Criteria for Road Rehabilitation

Determining how to rehabilitate the Road involves more than just the cost and duration of the work. Careful consideration of historical, cultural, and environmental resources, preservation of natural resources, and long-term maintenance issues, along with visitor and socioeconomic impacts, is paramount in the selection of the rehabilitation alternative. As a result of the condition assessment, rehabilitation alternatives are based on the following criteria:

- Construction staging, stockpiling, material sources, waste materials, and handling
- Visitor staging, visitor capacity, trails, traffic management, and public transportation
- Circulation – vehicle and pedestrian
- Visitor experience and use
- Construction duration and scheduling
- Construction techniques and material types
- Construction restrictions
- Design and phased construction costs
- Schematic design
- Risk management
- Maintenance and operation
- Contract packaging

Figure 77: A multi-disciplinary team investigates alternative rehabilitation techniques

The key elements of the criteria for the development of the rehabilitation alternatives are grouped into the following general topics:

- **Engineering, Design, Historic and Cultural Considerations and Alternatives**
  Drainage, slope stability, retaining walls, guardwalls, and roadway pavement

- **Techniques and Materials Considerations and Alternatives**
  Mobilization and staging, scheduling, material sources and handling, maintenance and operations, constructibility, and contract packaging

- **Traffic Management Operations**
  Two-way stops, alternating one-ways, intermittent stops, and closures

- **Visitor Management Strategies**
  Visitor staging and circulation, public transportation, parking, comfort stations, trails, signing, and interpretive and orientation information

- **Risk Management Considerations**
  Health and safety for the visitor, service personnel, rehabilitation workers, and issues of catastrophic events

The following discussion identifies specific considerations, alternatives, and recommendations for the rehabilitation of the Road as related to the general topics defined above.

Engineering, Design, Historic and Cultural Considerations, and Alternatives

Great care should be taken in the engineering and design process to preserve the historic and cultural significance, as well as the natural resources of the Road. Treatment of important roadway features should be carefully considered during the design stages of project development, and thoroughly conveyed to the potential rehabilitation contractors during the contract bid process to minimize risk factors and ensure practical and viable adherence to NPS requirements.

Historic features discussed in the body of this report include the many miles of stone masonry guardwalls and retaining walls, trailhead parking and vista points, stone arch drainage structures, bridges, and tunnels throughout the length of the Road. Also, the roadway alignment, width, grade, and consistency of construction material are of historic significance and should be preserved as practical.

Figure 78: An arch along McDonald Creek exhibits exceptional workmanship.

New and innovative ideas and procedures have been considered in the engineering analysis, and should be further investigated and included as appropriate in the various design and construction phases. These ideas and procedures should be sensitive to short-term and long-term maintenance requirements, roadway construction operations, visitation and traffic control needs, weather-related phenomena, and other parameters specific to the Road.

In the discussion of the engineering and design considerations and alternatives that follow, several references are made to traffic control methods as a component of the work. Please refer to the section on *Traffic Management Operations* later in this chapter for a discussion of recommended traffic control methods using alternating one-ways, two-way stops, intermittent stops, and closures.

Drainage Considerations and Alternatives


Figure 79: A scupper in an historic wall provides drainage from the roadway

Drainage and hydraulic considerations are of paramount importance in construction and rehabilitation work on the Road, and should be addressed early in the rehabilitation to avoid further deterioration.

Improvement of the overall roadway drainage is strongly recommended, as inadequate drainage is the single greatest cause of the deterioration of the Road and its structures. Water flowing across the roadway seeps into retaining walls, guardwalls, and other structures, which in turn breaks up the integrity of the structure through freeze-thaw cycles, and causing unpredictable movement of the structures. Water intrusion under roadways tends to move the fines in the roadbase, creating voids in the base and subsidence of the roadway. Without a reduction of the energy of falling water along drainageways, inlets and headwalls are damaged by impact and abrasion. Erosion occurs when water falls onto unprotected slopes. Without an adequate number of properly sized inlets, and well-maintained inlets, culverts, and cross-drains, water is likely to back up and spill over structures, and again potentially reduce structure integrity. Therefore, all roadway design and construction activities must be sensitive to existing and potential moisture intrusion throughout the roadway cross-section.

Overall Roadway. Where water is allowed to flow freely across the roadway, drainage features should be added to minimize water intrusion into structures and roadway pavement. Pavement should be kept sealed from water entering the roadbase. Valley pans (Figure 80) should be added where appropriate to seal the interface between the roadway and retaining walls or guardwalls, and to direct flow to inlets or through scuppers in the walls. Cross-drains -- grate-covered trench drains askew to the roadway -- should be added where necessary to catch sheet flow and direct water across the roadway.

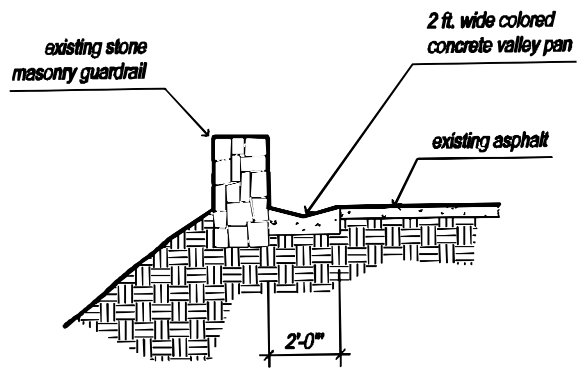

Figure 80: Installation of valley pan on guardwall face

In cases where the roadway has experienced subsidence due to water intrusion, two basic alternatives are available:

- Rebuild the roadbase by removing all unsuitable roadbase material, and replace it with suitable material in layers separated by geotextile fabrics.
- Using high pressure, inject a polyurethane grout into the material below the roadway to fill the voids and create a water barrier against future intrusion.

From a construction standpoint, rebuilding the roadbase is the less expensive alternative than the polyurethane injection method. Rebuilding the roadbase, however, will require traffic control using alternating one-ways, intermittent stops, and some two-way stops. Polyurethane injection would likely not require any two-way stops and therefore would have less impact on the visitor. Rebuilding the roadbase is also a task that most contractors can perform without extensive knowledge and special equipment, whereas polyurethane injection would require specially trained workers and special equipment. For the purposes of this study, rebuilding the roadbase is carried through the cost estimating and scheduling. During the design phase, alternatives should be considered at specific sites. If rebuilding the roadbase to rehabilitate the roadway is chosen, it is recommended that these operations be scheduled in September or October to have a minimum impact on visitors.

Culverts. Determining the proper number and size of culverts is a function of local hydrology, and site-specific hydrologic study should be undertaken during the design phase. Where inadequate flow capacity exists, the alternatives include:

- Removal of existing culverts and replacement with properly sized culverts. In cases where the inlet or outlet of the culvert is in a historic wall, attention must be given to the size of outlet with respect to historic significance.
- Installation of additional culverts near existing undersized culvert, with an effort made to avoid impacts to historic features.

In most cases, structures that cross the roadway will require alternating one-way traffic control for the duration of construction and/or installation (usually one to two days for a typical 36” CMP about 30 to 40 feet long, if proper equipment, materials, and personnel are readily available). Two-way stops may be needed in areas where the width of the roadway does not allow both a continuous travel lane and enough area for the work. It is recommended that these structures be designed considering ease of maintenance as well as practicality and hydraulic properties. To minimize traffic disruption, the contractor could use multiple crews and install a number of culverts through a traffic control zone. Also, steel plates or grates could be temporarily installed over open culvert trenches to expedite movement of traffic.

Installation of culvert linings may be considered as an alternative to replacing existing culverts with new structures. This option would allow for rehabilitation under controlled traffic. A corroded culvert pipe can be returned to nearly new flow characteristics without replacing the original pipe and with a minimal adverse effect on traffic flow. The cost of this procedure is usually about half the cost of a new culvert installation; however, its life span is not proven and would not be that of a replacement culvert.

Installing additional culverts would be a more expensive solution, especially with added wall outlet work. It would also require some additional time, depending on the installation detail. The rehabilitation cost estimates include replacement and new culvert installations for best serviceability and life cycle.

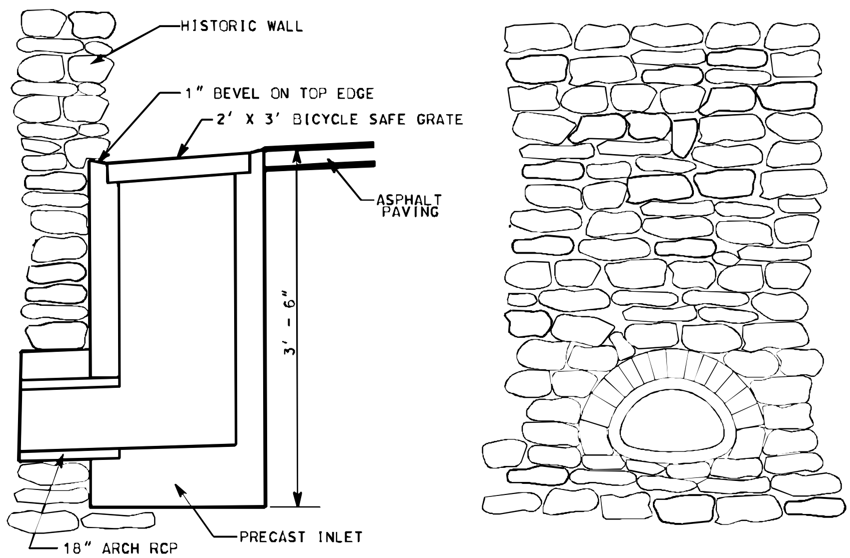

Figure 81: Installation of a drainage inlet on the roadway next to a stone masonry wall

Figure 82: Catch basins require some type of barrier to protect errant vehicles

Inlets, Catch Basins, and Trash Grates. Cleaning of inlets, catch basins, and trash guards should be a regular maintenance practice to allow the free flow of water into culverts that carry flow underground. Replacement of inlets should be made during roadway template rehabilitation. Inlet protection should include trash grates in areas off the Road to prevent accumulation and plugging of debris inside the culverts. Where inlets are located on the traveled roadway, cover grates should also be rated for bicycle traffic, and outlets should be constructed in concert with the historic nature of the wall (Figure 81). Historic catch basins in most places along the Road require some sort of protection for errant vehicles. They may be either the log barriers currently used (Figure 82), or removable barriers at the catch basin perimeter.

This work should be scheduled with other work within a specific area for integrated traffic control operation. Otherwise, most of this type of work can be accomplished with alternating one-ways.

Drainageways. On steep slopes, current drainageways are often plated with rock that creates a pleasing look, especially above the Road. This allows free flow of water and debris down the drainageway. With a smooth rock surface, very little debris hangs up in the drainageway and erosion is minimized along the water's path. A trash guard usually blocks debris from entering culverts; these guards require periodic maintenance.

The problem with drainageways lined with a smooth rock surface is that water and debris impact and abrade the historic headwalls and bottom slabs of concrete box culverts. One alternative to this is to secure larger rocks in a pattern along the drainage way to dissipate some of the energy from the falling water and debris and reduce the resulting abrasion on the headwalls. Some debris may hang up on the secured rocks and may require periodic maintenance; however, the reduction of abrasion and impact on the headwalls will help ensure their long-term integrity.

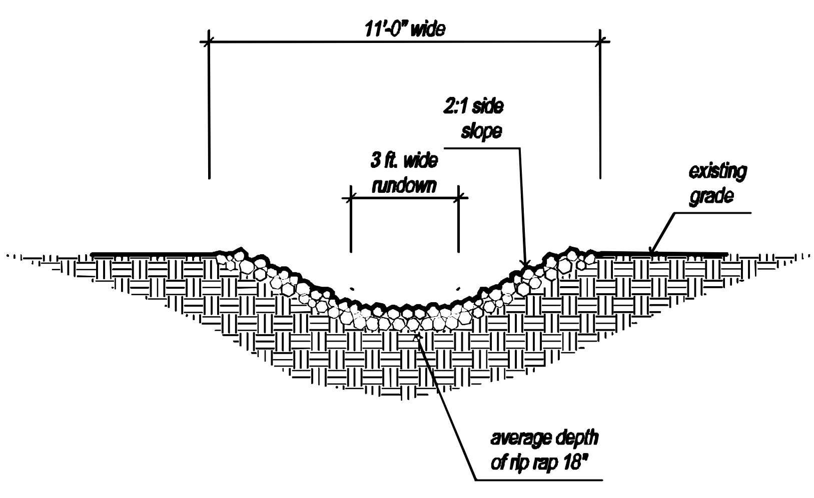

Figure 83: Installation of grouted rip-rap drainage rundown

To a lesser degree, in areas where water falls onto unprotected slopes and erosion is occurring, a grouted rip-rap drainage rundown can be constructed as shown in Figure 83.

Headwalls. The rehabilitation of headwalls requires the same basic rehabilitation

Figure 84: A guardwall in need of rehabilitation near MP 24.6

Slope Stability Considerations and Alternatives

Of the approximately 50 miles of Road, approximately fifteen miles have geotechnical concerns, most of which are concentrated in the Alpine Section. The geotechnical concerns fall into six general categories:

- Rockfall
- Unstable soil slopes above the Road
- Sloughing and erosion of slopes undercutting the Road or retaining walls
- Slump failures encroaching on the Road
- Debris flows onto and across the Road
- Avalanche areas and chutes

Figure 85: Rockfall area west of Logan Pass

Rockfall problems usually start at the edge of the pavement, as there is no shoulder or catch ditch in most locations. Rock faces are very steep and occasionally overhang the Road; they can range up to mountain-scale heights as shown in Figure 85. Hazards include loose rock detaching from the cut or cliff above the road, and boulders or loose rocks tumbling onto the Road from natural slopes above rock cuts. Potential mitigation measures include scaling of loose material, rock bolting, mesh, shotcrete, rockfall fences, rockfall sheds, and signing. Some controlled blasting may be required and extensive scheduling of shots must be carefully planned. Each of these mitigation measures can reduce some risk. The choice of mitigation must also consider historic significance, and for this reason, only rock scaling activities will require closure of two lanes for short periods of time. Rock scaling is not suitable for night-time work. Rock scaling can reduce rockfall hazard when applied to specifically identified locations of loose material, but cannot eliminate all rockfall hazards on the Road. The quarter-mile section west of Logan Pass is regarded as a primary rockfall hazard area. However, it is not deemed practical or effective to undertake scaling or bolting on this area of roadway.

Soil slope instability occurs as raveling of poorly vegetated, steep cut slopes continues, releasing rocks and boulders as shown in Figure 86. In a few locations, soil falls over rock cuts or cliffs onto the Road. The hazards include rocks and boulders tumbling onto the road as they are released by erosion, or soil/mud flows. The risks to public safety are similar to rockfall events, but are less prevalent. There are soil slopes immediately above the Road for an estimated two miles or less of the Road. Most are found along the east slope of Siyeh Creek; there are other smaller, isolated locations elsewhere. The Siyeh Creek area can be mitigated by bio-remediation and realigning the roadway to provide an adequate catch area.

Figure 86: Weakened fill adjacent to the roadway

Bio-remediation may be a good alternative on several of the steep soil cuts. This includes the use of a specialized material consisting of wire mesh and "biomat" to encourage revegetation on the slopes, making them more stable. The biomat is designed to hold soil, seed, and moisture to facilitate revegetation. The wire mesh component of the material snares loose rocks and prevents uncontrolled tumbling onto the roadway.

Colluvial slopes that "creep" are usually stable during dry periods, but may be prone to movement during wetter periods. Over time, these slopes may deform enough to damage the road surface and tilt guardwalls. Deeper-seated slumps may behave similarly, but at a later date may undergo larger displacements that could result in closure of the Road until repairs can be made.

Figure 86: Steep colluvial slopes along the roadway

Where steep colluvial or fill slopes exist below the Road, erosion and sloughing of poorly vegetated slopes erode back, undercutting pavement as shown in Figure 87. This problem is most dramatic where road drainage outfalls are eroding the slope below the Road. This is primarily evident in the alpine section, where slopes are steep adjacent to the Road. The problems will continue to worsen unless action is taken. The hazards include deterioration of road shoulder and loss of pavement width, loss of structural support for the roadway, safety of motorists, and loss of historic walls.

Potential mitigation measures include retaining walls, reinforced earth, tiebacks or micropiles, cantilevering the Road, realigning the Road toward the uphill side, and preservation of existing slopes from further erosion by soil nailing and armoring. Without action, the Road will continue to deteriorate. As the problem becomes worse, the repairs become more expensive and time-consuming. Realignment or cantilevering of the roadway may be restricted due to conflicts with the Road's historic elements. Construction of a new road deck or slab, anchored with tiebacks or micropiles, may be a suitable solution in these areas.

The Big Drift area (Figure 88) and a section east of the East Tunnel (Figure 89) are the areas most urgently in need of correction of this type of damage. The pavement is being undermined in some locations, guardwalls have been toppled and lost by undermining, and the drop from the Road is precipitous.

Figure 88: The Big Drift area

Figure 89: The area east of the East Tunnel

In several instances, slump failures continue to damage the Road and require periodic patching. The damage often affects both lanes, and some instances involve historic walls. The hazards include damage to the pavement and possible loss of structural support for the Road, possible road closures, and loss of historic walls.

Slump failures are generally limited to approach sections where colluvial or fill deposits underlie the Road, and in short roadway sections at widely scattered locations. Potential mitigation measures include the construction of reinforced earth, tieback anchors, and subsurface drainage. Reinforced earth would be highly effective; however, it usually means that all or part of the stone masonry wall must be rebuilt. Adding subsurface drainage is non-intrusive to the historic character, however it may not be applicable or effective at all locations. Further geotechnical investigation is needed at these locations prior to design so that most the appropriate remedy can be selected.

More widespread is the phenomenon of slope “creep” which occurs in colluvial deposits. Damage from slope creep is generally confined to the outboard lane, and in most cases is “remedied” by periodic repaving. More severe cases can be mitigated by construction of a structural road deck or slab and footer on the edge of the outboard lane.

Debris, mostly bed load rock material, flows onto and over the roadway during high runoff events and avalanches as shown in Figure 90. Debris flows are generally confined to avalanche chutes and drainageways. However, there is a hazard of sudden flow onto the Road, sometimes of considerable volume. The risks in such cases include loss of guardwalls and other structures, road closures, and possible engulfment of vehicles and/or visitors who may be present during high runoff events. The extent of the problem is limited to approximately twenty easily-identified locations of drainageways and gully crossings. Potential mitigation measures include the installation of improved drainage crossings, debris barriers, signing, and road closure during high runoff events. While signing and road closures during high runoff events would reduce safety risk, they would do nothing to solve the problem. Debris barriers placed in gullies and drainageways will help solve the problem; however, they may be visually intrusive from the Road and would require periodic maintenance.

Figure 90: Debris flows onto and over the Road in this area

Avalanches are pervasive throughout the park (Figure 91). Their primary impact is damage to retaining walls and guardwalls. As their probability is very low during the peak visitor season, they are not addressed as a public safety issue for the Road. However, a hazard exists for park maintenance personnel during snow removal operations and maintenance activities in the spring. Existing procedures during these operations include personnel watching for conditions that may signify an event. The park should maintain these procedures and consider other means for early detection of avalanches. Avalanche-resistant sections of roadway and guardwall can be constructed in some locations. The use of seasonally removable guardrail, recently approved by FHWA, may be more practical in the more active areas such as Haystack Creek in the Alpine section.

Figure 91: Avalanche chutes scar the face of the mountain

Retaining Wall Considerations and Alternatives

The stone masonry retaining walls are of considerable historic significance, and will require rehabilitation to as near their original condition as feasible. The FHWA has conducted a thorough inventory and review of these structures, and documented evidence regarding deficiencies noted and recommended rehabilitation strategies. The FHWA has established a priority listing of wall sites and has completed preliminary and final designs for many of the necessary repairs. The FHWA submitted a report to the park in 1998, which it updated in 2000. The report was reviewed and the information and recommendations found therein compared very closely to the results of this independent study. With minor exceptions, the FHWA report is considered inclusive

Figure 92: Retaining walls allowed construction of the Road through alpine terrain

and accurate. The minor exceptions include areas where deterioration has progressed in and around the retaining walls since the last FHWA evaluation. The additional costs associated with these exceptions are included in the cost estimate for the overall rehabilitation.

In order to retain the serviceability and integrity of the Road until the overall rehabilitation commences, it is recommended that the FHWA-established work on retaining walls continue as scheduled until a Record of Decision from the EIS and final design are implemented.

FHWA has identified approximately 132 stone masonry retaining walls on the Road. As indicated in the Conditions Assessment, many of these walls are in need of repointing and other work such as repair of foundation supports, contingent guardwalls, and drainage facilities. Five of these walls are known to require major reconstruction or rehabilitation work as identified in the Conditions Assessment. Of the total, 41 were shown to be on known avalanche chutes. Three (MP 26.89, MP 26.97, and MP 27.09) were identified as having recent avalanche damage and subsequent repairs. Others may also require major reconstruction pending further analysis.

The continued use of the rehabilitation methods developed by FHWA and the park for retaining walls is recommended, and includes the following three principal techniques:

- Rebuild the roadbase by removing all unsuitable roadbase material, and replace it with suitable material in layers separated by geotextile fabrics, thereby mechanically stabilizing the earth (MSE) and reducing or eliminating the load on the wall. This method is cost effective, relatively simple, and has the ability to generally maintain the integrity of the wall during repair. The downsides to this method are that it will most likely require two-way stops and more hauling traffic on the roadway, and there are safety issues associated with large, open excavations.

- Construct a concrete slab across all or part of the roadway that is anchored with micropiles, thereby taking the load off the wall (Figure 93). This method is faster than rebuilding the roadbase, can be accomplished with alternating one-ways, and maintains the overall integrity of the wall during repair. This method, however, is a newer technology, more expensive, and requires specialty contractors to perform the work.

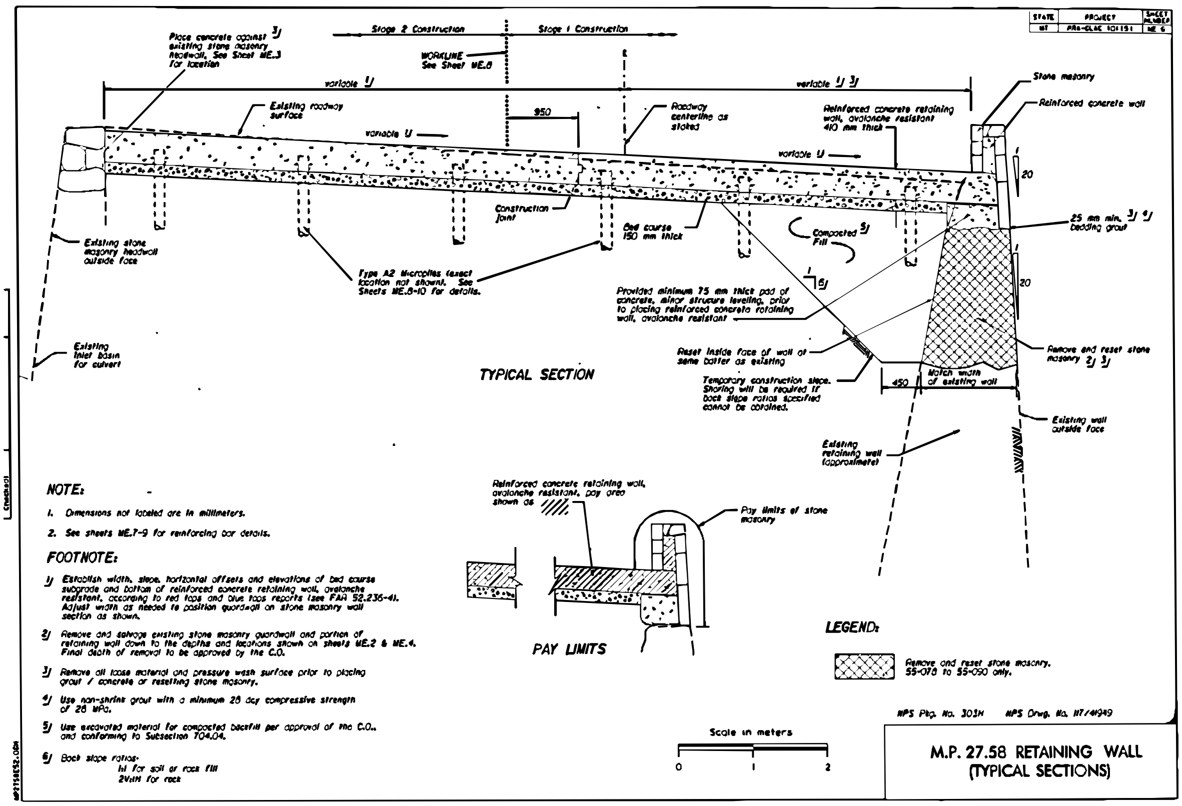

Figure 93: The FHWA design for retaining wall repair uses a concrete slab anchored with micropiles

- Stabilize backfill in place by high pressure injection of high-strength grout directly through the face of the rock wall and/or through the pavement and base courses into the underlying foundation (Figure 94). Either cementatious or polyurethane grout can be used; however, polyurethane is considered better for this application as it is not soluble in water and is therefore more effective in saturated soils. This technique can be used for locations where evidence of wall tilting is not present. This is the quickest method of repair, can be accomplished using alternating one-ways, and does the best job of maintaining the integrity of the wall during the repair. Both cementatious and polyurethane grout injection require speciality contractors, especially for polyurethane injection. The life cycle of this method is shorter than the other methods discussed, as it does not take the load off the wall.

In all cases, retaining walls should be restored to their original historic condition insofar as practical. In general, this rehabilitation should be completed prior to any work on a roadway segment.

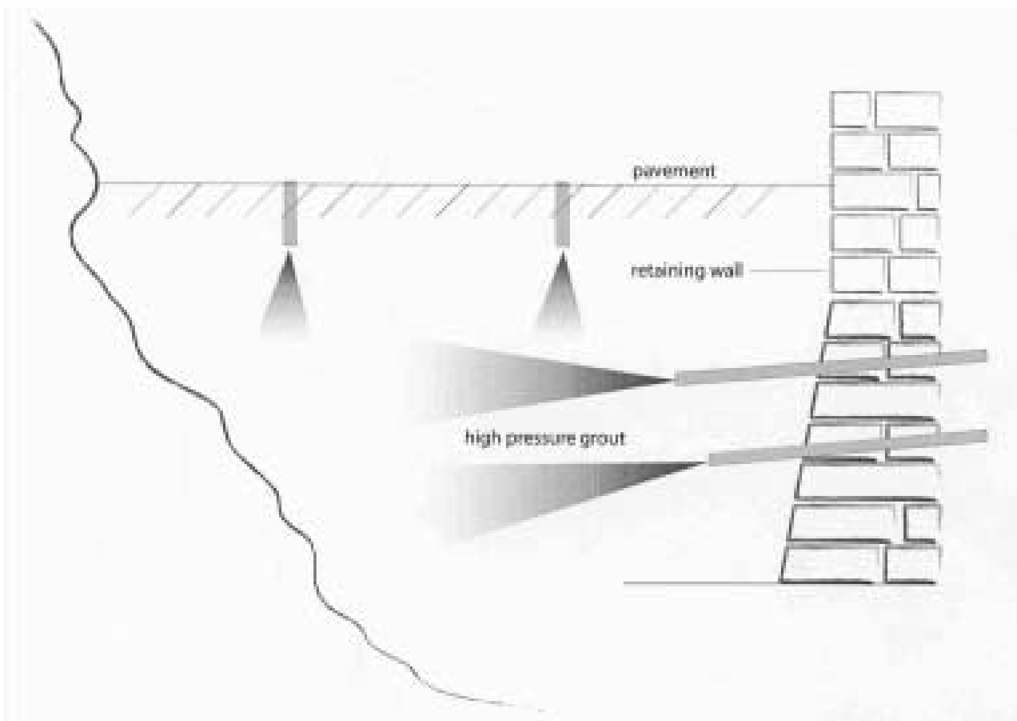

Figure 94: Repairing a retaining wall by injecting grout to stabilize the road base

Specific repair options will vary considerably with respect to the location and degree of repair required for each wall. The design for each wall should be site-specific with respect to location, geometric configuration, safety, and historic and cultural values. It is recommended that the park continue using the methods developed by FHWA, including rebuilding the roadbase with MSE, concrete slabs anchored with micropiles, and grout injection techniques as successfully implemented by FHWA.

In addition to the techniques developed by the FHWA and the park, alternative construction procedures for retaining wall rehabilitation may be considered in certain locations, for walls not designated as emergency repairs by the FHWA and the park. These include the following modifications to the FHWA methods, as well as new alternatives for consideration.

- Construct a concrete slab across all or part of the roadway that is anchored with micropiles as in the FHWA design, adding tieback anchors to tie the slab back into the slope to reduce or eliminate lateral movement. This would add further integrity to the walls and roadway by tying it to bedrock, and is particularly effective in avalanche chutes and areas that receive impact loads from water and rock fall.

- Stabilize backfill in place by high pressure injection of high strength polyurethane grout (not cementatious) directly through the face of the rock wall and/or through the pavement and base courses into the underlying foundation, with the intent of stabilizing the structure and providing a barrier to prevent further water intrusion.

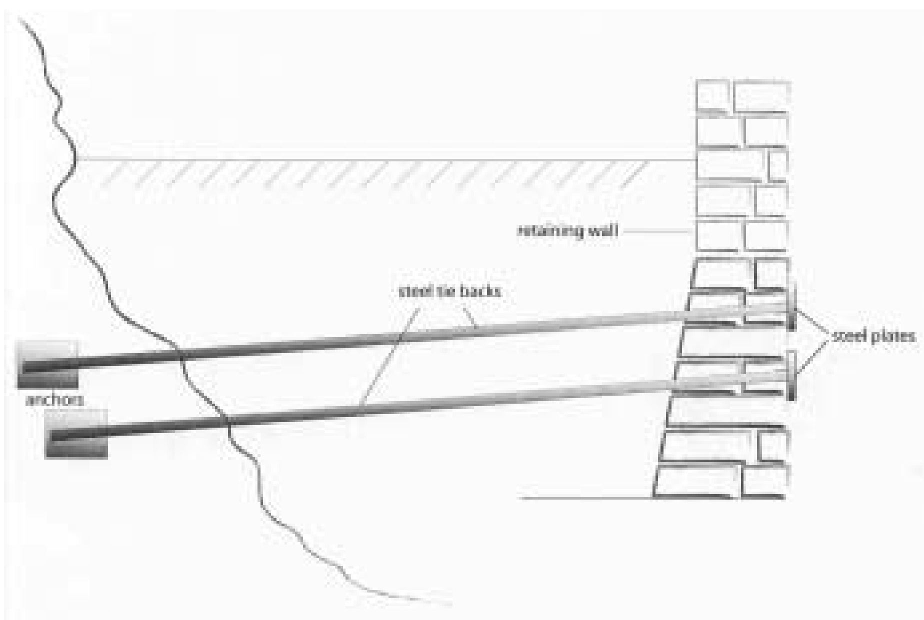

Figure 95: Installation of rock anchor tiebacks

- Install rock anchor tiebacks (steel dowels or cable anchors) through the wall face and into the solid rock backslope as shown in (Figure 95). For this application to work well, the wall must be of sound integrity, as anchor points on the stone face are minimal compared to the area of the wall. This alternative could provide a cost- effective short-term solution.

- As described in the drainage section earlier, install surface drainage intercept ditches and cross-drains, as well as subsurface curtain drains and underdrains on the uphill side of the roadway to mitigate drainage influence. Most of this method will require alternating one-ways for repair.

- Rebuild the foundation of the retaining wall in place by first providing temporary lateral support on the wall; then partially remove the ground underneath the wall, and form and pour a concrete footing in place. As most of the work is off the road-way in this alternative, minimal traffic control will be needed and alternating one-ways will be sufficient.

- In cases where the retaining wall and its foundation have deteriorated beyond repair, rebuilding the wall on micropiling and a footing is recommended to provide a long life cycle. Surface drainage intercept ditches and underdrains should be included (Figure 96). This is the most intrusive, costly, and time-consuming repair method, and could require two-way stops for traffic control.

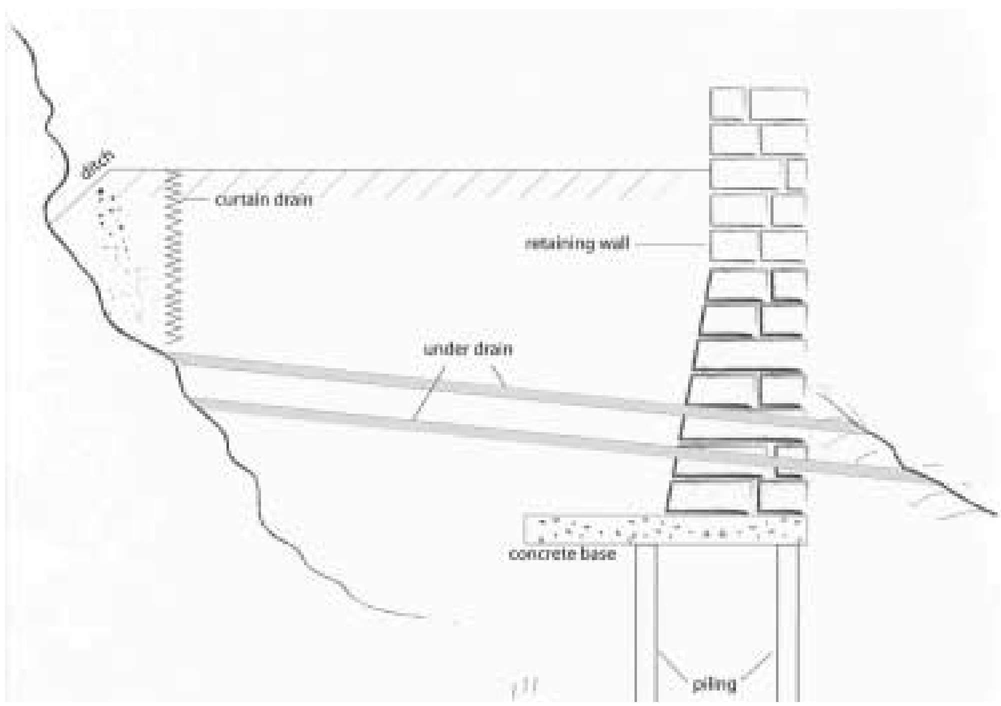

Figure 96: Total reconstruction of retaining wall

- For a large percentage of retaining wall repairs, only the top portion (three to eight feet) of many wall sections requires rehabilitation. Construction options are similar to guardwall rehabilitation discussed in the next section. For these areas, a moment slab on the roadway would tie the retaining wall to the roadway and stable ground. A guardwall would be placed on the moment slab to perform as its footing.

Several reinforced concrete retaining walls were observed which were partially finished with stone veneer. In the past, the use of veneer has been an accepted practice within the park when other, more historically appropriate methods were deemed impractical. This approach was acceptable to the Montana SHPO. In general, the stone veneer was of somewhat differing consistency and visual appearance from the original stone masonry work. The structural sufficiency of the concrete core of these walls appears sound. These walls are not historically appropriate; however, it is not prudent to remove them. Two feasible alternatives remain:

- Finish the remaining rock veneer work in the same fashion as it was started; or

- Remove the existing veneer, add a footing extension to the retaining wall where practical, and face the concrete wall in a historically appropriate pattern. Challenges will include access to the work and the constructibility of the footing extension.

Major rehabilitation activities on retaining walls will require alternating one-ways in most locations, with some two-way stops. Specialized equipment may also be required in order to complete these activities in a timely and practical manner. Skilled craftsmen should be employed to complete all rehabilitation work. Due to the precarious location of many of the walls, special care should be taken to provide for the safety of workers. Mobile working platforms, such as bridge deck stripping buggies, should be utilized to accommodate each individual site in a safe and practical manner.

The selection of method for the proper rehabilitation of retaining walls is wholly a function of specific site conditions. Designs must be matched with conditions. and there is little room for alternative selection, other than in the engineering specifics. FHWA has done an excellent job in selecting appropriate repair procedures for retaining walls.

Guardwall Considerations and Alternatives

The stone masonry guardwalls are of historical significance and, due to their immediate proximity to the traveled way and exposure to the public, usually have a greater visual impact on the visitor than retaining walls. There are approximately seven miles of stone masonry walls on the Road, most of which will need to undergo some form of rehabilitation work. The overall rehabilitation plan should consider the optimum work limits for each of the guardwall sites to determine the most effective traffic management plan. Generally, alternating one-ways will provide the necessary traffic control to perform the rehabilitation.

Figure 97: Guardwalls are contributing elements in the historic significance of Going-to-the-Sun Road

Most of the original guardwalls have experienced significant mortar deterioration, foundation failure (leaning or subsidence), stone displacement and deterioration, and moisture intrusion. Many of the walls that were “refurbished” through earlier maintenance activities also exhibit significant mortar deterioration and stone displacement. It is recommended that rehabilitation be undertaken to restore all guardwalls to their original location, appearance and structural soundness insofar as practical. The techniques for reconstruction, rehabilitation, and reinforcement of guardwalls described here are subject to safety considerations and historic resource guidelines and should be selected on a site-by-site basis. Alternatives for consideration in the rehabilitation of the guardwalls include:

- Lowering the existing roadway to expose the former height of guardwalls. In many areas, this work is necessary to correct grade and superelevation problems in the roadway template.
- Repointing and patching of existing guardwalls. Close attention should be paid to the mortar mix design and rehabilitation techniques to ensure a long-lasting repair and an historically appropriate result.
- Removal and reconstruction of certain sections of guardwall that have advanced foundation failure and/or loss of significant sections of stone (Figure 98). The concrete slab in this detail could be precast and delivered to the rehabilitation site to expedite installation.

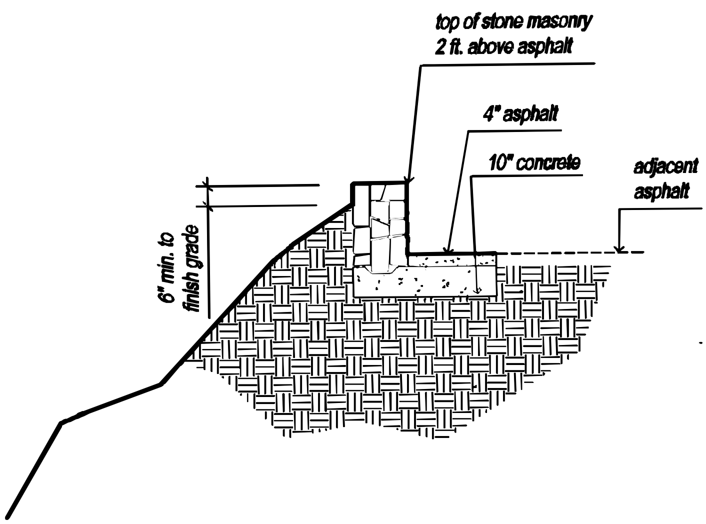

Figure 98: Typical installation of stone masonry guardwalls

- Construction of reinforced concrete footings under new or replaced guardwalls. This procedure has been used on a number of existing guardwalls, and appears to be very effective in increasing the durability and structural stability of the guardwalls.
- Construct avalanche-resistant reinforced concrete core guardwalls. These walls have been successfully installed within the park and appear to be functioning well. In this application, stone masonry veneer is placed on both faces and on top of the core to provide a visually accurate finished product, as shown in Figure 99.

- The installation of dowels may be useful to add support and stability to new or existing guardwalls on top of retaining walls, as illustrated in Figure 100.

As stated above, selection of the appropriate means for rehabilitation of guardwalls is site-dependent, and during the rehabilitation, the masons and historian should discuss the procedures for each section of wall to be rehabilitated. Guardwall rehabilitation techniques included in the cost estimate address the needs of each road segment and the recommended life cycle. Guardwall rehabilitation should follow these general guidelines:

- Ideally, local native stone should be used for guardwall rehabilitation in order to preserve the historic significance of the Road and the natural resources of the park. A discussion of native stone collection is located below in the section titled *Techniques and Materials.*

- If enough suitable stone cannot be located in the park, then the best stone

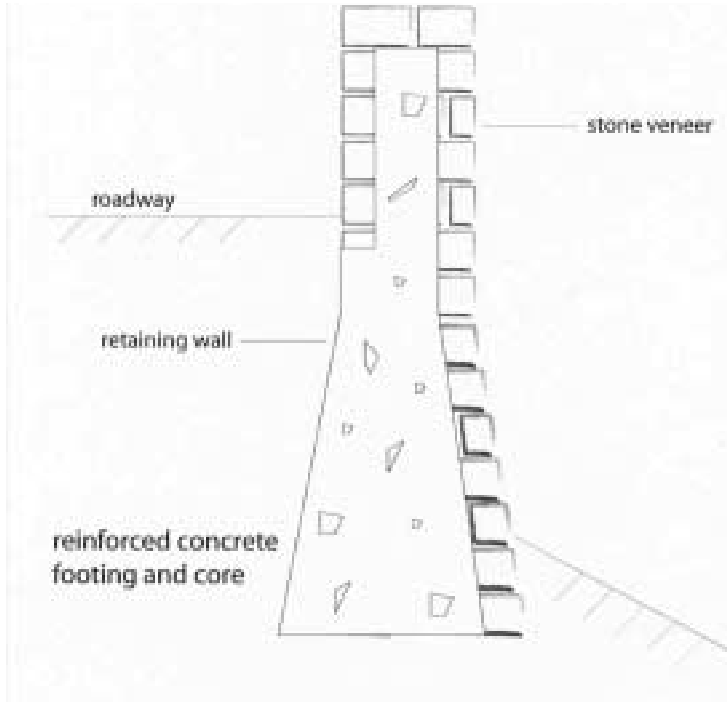

Figure 99: Avalanche-resistant reinforced concrete guardwall

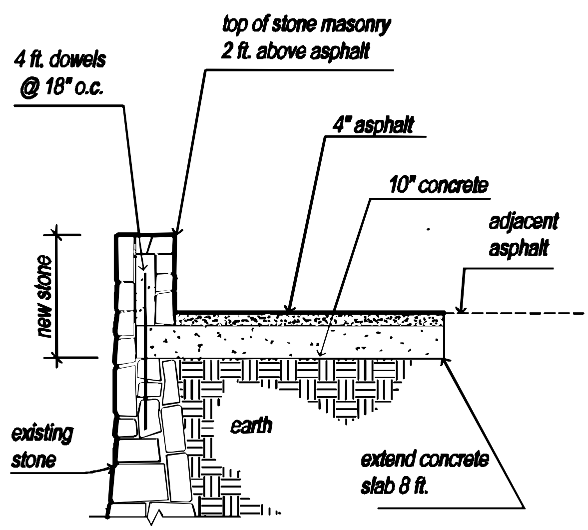

Figure 100: Installation of avalanche-resistant guardwall on existing stone guardwall

found in the park should be used for the most visible areas of the guardwall -- the side facing the roadway and the top. It is also possible to cut stone found in the park to make rock veneer. Stone material sources can be sought outside the park; however, the quality and historic appropriateness may be compromised.

- Drainage of the roadway should be considered in the rehabilitation. Weepholes or scuppers should be installed at necessary locations in all guardwalls. Historic appropriateness at each location should be discussed with the historian.

Most guardwall work could be completed within the constraints of alternating one-way lane traffic options. Additional minor traffic delays could be experienced for materials delivery, equipment repositioning, and other activities.

Roadway Considerations and Alternatives

The roadway itself requires rehabilitation in many areas. The elements of the roadway to be considered in the rehabilitation include alignment and width, template adjustment, resurfacing options, and pavement marking.

Roadway Alignment and Width. The roadway alignment and width are integral elements of the Road's historical significance and should be preserved. Site-specific consideration should be given for minor deviations in alignment and width in areas where the safety of the visitors, workers, or park personnel may be compromised. This may include intersections, pullouts, trailheads, pedestrian areas, and areas with unstable ground.

Figure 101: Elements of the Road such as alignment and width contribute to its historical significance

Roadway Template Rehabilitation. Many areas of the roadway are failing due to water intrusion, slumping, and sliding. Each section of roadway was investigated, and basic alternatives were developed to provide lasting rehabilitation.

- In areas of minor subsidence and where unsuitable material in the roadway template is limited to *four feet or less*, rebuild the roadway template by removing all unsuitable material, and replace it with suitable material in layers separated by geotextile fabrics. This is commonly referred to as mechanically stabilized earth (MSE) construction. This presents a cost-effective and time-effective solution for the many areas of minor subsidence encountered on the roadway.

- In areas of significant subsidence, and where unsuitable material in the roadway template is *greater than four feet*, rebuild the roadway template by removing all unsuitable material, and replace it with suitable material in layers separated by geotextile fabrics. This technique is less expensive than constructing an anchored concrete slab; however, it requires two-way stops or closures during implementation.

- A second option in areas of significant subsidence where unsuitable material in the roadway template is *greater than four feet* is constructing a concrete slab across all or part of the roadway, which is anchored with a combination of micropiles and tieback anchors. Although more expensive than MSE construction, an anchored concrete slab can, in most cases, be installed with alternating one-ways.

Three variations of this method are recommended, based upon site-specific conditions ranging from the least deterioration to the most deterioration. Figures 102, 103, and 104 illustrate three types of concrete slabs, and three alternatives for guardwalls in sections which require template rehabilitation: a stone masonry wall, an avalanche-resistant guardwall, and a removable rail. The slab type and guardwall type can be used in any combination:

- An eight-foot concrete slab, anchored with micropiles (shown with a stone masonry guardwall, Figure 102)

- A twelve- foot concrete slab, anchored with micropiles (shown with a removable guardwall, Figure 103)

- A twelve-foot or greater concrete slab, anchored with micropiles and tiebacks (Figure 104)

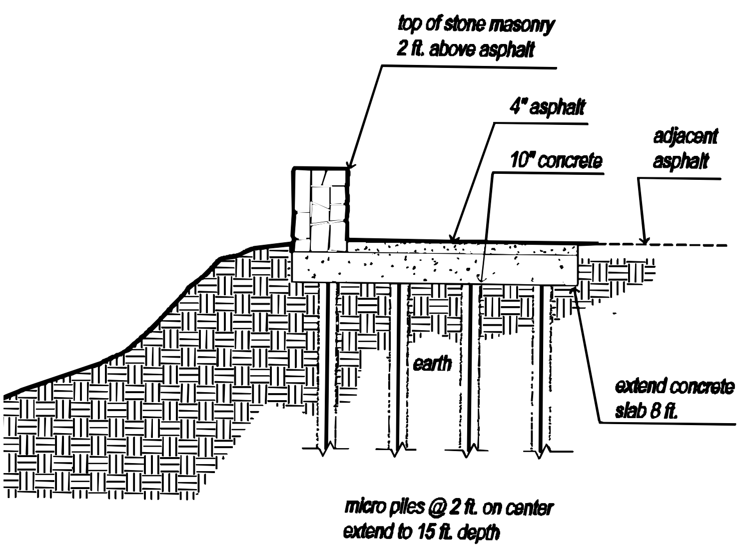

Figure 102: Installation of stone masonry guardwall on concrete slab, anchored with micropiles

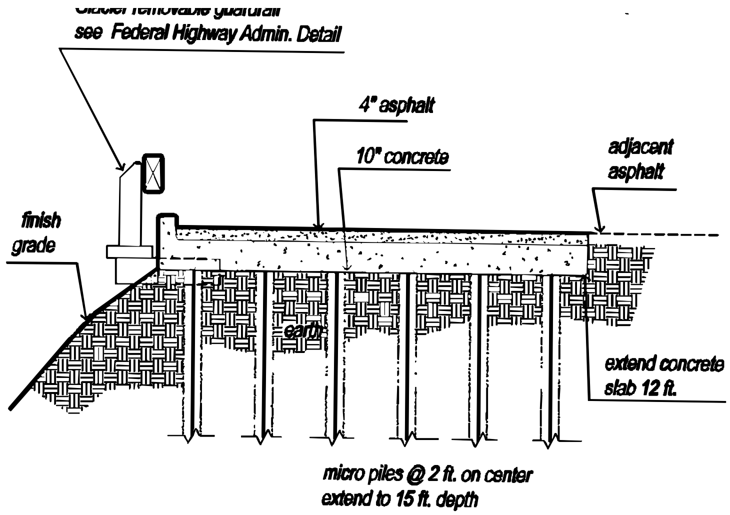

Figure 103: Installation of removable guardrail on concrete slab, anchored with micropiles

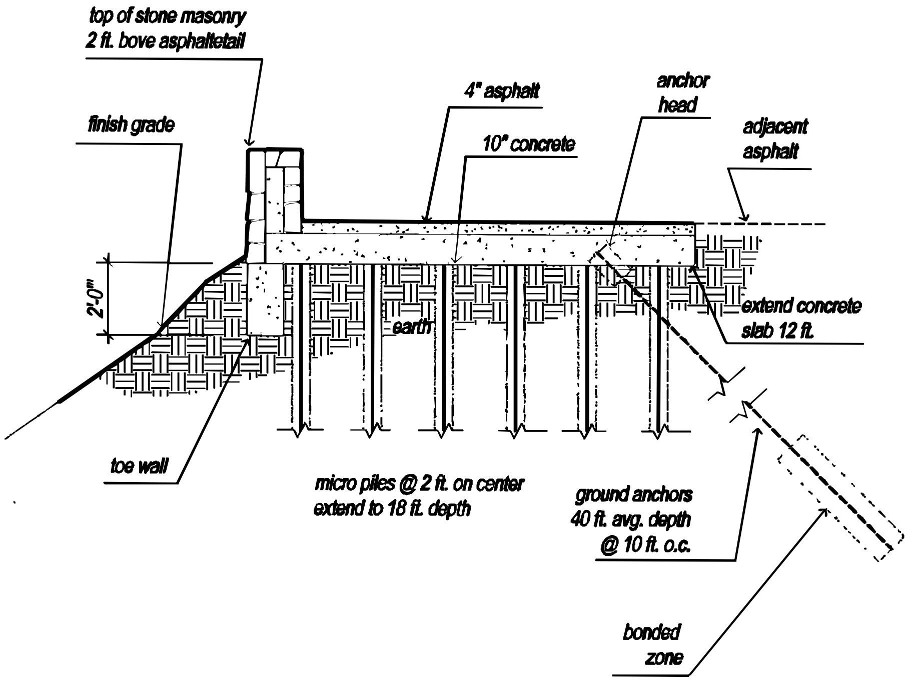

Figure 104: Installation of avalanche-resistant guardwall on concrete slab, anchored with micropiles and tiebacks

If site-specific design analysis determines that the roadway template can be rebuilt using MSE construction on an extensive basis, it is recommended that the work be scheduled in September or October to reduce the impact on visitors.

Resurfacing Options. There are several options for resurfacing the Road. The option selected for each area should be based upon specific resurfacing needs and conditions, and additional field testing is required prior to selection of a resurfacing option for each area. Asphalt technology is advancing steadily, and new design mixes are emerging regularly. Selection should be based upon the projected life cycle of the pavement. At this time, standard hot mix asphalt should be used in pavement applications. More detail on resurfacing and pavement options is located in Appendix E.

The roadway through the Lake McDonald and St. Mary sections may require just an overlay. There are some areas where past surfacing operations have increased the depth of the surface to a point where the effectiveness of the guardwalls is diminished. In these areas, it will be necessary to remove asphalt and/or roadbase prior to resurfacing in order to restore an acceptable guardwall height. Due to the advanced deterioration of the roadway through most of the West Tunnel Section, Alpine Section, and Baring Creek Section, all require milling and resurfacing.

Viable resurfacing options with the most value in terms of time, cost, and preservation of natural resources include the following:

- Chip seal the surface, as is currently the practice on some areas of the Road. This provides good value in some instances and should be considered. Although chip seal could be done one lane at a time using alternating one-ways with intermittent stops, the overall visitor experience may be much better if a closure is used during periods of low visitor use. In particular, the early part of the season is best for chip seal operations, as warmer temperatures produce a better product. Chip seals offer a cyclic roadway repair for the wear surface, but should not be considered for areas requiring roadway template repairs.

- Overlay the existing structure with additional layers of asphalt pavement. This allows the new surface to utilize the integrity and strength of the old surface. Most areas can be resurfaced using alternating one-ways with intermittent stops. In tight areas, traffic may need to be stopped in both directions for a few hours.

- Remove existing pavement and part of the base material, and replace it with suitable new material. Haul waste material to a suitable stockpile location, such as Moose Country, and process the material for reuse in roadway template rehabilitation or recycle it into the new asphalt pavement. This method is necessary if the underlying pavement and base material are failing, such as in the West Tunnel, Alpine, and Baring Creek Sections of the Road.

- In areas where guardwall height is not an issue, leave recycled material in place and pave over it.

- Replace the roadway with concrete pavement. This option would provide the longest life cycle; however, the cost, duration, constructibility issues, and visitor impact of this construction would be enormous.

For the purposes of this study, the rehabilitation cost estimates include the costs for the asphalt overlay and remove-replace-reuse options for best life cycle.

Pavement Marking. Striping and delineation of the Road must consider safety and historic context, and each site should be discussed separately. Newly available reflectorized paint could be utilized for the roadway centerline and edge pavement markings. Reflectorized tabs on the pavement could be used to restrict parking and further delineate the roadway.

The best life cycle pavement marking available at the time should always be used on new asphalt. Traditional pavement marking paints must be used with chip seals or emulsified seals.

Techniques and Materials Considerations

Mobilization and Staging

The cost and effectiveness of mobilization and staging are primary concerns. Mobilization includes securing and moving personnel, materials, and equipment to, within, and from the project site. Staging includes location, space, and provisions for delivery and storage of materials; maintenance and dispatch of equipment; establishment of office facilities; and accommodation of contractor personnel housing and commuting needs. Coordinating staging areas with construction sequences minimizes damage to completed rehabilitation work.

Mobilization is usually included as a bid item by the contracting firm, and the cost is dependent upon the size, location, and type of work, equipment, work schedule, and the availability of staging or storage areas at or within a reasonable distance from the project site. Mobilization and staging costs should be minimized by identifying potential material sources and staging areas as part of the rehabilitation contracts. The Environmental Impact Statement will provide further detail as to the environmental considerations for staging areas. It is recommended that the park designate the staging areas listed below for use during the rehabilitation work, and forward this list for consideration in the EIS, along with those in Appendix D.

Sidebar: The General Management Plan requires that the development and management of staging plans be coordinated closely with the NPS. In this way, focus can be placed on the preservation of natural resources at each site, and the needs for park maintenance operations during the rehabilitation can be addressed. Actual staging needs can only be identified once the rehabilitation plan is developed and designs are complete, as specific areas needed for staging are defined by the specific rehabilitation efforts in an area.

NPS-Provided Staging Areas Inside the Park. The choice of staging areas depends on the availability of needed space, efficiency in delivery of materials to the worksite, and visitor and environmental impacts. The most feasible staging locations in the park are those in the following list. Each may require some additional site clearing.

- ***Sun Point.*** A large area that can accommodate most staging needs for rehabilitation on the east side of Logan Pass. Most of the area of this site will be needed for large rehabilitation efforts. The staging operations at this site would include material stockpiling, sorting, loading and delivery, precasting, fabrication, and maintaining equipment. With snow plowing, access and use of this site can extend beyond the normal construction season.

Figure 105: Sun Point

- ***Logan Pit.*** A staging site for current rehabilitation operations and maintenance operations. The site is very close to McDonald Creek, and special care should be taken to ensure there is no impact to the environment or natural resources of this area. The staging operations at this site would include material stockpiling, sorting, loading and delivery, precasting, fabrication, and maintaining equipment. Judicious enlargement of this area would help the overall staging efforts.

Figure 106: Logan Pit

- ***Moose Country.*** Currently used as a stockpile area, this location can be effectively used for continued staging and material handling for rehabilitation efforts, especially on the west side of Logan Pass. Staging operations at this site would include material stockpiling, sorting, loading, and delivery.

- ***Rehabilitation Sites.*** The lane cleared for rehabilitation work in a one-way traffic control scheme could be used for staging of materials and equipment for that site.

- ***Pullouts.*** Existing or new pullouts near the rehabilitation sites could be used for local staging or the caching of rock for stone masonry rehabilitation.

- ***Discovery Center.*** Within the general area of Apgar, a potential visitor center is under consideration. Prior to development, the site could be used as a staging area during the rehabilitation. This would be an especially good site for the staging of park maintenance operations, allowing full use of the staging sites listed above for the contracted rehabilitation work.

With snow plowing, access to Sun Point, Logan Pit, Moose Country, and the Discovery Center site can be extended beyond the normal construction season. This would allow mobilization and staging of some materials

Contractor-Provided Staging Areas Outside the Park. Contractor staging areas and responsibilities could be included as a contract bid item, to be secured at the option of the contractor. The contractor can usually find adequate space outside the park limits (private or commercial sources) to accommodate most staging needs. The main drawback to this option is that staging areas outside the park may be remote from work site areas, thus increasing the cost and difficulty of supplying equipment and material to the project in a timely manner, while creating extra congestion on the Road.

Delivery of materials and supplies could be enhanced by optimum scheduling with material suppliers, as well as by the innovative use of equipment, such as temperature-controlled and/or articulated vehicles, high flotation tires and suspensions to minimize damage to the existing roadway cross-section, and transportation equipment with self-contained loading/unloading capabilities. Consideration should be given to the use of helicopters for delivery of materials and for access to rock scaling operations.

Scheduling

Balance is the key to scheduling the rehabilitation of the Road. There are more factors to consider in developing a balance for this project than for typical construction projects due to the need for historic, cultural, environmental, and natural resource preservation, and visitor use issues in the park. These factors include:

Type of work. Good scheduling takes into account the kind of work needed. This includes the packaging of similar types of work into a single contract. For instance, it makes good scheduling sense to lump similar work at sites that are closely located into one project, or rock scaling into one project, so that the contractor can provide for cost-effective and schedule-effective prosecution. In addition, mobilization, staging, and traffic control management can be efficiently coordinated. As the work consists of rehabilitating a National Historic Landmark, it will require close attention to detail, and the work schedule should provide ample time for achieving quality work without severe schedule restriction. Controlled blasting may be required in some slope stability work and for the installation of some drainage and roadway improvements. Scheduling of the type of work must also include other considerations, including wildlife and landscape, and the location of the work.

Location of work. With work spread over a 50 mile roadway, scheduling must consider where each individual site is located in order to efficiently select staging areas and distances to work sites. Long distances between work sites should be minimized to provide efficient access and movement between sites.

Consideration should be given to including the bulk of the work in the Alpine Section and some work in the lower elevations in the rehabilitation contract. In this way, the contractor can start working on the lower elevations during the spring while the alpine areas are still covered with snow.

Scheduling must also consider the best way to keep construction traffic from running over newly rehabilitated sections of the roadway, thereby preventing unnecessary damage.

Time of day (Night Work). It is recognized that conducting certain construction operations at night would provide a higher quality visitor experience during daytime hours; however, the inherent safety risks to the contractor, the anticipated increase in construction costs, and adherence to stringent environmental regulations should be carefully analyzed in each case. Certain sections of the Road may be considered too hazardous for normal night-time operations due to potential rockfall risks or other safety issues. Lighting of work is often complicated, as in many cases either shadows are cast over the work area or glare from the lights makes it difficult to see the work. This directly affects both safety and quality. Night-time air temperatures are generally significantly colder, and certain operations such as asphalt paving or masonry wall repointing work could be very restricted. Productivity during night-time operations is usually 20 to 40 percent less than for work performed during the day, due to the extra work associated with establishing a safe work site. Also, careful consideration must be given to moving visitor traffic through active construction areas during night-time operations. Work done during the night must be carefully chosen to provide for safety of the workers and the public, as well as for cost-effectiveness.

Weather conditions. Scheduling of the work must consider the season, in that certain work can only be accomplished cost effectively when the weather and ambient air temperatures are consistent with the specifications for installing specific materials. Shoulder season opportunities (early spring and late fall) can be utilized to accomplish work on the Road that might otherwise adversely affect visitation traffic. Work during the fall and early winter season may be more productive than during the early spring, due to the residual spring snow pack and the limited accessibility to certain sections of the Road.

Under most circumstances, rock scaling should be accomplished in the fall to minimize the impact to visitation. All rock scaling requires stopping traffic in both directions. Scaling operations are more efficient if the traffic can be stopped for a few hours at a time, as the repeated cleanup of scaled material from the roadway diminishes the time available for scaling operations.

Lower sections of the Road may continue to be readily available for late season or winter construction activities long after the alpine section is inaccessible due to the differences in snow accumulations and inclement weather conditions. Major construction activities within these lower sections could well be delayed until after winter shutdown in mid-October to promote effectiveness and cost savings. Early/late season work at higher elevations (alpine section) is generally not feasible due to heavy snows, low temperatures, and the threat of avalanches. Certain masonry work such as stone shaping, prefabrication of guardwalls and drainage structures, etc. may proceed off-site during the winter and then be transported into place at a later date.

Availability of work force. The availability of the local work force is a major consideration in the scheduling of the work. Work forces on projects near the park need to be considered in determining the appropriate scheduling for the rehabilitation of the Road, to ensure the availability of the necessary workers. Specially skilled craftsmen will be needed to fulfill historic rehabilitation requirements, and consideration should be given to pre-qualifying these craftsmen and determining their availability as part of scheduling the rehabilitation. Speciality contractors will be necessary to accomplish much of the rehabilitation, which uses techniques not normally associated with ordinary road construction, including installation of tiebacks, micropiles, polyurethane injection, and high rock scaling.

Environmental impacts. Scheduling of the work must consider environmental impacts, especially on wildlife. Restrictions on work identified in the Environmental Impact Statement need to be incorporated into the scheduling.

The recommendations include certain elements to preserve the natural resources of the park. From the standpoint of rehabilitation, this not only includes attention to the environment, but also the material resources in the park. Rock scaled from rock cuts and gleaned from slopes should be used in stone wall rehabilitation. Material dredged from creeks and around culverts and bridges should be sorted and used as fill in other areas. Asphalt millings should be recycled as appropriate. With regard to the issue of scheduling, costs can be reduced by minimizing the handling of materials. Efforts should be made to schedule concurrent projects that balance the recovery, handling, and reuse of essential resources.

Visitor impacts. As it is critical to minimize disruptions to visitor use in the park, a balance must be reached between visitor use and rehabilitation efforts. This balance should consider peak visitor usage on a seasonal and daily basis. One concept presented in the rehabilitation alternatives provides for minimal delays during peak times of the day (approximately 10 a.m. to 2 p.m.), some delays (30 minutes) during the off-peaks (approximately 7 a.m. to 10 a.m. and 2 p.m. to 7 p.m.), and major delays (up to four hours) during the evenings and nights (7 p.m. and 7 a.m.). Similar concepts would be used for weekends and holidays. These concepts need to be incorporated into the rehabilitation schedule to develop a realistic balance in getting the work done and minimizing visitor delays.

The complementary *Transportation and Visitor Use Study* discusses in detail a menu of choices for managing visitor impact. The choices fall into three general categories:

- Increase transportation alternatives
- Increase visitor amenities
- Redistribute visitor amenities

Significant efforts should be made to implement transportation and visitor use strategies concurrent with the start of rehabilitation. Given the amount of work required on the Road, increased visitor choices in the right areas will be key, as will providing good transportation alternatives. One important element in visitor management is to provide accurate and timely information. The best way to get information to many visitors is through the internet, and a web site can be developed to provide this information. Internet access can be provided at visitor areas, be connected to variable message signing, and provide dial-up messaging. Perhaps in a few years, it will be available in cars.

Funding levels. The amount of funding available is also a key factor in determining the rehabilitation schedule. The funding allotment should provide for the best possible balance of the elements listed above in a given season. Consideration should be given to awarding rehabilitation contracts for one year at a time so that if issues arise which create a delay during the rehabilitation, the following year's work will not be impacted. This would minimize the potential for a series of progressive delays to other work over subsequent years.

Current traffic control restrictions as established by park policy make it difficult to undertake significantly more rehabilitation on the Road than what is presently occurring. In order to achieve an efficient level of rehabilitation effort, considerably more work needs to be completed in a year than at present. In particular, the number of project sites working at one time must be increased from two to at least six, with traffic control coordinated for all sites. Based on the experience of the project team, between $10 and $15 million per year could be spent on the rehabilitation effort with a traffic management system that provides a better balance of work and visitation.

Material Sources and Handling

Material specifications should continue to emphasize the status of the Road as a National Historic Landmark. Original stone for masonry work was obtained from within the park and it is recommended that slopes, the original quarry sites, and other potential sources of material from within the park be evaluated and utilized insofar as possible. Using rock from within the park truly provides a cultural framework for the rehabilitation.

Naturally occurring rock fall material or material gleaned from rock scaling operations should also be utilized whenever practical. Stone walls were generally built with the stone found closest to the installation, usually at rock cuts. Many of these rock cuts are in need of scaling. During scaling operations, a field geotechnical engineer should be present and in consultation with the historian and mason to preserve appropriate rock material as it is scaled. Also, near many rock cuts and landslide areas, rock cast over the side of the Road should be salvaged. Much of the material can be salvaged using a slusher, an air-powered, ground-mounted dragline of the type d in underground mining. The slusher, essentially a clutch controlled set of drums with cables attached to a scrapper bucket, could pull rocks up the side of the slopes, mostly with temporary one-way traffic control.

Material sources outside of the park boundaries are quite often left to the discretion of the contractor with respect to determining practicality and availability. In the past, contractors have obtained material from various sources outside the park. These sources have been generally unsatisfactory with respect to visual character and workability. Securing acceptable material from outside the park would be difficult, and efforts should be focused on obtaining rock within the park, especially in locations close to the actual rehabilitation. An extensive investigation into sources outside the park should only be undertaken if it is determined in the design phase that the amount of necessary rock cannot be obtained within the park.

Other major materials are dependent upon contractor operations and can be obtained from many different sources. Construction specifications will be required

Discreetly chosen material sources may help retain the historic and visual integrity of the Road, as well as provide high quality material. It is recommended that rock collection commence as soon as practical with small caches located near the rehabilitation sites or a larger, sorted stockpile located at Moose Country.

in the contract documents to ensure that appropriate materials such as gravel, pavement, and concrete are used on the Road.

Water resources for dust abatement, compaction efforts, and other contractor operations should be identified and made readily available. Contractor operations should be made secure to prevent contamination of natural water resources, as well as environmentally sensitive areas and other resources. The potential for wastewater and runoff water through construction zones should be recognized; mitigation plans should be developed and actions undertaken to negate or minimize adverse affects. These plans should be available to the contractor during the project review and contract bid process in order to facilitate contractor operations in a practical manner.

Planting will be required after rehabilitation is complete at each of the sites. Continuing effort should occur to enhance NPS nursery activities to provide for plants for the rehabilitation. There are two inherent advantages to this concept. First, the quality and quantity of plants can be controlled to be consistent with the overall rehabilitation schedule. Second, a head start on the rehabilitation efforts will provide for cost effective nursery growing.

Maintenance and Operations Considerations

The life cycle of the engineering alternatives has been considered and is discussed above in each of the rehabilitation topics in this chapter. Wherever practical, the most prudent solution with the longest life cycle is recommended. In one case, the solution with the longest life cycle -- resurfacing the roadway with concrete pavement -- was not recommended. Although concrete pavement has the longest life cycle, it is inappropriate for the entire roadway, primarily due to constructibility issues. Other issues include cost, duration of construction time, and visitor impact.

A discussion of maintenance and operations is the subject of Chapter 5 of this study.

Constructibility

Discussion of constructibility for the rehabilitation has been ongoing throughout this study. During the field reconnaissance in June 2001, the team included construction managers specifically experienced in environmentally sensitive alpine terrain. Constructibility has been considered in all recommendations included in this study. Further, a conceptual engineering design and constructibility study was conducted with emphasis on transportation/visitor use considerations and roadway rehabilitation options. These options were based upon roadway condition assessments, engineering and socioeconomic analysis, and projected needs within Glacier. A review of ongoing construction projects and traffic control at MP 23.5 (The Loop) and at MP 30.1 (west side of the Garden Wall) was also conducted.

A two-stage constructibility workshop was conducted as part of this study to discuss engineering design and constructibility factors, and to identify and analyze potential traffic management alternatives and rehabilitation options. In September 2000, park personnel, FHWA, and the consultant team gathered for a workshop in Denver. The second stage of this workshop was conducted during December 2000 and involved participation of four experienced and knowledgeable construction contractors:

- Norm Jones Contracting, Missoula, Montana
  Specializing in roadway subgrade construction and rotomill operations

- Alpine Construction, Inc., Missoula, Montana
  Specializing in traffic control during roadway construction

- A-1 Paving, Kalispell, Montana
  Specializing in asphalt paving

- Valentine Surfacing, Portland, Oregon
  Specializing in roadway surfacing reclamation operations

These firms were selected and interviewed with respect to potential roadway rehabilitation activities and traffic management alternatives for the Road, as well as their experiences with Federal, State, and local agencies. Alpine Construction, Inc. and A-1 Paving have had experience on the Going-to-the-Sun Road in recent years. Further input was received from Federal Highway Administration engineers and traffic control experts located in Vancouver, Washington and in Denver, Colorado; from NPS personnel located in Colorado and in California; and from international sources located in Switzerland. The constructibility workshop included discussion on preservation of historic features, contract types, mobilization and staging considerations, material sources, traffic management observations, safety, night-time operations, shoulder season work, winter season work, local labor, paving considerations, and drainage considerations. Conclusions reached by constructibility workshop partici-

pants have been incorporated into the engineering analysis presented earlier in this chapter.
As site-specific rehabilitation designs are developed, constructibility analysis should continue to be an integral component of the design.

Contract Packaging

Contract packaging defines what project sites or types of work are to be included in a given contract. The contract packaging also defines the project delivery method (design-bid-build, design-build, or other means of project delivery). In the rehabilitation of the Road, contract packaging has a significant effect on overall cost effectiveness, scheduling, and impact.

An example of a contract package may include all the rehabilitation needed between Logan Pass and Siyeh Bend. With close coordination, good work scheduling, and appropriate traffic control, the work in this area could be accomplished in about fourteen months, if the work started in September. Work requiring two-way stops, such as rock scaling and roadway template adjustments, could occur in September and October. Material caches at work sites could store rock and other materials for the work over the winter. Work could commence again in the spring using alternating one-way traffic flows for the remainder of the peak season. Work could be complete by November, provided the weather cooperates.

The choice of contract type should be carefully considered respective to the scope of work as well as the inherent risk and cost factors of each contract. Considering the rehabilitation in terms of historic, cultural, and environmental resources, visitor use, cost, schedule, and risk, we recommend factoring in the following:

Unit Price Contracts should be used for the majority of the rehabilitation. Most construction contracts use this method. Items and quantities are identified in the contract for bidding purposes, and payment is made based on actual quantities. This is a good vehicle for most of the rehabilitation work, as changes to quantities are easily made, administration of the work is simplified, and the risk is balanced between the owner (the park) and contractor.

Design-Build Contracts are not recommended for the rehabilitation, although they have a two-fold advantage for other types of construction. First, a design-build contract compresses the design and construction schedule by allowing construction to start with design that is 30 to 60 percent complete. Second, it provides an opportunity for more innovation, in that those normally engaged in specialty work usually are at the forefront of innovative techniques. Due to the restrictions and constraints placed by the historic, cultural, environmental, and visitor use aspects of this rehabilitation, it is not prudent to commence construction until final design is complete, thereby eliminating the advantage of schedule compression. The other advantage -- providing innovation in techniques -- can still be realized in a modified way, using a Unit Price Contract with design-build components.

Unit Price Contracts with Design-Build Components have been successfully used in mountainous terrain in Colorado, as well as other areas. A unit price contract provides the basis for the work. In the unit price contract, provisions are made for design-build delivery of those items where innovation is prudent. Design-build opportunities that could be included are slope and rock face stabilization, resurfacing operations, culvert replacements, and other work items which have well defined specifications for historic, cultural, environmental, and visitor use values.

A + B Contracts have the Unit Price Contract as a basis, but require the contractor to bid both the price and the time for completion. In evaluating the bids, a factor is used for the time bid for the contract and added to the contract price to determine the most responsive bid. This could improve cost effectiveness by encouraging contractors to focus their resources to provide the best schedule for the work at the best price, while still adhering to historic, cultural, environmental, and visitor use requirements.

Indefinite Delivery / Indefinite Quantity Contracts are essentially time and materials contracts and should be restricted to specialty work only, as without quantities or schedules to bid on, unit bid prices tend to be less cost effective. These contracts could be used where small scale work is undertaken and work requirements are difficult to specify.

Contractor incentives could be established as part of any of the contracts mentioned here. Incentives could be used to encourage early completion and minimizing visitor delays.

Prequalification of contractors provides for selection of contractors or craftsmen prior to the bidding. Qualifications, experience, and actual work are evaluated to determine the best contractor or craftsman to perform the work. A list of prequalified contractors is developed and given to the general contractors prior to bidding the work, requiring the use of one or more of the prequalified contractors or craftsmen for the work. Masons will be key in rehabilitating various structures, and their selection by prequalification is strongly recommended. Contractors providing rockfall scaling and other high work should also be subject to prequalification selection.

Traffic Management Operations

Traffic management is a critical element in planning the rehabilitation. Traffic management directly affects the cost and duration of the rehabilitation, visitor impacts, and socioeconomic impacts. Although maximum rehabilitation efficiency is generally achieved when the construction site is closed to public traffic and construction operations can proceed uninterrupted, the visitor impacts would be enormous, which in turn would affect socioeconomic conditions. A balance must be achieved whereby the rehabilitation contractor can execute the work in an efficient manner while minimizing the impact to the visitor. During the field reconnaissance, special attention was paid to the needs of traffic management for the recommended rehabilitation. Based on observation of the current traffic control operations in the park, and familiarity with construction traffic management in tourist areas in mountain terrain, the project team developed basic concepts for traffic management during the rehabilitation of the Road.

Traffic management includes both traffic control operations and information systems. Traffic control is established by developing a traffic control zone through the rehabilitation sites. Each zone should be approximately 1,000 feet in length, providing traffic control for one rehabilitation site. Multiple rehabilitation sites along the Road are recommended in order to achieve a realistic overall duration for the rehabilitation. Integrated traffic control operations are recommended among the sites to minimize the overall delay to the visitor. Currently, the park allows only two rehabilitation sites on the Road at one time, one on each side of Logan Pass. This system works well for repairing and rehabilitating on an as-needed or priority basis. However, for a major rehabilitation effort, the entire rehabilitation will not happen within a reasonable amount of time, nor will it be efficient. The number of sites that can operate concurrently without excessive delays to the visitor is a function of the type of work, the proximity of the sites, and the integration of traffic control among the sites. These factors, along with the priority of the repairs or rehabilitation at each site, should be the basis for overall traffic control during rehabilitation. Work should be scheduled in order to take advantage of low visitor periods, such as early mornings, late evenings, nights, and during low visitor seasons.

The four essential methods of traffic control for the rehabilitation efforts are:

Alternating One-Ways. Work is restricted to one lane while the other lane is kept open for traffic. Traffic is allowed to flow in one direction while the other direction is stopped. When a specified time elapses, or when the traffic queue clears the site, traffic is allowed to flow in the opposite direction. This method is successfully used in the park at present, and it will be the prime means of traffic control during the rehabilitation effort. More than 70% of the rehabilitation work can be effectively accomplished with the closure of one lane. Alternating one-ways usually provide the fewest overall delays, as one travel lane is kept open at all times.

Intermittent Stops. When only short periods of time (ten minutes or less) are needed for work on both lanes of the Road, intermittent stops are most effective for controlling traffic and minimizing delays. This method expands the concept of alternating one-ways by stopping traffic in both directions when work is necessary on both lanes. Alternating one-ways resume once the travel lane is cleared. Approximately twenty percent of the rehabilitation will require intermittent stops. This method can be used for access to the rehabilitation site, material delivery, crane picks, and paving.

Two-Way Stops. When work must be performed on both lanes of the Road, traffic is stopped in both directions while the work is executed. Traffic remains stopped in both directions until both lanes are available for traffic. Two-way stops range from 30 minutes to four hours or more. Less than ten percent of the rehabilitation will require two way stops as the only means for traffic control; this includes rock scaling and some roadway template adjustments.

Closures. Certain operations that encompass the entire roadway width will require sustained closure of segments of the Road. These include complete subgrade or retaining wall reconstruction in areas where the width of the roadway does not provide enough room for both a travel lane and a work area. Less than two percent of the rehabilitation will require closures of more than four hours.

Figure 107 shows the general rehabilitation work under the associated traffic control method, based upon the recommended engineering alternatives for the work.

Figure 107: Rehabilitation Work and Associated Control Methods

Alternating One-Ways	Two-Way Stops	Intermittent Stops	Closures
• Culverts and cross-drains • Valley pans, inlets, and outlets • Soil slope stabilization • Rock bolting • Retaining wall rehabilitation • Guardwall rehabilitation • Roadway template adjustment	• Rock scaling • Roadway template adjustment	• Access to work site • Material delivery • Crane picks • Soil slope stabilization • Asphalt removal • Resurfacing • Debris removals	• Roadway rehabilitation with MSE • Major retaining wall rebuild • Bridge deck repairs • Blasting rock overhangs

Traffic control operations can be managed in two ways, either by the rehabilitation contractor or by the park (or its designee). In cases where only a few sites are undergoing rehabilitation, the contractor usually provides the traffic control and management. When multiple sites are working simultaneously, it is recommended that the park (or its designee) assume the responsibility for traffic control to ensure integration and coordination of individual traffic control operations and to minimize the overall delay to the visitor. Overall traffic control operations similar to those in the construction of I-70 through Glenwood Canyon in Colorado is a good example of this recommendation. Traffic control devices, flaggers, and traffic control supervisors were provided by a traffic control contractor for all projects on a yearly basis; overall traffic control for all projects was managed by a consultant working for the agency.

A vital component of traffic management is the timely and accurate distribution of information related to operations to all those who may be affected. Information must be provided by various means to reach travelers, and should include advisory signing, in displays at visitor centers and other places frequented by tourists, the media, and the Internet. The information must be accurate so that visitors can rely on what is broadcast, and the information must be timely, as most people can make good choices given accurate information.

As currently practiced on the Road, emergency traffic should be allowed to flow without delay though rehabilitation sites. This should be a part of the rehabilitation contract documents. Consideration should also be given to providing emergency roadside services to traffic that becomes disabled within a rehabilitation zone. In both of these instances, good communications are essential among the rehabilitation contractors, the park, and those providing the services. Communication technology is advancing rapidly, and by the time rehabilitation is scheduled to commence, several means should be available to easily provide information.

Visitor Management Strategies

The goal of developing visitor management strategies is to maintain and/or enhance the visitor experience during the rehabilitation. Effective strategies will minimize disruptions and provide new opportunities for interpretation of the Road, its historic significance, and its rehabilitation. Including the rehabilitation of a National Historic Landmark as part of the visitor experience will provide a new opportunity for all types of visitors, and help to minimize the negative effects of any delays caused by the work.

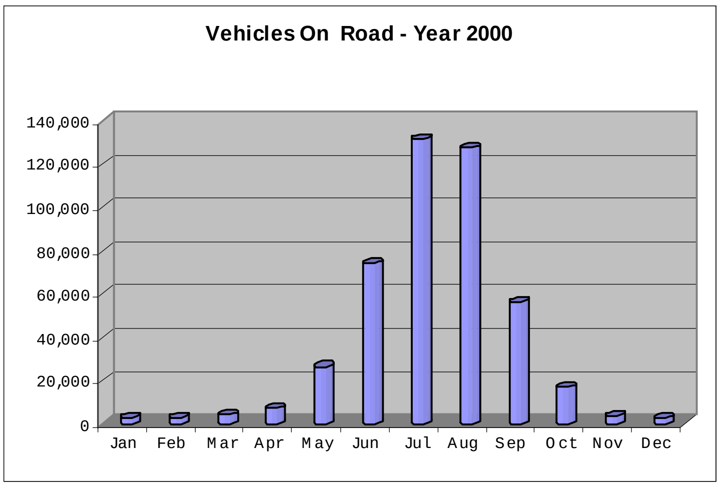

Figure 108: Vehicles on the Road during 2000

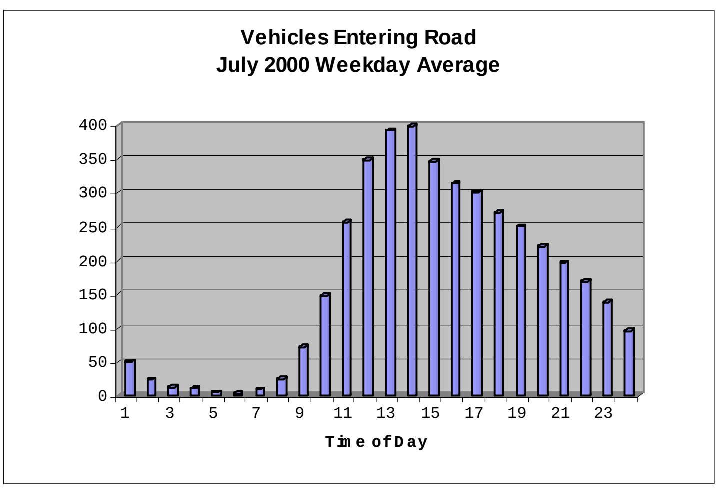

Figure 109: Vehicles Entering the Road
July 2000 weekday average

An innovative information and interpretive system will be essential in creating a positive experience for the visitor and is further detailed in *Signing, Interpretive, and Orientation Information* below.

Traffic management strategies are critical in managing visitors. The basic concept is to allow traffic to move as freely as possible during peak visitor usage and delay traffic during lower visitor usage, balancing the needs of the visitor (Figures 108 and 109) with the need to cost-effectively rehabilitate the Road.

Special park events can be scheduled to coincide with major rehabilitation efforts, providing the visitor with other opportunities in the park. Other concepts for visitor management are further detailed in the *Transportation and Visitor Use Study.*

Visitor Staging and Circulation. Visitor circulation and staging will depend on the areas undergoing rehabilitation. As much as possible visitor circulation and staging should remain as is or be enhanced during the rehabilitation of the Road. Stop stations should be positioned at rehabilitation sites to provide visitor safety, adequate room for the rehabilitation, and preferably an area where visitors can exit their vehicles. At areas where closures will occur, sufficient turnaround areas will be required and should automatically be included. Traffic control personnel stationed at the stop stations would also serve as public relations personnel in attending to stopped vehicles.

Consideration must be given to events for the Lewis and Clark Celebration that will be scheduled in or near the park during 2005 and 2006, when visitor usage is expected to increase. Close coordination with the organizers of these events should be made to ensure a positive visitor experiences.

Public Transportation. Public transportation can be a viable means of moving visitors during the rehabilitation work. Transportation concepts are discussed in more detail in the *Transportation and Visitor Use Study*.

Parking. Insofar as practical, parking should remain the same. Alternate areas for parking should be developed for those sites where rehabilitation work is underway. Discussion should continue on the development of replacement parking areas within the park, and replacement parking should be provided for all rehabilitation projects. Parking for contractor employees should be minimized within the park. Workers should be shuttled to the work site from outside the park if possible.

Comfort Stations. It is recommended that portable comfort stations be available at the stop stations during the rehabilitation work.

Trails. Trail usage restrictions should be considered for trail areas that are located above work zones. These restrictions may involve placement of mesh fences or other devices adjacent to the trail to curtail small rock displacements. Particu-

Efforts to provide interpretive and orientation information should be expanded during the rehabilitation work, especially with regard to the historic nature of the Road and the ongoing rehabilitation efforts.

larly hazardous locations such as the Garden Wall or trails should be closed to traffic during active roadway construction periods.

Signing, Interpretive, and Orientation Information. The project team observed various informational and directive signs in the park. Due to the inherent safety hazards in certain areas (rockfall, narrow road and constricted areas, switchback sections, no passing zones, etc.) it is important to provide proper signing at all times. Construction signing, lane delineation, flaggers, and other traffic control devices must be considered for all alternatives. Ease of maintenance and effectiveness of signing are important considerations in each case.

An innovative information and interpretive system can be developed to enhance the visitor experience. Most visitors can plan their stay in the park if they know which areas are under rehabilitation, when traffic will be delayed, and the relative congestion in areas of the park. With information provided at the visitor center, along the Road, at pullouts, and at rehabilitation site stops, visitors can easily judge where they desire to be and when, and plan accordingly. As wireless technology expands, the information and interpretive system can be established electronically and displayed at kiosks throughout the park and on the website. Advances in technology will provide opportunities to expand the system to include a portable real-time audio and visual information system that can be carried in the visitor's vehicle, similar to the audio systems currently used in museums and galleries. This system would provide Road rehabilitation information and interpretive information about the park.

Risk Management Considerations

Health and Safety. Safety, both for the traveling public and rehabilitation personnel, is of paramount importance. Proper traffic control measures should be adhered to, and special actions and work scheduling should address the issue of safety. A specific safety plan should be drawn up and included as part of the contract. At a minimum, this plan should cover the following:

- ***Traffic Management Through Construction Zones.*** This item may include courtesy information brochures and verbal communication by Park Service or contractor personnel. Construction scheduling and traffic management should be organized in order to minimize hazards and visitor impacts.

- ***Rockfall.*** Traffic should never be stopped or delayed in known rockfall areas. Work proposed in "high hazard" rockfall areas such as the Rim Rock segment (MP 30.0 through 31.0), should include specific provisions for the conditions present. For example, work on the guardwalls and retaining walls below the Rim Rock segment should include temporary rockfall netting over the cliff above to protect workers during construction, who will necessarily have significant exposure.

Figure 110: Park service personnel and visitors need be aware of safety issues at this rock face near Logan Pass

- ***Physical Safety Features.*** In addition to increased education of visitors, incorporation of physical safety features such as delineators, pedestrian fences, and signing should be considered to increase safety through construction zones.

- ***Hazard Alert.*** Warning devices (both audio and visual) could be developed and utilized for contractor operations, and in rockfall areas, constricted roadway sections, etc. These devices could be automatically activated and designed to facilitate both daytime and night-time construction and traffic management operations. Contractor personnel could supplement these devices as necessary in particularly hazardous or sensitive areas.

Catastrophic Events. At best, it is difficult to predict catastrophic events or failures. For example, many types of rockfall rarely provide warning. However, in many cases the movement of landslides and slumps can be highly effective in predicting the onset of a sudden failure event. Monitoring of these types of features may allow costly mitigation to be deferred until the monitoring indicates that major damage is likely. It is recommended that an instrumentation and monitoring program be established in the identified areas of slumps and landslides. This program should be implemented as soon as possible to establish baseline conditions and monitor subsequent changes. A contingency plan should be developed that provides for personnel contacts, management responsibilities, specific objectives, and detailed emergency actions for handling various types of catastrophic events.