World of Dirt: Emergence of an Underdeveloped Sector of Transportation Asset Management). Also of interest are a report about the use of LiDAR by Washington State DOT and a report about FHWA's DIGGS system for standardizing geotechnical data.
- The Road Structures Inspection Manual of the Victoria (Australia) Highway Department includes inspection sheets and a condition rating system for retaining walls.

Consultation with Experts

We interviewed state and federal experts selected for their authorship of geotechnical asset management publications, reported activity of their agencies in developing retaining wall asset management programs, and participation in the TRB Geotechnical Asset Management Subcommittee (https://sites.google.com/site/trbcommitteeafp10/Welcome/geotechnical-asset-management-subcommittee). Agencies of interest that we were unable to interview within the scope of this TRS include the Nebraska, Ohio, Pennsylvania and Utah DOTs, and the cities of Cincinnati and New York. We also tried but were unable to reach three state DOTs of specific interest to MnDOT: Michigan, Missouri and New Jersey.

FHWA

Matt DeMarco, Geotechnical Engineer, Federal Highway Administration, matthew.demarco@fhwa.dot.gov, (720) 963-3520.

Inventory Methods: FHWA located 3,500 walls for its NPS survey and relied solely on maintenance staff guidance and "following their nose in the field." Matt DeMarco says the staff did a very good job of locating below-grade walls that were close to the road, which is most often the case. In some locales (mostly Eastern parks), walls were built well downslope to hide them from the traveling public. DeMarco believes the staff missed some of these in the survey. As-builts help, but they are hard to come by.

Attributes: This varies regarding what data is needed to support programming. The referenced guide manual that DeMarco compiled (see Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**) has a complete data library with definitions. FHWA collected far more information in this guide than would be necessary for an asset program. According to DeMarco, the devil is in the details: Defining wall parameters is not nearly as simple as it may seem on the surface. For example, wall height would be a common measurement in most programs. However, "wall height" might mean the exposed wall height, the height including the embedded portion, only that portion retaining soil, the height including the parapet, the height based on certain setback widths for compound or tiered walls, and so on. It's a simple idea, but hard to define in all settings. DeMarco recommends keeping the first round of data collection simple.

Inspection: See the chapter on criteria in Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**. FHWA had special circumstances that required some odd criteria, but it may be beneficial to see the twists that may be involved. Most of the walls (70 percent) were stone masonry structures, which drove a lot of FHWA's thinking.

Useful Life: DeMarco is at a loss on how to manage useful life in the WIP database. The stone walls are either functioning or (in very few cases) failing. Concrete walls (1940s and 1950s era) are showing signs of deterioration, and many need repair. Corrugated steel bin walls (1960s era), surprisingly used in near-coast applications, are rotting and failing from corrosion. MSE walls are still in good shape for the most part, including the first RECo panel walls built in the 1970s on the Foothills Parkway. FHWA has only conducted one inventory and condition assessment, so it doesn't have data on life-cycling. Based on information from the database, DeMarco estimates that stone walls are working the best, with more modern wall designs (steel elements) degrading the most and heading toward replacement quickest.

Performance Measures: See the data collection forms and libraries in Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**. FHWA looked at traditional internal and external wall stability, but also looked at peripheral appurtenances such as traffic barriers, adjacent slopes, drainage and pavement conditions. Wall construction elements play a big role as well.

Risk Management: In the WIP database, less than 1 percent of the walls required replacement or substantial repair. About 3 percent required replacement of some elements. The bulk of the rest of the maintenance recommendations primarily involved drainage cleanouts, stone resetting/repointing and vegetation removal. The failing walls were promptly identified for the NPS to program through its PMIS process. Some of the walls have come up on the funding radar thus far (including one on the Blue Ridge Parkway recently). Other than that, no risk analysis has been completed. FHWA examined rate failure consequence, but did not roll up in the wall condition rating.

General Recommendations: The best approach to creating a program is to develop a simplified inventory and condition screening method to locate and describe walls (type, size and location) on any given route using the cheapest labor available. DeMarco used IT staff members for a pilot project, and they were very capable of gathering preliminary information to start a retaining wall asset management program: locating and defining the geometrics of a wall; determining the composition of a wall; photographing it; and determining if it was functioning as intended, if it needed repair or if it was falling down. This information will answer questions about the size and type of assets as well as the general state of their performance. Subsequently, agencies can focus on the asset management aspects.

DeMarco also recommends a robust location method. FHWA did not use GPS for the NPS program because it is unreliable in many park settings. Instead it used milepoints from ARAN pavement surveys (which also had roadway GPS). This system worked well, but not without some issues while new ARAN cycles come online.

State Practitioners

Alaska

Dave Stanley, Chief Engineering Geologist, Alaska Department of Transportation & Public Facilities, dave.stanley@alaska.gov, (907) 269-6236.

Barry Benko, Geotechnical Engineering Assistant, Alaska Department of Transportation & Public Facilities, barry.benko@alaska.gov, (202) 684-6278.

Dave Stanley
Dave Stanley is developing a geotechnical asset management program for Alaska DOT&PF. One of its programs is a retaining wall inventory, which has been assigned to geotechnical engineering assistant Barry Benko. Alaska DOT&PF is only beginning its program and at this point does not even know where its walls are located, much less what condition they are in. However, Benko has started the inventory process and has developed a preliminary data dictionary.

Barry Benko
Inventory Methods: Thus far, Alaska DOT&PF uses only records. Barry Benko recruited seasonal engineering techs to start compiling information for a preliminary phase relying simply on an office-based survey of internal records to catalog wall locations and basic data.

From the Wall Inventory Procedures Statement (Appendix A; the statement has been incorporated into Alaska DOT&PF's Wall Inventory Procedures Manual):

> This preliminary phase of the Wall Inventory relies on gathering information from internal AKDOT&PF records, including—but not limited to—
> - As-builts
> - Road viewers
> - AKDOT& PF *Digital Roadway Viewer Alaska*

- DOT Highway Data Port [http://www.dot.state.ak.us/hdpapp/forms/Reports.html?categoryId=HDP+Route+Log/List+Query+Reports]
- Bridge inventory/PONTIS
- Statewide Culvert Inventory
- [Compilation of Bids (COB)] sheets

The individuals who gathered data informed Benko that they had not expanded beyond construction as-builts and COB sheets during their work. The inventory workers input to a Web interface that uses ArcGIS 3.1 for Flex as the platform.

For the next phase of Alaska DOT&PF's retaining wall inventory, Benko plans to recruit techs to collect data in the field. He will deploy the data collectors in a systematic order that targets critical routes and areas first. They would hopefully interview district maintenance station personnel for institutional firsthand knowledge of retaining wall locations. According to Benko, this step would be valuable for capturing walls that may be concealed or otherwise difficult to find. The field inventory workers would confirm the records already input to the database and also input data for newly discovered walls.

At this early stage of its inventory, the methods used to find and inventory retaining walls are likely limited to a review of internal records, interviews with maintenance personnel and a field reconnaissance survey. At this time, Benko doesn't envision using technology such as LiDAR, but hopes to use such techniques when Alaska DOT&PF moves into the wall program phase focusing on condition assessments of critical walls.

Attributes: While Benko believes that the set of attributes is still up for argument, the attribute list he developed for Alaska DOT&PF's preliminary inventory is reflected in the fields used in the Web interface database as described and listed in its Retaining Wall Inventory Procedures Manual (Appendix A).

Inspection: Alaska DOT&PF has not yet developed guidelines, criteria and time frames for wall inspection. Benko thinks this will largely depend on the labor resources available to the agency. If the approach is to use a limited group of agency staff, he envisions a limited scope of initial field inspection. The first field effort will emphasize capture of basic attributes along with a field appraisal of the general condition of the walls. Benko thinks a rather simple, scaled approach would probably be sufficient when the agency develops a list capturing most of the critical walls in the state. The next step would be more detailed inspections of the critical walls by qualified engineers.

Benko generally likes the procedures developed by FWHA for the NPS WIP (see Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources**) and expects to mimic some of the guidance in that document.

For inspection time frames, Benko does not think most wall programs could match the two-year inspection requirement applied to bridges. He thinks every five years will be a target for the retaining wall inventory program in Alaska.

Other: Alaska DOT&PF has not yet developed criteria for useful life, performance measures or risk management strategies. Currently the biggest issue Alaska DOT&PF needs to resolve is how to integrate its retaining wall management program with its bridge program.

Colorado

Joshua Laipply, Bridge Branch Manager, Colorado Department of Transportation, joshua.laipply@state.co.us, (303) 757-9190.

To date Colorado DOT has no retaining wall asset management program. It currently has a draft RFP (Appendix B) to solicit a consultant to start a program. Task Order 1 will consist of identifying a risk-based approach for the most critical walls and establishing inspection parameters. Laipply will be much more knowledgeable in about six months when this task is under way. We asked Colorado DOT to provide a copy of the draft RFP and are awaiting a response. See also Feasibility of a Management System for Retaining Walls and Sound Barriers in **State and Local Practices**.

New York State

Doug Hadjin, Engineering Geologist, New York State Department of Transportation, dhadjin@dot.state.ny.us, (518) 457-4728.

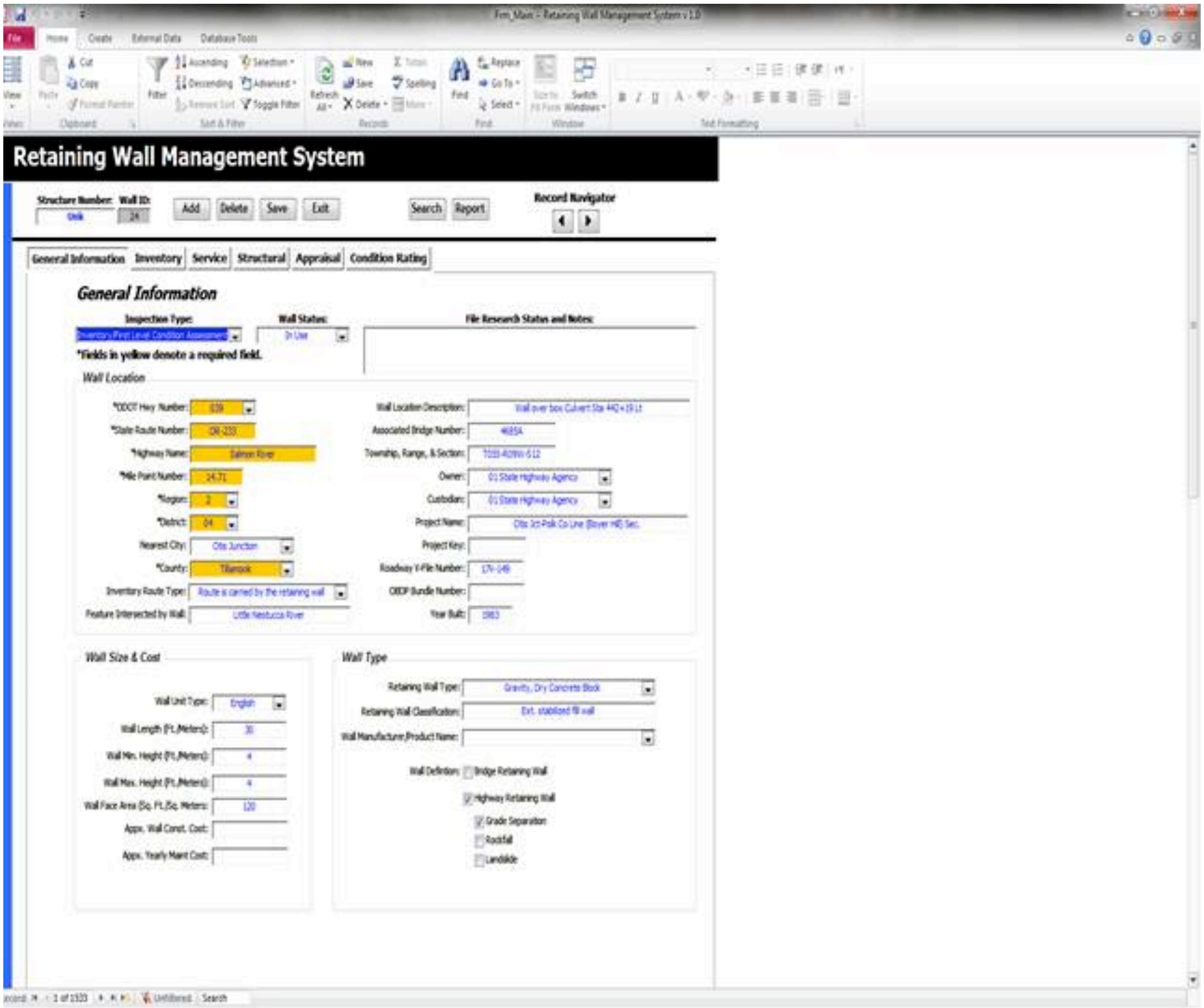
New York State DOT has a database of MSE walls only. This database does not have a great deal of information—only location, length and contract information. Data was collected by searching contracts and finding approximate wall locations using aerial photographs in ArcMap. New York City has its own extensive wall inventory, created after a large retaining wall collapsed on the West Side Highway. (See Struggling to Keep an Eye on 2,000 Retaining Walls in **Related Research**.)

Oregon

Don Turner, Geotechnical Designer, Oregon Department of Transportation, donald.c.turner@odot.state.or.us, (503) 986-3778.

Inventory Methods: Walls have been located if they are visible using Google Maps and Bing Maps. If they are not visible, a field visit is needed to locate and compare to the existing as-constructed plans.

Attributes: According to Don Turner, quite a few attributes can be identified for walls, depending on what level of detail is desired. Oregon DOT has developed an Access database with basic type, size and location information, followed by route information, structural information and, finally, a condition assessment. On the following page is a screenshot of the first page of the database:



Inspection: The only part of a wall that can be inspected is the face, so it is important to carefully look at the wall type and inspect it from the perspective of how different wall types would behave over time. For example, an MSE wall might show distress differently than a soldier pile or cast-in-place wall. So the inspection guidelines would be slightly different for each wall, but have some general similarities for all walls. General wall inspection frequencies might be five years for regular or routine inspection and increased frequency for walls that show distress.

Other: The issues of design life, useful life, performance measures and risk management have not been addressed and are only now being looked at through research with TRB and others.

See also Retaining Walls Asset Assessment—State of Oregon in **State and Local Practices**.

Vermont

Thomas Eliassen, Transportation Geologist, Vermont Agency of Transportation, tom.eliassen@state.vt.us, (802) 828-6916.

Vermont Agency of Transportation has barely begun inventorying geotechnical assets and hasn't gotten very far. Consequently, it cannot provide any guidance in this area.

Washington State

Thomas Badger, Geotechnical Office, Washington State Department of Transportation, badgert@wsdot.wa.gov, (360) 709-5461.

Tony Allen, State Geotechnical Engineer, Washington State Department of Transportation, allent@wsdot.wa.gov, (360) 709-5450.

According to Thomas Badger, Washington State DOT does not have an inventory or formal asset management program for retaining walls, though this was considered in years past. He referred us to Tony Allen, who confirmed that Washington State DOT had considered a program but did not pursue it because of lack of funding. Allen will do some research to answer more detailed questions based on Washington State DOT's prior plans and will respond by email in June 2013.

State and Local Practices

Retaining Wall Data Collection and Management

AASHTO/FHWA Transportation Asset Management Webinar: Geotechnical Asset Management, Part II, June 24, 2013, 2 p.m.
http://www.fhwa.dot.gov/asset/events/gam.cfm
This webinar will include presentations about retaining wall asset management programs at the Oregon and Utah DOTs.

Asset Management for MSE Walls, Robert Gladstone, Ohio Transportation Engineering Conference, Columbus, October 2009.
http://www.dot.state.oh.us/engineering/OTEC/2008%20Presentations/14A.pdf
This presentation gives an overview of Oregon DOT's asset management of MSE walls. It recommends several methods for condition assessment, including the use of polarization resistance measurements, coring and monitoring stations.

Related Resource:

> **MSE Wall Inventory and Inspection Program**, Tony Vogel, Office of Structural Engineering, Ohio Department of Transportation, inter-office communication, December 15, 2005.
> http://www.dot.state.oh.us/Divisions/Engineering/Structures/standard/MSE/Documents/IOC%20-%20MSE%20Wall%20inspection.pdf
> This communication provides the background and procedures for Ohio DOT's inspection and inventory program for MSE walls.

Asset Management Inventory and Data Collection, North Carolina Department of Transportation, Report No. FHWA/NC/2008-15, October 2009.
http://www.ncdot.gov/doh/preconstruct/tpb/research/download/2008-15FinalReport.pdf
This report documents the findings of a study to determine the best methods for collecting roadway asset management data. A literature review "shows a lack of a structured and widely accepted system for management of walls as a highway asset" (page 155). As a demonstration of the system developed in this study, four retaining walls in North Carolina were inventoried (pages 155 to 157), detailing attributes that include year built, height, length, wall type, backfill material and reinforcement. Section 5.6.2 (pages 157 to 158) gives an example of the use of LiDAR to automate condition assessment.

Retaining Walls Asset Assessment—State of Oregon, Oregon Department of Transportation Asset Management Program, May 14, 2007.
http://www.oregon.gov/ODOT/TD/asset_mgmt/docs/committees/execsteeringcommittee/31july2007/03d-retaining_walls_asset_assessment.doc
This document gives an overview of Oregon DOT's very limited retaining wall asset management as of 2007.

Feasibility of a Management System for Retaining Walls and Sound Barriers, Colorado Department of Transportation, Report No. CDOT-DTD-R-2003-8, May 2003.
http://ttap.colostate.edu/downloads/library/CDOT/CDOT-DTD-R-2003-8.pdf
From the abstract: This report includes proposed inventory record for walls and barriers, elements for walls and barriers, the use of components for hidden elements of walls, condition states, and appraisals, together with initial recommendations on inspection practice and intervals. … No impediment is found to full development of standard data and procedures for walls and sound barriers. Moreover, wall/barrier management can be implemented within existing software for bridge management such as AASHTO's Pontis management system.

The literature review (Chapter 2) includes a review of practices by Wisconsin and Illinois. Chapter 3 develops a conceptual management system, including data categories and fields. Researchers conclude that in "many aspects, and importantly in the software required, a system for wall/barrier management can strongly resemble bridge management systems" (page 40).

National Resources

Retaining Walls

Data Collection and Management

Retaining Wall Inventory and Condition Assessment Program (WIP), National Park Service Procedures Manual, Federal Highway Administration, FHWA Publication No. FHWA-CFL/TD-10-003, August 2010.
http://www.cflhd.gov/programs/techDevelopment/geotech/WIP/01_retaining_wall_inventory_condition_assessment_program.pdf
This manual documents data collection and management processes, wall attribute and element definitions, and team member responsibilities for conducting retaining wall inventories and condition assessments as part of the NPS Retaining Wall Inventory Program (WIP). The manual recommends an inspection cycle of once every 10 years at most (page 6). Chapter 2 includes detailed data collection processes and procedures, and Chapter 4 provides an overview of wall attributes that are collected, including data related to wall location, description and condition (page 39). Pages 97 to 101 offer guidance on rating the condition of wall elements. Appendices include related forms and a database user's manual. More information about this manual is available in this TRS in **Consultation with Experts**.

Related Resource:

> **"Retaining Walls are Assets Too!,"** Matthew DeMarco, Scott Anderson, Amit Armstrong, *Public Roads*, Vol. 73, Issue 1, July/August 2009: 30-37.
> http://www.fhwa.dot.gov/publications/publicroads/09julaug/05.cfm
> This article gives an overview of the NPS retaining wall inventory program: "The mission of the wall inventory program (WIP) is to define and quantify wall assets associated with park roadways in terms of their location, geometry, construction attributes, condition, failure consequence, cultural value, apparent design criteria, and cost of structure maintenance, repair, or replacement. The WIP data will feed into the

Facility Management Software System, the existing data hub that NPS uses to document, manage, and plan efforts related to park assets."

Guide to Asset Management of Earth Retaining Structures, National Cooperative Highway Research Program, October 2009.
http://onlinepubs.trb.org/onlinepubs/nchrp/docs/nchrp20-07%28259%29_FR.pdf
From the introduction: This publication is designed to help highway agencies to establish an Inventory and Inspection (I&I) program resulting into an Asset Management program for their earth retaining structures (ERS). … It is based in part on a survey of highway agencies conducted in late 2008 and early 2009. Of the 40 agencies that responded to the survey, 13 reported having implemented Inventory and Inspection programs for at least some of their ERS (see pages 4 to 5). Most agencies do not know the number, location and condition of their retaining walls.

Chapter 2 covers the initial requirements of a retaining wall inventory and inspection program, including agency resources, data management, asset definitions, field processes, personnel requirements and costs. See page 13 for a chart of retaining wall types. Chapter 3 addresses in-house preparation for the inventory, including a review of existing data, training and preparation of field survey forms. Chapter 4 reviews field inventory procedures; Chapter 5, condition assessment (including a discussion of the consequences of failure rating in Section 5.5); Chapter 6, data input; and Chapter 7, quality control and assurance. Chapter 8 recommends an inspection cycle (page 48) of five years, based on responses to its survey of agencies.

Earth Retaining Structures and Asset Management, Federal Highway Administration, 2008.
http://www.fhwa.dot.gov/asset/if08014/08014.pdf
This brochure gives a brief overview of the need for asset management of retaining walls. It notes that Oregon DOT, Cincinnati and the NPS have retaining wall programs.

Condition Assessment

Assessing the Long-Term Performance of Mechanically Stabilized Earth Walls, *NCHRP Synthesis 437*, 2012.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_437.pdf
This report includes a literature review and survey of the state of the practice for asset management of MSE walls. It confirms that MSE walls and retaining walls in general are overlooked assets for most agencies, and generally advocates that:

> In examining various reported practices for inventorying and assessing the performance of MSE walls, those appearing to be more effective are: (1) use of inventory and assessment systems with features that are simple to use and as objective as possible; (2) use of rating criteria that are specific to particular wall elements and/or conditions; (3) use of numeric rating scales that correspond to other scales already in use for other asset classes such as bridges; and (4) the incorporation of MSE wall inventory and assessment systems into systems for other asset classes.

Chapter 2 discusses the state of inventory practice, and includes a list of agencies with inventories (page 6) and tables describing the tools used and data collected (pages 8 to 9). Chapter 3 covers data collection and reviews the types of data collected by the NPS and Nebraska, Ohio, Utah and Pennsylvania DOTs. (Pages 14 to 16 discusses Pennsylvania DOT's well-defined retaining wall inspection program.) Inspection frequency (two to five years for routine inspections) is also discussed (page 16). Chapter 4 covers data assessment and rating systems, including risk assessment (page 23). This synthesis concludes (Chapter 6) that:

- MSE walls are often overlooked by agencies; there is no widely used, consistently applied system for managing them; and less than one-quarter of state agencies have inventories.
- The most well-implemented inventory assessment system is that of the NPS, and other programs of note include those of Pennsylvania and Nebraska DOTs.

Appendix E provides examples of methodologies and tools used by other agencies, including Nebraska's Retaining Wall Inspection Manual.

Estimating Life Expectancies of Highway Assets, *NCHRP Report 713*, Vols. 1 and 2, 2012.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_713v1.pdf
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_713v2.pdf
From the abstract: This two-volume report provides a methodology for estimating the life expectancies of major types of highway system assets, in a form useful to state departments of transportation (DOTs) and others, for use in lifecycle cost analyses that support management decision making. Volume 1 is a guidebook for applying the methodology in DOT asset management policies and programs. Volume 2 describes the technical issues and data needs associated with estimating asset life expectancies and the practices used in a number of fields—such as the energy and financial industries—to make such estimates.

LRFD Metal Loss and Service-Life Strength Reduction Factors for Metal-Reinforced Systems, *NCHRP Report 675*, 2011.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_675.pdf
From the abstract: NCHRP Report 675 presents the findings of research conducted to develop metal loss models for metal-reinforced systems that are compatible with the AASHTO "LRFD (Load and Resistance Factor Design) Bridge Design Specifications." The report will be of immediate interest to engineers in state highway agencies and industry with responsibility for the construction and maintenance of bridges and structures, with particular emphasis on mechanically stabilized earth (MSE) walls.

Geotechnical Asset Management in General

Geotechnical Asset Management: Implementation Concepts and Strategies, Federal Highway Administration, Report No. FHWA-CFL/TD-13-003, January 2013.
http://www.cflhd.gov/programs/techDevelopment/geotech/GAM/documents/GeotechnicalAssetManagementImplementationConceptsAndStrategies.pdf
This document presents the general concepts for managing geotechnical features associated with transportation infrastructure. Chapter 3 outlines the components of a geotechnical asset management program, including a general discussion of agency goals, data management, data collection, performance measures and performance analysis. Chapter 4 covers current state of the practice, noting that currently "there does not appear to be a standard of practice for geotechnical asset management within state and federal transportation agencies in the United States" (page 35). The author notes that there are "limited examples of a formalized management program within state and federal transportation agencies," but points to Oregon and Alaska as two states active in this area. (Alaska is initiating a program that will include retaining walls.) Chapter 5 provides recommendations for developing a geotechnical asset management program, which should include the following components (page 37):

- Data management
- Inventory and condition surveys
- Levels of service
- Service life
- Performance measures and condition indices
- Risk management
- Life-cycle and benefit and costs analyses
- Decision support

A flowchart of these processes is given on page 38. The chapter also covers establishing performance measures, defining geotechnical features to incorporate into a single asset, performing assessments, completing a risk screening and using assessment data to support the transportation asset management program. Table 5 (page 46) provides quantitative risk assessment results for an example geotechnical asset management plan, and Appendix A (page 61) includes a sample asset management decision tree for a retaining wall.

General Transportation Asset Management Resources

Below are general asset management resources with principles that can be applied to retaining walls and other geotechnical assets:

- **AASHTO Transportation Asset Management Guide**, American Association of State Highway and Transportation Officials, Report No. RP-TAMG-1, November 2002.
http://downloads.transportation.org/AMGuide.pdf
- **Supplement to the AASHTO Transportation Asset Management Guide: Volume 2—A Focus on Implementation**, National Cooperative Highway Research Program, Report No. NCHRP 08-69, May 19, 2010.
http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-69_TAM_GUIDE_VOLUMEII.pdf
- **An Asset-Management Framework for the Interstate Highway System**, *NCHRP Report 632*, 2009.
http://www.camsys.com/pubs/nchrp_rpt_632.pdf
- **Use of Transportation Asset Management Principles in State Highway Agencies**, *NCHRP Synthesis 439*, 2013.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_439.pdf

Related Research

Retaining Walls

Data Collection and Management

"Network-Level Data Collection for Asset Management of Retaining Walls and Approach Slabs," Mohammed Gabr, North Carolina State University, Raleigh, *91st Annual Meeting of the Transportation Research Board*, January 2012.
Abstract at: http://pressamp.trb.org/conferenceinteractiveprogram/PresentationDetails.aspx?ID=46287&Email=
From the abstract: Asset management is a relatively new concept in geotechnical engineering. In general, the nature of performance data, and response of structures within the realm of geotechnical engineering render the concept of asset management a valuable tool that, if effectively implemented, can lead to increased operation efficiency and cost control. Work reported in this paper was conducted in association with the North Carolina Department of Transportation 2008 Workshop on Highway Asset Management and Data Collection. This paper presents a summary of geotechnical asset management (GAM) focus on network level collection of data related to settlement of bridge approach slabs, and retaining walls inventory and profile measurements. These two areas were selected since they represent a myriad of challenges faced by departments of transportation across the nation and worldwide and there are off the shelf tools available for collection of data on these assets. Results in the paper demonstrates aspects of data collection on a network level for the bridge approach slabs and four retaining walls, and summarize important features of data collection approaches, and challenges associated with data management and manipulation.

Road Structures Inspection Manual, VicRoads, April 2011.
http://www.vicroads.vic.gov.au/NR/rdonlyres/5E40D538-608D-45B8-B9F4-4144C3799B5B/0/Road_Structures_Inspection_Manual_Apr_2011.pdf
The road inspection manual for the Victoria (Australia) Highway Department includes guidance about retaining wall inspection (pages 21 to 23). GPS readings for each end of the wall are required. The manual includes a retaining wall structure condition inspection sheet (page 50) and a condition rating system for retaining wall elements, including facing panels, column supports, foundation and connections (pages 273 to 287).

"Condition Assessment of Earth Reinforcements for Asset Management," Kenneth Fishman, Robert Gladstone, John Wheeler, Jr., *Proceedings of the 60th Highway Geology Symposium*, 2009: 348-365.
Abstract at: http://trid.trb.org/view/2009/C/902636
From the abstract: Mechanically Stabilized Earth (MSE) structures have been constructed in the United States since 1971 using galvanized steel soil reinforcements. Currently there are more than 45,000 MSE structures with steel reinforcements in service throughout the United States. These critical components of the surface transportation network should be included in a Transportation Asset Management (TAM) program, and this paper briefly describes techniques and data tools to collect and analyze data and measure performance of MSE structures.

"Asset Management Systems for Retaining Walls," Scott Anderson, Daniel Alzamora, Matthew DeMarco, *GEO-Velopment: The Role of Geological and Geotechnical Engineering in New and Redevelopment Projects*, 2008: 162-177.
Abstract at: http://cedb.asce.org/cgi/WWWdisplay.cgi?166708; for the full text, search on "retaining wall" in: http://books.google.com/books?id=jOAYGiBP9OUC
This paper gives an overview of the retaining wall asset management system of the NPS. It notes that as of 2004, only seven DOTs and one municipality had any substantive experience inventorying wall assets: "In most of these cases, inventories have been limited to simple cataloguing systems tied to bridge or roadway infrastructure surveys, only include new walls," or have focused only on one wall type (MSE walls). The city of Cincinnati has an advanced system, and Colorado DOT conducted a related feasibility study in 2003. (See Feasibility of a Management System for Retaining Walls and Sound Barriers in **State and Local Practices** and our interview with Colorado DOT in **Consultation with Experts**.) The report concludes that the NPS system is simple yet versatile. (See Retaining Wall Inventory and Condition Assessment Program (WIP) in **National Resources** for a full description of this program.)

"Inventory System for Retaining Walls and Sound Barriers," G. Hearn, N. Abu-Hejleh, J. Koucherik, *Transportation Research Record*, Issue 1866, 2004: 85-91.
Abstract at: http://trid.trb.org/view/2004/C/741245
From the abstract: An inventory system for retaining walls and sound barriers includes information about location, age, service, type, dimensions, and appraisals of a structure together with element-level models and element-level condition reports. Many of the inventory items and appraisals are adapted from the U.S. National Bridge Inventory record. Elements for walls and barriers indicate structural form and material, much like Commonly Recognized (CoRe) bridge elements. Potential uses of the inventory system in maintenance management and asset preservation are noted.

"Struggling to Keep an Eye on 2,000 Retaining Walls," Michael Luo, Sewell Chan, *The New York Times*, May 14, 2005.
http://www.nytimes.com/2005/05/14/nyregion/14retain.html
This article notes that New York City start a retaining wall inventory system after a retaining wall collapse in 1998.

Condition Assessment

"Investigation and Implications of MSE Wall Corrosion in Nevada," John Thornley, Raj Siddharthan, Barbara Luke, J. Mark Salazar, *TRB 2010 Annual Meeting C-ROM*, TRB Paper #10-0480, 2010.
http://docs.trb.org/prp/10-0480.pdf
From the abstract: Nevada Department of Transportation has over 150 mechanically stabilized earth (MSE) walls at 39 locations. Recently, high levels of corrosion were observed due to accidental discovery at two of these locations. The resulting investigations of these walls produced direct measurements of metal losses and electrochemical properties of the MSE reinforced fill. One MSE wall was replaced with a cast-in-place concrete tie-back wall at great expense. The paper incorporates a statistical analysis that addresses the variability in measured corrosion and electrochemical data to predict corrosion behavior. It is shown that the original MSE reinforced fill approval electrochemical test results are significantly different from those measured in post-

construction investigations. A correlation has been developed between two distinctly different soil resistivity test methods, namely the Nevada T235B and AASHTO T-288 methods. Over-prediction made by the Nevada T235B method has proved detrimental to the service lives of MSE walls. The internal stability analyses (using AASHTO 2007 LRFD) of two remaining MSE walls at an intersection were also performed using metal loss models developed from the statistical analysis. The findings of the study were subsequently extrapolated to other Nevada MSE walls. Through review of the reinforced fill approval data, suspect Nevada MSE walls have been identified relative to estimated reinforced fill aggressiveness.

Assessing Corrosion of MSE Wall Reinforcement, Utah Department of Transportation, Report No. UT-10.20, September 2010.
http://www.udot.utah.gov/main/uconowner.gf?n=1893932742874301
From the abstract: The primary objective of this study was to extract reinforcement coupons from select MSE walls and document the extent of corrosion. In doing this, a baseline has been established against which coupons extracted in the future can be compared. A secondary objective of this project was to develop and assess techniques for removal of coupons on two-stage MSE walls. Twenty-two wire coupons were extracted from MSE walls that are approximately 11 to 12 years old. Based on field observations, coupon galvanization appeared to be intact but exhibited a variable amount of white oxidation product. In some places the galvanization appeared to have flaked or spalled from the underlying steel, and a minor amount of localized steel corrosion was observed on several of such specimens. Based on laboratory acid-stripping tests, the average thickness of the galvanization on all of the extracted coupons currently exceeds the minimum value specified for the time of installation. Because the initial conditions are unknown, a reliable corrosion rate could not be determined using the direct measurement methods employed in this study. However, the data collected regarding current conditions can be used as baseline information going forward to compute corrosion rates in the future. No readily discernible difference in corrosion conditions as a function of distance away from the wall face was found. There was significance difference in the coupon pullout resistance between one-stage and two-stage MSE walls. The reasons for this behavior and their implications for design and performance should be investigated further.

Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, NHI Courses No. 132042 and 132043, National Highway Institute, Federal Highway Administration, Report No. FHWA-NHI-09-087, November 2009.
http://www.fhwa.dot.gov/engineering/geotech/pubs/nhi09087/nhi09087.pdf
From the abstract: This manual provides criteria for evaluating corrosion losses when using coated or uncoated steel reinforcements, and for determining aging and installation damage losses when using geosynthetic reinforcements. Monitoring methods for in-situ corrosion rates for steel reinforcements are evaluated and remote methods using electrochemical methods are recommended. Monitoring methods for determinations of in-situ aging of geosynthetics are evaluated and protocols for implementation are recommended.

"Condition Assessment of Earth Reinforcements for Asset Management," Kenneth Fishman, Robert Gladstone, John Wheeler, Jr., *Proceedings of the 60th Highway Geology Symposium*, 2009: 348-365.
http://www.highwaygeologysymposium.org/uploads/pastmeetings/60_hgs.pdf
This paper describes techniques and data tools to collect and analyze data and measure performance of MSE structures by the New York State DOT. With regard to asset management, the authors conclude (page 352):

> Well-designed and constructed MSE structures are expected to have service lives of 75 years (in some cases 100 years), but service life is uncertain and should be monitored for confirmation or to enable remediation. Therefore, relatively rapid, non-intrusive, and nondestructive test techniques are needed to collect data necessary for corrosion monitoring and condition assessment of MSE structures. Results from corrosion monitoring indicate if, or when, accelerated corrosion is occurring, while condition assessment can help transportation agencies decide on the most appropriate course of action when drainage, environmental and/or subsurface conditions are unfavorable. Agencies can also use these data to evaluate the variance associated with the performance of an inventory; this is valuable information for those with an interest in making reliability-based decisions.

NCHRP Project 24-28 developed a database of MSE structures from 170 sites worldwide; a summary of state DOT MSE wall corrosion assessment programs is given in Table 2 (pages 356 to 357).

"Review of Mechanically Stabilized Earth Wall Performance Issues," Daniel Alzamora, Scott Anderson, *TRB 2009 Annual Meeting CD-ROM*, 2009.
http://docs.trb.org/prp/09-2745.pdf
From the abstract: For approximately 35 years, Mechanically Stabilized Earth (MSE) walls have become increasingly popular in the development of transportation and other projects. The first U.S. MSE wall was constructed in California in the early 70's. Since that time MSE walls have become generally accepted as a standard wall type on America's Highways. MSE walls regularly reach heights in excess of 12-meters and can be technically and economically feasible to heights in excess of 30-meters. Very few MSE walls fail completely, but there are many walls which haven't performed as well as intended. In order to address this issue, several transportation departments have completed or are in the process of reviewing their design and construction practices in order to improve the overall performance of their MSE walls. Ten typical problems identified by these reviews are related to geometry and wall layout, obstructions, wall embedment, surface drainage, contractor experience, claims, backfill placement and compaction, panel joints, leveling pad [and] durability of facing. Furthermore, asset management techniques are recommended as a tool to help optimally manage and maintain MSE and other wall types.

Evaluation of Corrosion of Metallic Reinforcements and Connections in MSE Retaining Walls, Final Report, Oregon Department of Transportation, Report No. FHWA-OR-RD-08-10, May 2008.
http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2008/MSE_Retaining_Walls.pdf
From the abstract: Mechanically Stabilized Earth (MSE) retaining walls have become the dominant retaining wall system on Oregon Department of Transportation (ODOT) projects. The permanent MSE walls constructed on ODOT projects, in recent years, use metallic reinforcements and facing connections buried directly in the backfill soil. Accelerated deterioration of these structural elements would have serious financial and safety impacts for the Department. Classical MSE wall design incorporates an estimate of deterioration of reinforcement by corrosion. Monitoring of actual corrosion performance, however, is an important element of managing the current inventory of MSE walls. Monitoring could answer key questions that can provide for the best management of the existing walls, and provide feedback to the design process for future installations. This report details a literature review of methods for estimating and measuring deterioration of structural reinforcing elements in both concrete and MSE walls. It also presents a selected history of metallic reinforcement design specification and utilization. A listing of the MSE walls that can be identified in the ODOT Bridge Data System is included.

Geotechnical Asset Management in General

"Corridor Management: A Means to Elevate Understanding of Geotechnical Impacts on System Performance," Scott Anderson, Benjamin Rivers, *TRB 92nd Annual Meeting Compendium of Papers*, 2013.
http://docs.trb.org/prp/13-3018.pdf
This paper discusses the application of asset management principles to geotechnical assets, including inventorying, condition assessment and condition prediction. It notes that no states have gone beyond inventorying and condition assessment for geotechnical assets, and states (such as Washington and Colorado) have cut back even on these steps because of their cost. Further, condition prediction is a significant technical challenge (to which it provides some references for addressing; see the "Geotechnical Challenges" section).

Related Resource:

> **"Capturing the Impacts of Geotechnical Features on Transportation System Performance,"**
> S. Anderson, B. Rivers, *Proceedings of the Geo-Congress*, 2013: 1633-1642.
> Abstract at: http://ascelibrary.org/doi/abs/10.1061/9780784412787.164

From the abstract: The primary assets of a transportation agency are the transportation corridors that have been established to provide means for moving people and goods safely and efficiently. A corridor's performance in this regard is only as good as its weakest link. Therefore, the way an agency can manage an asset such as a corridor to a standard for system performance is to consider its components concurrently, not in stovepipes. A corridor might well have embankments, slopes, walls, bridges, and pavements, and considering individual features separately just doesn't make sense from a system performance perspective. Bridges and pavements have received early attention because of safety or cost implications, but embankments (often with culverts), slopes and walls are geotechnical features that can have equal impact on performance. Generally, landforms through which highway corridors traverse are in a quasi-equilibrium based on their environment and earth material properties before a corridor is constructed and nature sets to work immediately on restoring that equilibrium once construction has occurred. This leads to things like settlement, slope instability, rockfall, erosion and corrosion, all of which can be surprising, or recognized *a priori* and managed. Consider for example the performance impact recently when three major Interstate highways closed and hundreds of miles of detours were needed because of slope and embankment failures. The corridor concept can bring geotechnical assets into consideration and result in better management for system performance. There is need and opportunity for geo-professionals to develop tools and practices for inventorying, assessing performance and predicting life-cycle costs and degradation or risk associated with geotechnical features.

"Risk Based Methods for Management of Geotechnical Features in Transportation Infrastructure," Mark Vessely, ASCE Geo-Congress, *Proceedings of the Geo-Congress*, 2013: 1625-1632.
http://cedb.asce.org/cgi/WWWdisplay.cgi?300819
From the abstract: The purpose of transportation asset management is to meet life-cycle performance goals through the management of physical assets in the most cost-effective manner. The performance goals can include safety, mobility, preservation, economics, and environmental aspects. Example geotechnical features that can be incorporated into the broader practice of transportation asset management include engineered and native slopes, embankments, tunnels, and earth retaining structures. Currently, many agencies address geotechnical features on the basis of "worst-first" conditions, reacting to failures and often incurring significant safety, mobility, environmental, and intangible costs. The goal of risk based methods for management of geotechnical features is to implement project planning, selection, and maintenance on the basis of "most-at-risk", by identifying and managing the features with the greatest probability of failure and consequence. When analyzing risk, it is important to recognize the process will only be successful when all features that create risk are included. Further, the use of multi-tier risk based assessment approaches can identify geotechnical features with the greatest risk to transportation performance goals. The concepts presented in this paper can be used to implement risk based management of geotechnical features.

Geotechnical Presentations from the Ninth National Conference on Transportation Asset Management, 2012.
Several presentations discuss the application of asset management principles to geotechnical assets:

- **"The Great Impact of Geotechnical Features on System Performance and the Need for Management,"** Scott Anderson, Federal Highway Administration.
  http://onlinepubs.trb.org/onlinepubs/conferences/2012/assetmgmt/presentations/Geotechnical-Anderson.pdf
- **"Asset Management of MSE Walls: Critical from Design through Design Life,"** Robert Gladstone, Scott Anderson, Richard Barrows, Federal Highway Administration.
  http://onlinepubs.trb.org/onlinepubs/conferences/2012/assetmgmt/presentations/Geotechnical-Gladstone-Anderson-Barrows.pdf
- **"Incorporation of Geotechnical Elements as an Asset Class within Transportation Asset Management and Development of Risk Based and Life Cycle Cost Performance Strategies,"** Mark Vessely, Richard Barrows, Matt DeMarco, Federal Highway Administration.
  http://onlinepubs.trb.org/onlinepubs/conferences/2012/assetmgmt/presentations/Geotechnical-Vessely-DeMarco-Barrows.pdf

"Geotechnical Asset Management for the UK Highways Agency," C.M. Power, D.A. Patterson, D.M. Rudrum, D.J. Wright, *Engineering Geology Special Publications*, Geological Society of London, 2012: 33-39.
Abstract at: http://egsp.lyellcollection.org/content/26/1/33.abstract
From the abstract: This paper outlines the Geotechnical Asset Management Strategy of the Highways Agency (HA). The strategy operates in a series of key stages, from setting standards and advice, through data collection and analysis through to the ultimate aim of providing and maintaining an asset that meets the service level that it is required to attain. These key stages are outlined, and illustrated with examples where appropriate. The HA, and its managing agents, have progressed a significant way along the 'roadmap', but further work is still ongoing. A key tool for the delivery of the HA Geotechnical Asset Management Strategy is the Geotechnical Data Management System (HA GDMS). This is discussed throughout the paper, and examples of the functionality of the system are given.

"Asset Management in a World of Dirt: Emergence of an Underdeveloped Sector of Transportation Asset Management," David Stanley, *TR News*, Issue 277, November/December 2011: 18-22.
www.fhwa.dot.gov/asset/pubs/trn277.pdf
This article describes the application by transportation agencies of asset management principles to geotechnical assets, noting that "[m]ost geotechnical asset management (GAM) efforts have halted at inventorying and conducting condition surveys, without progressing along the TAM spectrum." Programs of interest include the following (page 19):

- The Alaska Department of Transportation and Public Facilities (DOT&PF) is conducting research for a program that will apply asset management principles to the management of unstable slopes.
- Wyoming DOT has created a geology database to track and manage geologic maps, aggregate sources, and project information.
- The National Park Service has developed a Retaining Wall Inventory and Condition Assessment Program.
- Ohio DOT has a Retaining Wall Asset Management Program.

Research needs include devising performance standards and measures, and understanding the expected performance of geotechnical assets. Most state DOTs have not identified such standards.

LiDAR for Data Efficiency, Washington State Department of Transportation, Report No. WA-RD 778.1, September 2011.
http://www.wsdot.wa.gov/research/reports/fullreports/778.1.pdf
From the abstract: This report documents the research project "LiDAR for Data Efficiency" for the Washington State Department of Transportation (WSDOT). The research objective was to evaluate mobile Light Detection and Ranging (LiDAR) technology to enhance safety, determine efficiency gains, accuracy benefits, technical issues, and cost benefits of using this technology with a focus on collection, processing, and storage of the data into current WSDOT business processes. Vehicle mounted terrestrial mobile LiDAR systems have been developed to capture geospatial data of large highway areas at highway speed for highway surveying, asset management, as-built documentation, and maintenance operations. This tool presents an opportunity for WSDOT to consolidate geospatial data collection operations, and improve efficiency, safety for workers, and mobility of the traveling public. A field pilot study was conducted to collect empirical data for feasibility evaluation and cost benefit analyses. While the pilot study demonstrated the potential positive impact in WSDOT business processes, it also highlighted the need for best practices documentation for using mobile LiDAR for WSDOT to ensure consistent and accurate results. Details of data collection methods and cost for WSDOT Roadside Feature Inventory Program (RFIP), bridge clearance measurement, and Americans with Disabilities Act (ADA) feature inventory were gathered. These programs would achieve direct cost saving in deploying the mobile LiDAR system. Cost benefit analyses of seven mobile LiDAR deployment options are presented. Purchasing and operating a survey grade mobile LiDAR system produced the highest savings of $6.1 million in six years. Although deploying the survey grade mobile LiDAR system costs more, the benefits and cost saving from the bridge clearance operation and ADA feature inventory outweighs the higher cost and produces higher saving. Mobile LiDAR technology lowers the number of Full-Time Equivalents (FTEs), vehicles, and carbon dioxide emissions for data collection. The major intangible benefactors are WSDOT's GeoMetrix Office, Geotechnical Office, Planning Office, Environmental Office, and Attorney Generals (AG) Office. The technology could also be

useful in other state agency application areas such as cultural heritage preservation, homeland security, construction inspection, and machine guidance in construction. Deployment of a mobile LiDAR system is recommended.

"Trial of Geotechnical Asset Management for Highway Embankments Constructed on Soft Clay Foundations," H. Ohta, T. Takeyama, K. Okubo, S. Yokota, T. Ishigaki, S. Omoto, *Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering*, 2009.
Abstract at: http://geolifi.geoengineer.org/index.php?main_page=product_info&products_id=1880
From the abstract: This paper describes a trial of geotechnical asset management for highway embankments placed on very soft clayey grounds at Ebetsu, Hokkaido in Japan. The highway was constructed 30 years ago and is still settling year by year requiring a considerable cost of maintenance. The paper consists of (i) characterization of the ground conditions at the sites, (ii) the class B predictions of the mechanical behaviour of embankments during construction works employing a soil/water coupled finite element code, (iii) predictions of long-term settlement of the embankments based on the information obtained at the stage (ii), (iv) estimates of maintenance cost of the embankments based on the computed long-term settlement and (v) verification of the proposed method of geotechnical asset management by comparing the maintenance cost estimated based on the above stated method and the maintenance cost actually needed in the past 30 years.

"DIGGS: Setting the Standard for Geotechnical and Geoenvironmental Data Management," Thomas Lefchik, Corey Bobba, Kirk Beach, *58th Highway Geology Symposium*, October 2007.
http://www.efl.fhwa.dot.gov/files/technology/Geotech-Management-System-2007-Symposium-paper.pdf
From the abstract: The Federal Highway Administration (FHWA) in conjunction with the Ohio Department of Transportation formed a work group comprised of 11 State DOTs, United Kingdom Highway Agency, USGS, USEPA, US Army Corps of Engineers, FHWA Ohio Division, and FHWA Office of Federal Lands Highway to oversee the development of data dictionaries and data formats for geotechnical management systems through Transportation Pooled Fund (TPF) project TPF-5(111) "Development of Standards for Geotechnical Management Systems". One of the products being produced through the pooled fund project is a geotechnical and geoenvironmental data exchange standard called Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS). The first version of DIGGS is being released in 2008 and will include standards for borehole, laboratory test, deep foundation, and borehole geophysics data. DIGGS provides a standardized means of geotechnical and geoenvironmental data exchange between disparate databases. There are several significant advantages to the user of DIGGS including: ability to exchange data between databases within an organization and with external organizations, ability to efficiently incorporate data from consultants into any database, ability to perform software-automated data checks, ability to exchange data between compatible software packages, and the ability to merge databases and incorporate software into an integrated geotechnical management system. DIGGS facilitates the seamless flow of geotechnical and geoenvironmental data from point of generation, through project usage, to storage, and then reuse. Several DIGGS compatible tools will be available at the time of the release of DIGGS version 1.0. These tools include: a database with GIS interface for state transportation agencies, software for subsurface data reporting, a virtual data center that enables data exchange across organizational boundaries, and the United Kingdom Highway Agency geotechnical management system. Several geotechnical and geoenvironmental software vendors have already included DIGGS translators in their software.

"Geotechnical Asset Management: A Case Study of Practice in the Highways Agency," David Patterson, Mark Rudrum, Catherine Dew, *Routes/Roads*, Vol. 335, 2007: 64-77.
Abstract at: http://trid.trb.org/view/2007/C/814701
From the abstract: In England, the geotechnical asset of the Highways Agency (HA) comprises, on over 7,400 km of motorways and trunk roads, an estimated 14,700 linear km of earthworks. The geotechnical asset supports landscaping (soft estate), communications, drainage, and highway structures, as well as road pavement. With an approximately £10 billion value, 14 managing agents/managing agent contractors (MAS) maintain it for the HA, with each MA responsible for a section of the overall strategic road network. The authors discuss the current and maturing geotechnical asset management approach as implemented by the English HA and their MAS and defined in current standards. PAS 55 ("Specification for the Optimized Management of Physical Infrastructure Assets") is discussed. PAS 55 distinguishes between physical and other types of assets, considers asset interrelation, and

provides a framework when considering the components and procedures of a particular asset management system. In addition, elements of all asset management process levels, from risk assessment, information management systems, performance targets, continual improvement, policy, to strategy are linked together in PAS 55. Asset management policy and strategy, data management systems, asset management procedures, asset data analysis, performance management, and geotechnical performance indicators are all examined.

"Asset Management Framework for Geotechnical Infrastructure," Kristen L. Sanford Bernhardt, J. Erik Loehr, Daniel Huaco, *Journal of Infrastructure Systems*, Vol. 9, Issue 3, September 2003: 107-116.
Abstract at: http://cedb.asce.org/cgi/WWWdisplay.cgi?0304099
From the abstract: A significant limitation of current asset management systems is lack of consideration of geotechnical issues. This paper presents a simple framework for managing geotechnical facilities using asset management principles. The framework is based on mapping a previously developed generic framework proposed by the Federal Highway Administration with consideration given to several unique aspects of geotechnical structures, the roles these assets play in the transportation infrastructure, and the interaction among "geotechnical assets" and other types of assets such as pavements and bridges. The paper discusses several unique issues that arise when applying asset management principles to geotechnical facilities and offers recommendations for future work to improve and facilitate implementation of such a system. Examples for specific application to maintenance of highway embankments/slopes are given throughout the paper to illustrate implementation.

APPENDIX A

Alaska Department of Transportation and Public Facilities

Retaining Wall Inventory Procedures Manual

Draft, February 2013

Table of Contents

INTRODUCTION

This draft document provides a description of procedures and guidelines for a preliminary inventory of retaining structures along routes that are owned and/or maintained by AKDOT&PF.

The **Retaining Wall Inventory (RWI)** is just one component of the Department's Retaining Wall Management Program (RWMP). The preliminary inventory phase relies on an office based survey of internal records to catalogue wall locations and basic data. This phase will be followed by phases that target field verification and collection of wall data, wall condition assessment, and establishment of performance measures that result in effective management of this transportation asset.

Personnel working on the RWI should follow this basic sequence of steps:

1. **Read and become familiar with the information in this manual.**
2. **Gather/locate/access internal records sources.** **SEE *DATA SOURCES***
3. **Apply the general acceptance criteria to determine if a wall or other retaining structure should be included in the inventory.** **SEE *WALL ACCEPTANCE CRITERIA***
4. **Generate record IDs for each structure found by plotting the location in the web-accessible GIS-application database at this URL:** http://158.145.167.187/edits/RetainingWalls/).
5. **Input information to the appropriate data fields in the database.** **SEE *DATA FIELDS***

WALL TERMINOLOGY AND APPLICATIONS

For the purposes of this inventory, the terms *earth retaining system*, *earth retaining structure*, and *retaining wall* are used interchangeably.

An earth retaining system (ERS) is defined as ***"any structure intended to stabilize an otherwise unstable soil mass by means of lateral support or reinforcement" (***FHWA, 1997). Retaining walls, which have a vertical or near vertical face, are by far the most familiar type of ERS

For highway applications, the most common uses of retaining walls are for grade separations, bridge abutments, slope stabilization, and excavation support.

Because one of the principal goals of the inventory phase of the State's Retaining Wall Management program is to classify the walls, **significant emphasis is placed upon identifying – for each wall in the inventory – the *wall category*, *wall function* (or *application*), and *wall type*.**

WALL ACCEPTANCE CRITERIA

The wall inventory to be completed within the AK DOT&PF Retaining Wall Management Program (RWMP) will result in the identification and cataloguing of <u>most</u> retaining walls owned and/or maintained by AK DOT&PF.

Use these criteria for determining if a wall should be inventoried:

- Serves as an earth retention structure;
- Belongs to a roadway asset that is owned and/or maintained by AKDOT&PF;
- Culvert headwalls/wing walls ≥6 ft (total height, exposed plus embedded);
- Face angle ≥45°.

Applying the set of criteria listed above results in the exclusion of some walls. Sound walls, for instance, would not be counted since they don't retain earth.

Many of the state's seawalls would not qualify, as many are not coupled with a roadway asset. Similarly, a bulkhead structure that is designed to protect a dock or wharf would not be captured in the RWI.

The specification for height of culvert headwalls is proposed as a means to limit the capture of headwalls that serve more primarily in support of the culvert, rather than to retain embankment fill. The goal is to capture a majority of culvert headwalls that are critical to embankment stability, and to reduce the instances of "double capture," where in a headwall is inventoried within two programs – the RWI as well as the culvert inventory managed by M&O division of the agency.

The criterion regarding face angle is meant to allow for capture of retaining structures that are not "walls." In fact, the FHWA defines a retaining wall as having an internal face angle greater than or equal to 70°. We want, however, to allow for capture of structures such as rockeries or tiered walls.

If the inventory worker is in doubt regarding the qualifications of a particular retaining structure for inclusion in the RWI, he should error on the conservative side and include the wall. It should be kept in mind that this is a preliminary inventory only. The walls in the inventory will later be verified and assessed in the field, which will lead to programming for repair or replacement of failing and high risk structures.

ASSIGNMENT OF WALL IDENTIFICATION

Undoubtedly, there are cases that will be problematic and challenging as far as wall qualification and/or identification. There will be questions regarding cases involving tiered walls or possibly back-to-back walls. A tiered wall system features a vertical arrangement of two or more walls supporting a slope, with a setback or unsupported area between the top of one wall and the base of the wall above it. The policy proposed for the RWI is to identify the tiered wall system as one wall, with one ID.

Similarly, we anticipate questions regarding wall segmentation and grouping at bridge sites or overcrossings. Statewide Materials Section is working with Bridge Section to establish coordination between the programs. Under federal bridge inspection inventory and inspection requirements, the AKDOT Bridge Section is required to maintain an inventory and rigorous inspection regimen for bridge structures. And the Bridge Section is responsible for designing non-proprietary walls ≥4 ft tall.

Due to the currently unresolved status of demarcation of inventory responsibilities and practices at bridge sites, personnel compiling wall inventory data should disregard abutments and associated walls at bridge sites.

WALL DATABASE

Wall information is to be entered into a GIS-based database via a web interface.
For each wall, the data collector creates a point in the map interface, with symbols assigned by wall type. Point activation displays a window with a set of data fields to be filled either manually or via menu pull-down options. The **data fields, menu selections, and data dictionary** are listed in **TABLE 1**. Additional explanations are provided below in the section *Data Fields*.

DATA SOURCES

This preliminary phase of the RWI relies on gathering information from internal AKDOT&PF records, including – but not limited to – the following:

- As-builts;
- Road viewers, e.g. Google *Street View*®;
- AKDOT& PF *Digital Roadway Viewer Alaska* [http://web.dot.state.ak.us/stwdplng/GIS/photolog];
- DOT Highway Data Port [http://www.dot.state.ak.us/hdpapp/forms/Reports];
- Bridge inventory/PONTIS;
- Bridge section inventory of state owned minor structures (culverts with diameter 10-20 ft and separated pedestrian structures adjacent to public highways);
- Statewide Culvert Inventory;
- COB sheets.

If the retaining structure being considered meets – or if the structure MIGHT meet – the general acceptance criteria, the data collector can proceed with inputting data for the structure into the database.

DATA FIELDS

This section of the manual serves as a data dictionary and provides explanations for the set of data fields within the database accessed via the web interface (http://158.145.167.187/edits/RetainingWalls/).

GENERAL DATA

Preliminary Inventory Record ID

At this time, the functional ID for a wall in the inventory corresponds with the auto-assigned FID within the ArcGIS component of the database. [NO INPUT NECESSARY]

A final, unique ID number will eventually be assigned to each wall entered into the RWI. The numbering scheme will likely include coding associated with wall type, route number, and position with respect to the roadway.

Log Entry By

Name of person creating the original inventory record for a wall.
[NO INPUT NECESSARY]

Log Entry Date

Date of original input of data for a wall. [NO INPUT NECESSARY]

This date should remain as an original record creation date, not to be revised when a minor addition or retraction of data is done at a subsequent date.

Log Revision Date

Enter date of subsequent changes to the wall record. [NO INPUT NECESSARY]

Data Source(s)

For purposes of the preliminary inventory, these include paper or digital records maintained by AKDOT &PF, or perhaps other agencies (for walls along routes maintained by − but not owned by − State of Alaska).

The *eDOCS* system should be checked, as the State's existing comprehensive document management database. However, input to that system is not consistent among the agency's divisions/sections. Many of the relevant records, therefore, will likely not be accessible through the *eDOCS* system.

Examples of internal records with information related to retaining walls include:

- As-builts;
- Final construction reports;
- Road viewing application such as Google Street View™
- DOT Highway Data Port
  http://www.dot.state.ak.us/hdpapp/forms/Reports.html?categoryId=HDP+Route+Log/List+Query+Reports
- Bridge inventory/PONTIS;
- Statewide Culvert Inventory;
- COB (Compilation of Bids sheets).

State Project Number

State (AKSAS) project number for the construction project that created the wall.

In cases where walls were replaced or rehabilitated, use the project number associated with the existing wall, rather than the number of the project that constructed the original wall.

Federal Project Number

Federal project number for the construction project that created the wall.

Construction As-Built Date

Use the official date of the final As-Built document as the approximate date of wall construction.

LOCATION DATA

AKDOT & PF Region

Specify the DOT region where the wall is located – Northern, Central, or Southeast Region.

Alaska Borough

Specify the Borough in which the wall is located.

The organized boroughs do not cover the entire land area of the state. Areas not lying within organized boroughs officially belong to the *Unorganized Borough*.

Route Name (CDS)

Official route name in the *Coordinated Data System*, as assigned by the Transportation Information Group, within the Program Development Division of AKDOT&PF.

[menu-listing to be added to data fields]

Route Number (CDS)

Official route number in the *Coordinated Data System*, as assigned by the Transportation Information Group, within the Program Development Division of AKDOT&PF.

[menu-listing to be added to data fields]

Route Mile point (CDS)

Mile point (to 0.1) along route.

Note that the mile point does not necessarily equate with the posted mile post (MP).

Offset

Offset from route centerline, direction left (L) or right (R) and distance in feet.

Latitude

A geographic coordinate that specifies the north-south position of the wall on the earth's surface.

Latitude is auto-tagged by the GIS application. [NO INPUT NECESSARY]

Longitude

A geographic coordinate that specifies the east-west position of the wall on the earth's surface.

Longitude is auto-tagged by the GIS application. [NO INPUT NECESSARY]

Longitude plus latitude together is used to specify a precise location. Conversions using the *lat/long* are done for various coordinate systems. Due to its common usage in Alaska and the United States, we will likely store the spatial data for walls using the Alaska Albers Equal Area Conic, NAD83 projected coordinate system.

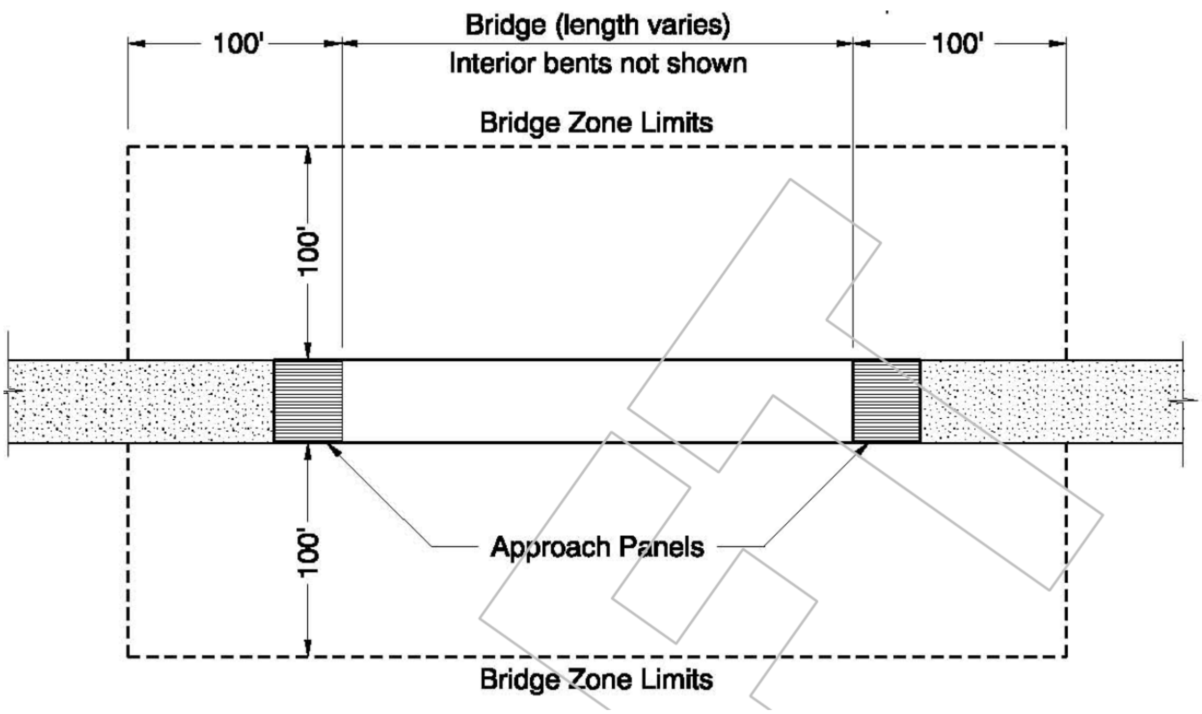
WALL CLASSIFICATION DATA

Wall Category [AK DOT&PF]

A classification related to allocation of responsibility for design of retaining walls to the Department Regional sections, Statewide Bridge Section, or Statewide Materials Section. This system of categorization closely follows the system used by Oregon DOT.

<u>*Bridge Abutment*</u>
The structural element at each end of a bridge, installed to support the end of the bridge span and to retain fill material on which the roadway rests immediately adjacent to the bridge. This category also includes wing walls that are monolithic with the abutment.

<u>*Bridge Wall*</u>
Retaining wall within the "Bridge Zone" (see diagram below) that does not meet the definition of a bridge abutment.



<u>*Highway Retaining Wall*</u>
Wall that is not inside a *bridge zone*, and does not meet the definitions for *minor retaining wall* or *culvert headwall.*

Minor Retaining Wall
Wall that is:

- not inside a bridge zone,
- has a total height (exposed plus buried) not exceeding 4 ft at any point along the wall, and
- is not a *culvert headwall.*

Culvert Headwall
Culvert headwalls located outside of bridge zone and ≥6 ft total height (exposed height plus embedment).

Note that for headwalls with attached wing walls, the three individual component walls would be identified in the inventory as one wall.

Wall Function/Application

Assign according to the primary purpose for the wall.

Remember, the subject structure must meet the general criteria first. Seawalls and flood control walls – for instance – that are not associated with a roadway would not qualify.

Bridge associated
Grade separation
Slope stabilization
Earth retaining, cut
Earth retaining, fill
Pedestrian undercrossing
Flood control
Seawall
Other

Wall Type

A wall classification based on structural type or construction materials used in the wall.
The wall types listed in this field correspond directly to those used by the FHA, Central Lands Highway Division in their *National Park Service Retaining Wall Inventory* (2010).

The wall type menu selection items are specific versions of the generic wall type groups defined below (Brutus and Tauber, 2009).

anchored wall	Wall that is provided with additional support by tiebacks (ground anchors) to a grouted zone or deadman anchors.
bin wall	A gravity retaining structure made up of interlocking metal or concrete bins. These are filled with granular, free-draining soil compacted in each unit.
cantilever wall	Wall that resists the lateral pressure of the retained soil partly or entirely by the use of countervailing soil forces. Cantilever walls may be straight (embedded) or may be shaped like an L or an inverted T.
crib wall	A gravity retaining structure made of interlocking timber or concrete elements stacked log-cabin style to form a series of gridwork compartments or cribs, which are filled with granular material or stone.
gravity wall	Retaining wall that is prevented from overturning or sliding by its own dead weight.
mechanically stabilized earth (MSE) wall	Wall systems that employ either metal (strips, grid, wire mesh) or polymer (strip, grid, sheet) reinforcements in the backfill soil to stabilize it. The reinforcement is connected to a vertical or near-vertical wall facing.
pile wall	Wall consisting of a row of piles.
soil nail wall	System in which in situ soil is reinforced by the insertion of steel reinforcing bars which are drilled and grouted. The bars are relatively closely spaced (3 to 6 ft) and are anchored at the wall face, which may consist of shotcrete or precast facing panels.

Refer to the FHWA publication *Geotechnical Engineering Circular No. 2: Earth Retaining Systems* for additional descriptions of wall types used in highway projects.

AK DOT& PF has issued standard drawings for cantilever retaining walls (B-04.00 and B-05.00) and bin walls (B-08.00), available in the *Alaska Standard Drawings Manual.*

WALL DIMENSION DATA

Maximum Exposed Height (ft)

Along the length of a wall, the greatest vertical distance measured from the finish grade at the bottom of the wall to the top of the wall.

This height does not include any embedded portion of the wall, and does not include attachments (e.g., parapet).

Maximum Total Height (ft)

Along the length of a wall, the greatest vertical distance measured from the base of the wall structure to the top of the wall.

This height combines the exposed height of the wall along with the embedment depth, and does not include attachments (e.g., parapet).

Length (ft)

The total length of the structure.

COMMENTS

Input any additional information or any comments that may prove helpful in resolution of apparently contradictory data.

E-DOCS HYPERLINK

Provide URL for source document accessed in Alaska DOT&PF *eDOCs* system (also known as EDMS, *Electronic Document Management System*) system.

http://web.dot.state.ak.us/eDocs/index.html

ATTACHMENTS

[Click on *show attachments* to add additional files, e.g. photographs.]

TABLE 1 - DATA FIELDS FOR AK DOT RETAINING WALL INVENTORY

Preliminary Phase: Survey of Internal Records

DATA FIELD		MENU SELECTION LIST	DATA FIELD DICTIONARY	REMARKS
GENERAL DATA	Preliminary Inventory Record ID	[not indicated in the record edit display]	Wall ID no.	[auto-tagged] FID assigned by ArcGIS in database serves as the prelim ID no. A final, formal ID for each wall will be assigned later.
	Log Entry By	[not indicated in the record edit display]	Name of person entering the record.	[auto-tagged]
	Log Entry Date	[not indicated in the record edit display]	Date of original data input.	[auto-tagged]
	Log Revision Date	[not indicated in the record edit display]		[auto-tagged]
	Data Source(s)	**recon/state record/other**	Source(s) of information used for this collection of wall data.	
	State Project No.	**-**	AKSAS no.	
	Federal Project No.	**-**	Fed proj no.	For existing wall (supersedes original construction project number in cases of replacement or rehabilitation).
	As-Built Date	**-**	Date of final as-built drawing.	Use date for <u>existing</u> wall.
LOCATION DATA	**AKDOT&PF Region**	**Northern/Central/Southeast**	Region in which wall is located.	Specify region in which wall is <u>located</u>.
	Borough	**[list of AK Boroughs]**	Borough in which wall is located.	
	Route Name (CDS)	**[tie menu to regional selection]**	Official route name in *Coordinated Data System*	As defined by AK DOT&PF Transportation Information Group. Applicable routes include those owned and/or maintained by AKDOT&PF.
	Route Number (CDS)	**[tie menu to regional selection]**	Official route number in *Coordinated Data System* .	As defined by AK DOT&PF Transportation Information Group.
	Route Mile point (CDS)	**-**	Mile point location on the route.	As defined by AK DOT&PF Transportation Information Group. Not physical milepost marker.
	Offset (L or R)	**L/R**	Offset from route centerline.	
	Latitude	**-**	Geographic coordinate specifying N-S position of wall.	Auto-tagged in the web interface.
	Longitude	**-**	Geographic coordinate specifying E-W position of wall.	Auto-tagged in the web interface.
WALL CLASSIFICATION DATA	**Wall Category [AK DOT&PF]**		Categorization based on responsibility assignments (design, management, and maintenance).	Reference Alaska DOT&PF Policy + Procedure: *Temporary Policy and Procedures for Roles and Responsibilities for Design of Retaining Walls.*
		Bridge Abutment		Also includes wing walls that are monolithic with abutment.
		Bridge Zone Retaining Wall	Within *Bridge Zone*. Walls that do not qualify as abutments.	
		Highway Retaining Wall	Wall located outside of *Bridge Zone,* and ≥ 4 ft tall (exposed ht).	
		Minor Retaining Wall	Wall located outside of *Bridge Zone,* and is ≤ 4 ft tall (exposed ht).	
		Culvert Headwall	Culvert headwalls located outside of *Bridge Zone* and ≥6 ft.	
	Wall Function/Application		Primary purpose of the wall.	
		Bridge associated		
		Grade separation		
		Slope stabilization		
		Earth retaining, cut		
		Earth retaining, fill		
		Pedestrian undercrossing		
		Flood control		
		Seawall		
		Other		Such as tunnel face, storage bunker….
	Wall Type	**Anchor, Tieback h-Pile**		For general wall type descriptions, refer to Geotechnical Eng Circ No. 2 – *Earth Retaining Systems (* FHWA-SA-96-038) For descriptions and photo examples for the wall type menu items, refer to pages 53-69 in *Procedures Manual – National Park Service Retaining Wall Inventory and Condition Assessment Program (WIP)[FHWA publication no. FHWA-CFL/TD-10-003]* AK DOT& PF has issued standard drawings for cantilever retaining walls (B-04.00 and B-05.00) and bin walls (B-08.00), available in the *Alaska Standard Drawings Manual* **.**
		Anchor, Micropile		
		Anchor, Tieback Sheet Pile		
		Bin, Concrete		
		Bin, Metal		
		Cantilever, Concrete		
		Cantilever, Soldier Pile		
		Cantilever, Sheet Pile		
		Crib, Concrete		
		Crib, Metal		
		Crib, Timber		
		Gravity, Concrete Block/Brick		
		Gravity, Mass Concrete		
		Gravity, Dry Stone		
		Gravity, Gabion		
		Gravity, Mortared Stone		
		MSE, Geosynthetic Wrapped Face		
		MSE, Precast Panel		
		MSE, Segmental Block		
		MSE, Welded Wire Face		
		Soil Nail		
		Tangent/Secant Pile		
		Other, User Defined		
WALL DIMENSION DATA	**Max. Exposed Height (ft)**	-	The greatest vertical distance measured from the finish grade at the bottom of the wall to the top of the wall.	This height does not include any embedded portion of the wall, and does not include attachments (e.g., parapet).
	Max. Total Height (ft)	-	The greatest vertical distance measured from the base of the wall structure to the top of the wall.	This height combines the exposed height of the wall along with the embedment depth, and does not include attachments (e.g., parapet)
	Length (ft)	-	Total length of the structure.	
COMMENTS			Additional information.	
ATTACHMENTS			[Reserved]	Data source link, attached reports, photos.

Colorado Department of Transportation
Scope of Work for Retaining Wall and Sound Wall Inspection
and Asset Management Services

I. GENERAL

The goal of this project is to develop a risk based inspection program for retaining walls and sound walls, inventory and inspect the retaining walls and sound walls on Colorado's state highway system, report the conditions of the individual walls to the Colorado Department of Transportation (CDOT), Staff Bridge, utilize a web based data management to gain efficiency in collecting and distributing data that integrates with our PONTIS and NBIS databases, and meet compliance with any FHWA requirements and guidelines. Retaining walls and sound walls will be referred to as "structures" hereafter in this Scope of Work (Scope). The Colorado Department of Transportation will be referred to as the "Owner" hereinafter in this Scope.

The purpose of this scope is to update the inventory, conduct inspections and report the findings to the Owner on the state's structures in accordance with the most current version of the Recording and Coding Guide for the Inventory and Inspection of Colorado's Retaining Walls and Sound Walls. The guide will be developed in this project.

It is anticipated that task orders will be written to this contract for a period of four years to perform the following work:

A. Development of a CDOT Recording and Coding Guide for the Inventory and Inspection of Colorado's Retaining Walls and Sound Walls.

B. Development of a web based data management system compatible with the CDOT PONTIS version 5.x and NBIS databases.

C. Development of a risk based inspection program and asset management plan for retaining walls and sound walls.

D. Inventory and inspection the retaining walls and sound walls on Colorado's state highway system.

II. DEFINITIONS

A. **AASHTO** – American Association of State Highway and Transportation Officials.

B. **BRIAR** – Bridge Ratings, Inspections and Records

C. **ELECTRONIC DATA FILES -** Electronic files containing inventory and inspection data for each structure in the version of Pontis AASHTOWARE, or other database format as specified by the Bridge Inspection Engineer. Electronic sketches of structures in a MicroStation compatible format as needed. PDF files of all inspection reports. JPG files of structure photographs.

D. **ENGINEER** – CDOT Bridge Inspection Engineer or his/her designee.

E. **FHWA** – Federal Highway Administration.

F. **FY –** Fiscal Year

G. **MUTCD** – Manual on Uniform Traffic Control Devices

H. **NEW STRUCTURES** – Structures not previously inspected such as newly constructed structures requiring initial inspection or structures found to be qualifying and without prior inspections.

I. **NHS** – National Highway System.

J. **PEI** – Pontis Element Inspection form. A structure inspection form found within the inspection module of Pontis AASHTOWARE, on which the applicable structure element condition states and comments are reported for each structure inspected.

K. **SI&A** – Structure Inventory and Appraisal form, (formerly CDOT Form #422). An inventory and appraisal form found within the Pontis AASHTOWARE inspection module that contains information about a structure.

L. **STRAHNET** – Strategic Highway Network

III. INSPECTION STANDARDS

The work shall be carried out in accordance with the following documents and revisions thereto:

A. Bridge Asset Management and Inspection Manual (BRIAR Manual)

B. CDOT Pontis Bridge Inspection Manual,

C. AASHTO Manual for Bridge Evaluation

D. Bridge Inspection Reference Manual

E. Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges (Report No. FHWA-PD-96-001)

F. Other documents as defined by individual task orders.

IV. CONSULTANT QUALIFICATIONS

The consulting firm shall be pre-qualified to conduct bridge inspection work for the State of Colorado, Department of Transportation.

The individual in charge of the organizational unit, in charge of the inspection team, and the bridge inspectors, shall meet the qualifications as stated in the Code of Federal Regulations, 23 CFR, 650.309.

V. PROJECT MANAGEMENT AND COORDINATION

The Contract Administrator for the work is:

Joshua R. Laipply, P.E.
Bridge Engineer
Colorado Department of Transportation
4201 East Arkansas Ave.
Room 107
Denver, Colorado 80222
(303) 757-9309

The Bridge Inspection Engineer and Project Manager for the work is:

Lynn E. Croswell, P.E.
Bridge Inspection Engineer
Colorado Department of Transportation
4201 East Arkansas Ave.
Room 107
Denver, Colorado 80222
(303) 757-9188

VI. PROJECT LOCATION

The project location will be state-wide. The structures to be inspected will be listed within the individual task orders.

VII. PROJECT DURATION

A. The work shall commence on the date specified in the notice to proceed and shall be completed as specified in the individual task orders.

B. Completion is defined as (1) having submitted all structure inspection reports in the required format to the Project Manager or his/her designee for review, (2) the Project Manager or his/her designee having reviewed and approved the reports and (3) presentations of the final reports given to CDOT.

VIII. CONSULTANT RESPONSIBILITY

A. The Consultant shall be responsible for the development of a Recording and Coding Guide for the Inventory and Inspection of Colorado's Retaining Walls and Sound Walls.

B. The Consultant shall be responsible for the development of a web based data management system compatible with PONTIS version 5.x and NBIS databases.

C. The Consultant shall be responsible for the development of a risk based inspection program for retaining walls and sound walls.

D. The consultant shall draft a risk based wall asset management plan for review and potential adoption by the owner.

E. The Consultant shall be responsible for the complete, timely inspection and reporting of all structures identified in individual task orders.

F. The Consultant shall furnish all electronic equipment such as computers, laptops, tablets or other as necessary to complete the work.

G. The Consultant shall submit completed inspection reports to the Project Manager.

H. The Consultant shall conduct the work in accordance with all governing safety rules and regulations applicable to the work.

I. The Consultant shall provide for their own lane closures, working with the appropriate maintenance sections and Region Traffic Engineers to close lanes when required. A list of contacts will be provided to the Consultant upon request.

J. The Consultant will provide all necessary inspection and testing equipment, personal protective equipment (PPE), vehicles for transport and access to properly and adequately perform the work described herein.

IX. INSPECTION REQUIREMENTS

A. Inspections and structure evaluations will be performed via normal and customary visual means as defined by the following references and will include evaluation of all accessible structure components within reason unless noted otherwise to identify changes from previously recorded conditions, and to determine their physical and functional condition. All structure coding items shall be completed per the requirements of the NBIS and CDOT in accordance with the most recent editions of the following:

1. The FHWA manual Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Structures, December 1995 (Federal Coding Guide), except that English Units shall be recorded.

2. The CDOT Structure Inventory Coding Guide.

3. The CDOT Pontis Bridge Inspection Coding Guide. The condition states and comments for the Pontis elements applicable to a structure shall be reported in the Pontis inspection module.

4. AASHTO Manual for Bridge Evaluation

5. Bridge Asset Management and Inspection Manual (BRIAR Manual)

6. Other documents as defined by individual task orders.

All of the above material will be supplied to the Consultant by CDOT upon request.

B. Inventory digital color photographs are required for each structure as defined by individual task orders.

C. Supplemental digital color photographs and sketches shall be taken and/or developed as necessary to give a clear understanding and documentation of distressed conditions.

D. Digital cameras shall be a minimum of 2 megapixel resolution capabilities and be Global Positioning System (GPS) enabled. Photos shall be submitted in the Joint Photographic Experts Group (jpg) format. The photos shall be submitted on a compact disk (CD), DVD or flash drive.

E. The PEI condition states and comments and the SI&A items shall be reported with the PONTIS Inspection Report as directed by the Project Manager or his/her designee. The PEI and SI&A information shall be revised, if necessary, to reflect the actual elements, quantities, comments and items found in the structure.

F. Completed inspection reports shall be submitted to the Bridge Inspection Engineer and his/her designee at the end of the month following each inspection or at the end of the Task Order period whichever is earlier. For example, a submittal would be required on April 30th for field work completed in March.

G. Each inspected structure shall be located using GPS equipment to obtain longitudes and latitudes as defined by individual task orders.

X. UNDERWATER INSPECTIONS

A. Underwater inspections shall consist of any appropriate method, short of employing diving or remote submersibles, to evaluate the structure below the waterline. For water depths up to 3 feet, the consultant shall investigate the foundation conditions by probing and/or feeling for undercutting of the foundation or other problems such as deterioration of foundation elements.

B. All structures with typical water depths in excess of 3' throughout the year shall be recorded in the inspection notes in the report and a list shall be provided to the Bridge Inspection Engineer.

XI. REPORTING

A. All inspection data shall be submitted electronically.

B. Completed inspection reports containing PEI and SI&A information shall be submitted to the Project Manager or his/her designee.

C. All forms shall include the inspector's original or electronic signature and the appropriate date.

D. As necessary, supplemental sketches, photos, plans, etc. shall be prepared and included as part of the final report to document the structures condition.

E. Electronic report shall be submitted on a CD in the Pontis AASHTOWARE version specified by the Bridge Inspection Engineer and compatible with IBM

PC microcomputer systems. Alternately, electronic files may be e-mailed. In lieu of submitting separate CDs, all information can be included on a single CD, DVD or flash drive at the consultant's option.

XII. SERVICES AND MATERIALS AVAILABLE FROM CDOT

The following services and materials will be available to the consultant from CDOT:

A. CDOT Structure Inventory Coding Guide, CDOT Pontis Bridge Inspection Manual, Pontis User's Manual, and BRIAR Manual.

B. CDOT Staff will be available for reference on coding, or other related concerns.

C. Most current designated STRAHNET and NHS routes (identified in the database).

XIII. FINAL REVIEW

A. Each electronic structure folder will be reviewed by the project manager for completeness and consistency. Each incomplete or inconsistent report will be returned to the consultant for review and for corrections

B. The consultant shall hold a final report presentation meeting with CDOT when all inspection work is completed and reports have been accepted by the project manager. This presentation shall occur no later than 60 days from the date that the final reports are accepted by the project manager.

C. The Bridge Inspection Engineer or his designee may accompany the consultant during field inspections or visit the office of the consultant to review procedures and inspection reports and to verify billings.

XIV. METHOD OF PAYMENT

These contracts will be paid for on a cost plus fixed fee basis. The consulting firms will bill for their actual costs, using the negotiated rates, incurred while performing the work. Consultants will bill monthly and include a project status update with each billing.

APPENDIX A
IDENTIFICATION OF CRITICAL WALL CONDITIONS

A. PURPOSE: This appendix establishes the procedures of the Colorado Department of Transportation, Staff Bridge Branch regarding the general subject of critical inspection findings (CIF). The term "critical" as contained within these procedures is intended to mean a structural or safety related deficiency that requires immediate follow-up inspection or action.

B. TYPICAL CONDITIONS: The following represents typical but not all inclusive inspection findings which are considered to be a CIF:

1. Retaining Wall Structures
   a. A portion of the wall may fall and injure a person or damage property
   b. Scour, drainage, damage, deterioration, or corrosion that threaten the structural integrity of the wall
   c. Scour under a spread footing, which has caused a loss of 15% of the bearing area

2. Sound Wall Structures
   a. A portion of the wall may fall and injure a person or damage property
   b. Scour, drainage, damage, deterioration, or corrosion that threaten the structural integrity of the wall

C. It shall be the responsibility of the bridge inspection team leader performing an inspection to be alert for conditions other than identified above which may also be considered a CIF. Such a finding shall be reported to CDOT upon return from the inspection or, if deemed necessary, immediately by telephone or in person.

D. The criticality of the deficiency will result in one or more of the following actions with an importance described as follow:

1. Immediate closure.
2. Restricted traffic usage.
3. Urgent repairs.

E. SPECIAL ACTIONS REQUIRED OF THE INSPECTION TEAM LEADER:

1. The team leader shall notify CDOT by phone, or in person, when the actions identified as 1 (Immediate closure) or 2 (Restricted traffic usage) above are appropriate. He or she should describe the unsafe condition and recommend immediate steps to be taken to insure safety to the traveling public. The consultant shall follow-up all verbal communication in writing within 3 business days.

2. The consultant shall notify CDOT in writing, within one week, when the action identified as 3 (Urgent repairs) above is appropriate. This notice should include comments relative to an appropriate repair. This does not mean that the consultant must provide a design for the repair.

3. The team leader shall provide written confirmation to CDOT for any action required above. E-mail confirmation with supporting documentation shall be sent to the Bridge Inspection Engineer with "cc" to other as directed by the Bridge Inspection Engineer or his/her designee on all essential inspection finding correspondence.