Resource Brief

National Park Service
U.S. Department of Interior

Mount Rainier National Park
Division of Natural and Cultural Resources
MORA Geology & Imminent Threats Group

White River Campground Road rock barbs

Construction, reconstruction and recommendations for future actions

May 2019

Taylor R. Kenyon, Robert P. Jost, and Scott R. Beason

A partially constructed barb 6 at the end of a work day. View looking upstream in the White River watershed (Photo: NPS/Taylor Kenyon).

This report is intended to assess the application and success of the White River Campground Road rock barbs, provide a clear description of the project as it occurred, note deficiencies and improvements to be made for the next actions taken on the project, and clearly detail the current condition of the structures to aid future permitting and decisions. Any edits, missing information, or questions regarding this document should be directed to either Taylor Kenyon or Scott Beason, NCR Geology Division.

1.0 Background

Mount Rainier is a 4,392 m (14,410 ft.) stratovolcano located in southwest Washington State, approximately 90 km (56 mi) south-southeast of Seattle. The volcano occupies most of the 956 km^2 (369 mi^2) of Mount Rainier National Park (MORA) and is visible from much of western Washington State (Figure 1). As a heavily glaciated peak, MORA is home to fluvial systems with intense sediment fluxes and increasing discharge levels due to glacial recession (Beason et al., 2015). Glacial recession at Mount Rainier is attributed to higher river discharges due to increases in glacial melt, and increases in sediment transport through the watersheds due to newly exposed glacial sediment stockpiles in the form of moraines (Beason, 2017; George and Beason, 2017; Magirl et al., 2017). These new conditions have led to a general trend of river aggradation and floodplain widening (Beason et al., 2015; Beason, 2006). As a result the design condition upon which much of the park's infrastructure was built has changed, placing many roads and other structures at risk of flooding or exposure to mass wasting events.

The White River transports a tremendous amount of sediment to the Puget Lowland, with a minimum of 60 percent the sediment that enters the Puget Lowland via the Puyallup watershed being sourced from within the park boundary (Czuba et al., 2012). This condition is resultant of and compounded by predicted trends in climate. Models predict up to 12 percent increases in precipitation from October-March and 18 percent decreases in precipitation totals from April-September within the next 25 years (Czuba et al., 2012). These trends are expected to exacerbate an already increasing trend of sediment transport and storage on the White River, with most appreciable increases in storage and channel width are contained within the park boundary (Czuba et al., 2012). Much of this change in storage is expressed by increases in channel width in the high reaches of the White River, continually leading to greater exposure of local infrastructure to fluvial hazards.

Figure 1: Location and vicinity map of the White River Campground Road, Campground, and construction site relative to the Seattle metropolitan area (Figure: NPS/Ian Bailey).

1.1 Purpose and Need

The White River Campground Road is the only access to the White River Campground. Visitation to the White River Campground totaled 21,748 visitors in 2018, making the campground among the top three visited campgrounds in the park, and a substantial source of fee revenue for the park (NPS, 2018). In 2006, MORA experienced the flood of record, with a total of 18 inches of rain fall in 36 hours (Bullock et al., 2007). Resulting floods were observed in every watershed within the park, and every roadway near a river experienced some degree of damage. The White River Campground Road was rendered non-functional when over half the road width was lost in multiple sections along the centermost reach of the road, where the valley makes a ~45 degree turn to the SE (Figure 1).

The Geology division has identified the change in valley orientation as most basic controlling factor for the problems at this site. Channel-spanning flood stages that fill the valley bottom ignore bedform controls on flow paths due to their immense capacity to rearrange alluvial sediments, and will then be controlled more by the total valley orientation and hillslope contacts with the active channel. There are two primary issues that result: first, the presence of this valley turn at high flood stage allows the river to treat the road embankment (river left) as its cut bank, rapidly causing significant bank erosion damage once occupied; and second, the same condition also causes the river to aggrade against the right bank. This has resulted in a cross-channel gradient up to 8 percent in the valley turn, which is steeper than the valley average downstream gradient through the reach. The net effect has been to force the mainstem of the White River to preferentially occupy the left bank where the road is located, allowing much smaller flow stages to impact the road than could before the 2006 flood. To solve the recurring issues to the road, the park needed to effectively reduce the shear stress exerted on the left bank, and chose to experiment with the use of rock barbs as the mitigating design.

Rock barbs are a design originally produced as a mitigating structure for bank erosion in meandering rivers (Matsuura and Townsend, 2004). The White River however, has a need for more serious flood resistance to mitigate the dramatic conditions common to the site. As such these designs were somewhat experimental for the park both functionally and as an accepted practice. The designs rely on the generation of slow water “weirs” on the upstream edge of the barb, and the deflection of the flow toward the valley center as it crosses the downstream edge (Matsuura and Townsend, 2004). To better fit the setting these barbs were designed to be longer, taller, wider, and have a greater angle from the upstream bank. These barbs only fully function during flood stages because only flood stages can occupy their upper surface and be deflected by the working edge. The park contracted for the original barb design used, which was completed by Donald Reichmuth of GeoMax consulting.

1.2 Original Construction

Initial construction of the White River rock barbs was performed in June 2007 when winter conditions subsided and allowed for return access to the site. Three sections of the roadway had lost around half of the road prism and needed reconstruction. The barbs built to mitigate future erosion of the road span from milepost 0.4-0.6 on the White River Campground Road (Figure 2). Little documentation could be found detailing the timelines of the project, material costs, or as-built size of each barb upon completion. This is the result of the original barbs construction being part of the $36 million emergency relief fund after the flood of record in 2006. Informal accounts of maintenance personnel involved in the original construction place the original as-built size of the barbs around 60 feet or more in most cases, with accounts stating that one barb was roughly 75 feet long.

1.3 Monitoring Efforts

Since the original construction of the barbs the park Geology and Geomorphology divisions have been attempting to track the degradation of the structures. The primary methods used for this were qualitative assessments of the barbs through field investigations performed by individuals that had seen some prior condition of the barbs, and by tracking volume loss on the structures through surveys. Qualitative field assessments yield only simple true/false conclusions: Were the barbs damaged during the previous wet season? While such assessments are internally useful to the divisions they yield no helpful results for any other park staff. Measuring volume loss was adopted as a more tangible product that could be used to better inform park management and maintenance. These observations and data sets were collected in 2013, 2015, and 2017 (Appendix Table 1). All other tracking of structure conditions comes from informal accounts of park visitors and other park employees, most of whom are not trained for engineering or geomorphic assessments.

Figure 2: Plan view of the barb locations, construction access points, wilderness boundary, roadway, and “ordinary high water line”. Figure was produced to show the existing condition of the barbs prior to the 2018 reconstruction efforts (Figure: NPS/Ian Bailey).

2.0 Reconstruction of 2018

2.1 Project Timeline

Operations for the project began on September 10, 2018 and continued through October 23, 2018, falling within the September 10 – October 31 work window detailed in the project permitting. Machine work in the dry began on September 17, 2018, while in-water work began on September 24, 2018. The first work days of September 10-13 were limited to activities such as the delivery and staging of machines and building materials. Material staging sites were limited, and had a direct impact on the project schedule. Most staging sites for equipment and rock were on top of barbs, on pullouts for the White River Campground Road, and after the diversion efforts rock was also stored on dry floodplain. Machine work began on Monday, September 17, 2018. During the first week of machine work, barbs 1 through 4 were completed by working in the dry. Work on barbs 3 and 4 required the crew to pump hillslope inputs from culverts on the north side of the road either farther along the ditch or out into the mainstem White River to be considered dry.

In-water diversion work began on September 24, 2018 to accommodate the construction of barbs 5 and 6. The river was gradually partitioned into a diversion channel identified by the park imminent threats team until the original mainstem had sufficiently low enough flow to safely enable the aquatics division to perform fish collection. Water in the original mainstem remained too turbid for effective fish collection. The process was repeated the next day (9/25) to ensure effectiveness. Fish block nets remained in place at the low end of the old mainstem to trap fish leaving the reach and prevent others from entering the now abandoned channel.

With the onset of in-water work, it was necessary to begin monitoring turbidity levels in the White River. Water sampling stations were established near barb 1 as a control for the site, 300 feet downstream of barb 6, 600 feet downstream of barb 6, and an automated turbidity meter measuring at 5 minute intervals was established on the park stream gauge 0.5 miles downstream of barb 6 at the White River bridge (Figure 3). Sampling at the control, 300 foot, and 600 foot sites was done in 15 minute intervals during the diversion work.

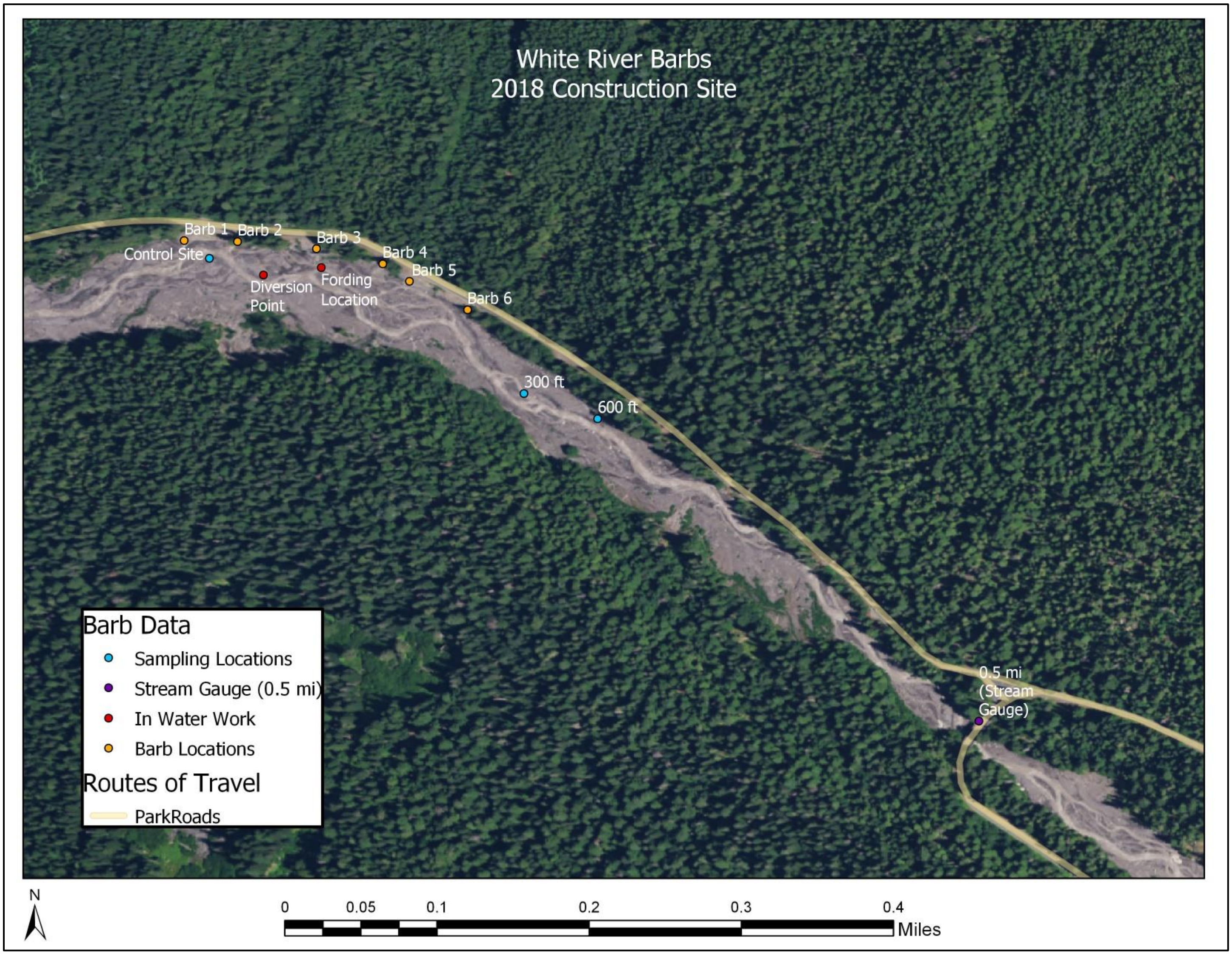


Figure 3: Map detailing key locations on the White River barbs construction site. Includes location of all barbs, sampling locations for turbidity monitoring, and in-water impact locations.

Once the fish removal was complete, work began for barbs 5 and 6 on September 25, 2018. These represent the last and farthest downstream section to be completed. Work along this last section included major reconstruction of both barbs and the addition of a 3:1 rip-rap bank that spanned the length of roadway between barbs 5 and 6.

The reconstruction of the barbs was completed on October 1, 2018, and the remaining rip-rap construction was completed on October 4. These actions concluded the large rock placement, leaving on the gravel harvest and site cleanup to complete the project. Gravel rearrangement in the White River ran from October 8 to 11. Once gravel rearrangement was completed, crews demobilized equipment from the site and closed the campground road for the season. The geologist on site made a final viewing of the as-built condition on October 17, 2018, thus ending actions on site for the White River rock barbs reconstruction of 2018.

2.2 Final Products

The project was completed as expected and resulted in the reconstruction/modification of all six existing rock barbs along the White River Campground Road. Functional results from the project include the reconstruction of the barbs, restoration of a damaged bank along the road, addition of space to pullouts and road shoulders, and redistribution of alluvium in the floodplain. All actions were performed during appropriate work windows and the project was officially marked completed as of October 23, 2018. Final measured dimensions of all barbs and installed wood is available in Appendix Table 2.

The reconstruction of the barbs went relatively smoothly with a few administrative hiccups early on. Barbs 1 and 2 required the least input because they had lost the least material. It was decided by park machine operators and the geologist on site that less than 100 tons of rock would be used for each to extend their nose, and no excavation would be performed to install wood. Barbs 3-6 all required enough reconstruction to allow for excavation to install large wood without dismantling the structures. Barb 3 received one log while barbs 4-6 were given two logs. Logs were placed with their ends oriented to resist the likely flow direction of a moderate to heavy flood event. Some wood in the floodplain was available to harvest based on guidelines in the categorical exclusion. Such wood was added to the barbs by wedging it in between installed logs in an attempt to add stable roughness elements to their face (Figure 4).

Figure 4: Photo showing the fully constructed condition of barb 4. The two chainsaw cut logs are installed with the barb as ballast, while all other wood was taken from the floodplain and strategically placed along the barb face to slow high flows (Photo: NPS/Taylor Kenyon).

Excavation was not permitted for the original project, but since excavation was allowed for wood installation we took advantage by keying in the toe of the structures. Once the pits were dug and logs placed special care was taken to fill the pits as tightly as possible with the largest rock available (Cover photo). The intended effect is to embed the structure into the river and resist future toppling failure of the nose. The unstable nature of disturbed alluvium also left the possibility that filling the log pits with river sand could undermine the stability of the new work. The geologist on site also chose to exclude the practice of filling the barbs with layers of alluvium during construction. All parties involved during the project agreed that because the structure relies on rigid contact along edges and corners of installed rock, the inclusion of large rounded cobbles would reduce the internal friction of the structure.

To replace the eroded bank between barbs 5 and 6 the park chose to install a 3:1 rip-rap embankment. This portion of the site required the most rock of any piece of the project by far, totaling around half of the purchased material. Completion of this restored several feet of lost bank and straightened the length between barbs 5 and 6, repairing the effects of a meander cut bank working into the road during the last storm. While a 3:1 slope is the standard for lower elevation rivers, it is the opinion of the imminent threats team that if rip-rap banks are installed in future projects, a 4:1 slope should be considered to accommodate transport capacity of Rainier rivers.

The imminent threats team saw an opportunity to take greater advantage of the permitted gravel harvest within the actions permitted by the categorical exclusion. The gravel harvest is intended to cover material the barbs with alluvium to disguise them from visitors and remove machine tracks visible in the riverbed. We expanded this process by carefully selecting where the extents of gravel harvest would be performed, and ensuring that all rearrangement left a local cross-channel gradient that can direct flow away from the barbs and toward the valley centerline. This action primes the floodplain to behave favorably during the first storm to reach the site after construction, hopefully promoting aggradation around the barbs and establishment of the White River toward the valley center.

2.3 Construction Impacts

Impacts incurred by construction on site are thought to affect endangered species and visitors. Endangered species must be considered for virtually any serious construction effort in the park. Northern Spotted Owl (*Strix occidentalis caurina*) and Marbled Murrelet (*Brachyramphus marmoratus marmoratus*) are among the first to be considered in almost all cases. For the 2018 reconstruction effort, it was decided the project *may affect, but is unlikely to adversely affect* both Marbled Murrelet and Northern Spotted Owl. No special considerations were made for planning around these species. For detailed information regarding impacts to natural resources and wildlife see the U.S. Fish and Wildlife Service monitoring report, reference number 01EWFW00-2018-F-1048 (Lofgren et al., 2019).

The primary impact of concern is effects to Bull Trout (*Salvelinus confluentus*) and their critical habitat. Bull Trout are of concern because the project required the use of heavy machinery below the bankfull elevation, and directly in the water course for part of the project. Direct and indirect impacts related to turbidity inputs, changes in channel morphology, use of rock barbs, and changes in wood dynamics are all listed as concerns for Bull Trout. It is also stated that the design is such that it will have a net benefit to Bull Trout habitat in the long term by stabilizing river banks and including large wood in the structures. The final decision was to declare the project *may affect, and is likely to adversely affect Bull Trout/designated critical Bull Trout habitat*, because the beneficial effects do not negate the short-term impacts. With this level of listed effect the project permits requires dewatering of the channel abutting the construction site, fish collection from the dewatered channel, and monitoring of turbidity produced on site. Fish collection in the dewatered channel yielded 13 Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*), with 11 being fingerlings (~120 mm) and two being adults (~180 mm). Turbidity inputs were monitored according to the Washington Department of Fish and Wildlife (WDFW) standards, and are detailed in the WDFW required monitoring report. The only substantial turbidity inputs were relatively brief, and took place on September 24, 2018 during the river diversion work.

Impacts to visitor experience and aesthetic quality were a matter of concern for the final products on site. Maintenance, Compliance, and Aquatics coordinators were worried about the aesthetic impact on the river bed. Without care, visible disturbance in the form of freshly moved sediments and track marks left by heavy machinery would blanket the riverbed until the next heavy rain. These impacts were mitigated by skilled machine operators who were committed to cleaning up signs of their work to leave behind a more natural scene for the public. Aesthetic values were impacted to a lesser extent by the presence of heavy machinery and other construction equipment on the road for the duration of the project. The project geologist on site found that likely the most significant impact was not predicted, and came in the form of direct exposure of hikers to the construction site. This was the result of inaccurate signage detailing river crossing conditions at both the White River Campground and the eastern crossing of the Wonderland Trail over the White River. These signs incorrectly detailed the capacity for the bridges to “wash out with no warning at any time” and suggested that visitors travel the road to bypass the crossings. The result of this was for a few dozen Wonderland Trail hikers to direct themselves through an active construction site with no access to high-visibility gear or other PPE. Given that the threat of crossing the White River was negligible for the duration of the project, this signage actually increased the risks posed to visitors rather than mitigating them.

3.0 Project Challenges and Resulting Deficiencies

Communication and planning leading into the barb reconstruction went far from smoothly and led to several deficiencies in the project. Some of these aspects led to the incursion of additional costs while others led to a reduction in quality of the final structures. Significant difficulties and deficiencies noted during the project are listed, including a description and the likely consequence.

3.1 Scheduling Conflicts

The first struggle to impact the project success was a miscommunication about permitted work windows. Originally the maintenance division was told to operate on the assumption that the work could begin on September 10 and would be open to wet work starting September 24. An excavator was rented and delivered based on this timeframe, but one final permit took until September 17 to be given approval. This shuffle inevitably resulted in the machine being delivered a week ahead of the new schedule with no capacity to work, adding $5,500 to the project cost for an additional week of rental time for the excavator.

The shortened timeline also led to issues with material delivery along with material and equipment staging. The capacity to store both materials and the machinery on site was limited, forcing the roads crew to use the majority of material each day rock was delivered. The schedule also forced the crews to work from upstream to downstream in order to remain in the dry until our permit to divert the mainstem took effect on September 24. Overall the two farthest downstream barbs and the bank between them needed the most work, and the floodplain would not work as a storage area until the White River could be diverted. When all these circumstances interacted it necessitated our crews to use up material as soon as possible for the first week due to a lack of storage space or ability to work on the largest structures, and resulted in a minimal level of input on barbs 1 and 2 to accommodate estimates of material need. Additional work should also have been applied to barbs 3 and 4, but could not have been done unless the timeframe had permitted them to be modified during the in-water work window.

3.2 Material Needs

Quality and abundance of building materials had a significant impact on the final quality of the structures. Some issues stemmed from limited availability and transport difficulties, others were unexpected pitfalls of a chosen material source, or the ordering process itself.

The total amount of rock ordered for the project was based on an outdated assessment from 2015, and did not include the most recent volume assessment of 2017. This locked in the quantity early on and prevented the acquisition of additional material. Up to 3,000 tons (a 25 percent increase) of rock would have been a more adequate quantity for reconstructing the barbs to their original size. It would, however, still have been necessary to expand the in-water project window to accommodate the additional length needed for barbs 3 and 4. Similar to the total volume ordered, the size class of rock ordered lacked the large ballast material needed. In all previous assessments by the geology division it was recommended that jetty rock be used to properly stabilize any additions to the barbs. Rock ordered for the project however did not include any jetty rock, and 85 percent of all rock ordered was class three and four rock[1]. Park machine operators, with experience building rock barbs in multiple settings including the original rock barbs on site, expressed concern for the stability of their work without use of the jetty rock they expected.

The last noteworthy issue with the rock was an unexpected consequence of the material source location. The rock used for the original barb construction is an incredibly hard crystalline igneous rock that has survived exceedingly well under the erosive influence of the White River. This rock has no fracture patters endemic to the matrix and shows little to no breakdown of larger rock since they were installed. The rock used for the reconstruction was also partially crystalline and appears to be of a similar quality, but upon transit and manipulation we found that it is structured from many repeating bedding planes that each serve as a weak point. It was a common occurrence for rock on site to split into half or occasionally smaller when park machine operators attempted to move or place them. This effect compounded to further reduce the amount of class five rock[2] available for the reconstruction, leaving some rock too small to expect to stay in place through winter and spring high water.

Collection and use of large wood and logs for projects is a continuing struggle for MORA. Much of this trouble stems from difficulty in collecting and transporting geomorphically effective wood throughout the park. Intact logs with rootwads are far heavier than normal logs, and consume much more space in transit. Even if we can transport the logs effectively, it is often too difficult to collect most viable logs with rootwads due to where we are able to mobilize heavy machinery for their collection. The project did receive seven intact logs with diameters no less than 19 inches, but none of these logs had rootwads. To fully match the design recommendations, barbs should all include logs with attached rootwads. In their current state, only four barbs include wood. It should be noted that barbs 1 and 2 did not have wood added because a significant amount of dismantlement would have to occur and would both exceed the project deadline and cause undue disturbance to the floodplain.

3.3 Administrative Guidance

A lack of clarity detailing the intended designs and allowed project actions became a significant hindrance to project efficiency. The first problems felt in the project was a lack of AutoCAD designs individual to each barb. This led to the geologist on site needing to guess how much material should be used on each barb to enable the maintenance crew to plan around how to stage material for each barb as the project progressed. This complicated the already tightened timeline and left the roads crew with only the AutoCAD "typicals" on which to base their designs (Appendix Figure 1).

These typical schematics were also found to have design flaws. Small details with potentially large effects needed to be changed. The filling of voids with river alluvium was determined by both maintenance and the imminent threats team to be structurally unsound, and dimensions of these new typicals are smaller than the original typicals provided by GeoMax. Machine operators involved in the original construction noted that many of the barbs were 60 feet or longer on the working edge upon installation, so downsizing the typical design would be a mistake for the application of these structures in the White River based on the high stream power and flooding potential. On a conceptual note, the imminent threats team disagrees with using the term "ordinary high water" in these designs. The term "ordinary high water" exists in rock barb schematics because these designs were originally developed for low slope, low elevation rivers where the main concern is meander migration during the high water season. The White River rock barbs serve the same basic purpose to accommodate yearly changes in river position but have also been adapted to act as flood erosion resistance measures in the high slope, hydrologically flashy Emmons Glacial basin. As such new designs should be built around the level of flood risk the park decides to mitigate.

Additional clarity for actions allowed by the categorical exclusion should be considered in future efforts. This in particular was the source of several delays and much frustration early on in the project. Conflicting opinions were being heard from resources personnel, and the expectations of the park compliance officer were seen as unclear until she was able to visit the site. It is the recommendation of the imminent threats team that all resource and maintenance specialists and supervisors hold a meeting upon beginning major projects to address the concerns of anyone relevant to project operation. This group should include maintenance foremen and administrators, machine operators, compliance officers, and all resource specialists involved with the project. All persons listed can

---

[1] Class three riprap is defined as "No more than 10% of stone has a diameter greater than 22 in; no more than 50% of the stone has a diameter greater than 16 in; and no more than 10% of the stone has a diameter less than 8 in." Class 4 riprap dimensions are 27, 22, and 10 inches, respectively, with respect to the class three definition.

[2] Class 5 riprap dimensions are 34, 27 and 16 inches, respectively, with respect to the class three definition.

potentially have questions or concerns capable of halting the project to determine what actions are permitted or necessary, and providing opportunities for personnel to receive clarity for the goals and operations will streamline the project and save project costs by avoiding unnecessary delays.

4.0 Conclusions

4.1 Recommendations for Future Designs

With another opportunity to build and observe the construction of the barbs comes the same chance to improve upon their design. It should be noted that all recommendations provided would require the use of a greater volume of rock than the 2018 reconstruction effort. The most straightforward improvements would be to the overall size and distribution of the barbs. Informal accounts place most of the barbs as much larger after the original construction than their condition after the 2018 reconstruction. The original barbs were successful for 11 years, and once their size diminished over time damage to the bank accelerated. This suggests that the overall size of the barbs should be constructed back to their original as-built condition if possible, which mostly suggests increased length of every structure with small additions to height for some. The encroachment of the cut bank between barbs also suggests they are spaced too widely for the site (Oregon NRCS, 2005). Barb guidelines and field evidence suggest that up to 3 barbs could be added to the array. In order of priority, barbs that could be added would half the distance between barbs 2-3, between barbs 5-6, and between barbs 3-4. The addition of at least one new barb between barbs 2-3 should be seriously considered for the next construction effort.

Changes to the design of individual barbs should be made to resolve issues of durability, eddy erosion and toppling of the toe, and a lack of roughness elements. In future efforts rock of a higher hardness should be used if at all possible. The current material is by no means substandard, however part of the effectiveness of the original barbs came from the use of rock considerably tougher than almost all of the native material transported through the reach. The current rock will likely break down mechanically around the front and nose of the structures, reducing the lifespan of the barbs. It is recognized that such discrimination of materials may be infeasible due to the transport limitations of construction in MORA.

It is imperative that rock for the next construction effort include an effective quantity of jetty rock, and heavier weighting toward large rock classes in general. It is clear that we must use transport limited materials for such a project, and ensure the material used for the project truly is transport limited for significant flooding events in the White River. The next round of designs should include additional armoring/roughness for the nose of the barb and just downstream of it. These outer areas are the most prone to bed scour with this design and are often the first to fail, so additions designed to protect them would be among the cheaper and more reliable ways to lengthen the lifespan of the barbs. Armoring for erosion along the back edge should also include wood for greater stability and roughness.

A general recommendation for future projects is the use of a greater width to depth ratio (H:V) in projects that require rip-rap. While the use of rip-rap should be discouraged whenever possible projects which do necessitate the use of rip-rap should be built with closer to a 4:1 slope to accommodate the destructive nature of Rainier rivers, especially for projects like the barbs where no excavation could be performed to key the rock into the riverbed.

Future design specifications and material needs should be collectively determined by the park civil engineer, maintenance, and geology divisions. Input from the imminent threats team should be considered standard for this project moving forward, and any other project where rock barbs are the chosen design.

4.2 Project Final Assessment

The geology division considers this project to have been completed successfully despite difficulties with the timeline and material availability. All efforts were made by the maintenance division, often beyond requirements, to accommodate environmental concerns for the site. Work for the structures themselves was done efficiently and creatively to accommodate design requests by the geologist on site, enough so to partially mitigate the loss of the first week of heavy machine rental. The final structures were altered from the expected design in small ways which helped to mitigate the deficiencies in needed material and reduce the amount of alluvium moved for the project. Special care was taken to fill excavation voids made for wood with large rock as ballast which also keys the nose into the river, and to target the gravel harvest to improve the conditions for the barbs during the next flood event. All such fixes are minor, but should lend substantial improvements to the total lifespan of the structures. The final products were agreed by maintenance and the geologist on site to be satisfactory both functionally and aesthetically.

While the reconstruction went smoothly despite complications, it must be stated that the White River rock barbs will continue to be a high profile project for the foreseeable future in the park. It is apparent that the current iteration of the barbs is less capable of permanence than their original incarnation, and their design has not yet been perfected for use in the high watersheds of MORA. While it may be possible to design the barbs to be robust and effective enough to withstand the system, such an advancement must also be accompanied by a project effort with an abundance of high-quality material and a longer timeframe. Until such an action can take place and be proven adequate, the barbs must be considered a cyclic maintenance issue to protect the White River Campground Road and access to the White River Campground.

For more information:

Taylor R Kenyon
Imminent Threats Technician
Taylor_Kenyon@nps.gov

Robert Jost
Imminent Threats Technician
Robert_Jost@nps.gov

Scott Beason
Park Geologist
Scott_Beason@nps.gov

References cited:

Beason, S.R., 2017, Change in glacial extent at Mount Rainier National Park from 1896-2015: Natural Resource Report NPS/MORA/NRR-2017/1472, National Park Service, 98 p.

Beason, S.R., 2007, The environmental implications of aggradation in major braided rivers at Mount Rainier National Park, Washington: M.S. Environmental Science Thesis, University of Northern Iowa, 165 p.

Beason, S.R., L.C. Walkup, and P.M. Kennard, 2015, Aggradation of glacially-sourced braided rivers at Mount Rainier National Park, Washington: Summary report for 1997-2012: Natural Resource Technical Report NPS/MORA/NRTR-2014/910, National Park Service, 166 p.

Bullock, A.B., K. Bacher, J. Baum, T. Bickley, and L. Taylor, 2017, The flood of 2006: 2007 update: Unpublished Report, Mount Rainier National Park, 43 p.

Czuba, J.A., C.S. Magirl, C.R. Czuba, C.A. Curran, K.H. Johnson, T.D. Olsen, H.K. Kimball, and C.C. Gish, 2012, Geomorphic analysis of the river response to sedimentation downstream of Mount Rainier, Washington: United States Geological Survey Open-File Report 2012-1242, 150 p.

George, J.L. and S.R. Beason, 2017, Dramatic changes to glacial volume and extent since the late 19th century at Mount Rainier National Park, Washington, USA: Poster #158-6, Geological Society of America Abstracts with Programs, Vol. 49, No. 6, doi: 10.1130/abs/2017AM-299694 .

Magirl, C.S., J.A. Czuba, C.R. Czuba, and C.A. Curran, 2017, Sediment from Mount Rainier, Washington, USA: Generation, transport, and impact on downstream rivers: Presentation #50-5, Geological Society of America Abstracts with Programs, Vol. 49, No. 6, doi: 10.1130/abs/2017AM-304140.

Matsuura, T. and R. Townsend, 2004, Stream-barb installations for narrow-channel bends – a laboratory study: Canadian Journal of Civil Engineering, Vol. 31 No. 3, pp. 478-486, doi: 10.1139/104-017.

Oregon Natural Resources Conservation Service, 2005, Design of Stream Barbs Version 2.0: Engineering Technical Note 23, United States Department of Agriculture, 26 p.

National Park Service, 2018, Stats Report Viewer [Online], U.S. Department of the Interior, accessed Nov. 2 2018, at https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Park%20YTD%20Version%202?Park=MORA

See Also:

Lofgren, R.., Kenyon T.R., Symonovicz, C., 2019, Mount Rainier National Park White River Repair Project Monitoring Report, Compliance Monitoring Report, Mount Rainier National Park, Ashford, WA, 14 p., U.S. Fish and Wildlife Service Reference: 01EWFW00-2018-F-1048.

Please cite this resource brief as:

Kenyon, T.R., R.P. Jost, and S.R. Beason, 2019, White River Campground Road rock barbs: Construction, reconstruction, and recommendations for future actions: Resource Brief, Mount Rainier National Park, Ashford, WA, 13 p.

Appendix A

Appendix Table 1: Volume survey data for White River rock barbs. Data for original size was based on estimates, and data for the “as built” size came from a total station survey performed in 2015. Additional survey data from 2017 was not included by the park civil engineer. Table taken from the Categorical Exclusion written for the project in 2018.

Barb #	Length (ft)	Base Avg. (ft)	Height Avg. (ft)	As built Volumes (ft^3)	Est. Volume Washed Away and/ or to be replaced (ft^3)	Est. Volume of Barbs in original state (ft^3)
1	46.90	18.83	5.12	4,523.00	588.80	5,111.80
2	38.79	27.94	3.98	4,313.49	1,262.60	5,576.09
3	51.75	37.20	2.57	4,947.50	7,257.60	12,205.10
4	54.00	25.50	7.63	10,499.60	1,090.60	11,590.20
5	38.32	23.75	7.78	7,080.60	2,156.90	9,237.50
6	30.00	34.20	6.80	6,976.80	1,708.29	8,685.09

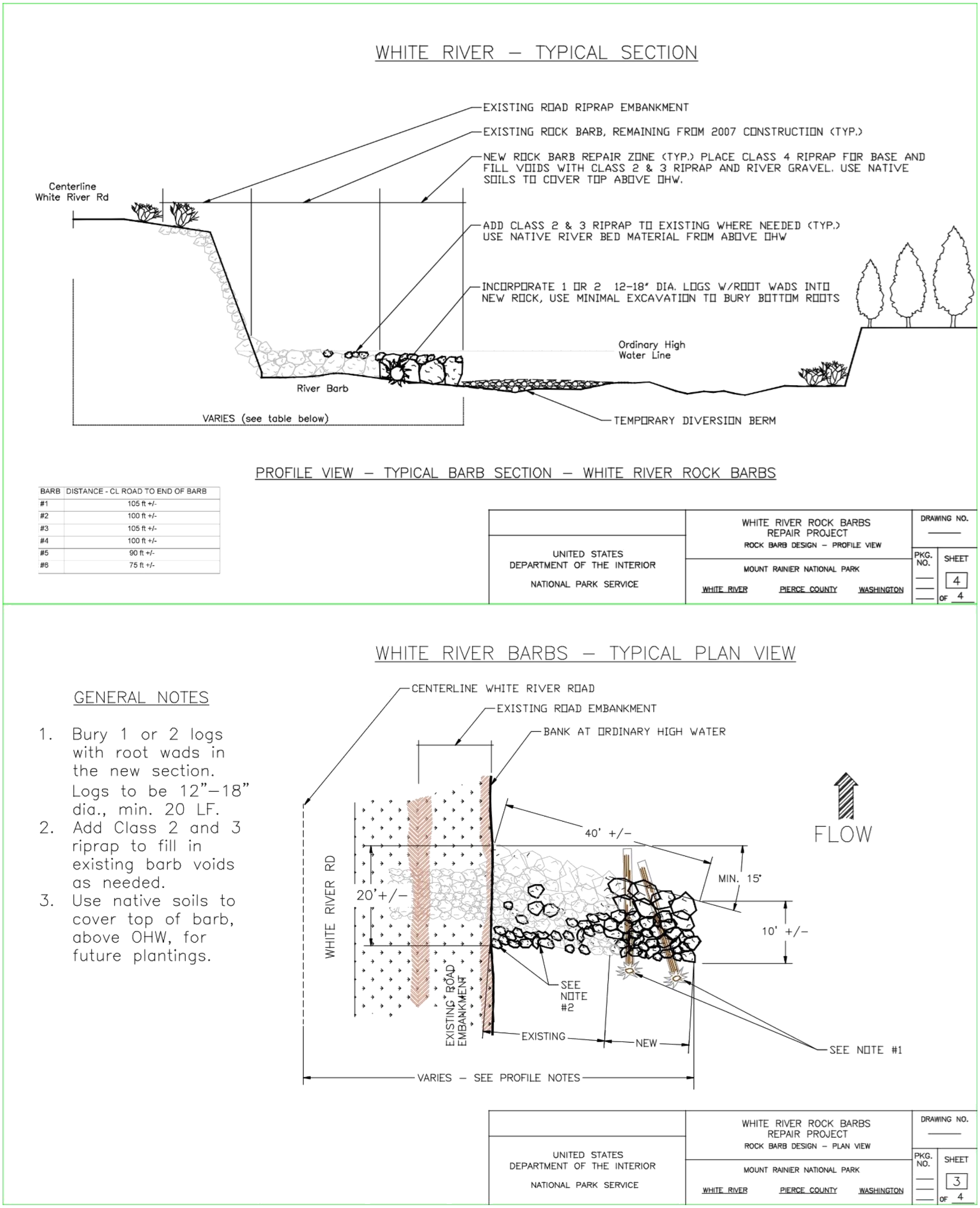
Appendix Table 2: Dimensions of each barb after the 2018 reconstruction. Physical dimensions and orientations are given for each barb along with data detailing the size and orientation of installed wood for each. Variable descriptions included in bottom of table. Dimensions are intended to enable re-drafting of AutoCAD documents to show as-built conditions.

Variable	**Barb 1**	**Barb 2**	**Barb 3**	**Barb 4**	**Barb 5**	**Barb 6**
Rock Dimensions						
θ_w	8	21	30	50	10	27
L_w	44.5	39	65	61	36	46
Az_w	22/202	24/204	38/218	64/244	45/225	45/225
θ_f	88	76	67	56	83	72
L_f	36	34.5	38.5	48	37	42
Az_f	16/196	17/197	11/191	48/228	42/222	36/216
W_n	12	17.5	13	16	13	15
Az_n	95/275	98/278	98/278	107/287	110/290	112/292
H_n	4.5	4	7.5	6	4.5	5
W_r	18.5	30	43	30	14.5	19.5
Az_r	104/284	93/273	78/258	104/284	125/305	108/288
Hr_{us}	4.5	5	5.5	7	5.5	5.5
Hr_{ds}	6.5	9	9	9	7.5	8.5
Variable	**Barb 1**	**Barb 2**	**Barb 3**	**Barb 4**	**Barb 5**	**Barb 6**
Wood Dimensions						
D_o	--	--	25.5	20.5	20	21.5
Hb_o	--	--	42	43	43	60
θs_o	--	--	10	14	12	13
Az_o	--	--	85/265	99/279	96/276	94/274
D_i	--	--	--	24	19	21.5
Hb_i	--	--	--	38	60	45
θs_i	--	--	--	15	17	13
Az_i	--	--	--	92/272	105/285	94/274
Spacing	--	--	--	60	67	107

Variable name explanation:

θ_w	The angle between the working (downstream) edge and a line perpendicular to the road prism (degrees).
θ_f	The angle between the front (upstream) edge and the road prism (degrees).
Az	Azimuth of any given edge (degrees); includes: working (downstream) edge (Az_w), front (upstream) edge (Az_f), nose (Az_n), road edge (Az_r), outside (Az_o), or inside (Az_i) dimensions.
L	Length of either the front (L_f) or working edge (L_w) (feet)
W	Width of either the barb at the road edge (W_r) or nose (W_n) (feet)
Hb	Greatest height above bed measured to center of log at inside, middle, or outside log (inches)
Hr	Height of barb above the bed at the road embankment, upstream (Hr_{us}) or downstream side (Hr_{ds}) (feet)
D	Diameter of the inside, middle, or outside log (inches)
θ_s	Greatest surface slope of inside, middle, or outside log (degrees)
Hn	Height of the barb above the bed measured at the nose

Note: “outside” refers to parts of the barb (logs in particular) that are closest to the river, and “inside” refers to parts closest to the road.



WHITE RIVER – TYPICAL SECTION

EXISTING ROAD RIPRAP EMBANKMENT

EXISTING ROCK BARB, REMAINING FROM 2007 CONSTRUCTION (TYP.)

NEW ROCK BARB REPAIR ZONE (TYP.) PLACE CLASS 4 RIPRAP FOR BASE AND FILL VOIDS WITH CLASS 2 & 3 RIPRAP AND RIVER GRAVEL. USE NATIVE SOILS TO COVER TOP ABOVE OHW.

ADD CLASS 2 & 3 RIPRAP TO EXISTING WHERE NEEDED (TYP.) USE NATIVE RIVER BED MATERIAL FROM ABOVE OHW

INCORPORATE 1 OR 2 12-18" DIA. LOGS W/ROOT WADS INTO NEW ROCK, USE MINIMAL EXCAVATION TO BURY BOTTOM ROOTS

PROFILE VIEW – TYPICAL BARB SECTION – WHITE RIVER ROCK BARBS

BARB	DISTANCE - CL ROAD TO END OF BARB
#1	105 ft +/-
#2	100 ft +/-
#3	105 ft +/-
#4	100 ft +/-
#5	90 ft +/-
#6	75 ft +/-

WHITE RIVER BARBS – TYPICAL PLAN VIEW

GENERAL NOTES

1. Bury 1 or 2 logs with root wads in the new section. Logs to be 12"–18" dia., min. 20 LF.
2. Add Class 2 and 3 riprap to fill in existing barb voids as needed.
3. Use native soils to cover top of barb, above OHW, for future plantings.

Appendix Figure 1: AutoCAD "typical" design for barbs to be installed. Based on a GeoMax design from the original barb construction in 2007. These designs were meant aid the production of individual AutoCAD designs for each of the six barbs, but no such schematics were produced by the park civil engineer before the project start.