

## CHAPTER 1 – INTRODUCTION

This Procedures Manual documents the data collection and management processes, wall attribute and element definitions, and team member responsibilities for conducting retaining wall inventories and condition assessments as part of the National Park Service (NPS) Retaining Wall Inventory Program (WIP). The procedures described herein are based on a multi-phase development effort involving:

- Reviews of similar programs undertaken by state transportation departments and municipalities;
- Development of a customized retaining wall inventory and assessment program aligned with specific NPS asset management requirements;
- Piloting of the proposed data collection methodology at several parks nationwide; and
- Completion of inventories within 32 National Parks, Monuments, Recreation Areas, Parkways and Seashores accounting for nearly 3,500 retaining walls within the WIP database.

Although primarily intended to serve the Wall Inventory Program as it moves forward, this Procedures Manual should find application within a broader national audience as federal, state and local agencies tackle retaining wall asset issues tied to transportation infrastructure.



**Figure 1. Photo. Two-man inventory team measures and assesses the condition of a mortared stone masonry gravity fill wall, with integral guardwall parapet, at Mount Rainier National Park.**

## 1.1 PURPOSE AND NEED FOR A WALL INVENTORY PROGRAM

The National Park Service (NPS) is responsible for the management and maintenance of nearly 5,500 miles of paved roads and parkways across more than 250 park properties nationwide. In addition to the primary pavement asset, the NPS is also responsible for appraising and managing deferred maintenance needs of numerous subsidiary roadway features, including bridges, retaining walls, culverts, traffic barriers, signage, lighting facilities, etc. Referred to as “equipment” in asset management parlance, these features are major contributors to the safety and accessibility of the NPS roads system and represent substantial roadway infrastructure investments. Given the wide range of geographic settings and public usage comprising the NPS network of roads, defining the backlog of roadway equipment is a major challenge to the park program.

The purpose of the Wall Inventory Program is to define, quantify, and assess retaining wall assets associated with park roadways in terms of their location, geometry, construction attributes, condition assessment, failure consequence, cultural aspects, apparent design criteria, and cost of structure maintenance, repair or replacement. The main intent of this effort is to determine the backlog of needs associated with retaining wall assets – equipment features ascribed to the “parent” roadway asset, which is defined and evaluated under the NPS Road Inventory Program (RIP). Prior to development of the WIP, the vast majority of retaining walls were not accounted for in the park asset management program. Based on WIP inventory work to date, NPS wall assets are valued at well over \$400M.

Ultimately, condition assessments for retaining wall structures are expressed as deferred maintenance costs, which are then divided by current year replacement costs to arrive at a “Facility Condition Index” (FCI). Coupling this condition prioritization index with an “Asset Priority Index” (API), which measures the feature’s importance to the mission of the park, capital asset investments are made more efficiently. This approach appropriately focuses maintenance and construction priorities on value, rather than solely on cost. Wall inventory condition and cost data are readily transferred from the WIP database to the NPS Facility Management Software System (FMSS), the primary asset documentation, management and planning platform maintained at each park. In addition, wall data are also provided to the Road Inventory Program to update equipment assets associated with the parent roadway asset. Bridge, culvert and traffic barrier data are also provided to FMSS and RIP via other inventory programs.

This asset inventory program has been commissioned at the request of the NPS Washington Office (WASO), Park Facility Management Division. The program is supported by both NPS WASO personnel and staff from the Federal Lands Highway Division (FLH) of the Federal Highway Administration (FHWA). NPS personnel are primarily responsible for integration of WIP wall data within the FMSS asset management system, while FLH personnel have taken the lead for delivery of field inventories. Similar to the RIP, it is the intent of the wall program to periodically reassess retaining wall resources at program parks to ensure timely, accurate information is available to support NPS asset management initiatives and park resource planning and maintenance activities. Thus, the WIP is ultimately for the purpose of asset management.

## 1.2 BACKGROUND OF PROGRAM DEVELOPMENT

The Wall Inventory Program has been developed and initially delivered under three well-defined phases of work. Phase 1 investigated the feasibility of developing and conducting retaining wall inventories for the NPS, ultimately providing specific recommendations for inventory methods and practices supporting the needs of the FMSS asset program. This initial phase concentrated on the following key program subjects:

- *State-of-the Practice Literature Review*: Summary of current efforts by federal, state, and local agencies to develop retaining wall inventory programs. Aside from the current NPS road and bridge inventory programs, variations of wall inventories were evaluated from seven state departments of transportation and one municipality.
- *Wall Types, Definitions and Associated Costs*: Identification of the range of wall types and components to be encountered on park roads; development of wall and adjacent feature definitions; preliminary estimation of costs for wall rehabilitation, repair and replacement.
- *Inventory Scope*: Determination of inventory size and breadth to reliably characterize the NPS retaining wall asset base.
- *Information Tracking*: Development of a wall data collection scheme that is consistent with existing bridge and road inventory programs and supports the long-term needs of FMSS.
- *Risks Associated with Poor Wall Performance*: Development of an assessment methodology that defines wall component distresses and describes modes of failure and poor performance.
- *Cultural Resource Considerations*: Development of procedures to determine when a wall should be considered a cultural resource, and how cultural considerations should be incorporated in wall assessments and repair/replace recommendations.



**Figure 2. Photo. Assessment of a culturally significant culvert headwall at Acadia National Park.**

Phase 1 resulted in an interim report published by FLH in April 2005, entitled “National Park Service Retaining Wall Inventory and Assessment – Phase 1 Report.” This document is available from the Geotechnical Group, Central Federal Lands Highway Division, FHWA, Lakewood, CO.

Following Phase 1 review and concurrence by contributing agencies in early 2006, work was initiated under Phase 2 to develop, refine, and test data collection methods and processes. Program efforts focused on the refinement and definition of approximately 65 wall attributes; development of field data collection procedures, field forms, field guides and general cost information; advancement of FMSS data management and transfer processes; and the development of a fully searchable database using Microsoft Access and Oracle platforms. Several developmental pilot studies were conducted during Phase 2, beginning with Sequoia and Crater Lake National Parks during the summer of 2006. Full-scale production pilots were conducted in late-2006 at Wind Caves, Zion and Mesa Verde National Parks, Capulin Volcano National Monument, and Delaware Water Gap National Recreation Area.

Data collection, storage, and transfer methods and processes were finalized in March 2007 prior to initiating full-scale park inventories under Phase 3. Program training was also provided at that time to approximately 25 inventory participants, including multi-disciplinary engineers and support staff from the NPS and the three FLH division offices. Phase 3 fieldwork began in April 2007 and concluded in November 2008, with inventory teams completing assessments on nearly 3,500 retaining walls in 32 NPS properties across the U.S. This initial inventory effort, believed to encompass the majority of retaining wall structures within the parks system, serves as the basis for updated program developments included in this Procedures Manual.

### 1.3 A PROGRAM PERSPECTIVE ON DEFERRED MAINTENANCE

“Deferred maintenance” is the practice of allowing infrastructure to deteriorate by postponing prudent but non-essential repairs to save cost, labor and/or material. Although a policy of continued deferred maintenance will generally result in higher repair costs or structure replacement due to failure than if normal maintenance had occurred, deferring maintenance until structure deterioration begins to accelerate can be cost-beneficial to an organization seeking to optimally divert maintenance funds to other priorities or projects. Competition between annual maintenance and project funds drives the need for quantitative asset management to identify these priorities, and underlies the justification for periodically assessing and monitoring structure condition and performance over its service life.

The ultimate goal of the asset management program is to determine at what point in time maintenance dollars are best spent to sustain structure performance, extend service life, and avoid extensive repairs and/or replacement of structure elements.

In the Wall Inventory Program a measure of deferred maintenance prioritization is not determined until the wall condition assessments are uploaded to the NPS FMSS asset management system – when the aforementioned Facility Condition Index is calculated based on

required maintenance/repair/replace costs versus the structure replacement cost. As a result, the FLH inventory field team acquires only a limited knowledge of the park's scheduled maintenance activities before assessing wall condition and performance. Therefore, *the focus of the WIP inventory is less on park-scheduled preventive maintenance activities and more on re-establishing and/or maintaining required wall performance through non-routine maintenance, wall repair, and wall replacement.* Although this approach may not follow the strict definition or intent of a deferred maintenance program, retaining walls are typically long-life structures where deterioration and loss of performance occurs gradually over many years. Within an approximate 10-year inspection cycle, for example, it can be expected that significant wall deficiencies – those requiring action prior to the next inspection – will be appropriately expedited within annual maintenance budgets.

In some cases, it can be a challenge for the inventory team to discern whether the deterioration of a wall element warrants some type of action, particularly when the element condition history is not known. Limiting the term of consideration to the next inspection, rather than requiring the inspecting engineer to evaluate wall elements based on the life expectancy of the structure, helps to focus non-routine maintenance and repair activities on near-term performance issues. This approach allocates limited dollars where they can do the most good, and avoids high routine maintenance costs when wall performance may be only marginally improved.

Repointing of mortared stone masonry walls illustrates how the inspecting engineer should approach the issue of what constitutes a needed and justified wall repair within the Wall Inventory Program. To date, the WIP has evaluated nearly 3,500 retaining walls, with ~75% representing historic stone masonry and placed stone structures. Of that 75%, nearly a third are mortared structures, accounting for over 800 walls in the inventory. Most of these structures were built 60+ years ago, and although virtually all of the walls are showing signs of gradual deterioration, the vast majority is performing well. Over the service life of these structures it is common for mortared joints to show signs of shrinkage cracking and debonding from the rock, along with associated seepage throughout the height of the wall. Although the cracking may be extensive, the wall may show no additional signs of significant distress, such as bulging, rotation, toppling, settlement, etc., suggesting that the mortar is providing sufficient interlock to maintain wall stability (perhaps performing as a well-chinked, dry-laid stone wall). Without the benefit of several decades of wall performance experience, the inspecting engineer might be tempted to characterize shrinkage cracking following wall construction as a substantial deficiency potentially impacting service life and, thereby, warranting repointing of the entire structure (replacement of the outer 1-2 inches of mortar). However, the longer-term performance history of walls currently in the WIP database clearly shows that such cracking/debonding is, by itself, neither a performance issue nor a regularly occurring maintenance item, but rather an occasional repair item when coupled with other developing distresses. In this case, attempting to bring the wall back to its original, as-constructed mortared condition would have been an unnecessary maintenance expense since wall performance was not being affected – and an expense that could have been realized several times over the service life of the wall.

Since the Wall Inventory Program has only just begun, development of performance histories for the many wall elements captured by the inventory is still in its infancy. As the program moves forward, the distinction between regular minor maintenance and performance-related non-routine

maintenance and wall repair will become more evident. In the meantime, the inspecting engineer needs to identify those deficiencies and distresses to wall performance that must be addressed in the near-term (before the next inspection) to mitigate more costly repair/replace measures.

#### 1.4 RECOMMENDED INVENTORY AND ASSESSMENT CYCLE

The efficient management of retaining wall assets over their expected life cycle requires on-going, systematic performance assessment of all or a portion of the total asset inspected in the initial inventory. The period, breadth and depth of recurring wall assessments and manner in which future assessments may be undertaken (e.g., NPS and/or FLHD personnel) are a function of several considerations, including:

- **Reinspection Cycle Based on Total Asset Performance:** Of the approximate 3,500 walls inventoried in the Cycle 1 assessment, only about 1% required replacement and 3% required significant to substantial repair. Despite the 60+ year age of a majority of the total asset inventoried, the overall performance of retaining walls in the 32 parks inspected was very good, with a relatively low Facility Condition Index (FCI) as compared to other park assets.
- **Reinspection Cycle Based on Wall Type:** The total asset inventory is comprised of numerous wall types with different performance attributes and life-cycles. For example, a high percentage of the stone masonry walls built in the 30's and 40's are performing well today with little to no signs of significant deterioration, whereas a significant percentage of corrugated metal bin walls built in the 60's and 70's are indicating rapidly deteriorating metal facing elements. The inspection cycles for metal- and wire-faced walls may need to be shorter than for stone masonry walls to optimize life-cycle maintenance.
- **Reinspection Cycle Based on Wall Location:** Environmental factors can greatly impact wall performance. For example, some of the worst examples of wall deterioration in the Cycle 1 inventory were seen in concrete and metal-faced walls subject to coastal marine environments. Parks subject to high annual precipitation, extreme freeze-thaw cycles, and/or heavy, rapid vegetation growth are also highly susceptible to accelerated wall deterioration.
- **Reinspection Due to External Event/Park Request:** Qualifying emergency relief (ERFO) events, global geotechnical events (e.g., landslides), rapidly developing wall failures, recent wall construction in the park, etc. may also trigger the need for updated inspections.

In general, if the reinspection cycle is too short, the cost of the program quickly outweighs the benefits; too long, timely maintenance activities may be missed, seriously impacting effective life-cycle asset management. Based on the results of Cycle 1 inspections, indicating good overall health of the retaining wall asset within the 32 parks inspected, WIP reinspection should be based on the following recommendations:

- (1) The total wall asset should be reinspected, per the following guidelines, on a maximum 10-year cycle;
- (2) Reinspection of the total asset should include full assessment of walls with condition ratings less than 70 and/or walls with prior recommendations and associated work orders to replace wall elements or replace the entire wall;

- (3) Spot checks should be done on walls with prior recommendations for Maintenance or Minor Repair;
- (4) Walls previously identified as requiring Further Investigation should be fully reassessed, with investigation results reviewed and incorporated within the updated assessment (if available);
- (5) Walls constructed since the previous inspection should be fully assessed and added to the park database; and
- (6) Walls potentially impacted by qualifying ERFO events should be fully reassessed shortly following the event.

To the extent practical, FLH geotechnical and structural engineering personnel should conduct reassessments of at-risk walls, including walls rated in poor condition, walls with element(s) repair and/or replace work orders, and/or walls requiring additional investigation. Spot-checking can be most efficiently accomplished by park maintenance staff, and should be done on a more regular cycle (e.g., every 2-3 years) to identify developing problems.

## 1.5 TRAINING REQUIREMENTS

Retaining wall assessments are most commonly conducted by teams of two to three individuals knowledgeable in wall components and construction, and skilled in recognizing a wide range of element distresses and failure modes. Teams are generally led by a Geotechnical, Geological or Structural Engineer, and are supported by additional engineering or technical staff from the survey, design and/or construction disciplines. The primary goals of the team are to readily identify and consistently document the many factors contributing to a wall's overall condition and performance, and to then determine the appropriate course of distress remediation required, if any. Upon completion of the field inventory, team members are also responsible for entering wall data into the WIP Database and reporting FMSS information to park management.

To prepare for field evaluations, teams should be fully trained on the various components of the wall inventory program documented within this Procedures Manual, including:

- Park communication process and information gathering requirements prior to site work;
- Pre-field preparation, including acquisition of RIP roadway and Visidata information, BIP bridge information, and necessary field equipment, forms, etc.;
- Proper means for filling out inventory field forms, including a complete knowledge of the definition, intent, and application of each attribute and element within the form;
- Proper use and interpretation of the information contained within the WIP Field Guide;
- Proper use and interpretation of the information contained within the WIP Cost Guide;
- Use of the WIP database for entering/extracting field data and archiving wall photos;
- Park communication process and information delivery requirements following site work; and
- Management of key documents, including park communications, field forms, photos, etc.;
- Safety training.

The remaining chapters in this Procedures Manual contain detailed information regarding the various processes and procedures to be followed throughout a retaining wall inventory effort, including definitions for each of the inventoried wall attributes and elements. *Poor quality field assessments, including incomplete forms, minimal or non-descriptive element condition narratives, or similar deficiencies, are directly attributable to a lack of training on program requirements.* Therefore, it is imperative that all team members are well-versed on the contents of this Procedures Manual before undertaking field inventories. It is further required that team members practice, as a group, logging assessments on standard field forms for several different wall types prior to full-scale park inventory work. A full day of hands-on training will greatly expedite field work, assist team members in learning how to best work together, and ensure complete, consistent wall assessments from the onset. Refresher training should also be a part of every field inventory, with multiple inventory teams working together the first day in the park to ensure data collection and reporting consistency.



**Figure 3. Photo. Safely accessing walls requires not only awareness of wall hazards but also specialized skills to mitigate risks encountered when conducting field inventories.**

In addition to the aforementioned process and procedures training, teams should also participate in formal safety training. Retaining walls, by their very nature and often located in steep settings, are extremely hazardous structures to investigate. Safely locating and accessing walls begins with roadway safety precautions (e.g., proper signage, flagging, vehicle pull-offs, etc.), and further includes proper personal safety gear and the use of personal protective equipment when evaluating the wall structure (e.g., ropes and harnesses). Communicating safety concerns and needs with park personnel is also an imperative component of the inventory process – including not only wall access issues, but also awareness of potentially dangerous encounters with wildlife, insects and poisonous plants. The Team Leader is responsible for coordinating safety requirements with the team and park personnel, and for ensuring that team members know and



understand their roles and responsibilities in practicing the highest standards of safety at all times during field work.

It cannot be overstated... *Comprehensive team training is essential for safely conducting wall inventories and providing consistent, high-quality assessments of wall performance.*

## 1.6 PROCEDURES MANUAL ORGANIZATION

The remainder of this Procedures Manual focuses on the processes, methods and definitions supporting the NPS Wall Inventory Program. Chapter 2 describes pre-field, field, and post-field data collection, storage and transfer procedures, as well as the responsibilities of team members in carrying out effective, high-quality field assessments. In addition, Chapter 2 includes a brief overview of current data management practices – recognizing that information technology systems are ever-changing. Requirements for both wall assessment and field safety training are also described in Chapter 2. Chapter 3 presents wall acceptance criteria for determining whether a wall should be included in the inventory. In general, the criteria attempt to qualify walls for the WIP inventory program based on association with park roadways, contribution to roadway stability and safety, and wall geometry. Finally, Chapter 4 defines the many wall attributes and elements that are logged, measured, calculated or assessed during field inventories. Recognizing that there exists a vast range of wall settings and conditions in the field, this section offers guidance and examples for evaluating each wall attribute and element. Program letter templates, blank data forms, and detailed user and cost guides are provided in the appendices.

