GUIDE TO
ASSET MANAGEMENT OF
EARTH RETAINING STRUCTURES

Prepared for:

National Cooperative Highway Research Program

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1. INTRODUCTION

1.1 Purpose of this Document

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 intended for the guidance of public officials, agency managers, engineers and others with responsibilities for the safety and maintenance of highway facilities.

By having reliable information on the characteristics of their ERS, and keeping track of their condition, agencies can:

- Greatly reduce the likelihood of ERS failures resulting in injuries, property damage, and disruption of highway operations.
- Save money by identifying problems at an early stage, when they are still relatively inexpensive to fix.

An inventory and regular inspections also provide information essential to any broader program of Asset Management. The ERS Asset Management Program is primarily focused on optimizing the service life of a structure at minimal life cycle cost – matching investment with service. Getting to this ideal requires the I&I program data. The I&I is part of the informational stage of the Asset Management of ERS as shown in Figure 1.

1.2 What are Earth Retaining Structures (ERS)?

An earth retaining structure is any structure intended to stabilize an otherwise unstable soil mass by means of lateral support or reinforcement.[1] Retaining walls, which have a vertical or near vertical face, are by far the most familiar type of ERS.[2] In general, a retaining wall is defined, by the National

[1]. Federal Highway Administration. "Geotechnical Engineering Circular No. 2 - Earth Retaining Structures". FHWA-SA-96-038, February 1997, p.4.
[2] DeMarco, Matthew, FHWA Central Federal Lands Division. Personal communication. September 2, 2009.

Highway Institute (NHI), as wall which face makes an angle of at 70 degrees or more with the horizontal and retains earth. This definition covers most conventional cut and fill wall designs. Recognizing that other earth retention structures may need to be captured in the I&I program, some groups have changed this criterion to a 1:1 face angle to also include earth retention structures such as rock buttresses, gabion walls, rockeries, etc. that don't directly meet the NHI design definition; but are nonetheless critical earth retention assets. Some groups have also developed subcategories of walls to track a particular structure type within the I&I program, such as seawalls, culvert head and wingwalls, and walls associated with bridges that are not directly part of the bridge abutment or pier structure. To avoid repetition, walls will be referred to as *retaining walls* or just *walls.* Unless otherwise clear from the context, these references should be understood to apply to other kinds of ERS as well. A more detailed description of the different types of retaining walls is provided in Appendix C.

1.3 Why Be Concerned About Earth Retaining Structures?

Catastrophic failures of Earth Retaining Structures (ERS) are relatively rare, but some serious incidents in recent years have called attention to the need for better management of ERS. Some of these wall failures occurred in Davis County, Tennessee[3]; in New York City, NY[4]; and on Blue Ridge Parkway[5] at Mile Post 364.6. The major impetus behind the expanding asset management effort within AASHTO comes from the success of the mandated road and bridge inventory and assessment programs. States are now broadening their asset programs to include all roadway appurtenances (guardrails, lighting, utilities, striping, curbs, manholes, sidewalks, etc.). ERS were actually the forgotten major assets in this picture for awhile before a few states and one federal agency actually began undertaking the effort several years ago.

There are thousands of Earth Retaining Structures along U.S. highways. Nobody knows the exact number because only a few highway agencies have inventoried their ERS. But it is clear that, in the last two decades, urban development and the expansion of transportation networks have greatly increased the number of ERS along our highways.

As the Federal Highway Administration (FHWA) has noted, many of these are "constructed in challenging site conditions, including mountainous terrain, soft ground, and sites that are below water". Moreover, newer ERS systems "require that engineered materials such as plastics, concrete, and steel be buried in harsh underground environments…that may adversely influence the long-term engineering properties of the materials. ERS often have assumed design lives of 100 years, but knowledge of actual design life for these structures is minimal and failures that have occurred to date have happened without warning. Repairing these failed structures is very expensive, complex, and difficult". Repairs of even a single, moderately sized ERS installation often cost millions of dollars.

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[3] Tennessee Department of Transportation. "Retaining Wall Failure: Jefferson Street On-Ramp to I-40 West, Davidson County". September 17, 2003. http://www.tdot.state.tn.us/news/2003/Preliminary%20Findings.pdf. Accessed December 4, 2008.

[4] New York City Department of Buildings. "Board of Inquiry Report: Castle Village Retaining Wall Collapse" [on May 12, 2005]. April 2007.

[5] Virtual Blue Ridge. February 26, 2008. "Parkway Section Closed to Repair a Failed Retaining Wall". http://www.virtualblueridge.com/news-and-events/news-260.asp. Accessed March 17, 2009.

A further concern is that a large number of our ERS date from the major Interstate Highway construction in the late 1950s through the 1970s. The earliest of these Interstate-era walls are approaching the end of their anticipated service lives. In the case of the U.S. National Park Service (NPS), most of the walls dated to the 1930's thru 1940's, when most of the major parks were developed.

1.4 Asset Management of ERS

Asset Management is a systematic way of identifying the optimal allocation of resources. In the transportation field, it has enabled highway agencies to improve the cost-effectiveness of decisions about the inspection, maintenance, repair and replacement of various types of physical infrastructure. Again, as stated before, the goal is to optimize the service life of the ERS at minimum life cycle costs. The objective is to optimize the service life of an asset while minimizing its overall life-cycle cost. An I&I program is a necessary step toward this ideal. Currently, Asset Management is most widely used for the management of bridges, pavements, and signage. A few states are broadening their programs to include such roadway appurtenances as lighting, guardrails and sidewalks.[6] Up to now, however, Asset Management has not been widely applied to ERS. (See following Section 1.5 Current State of Practice)

Asset Management can be thought of as progressing through three stages: informational, analytical, and policy-making (as illustrated in Figure 1). The first stage is the systematic organization of information. Relatively inexpensive database software has made it possible to compile detailed data on characteristics of individual walls and to quickly access that data in a variety of ways. The database can also readily incorporate links to maps, photos, contract drawings, inspection reports, and other documents related to individual walls.

The Informational Stage enables managers to identify ERS assets most in need of action to avoid further deterioration or failure. In addition, it gives managers a quantitative overview of ERS assets that will enable more accurate estimates of budget and personnel requirements.

Figure 1: Stages of Asset Management of ERS.

[6] DeMarco, op. cit., p. 1.

Over the longer term, the database can be used to build up a record of the agency's experience with its ERS. This will include condition information from successive inspection reports, as well as cost-experience data for maintenance, repair and replacement. With such information in hand, Asset Management can move into the Analytical Stage. Here, the data can be analyzed to provide increasingly reliable projections of unit cost, service life, and failure risk for various ERS types and components.

Finally, a mature Asset Management system will yield information that can be used at a Policy-Making level, for example, in revising standard specifications or in determining conditions appropriate for the use of various ERS structural types or materials.

As noted by FHWA, "While the transportation community's knowledge of deterioration mechanics and methods to assess in-service performance has been limited to date, asset management (AM) offers important tools and techniques to help in evaluating ERS assets."[7]

1.5 Current State of Practice

This report is based in part on a survey of highway agencies conducted in late 2008 and early 2009. Survey questionnaires were sent to the transportation departments of all 50 U.S. states. Questionnaires were also sent to ten additional agencies identified in a literature search as having conducted inventories of their ERS as shown in Table 1. They included the transportation agencies of six cities, three Canadian provinces, and the Federal Lands Highway Division of the FHWA. Of the 40 agencies that responded to the survey, 13 reported having implemented Inventory and Inspection programs for at least some of their ERS. Of these:

- 8 had an inventory program and regular inspections,
- 3 had an inventory but no regular inspections,
- 1 reported that it inspected retaining walls but had no formal inventory, and
- 1 had an inventory and inspection program limited to monitored walls and those not built to state standard designs.

Nine additional agencies had no current ERS management program, but reported internal discussion, research, or planning activity related to such a program.

The agencies with an inventory / assessment system for retaining walls included:

1. Federal Highway Administration (FHWA) / US National Park Service (NPS),
2. California Department of Transportation,
3. Colorado Department of Transportation,
4. Kansas Department of Transportation,
5. Maryland Department of Transportation,
6. Minnesota Department of Transportation,

[7] FHWA. "Earth Retaining Structures and Asset Management". FHWA IF-08-014, 2008

7. Missouri Department of Transportation,
8. New York State Department of Transportation,
9. Oregon Department of Transportation,
10. Pennsylvania Department of Transportation,
11. The City of Cincinnati,
12. New York City Department of Transportation, and
13. British Columbia Ministry of Transportation.

Many responses also included sample forms, documentation, and procedures in place within the agency, giving a clear overview of the asset management system or program.

Agencies without an inventory / assessment system also provided feedback regarding the lack of asset management infrastructure within their agency, their desire to establish such a system in the near future, and the overall approach to start developing an ERS asset management system. For instance, Nebraska DOT planned to have a Mechanically Stabilized Earth (MSE) wall management system by the end of 2009. Some of these respondents used the "PONTIS" database to inventory their ERS.

Only 4 agencies (FHWA/NPS, Pennsylvania DOT, City of Cincinnati, and British Columbia Ministry of Transportation) reported using their I&I program data in more advanced Asset Management activities such as planning, budgeting, and resolving ownership and jurisdiction. For additional information on the survey results, see Appendix A.

US Federal agency	1
U.S. State agencies	50
Other U.S. Territorial agencies	2
City agencies	3
Canadian agencies	3
Canadian City agency	1
Agencies Contacted	**60**

Table 1: Breakdown of Agencies Contacted During the Survey of Current Practice.

Overall, these responses provided detailed information about different ERS asset management practices currently in use within the United States and abroad.

1.6 Reasons for Focus on Inventory and Inspection

Based on the survey responses, most highway agencies in the United States have only fragmentary data about their ERS assets. Agencies that have conducted inventories typically discovered numerous walls that were not reflected in their records. In reality, most agencies have a difficult time simply locating all of their ERS, and may initially greatly underestimate numbers of ERS. Most of the agency responses were along the lines of the following statements:

- We do not know how many ERS we have.

- We do not know where they are.
- We do not know their size.
- We do not know their condition.
- We do not know how much they would cost to replace.

As these structures age, the lack of such basic information has troublesome implications for both public safety and highway operations.

The premise of this publication is that an investment in an ERS inventory and inspection program will more than repay itself by preventing ERS failures. The other equally compelling reason is the avoidance of costly repairs of poorly performing ERS by identifying them in a timely manner, thereby extending the service life at minimal cost.

1.7 Components of an Inventory and Inspection Program (I & I)

An I & I program can be divided into four basic phases. (See Figure 2)

1. - **Office Research and Planning** – The office research, planning, and scoping efforts consist of using existing agency records to identify ERS locations to the extent possible; to plan the field survey effort; and extract information that will be useful to survey teams and inspectors.

2. - **Field Work** – The field work includes both the inventory (a) and the condition assessment (b) efforts. Depending on personnel and logistical considerations, these two activities can be done together or in a two-step process.

   (a) The Inventory Effort consists of recording basic information about each ERS that meets the inventory criteria.

   (b) The Condition Assessment Effort consists of inspecting the wall to evaluate its condition. A qualified engineer will also report symptoms of structural deterioration. If the engineer finds that a significant problem exists, he or she will recommend appropriate further action.

   There are a couple of ways to inspect retaining walls: (1) send a technical crew to locate and describe basic wall features, screening for wall problems that are later reviewed by an engineer, or (2) send a crew fully qualified to inventory and assess in the field all at once. The agency will need to determine the general composition of their anticipated inventory to determine which is more cost-effective.

   For example, a DOT who is only interested in looking at walls along a readily accessible major interstate segment – where the walls are only 20-40 years old – may opt to have technicians screen for problems before engaging an engineer. However, in the case of the FHWA / NPS I&I program, the remote locations of the survey areas, and the fact that the wall inventory was assumed to be very old dictated a single mobilization of qualified personnel.

3. - **Office Inputs** – The data from the field are checked; input to the inventory database; and augmented by additional information from agency records and other sources.

4. - **Periodic Inspection** – All ERS in the database will be scheduled for periodic inspections. The frequency of inspection may vary depending on the conditions found. As each inspection is completed, the findings will be added to the database to provide a long-term record of changes in condition at each ERS.

The next two chapters (2 and 3) present initial requirements and preparations for an I&I program. Chapters 4 through 7 discuss procedures for each of the four phases outlined above. Chapter 8 overviews Quality Control and Quality Assurance (QC/QA), and Chapter 9 discusses the potential uses of an ERS database in improving management of ERS assets. Chapter 10 discusses avenues of additional research that would improve ERS asset management.

Figure 2: Basic Activities of an Inventory and Inspection Program.

2. INITIAL REQUIREMENTS AND CONSIDERATIONS

2.1 Review of Existing Agency Resources and Practices

In this chapter, the key decisions that must be made in planning an I&I program are discussed. Prior to making any decisions, however, the agency should review its existing practices and resources to see how they may relate to a new ERS program.

- How many of the agency's existing staff are qualified to perform ERS inspections? How many would realistically be available for the initial field effort, to train others, or for the ongoing inspection program?
- What ERS are included in your existing bridge inspection program? What are the criteria for inclusion or exclusion of an ERS? Within the agency's bridge inventory, is there any breakout of data on ERS?
- Does your agency have an I&I program for culverts? If so, how much attention is paid to the performance of culvert headwalls as retaining structures?
- What other asset inventories does the agency have (e.g. pavements, guard rails, signage)? Have they produced any information, such as continuous video recordings, that could be used to identify ERS locations?
- Will some NBI and "Pontis" System data field be imported for data consistency with bridge inventory?
- For all existing asset inventories, how are records kept? What numbering systems are used for various types of assets? What assets are identified on existing GIS mapping?
- What kinds of software and hardware does the agency use for field data collection, database management and GIS mapping? Are people satisfied with these systems or are changes likely in the near future?

- Where and how does the agency keep its older records of in-service facilities, including as-built drawings, design documents, test data, and maintenance and repair records?

2.2 How the Data will be Managed?

One of the reasons for the growth of Asset Management in recent years is that computers have made it progressively cheaper and easier to manage a data. An inventory and inspection program for ERS will involve three basic kinds of data:

- The core alphanumeric data, which will be managed with a database program;
- Geospatial data, which will be managed with GIS mapping software; and
- Images, including photos, drawings, documents and videos, stored in standard file formats (jpg, pdf, etc.) in an image archive.

A choice of standard software is available for managing all three types of data. But for maximum efficiency, all three should be accessible through a single user interface. The interface is a bundle of application technologies, tailored to the agency's requirements, that determines what the user sees and interacts with on the screen. Photos and location maps can be automatically displayed alongside a specific wall record, or can be linked to specific data fields within that record. Also, through the interface, authorized users can input to or edit the database and GIS map simultaneously.

The user interface can reside on a server or a stand-alone workstation. Depending on your needs, it can be designed to accommodate simultaneous users, or to be accessible through the internet as a hosted system.

Figure 3 is a schematic of a Wall Asset Management System (WAMS). Since data management software is constantly being improved, plan on a thorough review of software and hardware options before making any procurement decisions.

2.3 Defining the ERS that will be included in the Inventory and Inspection Program

As a practical matter, ERS inventories should be limited to those walls whose failure would pose a significant risk to persons, property, or highway operations. The most important component of such risk is the height of the wall. However, the height criterion is usually applied in combination with one or more other criteria, including:

- Proximity to the roadway,
- Batter or Face Slope,
- Wall Ownership or Jurisdiction,
- Structural Type, and
- Relationship to Bridges or Culverts.

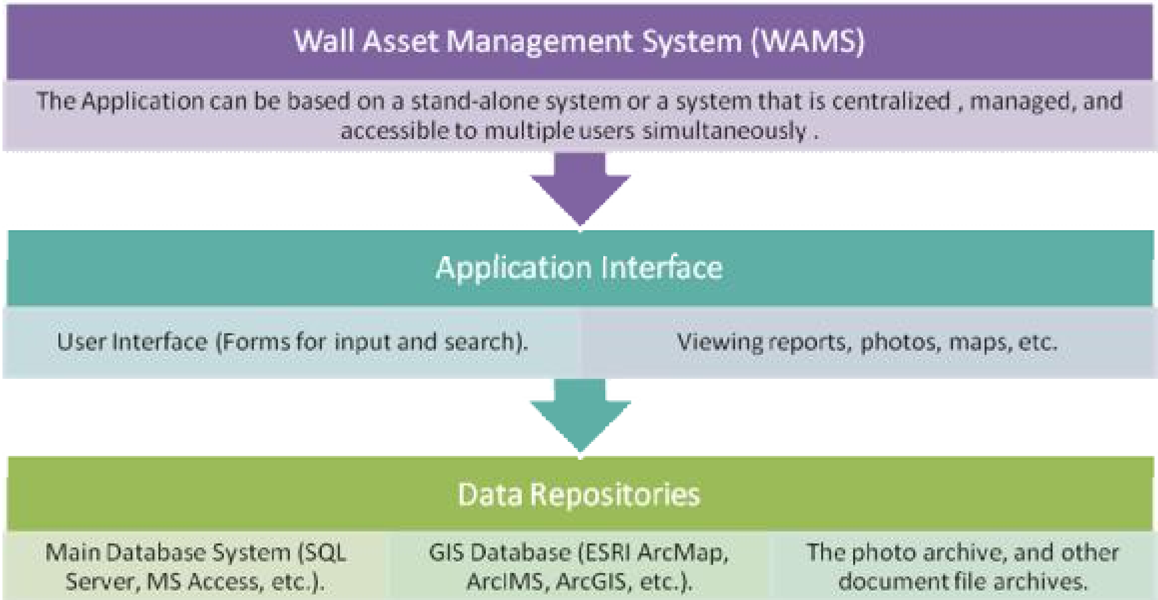

Figure 3: Wall Asset Management System Components.

The criteria need to be carefully considered, since a small change in a single criterion, such as wall height or proximity to the roadway, can make a big difference in the number of ERS to be inventoried and, therefore, in the cost of the overall I&I program.

The criteria should be defined so that they are easy for survey teams to interpret and to apply in the field. On the other hand, field personnel should be allowed flexibility in applying the criteria in special circumstances. For example, a wall somewhat under the height criterion might be included if it is more than 100 feet long or if its distance from the roadway edge is less than the standard shoulder width of 10 feet.

2.3.1 Height Criteria

Height of Wall vs. Height of Retained Soil - Height can be defined in different ways. One question is whether to use the actual height of the wall or the height of the retained soil. Since the height of the retained soil may change over time, it is important to know the relationship between the two. However, as a criterion for inclusion in the inventory, the height of the wall itself is more straightforward, easier to measure, and more conservative from the standpoint of safety.

Visible Height vs. Total Height - The full height of an ERS is rarely apparent, since part of it is normally embedded in the soil. For inventory purposes, it is simplest to use the exposed or visible height of the wall as the criterion for inclusion. The actual design height or total height of the wall should also be documented as part of the inventory process. However, that will be determined from record drawings or, if absolutely necessary, by digging a test pit.

ERS of Variable Height - Most ERS do not have the same height along their entire length. For the purposes of the inventory, the maximum height should govern. A further question is whether the inventory should include the entire length of an ERS or only those portions that meet the height criterion. It is best to consider an ERS as a whole. Some problems may show in shorter portions of a wall before they can be detected in the taller ones. And if repairs are needed, the work may extend well beyond the portions meeting the height criterion.

Tiered Walls - In some locations, there are two or more distinct walls on the same slope, one above the other, that would not meet the height criterion if considered separately. It is suggested that such walls be considered together if the vertical gap between them is less than one-half the height of either of the adjacent walls[*]. Once that determination has been made however, the individual tiers may have to be inventoried separately since they may have been built at different times, be structurally different or be affected by different soil conditions.

The interpretation of tiered walls as one or more structures can be very complicated: for instance, when asked if there is a difference between tiered MSE structures, where reinforced zones overlap vertically versus tiered cut-wall structures.

Inclusion of Top-of-Wall Attachments - Another question is whether the height of an ERS should be taken to include top-of-wall attachments such as a parapet, railing or noise barrier, which are not intended to retain soil. Among agencies that have existing inventories, it appears that most do not include attachments in applying their height criteria. However, a recent New York City law on retaining wall inspections includes the height of a top-of-wall attachment if it is capable of holding material[8]. In any event, the height and type of attachment should be recorded for each included ERS.

Current Practice and Recommendation

Most existing inventories use a height criterion of either 6 feet or 2.0 meters. A few programs are more inclusive. Oregon DOT uses 4 feet, the height at which many building codes require a retaining wall to be designed by a licensed engineer. Colorado DOT uses 5 feet, but includes lower walls if they are more than 100 feet long. The City of Cincinnati includes all walls of 2 feet or more in height.

New York City's inventory has a height criterion of 6 feet. However, a 2008 law requiring inspections of privately owned retaining walls every 5 years applies only to walls 10 feet or more in height, including top-of-wall attachments that can retain material.

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[*] This is analogous to the FHWA rule for determining when adjacent multiple culverts should be considered as a bridge.

[8] New York City Council. "A Local Law … in relation to the inspection, maintenance and repair of retaining walls". Local Laws of 200, No. 37. 2008.

2.3.2 Relationship to Bridges and Culverts

To avoid duplication of effort, it is important to look at how an ERS Inventory and Inspection program will relate to the agency's existing systems for managing bridges and culverts.

Bridges

The FHWA's Bridge Inspector's Reference Manual makes it clear that where a bridge wingwall is not integral with a bridge abutment – i.e., it is separated from the abutment by a joint and does not play a role in supporting the bridge deck – its function and behavior are that of a retaining wall. From a highway agency's standpoint, there are two questions to be decided here:

- Should such "non-integral" wing walls or other bridge-related walls (e.g. approach-road walls, abutment toe walls, pre-existing channel walls) be included in the inventory?
- If they are included in the inventory, will they be inspected as part of bridge inspection or in the separate ERS inspection program?

Transportation agencies have different criteria for the length of wingwall - in the sense of a wall extending from the bridge abutment - which they cover in bridge inspections. In some jurisdictions, wing walls are included up to a specific distance from the bridge abutment (e.g., 40 feet), with anything beyond that treated as a retaining wall. One agency has no limit on wing wall length; another includes wing walls only up to the first joint.

Some agencies have their bridge inspectors inspect nearby walls, even though they are unrelated to the bridge. This makes economic sense, since the inspectors and their equipment are already deployed. If walls are covered by an existing inspection program, they can be excluded from the initial field survey effort. However, they should be included in the eventual ERS database since the information gleaned from their successive inspections - whoever performs them - will be valuable in the management of ERS generally.

Culverts

Many jurisdictions have inventory and inspection programs for culverts. In such programs, culvert headwalls and wingwalls tend to be evaluated more in relation to water flow through the culvert rather than as earth retaining structures. If you are going to rely on an existing culvert inspection program for coverage of this type of ERS, make sure that program adequately addresses situations where a large culvert wall is supporting a roadway or other feature with high consequences of failure (COF). Data on relevant headwalls should in any event be included in the eventual ERS database.

CHART OF PRINCIPAL ERS STRUCTURAL TYPES

(Adapted from FHWA Geotechnical Engineering Circular No. 2, 1997)

Fill-Constructed Walls

(Built from the Bottom Up)

Externally Stabilized	**Internally Stabilized**
Rigid Gravity Walls --Masonry gravity walls (stone, concrete, brick) --Cast-in-place (CIP) concrete gravity walls	Mechanically Stabilized Earth (MSE) Walls --Segmental, pre-cast facing MSE wall --Prefabricated modular block facing --Flexible facing (geotextile, geogrid or welded- wire facing)
Rigid Semi-Gravity Walls --CIP concrete cantilever T-wall or L-wall (including counterforted walls and buttressed walls)	Reinforced Soil Slopes (RSS)
Prefabricated Modular Gravity Walls --Crib wall --Bin wall --Gabion wall	
Rockeries	

Cut-Constructed Walls

(Built from the Top Down)

Externally Stabilized	**Internally Stabilized**
Non-Gravity Cantilevered (Embedded) Walls --Sheet-pile wall (steel, concrete, timber) --Soldier pile and lagging wall --Slurry (diaphragm) wall --Tangent/secant pile walls --Soil-mixed wall (SMW)	In-situ Reinforced Walls --Soil-nailed wall --Micropile walls Root-pile wall Insert pile wall
Anchored Walls* --Ground anchor (tieback) --Deadman anchor	

*Anchors are often used in combination with embedded walls of various types and may also be used in combination with semi-gravity cantilever walls.

Table 2: Suggested Classification of Wall Structural Types.

2.3.3 Structural Type

Because of resource constraints and issues cropping up with some structural wall types, a few agencies have I&I programs limited to a specific structural type, usually Mechanically Stabilized Earth (MSE) walls. In general, however, an inventory should include walls of all structural types. One of the purposes of having an ERS Asset Management System is to enable comparisons between different types of walls. Also, there are situations where even an experienced engineer may be unable to determine a wall's structural type just by looking at it. Table 2 is a suggested classification of structural types.

2.3.4 Wall Ownership or Jurisdiction

Highway agencies are primarily concerned with structures within their right-of-way. But an ERS inventory will be most useful if it includes all walls, regardless of ownership, whose failure might impact the highway facility. The 2005 failure of a private wall in New York City, causing millions in damage and closing the northbound lanes of a major highway for three days, illustrates the need to keep track of non-agency ERS.[9]

Legal or liability issues may make it impractical to have agency personnel access privately-owned walls for inspection or even data collection. Nevertheless, once the wall has been identified in the inventory, missing information may be obtainable from the owner or from another public agency with jurisdiction, such as a buildings department, or a utility commission. If no agency has clear jurisdiction to require that the wall be inspected and to mandate repairs, it might be necessary to seek legislative remedies, as happened in the aftermath of the above-mentioned New York City wall collapse. For example, NYSDOT initiated a program of monitoring non-NYSDOT-owned retaining walls whose failure could affect the operations of highways under NYSDOT jurisdiction. Appendix D shows two sample letters that were sent out by NYCDOT to the owners of these retaining walls to inform them regarding the unsafe retaining walls. These letters could provide a good example on how states could handle possible liability implications.

2.3.5 Proximity

A distance criterion is appropriate for ERS that are outside of the highway right-of-way, but which could affect highway operation or property in the event of failure. The distance criterion can be related to the height of the wall. For example, an ERS outside of the ROW might be included if its distance from the edge of the ROW is less than, say, 150% of its maximum height.

Should the managing agency of the roadway sponsor a legal basis for establishing this criterion, thereby allowing access to these structures for inspection? If so, would they have the right to mandate repairs?

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[9] NYC Dept of Buildings, op. cit., p. 2.

2.3.6 Wall Batter or Face Slope

Wall batter, or face slope, may be a significant criterion for some types of ERS. The National Highway Institute has defined a retaining wall as having a face angle of at least 70 degrees, but some ERS can have much shallower slopes. For example, the stepped units of a gabion wall or modular wall can result in a 45 degree face slope, which is the minimum slope criterion used in British Columbia's ERS inventory. (See Appendix A)

2.4 Fieldwork Process

The field effort will involve two basic activities: data-collection and condition assessment. Data-collection can be done by junior engineers, surveyors, or technicians with relatively brief specialized training. Condition assessment must be done by licensed engineers or other qualified inspectors, who are scarcer and more highly paid.

Data collection and condition assessment can be done either at the same time or in two separate steps. In a one-step field effort, the inspector travels with the survey team. While others locate walls, record data and provide assistance, the inspector evaluates the condition of each wall. If a significant problem is found, he or she can immediately recommend remedial action.

In a two-step process, the survey team locates ERS and collects basic data. In addition, they perform a screening to identify visible symptoms of distress (e.g., cracks, uneven settlement) that may warrant priority attention by the inspector. The inspector then performs the condition evaluations in a separate field visit, giving priority to ERS where distress symptoms were found. Traveling separately (though normally with at least one assistant) the inspector can move faster because visits are limited to walls that are known to meet the inventory criteria and that have already been precisely located.

You will have to figure out which arrangement is more economical for your jurisdiction (or part thereof). If the choice is not clear, you can use the pilot surveys discussed below in Section 3.7 to test both methods.

2.5 Personnel Requirements

Developing an Asset Management program for ERS involves a significant commitment of personnel. Just how large a commitment will, of course, depend on the number and geographical distribution of the ERS, the adequacy of the agency's records, and the actual condition of the walls themselves. For a jurisdiction the size of a state or a large city, the initial inventory and condition assessments can be expected to require the full-time equivalent of 8 to 20 people over a period of several months to a few years. After that, a smaller dedicated staff will be required for the ongoing inspection program and to maintain the system.

Following are suggested job descriptions of the personnel typically required for an I&I program. The descriptions assume a two-step field process, since that is slightly more complicated. The first five titles describe people who would be working on the project full-time until the field survey work is completed and the database is established.

Apart from the manager, the numbers of people in each category will depend on the size of the jurisdiction and the numbers of ERS to be inventoried.

(1) Manager – The project should be managed by a licensed civil, structural, or geotechnical engineer experienced in conducting and supervising bridge inspections or comparable structural inspections involving interactions of structures and soils. He or she will be responsible for mobilizing, training, and supervising project personnel; scheduling field and in-house activities; reviewing results of field surveys and, where potentially unsafe conditions have been found, recommending appropriate action.

(2) Deputy Manager – The project will need an engineer, surveyor, geographer or comparable professional who is experienced in working with Geographic Information System (GIS), Global Positioning System (GPS), and database software; as well as interpretation of aerial photographs, and other sources of topographical information. He or she will assist the manager in designing the database, identifying areas to be surveyed (preliminary mapping), identifying relevant data from agency records and outside sources, and supervising its input to the database.

(3) Survey Team Members – Junior engineers, surveyors or technicians will identify, physically access, and photograph each ERS meeting the inventory criteria. They will establish ERS locations using GPS devices; take measurements using mechanical and electronic measuring devices; and record other relevant information about the ERS and its environs. In a two-stage fieldwork process, they will also identify and photograph conditions that may be indicative of ERS deterioration or distress. A survey team should consist of at least two people. Additional team members may be needed at locations that are difficult to access or where special equipment, such as climbing gear is needed.

(4) Inspectors – These will be licensed engineers or other experienced persons qualified to perform bridge inspections or comparable structural inspections. Prior to visiting a site inspectors will obtain and review as-built drawings, repair records, and similar existing information. They will inspect each ERS, evaluate its condition, assign condition to the ERS and, if appropriate, to specific elements, and prepare an inspection report including appropriate recommendations for further action (e.g. maintenance, monitoring, repair). In a one-step survey process, the inspector will also head the inventory team.

(5) Database Personnel – They will check field survey forms and inspection reports for completeness and consistency and will enter approved field data in the appropriate database fields. They will extract information from maps, agency records and other sources for entry into the database. They will also assist inspectors in retrieving information, such as as-built drawings, needed to prepare for an inspection.

In addition to the above, the project will require at least the short-term or part time services of the following:

(6) Records Specialist - This person, preferably a veteran agency staff member, will work with various bureaus within the agency (e.g., design, maintenance, geotechnical) to identify pertinent records; evaluate their condition and usefulness for the I & I program; and arrange for access, copying, scanning or conversion as appropriate. He or she should also be able to assist the Manager and Deputy Manager in obtaining necessary records from other agencies.

(7) IT Specialist Team – An experienced team of IT professionals, with various expertise like networking and programming, will be needed to recommend and procure hardware and software, as well as architect, develop and implement the underlying application. He or she should be able to set up the system, including security measures, so that it will be appropriate to the project needs. The IT specialist will instruct project personnel in using the system and will troubleshoot as necessary.

(8) Safety Engineer – An experienced traffic safety engineer will be needed to design Maintenance and Protection of Traffic (MPT) schemes at locations where required. He or she will also instruct project personnel in worksite safety procedures, and will assist in procuring safety equipment and services.

(9) Additional Safety Personnel and Equipment Operators – Additional help may be needed at some sites as flaggers, to place and remove safety devices, or to operate shadow vehicles; or special access equipment.

(10) CADD Operator – A person that will prepare drawings as required for inspection reports, MPT designs and similar purposes.

2.6 Cost Factors

The cost of establishing an I & I program will depend on:

- The size of the jurisdiction,
- The nature of its terrain and vegetation,
- The number of eligible ERS,
- Their geographical distribution
- Their physical condition, and
- The state of the agencies records.

The principal cost, of course, will be the field and office personnel involved in collecting the data and creating the data base. Before getting to that, however, you will have to count on another large in developing the program (see Chapter 3). The third biggest cost is long-term and includes IT support on database (development,-management and maintenance). Smaller ancillary costs will include equipment, training and documentation.

3. IN-HOUSE PREPARATION FOR THE INVENTORY

3.1 Review of Existing Records

Before deploying people in the field to gather information on ERS, it is important to know where to look and what information you already have. In a large highway agency, several different divisions may have useful records pertaining to ERS. These records may be in different locations and in different formats (paper, microfilm, and microfiche). An experienced person, preferably a veteran staff member with some institutional memory, should be in charge of rounding up potentially useful records. This "records wrangler" should contact appropriate units within the agency, evaluate their relevant records, and arrange for the records to be borrowed, copied or converted for use in the ERS program.

ERS location information should be incorporated in the preliminary mapping (see below). As-built drawings, repair records and similar information should be flagged for use by the inspectors who will perform the condition evaluations

3.2 Preliminary Mapping

Preliminary mapping is essential to plan the field effort efficiently. The purpose of the preliminary mapping is to identify, to the extent possible:

- Locations of known eligible ERS;
- Locations where additional eligible ERS are likely (or unlikely) to exist;
- Locations where access to the ERS will require special equipment, such as a cherry picker or rock-climbing gear; and
- Locations where the survey work will require safety measures such as lane closures, flaggers, or shadow vehicles.

In many cases, the preliminary mapping can be compiled entirely from an agency's in-house files of highway topographic surveys, aerial photography, Light Detection and Ranging (LiDAR) surveys, ARAN surveys, and as-built drawings. Where there are gaps, additional information may be obtained from other sources such as Federal Emergency Management Agency (FEMA) flood insurance maps; wetland and drainage maps, and mapping prepared by local governments and public utilities. Document research is especially important for fill walls, which are nearly impossible to pick up in aerials or road surveys because they are below the roadway grade.

It would be useful to begin the preliminary mapping effort with a kickoff meeting of relevant agency personnel and outside agencies to identify potential sources of information. Later, a draft version of the map can be posted on the internet, with agency personnel and (through a press release) the public invited to contribute information.

Some DOTs have emphasized the value of contributions from their veteran regional or district personnel. Local maintenance personnel and engineering personnel should be asked to participate in reconnaissance tours. These are the so called "institutional memory" of any agency. The reconnaissance survey would be most productive with their assistance right from the beginning, because they know the existence of walls whether they are shown on a map or not.

The preliminary mapping should be in a format that can be used in the field. If survey teams are able to access GIS mapping through portable devices, the mapping can be prepared directly on the agency's GIS system. If not, the information can be compiled manually on U.S. Geological Survey (USGS) quad sheets or comparable paper maps.

3.3 Preliminary List of Inventory Data Fields

Before embarking on an Inventory & Inspection program, make a preliminary list of the data fields that you would like to have in the eventual database. Your list should make provision for:

- Data to be collected by the field survey teams,
- In-office inputs from existing records or other sources,
- Data from initial condition assessments and future periodic inspections, and
- Data from future maintenance and repair activities.

In addition to numerical data and text, data fields may include links to digitized photographs, as-built drawings and other images. **Error! Reference source not found.** lists data fields that should be considered for inclusion in the inventory database. The list has been compiled from inventory forms or reports provided by several agencies that currently maintain ERS asset management inventories. Not all of the data fields or items listed will be appropriate for any given agency.

The two rightmost columns indicate whether the data will be primarily from field (**F**) or office (**O**) sources. The level of detail selected by a highway agency will depend on its objectives, budgetary constraints, and other factors. Whatever the level of detail in the database itself, its information can be augmented by links to source documents such as survey forms, inspection reports, photographs, and contract drawings. A data dictionary, with definitions and explanations of each field in the Table is provided in Appendix B.

Survey Log Data – When the survey was taken and by whom; additional information such as weather and soil conditions.

Location– GPS coordinates, location by route number and milepoint or other reference; highway district; political subdivision.

Function – Whether a cut wall, fill wall, specialty wall function (e.g., seawall, bridge wall, culvert wall, etc.); features supported and/or protected.

Dimensions – Measurements of height, length, offset, face slope, batter, face angle, internal wall face angle, etc.

Structural Data – (Structural type, materials, elements, attachments). A suggested classification of retaining-wall structural types is shown in Table 2.

History and Ownership – Date(s) of construction or substantial reconstruction; ownership or maintenance responsibility if other than the highway agency; record of maintenance and repair actions.

Condition – Condition ratings and related data from survey team observations and subsequent inspections.

Consequences-of-Failure Factors – Traffic volumes (daily, seasonal), adjacent facilities, alternative routes, loss of service, type of traffic, etc.

Management Actions – Priority ratings, actions taken, status.

ERS DATA OPTIONS TABLE				
MINIMUM	**RECOMMENDED ADDITIONAL FIELDS**	**ADDITIONAL DESIRABLE FIELDS**	**F**	**O**
SURVEY LOG DATA				
1. ID number			**X**	**X**
2. Date of survey			**X**	
3. Times of arrival and departure			**X**	
4. Surveyed by			**X**	
5. Weather			**X**	
	6. Soil moisture		**X**	
		7. Work-zone safety devices or measures	**X**	
		8. Special access equipment	**X**	
LOCATION DATA				
9. GPS location coordinates			**X**	
10. Location			**X**	
11. Offset			**X**	
12. Location photos			**X**	
	13. District / political subdivision			**X**
	14. End coordinates		**X**	
	15. Bridge / culvert association		**X**	
	16. Other related feature (		**X**	
		17. Block and lot number		**X**
	18. Access constraints		**X**	
	19. Did constraints affect accuracy?		**X**	
		20. Photo(s) of access constraints	**X**	
FUNCTION DATA				
21. Functional type			**X**	
	22. Supported feature		**X**	
	23. Protected feature		**X**	
		24. Photo(s) of supported and/or protected features	**X**	
DIMENSION DATA, GENERAL				
25. Exposed height			**X**	
26. Total length			**X**	
27. Wall face slope			**X**	
	28. Exposed height at beginning		**X**	

ERS DATA OPTIONS TABLE				
	point			
	29. Exposed height at end point		**X**	
	30. Height above retained soil.		**X**	
31. Total height				**X**
32. Estimated area of exposed face			**X**	
		33. Criterion length	**X**	
		34. Offset of criterion portion	**X**	
		35. Photo(s) of top profile	**X**	
	36. Upslope angle		**X**	
	37. Downslope angle		**X**	
		38. Roadside features above	**X**	
		39. Roadside features below	**X**	
		40. Photos of roadside features	**X**	
STRUCTURAL DATA, PRELIMINARY				
41. Wall face material			**X**	
	42. Apparent wall type		**X**	
		43. Wall surface treatment	**X**	
		44. Wall top feature	**X**	
		45. Top of wall attachments	**X**	
		46. Wall face attachments	**X**	
STRUCTURAL DATA, VERIFIED				
47. Structural type				**X**
48. Total wall face area				**X**
49. Estimated replacement cost per square foot				**X**
50. Cost estimate reference				**X**
51. Estimated total replacement cost				**X**
	52. Foundation type			**X**
53. Wall face angle as built				
	54. Proprietary type.			**X**
				X
		55. Fill material		**X**
HISTORY AND OWNERSHIP				
56. Year built				**X**
57. New or retrofit				**X**
58. Design Service Life				**X**
59. Current owner				**X**
60. Owner contact information				**X**

ERS DATA OPTIONS TABLE				
	61. Original owner			**X**
	62. Original contract number			**X**
	63. Original cost			**X**
		64. Original designer		**X**
		65. Original contractor		**X**
	66. Maintenance /Repair/ Modification Record			**X**
CONDITION DATA, PRELIMINARY				
67. Checklist conditions.			**X**	
	68. Condition photos & sketches		**X**	
69. Inspection priority				**X**
CONDITION DATA FROM INSPECTION				
70. Inspection report				**X**
71. Inspection date			**X**	
72. Name of inspector			**X**	
73. Prior documentation reviewed			**X**	
74. Potential failure type			**X**	
75. Condition rating			**X**	
76. Performance Rating				
77. Projected replacement date			**X**	**X**
78. Recommended action type			**X**	
	79. Recommended action summary		**X**	
CONSEQUENCES-OF-FAILURE FACTORS				
80. Critical wall height			**X**	
810. Critical distance			**X**	
82. Roadway type and lanes			**X**	
83. Sensitive facility supported			**X**	
84. Sensitive facility protected			**X**	
85. COF rating			**X**	**X**
	86. Traffic volumes			**X**
	87. Interchange distances			**X**
		88. Detour length		**X**
		89. Affected locations		**X**
	90. Utilities near top of wall		**X**	**X**
	91. Utilities near base of wall		**X**	**X**

ERS DATA OPTIONS TABLE				
	92. Utilities on wall face (		**X**	**X**
ACTION PRIORITY				
93. Action approved				**X**
94. Action priority				**X**
95. Action date scheduled				**X**
96. Action completed				**X**

Table 3: ERS Data Options.

3.4 Prioritizing and Staging

Field survey activities are likely to be conducted over a period of months or even years. You will need to decide which areas or routes ought to be surveyed first and which should be done toward the end of the process.

If there is a particular area where ERS in poor condition are known to exist, it must be given priority. However, in the absence of such an obvious priority area, it may be best to start where there is a high concentration of ERS, such as a series of closely-spaced highway interchanges.

The survey field crews will need time to learn their tasks and get up to speed. In an area with a high concentration of walls, the initial surveys will be easier to supervise and, if there is an error or omission on a survey form, the cost of a repeat visit will be relatively low. A formal training program is recommended for the different teams involved in the I&I program. This training will also reduce the variance in inventory and condition assessment reporting.

Apart from the learning-curve factor, agencies should consider giving priority to:

- Areas with a history of landslides or seismic activity,
- Highways with high traffic volumes,
- Highways in areas without alternative routes, and
- Areas with a history of wall failure or high maintenance expenditures.

As noted above in Section 2.4, field work may be done as either a one-step or two-step process. All ERS that meet the inventory criteria will be inspected for an initial condition evaluation. However, it may or may not be cost effective to include a licensed engineer or other qualified inspector in the team performing the initial data collection.

Most agencies have used a two-step process. The initial data collection is performed by a specially trained team of junior engineers or technicians. Once they have determined that a wall meets the inventory criteria, the wall is scheduled for an inspection. The survey team can recommend that a wall be given priority for inspection if, following a checklist, they observe certain problem that may warrant early attention.

3.5 ID Numbering System

Generally, each ERS in an inventory is assigned a unique ID to make it easier to retrieve or sort information stored in the database. Some agencies use a variant of their system for bridge identification numbers (BIN). In other ERS numbering systems, the ID incorporates additional codes for location or jurisdiction. At least one agency simply uses the record number assigned by its database software.
Some agencies also tag their ERS with these numbers so that they can be accurately identified in the field.

In the initial survey work, field teams will assign a sequence number to each ERS surveyed along a given route. To minimize the chance of error, the ID numbering system can be designed so that the same numbers, perhaps with some prefixes or suffixes, can be used in the permanent database.

3.6 In-House Training

Whatever the prior qualifications of the field and office teams, they will need training in the use the Field Survey Form and the respective field and office procedures checklists. If possible, the field and office staffs should be trained together. It is important for the office staff to understand how the field data is obtained, and for the field staff to realize how the office staff will be using it. It is also possible that, in the course of the project, some field personnel may be transferred to in-house tasks and vice versa. Supervisors must also make sure that anyone assigned to the field has had adequate safety training. The training program should be formalized as it may be revisited years down the road as new inventories are undertaken.

3.7 Pilot Survey

In conjunction with the In-House Training, carry out a Pilot Survey on a sample of sample of ERS of various heights, types and location conditions. The Pilot Survey will test the project team members on their training. Equally important, it will test the usefulness and validity of the survey forms and procedural checklists that they are supposed to follow. It will also allow supervisors to gauge the time needed for data collection, and what additional training, equipment or safety measures will be needed for the survey team.

3.8 Field Survey Form

The survey teams must be provided with a form for reporting information on each ERS they visit. Prepare a preliminary form. It will almost certainly be refined and revised in the course of a pilot survey and in-house training (see Sections 3.5 and 3.6). Limit the form to data items that actually need to be collected in the field. The questions should also be organized in a “field-logical” sequence rather than in the order they will appear in the final database. Ideally, the Field Survey form should fit on one side of a single sheet. If desired, the back of the sheet can be utilized for entries by the in-house staff. Examples of field survey forms are shown in Appendix C.

A few years ago, such surveys were always done on paper forms. There are now a variety of hand-held electronic data entry devices that are relatively inexpensive. These devices also allow opportunities for user prompts and other aids such as drop-down lists. On the other hand, the use of the electronic hand-helds also requires a substantial upfront investment in programming and debugging as well as technical upgrades in the years to come. This cost may not be justified for a 1 or 2-year inventory effort that would probably not be repeated for years to come. Another consideration is that the process of transposing data from paper forms to the database provides potentially valuable opportunities for Quality Assurance and Quality Control (QA/QC).

3.9 Field and Office Procedure Checklist

Once you have your Preliminary Survey Form, think about the field procedures that will be necessary to fill out the form. (For an expanded discussion of field procedures, see Chapter 4). List the steps in a logical sequence and use them to develop a Field Procedure checklist. It should cover things to be done, observed or recorded by the field crews from the time they set out for a day of surveying until the time they return. The checklist will be used initially for training and pilot surveys, and will almost certainly be revised in the process. Later on, it will serve as a reference to be carried in the field and for quality control.

Complementing the Field Procedure Checklist, prepare a preliminary checklist of office procedures. It should detail the steps to be followed by the office staff as they check the forms received from the field, input the data into the data base, and augment it with data from other sources.

Like the Field Procedure checklist, the Office Procedure checklist will be used initially in training, and afterward as a reference for the office staff and a basis for QA/QC procedures. For a further discussion of office procedures, see Chapter 6.

3.10 - Survey Teams and Equipment

The field survey work will probably require a few different types of survey teams, depending on field conditions in various areas. For walls of moderate height, which can be safely scaled with a ladder and where there is good shoulder width, a two-person team will suffice. Where the shoulder width is limited, but no lane closure will be required or permitted, a third person may be needed to set out safety devices and/or act as a flagger to slow down oncoming traffic.

In locations where lane closures will be required, the survey team will need to be augmented by an MPT crew and shadow vehicle. In areas with very high walls, involving use of a cherry picker, man lift, or similar equipment, the team should include a qualified driver-operator. These locations may also entail lane closures.

In very rugged terrain, field surveys may require people qualified in the use of various types of climbing equipment, each of which has its own training and certification requirements. The preliminary mapping, along with the results of pilot surveys, will make it possible to determine the types of teams required and the person-hour requirements for each type.

4. FIELD INVENTORY PROCEDURE

This chapter describes, in general terms, the steps to be followed by field survey crews. A clear procedure will help to assure that field teams:

- Acquire all the necessary data,
- Record it in a consistent manner,
- Achieve a desired level of accuracy, and
- Conduct the work safely and economically.

You can tailor them to the requirements of your own I&I program as desired. Whatever procedure you adopt should be reflected in the Field and Office Procedure Checklist described above in Section 3.9.

4.1 Pre-Departure Safety/Equipment Check

Check the following before starting each day's work:

1. Vehicle fuel, tires, safety lights, etc.
2. Safety equipment and clothing including first-aid kit, safety signs, traffic cones, safety vest, hard hat, gloves, goggles, safety shoes.
3. Equipment and supplies such as laser range finder, GPS, digital cameras, batteries and/or rechargers, ladder, tape measure, plumb bob, clipboards, drinking water.
4. Sufficient supply of survey forms or, if a data recorder is used, it is in working order. Confirm that the correct ID number to start is used in numbering the day's survey forms.

Example of survey forms developed and used in other I&I programs are shown in Appendix C.

4.2 Site ID Numbers and Log

Assign an ID number and start with a new form for each ERS that *might* meet the inventory criteria. If after recording the criteria measurements, the wall does not qualify for the inventory, there is no need to complete the rest of the form.

Keep a log of the ERS covered in each day's work, including ID number, location, and whether the wall met the inventory criteria. The log should also indicate the approximate location of any ERS that had to be skipped because you could not safely stop or approach it.

4.3 Site Arrival

On arrival at a site, pull the vehicle completely off the road. Set out cones and other safety devices as required.

Note the time of arrival and weather conditions, including signs of recent precipitation. During periods of precipitation, signs of proper drainage conditions can be noted.

4.4 General Location and Function

Briefly record the location of the wall, either by highway number and mile post, or in relation to a crossroads or other feature. If the wall is part of an interchange, clearly identify the ramp or roadway.

Take at least one general photograph that can be used to identify the wall as seen from the road.[*]

Record the functional type of the wall (e.g., cut or fill) and the feature(s) supported and/or protected.

4.5 Special Access and Safety Conditions

Record any condition pertinent to work-crew safety at this location (e.g., steep grade, limited sight distance); and any condition preventing direct access to the wall (e.g. fence, steep slope).

If you are unable to stop safely, note the location so that it can be visited later by a team with appropriate equipment. Assign an ID number.

[*] Keep track of this and other photos taken at each site. Make sure you have enough information for later captioning.

If you are unable to physically access the wall, but can make measurements with a laser range finder, continue with the survey procedure. At a minimum, try to determine whether the wall meets the criteria for inclusion in the inventory. Complete the data form to the extent possible. Note any limitations in the accuracy of the data, for example, whether the height of the wall is partly obscured by vegetation.

4.6 Dimensions

Using a laser range finder or tape measure, as appropriate, measure and record your "criteria" dimensions, for example:

- Maximum height
- Total length
- Distance from edge of roadway

If the ERS does not meet the inventory criteria, do not continue. If the wall meets the criteria dimensions, complete the remaining items on the form. These may include other measurements, such as:

- Height of wall at left and right ends
- Length of wall meeting height criterion (if less than total length)
- Wall face angle or batter
- Estimated total area of wall face

4.7 GPS Readings and Location Photographs

Take a GPS reading at the approximate midpoint of the wall's length. This will be used in GIS mapping. For a long wall, or one that is not generally parallel to the roadway, get a reading at each end. If the wall is not directly accessible, take GPS readings at the closest point and indicate the distance and direction from the wall face. Record whether measured with a laser range finder or estimated.

Depending on its size, take one or more general photographs of the wall, preferably using a GPS camera to facilitate accurate captioning. . If the wall is protecting or retaining a non-mainline feature, such as a ramp or parking area; or a feature outside the ROW, such as a local road or a residential property, make sure at least one photograph shows that feature.

4.8 Structural Type and Materials

Note the apparent structural type. Field survey teams will often not be able to determine a wall's structural type simply by looking at it. For example, where the top thickness of a concrete wall cannot be observed, it will be hard to determine whether it is a gravity structure or a cantilever structure. On the other hand, certain proprietary wall systems, mainly MSE walls, are easily identified by their distinctive wall-facing units. Recognition of these proprietary walls can be included in survey-team training and they can be provided with sample photos for use in the field. However, the definitive determination of structural type will be made by the inspector, preferably on the basis of as-built records.

For all ERS, the survey team should note the wall-face material (stone, concrete, stucco) and the wall surface treatment, if any. .

4.9 Wall Attachments

Note the type and height of any top of wall feature or attachment such as coping, parapet, fence or traffic barrier. Note any lighting or other electrical conduits attached to the wall; or any fixtures such as lighting, traffic signals, or signs.

4.10 Nearby Utilities

Note the presence of any nearby above-ground utilities such as telephone poles and electrical transmission lines, either above the wall or near the foot of the wall. Indicate the support-type (e.g. wooden pole, metal pylon) and distance from wall. Also note the type and location of any manholes or markers indicating presence of underground utilities near the wall.

4.11 Consequences of Failure (COF) Factors

In addition to features directly supported or protected by an ERS (see 4.6 above), note and photograph any other nearby facilities that might be significantly affected by an ERS failure or a related roadway closure. COF factors should be considered without regard to the actual condition of the ERS.
These include:

- Ancillary facilities within the highway right of way, such as a service area or a scenic overlook; and
- Non-highway facilities, such as a school, shopping center, or recreation area.

Additional COF information will be added by the office staff. A good list of consequences of failure levels can be found in the FHWA Wall Inventory Program as seen below in Figure 4.

Low - No loss of roadway, no to low public risk, no impact to traffic during wall repair/replacement
Moderate- Hourly to short-term closure of roadway, low-to-moderate public risk, multiple alternate routes available
High- Seasonal to long-term loss of roadway, substantial loss-of-life risk, no alternate routes available

Figure 4: Sample Levels of COF.

4.12 Condition Observations

Check for the following conditions that may be indicative of stress or deterioration. Where appropriate, indicate specific locations on the wall in terms of height above the base and/or distance from right or left. Take additional photographs sufficient to illustrate all adverse conditions. If you can't determine a condition because you are unable to access part of the wall or because it is obscured by vegetation, note that fact.

1. Wall or parts of it, out of plumb, tilting or deflected
2. Bulges or distortion in wall facing
3. Some elements not fully bearing against load
4. Joints between facing units (panels, bricks, etc.) are misaligned
5. Joints between panels are too wide or too narrow
6. Cracks or spalls in concrete, brick, or stone masonry
7. Missing blocks, bricks, or other facing units
8. Settlement of wall or visible wall elements
9. Settlement behind wall
10. Settlement or heaving in front of wall
11. Displacement of coping or parapet
12. Rust stains or other evidence of corrosion of rebars
13. Damage from vehicle impact
14. Material from upslope rockfall or landslide adding to load on wall
15. Presence of graffiti (slight, moderate, heavy)
16. Drainage channels along top of wall not operating properly
17. Drainage outlets (pipes/weepholes) not operating properly
18. Any excessive ponding of water over backfill
19. Any irrigation or watering of landscape plantings above wall
20. Root penetration of wall facing
21. Trees growing near top of wall
22. Any other observations not listed above

4.13 Priority Rating

This rating is intended to assist the manager in prioritizing and scheduling follow-up inspections. It should be based mainly on the type and severity of your condition observations (see 4.11) but should also take into account the sensitivity of potentially affected facilities (4.6 and 4.10). If possible, use a rating scale that is both simple and consistent with existing agency practice. The following is an example: of such a scale:

1. Low
2. Moderate
3. High
4. Urgent

In the event of an Urgent rating, contact the inspection supervisor or coordinator for instructions.

4.14 Site Departure Checklist

1. Close any gates that you may have opened. Pick up all discarded material.

2. Collect all equipment used during inspection.

3. Note special site conditions such as sinkholes, snakes, poison ivy, etc.

4. Time of departure.

4.15 Back to Office

On returning to the office, make sure that:

1. All forms and log entries are complete and legibly written.

2. You have a form for each ERS on your survey log, including locations where you were unable to stop, and a log entry for each form. The log should also list any unusual occurrences that may have affected the survey, such as an accident or storm.

3. You retrieve the photos taken at each site, eliminate duplicate or unnecessary photos, and caption the remaining photos. For general location photos, the ERS ID Number will suffice as a caption. If the photo was taken to show a particular feature, facility or condition, add enough information to make clear what it is intended to show, e.g., "cracked wall unit."

4. On each survey form, you write the range of photo numbers for that ERS.

5. You make up a package of the day's work and transmit it to the office staff. The package should include the log, the survey forms, and a disk or other storage device with the photographs. Photographs should be transmitted at the original resolution so as to preserve detail if they have to be enlarged. The IT Manager should advise on the appropriate camera resolution.settings

5. CONDITION ASSESSMENT

5.1 Introduction

The assessment of a wall's condition is the most critical part of its inspection record. It will be the basis for decisions about maintenance, repair, the frequency of future inspections, and even possible replacement.

The process of inspection of ERS is not as simple as it may seem. There are many system types and although, in general, they will exhibit similar patterns of distress, each system will have different issues that may cause the distress, particularly MSE walls. New types of face connections, reinforcement, and face materials mean that an I&I program will have to develop procedures, training, and repair methods for each one.

A condition assessment is obtained through a hands-on inspection. This level of inspection involves physical access to the wall; close observation, sounding with a hammer; feeling the wall to detect differences in temperature and texture; and probing with hand tools. It generally does not include invasive procedures.

A condition assessment should be obtained for each wall that meets the inventory criteria. Reaching this goal is likely to take much longer than the original inventory. Inspections are done by skilled persons and require more time at each wall. Information obtained by the field survey teams will help in deciding which walls ought to be inspected first.

Inspections of ERS should be based to the extent possible on the relevant techniques and procedures used in bridge inspection. These are described in detail in the FHWA's Bridge Inspector's Reference Manual 2006 (BIRM 06).[10] These techniques reflect decades of experience and there is no need to reinvent them.

[10] FHWA. "Bridge Inspector's Reference Manual". FHWA NHI 03-002. 2006.

5.2 Personnel

Inspections of ERS, as distinguished from inventory surveys, should be performed by qualified bridge inspectors (as defined by the National Bridge Inspection Standards, 23 CFR 650.309), or by civil, structural or geotechnical engineers with comparable experience in inspections involving interactions of structures and soils.

The size of the inspection team will depend on different factors such as the size of the project, traffic control requirements, and accessibility. In a simple situation, two people will suffice; however, in complex situations, additional personnel may be necessary for safety backup and traffic control, to assist with measurements, or to operate special equipment. The size of the inspection team will also depend on the anticipated number of retaining walls, the distance between the walls, the size of the walls, and the need for traffic control devices.

5.3 Preparation

The inspection team's goal is to primarily assess both the condition and the performance of the ERS. While the condition of the ERS pertains to its state at inspection indicated by observed distresses for specific elements, and general wall distresses such as rotation, settlement, translation, and displacement; the performance of the ERS relates to its overall capability to perform as designed based on the variance between its current and previous states while considering any evidence of component problems such as prior repairs.

In preparing for the inspection, the engineer should obtain and review all available documentation about the ERS. This may consist of:

- The data and photographs from the field inventory survey.
- As-built drawings and other records of the original construction.
- Records of maintenance and repair activities.
- Records of any prior inspections.

All of this information should *eventually* be in the ERS Management System. That is, either in the database or accessible by links to photo files or files of scanned documents. Locating and scanning relevant records is part of the work of the office staff (See Chapter 6) but will take some time to complete.

If an inspection is needed in the early stages of system development, only the information from the field survey will actually be available in the system. However, the office staff should be able to assist the inspector in tracking down as-built drawings and other relevant records.

In addition to documentary sources, the engineer may be able to obtain useful information from highway maintenance personnel and owners of adjacent property.

5.4 Field Procedure

5.4.1 Identification of Wall Type

At the site, the engineer may not have additional documentation on the retaining wall being inspected. In this case, a visual determination of the type of wall should be made by the inspecting engineer. See Appendix C for a detailed description of ERS Structural Wall Types.

5.4.2 Assessment of Exterior Wall Elements

Primary Element Condition Ratings	
Piles and Shafts	Soldier piles, sheet piles, micropiles or drilled shafts, as well as supplemental structures such as walers, comprising part or all of the visible wall.
Lagging	Structural lagging between piles and walers.
Anchor Heads	All visible parts of tieback anchor, including pad (generally observed without removing cap).
Wire/Geosyn. Facing Elements	Visible facing/basket wire, soil reinforcing elements, hardware cloth, geotextile/geogrids and facing stone.
Bin or Crib	Visible portion of cellular gravity wall.
Concrete	Visible precast or cast-in-place concrete wall and footing elements (does not include piles, lagging, crib blocks, manufactured block/brick, and architectural facing).
Shotcrete	Visible shotcrete (does not include piles, lagging, architectural facing or other specific elements).
Mortar	Visible mortar used between uncut or masoned rock, manufactured blocks or brick, or used for wall repairs.
Manufactured Block/Brick	Manufactured blocks and bricks, including CMU's segmental blocks, large gravity blocks, etc. (does not include concrete lagging or crib wall components).
Placed Stone	Dry-laid or mortar-set *uncut* rock.
Stone Masonry	Dry-laid or mortar-set cut rock.
Wall Foundation Material	Soil or rock immediately adjacent to and supporting the wall.
Other Primary Wall Element	Any primary wall element not listed (provide detailed narrative definition).

Secondary Element Condition Ratings	
Wall Drains	Function and capacity of visible drain holes, pipes, slot drains, etc., that provide wall subsurface drainage.
Architectural Facing	Facing that is not relied on for structural capacity, including concrete, shotcrete, stone, timber, vegetation, etc.
Traffic Barrier/ Fence	Traffic barrier or fence above or below wall, and within the influence of the wall.
Road/ Sidewalk/ Shoulder	Road and/or sidewalk surface above or below a wall, and within the influence of the wall.
Upslope	Groundslope area above a wall affecting wall condition and/or performance.
Downslope	Groundslope area below the wall, distinct from the Wall Foundation Material element, affecting wall condition and/or performance.
Lateral Slope	Groundslope laterally adjacent to a wall affecting wall condition and/or performance.
Vegetation	Vegetation near wall or on wall face affecting wall condition and/or performance.
Culvert	Culverts and inlets/outlets through, below, or adjacent to walls.
Curb/ Berm/ Ditch	Lined or unlined surface drainage feature above or below wall.
Other Secondary Wall Element	Any secondary wall element not listed (provide detailed narrative definition).

Figure 5: Primary and Secondary Wall Elements as defined in the FHWA NPS WIFG.

The inspection team should assess the condition of individual wall elements which could affect the performance of the retaining wall. The inspection should also focus on the new information that became available since the last inspection. The continuing function of the wall elements is the principal factor to consider when performing the site inspection. The FHWA National Park Service (NPS) Retaining Wall Inventory Program Field Guide (WIFG) provides a very good example of the definition of the primary and secondary wall elements, along with their condition rating guidance. (See Figure 5).

In the NPS program, the engineer gives a condition rating to each wall element based on the severity of the following signs of distress: corrosion or weathering, cracking or breaking, distortion or deflection, and lost bearing or missing elements. (See Figure 6**Error! Reference source not found.**). To simplify the task of identifying which wall elements are more important to assess, based on the type of wall being inspected, the list of primary and secondary wall elements from the FHWA WIFG is a useful example. (See Figure 7).

The inspection engineer should look for missing or deteriorated joint fillers (and sealant), cracking or spalling of concrete surfaces, and for deteriorated mortar joints or missing pointing on masonry walls. If severe corrosion of the reinforcement or sulphate attack on concrete is suspected, the engineer should recommend further investigation and testing, and/or seek advice from a qualified structural engineer.

During the inspection of the retaining wall, signs of distress, such as settlement and tension cracks in the ground in close proximity to the retaining wall, severe cracking, deformation, tilting and bulging of the retaining wall, and dislocation of masonry blocks, should be noted and recommendations should be made for further investigation.

Condition Ratings	
Condition Ratings apply to all Primary and Secondary Wall Elements, and are intended to assist in consistently defining element **severity**, **extent**, and **repair/replace urgency** of wall element distresses.	
9-10 (Excellent)	-Any defects are minor and are within normal range for *newly constructed or fabricated* elements. -Defects may include those typically caused from fabrication or construction.
7-8 (Good)	-Low-to-moderate extent of low severity distress. -Distress present does not significantly compromise the element function, nor is there significantly severe distress to major structural components of an element.
5-6 (Fair)	-High extent of low severity distress and/or low-to-medium extent of medium to high severity distress. -Distress present does not compromise element function, but lack of treatment may lead to impaired function/elevated risk of element failure in the near term.
3-4 (Poor)	-Medium-to-high extent of medium-to-high severity distress. -Distress present threatens element function, and strength is obviously compromised and/or structural analysis is warranted. -The element condition does not pose an immediate threat to wall stability and road closure is not necessary.
1-2 (Critical)	-Medium-to-high extent of high severity distress. -Element is no longer serving intended function. Element performance threatening overall stability of the wall at the time of inspection.

Figure 6: Wall Elements Condition Ratings as defined in the FHWA NPS WIFG.

Weepholes or outlets of drainpipes provided to drain soil layers behind the retaining wall should be investigated for blockage.

WALL TYPE	PRIMARY ELEMENTS	Piles and Shafts	Lagging	Anchor Heads	Wire/Geosyn. Facing Elements	Bin or Crib	Concrete	Shotcrete	Mortar	Manufactured Block/Brick	Placed Stone	Stone Masonry	Wall Foundation Material	Other Primary Element	SECONDARY ELEMENTS	Wall Drains	Architectural Facing	Traffic Barrier/Fence	Road/Sidewalk/Shoulder	Upslope	Downslope	Lateral Slope	Vegetation	Culvert	Curb/Berm/Ditch	Other Secondary Element	WALL PERFORMANCE	Performance
[AH] Anchor, Tieback H-Pile		●	●	●									●			●			○	○	○	●						●
[AM] Anchor Micropile		●		●									●			●			○	○	○	●						●
[AS] Anchor, Tieback Sheet Pile		●		●									●			●			○	○	○	●						●
[BC] Bin, Concrete						●							●			●			○	○	○	●						●
[BM] Bin, Metal						●							●			●			○	○	○	●						●
[CL] Cantilever, Concrete							●						●			●			○	○	○	●						●
[CP] Cantilever, Soldier Pile		●	●										●			●			○	○	○	●						●
[CS] Cantilever, Sheet Pile		●											●			●			○	○	○	●						●
[CC] Crib, Concrete						●							●			●			○	○	○	●						●
[CM] Crib, Metal						●							●			●			○	○	○	●						●
[CT] Crib, Timber						●							●			●			○	○	○	●						●
[GB] Gravity, Concrete Block/Brick									●	●			●			●			○	○	○	●						●
[GC] Gravity, Mass Concrete							●						●			●			○	○	○	●						●
[GD] Gravity, Dry Stone											○	○	●			●			○	○	○	●						●
[GG] Gravity, Gabion					●								●			●			○	○	○	●						●
[GM] Gravity, Mortared Stone									●		○	○	●			●			○	○	○	●						●
[MG] MSE, Geosyn. Wrapped Face					●								●			●			○	○	○	●						●
[MP] MSE, Precast Panel							●						●			●			○	○	○	●						●
[MS] MSE, Segmental Block										●			●			●			○	○	○	●						●
[MW] MSE, Welded Wire Face					●								●			●			○	○	○	●						●
[SN] Soil Nail								●					●			●			○	○	○	●						●
[TP] Tangent/Secant Pile		●											●			●			○	○	○	●						●
[OT] Other, User Defined													●			●			○	○	○	●						●

● Wall elements that should always be rated for the given wall type (others may also apply).

○ 1 of 2 primary wall elements required depending on material observed.
2 of 3 secondary wall elements required depending on wall location relative to roadway.

Road/Sidewalk/Shoulder: Rate only when these elements lie within the influence of the wall. The shoulder is generally defined as extending no greater than 5 ft horizontally from the roadway/sidewalk, and less than -5 ft vertical offset.

Upslope: Rate the upslope condition for all walls above roadway grade, regardless of slope ratio. Rate the upslope condition for all walls below roadway grade, regardless of slope ratio, when the vertical offset to the wall from the roadway/shoulder is greater than 5 ft (otherwise evaluate the condition of the upslope under the "Road/Sidewalk/Shoulder" element).

Downslope: Rate the downslope condition for all walls below roadway grade, regardless of slope ratio. Rate the downslope condition for all walls above roadway grade, regardless of slope ratio, when the vertical offset to the wall from the roadway/shoulder is greater than 5 ft (otherwise evaluate the condition of the downslope under the "Road/Sidewalk/Shoulder" element).

Figure 7: Matrix Showing the Wall Elements that should be Rated based on the Wall Structural Type (As shown on the FHWA NPS WIFG).

For reinforced fill structures, the gaps between the facing panels should be free from any undesirable vegetation growth. The measures incorporated for the protection of the reinforcing elements and connections should be checked to ensure that their effectiveness is not reduced by post-construction activities in the vicinity of the structure, e.g., laying of utility services.

5.4.3 Assessment of the Potential Effect of Water Leakage

Leakage from water-carrying services, including water pipes, stormwater drains, sanitary sewers, catchwater channels, and water tunnels, may adversely affect the stability of retaining walls. Ducts carrying conduits can transmit an appreciable amount of water. The potential effect of water leakage on the stability of the retaining wall should, therefore, be considered and assessed. In locating buried water-carrying services within the vicinity of the retaining wall being inspected, the engineer should keep in mind that leakage from services can travel long distances via subsurface seepage paths through permeable materials.

The inspecting engineer should inquire owners of utility services about the presence of buried water-carrying services in the vicinity of the retaining wall. The engineer should look for unauthorized buried services and other discrepancies from available record plans. If no existing drawings are available, the engineer should make a note of unusual features and investigate. Other services in the vicinity of the retaining wall, such as manholes, should be examined for signs of leakage.

5.4.4 Assessment of the Potential Effect of the Lack of Drainage:

The potential for water ponding near the crest of the retaining wall should be assessed, and if necessary, improvement works should be recommended. The engineer should inspect the area beyond the boundary of the retaining wall, and check for the presence of gaps in the ground, alongside surface channels, that could permit surface water to infiltrate into the ground. For example, where there are culverts or natural drainage lines that may affect the retaining wall, these should be inspected for signs of cracking, blockage, or insufficient capacity. During the inspection, it is important for the engineer to consider all possible water flow pathways that might affect the retaining wall. Factors usually arising from the environment outside the confines of the inspection site should be carefully considered, and where necessary, the engineer should recommend actions to prevent or to protect against a failure of the wall.

Since it is easier to identify drainage problems by inspections during or after heavy rains, the inspection engineer should arrange for such inspections if the adequacy of the drainage system is in doubt. It may not be practical to do so when the retaining walls are located in remote areas, and the wall does not pose any danger to life or property.

Seepage traces on and adjacent to the retaining wall should be recorded on hand-sketched drawings and photographs. Flow from seepage sources, weepholes, cut-off drains, joints between masonry blocks, horizontal drains, etc. should be recorded and examined for signs of migration of solid particles or fines to check whether there is any internal erosion of the ground. If signs of abnormal seepage are detected from the surface of a masonry wall, or signs that the seepage has substantially increased, the causes should be investigated. The engineer should make recommendations for clearing weepholes where blockages are suspected. If traces of seepage are detected in an area of the retaining wall where weepholes or other kinds of drainage elements have not been located, the source of the seepage should be determined and the engineer should recommend installing adequate drainage.

5.4.5 Overall Condition and Performance of the ERS

Based on the major or minor defects observed for individual wall elements, the overall condition and performance of the wall should be rated using either a numerical scale or a standard set of terms. Following is a sample rating system based on a five-point scale. Another example, from the NPS Field Guide, is shown in Figure 8.

1. **Excellent**: No significant indication of distress or deterioration
2. **Good**: Some indications of distress/deterioration, but wall is performing as designed
3. **Fair**: Moderate or multiple indications of distress/deterioration affecting wall performance.
4. **Poor**: Significant distress/deterioration with potential for wall failure.
5. **Critical**: Severe distress/deterioration. Indications of imminent wall failure.

Wall Performance Condition Ratings		
Performance	Evaluation of overall wall performance as indicated by observations not necessarily captured by observed distresses for specific elements, including global wall distresses (rotation, settlement, translation, displacement, etc.) and/or evidence of prior repairs that may further indicate component problems.	**Good to Excellent** - No observation of distresses not already captured by individual element condition assessment. No combination of element distresses indicating unseen problems or creating significant performance problems. No history of remediation or repair to wall or adjacent elements.
		Fair - Some observed global distress is not associated with specific elements. Some observation of element distress combinations that indicate wall component problems. Minor work on primary elements or major work on secondary elements has occurred improving overall wall function.
		Poor to Critical - Global wall rotation, settlement, and/or overturning is readily apparent. Combined element distresses clearly indicate serious stability problems with components or global wall stability. Major repairs have occurred to wall structural elements, though functionality has not improved significantly.

Figure 8: Wall Performance Condition Ratings Table as defined in the FHWA NPS WIFG.

5.5 Consequences-of-Failure (COF) Rating

Although (in a two-step process) the survey team may have already recorded a COF rating, the inspector should make an independent judgment of the consequences of failure. Apart from his or her greater experience, the inspector is likely to have information, for example on traffic volumes, detour lengths and potentially sensitive facilities, that was not available at the time of the original survey..

The COF to be considered should include:

1. Death or injury to persons, including highway users and people in adjacent properties or facilities.

2. Damage to property including: vehicles, highway property or facilities, and property or facilities adjacent to the highway ROW.

3. Disruption of highway operations, including full or partial closure of the roadway, or ancillary facilities.

4. Disruption of adjacent utility lines, such as water mains or electrical conduits buried in the backfill.

5. Environmental consequences, such as damage to a significant wildlife habitat or protected wetland, or blockage of a watercourse.

6. Damage to cultural assets or sensitive land uses such as historic structures, schools, houses of worship, and cemeteries.

In assessing the consequences of failure of a retaining wall, the engineer should take into consideration factors such as:

1. The scale of a potential failure, considering the height and overall size of the ERS and the volume of earth retained.

2. Its proximity of the ERS to the roadway or other potentially affected facilities or structures

3. Intensity of usage of potentially affected facilities, such as traffic volume on a roadway or occupancy of a building

4. The resistance of buildings and facilities to the impact of the debris

5. The vulnerability of occupants and/or users

The COF rating is intended as an aid in setting priorities. It should be kept relatively simple. Following is a suggested three-level COF rating system, with examples of COF at each level.

1. **Severe**: High likelihood of injuries or death from debris falling on a heavily traveled roadway, on other heavily used adjacent areas, or from collapse of structures near top of wall. High likelihood of extensive or total-loss damage to vehicles or structures. Complete closure of a heavily traveled roadway requiring lengthy detours.

2. **Significant**: Low probability of injury to persons but likelihood of any of the following: (a) substantial property damage, (b) interruption of water or other utility service to a large area, (c) lengthy blockage of access to business properties or public facilities, (d) long-term damage to environmental or cultural resources, (e) closure of two or more lanes of a heavily traveled roadway, (f) full closure of any roadway with no alternative access or requiring lengthy detours.

3. **Minor**: Low probability of either injury to persons or of damage to vehicles or non-highway property or facilities. Full roadway closures where alternative access is available. Closure of a single lane on a heavily traveled roadway.

6. OFFICE PROCEDURE AND DATA INPUTS

6.1 Location of Agency Records

As the program proceeds, the office staff will need to look into available agency records: as-built drawings, specifications, records of maintenance and repair, and records of utility permits or easements. For the most part, this information will be retrieved on an as-needed basis for the use of engineers performing inspections and designing repairs. When such information is needed, it may be needed quickly for walls already deemed to be performing poorly and in need of some level of maintenance, repair or possible replacement.

At an early stage in the project, before survey data starts coming in from the field, the office staff should learn how the agency keeps its construction, maintenance and repair records. They should get to know what relevant records exist, where they are stored, in what formats, and who is in charge of them.

References to sources on a specific geographic area, such as highway contract numbers, can be incorporated directly into GIS mapping, enabling the map to serve as an index to available records.

6.2 Checking of Field Survey Forms and Photos

On receiving each package of data from the field (see Section 4.14), check to see that there is an ID number and form for each site listed on the log; that the brief location descriptions on the log are consistent with those on the forms; and that the information on the forms is legible enough for input.

Review the photos and check to see that their numbering corresponds to what is shown on the form. The system can be set up so that each photo is referenced to a specific field on the form, which serves as its caption. If not, make sure that all photos are adequately captioned, including the ERS ID number and appropriate keywords.

Once all photos are correctly captioned and/or referenced, the entire batch can be copied to a central photo from which the individual photos can be called up as needed.

6.3 Input of GIS Map Coordinates

It is useful to map locations of all reported ERS, even where the survey form could not be completed.

Bring up the GIS map. Input the ERS ID number at the map coordinates recorded on the survey form. Check that the location is consistent with the map and with the location description on the survey form. If the GPS coordinates are incorrect you may be able to get the coordinates from GPS data embedded in a photo file or by pinpointing a location that you can reliably identify from a photo. If not, the form must be sent back for clarification.

If there is no GPS location and no photo, as in a “no-stop” situation, get an approximate location from the description on the survey form and enter it with an appropriate cautionary note.

6.3.1 Location Description

After entering the location on the GIS map, check the location description on the survey form. If it is not adequate, add clarifying information such as names of cross roads or distance from the last intersection or bridge. This must be done correctly in the field by the field crew.

6.4 Input of Survey Data

Input the survey data from the forms to the appropriate fields in the data base. Each survey form results in a database record. The system can be set up to automatically flag records that require follow-up and transmit them to the appropriate people. These may include:

- Records of walls assigned a high or urgent priority for inspection.
- Records showing a specific distress conditions or a predetermined number of such conditions.
- Records that are incomplete because of access problems or because the survey team could not stop safely. These will be reassigned to a team with appropriate safety support or equipment.
- Records of ERS that support or protect a specific type of facility, such as a railroad.

Whether or not these selections are automated, you should be alert to any inconsistencies or unanswered questions in an otherwise complete form. These records must be referred back to the survey team for correction or clarification, with copies of the original form and photos, if necessary.

6.5 Additional Data Input

The ERS database will include various kinds of information that are not easily obtainable by the field survey teams.

6.5.1 Agency Data

As agency records are retrieved for inspections or other purposes, relevant data should be entered into the system. This may include:

- Dates of construction and any subsequent major repairs
- Structural type (if not previously identified)
- Additional dimensions (e.g. wall thickness, depth of embedded portion)
- Wall materials
- Backfill type
- Specific element types and manufacturers

Record drawings, including as-builts, shop drawings and details can be incorporated into individual ERS records via links to graphic files. The same can be done with entire documents, including inspection reports, specifications, and test data.

Where available, the database should include basic traffic-volume data and the year on roads potentially affected by an ERS failure or repair work.

6.5.2 Related BIN Numbers

If the ERS is currently included in the inspection of a related bridge, the ERS record should show the BIN number and the date of the last inspection.

If the ERS is near a bridge, but not included in bridge inspections, it may also be useful to know the BIN number and the distance from that bridge.

6.5.3 Non-Agency Data

Certain important non-agency data should be obtained and added to the database as soon as practicable.

The database should show the local political jurisdiction in which each ERS is located. The GIS system may be able to enter this automatically. If public safety coverage does not coincide with political boundaries, the database should also identify the police and fire departments covering the area where the wall is located.

Most highway ERS are entirely within the highway right-of-way. However, the database should identify the owner of any adjacent non-agency wall, as well as the owner of any property adjoining an agency-owned wall. This information is usually obtainable online from assessors' offices, even for public or tax exempt property. Include property identifiers such as tax map number, tax block and lot number.

For specific facilities that could be affected by a wall failure, include relevant data such as the enrollment of a school, the capacity of a parking lot, and the annual visitation of a park or tourist attraction.

7. QUALITY CONTROL AND QUALITY ASSURANCE

Quality Control (QC) refers to the measures that should be taken in the development of the ERS inventory to achieve a specified level of quality. Quality Assurance (QA) refers to sampling and other measures, undertaken by a manager or a third-party auditor, to verify that the Quality Control measures are adequate and that the quality standards are being met.

The survey effort should include QC/QA measures to assure accuracy and consistency. The agency should designate a specific person or persons to be responsible for QC/QA in the inventory effort. Some possible or suggested quality objectives for the inventory are:

- Identify 100% of eligible ERS;
- On roads with permanent mileposts, locations to be accurate within 10 feet;
- Dimension measurements for fully accessible ERS be accurate within, say, 6" or a foot;
- Error rate of < 1% in other field-recorded data, e.g. supported feature;
- Complete forms/database inputs;
- Complete electronic archive;
- Complete hard copy archive;
- Complete submittals of data to agency staff (GIS group, maintenance group, management/administrative group, etc.);
- Consistent condition assessment; and
- Identify walls that require special safety support or equipment for inspection.

These types of QA reviews will capture most of the problems at the time of the development of the inventory, and in the future when the database information is used in the field again. A QC check of the filled out data forms should be made in the field by the team members.

The following sections describe a few recommended quality control measures.

7.1 Preliminary Mapping

a. A kickoff meeting of relevant personnel and outside agencies to identify sources of information for the preliminary map.
b. Posting a version of the map (Google or similar) on the internet. Inviting agency personnel and (through a press release) the public, to contribute information.
c. Reconnaissance tours with local maintenance or engineering personnel.

7.2 Inventory Field Work--Training and Pilot Surveys

a. Preparation of a draft form for recording data, a draft field procedure to be followed at each ERS site, and a field guide to be used in preliminary assessments of condition and consequence-of-failure.
b. Classroom and field training of the teams in use of the draft form, procedure and field guide.
c. Pilot surveys to test the draft form, procedure and field guide on a sample of ERS sites.
d. Duplicate surveys by different teams to measure consistency of preliminary assessments of condition and consequences of failure.

7.3 Data Recording and Input

a. After survey information has been verified in the field, the reported data should be compared with the photographs taken to assure that they are consistent. As with the follow-up inspections, these checks should be done early enough to take corrective action, if needed.
b. Whenever an as-built drawing is linked to the inventory record, it should be checked to make sure that it is consistent with the data recorded in the field.

7.4 Quality Assurance

While the actual survey is ongoing, sample follow-up surveys should be made to assure that the data is being accurately recorded and properly entered. The follow-ups should be done early enough so that the corrective measures can be taken if needed.

The important thing to remember here is to collect good and reliable data, such as the wall location, the physical condition of the wall and wall elements, and what actions are required. This information will be useful in determining the cost of rehabilitation, the remaining service life, and asset management of ERS.

8. LONG TERM INSPECTION PROGRAM AND SYSTEM MAINTENANCE

8.1 Coordination with Bridge Inspection

Many ERS are bridge-related and may already be covered by your agency's current bridge inspection programs. Additional ERS, though not bridge related, are close to bridges and may be more efficiently covered as part of bridge inspections than in an ERS-specific inspection program. Whoever performs the inspections, the resulting data should be recorded in the ERS database. The same considerations apply to existing culvert inspection programs.

8.2 Inspection Cycle

Among the highway agencies that responded to our survey of current practices, only six provided information on the frequency of periodic inspections. Three agencies reported a 2-year interval. Three others reported intervals of 5 to 7 years. New York City requires privately-owned retaining walls to be inspected every 5 years[11]. For state and local government financial statements that base infrastructure valuations on an Asset Management system, the Government Accounting Standards Board (GASB) requires inspections every 3 years.[12]

A five year interval for routine inspections is therefore recommended. This refers to the inspection interval in the absence of any special condition or circumstance that makes it prudent to inspect more often. More frequent inspections of ERS may be triggered by:

- Walls that show poor performance.
- The environmental setting (regional climate, geology, etc.). In cold climates, for instance, walls susceptible to freeze-thaw cycles may require more frequent inspections.
- The age of the wall. Older walls may require more frequent inspections.
- Certain recent wall types (e.g., metallically reinforced earth retaining structures or MSEs) where long-term performance records are not available.
- The consequence of failure.
- Occurrence of an event, such as flood or weather-related damage, or a vehicle impact, or an earthquake, etc.

[11] New York City Council, op. cit., p.11.
[12] PB Consult, Inc., PricewaterhouseCoopers, LLP, Cambridge Systematics, Inc. and NuStats, Inc. "A Review of DOT Compliance With GASB 34 Requirements". NCHRP Report 522, 2004, p.2.

- A combination of all of the above.

Inspection interval periods may also be determined by analyzing historical trends in wall failures or maintenance requirements coupled with the results of an initial survey. Routine inspections should follow the guidelines and procedures proposed in Chapter 5.

8.3 System Maintenance

In order to properly maintain the data gathered through the inventory and inspection surveys and to extend the life of the EAMS, a regular maintenance schedule should be adopted for the different hardware and software elements of the ERS Asset Management System. For example:

- A regular backup schedule of the software and the repositories (e.g., databases, and file archives), is necessary to protect the information, and a frequent backup schedule is recommended for multiple point-in-time restore options.
- A regular update or upgrade policy is recommended to prevent security breaches and other issues stemming from a lack of stability of the system.

9. DATA ANALYSIS FOR ASSET MANAGEMENT

9.1. Utilization for ERS Management Decisions

ERS inspections are simpler than bridge inspections. On the other hand, ERS are far more numerous and geographically dispersed. As a result, the personnel and equipment costs of travel between sites are relatively high in relation to the time spent at each site. These costs can be minimized by using the capabilities of the ERS Management System. It can quickly generate lists and maps of ERS scheduled for inspection within given time periods. It can also be used to sort ERS sites requiring various kinds of special equipment or personnel.

Over the longer term, the ERS Asset Management System (ERS AMS) will include condition information from successive inspection reports, as well as cost-experience data for maintenance, repair and replacement. At a later stage, the ERS AMS can help in analyzing the information gathered to provide increasingly reliable projections of unit cost, service life, and failure risk for various ERS types and components.

Finally, a mature ERS AMS will enable an agency to make decisions at a Policy-Making level, for example, in revising standard specifications or in determining conditions appropriate for the use of various ERS structural types or materials.

9.2. Projections of Remaining Service Life

Current AASHTO guidelines state that "For most applications, permanent retaining walls should be designed for a minimum service life of 75 years … A greater level of safety and/or longer service life (i.e., 100 years) may be appropriate for walls which support bridge abutments, buildings, critical utilities, or other facilities for which the consequences of poor performance or failure would be severe".[13] (AASHTO HB-17, Division I, Sec 5)

In theory, it should be possible to project the remaining designed service life of an ERS from its construction date and the design service life stated in the construction documents. This assumes that the construction documents can be found, and that the date of construction is known; but it is not always the case. The actual service life of an ERS may differ from its designed service life, and it depends largely on the performance demands of the structure (which are related to the quality of construction, operational

[13] AASHTO HB-17 "Standard Specifications for Highway Bridges". 2002. Division I, Section 5.

environment and applied loads). In practice, there are numerous factors that can cause an ERS to deteriorate or fail well before the end of its design service life.

1. Since the 1970s, many ERS have been built using techniques or materials that are too new to verify their projected service life based on their actual field performance.

2. The service life of some materials can be severely affected by errors during construction; for example, improper application of shotcrete, or improper storage of certain geotextiles that are damaged by exposure to ultraviolet light.

3. After construction, ERS are exposed to the corrosive effects of chemical and electrical activity in the retained soil, as well as from external sources such as agricultural runoff, road salts, and leakage or stray currents from utility lines. None of these are fully predictable.

4. Existing ERS can be severely affected by adjacent land development, which can increase runoff; or by excavation for new utility lines, which can damage drainage channels and protective membranes. Either one can lead to saturation of the retained soil and buildup of lateral pressure behind the ERS.

The majority of these problems are hidden behind the wall face. They become evident only with the appearance of various external signs of distress such as bulging, deflection, cracking or staining. A reliable estimate of remaining service life can be obtained only by identifying these conditions and by observing their rate of change. This implies periodic inspections at regular intervals.

The evaluation and determination of the remaining service life estimate is vital to effectively progress the wall program from an inventory and condition assessment effort to an asset management effort. Without the remaining service life estimate, it is not possible to optimize the scheduled expenditure of maintenance and repair dollars.

There is no data available in technical literature on the estimate of designed service life or on construction or maintenance operations on old retaining walls built somewhere between 50 to 100 years ago. However, if the goal of the U.S. Government and the 50 States is to truly optimize capital expenditures for maintaining these assets, then reliable information needs to be acquired and developed.

There are two suggested approaches for developing the estimate of remaining service life of ERS. The recent walls are designed with an estimated design service life. However, the real or actual remaining service life will be different in many cases.

One approach is to repeat the inventory over many inspection cycles, and chart escalating maintenance and repair costs to project a remaining service life for a given class of asset (e.g., all MSE structures) using some criterion such as when the repair and maintenance costs exceed more than 50% of the replacement cost of the ERS. Another method is to measure the performance of similar wall structures built over a long period of time.

Both approaches are essential, the first to understand the agency's assets, and the second to take advantage of data generated by other agencies regarding the performance of a particular wall structure type under different conditions over a period of many years. As the Chinese proverb says "the journey of a thousand mile starts with a single step", it is hoped that each State DOT will initiate a modest program to inventory its ERS assets and develop data for the future benefit of the rest of the country.

10. RESEARCH NEEDS

Most of the research needs described below are related to inventorying, inspection, and condition evaluation. Some are related to the more advanced phases of asset management, such as the development of models for projecting service life.

Areas where research and technologies may be needed or used to enhance ERS asset management effectiveness are divided into seven categories:

10.1 Identification of Existing Retaining Walls
10.2 Imaging of Existing Wall Surfaces
10.3 Non-Invasive Subsurface Imaging of Existing Walls
10.4 Corrosion Monitoring of Reinforcements in ERS
10.5 Advanced Management System Technologies
10.6 Systematic Collection of Data
10.7 Development of Decay Curves

10.1 Identification of Existing Retaining Walls

Conventional aerial photography has been used to identify ERS, but some structures can be obscured by heavy vegetation even when trees are not in leaf. Bare-earth images produced by Aerial LiDAR (Light Detection and Ranging) might save time in the inventory process. Such images could:

a. Enable rapid identification of retaining walls that are dispersed over a large area, and
b. Disclose the presence and dimensions of retaining walls that are difficult to access or that have been wholly or partly obscured by vegetation.

Further information is needed on the costs and efficacy of aerial LiDAR in identifying ERS. A place to begin would be in states that already have LiDAR imagery for large stretches of highway. Among these are Iowa and North Carolina according to a report on the NCRST-E website.[14]

10.2 Imaging of Existing Wall Surfaces

The imaging of existing wall surfaces has been identified as an area where information is obtainable by existing methods. However, new procedures or arrangements may be needed to collect the data.

a. Substitution for As-Built Drawings.
   Laser scanning is a ground-based form of LiDAR. Where as-built drawings of an ERS are lacking, laser scanning can create an accurate 3D digital model, largely eliminating time

[14] National Consortium on Remote Sensing in Transportation-Environmental Assessment. "Economic Benefits of Remote Sensing in Transportation: Case Studies of Environmental Analysis in Transportation Planning". http://wwwghcc.msfc.nasa.gov/land/ncrst/rscostbene.html. Accessed May 26, 2009.

consuming field measurements. The model can then be used in CAD system to generate dimensioned drawings.

b. Monitoring of Movement.
In a study conducted in Northern Ireland laser scanning at 6-month intervals was used to monitor movement in a 5-meter high retaining wall along a railroad cut. [15] It was expected to detect changes greater than 5 mm. The method was reported to be faster, cheaper, and safer than conventional techniques. Further information is needed to determine costs and accuracy.

c. Condition Evaluation.
In an abstract for a forthcoming paper, Priznar, et al. report on the use of laser scanning by Arizona DOT to evaluate the condition of three rock retaining walls "in previously inaccessible terrain". [16] In a related project, ADOT combined laser scanning and panoramic photography to locate a steel rib canopy and 2,443 rock bolts supporting a tunnel. Details are not available at this time, but the method is reported to have reduced field investigation costs and increased the amount of usable data collected.

10.3 Non-Invasive Subsurface Imaging of Existing Walls

Certain non-invasive techniques are available that may be useful in investigating conditions beneath the surface of an existing ERS.

a. Ground Penetrating Radar.
Ground Penetrating Radar (GPR) is a well established technology for locating objects in soil or concrete. GPR has been used primarily on horizontal surfaces such as bridge decks, where it is able to locate rebar, post-tensioning, and some types of concrete defects. GPR devices for use on vertical surfaces are still in the developmental stage. Huston, et al. reported on the use of a prototype handheld GPS to scan a retaining wall at an I-189 overpass in Vermont. [17] More recently, Hugenschmidt and Kalogeropoulos have reported on testing of similar apparatus on a retaining wall in Switzerland. [18] Further study is needed on the benefits and reliability of GPS scans of ERS.

b. Thermal Scanning.
Thermal scanning is an infrared-based technology that is widely used to scan building walls and roofs for the presence of moisture. This technology may be useful in identifying accumulations of water behind retaining walls. To date, the investigators have found no published reports of its use for this purpose. Further investigation may be warranted.

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[15] Gridpoint Solutions Ltd. *"Wellington Cut – Retaining Wall Monitoring"*. March 2005. http://www.gridpointsolutions.com/gpsltd2/downloads/gpsltd%20case%20studies/Wellington_Cut_Case_Study_web.pdf. Accessed May 26, 2009.

[16] Priznar, Nick, V. Coxon, T. Freiman and B. Cummings. *"Using LiDAR Laser Scanning for Geotechnical Characterization"*. Abstract of paper to be delivered at 34th Southwest Geotechnical Engineers Conference. Phoenix, AZ, May 11-14, 2009. http://www.azdot.gov/Highways/Materials/Geotech_Design/Conference/PRIZNAR.PDF.

[17] Huston, Dryver R., Noel Pelczarski and Brian Esser. *"Inspection of bridge columns and retaining walls with electromagnetic waves"*. International Society for Optical Engineering, Symposium on Smart Systems for Bridges, Structures and Highways. Newport Beach CA, March 2001.

[18] Hugenschmidt, J., and A. Kalogeropoulos. *"The Inspection of Retaining Walls Using GPR"*. Abstract in Journal of Applied Geophysics, Volume 67, Issue 4, April 2009.

Thermal scanning is similar to thermography, which can detect subsurface defects in concrete by measuring differences in the rate of heating and cooling.]

10.4 Corrosion Monitoring of Reinforcements in ERS

Fishman has reported on monitoring of in-service metal reinforcements of MSE walls.[19] In North Carolina since 1990, and California since 1987, new MSE walls have been built with provision for access, wiring, and/or inspection during construction to enable future monitoring. In an ongoing NCHRP research project in both states, NCHRP 24-28, the half-cell potential (E_{comm}) of galvanized steel reinforcements is measured and compared with the E_{comm} of zinc and steel coupons to determine when zinc loss results in significant areas of reinforcing steel being exposed to the soil. Electrodes were also installed for measurements of soil resistivity. The results of the two types of measurements are being compared to identify soil characteristics associated with higher corrosion rates.

10.5 Advanced Management System Technologies

Many advanced management system technologies, compared to using a simple Microsoft Access database, can help in centralizing and sharing access to an ERS asset management system. The options can provide greater access to information and increase the response and analysis of a situation surrounding an ERS.

a. Advanced database systems can provide major options for storing and accessing large amount of data while providing a centralized access to information. Examples of such systems include transactional database systems such as Oracle, and Microsoft SQL Server.

b. Advance database and reporting technologies, such as Business Objects' Crystal Reports, and Microsoft SQL Server Reporting Services, can be customized to present the data stored in a clear and visual manner.

10.6 Systematic Collection of Data

Projections of remaining service life are limited by the lack of information about the actual behavior of buried ERS elements. A careful investigation is usually conducted after any catastrophic collapse, but such events are relatively rare. It is far more common for an ERS to be demolished, in whole or in part, because of a highway widening or realignment.

Highway agencies should take advantage of all such opportunities to collect information on newly exposed elements and materials, e.g. corrosion and section loss in metals, efficacy of coatings, performance of geotextiles and connectors, and changes in retained soil. Standard provisions for the collection of data and samples from demolished ERs should be incorporated in contract documents.

It is relatively rare for an ERS to deteriorate to the point of a sudden collapse. When that occurs, it usually triggers an investigation that can yield useful information for the design of future structures. But

[19] Fishman, Kenneth. L. *"Asset Management and Earth Reinforcement Testing"*. National Workshop on Highway Asset Management and Data Collection. Raleigh, NC, September 2008.

for every retaining wall that fails catastrophically, there are hundreds, perhaps thousands, which are demolished under less dramatic circumstances; sometimes because of poor condition, but more often because a roadway is being widened or realigned. Every ERS slated for demolition is a potential source of valuable information.

It would be useful to know whether any highway agencies routinely collect "post-mortem" information from ERS that are being demolished. If such post-mortem procedures do not exist, it would be worthwhile to develop them. It would also be useful to develop some central mechanism for collecting and sharing that information.

10.7 Development of Decay Curves

Since the condition of in-service ERS deteriorates over time, it would be very useful to develop a decay curve representing the relationship of variation of condition state to the percentage of effective life elapsed. The condition rating system for ERS could be utilized, in conjunction with the structure's actual age, to classify the remaining service life. The estimation of the remaining service life could also reflect the type of wall (e.g., MSE with metallic grid, MSE with geotextiles, etc.). Another way to estimate remaining service life would be to develop curves for the variation of condition state with the elapsed time for each ERS type. However, the development of these curves require a good amount of historical data along with the elapsed time, and the condition state of the in-service retaining walls; and such data are scarce. These curves would, over time, also help in evaluating priorities and action alternatives for ERS maintenance, repair, and replacement.

With multiple inspections, engineers will be able to build up a body of data on the performance of various types of wall designs, elements, and materials over a period of time. Until that time, asset managers should use design service life only as a general predictor for large populations of walls and not for individual structures.

GLOSSARY

Most of the definitions in the following glossary have been adapted from either the Bridge Inspector's Reference Manual, Geotechnical Engineering Circular No. 2, and the NHI Earth Retaining Structures Reference Manual.[20]

A
AASHTO - American Association of State Highway and Transportation Officials.
AADT – Average Annual Daily Traffic.
ADT - Average Daily Traffic.
aluminized - coated with aluminum for corrosion protection.
anchored wall - a wall, typically of the non-gravity cantilevered type (e.g.. sheet pile, soldier-pile-and-lagging) that is provided with additional support by tiebacks (ground anchors) to a grouted zone or deadman anchors. Anchors may be strand steel or bars.
anode - the positively charged pole of a corrosion cell at which oxidation occurs.
appurtenance - an element that contributes to the general functionality of a facility, such as lighting and rest areas to a highway, or a parapet to a retaining wall
as-built plans - plans made after the construction of a project, showing all field changes to the final design plans (i.e.. showing how the bridge was actually built)
asset management – a systematic way for the owner of assets to identify the optimal allocation of available resources to those assets
auger - a drill with a spiral channel used for boring piles and sometimes for mixing, as in the case of soil-mixed walls.
B
backfill - material, usually soil or coarse aggregate, used to fill the space between an earth retaining structure and the slope or material it is designed to support.
base width ratio - width of base, i.e. from front to back, needed for stability of a given type of wall, expressed as a function of wall height
batter – the deviation from the vertical of a wall face
berm – a low embankment or shelf of earth along the edge of a road. In some regions, the word is synonymous with shoulder.
bin wall - a gravity retaining structure made up of interlocking metal or concrete bins. These are filled with granular, free-draining soil which is compacted inside each unit.
bond length - The portion of an anchor tendon that is in contact with the grout.
***Bridge Inspector's Reference Manual (BIRM)* -** FHWA manual on inspecting and evaluating in-service highway bridges. Available at the following URL: *http://www.fhwa.dot.gov/bridge/bripub.htm*.
bulkhead - a waterfront structure designed to protect the shoreline and/or the substructure of a wharf, dock, or relieving platform. Bulkheads are usually vertical or near vertical, and may be

[20] National Highway Institute. "Earth Retaining Structures (Reference Manual)". FHWA-NHI-132036.

constructed of concrete, stone, timbers or steel sheet-piling...
buttress - a bracket-like wall, of full or partial height, projecting from another wall to strengthens and stiffen the latter against overturning. forces. All parts of a buttress act in compression. Compare *counterfort.*
C
cantilever wall - a 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 in profile like an L or an inverted T.
catastrophic failure – a sudden or very rapid failure that results in human injury or death, significant property damage or major economic disruption**.**
cathode - the negatively charged pole of a corrosion cell that accepts electrons and does not corrode.
cathodic protection - a means of preventing metal from corroding by making it a cathode through the use of impressed direct current or by attaching a sacrificial anode.
centralizer - A device for positioning a tendon in a drill hole so that minimum grout cover is achieved all around it. GEC2 p. 66
centroid – (1) that point about which the static moment of all the elements of area is equal to zero; (2) in mapping the location of a large three-dimensional object, the estimated point about which the object would be in balance.
cherry picker - a truck with a boom-mounted bucket or work platform, enabling a person to perform tasks high above the ground.
chipping hammer - hammer such as a geologist's pick or masonry hammer used to remove corrosion from steel members and to sound concrete for delamination.
chloride - an ingredient in deicing agents that can damage concrete and steel structural elements
component. - A major part or constituent of a structure, as distinguished from the smaller parts or units of which the component is made. For example, if a brick wall facing is a component of a retaining wall, then the individual bricks are elements.
condition rating – a measure of the overall condition of a wall, or of specific wall elements, expressed either on a numerical scale or a set of standardized terms**.**
consequences of failure – the potential adverse results of the failure of a specific ERS
consolidation - change in volume of a soil mass under compressive load caused by water slowly escaping from the pores or voids of the soil.
construction joint - a pair of adjacent surfaces in reinforced concrete where two pours have met. Reinforcement steel extends through this joint.
continuous footing - a common footing underneath a wall, or columns.
coping - a course of stone laid with a projection beyond the general surface of the masonry below it and forming the topmost portion of a wall.
corbel - a projection from the surface of a structure that is designed to support for something above it, such as a parapet or a luminaire.
corrosion protection - any of a number of methods to limit corrosion of metal elements;.for example, by galvanizing or cathodic protection.
counterfort - a bracket-like wall connecting a retaining wall stem to its footing on the side of the retained material to stabilize against overturning. A counterfort, as opposed to a buttress,

acts entirely in tension.
coupon - a sample of steel taken from an element in order to test material properties.
creep - an inelastic deformation that occurs under a constant load, below the yield point, and increases with time.
crib wall - A gravity retaining structure made of interlocking timber or concrete elements. These are stacked log-cabin style to form a series of gridwork compartments or cribs, which are filled with granular material or stone.
culvert - a structure carrying a stream or drainage channel beneath an embankment, for example, a corrugated metal pipe or a concrete box culvert.
curtain wall - a thin wall between main columns, designed to withstand only secondary loads. In relation to retaining walls, the wall portion of a buttress or counterfort wall that spans between the buttresses or counterforts
cut wall construction - an earth retaining system in which the wall is constructed from the top down, for example, a soil-nailed wall or a sheet-pile wall.
cut wall. (1) a wall supporting the side of a highway cut or other excavated area;. (2) a wall constructed from the top down. See *cut wall construction*.
D
deadman anchor - an anchor that extends from the wall face to a mechanical anchorage such as a concrete block. See also *ground anchor*. .
deflection - elastic movement of a structural member under a load.
deformation - distortion of a loaded structural member; may be elastic or inelastic.
deformed bars - steel reinforcing bars with projections or indentations (deformations) to increase the mechanical bond between the steel and the surrounding concrete or grout.
delamination - (1) surface separation of concrete into layers; (2) separation of glue-laminated timber piles.
diaphragm wall - see *slurry wall*.
differential settlement - uneven settlement due to deformation or loss of foundation material, resulting tilting in either the longitudinal or transverse direction.
drainage -a system designed to remove water from a an earth retaining structure or to prevent water from accumulating behind it. Drainage systems may include swales, ditches, gutters, perforated pipes, weep holes, filter membranes, gravel filters, etc.
ductile fracture - a fracture characterized by plastic deformation.
ductility - the ability to withstand non−elastic deformation without rupture.
E
earth retaining structure – a structure designed to maintain a difference in ground elevation or to prevent a mass of earth from assuming its natural slope.
efflorescence - a deposit on concrete or brick caused by crystallization of carbonates brought to the surface by moisture in the masonry or concrete.
elastic deformation - non-permanent deformation; when the stress is removed, the material returns to its original shape
electrolyte - a medium of air, soil, or liquid carrying ionic current between two metal surfaces, the anode and the cathode.
electrolytic corrosion - corrosion of a metal associated with the flow of electric current in an

electrolyte.
element: - a specific product, device or material that is used in the construction of an ERS and that remains a permanent part of the structure, such as a reinforcing strip, a wall-facing unit, or a coating.
embankment - a mound of earth constructed above the natural ground surface to carry a road or to prevent water from passing beyond desirable limits; also known as bank.
erosion - wearing away of soil by flowing water not associated with a channel; see SCOUR.
exposed Wall Height - the vertical distance measured from the finish grade at the bottom of the wall (i.e. lower soil grade) to the finish grade at the top of the wall (i.e. upper soil grade). This height does not include the wall and depth of footing below grade.
externally stabilized - refers to a wall system consisting of an external structural wall against which stabilizing forces are mobilized, for example, a cantilever wall or a sheet pile wall.
F
facing panel - a prefabricated concrete or metal unit used in construction of MSE walls and stabilized soil slopes.
failure - a condition at which a structure reaches a limit state such as cracking or deflection where it is no longer able to perform its usual function; a collapse or racture.
fill wall construction. An earth retaining structure in which the wall is constructed from the bottom up, for example, a CIP concrete wall or a bin wall.
fill wall. **-** (1) a wall supporting the side of a highway embankment or other elevated feature created by placement of fill; (2) a wall constructed from the bottom up. See *fill wall construction.*
flexible wall facing - MSE wall systems in which each layer of reinforcement (geogrid, geotextile or welded-wire) is wrapped around the overlying layer of backfill to form the wall face. For permanent installations, this may be covered by an additional facing of shotcrete, gunite, .galvanized mesh, or prefabricated concrete or wood panels.
floating foundation - used to describe a soil-supported raft or mat foundation with low bearing pressures; sometimes applied to a "foundation raft" or "foundation grillage".
footing - the enlarged base of a an ERS, which distributes the structure load either to the earth or to supporting piles; the most common footing is the concrete slab; footer is a colloquial term for footing
footing. - for prefabricated modular gravity walls, a longtitudinal member at the base which provides the necessary erection tolerances and transmits the load to the foundation. For walls designed with a front batter, the footing is inclined to the design batter (GEC2 p. 50)
foundation failure - failure of a foundation by differential settlement or by shear failure of the soil.
G
gabion wall - a gravity wall made up of rectangular baskets filled with stone. The gabions may be made of galvanized steel, geosynthetic grid, or PVC-coated wire.
galvanic action - electrical current between two unlike metals.
galvanized - refers to iron or steel elements that have been coated with a layer of zinc for corrosion protection.
Geographic Information System (GIS) – computer software that enables various kinds of data,

including text and photographs, to be associated with coordinates on a multilayered digitized map. Information can be stored, retrieved, manipulated and displayed by turning map layers on and off and by clicking on the appropriate points on the map.
geogrid. - one of a class of geosynthetic materials having relatively large openings, often used as reinforcement in MSE walls.
geotextile - a class of woven geosynthetic materials often used for reinforcement in MSE walls.
gravity wall - a retaining wall that is prevented from overturning or sliding by its own dead weight.
ground anchor - An anchor, typically a prestressed metal bar, that extends from the wall face back to a grouted zone. See also *deadman anchor*.
Ground Penetrating Radar (GPR) – a portable device used to locate buried objects in soil and to locate defects and reinforcements in concrete
grout - mortar having a sufficient water content to render it free-flowing, used for filling (grouting) the joints in masonry, for fixing anchor bolts and for filling cored spaces.
guide rail – A metal or concrete barrier designed to absorb impact energy and deflect vehicles from a hazardous object or a steep dropoff.
gunite. - a type of cement that is sprayed on a surface through a high pressure nozzle. The mixture is delivered dry, with water being added at the nozzle. See also shotcrete.
gutter - a paved ditch; area adjacent to a roadway curb used for drainage.
H
hands-on inspection - inspection within arms length, , close enough that the structure or element can be touched with the hands and inspected visually; may be supplemented by nondestructive testing.
headwall - a structure, usually concrete or metal, at the ends of a culvert to retain the embankment slopes, anchor the culvert, and prevent undercutting.
heel - the portion of a footing behind the stem.
hinge - a point in a structure at which a member is free to rotate.
honeycomb - an area in concrete where mortar has separated and left spaces between the coarse aggregate, usually caused by improper vibration during concrete construction.
horizontal alignment - a roadway's centerline or baseline alignment in the horizontal plane.
I
insert-pile wall. - a wall constructed of micropiles that are larger in diameter and spaced farther apart than those in a root-pile wall, and which penetrate the potential sliding surface.
in-situ reinforced wall - refers to systems employing metal bars or pipes driven into the retained soil. See *soil-nailed wall* and *micropile wall*
intercepting ditch - a ditch constructed to prevent surface water from flowing in contact with the toe of an embankment or causeway or down the slope of a cut.
internally stabilized - refers to wall systems employing reinforcements within and extending beyond the potential failure mass
inventory item – a field in the ERS inventory database**.**
J
joint - in masonry - the space between individual stones or bricks; in concrete, a division in

continuity of the concrete.
L
lagging - horizontal members spanning between piles to form a wall. See *soldier pile and lagging wall*.
laser scanning – technique used to create a three-dimensional digital model of an existing structure without having to take detailed field measurements.
leaching - the action of removing substances from a material by passing water through it.
levee - an embankment built to prevent flooding of low-lying land.
leveling pad. - for MSE walls using precast facing elements, an unreinforced concrete leveling pad is poured to achieve necessary construction tolerances. For prefabricated modular block facings, the leveling pad may be compacted gravel rather than unreinforced concrete.
LiDAR (Light Dimension and Ranging) – a laser-based remote sensing technique that can penetrate vegetation, providing unobstructed images of terrain and structures.
Lift. - a quantity of fill that is laid down and then compacted. In the case of MSE walls, a layer of backfill between layers of reinforcement is sometimes referred to as a lift although it may consist of more than one compacted lift.
log wall – a gridwork of logs placed in alternate directions, and filled with compacted backfill, similar to a *crib wall*.
luminaire - a lighting fixture.
L-wall - a cantilever wall shaped in profile like an L, with the horizontal part being toward the retained soil. Often used where there not sufficient space for a T-wall.
M
maintenance and protection of traffic - the management of vehicular and pedestrian traffic through a construction zone to ensure the safety of the public and the construction workforce.
marine wall - a wall supporting a wharf, quay or other waterfront feature.
masonry - that portion of a structure composed of stone, brick or concrete block placed in courses and usually cemented with mortar.
mechanically stabilized earth (MSE) - refers to 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
metallically stabilized earth. **-** Refers mechanically stabilized earth systems employing metal reinforcements.
moisture scanning – An infrared technology used to detect presence of moisture in walls**.**
micropile wall a wall system consisting of an array of micropiles, generally steel rebar or pipe, which are installed from the ground surface to an underlying stratum that is below a potential sliding surface. It does not form a visible wall and is often used to stabilize unstable slopes.
modular block facing. - refers to MSE wall facings made up of prefabricated concrete blocks. The reinforcements are secured between vertically adjacent blocks, either by friction or by special connectors.
mortar - a paste of Portland cement, sand, and water laid between bricks, stones or blocks
MPT - see *maintenance and protection of traffic*.
MSE - see(1) m*echanically stabilized earth* and(2) *metallically stabilized earth*

N
NBIS - National Bridge Inspection Standards, first established in 1971 to set national policy regarding bridge inspection frequency, inspector qualifications, report formats, and inspection and rating procedures
NCHRP - National Cooperative Highway Research Program
NDT - nondestructive testing; any testing method of checking structural quality of materials that does not damage them
NHI – National Highway Institute.
non-gravity cantilevered wall – a walls deriving resistance through shear and bending stiffness and embedment of vertical structural elements, such as a sheet-pile wall or a soldier-pile-and-lagging wall.
O
offset - a horizontal distance measured at right angles to a survey line to locate a point off the line.
overcompaction –compaction of backfill behind the wall face during construction such that there are excessive lateral earth pressures against the wall. Drainage systems may also be damaged.
overturning - tipping over; rotational movement.
P
parapet - a low, non-bearing wall along the top of a retaining wall, designed to protect vehicles and pedestrians or for aesthetic purposes.
passive inclusion. - a reinforcing element, such as a soil nail, that is not post- tensioned
perched wall – a wall located on a slope, i.e., with significant slopes both above and below**.**
pilot survey - a test survey to evaluate survey procedures, personnel or equipment
piping - removal of fine particles from within a soil mass by flowing water.
plastic deformation - permanent deformation of material beyond the elastic range.
plumb bob - a weight hanging on a cord used to provide a true vertical reference.
pointing - the compacting of the mortar into the outermost portion of a joint and the troweling of its exposed surface to secure water tightness or desired architectural effect; replacing deteriorated mortar.
pop-out - conical fragment broken out of a concrete surface by pressure from reactive aggregate particles.
portland cement - a fine dry powder made by grinding limestone clinker made by heating limestone in a kiln; this material reacts chemically with water to produce a solid mass.
portland cement concrete - a mixture of aggregate, portland cement, water, and usually chemical admixtures.
post-tensioning - a method of prestressing concrete in which the tendons are stressed after the concrete has been cast and hardens.
prestressed concrete - concrete with strands, tendons, or bars that are stressed before the live load is applied.
pre-tensioning - a method of prestressing concrete in which the strands are stressed before the concrete is placed; strands are released after the concrete has hardened, inducing internal

compression into the concrete**.**
PS&E - Plans, Specifications, and Estimate; the final submission of the designers to the owner.
public road. - the term ``public road'' means any road or street under the jurisdiction of and maintained by a public authority and open to public travel.
Q
quality assurance (QA) - the use of sampling and other measures to assure the adequacy of quality control procedures in order to verify or measure the quality level of the entire bridge inspection and load rating program.
quality control (QC) - procedures that are intended to maintain the quality of a bridge inspection and load rating at or above a specified level.
R
rehabilitation - significant repair work to a structure.
Reinforced Earth - proprietary MSE system using steel strips connected to concrete facing.
reinforced soil slopes - systems employing reinforcement (generally geogrid or geotextile) in the backfill, similar to MSE walls, but with the inclination of the slope face typically less than 70 degrees.
resistivity of soil - an electrical measurement in ohm-cm that estimates the corrosion activity potential of a given soil.
Retained Earth - proprietary MSE system using strips of welded-wire fabric connected to concrete facing.
revetment - A waterfront structure, usually sloping, designed to dissipate the force of waves, floods, or other water action.
rigger - someone who erects and maintains scaffolding or other access equipment such as that used for structural inspection.
rip-rap - stones, blocks of concrete or other objects placed upon river and stream beds and banks, lake, tidal or other shores to prevent erosion or scour by water flow or wave action.
roadway shoulder – the drivable area immediately adjoining the traveled roadway.
rock buttress – an inclined gravity structure of naturally shaped rocks, built at the toe of a slope to stabilize it. One or more horizontal benches may be cut into the face of the slope to provide a stable base for the rock buttress. Often used to stabilize a slope after a landslide.
rockery – a gravity wall consisting of uncemented, interlocking rows of large rocks (naturally shaped quarry stone or boulders) that are not tied together and have a low tolerance for movement. Typically, constructed to provide erosion control and support for marginally stable slopes. See also *rock buttress*.
root-pile wall. - a wall constructed of small-diameter micropiles, usually steel reinforcing bars, that are closely spaced in a criss-crossed three-dimensional array. The objective is to knit the soil together into a coherent mass that will behave as a gravity structure.
rotary percussion wheel – A gear toothed wheel used on concrete to detect subsurface defects by their sound.
RSS. See *Reinforced soil slopes.*
S
sacrificial anode - the anode in a cathodic protection system.

sacrificial coating - a coating over a base material to provide corrosion protection, such as galvanizing on steel and aluclading on aluminum.
sacrificial thickness - additional material thickness provided for extra service life of an element in an aggressive environment.
safety harness - harness with shoulder, leg, and waist straps of approved OSHA design u
scaling - the gradual disintegration of a concrete surface due to the failure of the cement paste caused by chemical attack or freeze/thaw cycles.
scupper - an opening in the deck of a bridge to provide means for water accumulated upon the roadway surface to drain.
seepage - the slow movement of water through a material.
seawall. a wall built in a coastal location, usually retaining soil behind it but primarily built to protect the shoreline from erosion by wave action. See also *bulkhead*.
secant pile wall. - A wall constructed of drilled concrete piles that are alternately reinforced and unreinforced. The unreinforced piles are placed first. They are spaced slightly closer than the diameter of the reinforced piles so that, when the latter are drilled, they cut into the sides of the unreinforced piles on either side, forming an interlock. May bhe constructed with anchors.
section loss - loss of a member's cross sectional area usually by corrosion or decay
segmental facing - Refers MSE wall facings made up of precast elements.
segmental gravity wall – a wall constructed of manufactured modular concrete units stacked in a running bond pattern without mortar or reinforcement.
semi-gravity wall, rigid - A wall that retains a soil mass by a combination of its dead weight and its structural resistance, such as a cantilever/counterfort wall
service life – The projected remaining life (in years) of an existing structure or structural component under normal loading and environmental conditions before major rehabilitation or replacement is required.
settlement - the movement of substructure elements due to changes in the soil properties.
shadow vehicle – a truck, usually equipped with flashing signs or other traffic warning devices, that blocks a travel lane to protect people working on the road in front of it**.**
sheet pile wall - Wall consisting of interlocking steel or concrete sections, which are driven, vibrated or pushed to the desired embedment depth.
shop drawings - detailed drawings developed from the more general design drawings used in the manufacture or fabrication of ERS components
shotcrete - cement sprayed on a surface through a high-pressure nozzle. It is delivered wet to the construction site, with air being added at the nozzle to carry the mixture to the target surface. Shotcrete is used for, among other things, the facing of soil nailed walls. See also *gunite*.
sight distance - the length of roadway ahead that is easily visible to the driver "
silt - very finely divided siliceous or other hard rock material removed from its mother rock through erosive action rather than chemical decomposition
slide - movement on a slope because of an increase in load or a removal of support at the toe; also known as landslide
sliding – a type failure, usually of gravity or semi-gravity walls, in which the wall is pushed forward at its base
slope protection - a thin surfacing of stone, concrete or other material deposited upon a sloped

surface to prevent its disintegration by rain, wind or other erosive action; also known as slope pavement
slurry wall - an embedded cantilever wall of CIP concrete or precast panels, constructed within an excavated trench by the slurry method. Also known as a *diaphragm wall*. Typically built with anchors.
slurry - a dense mixture of water and suspended solids, either mineral or polymer, which is used to retain the sides of an excavated trench prior to pouring of tremie concrete or placement of precast panels. Often used in waterfront locations or areas with a high groundwater table.
soil mixed walls - walls constructed in situ using an array of mixing augers through which cement grout is pumped as the augers drill into the soil, resulting in a panel of overlapping soil-cement columns. H-beam or steel pipe reinforcements are inserted in the soil-cement columns prior to curing. The process is repeated until the panels form a completed wall.
soil nail wall- a 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.
soldier pile-and-lagging - a wall system consisting of vertical piles driven at intervals, with the intervening spaces filled by lagging, i.e., horizontal timbers or precast concrete elements that retain the soil and transfer its load to the soldier piles.
sounding - tapping a surface, usually with a sounding hammer, to detect delamination (concrete) or decay (timber)
spacer - in multiple element tendons, a device separating wires, strands or bars so that each element is adequately bonded to the anchor grout.
spall – a depression in concrete caused by a separation of a portion of the surface concrete, revealing a fracture parallel with or slightly inclined to the surface.
spider - inspection access equipment consisting of a bucket or basket which moves vertically on wire rope, driven by an electric or compressed air motor.
spread footing - a foundation, usually a reinforced concrete slab, which distributes load to the earth or rock below the structure.
stage - inspection access equipment consisting of a flat platform supported by horizontal wire-rope cables; the stage is then slid along the cables to the desired position.
stationing - a system of measuring distance along a surveyed baseline.
stem - the vertical wall portion of a retaining wall.
straight abutment - an abutment whose stem and wings are in the same plane or whose stem is included within a length of retaining wall.
strain - the change in length of a body produced by the application of external forces, measured in units of length; this is the proportional relation of the amount of change in length divided by the original length.
stress - the force acting across a unit area in a solid material.
structural stability - the ability of a structure to maintain its normal configuration, not collapse or tip in any way, under existing and expected loads.
substructure - the abutments and piers built to support the span of a bridge superstructure.
surcharge - a vertical load on the retained soil that may impose a lateral force in

addition to the lateral earth pressure of the retained soil, for example a building, vehicles, or a significant upslope. Wind pressure against a solid fence or noise barrier atop a retaining wall may also impose additional lateral forces on the retaining wall.
surface corrosion - rust that has not yet caused measurable section loss.
swale - a drainage ditch with moderately sloping sides.
switchback wall – a wall located at a switchback such that it that protects a part of the road at its base while simultaneously supporting another part of the same road above it.
T
tagging – placing a permanent sign on a structure so that inspectors and maintenance personnel can readily identify it in the field.
tangent pile wall - a wall consisting of a row of tangentially touching, drilled, reinforced-concrete piles. Often constructed with anchors. See also *secant pile wall*.
team leader - individual in charge of an inspection team or survey crew.
tendon - a prestressing cable, strand, or bar.
tensile strength - the maximum tensile stress at which a material fails.
thermal movement - contraction and expansion of a structure due to a change in temperature.
thermography - an infrared-based technology used to detect subsurface defects in concrete by measuring differences in the rate of heating and cooling.
tieback - see *ground anchor.*
tiered wall – 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
toe – (1) the front portion of a footing from the intersection of the front face of the wall to the front edge of the footing; (2) the line where the side slope of an embankment meets the existing ground.
toe wall – a wall at the foot of a slope**.**
torque - the angular force causing rotation.
transducer - a device that converts one form of energy into another form, usually electrical into mechanical or the reverse; the part of ultrasonic testing device which transmits and receives sound waves.
T-wall. - A type of cantilever wall shaped in profile like an inverted T.
U
ultrasonic testing - nondestructive testing of a material's integrity using sound waves.
ultrasonic thickness gage - an instrument used to measure the thickness of a steel element using a probe which emits and receives sound waves.
V
vertical alignment - a roadway's centerline or baseline alignment in the vertical plane.
viaduct - a series of spans carried on piers at short interval
voids - an empty or unfilled space in concrete [also backfill?]
W
weep hole – an opening in a concrete or masonry retaining wall to allow drainage of water from the retained soil.
wingwall - the retaining wall extension of an abutment intended to restrain and hold in place the

side slope material of an approach roadway embankment.
wire mesh reinforcement - a mesh made of steel wires welded together at their intersections used to reinforce concrete; welded wire fabric.
wythe – in a masonry wall, a single layer of brick or stone in the thickness direction **.**

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APPENDIX A – REVIEW AND ASSESSMENT OF CURRENT PRACTICE FOR THE MANAGEMENT OF ERS

APPENDIX A – REVIEW AND ASSESSMENT OF CURRENT PRACTICE FOR THE MANAGEMENT OF ERS

Questionnaires were sent to 60 highway agencies. They included the DOTs of all 50 states, Puerto Rico, the District of Columbia, and the City of New York, the Federal Highway Administration, four additional cities, and two Canadian provinces that were identified in the literature search as having ERS management programs.*

Responses were received from 40 agencies, 13 of which reported having some type of ERS management programs. These 13 responses are summarized below:

- 8 had a substantial inventory and inspection program.
- 3 had an inventory but no regular inspection.
- 1 had an inspection program but no formal inventory.
- 1 had an inventory and inspection program limited to experimental or monitored walls, and those not built to state standard design.

Nine additional agencies had no current ERS management program, but reported internal discussion, research, or planning activity related to such a program.

The agencies with an inventory / assessment system for retaining walls included:

1. Federal Highway Administration (FHWA) / US National Park Service (NPS),
2. California Department of Transportation,
3. Colorado Department of Transportation,
4. Kansas Department of Transportation,
5. Maryland Department of Transportation,
6. Minnesota Department of Transportation,
7. Missouri Department of Transportation,
8. New York State Department of Transportation,
9. Oregon Department of Transportation,
10. Pennsylvania Department of Transportation,
11. The City of Cincinnati,
12. New York City Department of Transportation, and
13. British Columbia Ministry of Transportation.

Many responses also included sample forms, documentation, and procedures in place within the agency, giving a clear overview of the asset management system or program.

* "FHWA" refers to the ERS asset management system developed for the National Park Service by the FWHA's Central Federal Lands Office. Responses for New York State DOT and New York City DOT were provided, with their permission, by Gandhi Engineering, which was the consultant to both agencies.

Agencies without an inventory / assessment system also provided feedback regarding the lack of asset management infrastructure within their agency, their desire to establish such a system in the near future, and the overall approach to start developing an ERS asset management system. For instance, Nebraska DOT planned to have a Mechanically Stabilized Earth (MSE) wall management system by the end of 2009. Some of these respondents used the "PONTIS" database to inventory their ERS.

Overall, these responses provided detailed information about different ERS asset management practices currently in use within the United States and abroad. The questionnaire was divided into two parts:

- 1. ERS Inventory, and
- 2. ERS Condition, Performance, and Service Life.

The questions are listed below, with a summary of the responses to each.

1. **<u>ERS Inventory:</u>**

   a. **What is the current status of your ERS inventory/inspection program?
   If possible, how many walls have been surveyed**?

   Eight agencies had substantial ongoing programs of inventory and inspection, although some were confined to specific geographic areas or to specific categories of walls. The eight agencies and, where provided by the agency, the numbers of walls, were: FHWA/NPS (3,500), Kansas, New York State (2,100), Oregon (500), Pennsylvania, British Columbia, Cincinnati (7,000) & New York City (2,000).

   b. **How do you identify and locate retaining walls**?

   Six of the eight agencies responding to this question checked "Physically locating the wall in the field by walking or driving to the wall". The next ranking methods, each reported by five agencies were "Using aerial surveys" and "Researching old drawings or records". Four agencies reported "Using roadway video surveys". Three reported "Using Asset Identification" and one reported "Using a Geographical Information System". In addition to the methods listed in the form, two agencies reported using staff knowledge. One mentioned adding new walls as constructed.

c. Are all types of retaining walls included in the inventory, or only a particular type of wall?

Most inventories included all wall types. Five of 12 included walls associated with bridges. Three of the 12 included walls associated with culverts. New York State and New York City did not include railroad-owned walls.

d. Do you have an established wall identification system for retaining walls?

Eight out of eleven agencies replied that they had a unique wall identification system.

Are the walls tagged?

Three of nine respondents tagged their walls.

e. What criteria do you use to select the retaining walls in your inventory process?

Out of eleven agencies responding to this question, four used minimum height of wall and four used minimum height of retained earth. In either case, the most common criterion was 6 feet (2 m in the case of New York State and British Columbia). Oregon used 4 feet; Cincinnati 2 feet.

Pennsylvania also used minimum length of wall. Kansas excluded “landscape” walls, i.e., those that were less than 6 feet in height, had a level backslope and less than 100 psf surcharge. In addition to wall height, FHWA considered batter; location relative to roadway; and association with a bridge or culvert. British Columbia, in addition to minimum height, cited a minimum face slope greater than 45 degrees. No one mentioned a minimum surface area or a legal definition as a criterion.

f. How do you define a retaining wall, especially in situations where a retaining wall is attached to or part of another structure such as a bridge or culvert?

Most agencies excluded walls that would otherwise be covered by their existing bridge or culvert inventory and inspection programs. Some use a specific distance from the abutment; for example, 40 feet for FHWA, 100 feet for Pennsylvania, and 10m for New York State. However, most seemed to take a functional approach, i.e., if the wall retained earth independently of another structure, and would continue to do so even if the other structure were to be removed, it was considered a retaining wall and was included in the ERS inventory. Cincinnati, on the other hand, excluded any wall attached to another structure.

g. What general data categories are collected for each ERS in the inventory?

- Location. — 10
- Type -- 9
- Function — 7
- Geometrics — 8
- Condition of structure and components — 8
- Nature of roadway traffic levels and surrounding development—5
- Risks associated with the structure's failure – 3

Other items cited included: Restricted zone for permits (Minnesota); maintenance/ repair/ replacement work orders (FHWA); GPS coordinates (Oregon, New York State); wall attachments; adjacent features; external stability conditions (Oregon); date built (and reconstructed, if applicable); material; physical and component types (foundation / wall / backfill / post / mount); detailed dimensional data (including begin and end stationing, offset, distance to road, slope, clearance); historic eligibility; architectural forms (Pennsylvania); detour length; traffic class (British Columbia); photographs, letters; plans attached to inventory (Cincinnati, New York State).

h. Do you have a form or a checklist of items that must be completed as part of your inventory?

Of 11 responses, 8 were yes and 3 no.

i. What type of database and/or mapping software do you use for maintaining your inventory and inspection data?

Four respondents used Access and three Oracle. FHWA used both. Cincinnati used FoxPro. Cincinnati and NYS used ESRI GIS software. Three other agencies used GIS software, but did not identify the specific software.

j. Does your agency have a management system, i.e., computer software, to manage the walls?

Six of 10 respondents reported having computer software to manage their walls. Two of these noted that walls were included in their Bridge Management System.

k. If you do, how is your agency's wall management system (WMS) managed?

Eight of nine respondents reported that their system was managed from a central office location and one from district locations.

How many regions or districts do you have?

Numbers reported by U.S. states and British Columbia ranged from 6 to 14.

l. How is your agency using your WMS?

Of nine agencies responding, eight used WMS for inventory, two for planning and one for budgeting. FHWA used its WMS for all three, but lacked good age data for Life Cycle Cost Analysis (LCCA). Two other agencies said that they planned to use their WMS for planning and budgeting in the future. In addition, Minnesota reported using its WMS for permits; BC for inspection and ranking, and Cincinnati to determine ownership for repairs.

m. What office, division or branch is responsible for conducting and managing ERS inventories and condition assessments within your organization?

Of ten agencies responding, six said responsibility was with a bridge or structures unit, one with a maintenance unit, one with district offices, and two with a geotechnical unit.

n. Is your WMS linked to other management systems so they can communicate together? **If yes, how does your agency link and communicate among management systems?**

Of eight agencies responding, two answered "Yes" to this question. Minnesota's system was accessible by its permitting department, and British Columbia's was linked to its road inventory management system. FHWA noted that the TS&L (Type, Size, and Location) information was shared manually, but not under a formal data management architecture.

Is your retaining wall management system linked to pavement management system, maintenance management system and vice versa?

Of seven agencies responding to this question, four simply answered no. The other three reported as follows: FHWA said the NPS Road Inventory Program is the ultimate storage for all roadway features (walls, signs, guard rails, etc.). OR said no, but some "Pontis" tables can be imported for data consistency with bridge inventory. PA's WMS is linked to Roadway Management, Planning & Programming System, and Maintenance Management System.

2. ERS Condition, Performance, and Service Life:

a. Do you (or do you plan to) inspect the retaining walls on a regular cycle? If so, at what intervals?

Of nine agencies responding, three said no and six said yes. The inspection intervals ranged from 2 years to 7 years. Oregon inspected Good walls every 5 years, Fair or Poor more often, depending on evaluation. FHWA was considering a 5 to 7 year cycle.

b. What wall elements and characteristics are evaluated during your inspection or condition assessments?

In response to this question, six agencies sent copies of inspection forms or excerpts from their manuals. Specific items mentioned in replies included:

Wall type	Foundation	Wall alignment
Facing structure/treatments	Surface coatings	Attachments
Guardrails/parapets	Backfill material	Backfill slope
Drainage	Erosion	Vegetation
Roadway	Curb/Berm/SW/shoulder	Adjacent features

What type of rating system do you use? Please send us a copy of your inspection and rating forms.

Five agencies sent copies of forms. Additional specific replies were as follows: Oregon had a three level rating system (good/fair/poor), Cincinnati used a scale from 0 to 4, and New York State used a scale of 1 to 7. FHWA reported that wall elements and global performance were rated individually, and then rolled up into a wall rating. This rating was then considered along with consequence of failure, design criteria (quality of design), and cultural issues to make a decision (no action, repair, replace, etc.).

c. Do you use yellow or red flags to identify unsafe or hazardous conditions as a result of your inspection?

Of eleven agencies responding to this question, eight answered “No”. The “Yes” answers were clarified as follows: FHWA did call out hazards specifically in the rating, but did in follow-up letters to NPS. Oregon notified Bridge Operations Section and began detailed monitoring/inspection/evaluation. In Missouri, districts that spotted a problem notified the Bridge Division or Soils & Geology in the Construction Materials Division.

What percentage of retaining walls required emergency repairs?

Six agencies responded to this question. Cincinnati reported 10% in 1990 but only 1% in 2008. Generally, among the other five respondents, while some walls were found to need repairs, few or none were of an emergency nature.

d. Do you use any remote sensing technology to characterize buried components of retaining walls or to determine their condition?

There weren't any "yes" replies to this question. FHWA commented that "If we need additional investigation it is noted in the review form and expensed as an investigation under the work order".

e. Have you developed any method for estimating the remaining service life of existing retaining walls?

There weren't any "yes" replies to this question. FHWA commented **"**We were largely unsuccessful acquiring date of construction info during our first inventory efforts. We are currently going back to the parks for this info so we can correlate condition to age (if possible)". Minnesota noted that it has participated in research about corrosion of its MSE.

f. Do you use data from your wall inspection as an asset management tool for budgeting purposes?

Four of eight responses were "No." The "Yes" replies were explained as follows:

--FHWA: NPS used work orders to determine maintenance/repair expenses park-to-park (or track deferred maintenance).

--PA: Spreadsheet used inspection data to establish a hierarchy for repair/replacement.

--BC: Yes, but not fully developed.

--Cincinnati: Prioritized walls for repair.

g. Are there any training or qualification requirements for retaining wall inspectors? If yes, please provide details.

Four of eight replies were "no" or N/A. Two agencies required "trained" or "certified" bridge inspectors; or required a civil engineer with a Full Engineer (F.E.) certification. New York State required a Professional Engineer (P.E.). FHWA used a 2-man team (minimum) in which the licensed lead had to be a geotechnical engineer. "Office and field training are required … including steep slope rope access training".

h. Please explain how your agency optimizes its budget with respect to prioritizing earth retaining structure repairs and rehabilitation projects to improve the overall network performance measures within your agency.

Five agencies indicated N/A or said that walls were repaired on an as-needed basis. Three other agencies indicated that wall projects were considered in relation to other highway assets. Pennsylvania noted that walls rarely lead to a project. They were repaired or improved in conjunction with highway projects.

i. How does your agency identify, prioritize, select and track earth retaining structure improvement, rehabilitation and replacement projects?

Cincinnati had a specific wall and landslide program through which such projects were funded. In Oregon and Pennsylvania, wall projects were handled in Bridge Management programs. In British Columbia, projects were prioritized by the respective regions. FHWA reported that priorities were park-specific, not NPS wide.

j. Are risks associated with ERS failure assessed for each wall?

Three of the seven respondents to this question generally did not assess risks. The listed risks checked by the other four agencies were as follows:

- Failure potential: 4
- Extent of failure: 1
- Threats to life-safety: 2
- Link criticality / redundancy: 4
- Average Daily Traffic (ADT) impacts: 4
- Budget impacts: 2

APPENDIX B- DATA DICTIONARY

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Survey Log Data

1. ID Number - A unique identification number assigned to each ERS, which will be used in managing all data and documents related to that ERS. It may consist of a combination of letters and numbers. It is useful, but not essential, for the number to include location indicators such as highway route number or milepoint. The numbering system may be an extension or variant of existing asset numbering systems, such as for bridges or culverts. In any case, it should not conflict with those systems.

2. Date of Survey - Date style should be consistent with agency practice.

3. Times of Arrival and Departure - These items will be used to evaluate time needed per site and modify team deployments as necessary. Time of day information may also be helpful for evaluation of certain observed conditions such as wall moisture.

4. Surveyed by - List names of at least the two senior team members, using full surnames.

5. Weather - Give the temperature plus one or two brief descriptors such as *clear, overcast, moist* or *windy.* This information may be needed to evaluate observations on soil moisture and operation of wall drainage.

6. Soil Moisture - Indicate whether the soil around the base of the wall is dry, moist or saturated.

7. Work Zone Safety Devices/Measures - List safety devices/measures used (e.g. arrow board, flagger, and shadow vehicle) and any additional measures recommended for future visits tot his site.

8. Special Access Equipment - Indicate special access equipment used (e.g. lift truck, cherry picker, long ladder, rock-climbing gear) and other equipment recommended for future visits to this site.

Location Data

9. GPS Location Coordinates - A Global Positioning System (GPS) reading should be taken at the approximate center of the length of each wall. This will determine the coordinates that will be used in GIS mapping. The coordinate system should be consistent with agency practice. Transposition to other desired coordinate systems (latitude & longitude, UTM, etc.) can be calculated and added to the database automatically. For long walls of, say, 100 m (328 ft) or more, readings should be taken for beginning and end points. A single reading at the center should suffice for shorter walls.

10. Location - Give a location or address by which the ERS can easily be found in the field. If along a highway, indicate the route number, direction of travel and either milepoint or distance beyond a permanent point of reference such as a bridge or crossroad. If the wall is part of an interchange, indicate which ramp. If on a local street, reference the location to the nearest house number or cross street(s). If the inventory team was working from an ARAN (Automated Road Analyzer) or similar automated roadway survey, consider including the milepoint recorded in that survey.

11. Offset - Give the direction (R/L or compass direction) and minimum lateral distance from pavement edge.

12. Location Photos - This field will be used for links to one or more general location photographs.

13. District / Political Subdivision - To be entered in the office. Indicate the political subdivision (e.g., county, city) and/or the highway maintenance district. This information can be entered automatically from corresponding map layers in the GIS.

14. End Coordinates - For a long wall, say 100 m (328 ft) or more, take additional GPS readings at the beginning and end points.

15. Bridge/Culvert Association - To be entered in the office. If the ERS is associated with a bridge, indicate the BIN number, approximate distance from main span, and whether or not the ERS is currently included in inspections of that bridge. If the ERS is part of a culvert, the culvert number, if any, should be shown. In the broadest sense, an ERS can be considered associated with a bridge if it is close to be economically included in bridge inspections. A working definition of “associated” should be decided on at an early stage. Which ERS will actually be included in bridge inspections can be determined later, after there is a sufficient body of data on which to base decisions.

16. Other Related Feature - Indicate by type any non-highway facility (e.g. school, park, and store) or any non-mainline ancillary facility, such as a ramp, parking area or service road, of which the ERS is part or that might be affected if it failed. This will help to locate walls in the field or on aerial surveys, and to prioritize them for inspections or maintenance. Note that an ERS may be associated with a bridge and also related to an ancillary facility or non-highway property.

17. Block/Lot Number - To be entered in the office. If a related feature identified above is not on highway property, insert the tax block and lot number.

18. Access Constraints - Use this field to indicate such conditions as narrow or absent highway shoulders; fences, barbed wire, a water body, steep upslope or down slope, or dense vegetation.

Also indicate unusual or hazardous work zone conditions, such as falling rock or location on a curve with inadequate sight distance. Such information is important in preparing for future inspections or other work.

19. Did Access Problems Affect Accuracy? - Answer yes or no. If yes, indicate measurements or conditions that had to be estimated. The affected data fields can be listed by number.

20. Photos of Access Constraints.

Function Data

21. Functional Type - Indicate the general function type (e.g., cut, fill, switchback, slope protection, sea wall).

22. Supported feature - If applicable, indicate the specific feature(s) supported by the ERS, e.g., mainline roadway, deceleration lane, ramp, parking area, service road, sidewalk, bike path, stream, and canal. A single wall may both support features above and protect features below.

23. Protected feature - If applicable, indicate the specific feature(s) protected by the wall. See above.

24. Photos of supported and/or protected features.

Dimension Data, General

If the inventory is done in two stages, the following items can be obtained by the survey team in the first stage, except for item 31, Total Height.

25. Exposed Height - Indicate the exposed height of the wall at the maximum point, excluding any top-of-wall feature that is not designed to retain soil, such as a parapet or noise wall.

26. Total Length - This is the entire length rather than just the length meeting the criterion. It should also reflect the actual length of the wall rather than length along the roadway or other parent asset. The latter can be recorded separately or derived from the beginning and end points recorded under "Location."

27. Wall Face Slope - Indicate the wall batter or face slope in degrees of deviation from the vertical. If the wall face has rotated forward, so state, followed by the number of degrees of deviation. This will be compared with the as-built face angle in item 53.

28. Exposed Height at Beginning Point - For long walls. Exposed height excludes top of wall features not designed to retain soil.

29. Exposed Height at End Point - Exposed height measured as in the preceding item. Beginning and end points refer to the direction of travel indicated in the Location entry.

30. Height Above Retained Soil - This should be entered where the height of the retained soil is, say, 6 inches or more below the back of the wall. Wall height should be measured excluding any top-of-wall features not designed to retain soil.

31. Total Height - This includes the buried or embedded portion of the wall, but excludes top-of-wall attachments not designed to retain soil. If no as-builts or other records are available, the inspector may estimate the embedded portion. Indicate whether the height is based on records (R) or estimated (E).

32. Estimated Area of Exposed Face - This is estimate is helpful in planning and prioritizing further actions. It should not be used for cost estimates. The quantity shown should exclude top of wall attachments that are not designed to retain soil. .

33. Criterion Length - If only part of the wall meets the height criterion, give the length of that portion

34 Offset of Criterion Portion - If the wall portion above is not parallel to the roadway, or its offset is different from that shown in item 11, provide the minimum offset of the ERS portion meeting the height criterion.

35. Photo of Top Profile - To be included where the top profile is irregular**.**

36. Upslope Angle - Indicate the angle of any upslope above the top of the wall.

37. Downslope Angle - Indicate the angle of any downslope from the foot of the wall.

38. Roadside Features Above - Briefly describe any roadside features behind the top of the wall (e.g., berm, shoulder, guard rail, sidewalk curb).

39. Roadside Features Below - Briefly describe any roadside features at the base of the wall (e.g., berm, shoulder, guard rail, sidewalk curb).

40. Photos of Roadside Features

Structural Data, Preliminary

Information for most structural fields should be determined by the inspector. If the field work is done in two steps, data for the following fields can be recorded by the survey crew.

41. Wall Face Material - Briefly indicate the face material, e.g., stone, concrete panels, concrete block, shotcrete.

42. Apparent Wall Type - See the list of structural wall types in Table 2 located in Chapter 2 of the main report. This is a preliminary classification, to be confirmed by the inspector.

43. Wall Surface Treatment - Indicate any wall surface treatment, e.g., painted, galvanized, tar coated.

44. Wall Top Feature - Give the type and, if accessible, the width of any coping or cap at the top of the wall.

45. Top-of-Wall Attachments - Give the type and height of any top-of-wall attachment such as a parapet, fence, railing, noise wall, light pole or sign pole..

46. Wall Face Attachments - Briefly identify any attachments such as conduits, light fixtures, signs or traffic signals.

Structural Data, Verified

These fields will be completed on the basis of construction records and on-site determinations by the inspector. Additional detail will be provided in the inspector's report, which will be retrievable as a "pdf" file (see item 70)

47. Structural Type - Select the general structural type and sub type, for example "Conventional Gravity – CIP Concrete" using a standard classification such as that shown in Table 2. Use consistent terminology so that records can be easily sorted by structural type.

48. Total Wall Face Area - This should include the buried or embedded portion but exclude top-of-wall attachments that are not designed to retain soil. This quantity should be obtained from as-built drawings or other available records. If records are not available, it should be carefully estimated by the inspector.

49. Estimated Replacement Cost Per Square Foot - This should be based, to the extent that data are available, on the agency's records of construction costs for each type of wall. Failing that, it may be based on the original cost, if known, adjusted for inflation, or on industry references such as *RSMeans Heavy Construction Cost Data*.

50. Cost Estimate Reference - State the source of the above estimate, including the date.

51. Estimated Total Replacement Cost - This should be based on the unit cost in the preceding field, with appropriate additions for top of wall attachments or other ancillary features.

52. Foundation Type - Where applicable, indicate the foundation type (e.g., spread footing, drilled caissons, and piles) and depth.

53. Wall Face Angle as Built - To be obtained from as-builts or other records.

54. Proprietary Type - For proprietary wall systems or wall facings, give the system name and manufacturer.

55. Fill Material - Briefly describe the backfill material or cellular fill material

History and Ownership

56. Year Built - This will be the base year for determining service life and depreciation. Give the year of original construction. However, if the wall was substantially rebuilt so that it was restored to an essentially new condition, give the year of that reconstruction.

57. New or Retrofit - Was the wall built as part of a new highway project or retrofitted on an existing highway.

58. Design Service Life - To be obtained from design documents.

59. Current Owner - Indicate the current ownership or maintenance responsibility.

60. Contact - Give appropriate contact information for use in the event of an emergency or, for non-agency walls, a need to access the wall for inspection.

61. Original Owner - For publicly owned walls only, indicate the original owner if it was other than the current owning agency and the year jurisdiction was transferred.

62. Original Contract Number - If obtainable, list the original contract number

63. Original Cost - If obtainable, list the original cost. Do not adjust for inflation in this field.

64. Original Designer **-** Identify the actual designing agency or consulting firm. If unknown, so state. Do not use N/A.

65. Original Contractor - Identify the original construction contractor. If unknown, use the word *unknown* rather than N/A.

66. Maintenance / Repairs / Modification Record - This field is a listing of any significant repairs, non-routine maintenance or modifications to the original structure, e.g. crack repair, or the addition of a noise wall. This information may either be entered directly into the database or called up by a link to a separate document. For each action, give the type of work, date, contract number and contract amount. Where appropriate, also identify the designer and contractor.

<u>Condition Data, Preliminary</u>

67. Checklist Conditions - The condition of each ERS must be evaluated by the inspector. However, if the field work is done in a two-step process, it is useful for the field team to observe, report, and photograph any conditions that may be indicative of a problem. A suggested checklist of such conditions is given in Section 4.12 of the main report. Any conditions present should be reported in this data field. The survey team should also note any checklist condition that could not be observed because of access constraints or other circumstances. If the fieldwork is done in a one-step process, the same or a similar checklist should be used by the engineer and included in his or her report.

68. Condition Photos & Sketches - This field is for links to photos of conditions reported above. If appropriate, include a sketch showing the locations of the defects and keyed to the photographs.

69. Inspection Priority - If the field work is done in a two-step process, the survey team leader should recommend whether the wall ought to be given priority in scheduling a condition evaluation.. The recommendation should consider not only the condition of the wall but also the nature of any facilities that could be affected by a failure. The priority recommendation may be expressed numerically or on a simple scale such as “normal/moderate/high.”

<u>Condition Data From Inspection</u>

70. Inspection Report - Whether in a one-step or two-step process, the condition evaluation will be performed by a qualified inspector. The detailed inspection report, as well as reports of future periodic inspections, will be a standalone documents that can be retrieved and read through links to this field.

71. Inspection Date - This will be the date of the condition evaluation. In the future, as periodic inspections are performed, it will be the date of the most recent inspection.

72. Name of Inspector - Give full name and title. If a consultant, include the firm. This information will be updated for future periodic inspections.

73. Prior Documentation Reviewed - Indicate the types of documentation (e.g., as-built drawings, test reports) that were available and reviewed prior to the inspection.

74. Potential Failure Type - State the type of failure process identified or suspected, such as overturning, sliding, anchor failure. Where applicable, note the specific wall elements involved, such as piles, anchor heads, or facing panels.

75. Condition Rating - This should be an overall condition rating, using the 1-to-7 bridge rating scale or a comparable scale that is consistent with agency practice.

76. Projected Service Life - If the condition of the wall is consistent with normal aging, this will be based on the design service life minus years elapsed since construction. However, if there is evidence of distress or premature deterioration, the inspector should estimate when replacement will be required in the absence of major repairs or reconstruction.

77. Recommended Action Type - State the type of action, if any, recommended by the inspector, e.g., monitor, maintain, repair, replace. Use consistent terms that can be searched on.

78. Recommendation Action Summary - Briefly summarize the action recommendations given in the inspection report. Mention specific parts of wall and wall elements where appropriate.

Consequences-of-Failure Factors

The information in these fields is important for setting priorities, and for rapid and effective response in the event of an ERS failure. This information should be determined independently of the actual condition of the wall.

79. Critical Wall Height - For a protected feature, this is height of the wall at the point where it most exceeds the horizontal distance from the base of the wall to the edge of the roadway or feature.. For a supported feature, this is the height of the wall at the point closest to that feature

80. Critical Distance - This is the distance from the protected or supported feature at the point of critical wall height. If there are both protected and supported features, use the lesser of the two distances.

81. Roadway Type and Lanes - Using terms consistent with agency practice, indicate the roadway type and number of lanes in each direction.

82. Sensitive Facility Supported - Identify any sensitive facility near the top of the wall. A sensitive facility is one where there would be a higher than usual probability of injury, property damage or economic disruption in the event of a wall failure. Most sensitive facilities will be buildings or areas of pedestrian activity adjacent to the right of way. Sensitive facilities within the right of way may include service areas, scenic overlooks and picnic areas.

83. Sensitive Facility Protected - Identify any sensitive facility near the base of the wall. See also the above.

84. COF Rating - The potential consequences of failure (COF) for the wall should be rated independently of the actual condition of the wall. Consider the likelihood and potential severity property damage, personal injury, traffic disruption, length of detour, blockage of access to businesses or public facilities. The COF should be rated on a simple scale such as "moderate, severe, and very severe."

85. Traffic Volumes - Indicate the ADT or other appropriate measure of traffic volume. On a road with significant commuter traffic, provide peak-hour directional volumes if available.

86. Interchange Distances - If a limited access highway, give the distances to the nearest interchanges in each direction.

87. Detour Length - Give the length of the potential detour in the event of a highway blockage at this point.

88. Affected Locations - Identify any communities or specific facilities, such as a recreation area or a shopping center, which would be affected in the event of a highway blockage.

89. Utilities Near Top of Wall - List utility lines that might be affected by a wall failure. Indicate type of utility (water, sewer, electric, etc.), whether overhead or underground, distance from wall crest, and owner. If overhead, indicate the support type.

90. Utilities Near Base of Wall Do the same as above for utilities near the base of the wall.

91. Utilities on Wall Face List utilities that might be affected by a wall failure or that might have to be moved in order to repair the wall.

Action Priority

92. Action Approved - In a two-step process, this space can be used for inspection priority. After inspection, this space should be used for actions recommended by the inspector. Include the date of the approval and the person approving.

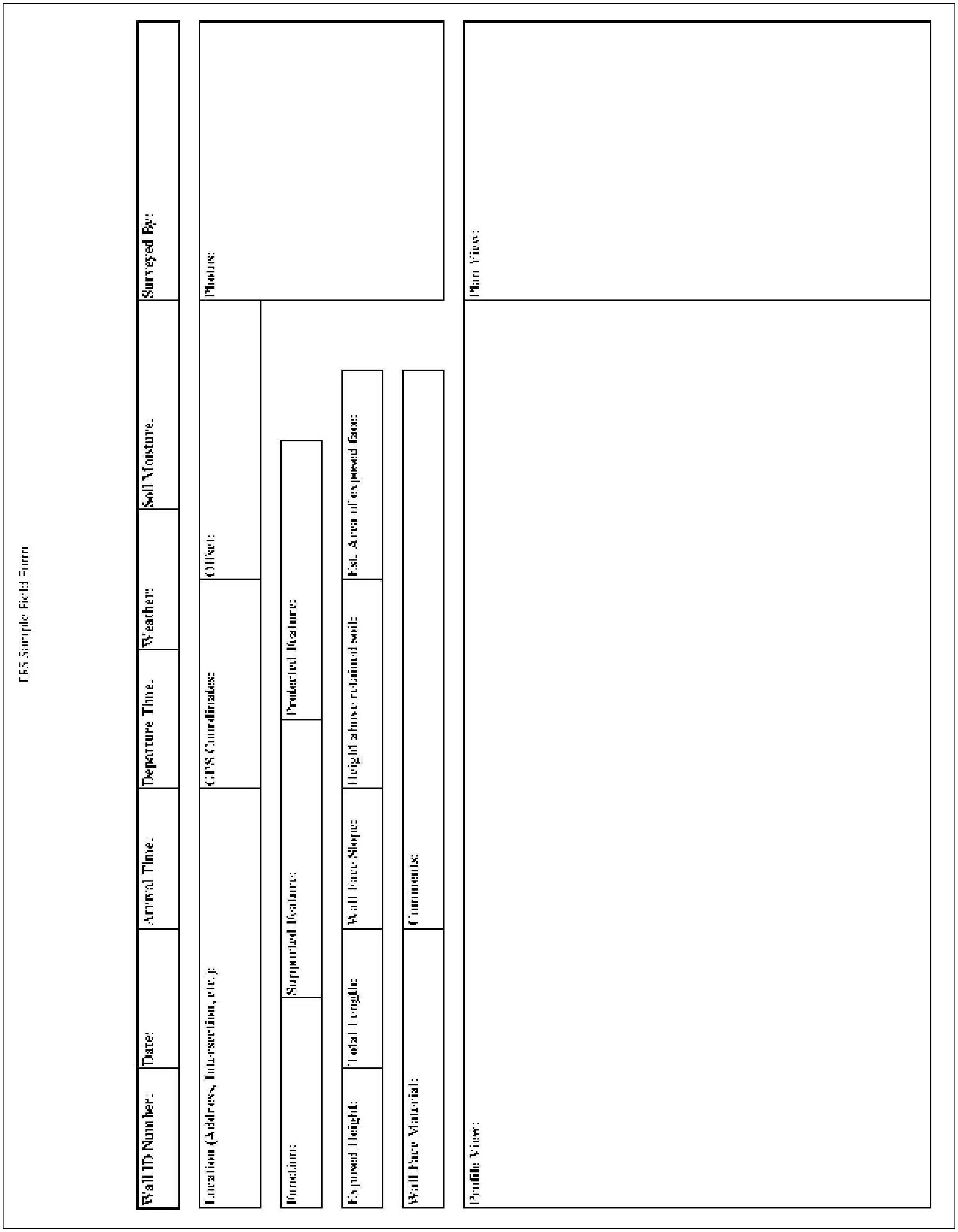
93. Action Priority - Indicate the degree of priority on a simple scale such as moderate, high, or urgent.

94. Action Date Scheduled - Enter the action date if and when assigned.

95. Action Completed - Enter the date the action was completed.

APPENDIX C – SAMPLE FIELD FORMS

SAMPLE INVENTORY FORMS


ERS Sample Field Form

Wall ID Number:	Date:	Arrival Time:	Departure Time:	Weather:	Soil Moisture:	Surveyed By:

Location (Address, Intersection, etc.):
GPS Coordinates:
Offset:
Photos:
Function:
Supported Feature:
Protected Feature:
Exposed Height:
Total Length:
Wall Face Slope:
Height above retained soil:
Est. Area of exposed face:
Wall Face Material:
Comments:
Profile View:
Plan View:

Figure 9: ERS Field Form Sample using the Minimal Required Fields described in Appendix B.

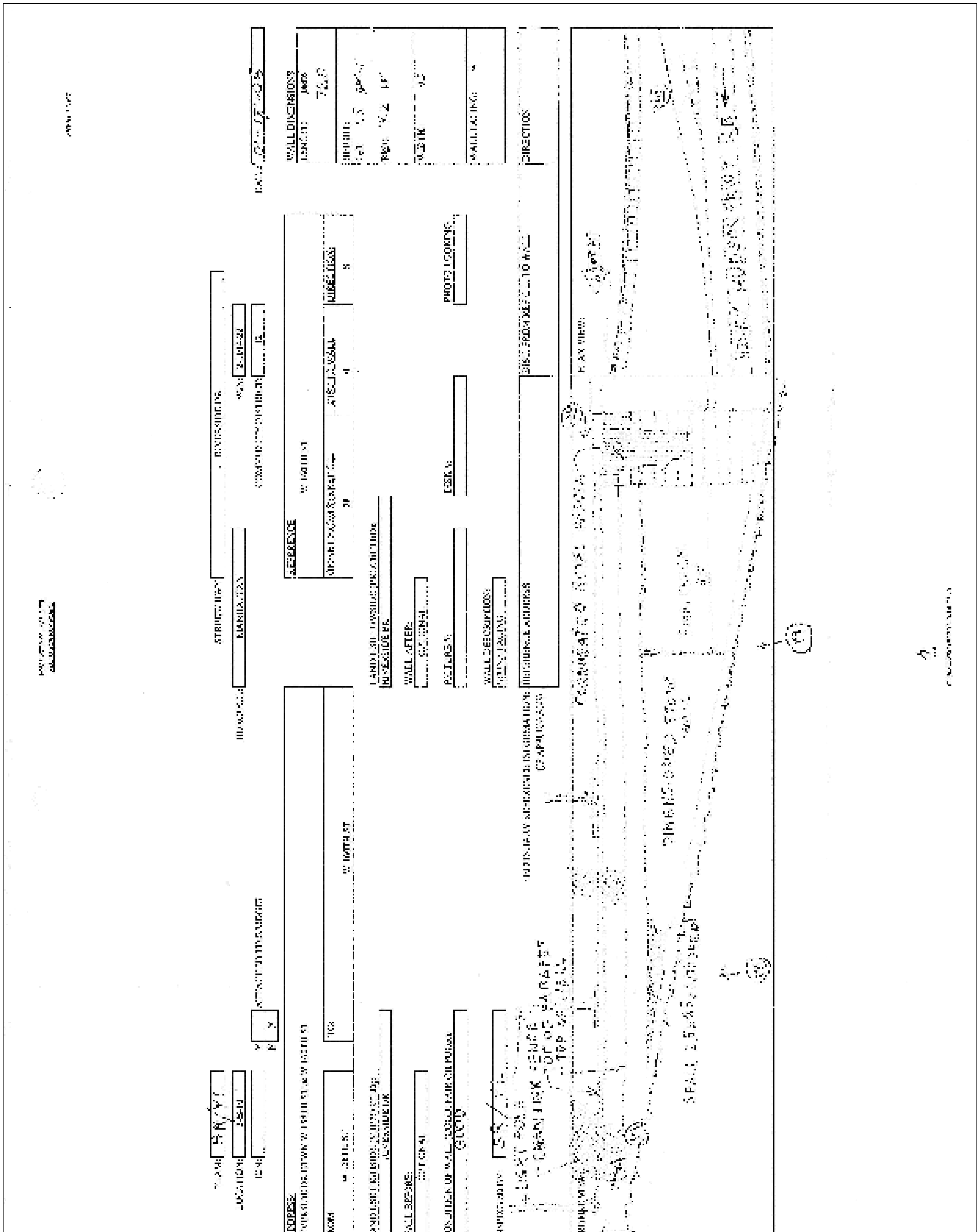


Figure 10: Example of a Field Survey Form used by New York City DOT and New York State DOT during the Development of their Retaining Wall Management System.

SAMPLE INSPECTION FORMS

Element	Condition Narrative	Condition Rating X	Weighting Factor =	Condition Score	Data Reliability
	Primary Wall Elements				
Piles and Shafts		1-10	8		1-3
Lagging		1-10	8		1-3
Anchor Heads		1-10	8		1-3
Wire/Geosynthetic Facing Elements		1-10	8		1-3
Bin or Crib		1-10	8		1-3
Concrete		1-10	8		1-3
Shotcrete		1-10	8		1-3
Mortar		1-10	8		1-3
Manufactured Block/Brick		1-10	8		1-3
Placed Stone		1-10	8		1-3
Stone Masonry		1-10	8		1-3
Wall Foundation Material		1-10	8		1-3
Other Primary Wall Element		1-10	8		1-3
	Secondary Wall Elements (WF=0.5 for CR=8-10/ WF=1.0 for CR=4-7/WF=5 for CR=1-3)				
Wall Drains		1-10	0.5-5		1-3
Architectural Facing		1-10	0.5-5		1-3
Traffic Barrier/Fence		1-10	0.5-5		1-3
Road/Sidewalk/ Shoulder		1-10	0.5-5		1-3
Upslope		1-10	0.5-5		1-3
Downslope		1-10	0.5-5		1-3
Lateral Slope		1-10	0.5-5		1-3
Vegetation		1-10	0.5-5		1-3
Culvert		1-10	0.5-5		1-3
Curb/Berm/Ditch		1-10	0.5-5		1-3
Other Secondary Wall Elements		1-10	0.5-5		1-3
	Wall Performance				
Performance		1-10	8		
WALL RATING	Weighting Factor (x10) and Condition Score Totals				
	Wall Condition Rating (= [Condition Score Total/Weighting Factor Total (x10)] X 100)				

Figure 11: FHWA / NPS Wall Inventory Program (WIP) Sample Inspection Form.

Element	Element Definition
Primary Element Condition Ratings	
Piles and Shafts	Soldier piles, sheet piles, micropiles or drilled shafts, as well as supplemental structures such as walers, comprising part or all of the visible wall.
Lagging	Structural lagging between piles and walers.
Anchor Heads	All visible parts of tieback anchor, including pad (generally observed without removing cap).
Wire/Geosyn. Facing Elements	Visible facing/basket wire, soil reinforcing elements, hardware cloth, geotextile/geogrids and facing stone.
Bin or Crib	Visible portion of cellular gravity wall.
Concrete	Visible precast or cast-in-place concrete wall and footing elements (does not include piles, lagging, crib blocks, manufactured block/brick, and architectural facing).
Shotcrete	Visible shotcrete (does not include piles, lagging, architectural facing or other specific elements).
Mortar	Visible mortar used between uncut or masoned rock, manufactured blocks or brick, or used for wall repairs.
Manufactured Block/Brick	Manufactured blocks and bricks, including CMU's segmental blocks, large gravity blocks, etc. (does not include concrete lagging or crib wall components).
Placed Stone	Dry-laid or mortar-set *uncut* rock.
Stone Masonry	Dry-laid or mortar-set cut rock.
Wall Foundation Material	Soil or rock immediately adjacent to and supporting the wall.
Other Primary Wall Element	Any primary wall element not listed (provide detailed narrative definition).
Secondary Element Condition Ratings	
Wall Drains	Function and capacity of visible drain holes, pipes, slot drains, etc., that provide wall subsurface drainage.
Architectural Facing	Facing that is not relied on for structural capacity, including concrete, shotcrete, stone, timber, vegetation, etc.
Traffic Barrier/ Fence	Traffic barrier or fence above or below wall, and within the influence of the wall.
Road/ Sidewalk/ Shoulder	Road and/or sidewalk surface above or below a wall, and within the influence of the wall.
Upslope	Groundslope area above a wall affecting wall condition and/or performance.
Downslope	Groundslope area below the wall, distinct from the Wall Foundation Material element, affecting wall condition and/or performance.
Lateral Slope	Groundslope laterally adjacent to a wall affecting wall condition and/or performance.
Vegetation	Vegetation on or near wall or on wall face affecting wall condition and/or performance.
Culvert	Culverts and inlets/outlets through, below, or adjacent to walls.
Curb/ Berm/ Ditch	Lined or unlined surface drainage feature above or below wall.
Other Secondary Wall Element	Any secondary wall element not listed (provide detailed narrative definition).

Element Condition Rating Guidance
Good to Excellent Rating (minor to no distress, minimal to no impact, few to no occurrences) ***Corrosion/Weathering*** • No evidence of corrosion/staining, contamination or cracking/spalling due to weathering or chemical attack. • Compacted, placed or masoned rock, and associated chinking, is dense, angular, fresh, and without post-placement fracturing or chemical degradation. • No significant weathering/weakening of bedrock, softening of soil, or saturated ground conditions evident. • No impacts from vegetation noted within the wall or within adjacent elements. ***Cracking/Breaking*** • No evidence of element cracking, breaking, or construction/post-construction damage, opening of discontinuities in rock, or cracks or gullies in soils. • Concrete, shotcrete, and mortar is sound, durable, and shows little or no signs of shrinkage cracking or spalling. • Drains are clearly open (flowing), and in full working order. ***Distortion/Deflection*** • Wall elements are as constructed, and/or show no signs of significant settlement, bulging, bending, heaving, or distortion/deflection beyond normal prescribed post-construction limits. ***Lost Bearing/Missing Elements*** • No wall elements are missing. • Wall elements are fully bearing against retained soil/rock units. • Foundation soils/rock are more than adequate to support the wall, consistently dense, drained and strong. • No slope failures have occurred either removing or adding materials to the wall area.
Fair Rating (moderate distress, significant to substantial impact, multiple occurrences) ***Corrosion/Weathering*** • Moderate corrosion/staining, contamination or cracking/spalling due to weathering or chemical attack. • Compacted, placed or masoned rock is not fresh or angular, showing significant weathering, post-placement fracturing, chemical degradation, and/or localized loosening. • Significant weathering/weakening of bedrock, softening of the soil, or saturated ground conditions evident. • Moderate impacts from vegetation are evident within the wall or within adjacent elements. ***Cracking/Breaking*** • Localized element cracking, breaking, abrasion and/or construction/post-construction damage, opening or discontinuities in rock or cracks or gullies in soil. • Concrete, shotcrete, and mortar is occasionally soft or drummy, has lost durability, and shows occasional cracking and/or spalling sufficient to intercept reinforcement. • Drains cannot be clearly determined to be fully operational. ***Distortion/Deflection*** • Wall elements show significant localized settlement, bulging, bending, heaving, misalignment, distortion, deflection, and/or dispacement beyond normal prescribed post-construction limits (e.g., wall face rotation, basket buldging, anchor head displacement, bin displacement). ***Lost Bearing/Missing Elements*** • Some wall elements are missing (e.g., chinking, lagging, brick-work) or non-functional. • Wall elements are generally bearing against retained soil/rock units, but localized open voids may exist along the back and top of the wall. • Foundation soils/rock are adequate to support the wall, but susceptible to shrink-swell, erosion, scour, or vegetation impacts. • Isolated slope failures have occurred either removing or adding material from the wall area.
Poor to Critical Rating (severe distress, failure is imminent, pervasive occurrences) ***Corrosion/Weathering*** • Metallic wall elements are corroded and have lost significant section affecting strength. • Concrete/shotcrete is extensively spalled, cracked, and/or weakened, and may show evidence of widespread aggregate reaction. • Compacted, placed or masoned rock is highly weathered, showing extensive post-placement fracturing, chemical degradation, and/or loosening within the placed volume. • Severe impacts from vegetation are evident within the wall or within adjacent elements. ***Cracking/Breaking*** • Extensive severe element cracking, breaking, abrasion and/or construction/post-construction damage, opening of discontinuities in rock, or cracks or gullies in soils. • Concrete, shotcrete, and mortar are consistently soft, drummy, or missing, has lost durability and strength, and shows pervasive cracking and/or spalling intercepting or exposing/weakening reinforcement. • Drainage is missing, clearly damaged, and/or chronically clogged and non-functional. ***Distortion/Deflection*** • Wall elements show extensive settlement, bulging, bending, distortion, misalignment, deflection and/or displacement well beyond normal post-construction limits, including loss of ground reinforcement and/or anchor. ***Lost Bearing/Missing Elements*** • Many or key wall elements are missing (e.g., placed wall stone, chinking, lagging) or non-functional. • Many or key wall elements are no longer bearing against retained soil/rock units with visible open voids evident behind a large portion of the wall. • Foundation soils/rock show signs of failure, excessive settlement, scour, erosion, substantial voids, bench failure, slope creep/spreading, and/or may be adversely impacted by vegetation. • Substantial slope failures have occurred either removing or adding materials to the wall area.

Figure 12: FHWA / NPS Wall Inventory Program (WIP) Sample Inspection Form.

RETAINING WALL CONDITION ASSESSMENT REPORT

ARRIVAL LOG WIN 2-1014-22

Date	Time of Arrival	Time of Departure	Temp (F)	Weather Cond	Other Cond
01-18-06	12:35 PM	2:20 PM	39°	SUNNY	

Wall Type	STONE(MASONRY)
Cap Feature	PARAPET
Facing	STONE WEST
Cap Features	10" MASONRY CAP
Utilities	NA
Sign Structures	N.A.
Railing/ Fence	N.A.

SKETCH

CONDITION ASSESSMENT

	Wall Elements					Additional				Deterioration							Flags Issued				
	Wall	Joints	Exposed faces	Top	Weep holes	Cap Stones	Railing/Fence	Utilities	Sign structures	Erosion	Vegetation Cover	Visible Cracks	Settlement	Tilting/bulging	General Condition		None	Red Structural	Yellow Structural	Safety	Recommend Further Investigation
Rating	6	6	6	6	8	7	7	8	7	7	7	6	7	7	6		X				

See Back for Comments

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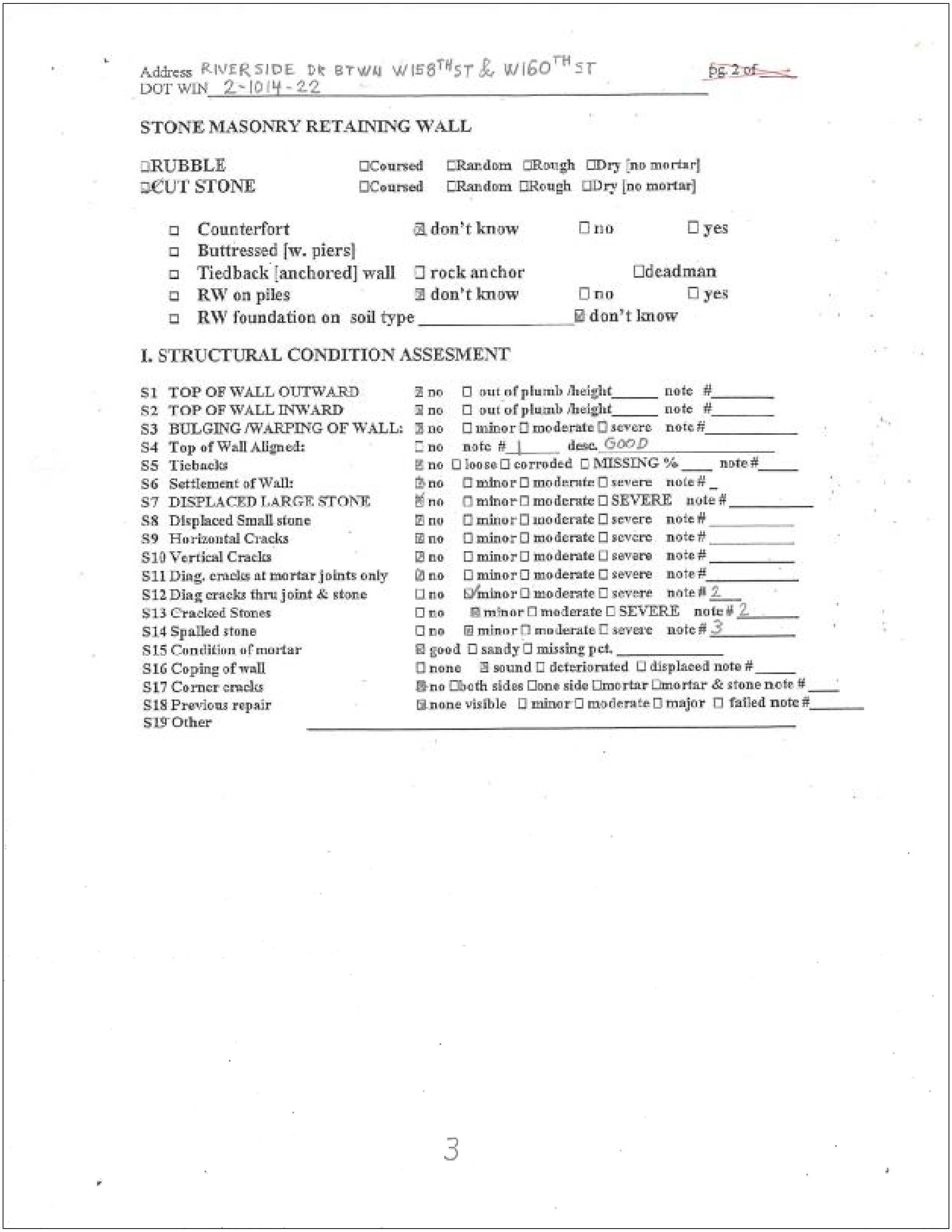
Figure 13: Example of an Inspection Form used by New York City DOT and New York State DOT during the Development of their Retaining Wall Management System.



Address RIVERSIDE DR BTWN W158TH ST & W160TH ST pg 2 of
DOT WIN 2-1014-22

STONE MASONRY RETAINING WALL

☐RUBBLE ☐Coursed ☐Random ☐Rough ☐Dry [no mortar]
☐CUT STONE ☐Coursed ☐Random ☐Rough ☐Dry [no mortar]

- ☐ Counterfort ☒ don't know ☐ no ☐ yes
- ☐ Buttressed [w. piers]
- ☐ Tiedback [anchored] wall ☐ rock anchor ☐deadman
- ☐ RW on piles ☒ don't know ☐ no ☐ yes
- ☐ RW foundation on soil type ________ ☒ don't know

I. STRUCTURAL CONDITION ASSESMENT

S1	TOP OF WALL OUTWARD	☒ no ☐ out of plumb /height____ note #____
S2	TOP OF WALL INWARD	☒ no ☐ out of plumb /height____ note #____
S3	BULGING /WARPING OF WALL:	☒ no ☐ minor ☐ moderate ☐ severe note #____
S4	Top of Wall Aligned:	☐ no note # 1 desc. GOOD
S5	Tiebacks	☒ no ☐ loose ☐ corroded ☐ MISSING %____ note #____
S6	Settlement of Wall:	☒ no ☐ minor ☐ moderate ☐ severe note #____
S7	DISPLACED LARGE STONE	☒ no ☐ minor ☐ moderate ☐ SEVERE note #____
S8	Displaced Small stone	☒ no ☐ minor ☐ moderate ☐ severe note #____
S9	Horizontal Cracks	☒ no ☐ minor ☐ moderate ☐ severe note #____
S10	Vertical Cracks	☒ no ☐ minor ☐ moderate ☐ severe note #____
S11	Diag. cracks at mortar joints only	☒ no ☐ minor ☐ moderate ☐ severe note #____
S12	Diag cracks thru joint & stone	☐ no ☒ minor ☐ moderate ☐ severe note # 2
S13	Cracked Stones	☐ no ☒ minor ☐ moderate ☐ SEVERE note # 2
S14	Spalled stone	☐ no ☒ minor ☐ moderate ☐ severe note # 3
S15	Condition of mortar	☒ good ☐ sandy ☐ missing pct.____
S16	Coping of wall	☐ none ☒ sound ☐ deteriorated ☐ displaced note #____
S17	Corner cracks	☒ no ☐ both sides ☐ one side ☐ mortar ☐ mortar & stone note #____
S18	Previous repair	☒ none visible ☐ minor ☐ moderate ☐ major ☐ failed note #____
S19	Other	____

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Figure 14: Example of an Inspection Form used by New York City DOT and New York State DOT during the Development of their Retaining Wall Management System.

Address RIVERSIDE DR BTWN W 158TH ST & W160TH ST Page 3 of 4

DOT WIN 2-1014-22

II. CONDITION ASSESSMENT OF SOIL/PAVEMENT ADJOINING WALL

1. BUCKLING/HEAVING OF RD/SDWLK AT BOTTOM ☒no ☐minor ☐moderate ☐SEVERE
   ☐approx. distance from wall _____ note #___
2. TENSION CRACKS IN SOIL AT TOP: ☒no ☐width of crack ________
   ☐approx. distance from wall _____
3. BUCKLING/HEAVING OF RD/SDWLK AT TOP ☒no ☐minor ☐moderate ☐SEVERE
   ☐approx. distance from wall _____ note #___
4. SINK HOLES IN SOIL/PAVEMENT: ☒no ☐dimensions ________
   ☐approx. distance from wall ________
5. Soil/Pavement at Base of Wall: ☒acceptable ☐disturbed ☐describe ________
6. Soil/Pavement at Top of Wall: ☒acceptable ☐disturbed ☐describe ________
7. Soil Separating From Back of Wall: ☒no ☐yes - width of separation ________
8. Other ________

III. CONDITION ASSEMENT OF WATER MANAGEMENT AREA SURROUNDING WALL

1. Weeps: ☒no ☐functioning? ________
2. Erosion of wall/soil by water: ☒no ☐describe ________
3. Wet spots at surface of wall ☐no ☒describe PAINTED SURFACE, SOME PEEL OFF
4. Water/silt filtering through wall: ☒no ☐minor ☐moderate ☐severe note #________
5. Water boiling at base of wall ☒no ☐describe ________
6. Area Drains/Piping present: ☒no ☐functioning? ________
7. Drywell/Catch Basin: ☒no ☐describe ________
8. Hydrant: ☒no ☐describe ________
9. Downspouts/adj. buildings: ☒no ☐describe ________
10. Soil drains away from wall: ☒no ☐describe ________
11. Other ________

IV. ATTACHMENTS TO WALL

1. Balustrade/Handrail ☐no ☒describe DIMENSIONED STONE MASONRY
   ☐condition GOOD
2. Ramp/Steps ☐no ☒describe COVERED WITH GLASS DEBRIES
   ☒condition GOOD
3. Tunnels ☒no ☐describe ________
   ☐condition ________
4. Light structure [shed/garage] ☒no ☐describe ________
5. Fence: ☐no ☒describe BEGIN PORTION AT LEFT
6. Trees/vegetation: ☒no ☐describe ________
7. Equipment/Storage at/near Top of Wall ☒no ☐describe ________
8. SPECIAL OVERBURDEN ☒no ☐describe ________
9. Other ________

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Figure 15: Example of an Inspection Form used by New York City DOT and New York State DOT during the Development of their Retaining Wall Management System.

Address RIVERSIDE DR BTWN W158TH ST & W160TH ST

Page 4 of 4

DOT WIN 2-1014-22

NOTES

1. CURVE SURFACE
2. ONE CRACK ALONG JOINT AT THE RIGHT OF THE WALL
3. LEFT BEGINNING SMAL CONCRETE SPALL
4.
5.
6.
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24.

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Figure 16: Example of an Inspection Form used by New York City DOT and New York State DOT during the Development of their Retaining Wall Management System.

APPENDIX D – SAMPLE SAFETY REPORT LETTERS

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
HUNTERS POINT PLAZA
47-40 21ST STREET
LONG ISLAND CITY, N.Y. 11101

DOUGLAS A. CURREY, P.E.
REGIONAL DIRECTOR

PHILLIP ENG, P.E.
DEPUTY REGIONAL DIRECTOR

THOMAS J. MADISON, JR.
COMMISSIONER

May 3, 2006

Deputy Chief Engineer, Bureau of Engineering Review and Support
NYC Dept. of Transportation
2 Rector Street, 6th Floor
New York, NY 10006

Re: **Safety Report - Retaining Wall No. : 2-908-015**
Located on right side of Jackie Robinson Parkway Eastbound under the
Bridge before Cypress Hills Cemetery, Queens

Dear Sir:

Gandhi Engineering, Inc. (GE) is under an agreement with NYSDOT to perform visual inspection of non-NYS retaining walls that are adjacent to highways under NYS jurisdiction, whose failure could impact the State Arterial System. The purpose of this inspection is to determine structural condition and stability of each wall. The reason for this letter is to inform you about one such retaining wall that we believe is under your jurisdiction.

While performing the visual inspection of the above referenced retaining wall adjacent to the State Highway, it was noticed that some panels of this 86 m long wall varying in height from 0.3 m to 5.1 m are leaning out of plumb by 35 mm to 125 mm. A 60 m _ length of railing surmounting the wall is broken and components of the railing are hanging over the top. There are three broken pieces of railing lying on the cemetery ground at the base of the wall. In the mid- length of the wall, there are two stacks measuring 8 m X 1.5 m X 1.0 m ht. of steel plating are located adjacent to the top of the wall. Each stack represents considerable surcharge on the backfill of the wall.

Figure 17: Safety Report for Retaining Wall No. 2-908-015 (Page 1 of 2).

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION

DOUGLAS A. CURREY, P.E.
REGIONAL DIRECTOR

PHILLIP ENG, P.E.
DEPUTY REGIONAL DIRECTOR

THOMAS J. MADISON, JR.
COMMISSIONER

We recommend that you investigate why the wall panels are leaning, repair the railing, and remove the overburden from this wall as soon as possible. We have enclosed location map, inspection report, and photos showing the deteriorated condition of the wall.

Please feel free to call me at (718) 482-4680 if you have any questions. Thank you for your kind attention to this matter.

Very truly yours,

Guy Lamonaca, P.E.
Project Manager.

Encl.

cc: Mahendra Patel, P. E. (Gandhi Engineering, Inc.)
Mahabal Shah, P.E. (NYCDOT)

Figure 18: Safety Report for Retaining Wall No. 2-908-015 (Page 2 of 2).

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
HUNTERS POINT PLAZA
47-40 21ST STREET
LONG ISLAND CITY, N.Y. 11101

DOUGLAS A. CURREY, P.E.
REGIONAL DIRECTOR

PHILLIP ENG, P.E.
DEPUTY REGIONAL DIRECTOR

THOMAS J. MADISON, JR.
COMMISSIONER

February 2, 2006

Chief Engineer
New York City Department of Parks and Recreation (NYCDPR)
Olmsted Center
Flushing Meadows-Corona Park
Flushing, NY 11367

Re: **Safety Report - Retaining Wall No. : 3-907-029**
Located Between Adam Clayton Powell Blvd. and
Southbound Harlem River Drive, at E.155th St., Manhattan

Dear Sir:

Gandhi Engineering, Inc. (GE) is under an agreement with NYSDOT to perform inspection of non-NYS retaining walls that are adjacent to highways under NYS jurisdiction, whose failure could impact the State Arterial System. The purpose of this inspection is to determine structural condition and stability of each wall. The reason for this letter is to inform you about one such retaining wall under the NYCDPR jurisdiction.

While performing a visual inspection of retaining wall no. 3-907-029 it was noticed that there is a 12mm wide, and 5 m long irregular vertical crack in the exposed face of the wall. In addition it was found that roots of 150 mm diameter tree had penetrated the cracks at 1/3 height from the top (Photos 1 and 2). GE also noted that the wall is leaning away from the vertical towards the sidewalk in the vicinity of the vertical crack. The leaning distance varies between 75 mm and 175 mm (see sketch on page 4).

Figure 19: Safety Report for Retaining Wall No. 3-907-029 (Page 1 of 2).

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION

DOUGLAS A. CURREY, P.E.
REGIONAL DIRECTOR

PHILLIP ENG, P.E.
DEPUTY REGIONAL DIRECTOR

THOMAS J. MADISON, JR.
COMMISSIONER

We recommend that you investigate why the wall is leaning, and repair this wall as soon as possible. We have enclosed location map, inspection report, and photos showing the deteriorated condition of the wall.

Please feel free to call me at (718) 482-4680 to discuss our submission. Thank you for your kind attention to this matter.

Very truly yours,

Guy Lamonaca, P.E.
Project Manager.

Encl.

cc : Mahendra Patel, P. E. (Gandhi Engineering, Inc.)
Mahabal Shah, P.E. (NYCDOT)

Figure 20: Safety Report for Retaining Wall No. 3-907-029 (Page 2 of 2).