CHAPTER 4 – WALL DATA COLLECTION GUIDELINES

As stated in Chapter 1, the purpose of the Wall Inventory Program is to define, quantify, and assess wall assets in terms of their location, geometrics, construction attributes, condition, failure consequence, cultural concerns, apparent design criteria, and cost of structure maintenance, repair or replacement. To this end, various wall attributes and elements are measured, calculated, assessed and rated within the following five data categories, and documented on the **Field Inspection Form provided in Appendix B**:

- **Wall Location Data**: Walls are located by park name, route number/name, side of roadway, RIP wall start and end milepoint, and calculated RIP wall start latitude/longitude.

- **Wall Description Data**: Walls are described by function, type, year built, architectural facings and surface treatments. Measurements are recorded pertaining to wall length, maximum height, face area, face angle, and vertical and horizontal offsets from the roadway. Photos are also logged for each wall, noting location relative to the roadway, major wall features, and overall element conditions.

- **Wall Condition Assessment**: Primary and secondary wall element conditions are described relative to extent, severity and urgency of observable distresses, and then numerically rated, giving due consideration to data reliability. The overall performance of the wall system is also evaluated and rated, with all ratings weighted and combined to arrive at an overall wall condition rating – the “Final Wall Rating”.

- **Wall Action Assessment**: Objective consideration is given to **(1)** the Final Wall Rating, **(2)** any identified requirements for further site investigations, **(3)** the apparent design criteria employed at the time of construction, **(4)** any cultural concerns, and **(5)** the consequence(s) of failure to determine a recommended action. Actions include no action; monitor the wall; conduct maintenance-level work; repair wall elements; replace wall elements; replace the entire wall.

- **Work Order Development**: Brief, yet descriptive work orders are prepared when maintenance, repair or replace actions are required. Unit costs for major work items are generated from the WIP Cost Guide, park cost data, etc., to arrive at order-of-magnitude costs (not inclusive of cultural assessment, engineering design or construction management costs).

These major wall data categories are located within the Field Inspection Form, are further defined in the following Chapter 4 subsections, and are quick-referenced in the WIP Field Guide. As previously noted, wall attributes and elements are defined to the extent practicable – and are generally easy to discern in the field. The inspecting engineer will nonetheless need to rely on their knowledge of wall systems and use good judgment when interpreting the intent of each wall attribute and element over the wide variety of wall settings and applications to be encountered.

The requirement for sound engineering judgment in the WIP is most apparent in the manner in which recommended wall actions are determined. Whereas similar condition-based inventory systems may directly correlate a numerical rating to a specific action, the WIP assessment methodology develops a numerical condition rating for applicable wall elements which is then objectively considered relative to other influencing factors to arrive at a recommended action. Other factors include such things as the consequences of wall failure, the cultural/historic significance of the structure – a very important aspect of the park program – and the reliability of the condition assessment data. The result is the selection of an appropriate action founded on a well-documented element condition and wall performance assessment, suitable for development of repair/replace work orders and associated cost estimates. The current wall assessment methodology meets the more comprehensive WIP goals of identifying walls in need of non-routine maintenance, repair or replacement, allowing statistical assessments of wall elements throughout the entire WIP database, and providing the baseline for all future wall assessments.

Figure 15. Photo. Retaining walls are found in a wide array of settings. Wall performance is impacted by factors other than constructed components, including foundation materials, top and side slopes, vegetation, drainage, etc.

Although emphasized earlier in this manual, it bears repeating that all team members must be fully trained and skilled at interpreting and applying the criteria and wall element definitions contained in this manual. ***Collected wall data must be accurate, concise and descriptive***. For example, park and route naming conventions must be followed to ensure proper wall location. Wall type and treatment codes must be properly recorded to accurately classify walls and their components. To ensure continuity of condition assessments throughout the WIP, condition narratives must closely follow the descriptive vocabulary found in the WIP Field Guide for characterizing the extent, severity and urgency of wall distresses. And although briefly stated, work orders need to thoroughly account for major work items to arrive at order-of-magnitude repair/replace cost estimates. By following the data collection and documentation standards and guidance presented in this chapter, each team will be able to produce high-quality wall assessments directly supporting the NPS FMSS asset management program.

4.1 WALL LOCATION DATA

The first step of the inventory is to locate the retaining wall relative to the park RIP road survey. The RIP Cycle 3 program (currently being replaced by Cycle 4 surveys) provides milepoints to approximate 5-ft accuracy (0.001 miles), as well as GPS latitude and longitude points every 106 ft (0.02 miles), along the centerlane in the direction of the survey. These redundant measurement systems provide a good basis from which to locate retaining walls associated with the roadway for years to come, allowing future WIP inventories to be incorporated easily within RIP.

4.1.1 Park Name

"Park Name" is the NPS four-letter "Park Alpha" abbreviation, available from the park or the RIP Route Inventory Report; for example, Golden Gate National Recreation Area – GOGA; Yosemite National Park – YOSE; Capulin Volcano National Monument – CAVO. It is important to check the current Park Alpha with the most recent cycle version of RIP to ensure naming conventions have not changed since prior surveys.

The three-letter abbreviation of the "NPS Region" associated with the park name is automatically loaded in the WIP database. The seven NPS regions include: [AKR] Alaska Region; [IMR] Intermountain Region; [MWR] Midwest Region; [NCR] National Capital Region; [NER] Northeast Region; [PWR] Pacific West Region; [SER] Southeast Region.

4.1.2 Inspected By/Date

The individual responsible for filling out the Field Form for a given wall lists their name in the "Inspected By" box. This person may be the Team Lead or a Team Member, but must always be an individual properly trained in wall data collection within the WIP – particularly in the manner in which wall element condition narratives are to be composed. The inspection date refers to the date the inspection is completed.

4.1.3 Route/Parking No.

"Route/Parking Number" is the complete four-to-seven-digit RIP route/parking area number, as specified in the RIP Route Inventory Report (e.g., 0010, 0915). For roadways not in RIP, use the park-supplied route number or the convention RRR#, designating the roadway "#" as 1, 2, 3, etc., as new roads are encountered (e.g., RRR1 for the first non-RIP road encountered). For parking areas not in RIP, use the park-supplied parking area number or the convention PPP#, designating the parking area "#" as 1, 2, 3, etc., as new parking areas are encountered. These unique alpha-numeric designations, unlike the all-numeric designations in RIP, will allow future WIP users to quickly determine which roads and parking areas were in the RIP database and which were not. Therefore, it is important to correctly log this information in the required format as this route number designation is then used to develop consistent, descriptive and comparable Wall Identification Numbers within the Park WIP Database.

NOTE: Non-RIP route and parking area numbers must be at least four characters long when entered into the Park WIP Database.

4.1.4 Route/Parking Name

"Route/Parking Name" is logged exactly as specified in the RIP Route Inventory Report. For roads and parking areas not in RIP, use either the park-designated name or an appropriate descriptor. For example, "South Falls Overflow Parking" or "Amphitheater Access Road" would be good descriptors identifying both the type of travelway and general location within the park. Route names such as "Parking Lot" or "Unnamed Access Road" are not acceptable. For non-RIP routes, describe the start and end termini in the General Wall Description notes to more clearly locate the roadway in the park.

4.1.5 Side of Centerline

"Side of Centerline" designates where the wall is located relative to the roadway; right (R) or left (L), when traveling in the direction of increasing RIP milepoints or increasing park mileposts when RIP data are not available. "Mileposts" are either physical mile markers or odometer mileage starting from a referenced intersection, logged in the General Wall Description Notes.

For parking areas, where no RIP milepoint or park-designated milepost information is available, walls are to be numbered in ascending order as they are encountered when traveling counterclockwise around the parking area (most common direction of traffic flow). Designate parking area walls as P1, P2, P3, etc., as new walls are encountered.

4.1.6 Visidata Event Milepoint

For park routes included in the RIP Route Inventory Report, Visidata is used to calculate equivalent RIP milepoints to the nearest 0.001 mile for wall locations. When wall milepoints are not already available in the Visidata features table (which is commonly the case), the milepoint of a nearby Visidata-listed feature, such as a guardrail end, culvert inlet, park sign, etc., is selected from the Visidata features table and recorded on the Field Inspection Form. Although the Visidata Event Milepoint is not uploaded to the WIP database, it is included on the Field Form for convenience in calculating the Wall Start Milepoint.

NOTE: RIP milepoint data does not exist for non-RIP roads, or for any parking areas (RIP and non-RIP), so no Visidata Event Milepoints are recorded.

4.1.7 Wall Start/End Milepoint

For RIP roads, the "Wall Start Milepoint" is either the available wall milepoint provided in the Visidata features table for the route or is calculated to the nearest 0.001 mile based on the distance measured from a nearby "Visidata Event Milepoint" to the start of the wall, as it is projected to the edge of the roadway. Since wall locations will be updated to RIP following completion of the inventory, existing RIP wall start locations should always be used to avoid recording duplicate walls in the RIP features tables (generally the milepoints will be slightly different, resulting in a double entry at the same approximate location).

For calculated wall start locations, the distance along the roadway from the Visidata feature to the start of the wall is converted to thousandths of a mile and then added/subtracted from the Visidata Event Milepoint to arrive at the equivalent RIP milepoint for the wall start. When the Visidata event feature is within 50 ft of the wall start, simply divide the distance by 5 to estimate thousandths of a mile (i.e., the estimated and actual distances round to the same thousandth). When the Visidata event feature is beyond 50 ft, a more accurate calculation is required.

For roadways without RIP Visidata information, log the approximate odometer mileage, corroborated by mileposts (if present), for the wall start. Log odometer values to hundredths of a mile, to the extent practical. For all parking areas (RIP or non-RIP), always log "0.000" for the Wall Start Milepoint, as milepoint data are not available (milepoints/mileposts are always shown to three decimal places).

The "Wall End Milepoint" (for both RIP and non-RIP roads) is calculated based on the "Wall Start Milepoint" and the measured distance along the roadway. The actual wall length is not used for this calculation, as it may be longer or shorter than the projected length along the roadway.

4.1.8 Wall Start Latitude/Longitude

"Wall Start Latitude" and "Wall Start Longitude" are the interpolated centerlane latitude/longitude adjacent to the wall start based on available Visidata centerlane milepoint latitude/longitude data. These values are calculated automatically for RIP routes within the WIP database once a Wall Start Milepoint is given. Latitude and longitude data are unavailable for non-RIP roads and all parking areas (no RIP-generated GPS data available). Due to varying GPS access across the country, the WIP does not currently attempt to acquire GPS data for walls beyond what is currently available in the RIP program.

4.1.9 WIP Wall ID

The "WIP Wall ID" is an identification number automatically generated in the WIP database in lieu of the NPS FMSS equipment number to eventually be assigned by park staff. The format for the Wall ID is "Park Alpha– Route/Parking No.–Wall Start Milepoint–Side of Centerline". Because there are several possible formats for the Route/Parking No. (RIP or non-RIP roads) and the Wall Start Milepoint (Visidata vs. odometer), there are several distinctive formats for the Wall ID (examples are given in the next subsection).

The "FMSS Asset Number" is an additional unique wall identifier used by the NPS, and is assigned by park asset management personnel following completion of the wall inventory. This unique FMSS identifier is added to the Central WIP Database upon receipt from the park.

4.1.10 Wall Location Examples

A couple of examples may help to better understand the wall location process for the various roadway and parking area designations to be encountered in the field.

RIP Route Example: A fill wall is located in the Bryce Canyon National Park (BRCA) below the right side of Park Route 0012 – Canyon View Road, a paved roadway surveyed under the RIP program. The wall is not visible from the roadway, and is not included as a feature in Visidata. The wall start, projected upslope to the edge of the roadway, begins 45 ft up-station from a drop inlet structure that is identified as an event feature in Visidata. The Visidata milepoint for the drop inlet is 1.234. The Wall Start Milepoint is 45/5 thousandths, or 0.009 miles, greater than the milepoint for the drop inlet, for a calculated Wall Start Milepoint of 1.243. The projected wall end location is 349 ft further up-station along the roadway. There are no nearby Visidata features to conveniently measure from to acquire the Wall End Milepoint, so the inspecting engineer calculates an additional 0.066 miles (or 349 ft/5,280 ft/mi) must be added to the wall start value to arrive at a Wall End Milepoint of 1.309. Wall start latitude and longitude are automatically calculated within the WIP database from GPS points acquired during the RIP survey. The WIP Wall ID is BRCA-0012-1.243-R.

Non-RIP Route Example: A cut wall, identified by park personnel during the kick-off meeting, is located along the left side of a non-RIP gravel service road in Acadia National Park (ACAD). The park refers to the road as Route 23 – Tower Station Road. There are no mile markers along the road, so the inspecting engineer begins taking odometer mileage from the intersection with Route 0010 – Main Park Road, noting this starting point in the Wall General Description Notes section of the Field Form. It is determined that the projection of the wall start to the edge of the roadway approximately begins at milepoint 1.15 (odometer estimated to nearest 0.05 miles), and is logged on the Field Form and in the WIP database as 1.150. The Wall End Milepoint is determined in the same manner as in the preceding example. Since the route is not in the RIP database, the WIP database cannot calculate latitude and longitude for the wall start. The WIP Wall ID is ACAD-0023-1.150-L.

WIP Wall ID formats vary depending on the availability of route number and milepoint data, and the location of the wall relative to the roadway or parking area. The following further defines the range of possible Wall ID formats:

RIP Route with Visidata: “MEVE-0010-1.204-R” represents a wall in Mesa Verde National Park, located on RIP route 0010 at milepoint 1.204, on the right side of the road when heading in the direction of increasing milepoints.

RIP Parking Area without Visidata: “CAVO-0910-0.000-P3” represents a wall in Capulin Volcano National Monument (Figure 16), located in RIP parking area 0910, with no milepoint data, and is the third wall in the parking area progressing counterclockwise from the entrance.

Non-RIP/Park-Designated Route with Odometer: “WICA-001B-0.250-L” represents a wall in Wind Caves National Monument, located on non-RIP/Park-designated route 1B (minimum of four characters) at odometer milepoint 0.250 (minimum of four characters), on the left side of the road when heading in the direction of increasing roadway mileposts.

Non-RIP/Non-Park-Designated Route with Odometer: “DEWA-RRR3-10.350-L” represents a wall in Delaware Water Gap National Park, located on inventory-designated non-RIP route “3” at odometer milepoint 10.350, on the left side of the road when heading in the direction of increasing roadway mileposts.

Non-RIP Parking Area: "ZION-PPP2-0.000-P1" represents a wall in Zion National Park, located in inventory-designated non-RIP parking area "2", with no Visidata, representing the first wall in the parking area progressing counterclockwise from the entrance.

Figure 16. Photo. An example of parking area walls at Capulin Volcano National Monument. The wall in the foreground would be designated P1, the wall at the far end would be P2, and the wall partially shown on the left would be P3 per the WIP counterclockwise wall numbering notation for parking areas.

4.2 WALL DESCRIPTION DATA

Once a wall has been located relative to the roadway RIP Visidata survey or odometer mileage, the next step in the inventory is to describe and measure wall attributes. Wall description data include function, type, architectural facings and surface treatments; wall measurements include length, maximum height, face area, face angle, and horizontal and vertical offsets from the adjacent road grade.

4.2.1 Wall Function

"Wall Function" refers to the purpose of the retaining structure (e.g., supporting cut or fill material). In addition to the more conventional applications of fill walls and cut walls, five additional wall functions have also been identified within the WIP inventory: bridge walls, (culvert) head walls, switchback walls, flood walls and slope protection. Although these additional functions may be classified as either fill or cut walls, they are sufficiently unique and important to include separately, allowing their occurrence in parks to be quantified by future database queries. In application, "Wall Function" should be first defined by one of these five specialty functions, if appropriate, rather than the more general options "fill wall" or "cut wall".

Table 1. WIP wall functions and associated field inventory codes.

Wall Function	Code
Fill Wall	FW
Cut Wall	CW
Bridge Wall	BW
Head Wall	HW
Switchback Wall	SW
Flood Wall	FL
Slope Protection	SP

Each category, with Field Form function code given in []'s, is further defined by the following:

Fill Wall [FW]: A "fill wall" (Figure 17) is an earth retaining structure supporting specified soil or aggregate backfill. Fill walls are typically located below roadway grade on the outboard side of the roadway or parking area, but may also exist above travelway grade in locations commonly associated with cut walls. The inspecting engineer should be careful to always characterize the wall by function, and not simply location relative to the roadway or parking area.

Figure 17. Photo. A gabion gravity fill wall under construction below roadway grade.

Cut Wall [CW]: A "cut wall" (Figure 18) is an earth retaining structure directly supporting natural ground; either constructed directly against the excavated soil/rock mass, or against a minor volume of drainage backfill. Cut walls are typically located above roadway grade on the inboard side of the roadway or parking area, but may also exist below travelway grade in locations commonly associated with fill walls. The engineer should be careful to characterize the wall by function, and not simply the location relative to the roadway or parking area.

Figure 18. Photo. A mortared stone masonry cut wall at Rocky Mountain National Park.

Bridge Wall [BW]: A "bridge wall" is an earth retaining structure associated with a bridge (defined as having a ≥20 ft span) that is not directly part of the bridge substructure, and is not already inventoried by the FLH Bridge Inspection Program (BIP). Such walls might include pre-existing walls (e.g., historic retaining walls left in place during bridge construction), cut or fill walls not associated with abutments and wingwalls, or extended cut or fill walls along bridge approaches. The Team Lead should acquire bridge inspection data from the BIP prior to the field inventory to assist in both determining which structures have been evaluated as bridges in the park and what earth retaining bridge elements have already been included in the BIP survey.

The following further defines retaining walls associated with bridge structures:

Bridge Wingwalls: For the purposes of the retaining wall inventory, bridge wingwalls are generally not considered qualifying retaining walls and should not be inventoried in the Wall Inventory Program – they are already inventoried and inspected through the Bridge Inventory Program. Wingwalls are limited in length (generally less than 40 ft), often taper in height, and can be parallel to or at any angle from the abutment face. Their purpose is to contain the roadway embankment at the immediate approach to the bridge. Walls adjacent to bridge abutments are only considered wingwalls in two specific construction conditions:

- When the wingwall is constructed integrally with the bridge abutment; and
- When the wingwall is built at the same time as the bridge, but separated from the abutment by a bond breaker or joint.

If wingwalls, as defined above, continue for more than 40 feet beyond the abutment without a change in construction type, the entire wall beyond the abutment (beginning immediately past the end of the bridge deck) should be considered a retaining wall and evaluated under WIP (Figures 19 and 20). If there is a change in construction type within 40 feet of the abutment, the point where the change occurs should be interpreted as the wingwall/retaining wall juncture (Figure 21). In lieu of these criteria for bridge walls, the inspecting engineer may determine that wingwall structures, despite size or construction method, are integral to the bridge and would be included in the BIP program.

Figure 19. Photo. Example of a highly battered, dry-laid stone masonry wall supporting the bridge approach at Acadia National Park. This wall is not integral to the bridge structure and, therefore, should be assessed as a retaining wall under the Wall Inventory Program.

Secondary Bridge Abutment Walls: Walls that are under a bridge and in front of an abutment are already inventoried and inspected through the bridge inspection program, and should not be inventoried in the retaining wall program. Walls that are not within the vertical projection of the bridge deck, and are not constructed integrally with either wingwalls or abutments, should be considered WIP-inventoried retaining walls. These structures are commonly found in front of or downslope from wingwalls (Figure 22).

Bridge Spanning Pre-Existing Wall: Bridges that are constructed on top of pre-existing or long channel walls are not considered to have wingwalls. In these cases, the portion of the wall within the vertical projection of the bridge deck should be considered the bridge abutment, and the remainder of the wall should be considered a retaining wall, potentially qualifying for inclusion in the wall inventory program.

Figure 20. Photo. Although the approach walls are integral to the bridge abutment, they extend sufficiently from the end of the deck to be considered fill walls primarily supporting the roadway. Approach walls such as these should be included in the WIP inventory if not already evaluated under the BIP program.

Figure 21. Photo. Example of approach walls clearly distinguished from the bridge abutment by a constructive joint, approximately 15 feet from the end of the deck.

Figure 22. Photo. Example of secondary bridge walls (tiered MSE walls extending from the abutment and approach walls) that are not part of the bridge abutment structure and should be included in the WIP inventory.

Large Culverts: Small bridges (more appropriately described as large culverts) that are 20 feet or less in total span along the centerline of the roadway are not typically defined as bridges or included in the Bridge Inspection Program. Therefore, any walls associated with these drainage/passage structures, and meeting the minimum wall acceptance criteria, should be included in the wall inventory as "head walls", if applicable and according to the headwall/wingwall definition given herein. Otherwise, walls associated with these structures (e.g., approach walls, secondary walls) should be defined as either cut or fill walls.

NOTE: Tunnel portals are generally covered under the Bridge Inspection Program. However, portal approach walls and/or secondary walls should be covered under the WIP inventory if the inspecting engineer determines they are not integral to the tunnel portal, following the same guidance for adjacent wall features described under Bridge Walls.

Head Wall [HW]: A "head wall" (Figure 23) is a cut or fill wall located at the inlet and/or outlet end of a drainage or passage structure (e.g., water culvert, animal passage). Head walls (including associated wingwalls) should only be included in the wall inventory if they meet the wall acceptance criteria – particularly the special 6 ft head wall height criterion and the intent to support or protect the roadway. If the head wall is of sufficient size, and would significantly impact the roadway were it to fail, it should be included in the inventory. If the same head wall would not directly or immediately impact the roadway if it failed (e.g., a head wall at the bottom of a long, well-vegetated fill slope), it should not be included in the wall inventory. The entire head wall/wingwall structure at either an inlet or outlet should be considered one continuous wall system, as opposed to evaluating each separately (the length would be measured from the end of one wingwall, across the head wall, to the end of the other wingwall).

Figure 23. Photo. Is it a fill wall with an elaborate culvert structure, or a culvert with an elaborate headwall? In this case, the outlet was considered a large retaining wall with a culvert, whereas the much smaller inlet was considered a culvert headwall.

Switchback Wall [SW]: A “switchback wall” (Figure 24) is a cut or fill wall located on the inside of a switchback curve, simultaneously supporting the upper roadway and protecting the lower roadway. The switchback wall is located and described as it is first encountered along the roadway when traveling in the direction of increasing milepost.

Figure 24. Photo. Example of a mortared stone masonry switchback wall at Sequoia National Park between upper and lower roadway on the inside of a switchback curve.

Flood Wall [FL]: "Flood walls" (Figure 25) encompass earth retaining structures constructed along flood channels, inland surge walls, and seawalls. Although inclusion of these walls in the WIP inventory requires they meet the aforementioned wall acceptance criteria (particularly noting the retained earth height requirements, since many floodwalls are non-earth retaining structures), a special case is worth noting: the flood wall clearly resides outside the road/parking area construction limits, but failure would nonetheless result in roadway/parking area damage. The inspecting engineer will need to use prudent judgment in determining if a flood wall structure sufficiently meets the intent of the program to include it in the inventory.

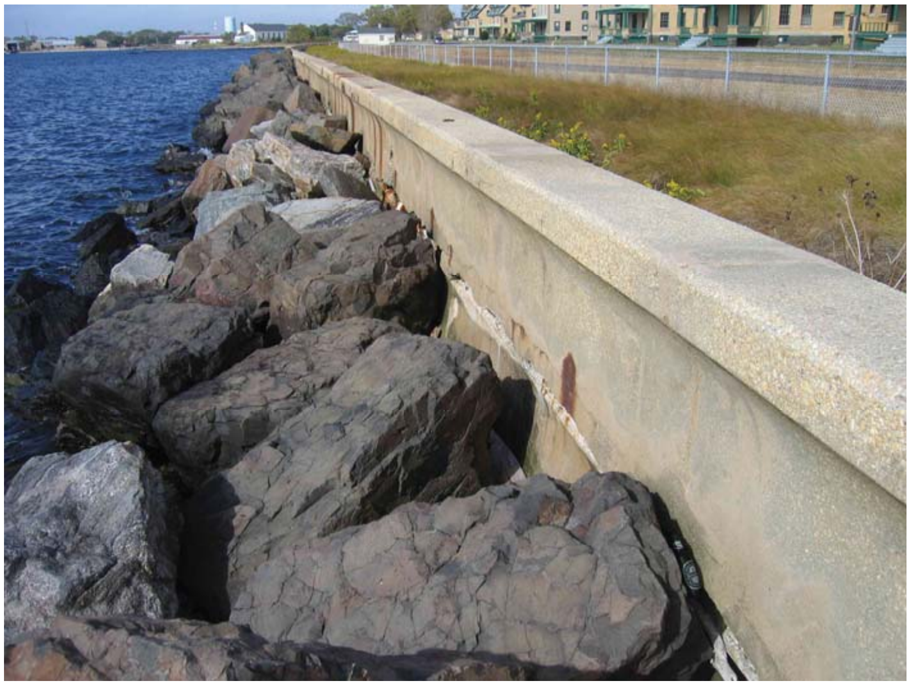


Figure 25. Photo. Although this seawall at the Sandy Hook unit of the Gateway National Recreation Area sits well outside the construction limits of the RIP-surveyed road (back right), failure of this structure would result in rapid and severe shoreline erosion, eventually impacting the roadway.

Slope Protection [SP]: "Slope protection" (Figure 26) includes earth retention and/or erosion control structures meeting the aforementioned general wall acceptance criteria that may not be considered conventional retaining wall structures. Such structures may include rock buttresses, grouted/ungrouted riprap, and stacked or grouted rock inlays constructed at slope ratios $\geq 45^{o}$ (1H:1V), and generally not exceeding 70^{o} (1H:2.5V). These structures are comprised of hand- or machine-placed rock, and should not be confused with over-steepened, end-dumped rock fills. Although not always adhering to the conventional definition or perception of an earth retaining structure, slope protection structures should be included in the inventory as they represent significant park assets supporting and/or protecting roads, and are best evaluated under the WIP inventory. For clarification, rockeries – retaining wall structures far more rigidly designed and specified than rock buttresses, and typically built at face angles $\geq 70^{o}$ – would typically be characterized as cut or fill walls, and not slope protection. Riprap rundowns, primarily used for water conveyance and not earth retention, would not be included as Slope Protection.

Figure 26. Photo. Machine- and hand-placed slope protection at Rocky Mountain National Park.

Clearly, conventional perceptions of what might constitute a retaining wall are stretched within the Wall Inventory Program to best accommodate a broadly defined asset base spanning a number of similar inventory efforts (bridge, culvert, and traffic barrier). The inspecting engineer should always lean toward including an earth retention structure when its function, geometrics and/or potential failure impacts to an adjacent travelway are difficult to discern.

4.2.2 Primary Wall Type

"Primary Wall Type" refers to the predominant earth retention structure and/or construction material comprising the retaining wall. When more than one wall type is present, engineering judgment is required to determine which wall type is providing the greatest contribution to earth retention and/or is the predominant support structure. Although, in many cases, the newest constructed portion of a multi-type wall might be considered the Primary Wall Type, older wall segments supporting newer wall construction may actually provide the predominant earth retention mechanism to the composite structure. In any event, composite wall structures should be described under "Wall General Description Notes" to clarify wall characteristics.

In many cases, it can be very difficult to determine the actual wall type. For example, soil nail walls commonly have a structural concrete facing or other decorative facing obscuring the soil nail reinforcement. Mechanically stabilized earth (MSE) walls may also have reinforcing elements obscured by an assortment of facings that may mislead the inventory inspection team. Although it is important to eventually determine the type of wall and its components, it is sufficient for the inventory team to describe the apparent wall type and its visible component performance during this initial inventory and assessment screening.

Wall types and inventory codes are listed in Table 2. General descriptions and examples of the various types of walls that may be encountered during an inventory are also provided below.

Table 2. WIP wall types and associated field inventory codes.

Wall Type Description	Code
Anchor, Tieback H-Pile	AH
Anchor, Micropile	AM
Anchor, Tieback Sheet Pile	AS
Bin, Concrete	BC
Bin, Metal	BM
Cantilever, Concrete	CL
Cantilever, Soldier Pile	CP
Cantilever, Sheet Pile	CS
Crib, Concrete	CC
Crib, Metal	CM
Crib, Timber	CT
Gravity, Concrete Block/Brick	GB
Gravity, Mass Concrete	GC
Gravity, Dry Stone	GD
Gravity, Gabion	GG
Gravity, Mortared Stone	GM
MSE, Geosynthetic Wrapped Face	MG
MSE, Precast Panel	MP
MSE, Segmental Block	MS
MSE, Welded Wire Face	MW
Soil Nail	SN
Tangent/Secant Pile	TP
Other, User Defined	OT

Anchor, Tieback H-Pile [AH]: A tieback H-Pile wall (Figure 27), or soldier pile tieback wall, is commonly comprised of H-piles driven on 6-10 ft centers, lagged with timber planks or concrete panels, and secured through the retained earth mass with tieback cables or bar ground anchors. Variations in pile and tieback configurations are common, ranging from flanged piles allowing tieback passage through the pile to tieback whaler assemblies spanning piles. Although generally a cut wall installation, this wall type can also be used as a fill wall in outboard wall applications.

Anchor, Micropile [AM]: The anchor micropile wall (Figure 28) is a rarely used variant of the H-pile tieback system. This cut wall installation, generally comprised of closely-spaced micropiles (3-6 ft), requires a structural wall facing for permanent applications. Shotcrete facings are most common.

Anchor, Tieback Sheet Pile [AS]: The tieback sheet pile wall (Figure 29) is more commonly used as a temporary excavation support measure than a permanent wall structure. However, this wall type may be commonly found in seawall applications. The piles may be steel or vinyl and a variety of coatings may be applied to the sheeting, whalers and ground anchor assemblies.

Figure 27. Photo. Timber-lagged soldier pile tieback wall at Mesa Verde National Park. A steel box-frame whaler assembly is used in this example as the bearing member for the ground anchors. Surface treatments are commonly applied to the timber lagging (weathering sealants) and exposed steel pile, whaler and ground anchor assemblies (paint).

Figure 28. Photo. Micropile tieback wall prior to shotcrete facing finish (ADSC, 2006).

Figure 29. Photo. Steel sheet piling with bar ground anchors placed through steel whalers. This cut wall is constructed "top-down", with the ground in front of the driven sheet piles excavated in lifts and ground anchor assemblies installed as the excavation proceeds to final grade.

Bin, Concrete [BC]: Concrete bin walls (Figure 30), employing large, steel reinforced concrete box construction are also rarely seen on NPS properties. New products employing hollow cast concrete boxes filled with aggregate and faced with various formliner patterns are becoming popular alternatives to cast-in-place concrete walls or solid block walls.

Bin, Metal [BM]: Metal bin walls (Figure 31) comprised a significant percentage of the walls inspected during the WIP Cycle 1 inventory and assessment. This type of wall was particularly popular within the western U.S. park system in the 60's and early 70's. The steel bins are comprised of individual units generally 8-10 ft wide and of varying depth into the slope, and may be galvanized or sprayed with other corrosion-resistant coatings.

Cantilever, Concrete [CL]: Concrete walls (Figure 32) comprised almost 10% of the total number of walls inspected within the Cycle 1 WIP inventory (most often occurring as culvert head wall/wingwall structures). The cantilever concrete wall, generally a cast-in-place fill wall (though smaller walls maybe precast and transported to the site), likely comprises the majority of the newer concrete wall structures inventoried owing to its cheaper construction. However, unless the stem wall thickness is exposed, it can be very difficult to discern this wall type from a mass gravity concrete structure.

Cantilever, Soldier Pile [CP]: The cantilever soldier pile wall (Figure 33) is of similar construction to the tieback version, less the ground anchors. Whereas the tieback version almost exclusively employs steel piling, the soldier pile wall may employ alternative concrete "piling" supporting both timber and concrete lagging. Generally a cut wall installation, this wall type can also be used as a fill wall in outboard wall applications.

Figure 30. Photo. Precast hollow concrete "bin" blocks, with a formlined architectural facing, are dry-laid at this cut wall installation and then aggregate filled for a rapidly-constructed, low-cost alternative to gravity concrete walls. (Courtesy Stone Strong, LLC)

Figure 31. Photo. Heavily corroded metal bin wall at China Beach, Golden Gate National Recreation Area. Constructed in the 60's, the protective coating on the exposed bin facing elements has long since deteriorated.

Figure 32. Photo. Cast-in-place concrete cantilever walls are commonly found serving as wingwall structures for large box culvert features within the WIP inventory.

Figure 33. Photo. Timber-lagged, soldier pile fill wall employing steel H-piles at Olympic National Park. To limit wall deflection, unanchored soldier pile walls are generally restricted to heights well under 15 ft, depending on the size of piling employed. Both piles and lagging are commonly treated for corrosion and dry rot, respectively.

Figure 34. Photo. Cantilever steel sheet pile cut wall with "deadman" anchors placed at the top of the wall to support the higher wall sections.

Cantilever, Sheet Pile [CS]: As with the anchored version, cantilever sheet pile walls(Figure 34) may be constructed of steel or vinyl, and are more commonly associated with applications near water bodies (e.g., coastal sites, bridges). A variety of coatings may be applied to steel sheet piles and metal fixtures. Occasionally, these structures may employ low-capacity "deadman" anchorage along the upper third of the pile, an element that may be overlooked during inspection.

Crib, Concrete [CC]: An open-faced version of the concrete bin wall, examples of the concrete crib wall (Figure 35) are scattered throughout the park system, coast-to-coast. These wall systems lend themselves to vegetated faces, but also suffer more rapid deterioration due to weathering and vegetation root damage than other wall types.

Crib, Metal [CM]: Metal crib walls (Figure 36) were rarely encountered in the WIP Cycle 1 inventory. Of similar construction to the concrete crib version, the metal crib wall also suffers rapid weathering and damage from unchecked vegetation. Crib walls commonly also employ some fashion of backing mat to retain wall fill, an element that should also be rated on this structure.

Crib, Timber [CT]: A popular wall construction method of urban landscape architects, the timber crib wall (Figure 37) is seldom encountered in the park system. Although some small timber crib walls, built with 4-6 inch square timbers, were inspected during the Cycle 1 inventory, the more common and robust construction involved large diameter, unshaped logs with crushed rock fill.

Figure 35. Photo. Concrete crib wall at Sequoia National Park. This wall is filled with crushed aggregate, though many similar structures may be constructed with planted faces.

Figure 36. Photo. Metal crib wall at Mesa Verde National Park. Large rock fill was used on this wall to avoid the need for facing mats to retain fill aggregate.

Figure 37. Photo. Timber crib wall at Yellowstone National Park employing large-diameter logs set "Lincoln Log" style on a placed rock fill.

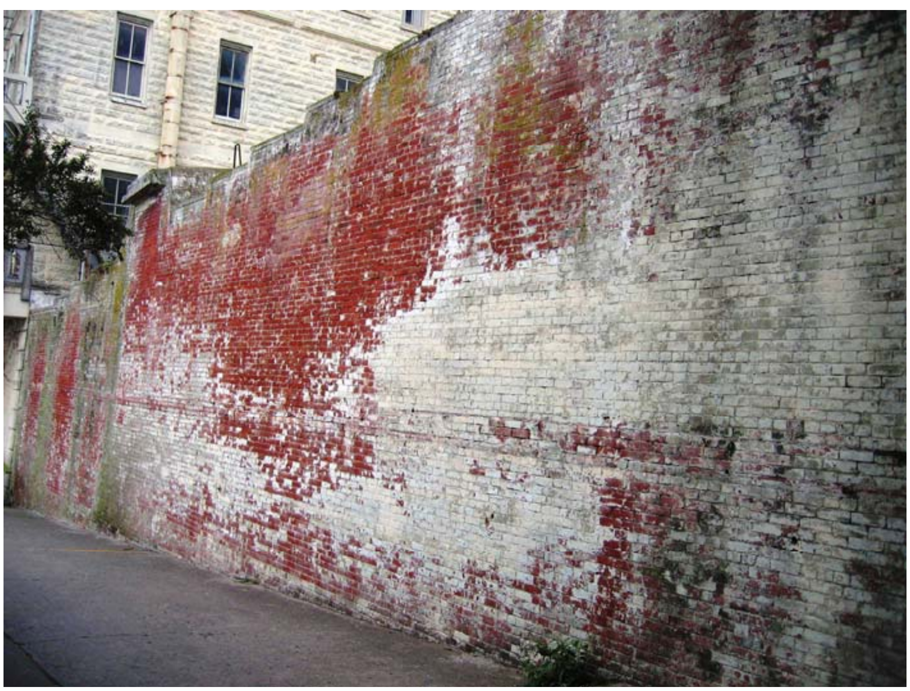


Figure 38. Photo. Tall painted brick wall at the Alcatraz unit of the Golden Gate National Recreation Area. Nearby concrete block walls suggest the interior of this wall may be constructed of larger blocks, with bricks added as a decorative facing.

Figure 39. Photo. Painted mass concrete gravity wall bordering Ft. Mason at the Golden Gate National Recreation Area. Although less aesthetically appealing than other wall types or facings, the inspecting engineer should nonetheless be aware of the cultural sensitivity of these structures.

Gravity, Concrete Block/Brick [GB]: Concrete block/brick walls (Figure 38) were rarely encountered during the Cycle 1 inventory. Many of these were quite tall (>8-10 ft), suggesting a different interior wall construction method (e.g., mass concrete gravity wall) employing a brick facing. Unless the interior of the wall is exposed, the wall should be classified as a brick structure.

Gravity, Mass Concrete [GC]: As noted earlier, concrete walls accounted for nearly 10% of all walls inspected in the Cycle 1 inventory. Mass concrete gravity walls (Figure 39) generally represented structures constructed prior to 1960. These structures may or may not be steel reinforced, and often suffer from chemical weathering and poor aggregate mixes.

Gravity, Dry Stone [GD]: Dry stone gravity walls (Figure 40), constructed as both cut and fill structures, represented nearly 25% of all walls inspected in the Cycle 1 inventory. Most of these walls were constructed in the 30's and 40's, and historic records indicate that dry-laid stone, either uncut or masoned, was generally used throughout the wall. It is common to find varying levels of workmanship within a single wall structure, requiring careful inspection of the entire wall face.

Gravity, Gabion [GG]: Wire-basket gabion gravity walls (Figure 41) were often encountered as outboard fill walls. In most cases, these structures were constructed at face angles flatter than 70 degrees, often approaching 1H:1V slope ratios. Although this wall system is often used as a facing for a reinforced soil mass (MSE design), unless the inspecting engineer knows otherwise the wall should be considered a gabion gravity structure.

Figure 40. Photo. Dry-laid stone masonry wall at Yellowstone National Park built atop lower stone masonry wall (different construction periods?). The dimension, degree rock cutting, and placement quality of stone masonry work can vary greatly – even within a single wall.

Figure 41. Photo. Angular rock fill gabion wall at the toe of a large fill along the Blue Ridge Parkway.

Figure 42. Photo. Mortared stone masonry head wall along the Blue Ridge Parkway. Although the mortar is often highly weathered in these structures, well-masoned and placed rock result in remarkably stable, high-performing, long-life structures.

Gravity, Mortared Stone [GM]: The mortared stone gravity wall (Figure 42) was the most common wall type encountered, accounting for nearly 50% of all walls inspected. This wall type is particular popular for constructing culvert head walls and wingwalls, employing both uncut and masoned stone. Mortared stone masonry is also often used as an architectural treatment for a number of other wall types (e.g., concrete walls, MSE walls, sol nail walls).

MSE, Geosynthetic Wrapped Face [MG]: The geosynthetic wrapped face MSE wall (Figure 43) is most commonly used either as a temporary wall structure or as a permanent wall with an architectural facing, making it difficult for the inspecting engineer to identify this wall type without prior knowledge of wall construction. These fill wall structures may utilize a variety of wall facing types, including sod-wrapped geogrids providing for a vegetated finish.

MSE, Precast Panel [MP]: Precast panel MSE walls (Figure 44) are very popular within urban areas as the architectural facing is integral to the wall structure, thereby expediting construction in congested traffic corridors. Integral panel construction should not be confused with precast architectural facing panels that simply cover the underlying wall face (typically a wire-faced wall). Both metallic and geosynthetic reinforcements are used with this wall type, though determining which has been used may not be possible during the site inspection.

MSE, Segmental Block [MS]: A wide variety of block styles and configurations may be used to build segmental block MSE structures (Figure 45). Reinforcements are generally geosynthetic fabrics or grids, and can often be seen extending beneath blocks along the face. As with the precast panel walls, blocks can also be used solely as architectural facings in front of wire-faced walls.

Figure 43. Photo. Multi-tiered, plantable, geosynthetic wrapped MSE wall. Although UV-resistant materials are available, the inspecting engineer should pay close attention to the degradation of exposed geosynthetics versus the age of the wall. (Courtesy Tensar Corp.)

Figure 44. Photo. Precast panel MSE wall at Great Smoky Mountains National Park. A variety of architectural facing options are available, including formlined concrete and stained or painted treatments.

Figure 45. Photo. Segmental block wall with geogrid reinforcement at Bryce Canyon National Park. Although MSE walls can tolerate substantial settlements, brittle facings such as blocks or precast panels can result in severe cracking with relatively minor differential displacements.

Figure 46. Photo. Wire-faced MSE wall, nearing completion at Colorado National Monument, utilizes a geosynthetic fabric to ensure retention of the metallic-grid reinforced aggregate. Left unprotected, this facing system would be susceptible to UV damage in the years to come.

Figure 47. Photo. Soil nail wall at Yellowstone National Park with a form-lined, cast-in-place simulated stone structural facing. The formliner is subsequently stained or painted to better simulate natural stone.

MSE, Welded Wire Face [MW]: Welded wire face MSE walls (Figure 46) are perhaps the most common MSE applications in the Cycle 1 database. Although standard wire mats are used to retain fill material at the face, supplemental materials such as hardware cloth and geotextiles may be used along with variable sized facing aggregate and face staining options.

Soil Nail [SN]: Soil nail walls (Figure 47) are a cut wall technique employing grouted steel bars (nails) as ground reinforcement. Permanent soil nail walls typically have at least a structural shotcrete facing, though a wide variety of facings can be employed, ranging from stone masonry work to extravagantly sculpted, stained and/or painted shotcrete. Unless the inspecting engineer is aware of the construction method used at the time of the inspection, correctly classifying a cut wall structure as a soil nail wall can be very difficult, particularly when a rock facing is used.

Tangent/Secant Pile [TP]: The tangent/secant pile wall (Figure 48) is a cut wall design typically employed where very small horizontal deflections can be tolerated and tieback systems cannot be used (e.g., urban constructions involving neighboring structures). These walls are typically faced with precast panels upon wall completion, so identifying them in the field would be nearly impossible without prior knowledge of the construction method.

Other, User Defined [OT]: “Other” refers to wall types rarely encountered in park roadway construction, including patterned ground anchors, segmental concrete “T” walls, cantilever “Z” walls, slurry walls, split-tire gravity walls, etc. (Figure 49 and 50).

Figure 48. Photo. Tangent pile cut wall constructed of drilled shafts. This expensive wall system is primarily used where top-down soil nail or ground anchor construction is not feasible due to subsurface obstructions within the retained ground mass.

Figure 49. Photo. "Other" wall type: geosynthetic reinforced earth wall with planted geocell facing. This wall facing method may prove to be a superior means for establishing face vegetation in high growth climates. Note the installation of the concrete leveling pad.

Figure 50. Photo. “Other” wall type: segmental concrete “T” wall at Zion National Park. Each precast “T” panel has concrete ribs extending into the compacted retained fill to serve as ground reinforcement and facing panel anchorage. The Ashlar block formliner was stained to match the surrounding country rock.

IMPORTANT
Depending on the wall type and facing systems used, it can be very difficult to determine the primary wall type. Always seek the expertise of park facilities, resource and maintenance staff to best determine the types of structures being inspected.

4.2.3 Secondary Wall Type(s)

“Secondary Wall Types” refers to one or more smaller walls that may exist in conjunction with the larger primary wall structure. While a secondary wall may not comprise a large percentage of the overall wall structure, it may nonetheless serve as a critical part of the soil/rock retention system. For example, and perhaps the most common occurrence of a secondary wall, an original short earth retaining structure that has been substantially built upon to extend the height of the wall may serve as an important foundation element of the newer wall, but would be considered a secondary wall type owing to its smaller contribution to ground support or overall size within the wall system. The Secondary Wall Type may, in some cases, be the same as the Primary Wall Type, but represent a different construction period.

4.2.4 Approximate Year Built

“Approximate Year Built” refers to the actual or approximate year the *primary* wall was constructed (+/- 5 years) per available construction data, park personnel knowledge, the age of similar structures in the park or region, and/or the year of roadway construction. This is a very important piece of data to query within the WIP database, so every reasonable effort should be made to determine when the wall was built. Default to "unknown" if no wall construction information is available or the approximate year built cannot be reasonably attributed to other known construction in the park. Document the approximate year built for secondary walls in the General Wall Description Notes.

4.2.5 Architectural Facings

"Architectural Facing" refers to any facing element that does not directly contribute to the support capacity of the structure. These would include manufactured block or rock facades/veneers, partial- or full-height precast panels, sculpted shotcrete, formlined concrete, etc. In some cases it will be difficult to discern whether the wall facing is a structural element (e.g., sculpted thick shotcrete finish over a suspected soil nail wall). When the structural contribution of the wall facing cannot be clearly determined, default to evaluating the facing as a contributing structural element.

Architectural facing types and inventory codes are listed in Table 3. General descriptions and selected examples of the various types of facings that may be encountered during an inventory are also provided below.

Table 3. WIP architectural facing types and associated field inventory codes.

Architectural Facing	Code
Brick Veneer	BV
Cementitious Overlay	CO
Fractured Fin Concrete	FF
Formlined Concrete	FL
Plain Concrete (float finish or light texture)	PC
Planted Face	PF
Sculpted Shotcrete	SC
Shotcrete (nozzle finish)	SH
Steel/Metal	SM
Stone	SO
Simulated Stone	SS
Stone Veneer	SV
Timber	TI
Other – User Defined	OT

Brick Veneer [BV]: Retaining walls are seldom constructed solely of brick. Generally, the interior of the wall is constructed of either mass concrete or larger concrete blocks (also referred to as concrete masonry units (CMU's), cement blocks, and cinder blocks). Figure 38 is a good example of a suspected brick veneer facing.

Cementitious Overlay [CO]: A cementitious overlay is a thin application of cement to a wall facing used to enhance the aesthetic appeal of the structure. The overlay may range from a plain, flat finish (possibly stained or painted) to a colored and/or textured application.

Figure 51. Photo. Example of one of the many "Fractured Fin" formliner architectural facing treatments available and commonly used in urban construction. (Courtesy Fitzgerald Formliners)

Figure 52. Photo. Although a seemingly accidental wall finish, a rough wood formliner was actually used in the construction of this concrete cantilever wall at Golden Gate National Recreation Area to simulate historical concrete construction practices throughout the park. This example emphasizes the need to discuss the cultural attributes of retaining walls with park resource staff prior to undertaking site inspections.

Fractured Fin Concrete [FF]: Fractured fin concrete (Figure 51) refers to a specific, yet popular category of formlined architectural treatments employing smooth/rough linear relief (striations, grooves, ridges – “fins”). This family of architectural concrete patterns is commonly seen throughout urban architecture, but is rarely seen within the park system.

Formlined Concrete [FL]: Formlined concrete (Figure 52) refers to a broad category of concrete facing finishes achieved by placing patterned molds within the concrete forms. Examples range from the aforementioned geometrical “Fractured Fin” patterns to simulated stone or brick patterns, to extravagant reliefs involving images of landscapes, animals, unique designs, etc. Figures 47 and 50 are typical examples of formliner applications within the park system. Surface treatments including color additives, stains and paint may be used in conjunction with formliner facings.

Plain Concrete (float finish or light texture) [PC]: As the name implies, plain concrete simply refers to a float finish with minimal texturing applied, if any. As illustrated in Figure 52, the inspecting engineer should be careful to not minimize the potential cultural importance of these facing finishes.

Planted Face [PF]: Planted face architectural treatments (Figure 53) are often found on geosynthetic-wrapped walls, but may also be used in conjunction with wire-faced MSE and gabion walls, as well as a variety of tiered wall types. Planting pockets can be sources for the onset of wall facing failures. The inspecting engineer should also consider that although it may be desirable for a particular wall face to be vegetated, not all forms of vegetation are good for long-term wall stability (e.g., trees growing from the facing).

Sculpted Shotcrete [SC]: Sculpted shotcrete (Figure 54) has been used on a limited basis in the parks, and is generally considered an architectural facing option for soil nail walls (where shotcrete finishes are often used). Color additives, staining and painting treatments are also commonly applied to enhance facing appearance or simulation of natural surfaces. This facing treatment may also be part of a secondary wall remediation effort, where shotcrete is used to quickly repair a failing wall section, and then sculpted for aesthetic purposes.

Shotcrete (nozzle finish) [SH]: Nozzle finished shotcrete is seldom seen in park applications, except where the wall is well hidden from the visiting public. In some circumstances, irregular surfaces, color additives, and/or staining may be used to further assist in camouflaging the structure.

Steel/Metal [SM]: Decorative metal wall facing treatments are very rarely used, and no examples of this treatment were readily apparent in the WIP Cycle 1 inventory. Decorative gabion facings could be interpreted to fall under this category, but would be better classified as “Other” to capture the gabion basket and rock fill architectural system.

Stone [SO]: Stone facings, mortared or dry-laid treatments comprised of one or more courses of stone across the thickness of the facing, are occasionally used in front of soil nail walls and MSE structures (Figure 55). Stonework can range from highly-masoned, “hand-sized” pieces to large machine-placed rockery material.

Figure 53. Photo. A well-vegetated wire-faced MSE wall in Siskiyou National Forest. Grasses, small bushes and other forms of light ground cover are appropriate for vegetated wall faces. Trees growing from the wall face or along the top of the wall, present a wall performance threat.

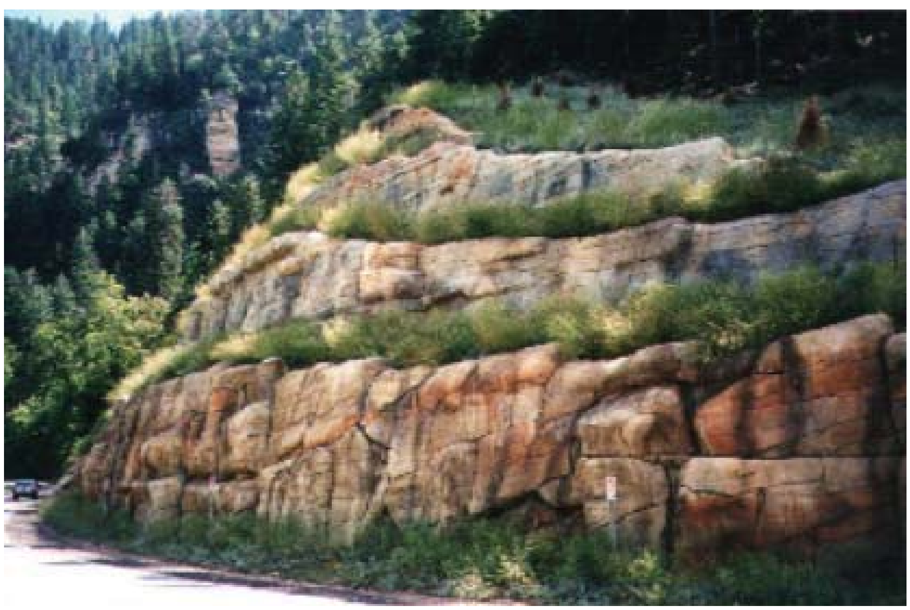


Figure 54. Photo. A dramatic example of the artistic range achievable with sculpted shotcrete. As time passes, the staining may fade along the wall, only to be replaced with natural staining due to annual weathering processes. The inspecting engineer will need to carefully evaluate both the condition of applied surface treatments and current visual quality of the facing when determining if remedial actions are required.

Figure 55. Photo. Single-course, mortared stone facing placed in front of an MSE wall structure. Well-built facings can make it very difficult to discern modern facades from historical structures. (Courtesy Mountain Village Metropolitan District, Telluride, CO)

Simulated Stone [SS]: Simulated stone (Figure 56) is generally considered a type of formliner treatment, but may also include such things as individual artificial stone products mortared on the wall face or precast concrete simulated stone masonry blocks (e.g., Ashlar blocks).

Stone Veneer [SV]: Stone veneer facings are comprised of thin plates of rock mortared to the wall face – commonly on concrete or shotcrete walls. Many of these veneers are historic, and close inspection often reveals the methods used to split the rock facing – an important item to consider when pricing repairs or replacement options.

Timber [TI]: Timber-faced walls (Figure 57) are rarely encountered in the park system, likely due to the maintenance requirements involved. Timber lagging and cribbing should not be confused as an architectural treatment. Lagging and cribbing are primary wall structural elements.

Other – User Defined [OT]: As noted above, a good example of an "Other" wall facing treatment would be the composite architectural aspects of a gabion-faced MSE structure (where the gabions are known to be non-structural). The gabion baskets allow for a wide array of basket geometries, rock fill colors and textures, and staining and planting options.

*****IMPORTANT*****
Depending on the wall type and facing systems used, it can be very difficult to determine whether a facing is structural or purely architectural. Always seek the expertise of park facilities, resource and maintenance staff to best determine the types of facing treatments being inspected.

Figure 56. Photo. Simulated stone using a deep-inset formliner and individually stained rock units. This application attempted to disguise the form joints by matching whole rocks panel-to-panel. (Courtesy Vail Associates)

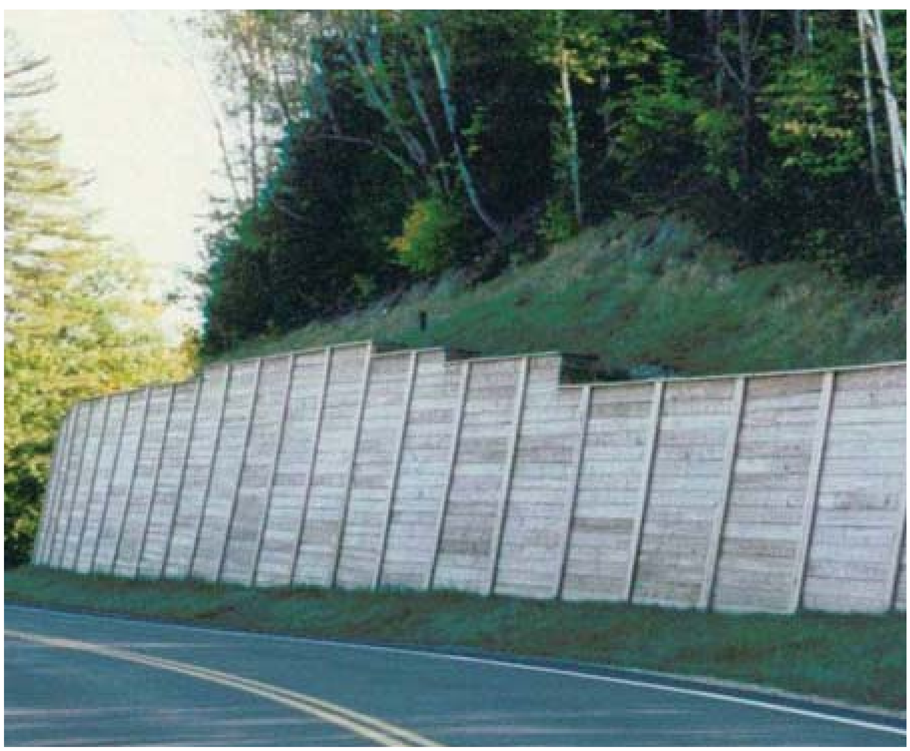


Figure 57. Photo. Timber-faced soil nail wall. (Courtesy New Hampshire DOT)

4.2.6 Surface Treatments

"Surface Treatments" includes all coatings or treatments used to color, preserve or protect wall elements. Surface treatments may include stain, galvanization, paint, tar coatings, wood preservatives, concrete sealers, color additives, or surface texturing (other than formliner applications). The inspecting engineer should note that more than one surface treatment might be present on a wall (e.g., painted piles and preserved wood lagging on a soldier pile wall).

Surface treatment types and inventory codes are listed in Table 4. General descriptions and selected examples of the various types of treatments that may be encountered during an inventory are also provided below.

Table 4. WIP surface treatment types and associated field inventory codes.

Surface Treatments	Code
Bush Hammer (tool-textured concrete)	BG
Color Additive	CA
Galvanized	GL
Painted	PA
Preservative	PS
Silane Sealer	SE
Stain	ST
Tar Coated	TR
Weathering Steel	WS
Other – User Defined	OT

Bush Hammer (tool-textured concrete) [BG]: A bush hammer is a masonry tool used to texturize stone and concrete (Figure 58). As the tool impacts the surface, a rough, pockmarked texture is created that simulates a naturally weathered surface. Tooling of the material may be done on site, in the case of cast-in-place concrete structures, or may be completed on precast wall elements prior to shipping. Although this surface treatment is rarely applied to park concrete structures, it is often seen on concrete panels used as architectural facings for MSE walls.

Color Additive [CA]: Color additives may be added to both cast-in-place and precast concrete wall elements (Figure 59), including modular blocks and architectural facing panels (Figures 44 and 49). Colored shotcrete is used for both sculpted and nozzle finish applications.

Galvanized [GL]: Galvanized metal wall elements are typically limited in park applications to coatings applied to facing and basket wires on MSE and gabion walls. When used on metal bin or crib walls, other forms of surface treatments (e.g., paint) may be used in conjunction with galvanization to minimize the visual impacts to the environment.

Painted [PA]: The most common application of paint-based treatments is corrosion protection of steel piling and non-galvanized steel fixtures (Figure 60). However, paint is also used on concrete, brick and wood surfaces, and ranges from poorly-applied, unprimed coatings to highly crafted applications simulating natural stone.

Figure 58. Photo. Example of concrete blocks textured with a bush hammer prior to placement. A range of textures can be created with this technique, depending on the hammer head size and configuration. (Courtesy Doublewal Corporation)

Figure 59. Photo. Example of float-finished, colored shotcrete applied over an MSE wall facing. (Courtesy Maricopa County, AZ)

Figure 60. Photo. Severe weathering distress is evident on painted steel sheet piling at the Sandy Hook Unit, Gateway National Recreation Area. Less conspicuous weathering of painted surfaces can be difficult to discern without close inspection and knowledge of the most recent paint applications.

Preservative [PS]: A variety of preservatives may be used to inhibit weathering of wood elements, including treatments applied by the manufacturer and subsequent treatments applied by park maintenance staff. Timber lagging on soldier pile walls and the exposed timber elements of crib walls are wood elements often treated several times over the lifetime of the structure.

Silane Sealer [SE]: Silane is a spray-on stone and concrete weathering protectant particularly known for its ability to permeate porous surfaces. A wide range of sealants are available spanning Silane, urethane and epoxy based treatments. Stain can also be introduced with these types of surface sealants.

Stain [ST]: Stains (Figure 61) can be applied to a wide range of wall types and architectural facings, including concrete, shotcrete, metal and wood elements, as well as rock fills in MSE and gabion walls. Although stains are generally applied for aesthetic purposes, many types of stain treatments also serve as wall element preservatives.

Tar Coated [TR]: Tar or bituminous coatings are most commonly seen in park applications as weathering treatments applied to timber crib or timber-faced walls (generally large timbers). These coatings may also be used as corrosion protectants on non-galvanized wall elements.

Figure 61. Photo. Example of sculpted shotcrete stained to match the surrounding landscape. Fading due to seasonal weathering and UV damage may require additional staining to meet aesthetics objectives.

Figure 62. Photo. Weathering steel, sold under the "CORTEN" trademark, can provide a long-life, low-maintenance surface treatment for wall systems in the right environment. (Courtesy Richer Metal, Dodge Center, MN)

Weathering Steel [WS]: Weathering steel (Figure 62), best-known under the trademark CORTEN steel, is a group of steel alloys developed to eliminate the need for corrosion protective coatings and painting, forming a rust-like appearance if exposed to the weather for several years.

Other – User Defined [OT]: "Other" simply refers to surface treatments not covered in Table 4.

*****IMPORTANT*****
Surface treatments can be difficult to discern and are *often* overlooked during wall inspection. The inspecting team should discuss with park facilities staff the types and durabilities of surface treatments being periodically applied to wall elements.

4.2.7 Wall General Description Notes

The inspecting engineer should briefly describe attributes of the wall structure not fully described in the wall inventory, including the purpose of the wall, the general setting/terrain in which the wall resides, the type of construction, presence of multiple wall types and/or different construction periods, and the consequence of wall failure. An example of an appropriate wall description might include…"Recently repointed mortared stone masonry fill wall, supporting seasonally high ADT Park entrance road, founded on steep slope with signs of seasonal seepage." In the case of bridge walls, the National Bridge Inventory System (NBIS) bridge number should be logged, if known. If the wall is located on a non-RIP route, additional location descriptors should be added here.

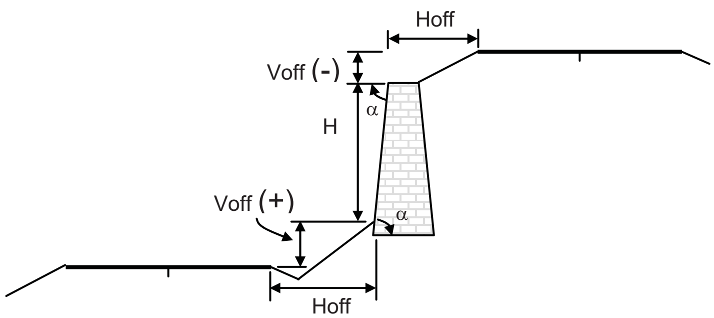
4.2.8 Wall Length

"Wall Length" is defined as the actual measured maximum earth retaining length of the wall, measured to the nearest foot, excluding non-earth retaining wall features such as guardwalls and parapets (Figure 63). Guardwalls, guard rails and other traffic barriers are covered under other inventories. In situations where long sections of guardwall are underlain by shorter, discrete retaining wall structures, the inspecting engineer must discern at what point the guardwall is a feature of the retaining wall supporting the roadway or is constructed atop a foundation structure built primarily to support the guardwall and not the roadway (which may approach the ≥ 4 ft wall height criteria). In situations where the guardwall foundation structure is determined to also serve as a retaining wall for the roadway, and meets the criteria and intent of the wall acceptance criteria, the structure should be included in the wall inventory.

When evaluating an undulating, variable-height wall with one or more intervening short-height sections (< 4 ft), the inspecting engineer needs to discern whether the wall is acting as one retaining structure or if sections are functioning independent of one another requiring separate inventories. Considering the wall type, construction materials, and cultural aspects, the inspecting engineer should determine if wall replacement would involve the entire structure or just the independent segment when determining how to include the wall(s) in the inventory.

4.2.9 Maximum Wall Height

"Maximum Wall Height" refers to the maximum *observable and/or verifiable* height of the wall (Figure 63), measured to the nearest foot. Estimated embedment and/or guardwall/parapet structures are *not* included in the maximum wall height. The maximum height measurement extends from the groundline at the wall toe to the top-of-wall groundline, or to the estimated original designed top-of-wall groundline for the case where retained material has been removed (e.g., surface erosion behind the top of the wall). An estimated maximum height shall be logged for fully buried structures based on available information or estimates provided by park staff.



H	Exposed wall height, ft
Voff	Average vertical distance from pavement to cut wall toe or groundline at top of fill wall (+ above/- below roadway), ft
Hoff	Horizontal distance to wall face from edge of pavement or gravel travelway, ft
Hmax	Maximum exposed or verifiable wall height, ft
α	Wall face angle, degrees
L	Total constructed wall length at top of wall ground line, ft

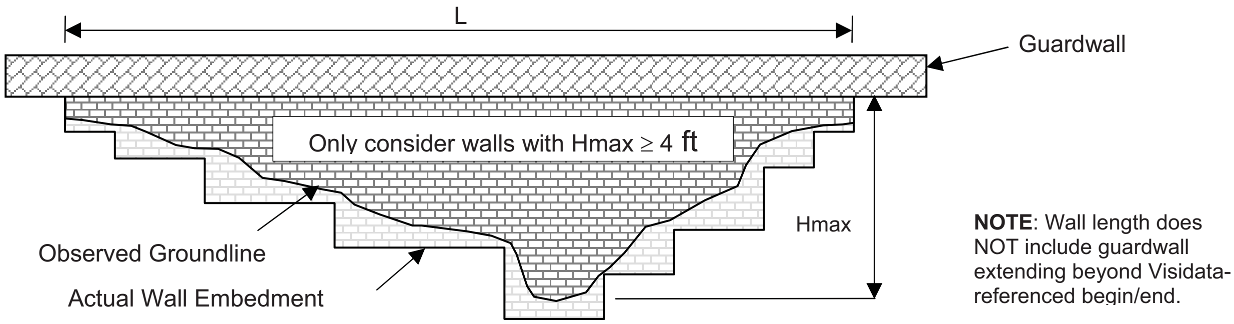


Figure 63. Graphic. Drawing showing required field measurements, including the observed maximum wall height, actual wall length, vertical and horizontal offsets from the edge of road, and wall face angle.

4.2.10 Wall Face Area

"Wall Face Area" is the field-calculated exposed area of the wall face, determined to the nearest 5 sqft, less culvert opening area when this area is estimated to be greater than 25% of the wall face area and guardwall/parapet area(s). The inspecting engineer should note that this value is akin to the "estimated vertical wall face projection area", as used in estimating wall construction. Several methods may be used to estimate the exposed wall face area; however, the preferred method is to divide the wall face into simple polygons, determine the area of each polygon, and sum the individual areas. This method requires multiple wall measurements, but generally results in more accurate estimates of wall face area.

4.2.11 Vertical Offset

"Vertical Offset" (Figure 63) is the average vertical distance, measured to the nearest foot, from edge of travelway to the toe of above-grade walls or groundline at the top of below-grade walls (recorded as + ft above travelway and - ft below travelway). For example, the toe of an inboard cut wall could be either above the nearest edge of road grade (+ vertical measurement) or within the ditchline below the nearest edge of road grade (- vertical measurement). Outboard fill walls are commonly at or below road grade (- vertical measurement).

4.2.12 Wall Start/End Offset

"Wall Start Offset" (Figure 63) is the approximate horizontal distance, measured to the nearest foot, from the edge of pavement to the wall face at the start of the wall. Similarly, "Wall End Offset" is the horizontal distance from the edge of pavement to the wall face at the end of the wall.

4.2.13 Face Angle

"Face Angle" (Figure 63) refers to the internal wall face angle measured from the horizontal to the nearest degree. The corresponding angle, or alternate interior angle to the internal wall angle, is the dip angle of the wall face, measured from the horizontal down the wall face. In most cases, the face angle will fall between the minimum acceptance criterion angle of 45^o and 90^o; however, negatively battered walls may be encountered (overhanging walls with face angles > 90^o).

4.2.14 Photo Description/No.

"Photo Description/No." requires the investigating engineer to photo document the retaining wall, logging the digital photo number taken in the field and a brief descriptor for each photo. In general, the use of photos should be limited. One to two reference photos per wall should be taken from locations that facilitate easy future identification. Additional photos may be taken to document the magnitude and extent of wall distresses or unusual circumstances and to allow tracking of distress progression over time. To avoid excessive file sizes, digital cameras should be set to "low" or "medium" resolutions.

The following types of photos are sufficient for capturing key wall elements (use only as needed):

- Wall Approach – taken from the roadway/parking area looking up-station at the overall wall setting;
- Wall Frontal Elevation – taken from directly in front of the wall or slightly off to one side, and from sufficient distance back from the wall so as to capture the majority or entirety of the structure (when possible);
- Top of Wall/Roadway – taken looking up-station along the top of the wall, and capturing the condition of the roadway/parking area and traffic barriers immediate to the structure;
- Wall Face Alignment – taken from the side of the wall (up- or down-station, as access permits), capturing the cross-sectional view of the wall face;
- Wall Face Detail – taken directly in front of the wall, capturing the details of major wall structural and/or facing elements; and
- Wall Failure/Deficiency Detail – taken at specific wall locations illustrating typical wall deficiencies or element distress.

Most walls may only require 2-3 photos for adequate photo documentation (culvert headwalls often only require a single photo), whereas long complex walls may require additional photos (generally limited to 6-7 photos whenever possible).

Upon returning from the field, all photos shall be renamed to include the unique wall identifier established in the WIP Database (Park Alpha + Route No. + Milepoint + Side of Road) plus a photo number (1, 2, 3…). For example, MEVE-0010-2.134-R-3 would be the third photo taken of a wall in Mesa Verde National Park on the right side of Route 10 at milepoint 2.134. All photos should be backed up to a laptop, thumb drive or CD *each day in the field* to ensure photos for each wall inspected are safely delivered to the Central WIP Database.

4.2.15 Park-Designated Wall ID

In addition to the unique "WIP Wall ID" generated within the database (Park Alpha + Route No. + Milepoint + Side of Road), the park may already have a naming/numbering convention in place for wall structures. Park-generated wall identification systems may use approximate or measured mileposts, may use the milepoint information provided by RIP, or may simply number walls by occurrence from a starting reference point (e.g., beginning of a route). Some parks employ sophisticated bar coding technologies, which may be directly tied to FMSS asset numbers. In some cases, more than one wall identification system may be used within a given park. For example, park maintenance may use a wall identification system developed at the time of roadway construction, park resource staff may uniquely identify wall structures of historical significance, and facilities management may have all or a portion of park retaining walls already posted to FMSS with assigned asset numbers. To the extent practical, when park-designated wall identification numbers exist they should be logged on the Field Inspection Form and added to the database. Previously assigned FMSS asset numbers should take precedence over all other park-designated wall identification numbers (if available).

4.3 WALL CONDITION ASSESSMENT

At this point in the field inspection, the retaining wall has been located relative to the RIP Visidata milepoint reference system, odometer mileage along the route, or parking area nomenclature and the wall attributes have been classified, measured, and photographed. **The next step in the field inspection is to assess the condition of primary and secondary wall elements relative to extent, severity and urgency of observable distresses, and then numerically rate each element, giving due consideration to data reliability.** In addition to the element assessment, the overall performance of the wall system is evaluated and rated considering "global" aspects of wall performance that may not be directly observable. Finally, all element and global ratings are weighted and combined to arrive at a "Final Wall Rating".

Successfully assessing the condition of a retaining wall structure requires **(1)** qualified and trained inspecting engineers, **(2)** a systematic, well-defined, element-based assessment methodology, and **(3)** a commitment to providing complete, consistent and concise element condition narratives and ratings. To this end, this section describes the "Primary" and "Secondary" wall elements to be evaluated and the assessment of overall wall performance, defines the minimum elements to be evaluated per wall type, provides guidance and examples for preparing quality element condition narratives, and defines how element ratings and weighting factors are selected and applied.

4.3.1 Wall Element and Overall Performance Definitions

An elemental condition assessment and rating system is used to evaluate overall wall condition, identify remedial actions that may be required immediately or in the near future, and provide condition measures to track performance changes with subsequent inspections. Primary and secondary wall elements are evaluated, as well as the performance of the overall system of wall elements. Primary elements include structural components; secondary elements include subsidiary features of the wall system and surrounding setting that contribute to wall performance.

"Elements", as used herein, are visible to the inspecting team. There are clearly wall components that are not visible, but are nonetheless important to the performance of the wall (e.g., MSE wall reinforcements). The rating of overall performance is the only way the performance and condition of these wall components are assessed in the WIP.

The following lists the primary and secondary wall elements to be evaluated, describes the overall wall performance features to be evaluated, and provides guidance on the minimum descriptive information required for the condition narrative. (NOTE: Specific types of element distresses to be captured in the assessment per wall element are described later in subsection 4.3.3 Element Condition Narrative Guidance.)

Primary Wall Elements

Piles and Shafts: "Piles and Shafts" include driven piles, micropiles or drilled shafts comprising all or part of the visible wall, as well as supplemental structures such as timber, steel or concrete walers (Figure 27). Identify the specific type of pile or shaft (e.g., timber pile; steel H-pile; pre-stressed concrete pile; vinyl sheet pile; cased micropile; secant drilled shaft) and describe the installation method (e.g., driven; drilled; cast-in-place), if known.

Lagging: "Lagging" refers to structural timber, concrete or steel lagging between piles and walers (Figure 27). Describe lagging according to material type, size, treatment and installation method (e.g., treated 6x6 timber lagging; pre-cast 8-ft-square concrete panels).

Anchor Heads: "Anchor Heads" refers to all visible parts of a tieback ground anchor system, including the pad and bearing assembly, generally observed without removing the anchor cap (Figure 27). Describe the bearing structure and manner in which the ground anchor is affixed within the wall structure (e.g., single row of strand ground anchors placed on 8-ft centers through steel, box-frame whalers).

Wire/Geosynthetic Facing Elements: "Wire/Geosynthetic Facing Elements" refers to the visible facing/basket wire, soil reinforcing elements, hardware cloth, geotextiles/geogrids, and

Figure 64. Photo. Not all MSE wall facing systems are the same. Mats may or may not be galvanized (left) and, depending on the size of facing fill versus the minimum wire mat opening, hardware cloth may or may not be required for fill retention (right).

facing stone that may be readily observable in the wall facing (Figures 46 and 64). Describe the component materials, placement location, special appurtenances (e.g., facing panel struts) and method of construction in the condition narrative (e.g., 4-in-square, galvanized wire mesh gabion baskets with 6-in to 8-in round river rock fill; sod-rolled, geogrid-wrapped, geogrid reinforced face).

Bin or Crib: “Bin or Crib” refers to the visible portion of a cellular gravity wall (Figure 35, 36 and 37). Describe the component materials and method of construction (e.g., 8x8 treated timber crib wall; 10x10 corrugated steel bin wall).

Concrete: “Concrete” refers to visible precast or cast-in-place concrete wall and footing elements (Figure 65). Concrete piles, lagging, crib blocks, manufactured block/brick, and architectural facing elements are <u>not</u> included under this element. Describe the type of concrete (if known), size of aggregate (if visible), and method of construction (pre-cast/cast-in-place) (e.g., non-reinforced, cast-in-place concrete with rounded “river run” aggregate).

Shotcrete: “Shotcrete” refers to visible structural shotcrete at the wall face, and does <u>not</u> include architectural facing (unless the facing is both structural and architectural). Describe the relative strength, thickness, color, and finish and application quality in the condition narrative (e.g., 8-in thick, fiber-reinforced, float-finished, steel-reinforced shotcrete with red color additive).

Figure 65. Photo. Severely weathered reinforced concrete headwall at Delaware Water Gap National Recreation Area.

Figure 66. Photo. Not all mortar applications are the same: (from left-to-right) highly-crafted mortar placement on fairly new wall at Bryce Canyon National Park; poor, inconsistent mortaring at Capulin Volcano National Monument; well-placed, yet highly weathered mortar showing signs of excessive seepage through headwall at Great Smoky Mountains National Park.

Figure 67. Photo. A mortared stone masonry headwall along the Blue Ridge Parkway, subsequently overlain with a dry-laid, placed-stone retaining wall built around trees growing at either end of the headwall.

Mortar: “Mortar” refers to visible mortar used between either uncut, “pitched” (hand-worked) or masoned rock, between manufactured blocks or brick, or used for wall repairs (Figures 66 and 67). Describe the type of mortar used (if known), placement quality, whether or not the mortar was placed at the time of wall construction, if repointing work is evident, and if mortar reinforcement was used (e.g., mortared stone masonry wall with unfinished mortar joints; trowel-finished, mortar set solid cinder blocks; trowel-finished mortar patch with chicken wire reinforcement). [NOTE: Additional discussion on repointing is provided in sections 1.3 A Program Perspective on Deferred Maintenance and 4.4.6 Recommended Action.]

Manufactured Block/Brick: “Manufactured Block/Brick” include concrete masonry units (CMU’s), segmental blocks (Figure 45), large gravity blocks (often referred to as “bin blocks”), etc., but does <u>not</u> include concrete lagging or crib wall components. Describe the specific type and size of manufactured block/brick and method of construction (e.g., decorative, dry-laid, 8-in by 18-in Keystone segmental block with tan color additive).

Placed Stone: “Placed Stone” refers to dry-laid, rockery, or mortar-set, rough or lightly worked, uncut rock. Describe the type, size range of rock, and construction method (e.g., dry-laid, rectangular12-in to 24-in long and 4-in to 10-in thick, limestone; mortared 6-in to 10-in diameter rounded, granitic river rock).

Stone Masonry: “Stone Masonry” refers to dry-laid or mortar-set cut or “pitched” (hand-worked) rock. Describe the type, size range of rock, and construction method (e.g., mortared, 8-in to 24-in rectangular, red sandstone “Ashlar” blocks).

Figure 68. Photo. Examples of deteriorating wall foundation conditions: (clockwise from upper left) outlet scour at culvert headwall, Great Smoky National Park; soft soil erosion from under mortared stone masonry walls at Yellowstone and Crater Lake National Parks; deteriorating rock foundation at Acadia National Park.

Wall Foundation Material: "Wall Foundation Material" refers to the visible soil and/or rock immediately adjacent to and supporting the wall, within 2-4 ft of the wall toe or noticeable bench in front of the wall on steep slopes (Figure 68). Describe the type of foundation material present or missing, apparent strength of the foundation material, and construction characteristics of the foundation (e.g., hard, intact bedrock foundation throughout; soft, clayey soil foundation, scoured beneath 50% of the wall). The performance of buried foundation elements such as spread footings or piles is not captured under this condition element but, rather, under the "Performance" element in the "Wall Performance" section of the condition assessment (described later in this section).

Other Primary Wall Element: "Other Primary Wall Element" includes any element providing structural capacity to the wall not listed. Describe the type of element, materials and construction methods, as appropriate.

Figure 69. Photo. Plugged "weephole" drain at bottom of mortared stone masonry wall.

Secondary Wall Elements

Wall Drains: "Wall Drains" refers to the function and capacity of visible drain holes, pipes, slot drains, etc., providing wall *internal or subsurface drainage* (Figure 69). Describe the type and occurrence of wall drain(s), as well as the occurrence and magnitude of seepage through and around the wall (e.g., PVC weephole drains at toe of wall on 50-ft centers). A lack of visible wall drains requires the inspecting engineer to judge the overall drainage capability of the retaining structure, noting the presence of such things as soft and/or wet foundation soils, retained material piping from the wall face, excessive corrosion staining/efflorescence at specific wall locations, distressed elements immediate to seepage locations, etc. In the absence of visible wall drains and potential water-related problem areas, Wall Drains should be judged as functioning as intended.

Architectural Facing: "Architectural Facing" includes any facing that is not relied on for structural capacity, including concrete, shotcrete, stone, timber, geosynthetic/vegetation, etc. (subsection 4.2.5). Describe the type of facing, thickness, and construction method in the condition narrative (e.g., 6-in thick, sculpted, colored shotcrete with staining; 4-in-thick mortared stone masonry veneer; 4x6 precast concrete panel façade hung from wire-faced MSE wall).

Traffic Barrier/Fence: "Traffic Barrier/Fence" (Figure 70) refers to the condition of barriers, guardwalls, parapets and/or fences above, below or within the influence of the wall. Only describe and rate the barrier relative to wall performance, <u>not</u> its performance as a barrier (traffic barrier performance is evaluated under other asset and/or roadway safety programs). Describe the type, size and location of the barrier relative to the wall in the condition narrative (e.g., galvanized "W" guardrail on wood posts; mortared stone masonry parapet serving as constructed guardwall). This element should not be rated when the barrier structure lies outside the known or assumed influence of the wall, including the retained earth volume and adjacent slopes.

Figure 70. Photo. A section of parapet along this mortared stone masonry wall at Glacier National Park has been damaged due to vehicular impact. This portion of the wall would be assessed and rated under the "Traffic Barrier/Fence" secondary element.

Figure 71. Photo. Severe roadway damage due to timber crib wall fill settlement, loss of fill material, foundation bearing failure or global slope instability (or combination thereof).

Road/Sidewalk/Shoulder: "Road/Sidewalk/Shoulder" (Figure 71) includes the road, sidewalk and/or shoulder above or below a wall, and within the influence of the wall. These features should only be described and rated relative to wall performance; for example, pavement performance should not be rated, however, wall fill settlement seen as roadway patches should be described and rated. Describe the type, size, location and construction method(s) for each of these elements (e.g., 20-ft wide asphalt road surface with 5-ft-wide gravel shoulders on 3H:1V outboard slope; 6-ft-wide concrete sidewalk). The shoulder is generally defined as extending no greater than 5 ft horizontally from the roadway/sidewalk, and with less than a -5 ft vertical offset.

Upslope: "Upslope" (Figure 72) refers to the groundslope above a wall affecting wall condition and/or performance. Describe and rate the upslope condition for all walls located above roadway grade, regardless of slope ratio. Rate the upslope condition for all walls located below roadway grade, regardless of slope ratio, when the vertical offset to the wall is greater than 5 ft (otherwise include the condition of the upslope under the "Road/Sidewalk/Shoulder" element). Look for slumps, cracks, seeps, bulges, erosion, etc. that may affect wall performance. Describe the approximate slope ratio, slope height, and slope soil/rock constituents (e.g., lightly vegetated roadway fill extending 15-ft above top of wall at a 1.5H:1V slope ratio).

Downslope: "Downslope" (Figure 73) refers to the groundslope area below a wall, distinct from the Wall Foundation Material element, and possibly affecting wall condition and/or performance. Describe and rate the downslope condition for all walls above or below roadway grade, regardless of slope ratio. In the case of above grade walls (e.g., cut wall above inboard ditchline), describe the downslope below the foundation materials, which may include the ditchline and roadway bench. For walls that toe into the bottom of steep upslopes (e.g., culvert inlet headwall in an inboard ditch), describe the downslope setting (actually grading uphill from the toe of the wall/inlet structure) and the slope conditions. For walls that toe into an inlet/outlet drainage, describe the condition of the drainage. Look for slumps, cracks, seeps, bulges, erosion, etc. that may affect wall performance. Describe the approximate slope ratio, slope height, and constituent soil/rock materials (e.g., 10-ft of highly eroded roadway fill material on a 1H:1V downslope over 100+ ft of highly weathered rock; inboard headwall toes at base of steep (4H:1V) stable rock slope; stream channel below outlet headwall is deeply incised in soil/cobble matrix, with signs of head-cutting to headwall and wingwall foundations).

Lateral Slope: "Lateral Slope" refers to the ground slope laterally adjacent to a wall affecting wall condition and/or performance. Describe and rate the lateral slope conditions for all retaining walls. Look for slumps, cracks, seeps, bulges, erosion, etc. that may affect wall performance. Describe the approximate slope ratio, lateral extent of influence, and constituent soil/rock materials in the condition narrative (e.g., approximate 1.5H:1V lateral soil slope with deep erosion at wall end; durable, intact rock outcrop abutting wall end). Walls laterally terminated within oversteepened slopes commonly experience erosion problems at one or both ends.

Figure 72. Photo. Assuming the head wall height meets the 6-ft criterion, the overlying slope would be evaluated as an "Upslope" secondary element.

Figure 73. Photo. MSE wall at Glacier National Park awaiting final facing. The bench in front of the wall would be evaluated as a "Wall Foundation Material" primary element. The rocky slope below the bench would be evaluated as a secondary element under "Downslope".

Figure 74. Photo. Left unchecked, trees will grow just about anywhere, and can cause severe damage to retaining walls.

Vegetation: “Vegetation” refers to all forms of vegetation near the wall or on the wall face affecting wall performance (Figure 74). Describe the type, size, relative age and extent of vegetation when current growth impacts wall performance, or may potentially impact wall performance in the future. The overall impact of vegetation should also be carefully considered – good or bad – and noted in the condition narrative (e.g., roots from approximate 6-in-diameter trees at top of wall are pushing dry-laid stones from wall face; shrubs growing above, between, and below gabion baskets are mitigating run-off erosion of soft, silty soils).

Culvert: “Culvert” refers to the presence and condition of culverts, inlets and outlets through, below or adjacent to walls. Describe the culvert material, type, size, location, design and construction method (e.g., 18-in-diameter corrugated metal culvert pipe outletting 6-ft above toe of wall; mortared stone masonry arch culvert inletting at toe of wall). As these structures concentrate water flows through walls, the inspecting engineer should be particularly mindful to evaluate the functionality and capacity of the culvert, noting seeps, staining, accumulated soils and debris, and inlet/outlet erosion issues, as well as the internal integrity of the culvert. This level of inspection is only suitable as it pertains to the WIP. Culvert inspections should be carried out by qualified Hydraulics Engineers.

Curb/Berm/Ditch: “Curb/Berm/Ditch” refers to lined or unlined *surface drainage* features above or below the wall. Describe the type, location, capacity, and construction method of each element (e.g., 6-in asphalt curb with overtopping erosion evident 6-ft back from top of wall face).

Other Secondary Wall Element: “Other Secondary Wall Element” includes any element not providing structural capacity to the wall not listed. Describe the type of element, materials and construction methods, as appropriate.

Wall Performance

The final item to be assessed and rated on the Field Inspection Form, “Performance” refers to the overall, composite functionality of the primary wall structure and secondary wall elements, as indicated by a broader view of wall performance not necessarily captured by observed distresses for specific elements. “Performance” includes global wall distresses (rotation, settlement, translation, displacement, etc.) and/or evidence of prior repairs that may indicate component problems. This rating element also allows the composite, relational performance between all wall elements to be evaluated, aside from just evaluating individual element conditions, and may include the impact of combined distresses. The inspecting engineer should also note whether wall repairs are evident, specifically what repairs were made, and whether or not the repairs were successful at returning the wall to its intended function and level of service. Performance may also take into account previous inspection information.

Figures 75 and 76 present examples of wall distress that would be captured in the overall wall “Performance” description.

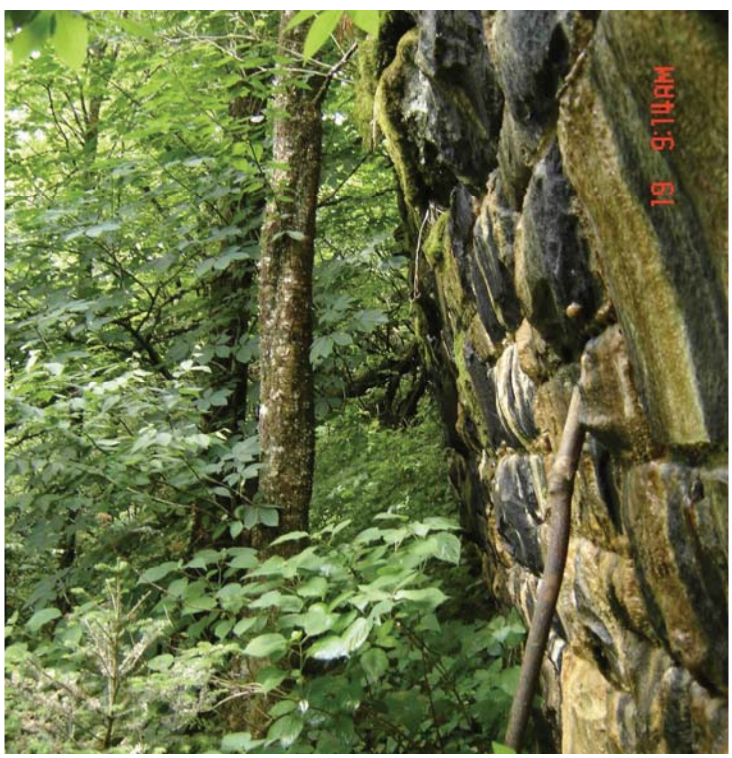


Figure 75. Photo. Overturning mortared stone masonry wall at Great Smoky Mountains National Park (assessment of primary/secondary elements alone would miss this obvious pending failure).

Figure 76. Photo. Developing wall problems at New River Gorge National River evidenced by post-construction remedial actions.

4.3.2 Minimum Element Rating Requirements

Specific primary and secondary wall elements are assessed and rated for each wall type listed in Table 2. For example, for a tieback H-pile wall, the assessment of "Piles", "Lagging" and "Anchor Heads" would be required; "Roadway/Sidewalk/Shoulder", "Upslope" and "Downslope" would be required depending on wall location relative to the roadway; and other primary and secondary elements would be assessed per their occurrence. "Wall Foundation Material" (primary element), "Wall Drains" and "Lateral Slope" (secondary elements), and "Performance" are assessed and rated for *all* walls. The chart in Figure 77 provides guidance on the minimum element assessment and rating priorities for each wall type listed in Table 2 (subsection 4.2.2 Primary Wall Type).

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 above or below roadway grade, regardless of slope ratio.

Figure 77. Graphic. Required wall assessment and rating elements per WIP wall type.

> *****IMPORTANT*****
> Although a wall or system of wall structures may possess a variety of contributing primary and secondary elements, the inspecting engineer must ensure that the wall elements identified in Figure 76 are assessed at a minimum (yellow items are collected for all wall types). Also, wall systems comprised of a primary wall type and one or more secondary wall types are evaluated as one overall retaining wall.

4.3.3 Element Condition Narrative Guidance

Once the pertinent primary and secondary wall elements have been identified for a given wall type, the inspecting engineer documents element condition on the back page of the Field Inspection Form (example provided in Appendix B). The "Condition Narrative", written for each wall element assessed, clearly and concisely describes an element's condition in terms of the ***type(s), severity, extent and urgency*** of observed element distresses. These narratives are then used to support the selection of appropriate element condition ratings, as discussed in the next subsection. The inspecting engineer should use the distress definitions and terminology provided in the "Element Condition Narrative Guidance", presented in Table 5 and in the Wall Inspection Field Guide, when developing descriptive narratives to encourage database consistency.

Table 5. Condition narrative guidance for typical wall element distresses within four general categories: Corrosion/Weathering, Cracking/Breaking, Distortion/Deflection, Lost Bearing/Missing Elements.

WALL ELEMENT CONDITION RATING GUIDANCE
GOOD TO EXCELLENT **(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 from the wall area.
FAIR **(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 rock, softening of 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 of discontinuities in rock, or cracks or gullies in soils. • 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 displacement beyond normal prescribed post-construction limits (e.g., wall face rotation, basket bulging, 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 materials from the wall area.
POOR TO CRITICAL **(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. • Extensive weathering/weakening of bedrock, softening of soil, or saturated ground conditions evident. • Severe impacts from vegetation are evident within the wall or within adjacent elements. **Cracking/Breaking** • Extensive severe element cracking, breaking, abrasion or construction/post-construction damage, opening of discontinuities in rock, or cracks or gullies in soils. • Concrete, shotcrete, and mortar is consistently soft, drummy, or missing, has lost durability and strength, and shows pervasive cracking and/or spalling intercepting corroding/weathering reinforcement. • Drainage is missing, clearly damaged, and/or obviously clogged and non-functional. **Distortion/Deflection** • Wall elements show extensive settlement, bulging, bending, heaving, distortion, misalignment, deflection, and/or displacement well beyond prescribed post-construction limits, including loss of ground reinforcement and retention. **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 over-steepening, and/or may be adversely impacted by vegetation. • Substantial slope failures have occurred either removing or adding materials from the wall area.

In some cases, limited wall access and/or vegetation, snow or water cover may obscure wall elements from direct observation. The inspecting engineer should note accessibility/visibility issues in the condition narrative, rate the element to the extent possible per the guidelines in section 4.3.4, and document the level of data reliability per the guidelines in section 4.3.6.

Examples of descriptive narratives following the aforementioned guidance include:

Lagging: Timber lagging moderately to highly weathered. Splitting/dry rot of 20% of the wall facing. 10-15% of timber lagging broken or missing. Wall backfill migrating through the face at several locations. Minor piping at top of wall where lagging is broken/missing.

Stone Masonry: No cracking; only minor weathering/chemical attack within sandstone masonry blocks. Isolated blocks are missing due to mortar failure, but not immediately affecting wall performance.

Piles and Shafts: Moderate to severe corrosion occurring at waler/H-pile junction welds over approximately 25% of the wall. Three adjacent piles show outward deflection indicating possible tieback anchor failure. No evidence of anchor failure seen in the anchor cap.

Concrete: Regular vertical/transverse cracking on 3-5 ft centers. Moisture seepage through lower wall cracks. Spalled concrete near wall start with exposed reinforcing steel showing substantial corrosion. No additional signs of chemical attack along the wall face.

Wall Drains: 4-in diameter PVC drain pipes exiting base of wall every 50 ft. Several pipes are broken at the face, but appear open and functioning. No signs of seepage through the wall face or wall foundation.

Upslope: 1.5H:1V soil upslope extends 15 vertical feet to roadway grade. No slumping or significant erosion due to good slope vegetation.

*****IMPORTANT*****
It is imperative that the inspecting engineer write element condition narratives sufficient to support both the element rating and to justify recommended maintenance, repair, and replace actions. This information serves as the basis for future inspections, requiring an accurate depiction of conditions from which to compare future wall element performance.

4.3.4 Element Condition Rating Definitions

At this point, the inspecting engineer has identified the type of wall being evaluated, determined the primary and secondary wall elements to be assessed (considering the minimum elements to be evaluated as shown in Figure 76), and prepared concise and descriptive condition narratives for each wall element. The next step is to provide a 1-10 numerical "Element Condition Rating" for each wall element per the rating definitions given in Table 6. Although there is some latitude regarding how element ratings may be interpreted, program experience indicates that rating variances among inspecting engineers are generally within ±2 rating points for a given element.

Although the Element Condition Rating does consider the nature and urgency of observed distresses, the inspecting engineer should *not* rate an element based on the anticipated action to be taken to maintain, repair or replace the element. **Only the condition of the element should be rated.** Although actions are closely related to element condition, final recommendations for wall repairs consider a number of factors, described in later section 4.4 Wall Action Assessment. Table 6 condition rating definitions apply to all primary and secondary wall elements, and are provided to consistently define element **severity**, **extent** and **repair/replace urgency**.

To provide a measure of the performance of wall elements that cannot be directly observed, as well as the overall earth retaining system, a "Wall Performance" rating is provided for all walls inventoried as well – commensurate with the requirement to assess the performance condition of each wall as described in the previous subsection. This allows the inspecting engineer to assess the composite performance of all wall elements acting together, including global wall distresses (rotation, settlement, translation, displacement, etc.) and/or evidence of prior repairs that may

Table 6. Primary and secondary wall element numerical condition rating definitions.

Element Condition Rating	Element Rating Definition
9-10 Excellent	No-to-very-low extent of very low distress. Defects are minor, are within the normal range for *newly constructed or fabricated* elements, and may include those resulting from fabrication or construction. In practice, ratings of 9 to 10 are only given to elements with very minor to no distress whatsoever – conditions typically seen only shortly after wall construction or substantial wall repairs.
7-8 Good	Low-to-moderate extent of low severity distress. Distress does not significantly compromise the element function, nor is there significant severe distress to major structural components. In practice, ratings of 7 to 8 indicate highly functioning wall elements that are only beginning to show the first signs of distress or weathering. For example, a ten-year-old soldier pile wall may have moderately extensive minor surface corrosion on piles where protective paint has weathered and peeled, and may have wood lagging beginning to split. Distresses are very low overall, present over a modest amount of the wall, and do not require immediate or near-term attention.
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 and/or elevated risk of element failure in the near term. In practice, ratings of 5 to 6 indicate functioning wall elements with specific distresses that need to be mitigated in the near-term to avoid significant repairs or element replacement in the longer term. For example, numerous anchor struts holding MSE wire facing elements in place are beginning to break due to corrosion and suspected over-stressing of the connections at the time of construction. Although the overall function of the reinforced earth wall is not in jeopardy, failing wall facing baskets are allowing facing fill to spill out. If several overlying baskets experience this isolated element failure, significant wall face sag and deformation may result at the top of wall, eventually impacting the overlying guardrail installation. This element should be inspected carefully along the entire wall and repaired as needed to forestall further facing basket deterioration.
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 closure is not necessary. In practice, a rating of 3 to 4 indicates marginally functioning, severely distressed wall elements in jeopardy of failing without element repair or replacement in the near-term. For example, mortar throughout a historic stone masonry wall is cracked, spalling, highly weathered, and often missing. Individual stone blocks are missing from the wall face, and adjacent blocks show signs of outward displacement. Although not an immediate threat to overall wall stability, stone block replacement and repointing throughout the wall in the near term are necessary to forestall rapid wall deterioration.
1-2 Critical	Medium-to-high extent of high severity distress. Element is no longer serving intended function. Element performance is threatening overall stability of the wall at the time of inspection. In practice, a rating of 1 to 2 indicates a wall that is no longer functioning as intended, and is in danger of failing catastrophically at any time. For example, a 15-ft-tall cast-in-place concrete cantilever wall has a large open horizontal crack running the full length of the wall at the base of the stem. Vertical cracks are also beginning to open up in the wall face. Water is seeping from most wall cracks, and is running from the basal horizontal crack at several locations. The wall face has rotated outward, resulting in a negative batter of several degrees. The overlying guardrail is highly distorted above the wall and the adjacent roadway is showing significant settlement above the retained fill. The wall is in imminent danger of failing catastrophically, requiring the overlying roadway be closed to all traffic until the wall can be replaced or retained soil backslope can be stabilized.

further indicate component problems or, conversely, functional improvements. Table 7 provides general guidance on defining overall wall performance and the numerical performance rating. The inspecting engineer should use this guidance in conjunction with the wall element rating guidance provided in Table 6 when determining an appropriate wall performance rating.

Table 7. Wall performance rating definitions.

Performance Rating	Performance Rating Definition
7-10 Good to Excellent	**Good to Excellent** No combinations of element distresses are observed indicating unseen problems or creating significant performance problems. No history of remediation or repair to wall or adjacent elements is observed.
5-6 Fair	**Fair** Some observed global distress is not associated with specific elements. Some element distress combinations are observed that indicate wall component problems. Minor work on primary elements or major work on secondary elements has occurred improving overall wall function.
1-4 Poor to Critical	**Poor to Critical** Global wall rotation, sliding, 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. Severe distresses are apparent on adjoining roadways.

For example, an MSE wall with a geogrid-wrapped face shows little sign of specific element distress (geogrid and backing geotextile are largely unweathered, drains are working, etc.). However, the wall is differentially settling at one end, as evidenced by a 3-6 inch vertical sag extending full-height in the wall face. A tension crack has begun to open at the top of the wall just beyond the estimated length of reinforcements, further indicating a global or external wall failure mechanism is actively developing. The inspecting engineer describes the overall wall performance as “low”, providing appropriate narrative describing the state of global distress, and rates the wall performance at a “4” per the rating definitions.

4.3.5 Weighting Factors

“Weighting Factor” simply refers to the weighting of the “Element Condition Rating” to account for various levels of element importance in the final “Wall Condition Rating”. “Primary Wall Elements” and “Wall Performance” apply a standard weighting of 8 to each element condition rating. Secondary wall elements apply a variable weighting scheme (0.5-5) dependent on the element condition rating: 0.5 for an element condition rating of 8-10, 1.0 for a rating of 4-7, and 5.0 for a rating of 1-3.

These element weightings have been determined to sufficiently discern element impacts on wall performance. However, as more wall inventory data are collected, weightings will be re-evaluated for appropriateness, and altered as needed to provide meaningful and consistent wall condition ratings.

4.3.6 Data Reliability Factors

"Data Reliability" is a 1-3 numeric rating describing the level to which the condition of a primary or secondary element could be observed. Although most of the aforementioned wall elements can be readily observed and assessed, there are occasions when elements are obscured by heavy vegetation, snow cover, water or are simply not readily accessible within the constraints of the inventory. This rating documents the relative reliability of the data based on observation access, and helps direct recommendations for future investigations. Table 8 provides simple data reliability factor definitions.

Table 8. Data reliability definitions.

Data Reliability Factor	Data Reliability Factor Definition
1 Poor	**Poor** Conditions cannot be sufficiently observed to rate element(s), warranting additional investigations to better define element performance and/or to determine the cause(s) of poor performance.
2 Good	**Good** Observed conditions are sufficient to rate the condition of wall element(s); however, additional investigations would be useful to better understand element performance.
3 Very Good	**Very Good** Observed conditions clearly describe wall performance. Additional investigations are not needed.

The need for additional investigations may result from several conditions. For example, the wall face may be inaccessible without a crane basket, snow, water or vegetation cover may preclude direct observation of wall elements, or causes of distress are not readily apparent. Following completion of the wall element condition assessment, the inspecting engineer reviews the data reliability for all wall elements and determines if additional investigation is warranted.

4.4 WALL ACTION ASSESSMENT

Once the overall wall performance and pertinent primary/secondary wall elements have been assessed and rated, the inspecting engineer rolls up the weighted element ratings into a "Final Wall Rating". This value ranges from 5-100, and is representative of the overall wall condition per the ratings definitions provided in Table 6.

Arriving at the Final Wall Rating is the first step in determining the appropriate action(s) to take relative to potential structure repairs or wall replacement – but other factors also need to be considered. Aside from the condition-based Final Wall Rating, the WIP action assessment considers four additional items: Are additional investigations required (how reliable is our assessment)?; What design criteria may have been used in planning the structure (was the structure engineered)?; What aspects of the wall structure are historic or contribute to the cultural context of the road asset?; What are the consequences of wall failure? Taken together, these five parameters allow the inspecting engineer to subjectively determine what action is required to sustain or improve wall performance: do nothing (the wall is performing as intended), monitor identified wall problems until the next inspection, perform routine maintenance, repair wall elements, replace wall elements, or replace the entire wall.

This approach is perhaps a departure from more conventional assessment schemes whereby a numeric wall rating is directly related to an action level, and not simply part of a decision process. In the case of the NPS program, the focus is on arriving at appropriate recommendations for sustaining/improving wall performance and developing early cost estimates for recommended actions – not necessarily on fitting a wall rating to an action. Within the WIP it is entirely possible to have walls with poor performance ratings given “No Action” work order assessments and, conversely, to have highly rated walls with high priority maintenance and/or repairs recommended. Although only a contributor to the final wall action assessment, numeric element ratings do allow the overall health of the NPS earth retaining structure asset base to be quickly assessed, point to common element problems within specific wall types, and help the inspecting engineer to arrive at consistent wall condition assessments.

Figure 78. Photo. A sizeable portion of this concrete crib wall is obscured by heavy vegetation. Although observed conditions are sufficient to rate the condition of wall elements, additional investigations might be required or recommended to better understand element performance, particularly if material or structural problems were suspected. (Data Reliability Factor = 2)

Clearly, the requirement to rate different primary wall elements per wall type, coupled with the potential for a range of secondary elements to be rated for any given wall, results in Final Wall Ratings that cannot be directly compared wall-to-wall. However, experience with developing ratings for many wall types indicates the WIP methodology satisfactorily characterizes the relative condition of walls sufficient to develop meaningful action recommendations and allow assessment of the total asset.

4.4.1 Final Wall Condition Rating

As noted above, "Wall Condition Rating" is the weighted average of all condition-rated wall elements and the wall performance, ranging from 5-100. While the rating is generally indicative of the level of action required (e.g., maintenance; repairs; element replacement*), it is directly related to the severity, extent and urgency of wall element distresses.*

4.4.2 Investigation Requirements

"Investigation Required?" (as shown on the front page of the Field Form in Appendix B) refers to whether the observational data are acceptable for characterizing wall distresses and overall performance, or if deficiencies exist, possibly warranting additional investigations *aside from routine geotechnical work involved with wall design/rehabilitation/replacement*. The inspecting engineer determines if additional investigations are warranted based on consideration of the overall element reliability ratings provided during condition assessment and, if so, prepares a work order for the investigation. For example, wall face elements may show little more than normal levels of distress for a structure 10-15 years old, yet the roadway above the retained fill section of the wall is showing substantial annual settlement, requiring regular roadway repair and repaving. A thorough inspection of the wall and adjacent elements does not immediately reveal the cause of the excessive fill settlement, suggesting the need for a preliminary subsurface investigation.

4.4.3 Design Criteria

"Design Criteria" is a measure of how well *current* design criteria are satisfied. The inspecting engineer should be knowledgeable of AASHTO wall design standards and aware of historic construction practices and workmanship sufficient to select from one of the following levels of applied design criteria:

- **None**: Does not meet any known design standards or systematic construction methods commonly used at the time of construction;
- **Non-AASHTO**: Does not meet AASHTO design standards (Figure 79), but is consistent with other structures of its type and period of construction exhibiting established construction workmanship and good performance; or
- **AASHTO:** Appears to meet AASHTO geometric, design, materials, and construction standards in effect at the time of construction.

For example, a newly constructed MSE wall, with proper facing fill, face batter, basket construction, toe and crest grading, apparent embedment, and systematic drainage in all likelihood meets AASHTO design requirements. Although clearly a non-AASHTO structure, intact and highly performing 70-year-old mortared stone masonry walls showing a high degree of craftsmanship and attention to foundation preparation and drainage would be considered a well-designed structure, consistent with other quality retaining structures of its period. In contrast, a rockery built with little consideration of stone size requirements, proper stone placement, or required drainage would be classified in the inventory as meeting no form of design criteria.

Figure 79. Photo. Although built to strict material and construction standards, this new rockery wall along the Guanella Pass Road in Colorado is a non-AASHTO design.

4.4.4 Cultural Concerns

"Cultural Concern?" refers to whether historic and/or cultural aspects of the wall should be considered and incorporated into the repair/replace recommendations. The inspecting engineer is required prior to the site visit, and at the time of the inventory kick-off meeting with park facilities and resource personnel, to determine if any or all park walls are culturally significant or are part of a cultural corridor, requiring special repair or replacement methods, materials, and/or construction standards. The specific types of repairs and processes for repair need to be well understood by the inventory team, with questions pertaining to specific walls directed to the park Cultural Resource Specialist at the time of the inventory. **All stone walls should be assumed culturally significant in the absence of additional information** (Figure 80).

4.4.5 Failure Consequence

The "Consequences of Failure" item provides a relative estimate of the cumulative risk to the public, associated roadway asset, and park facilities/operations were the wall to catastrophically fail. The inspecting engineer should become familiar with the park's alternate routes, daily traffic volumes, and road closure impacts sufficient to select from one of the following levels of failure consequence that most closely fits each situation:

- **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; or
- **High**: Seasonal to long-term loss of roadway, substantial loss-of-life risk, no alternate routes available.

Figure 80. Photo. Although this stone masonry-faced MSE wall at Bryce Canyon National Park is a relatively new structure built to AASHTO standards, it is nonetheless culturally sensitive as it contributes to the cultural context of the roadway corridor.

For the purposes of the NPS wall asset program, a more in-depth assessment of risk is not required. The WIP scope of data delivery is limited to a wall inventory and structure condition assessment. Risks associated with wall failure are best quantified and evaluated during later phases of asset management – those involving life-cycle cost analyses and budget prioritization – which are managed by the NPS within their FMSS program. By grossly assessing relative risk at this stage, attention can be drawn to walls requiring immediate or near-term attention.

NOTE: It should be emphasized to inspection teams that this wall action assessment factor is only related to public and asset risks following wall failure – it is not a measure of the risk potential for failure to occur. Structural (brittle vs. ductile failure), internal (reinforcement or tieback failure), external (sliding, overturning, bearing failure), or global failure modes should be discussed in the condition rating and described in the close-out memorandum to the park, as appropriate.

4.4.6 Recommended Action

The "Action" box on the Field Form (Appendix B) refers to the action to be taken to mitigate wall distresses, if present, and ensure the structure is functioning as intended. The inspecting engineer selects one of the following actions based primarily on the condition of wall elements (severity and extent of observed distresses), the urgency to mitigate distresses, and the consequence of wall failure – and *not* considering whether the work can be done by park facilities staff or must be contracted. Consideration is also given to whether or not additional investigations have been recommended, to what level specific design criteria were used in constructing the wall and may be required, and whether or not the wall is subject to cultural considerations that may direct specific types of repairs, repair methods and/or materials.

- **No Action**: The wall is fully functioning, with no action required at the time of the inspection.
- **Monitor**: The wall requires regular monitoring and/or investigation to determine the nature of observed distresses and what action may be required.
- **Maintenance**: Routine or cyclic maintenance is required to correct minor or low severity recurring deficiencies spanning a single wall element or the entire structure in order to minimize or delay further wall deterioration (Figure 81).
- **Repair Elements**: Minor to extensive repair of wall element(s) is required in the near-term to prevent rapid element deterioration, loss of performance or failure (Figure 82).
- **Replace Elements**: Replacement of specific wall element(s) or an entire section of wall is required in the near-term to preserve wall stability (Figure 83).
- **Replace Wall**: Replacement of the entire wall structure is required to reestablish the intended function of the wall (Figure 84).

For example, a 30-year-old metal bin wall is being evaluated along the main entrance road to a seasonally popular park. Significant corrosion has occurred in the exposed face of the bin wall, allowing the bin to be easily punctured with a geologist's pick. Several areas of the wall face, particularly near the bottom of the wall are beginning to develop open corrosion holes, with some loss of bin fill evident. Although the wall facing steel is highly distressed, the wall appears to be functioning well, with no signs of lost bearing capacity, settlement or displacement apparent in the wall face or along the overlying roadway. The inspecting engineer is concerned that the buried bin elements may also be suffering from significant corrosion, and has recommended additional investigation. The wall was built to well-defined standards at the time of construction and does not qualify as a cultural resource. The engineer, carefully considering all of these factors, determines that only minor maintenance is required at this time. However, due to the high ADT and critical-park-route nature of the roadway, it is recommended, and expensed within the work order, that a subsurface investigation be conducted to determine the integrity of the buried portion of the bin (is it better or worse than the facing steel?).

Field inspectors often have difficulty discerning "Maintenance" from "Repair" activities. Maintenance activities include items that are of a *cyclic or recurrent* nature: vegetation removal, cleaning wall drains, removing debris from culverts, replacing dislodged chinking, painting soldier piles, cleaning and sealing concrete and wood facings. Repair activities include non-routine fixing and restoring of wall elements to their intended function: resetting dislodged stonework, repointing stone masonry, regrading/reseeding adjacent slopes, patching concrete spalls, mending damaged wire baskets.

Figure 81. Photo. Culvert headwall along the Baltimore-Washington Parkway requiring removal of harmful vegetation along the top of the headwall. Vegetation removal was the most common type of maintenance item recommended throughout the Cycle 1 WIP inventory effort.

Figure 82. Photo. Much needed concrete repair on a cast-in-place gravity wall at Steamtown National Historic Site in Pennsylvania.

Figure 83. Photo. Dry-laid stone masonry elements in need of replacement at Yosemite National Park following minor slope instability.

Figure 84. Photo. Severely corroded metal bin wall in serious need of complete replacement at China Beach within the Golden Gate National Recreation Area.

As discussed in Section 1.3, nearly 25% of the total wall asset inventoried in Cycle 1 includes mortared stone walls (using mortared, pitched or rough stone). These structures generally represent the oldest walls in the WIP database and, therefore, it is common for the mortar to be highly weathered, cracked, spalled, broken or missing altogether. Although assessment of mortar condition is straightforward, following the guidance provided in Table 5, field inspectors were often confused as to whether maintenance or repair level work was required and, if so, which was more appropriate for the potentially large mortared stone wall asset within a given park. Should cracked and spalling mortar be repaired to restore the wall to its original condition, or should the wall be evaluated solely on performance, allowing the cracked mortar to be assessed similar to chinking in a dry-laid stone wall? Should mortar restoration work be simple crack sealing, a more comprehensive repointing effort, or should the wall or sections of the wall be disassembled and reset? Should this work be considered a recurrent maintenance activity or is it more appropriately defined as wall repair?

For consistency amongst inspectors, mortar will be evaluated per the condition assessment guidelines presented in subsection 4.3.1, recommended work will fall under the "Repair" category (non-cyclical/recurrent element restoration), and the need for repair will be based on wall performance, rather than on a requirement to restore the mortar element to its original condition. Giving due consideration to the potential for a 10-year reinspection period, the field inspector will need to exercise engineering judgment when determining whether mortar repairs are required.

4.5 WORK ORDER DEVELOPMENT

At this stage of the inventory/assessment process the wall has been located, the geometrics and functional characteristics described, the condition of specific elements and overall performance assessed, and actionable recommendations developed, as needed. If any action is recommended, including additional investigations or maintenance through full wall replacement, a brief work order description and "order-of-magnitude" (Class D) cost estimate is developed for general work items. The intent of the work order is to briefly characterize the work elements involved (e.g., labor, material, equipment) and provide a *very preliminary* cost suitable for comparison to other work orders within FMSS (excluding costs related to studies, engineering, permitting, procurement, etc., and location cost factors).

Work order costs are developed using the WIP Cost Guide provided in Appendix B, or other appropriate sources of cost information available at the time of the field inspection. The WIP Cost Guide provides costs related to wall and ancillary structure repair/replacement from three sources: **(1)** total wall replacement costs referenced in the 1997 edition of FHWA Geotechnical Engineering Circular No.2 "Earth Retaining Systems", updated to approximate 2007 costs (as available) with recent FLH wall construction bid histories, **(2)** cumulative costs for selected wall repairs based on recent project bid histories, price-indexed to 2007, and **(3)** 2007 price-indexed average costs for selected FLH pay items based on recent CFLHD project bid histories. The WIP Cost Guide, though far from complete and often requiring substantial estimation and interpolation, can serve as a useful reference when developing preliminary work order costs.

Prior to implementing future WIP inspection cycles, the FLH WIP Program Manager must update wall element and replacement costs per current year price indices. Field inspection teams should seek additional cost information from park facilities and maintenance staff to refine work order estimates to the extent practical.

Considerable variance in cost estimates can occur among inventory team members based on their interpretation of Cost Guide pricing, scope of work, and estimating experience of the inspector. Clearly, proper work order pricing is a subject in need of improvement for future inspection cycles. In the meantime, work order scoping and pricing consistency is best addressed through **(1)** standardized unit pricing based on FLHD bid histories, **(2)** training on proper work order development and pricing, **(3)** practical experience with field forms, condition narratives and work orders prior to conducting park inspections, and **(4)** collaboration between team members during wall assessments to get everyone on the same page regarding wall ratings and work order development. Park maintenance staff can oftentimes be invaluable sources for local construction costs, as well nearby material sources, concrete plants, fabricators, etc.

4.5.1 Brief Work Order Description

"Brief Work Order Description" is a very short, succinct description of the recommended work contained in the itemized repair/replace recommendations serving as the FMSS work order. This short description is used by the NPS in their FMSS asset management system in conjunction with the actual work order. For example, "replace broken wall lagging", "remove small trees from wall face", or "replace entire retaining wall" would be examples of suitable brief work order descriptions.

4.5.2 Repair/Replace Recommendations/Cost

"Repair/Replace Recommendations" is an itemized description of wall repairs, methods, estimated quantities, and costs per repair item, including consideration of constructability and cultural issues. Recommendations may also include, or even be limited to, additional site investigations required to fully scope the wall repair project. The inspecting engineer briefly describes the work items required to repair, rehabilitate or reconstruct wall elements, and then expenses each work item for the FMSS Work Order. Materials, equipment, labor and ancillary items (maintenance of traffic, staging area requirements, paving, etc.) should all be included in the cost breakdown. Design costs, construction management costs, and ancillary costs associated with such things as cultural/historic conservation activities are, however, not included. The current year WIP Cost Guide (2007; Appendix B) should be used for unit costs.

The following example illustrates an acceptable level of detail for the typical work order:

Remove trees growing from wall face. Remove damaged/broken masonry rock blocks, cleaning useable blocks and wasting unsuitable blocks. Replace damaged and missing interior wall and facing stones, and mortar in place. Repair/replace damaged and missing mortar around adjacent intact blocks. Reestablish curb drainage, cleaning debris accumulated along the top of wall and adding new curbing.
Labor: 4 man-days @ $550/day = $2,000
Dimensioned masonry, rock face finish: 4 cuyd @ $1,000/cuyd = $4,000

8-in asphalt curbing: 40 ft @ $10/ft = $400
Tree removal: 2 trees @ $100/tree = $200
Miscellaneous tools and equipment: $1,000 lump sum
Traffic control: 2 days (park-provided, gratis)
Total = $7,600

"Repair/Replace Cost", shown in the lower right corner of the Field Form, is the total estimated repair /replace and/or investigation cost based on itemized elements identified in the work order and priced per the current year Cost Guide. The minimum cost for qualified work is $55 – the estimated cost of one hour of labor.