Feasibility and Cost Study: Gardiner Pedestrian Bridge

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Western Federal Lands Highway Division
W. Schmidt

Old Yellowstone Trail South Improvements and Preservation
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Acronyms and abbreviations

ABA	Architectural Barriers Act
FLAP	Federal Land Access Program
Gardiner	Town of Gardiner
OYTS	Old Yellowstone Trail South
USFS	United States Forest Service
WFLHD	Western Federal Lands Highway Division
YNP	Yellowstone National Park

1. Introduction

Western Federal Lands Highway Division (WFLHD) is currently delivering the Old Yellowstone Trail South (OYTS) Improvements and Preservation project. Funded through the Federal Lands Access Program (FLAP), the OYTS project aims to improve both the road and trail in the 21-mile OYTS corridor, with a key benefit of reestablishing a secondary vehicular access route to the Town of Gardiner (Gardiner). The 2020 Corridor Study, which preceded the OYTS project, identified a pedestrian bridge across the Yellowstone River as an option to formalize access to the trail as well as enhance connectivity with Gardiner. An added benefit of the pedestrian bridge is the ability to install water and sewer lines on the structure. These utilities currently run beneath the river and were damaged by natural events in both 1992 and 2022. Relocation to a pedestrian bridge would prevent comparable damage in the future.

The OYTS project does not include the pedestrian bridge. This Feasibility and Cost Study is being performed to quantify viable structure type options; identify associated risks; and estimate the order of magnitude construction costs. The information will be used for grant funding applications and to inform design development of the project.

2. Project Location Map

The proposed pedestrian bridge is located in Gardiner, Montana. The northern end of the crossing would be situated on the riverbank behind the Gardiner Ranger Station office of the United States Forest Service (USFS). The southern end of the bridge would be situated near the abandoned railbed within Yellowstone National Park (YNP). A multi-use trail would extend beyond both bridge ends to provide connectivity to the OYTS trail on the south and the sidewalk adjacent to U.S. 89 on the north. Figures1 and 2 show both a vicinity map and site map.

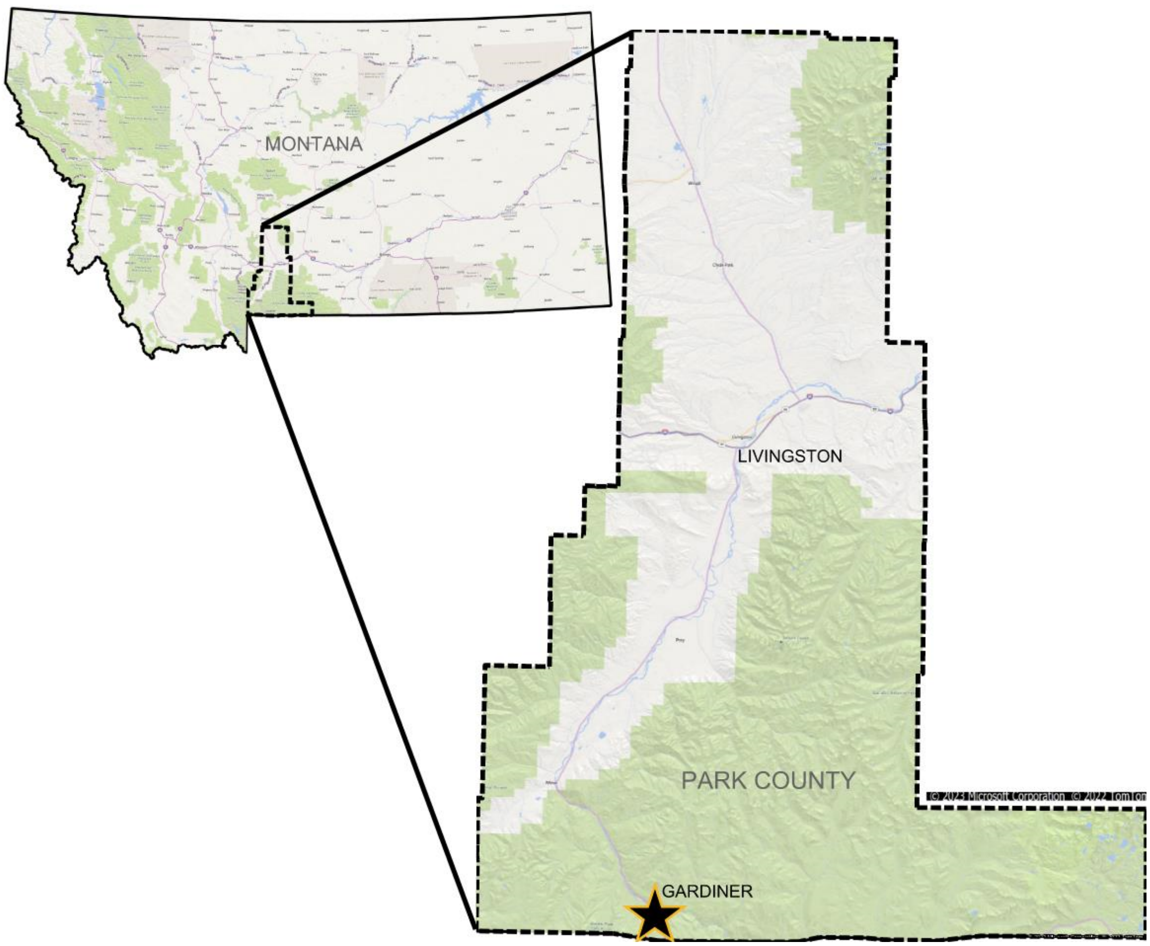


Figure 1. Vicinity Map.

Figure 2. Site Map.

3. Project Background

The 2020 Corridor Study developed three goals for the OYTS project. The first goal, which is most germane to this bridge study, seeks to "Improve the corridor to establish a throughway for vehicle and recreational use". Objectives of this goal include:

1) Providing secondary emergency access through the full corridor
2) Improving roadway elements to better road condition and increase user safety
3) Establishing a multi-use trail separated from the roadway where possible

An element of the third objective requires formalizing access to the OYTS trail. The trail currently lacks an official start, signage, and a formal connection to Gardiner. The study cited a pedestrian bridge over the Yellowstone River as one option to address these shortcomings. In addition to formalizing connectivity, such a crossing has the added benefit of carrying water and sewer lines across the river. The existing water and sewer lines run beneath the river and are at risk of being damaged by natural events; relocation to the bridge would eliminate this risk and reduce potential environmental impacts.

This report considers the pedestrian bridge alignment included in the 2020 Corridor Study and provided by Park County as the alignment to progress. This report also assesses the overall feasibility of the provided alignment, including the identification of adjustments required to meet accessibility criteria. Refinement of the alignment may occur in future design phases, should the project advance beyond the feasibility phase.

An on-site kickoff meeting was held with the project partners (Park County, YNP, USFS, WFLHD) on February 7th to initiate the feasibility study. The meeting started with an office session where the project partners shared their desires and considerations for the potential crossing. The meeting concluded with a visit to each side of the river to discuss site constraints and connectivity. In this document the phrase "project team" refers to the collective group of participants from Park County, YNP, USFS, WFLHD, and Jacobs Engineering Group, Inc. (Jacobs).

4. Purpose and Scope

While the OYTS project is funded, the pedestrian bridge element at the southern terminus is not. All parties involved in the OYTS project realize the benefits of the bridge solution and want to continue advancing the option. A critical next step in the process is to secure funding for the bridge option. To best support funding requests and avoid financial gaps, WFLHD elected to perform this cost and feasibility study.

WFLHD retained Jacobs to conduct the feasibility and cost study for the pedestrian bridge option. Jacobs worked with the Project Partners to develop the study, which includes the following elements:

- Identifying three structure types
- Confirming feasibility of preliminary alignment
- Developing construction cost estimates for the three bridge options
- Confirming design criteria
- Identifying environmental and other site constraints
- Identifying projects risks and developing risk management strategies

5. Site Description

5.1 Yellowstone River

The Yellowstone River is a key feature of Gardiner, Montana. It bisects the town and conveys an average peak seasonal flow of 16,779 cubic feet per second within its banks. At the proposed location of the pedestrian bridge, the Yellowstone River is approximately 125 feet wide, with steep slopes extending 30 to 50 feet in height above the river. At the time of the February 2020 LIDAR survey the water surface elevation below the proposed pedestrian bridge was 5,203 feet, with an observed ordinary high water elevation of approximately 5,215 feet. At the time of the completion of this report, a hydraulic analysis has not been completed. Therefore, scour and susceptibility of channel migration is unknown. Bank protection, stabilization, or scour protection may be required to prevent the undermining of bridge substructures. Installation of scour protection may require some degree of in-water work.

5.2 Site Conditions

The north side of the project is within USFS property. The southern half of the USFS property is not developed, and the proposed bridge abutment is located within a livestock corral. There is the ranger district's administrative offices and staff housing at the north end of the property. From the top of river bank the property slopes up toward US 89 rising 36 feet in elevation. The average slope of the property will require the proposed multi-use trail alignment to meander to achieve an Architectural Barrier Act (ABA) compliant grade.

The south side of the project is within YNP property. From the river's edge, grade slopes upward to the south, rising approximately 15 feet before encountering a near-vertical face that developed in the June 2022 floods. A relatively flat bench exists behind the near vertical face, spacing approximately 60 feet before encountering the bottom of the old railbed embankment slope. The railbed embankment slope runs south for approximately 40 feet at a 1V:2H slope. Beyond the southern limits of the railbed embankment is a staging and stockpiling area. An informal trail from a pull off along OYTS to the railbed skirts around the staging and stockpiling area.

5.3 Utilities

There are existing wastewater utilities, owned by Gardiner Park County Water and Sewer District, crossing the USFS property from east to west, including a lift station and manhole adjacent to the west property line. The underground power supplying the lift station was not located within the USFS property during this study. There are no known utilities within the limits of the proposed pedestrian bridge and multi-use trail construction on the south part of the project within YNP property. Figure 3 shows utilities in the vicinity of the USFS property (USACE, 2022).

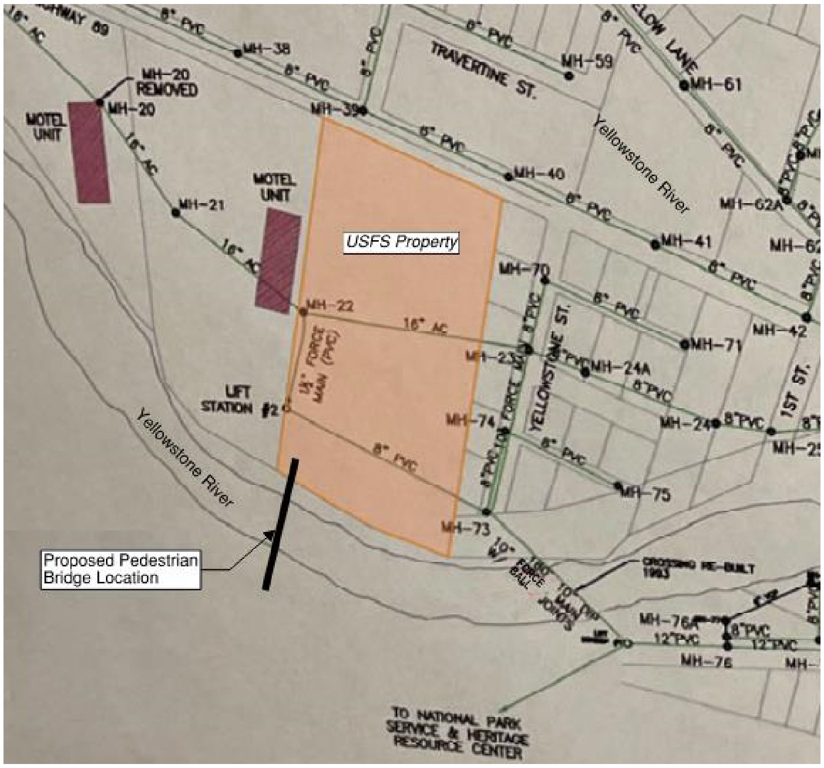


Figure 3. Utilities in vicinity of USFS property

There are no utility conflicts anticipated with the proposed pedestrian bridge; however, Gardiner Park County Water and Sewer District owns existing water and sewer lines running beneath the Yellowstone River upstream of the proposed pedestrian bridge location. These utilities were damaged during the 2022 flooding of the Yellowstone River and remain at risk of being damaged by future natural events. Relocation of these utilities by attachment to the pedestrian bridge has been incorporated into the bridge design criteria. Both utility lines are pressurized and can accommodate the geometry associated with each bridge type considered. Cost and feasibility of utility relocation is not included in this report. Additional utility location, coordination, and design will be required with future design efforts and project progression.

5.4 Site Vicinity Geology and Geologic Hazards

The proposed alignment for the pedestrian bridge is in a complex geological zone. A variety of geologic maps were reviewed as part of this desktop study including: Fraser et al., 1969; Berg et al., 1999; Lopez and Reiten, 2003; Pierce et al., 2018; and Nicholas, 2018, and others. The surface deposits at the proposed abutment locations are mapped as alluvial fan deposits (Lopez and Reiten, 2003). Pinedale flood deposits are mapped just east of the south abutment and were observed during a site reconnaissance, as shown in Figure 4. Pinedale flood deposits are described as a unit comprising boulders, cobbles, and sand deposited by high-energy early Holocene glacial processes, as shown in Figure 5 (Pierce et al., 2018). These deposits are well graded and include large granite boulders, greater than 8 feet, to sand and silt. Under this bouldery flood deposit, Pierce (2018) predicts a gravelly deposit with finer clasts, with potential for intermixed glaciolacustrine silty deposit. These geologic units could potentially be susceptible to liquefaction and are susceptible to scour.

Figure 4. Photo of the Pinedale flood deposits taken during a site reconnaissance.

Under the glacial deposits, Cretaceous sedimentary bedrock is expected, and depths are estimated to be 50 feet or more below the Yellowstone River elevation at the proposed bridge location. There are no bedrock outcrops in the vicinity of the bridge alignment, nor any clear delineation in available geotechnical data to constrain bedrock depth. Geologic mapping does indicate that there are complex bedrock faults and folds concealed by overlying landslide deposits, till, and alluvium. Based on this mapping, bedrock elevation is likely variable between the two abutments.

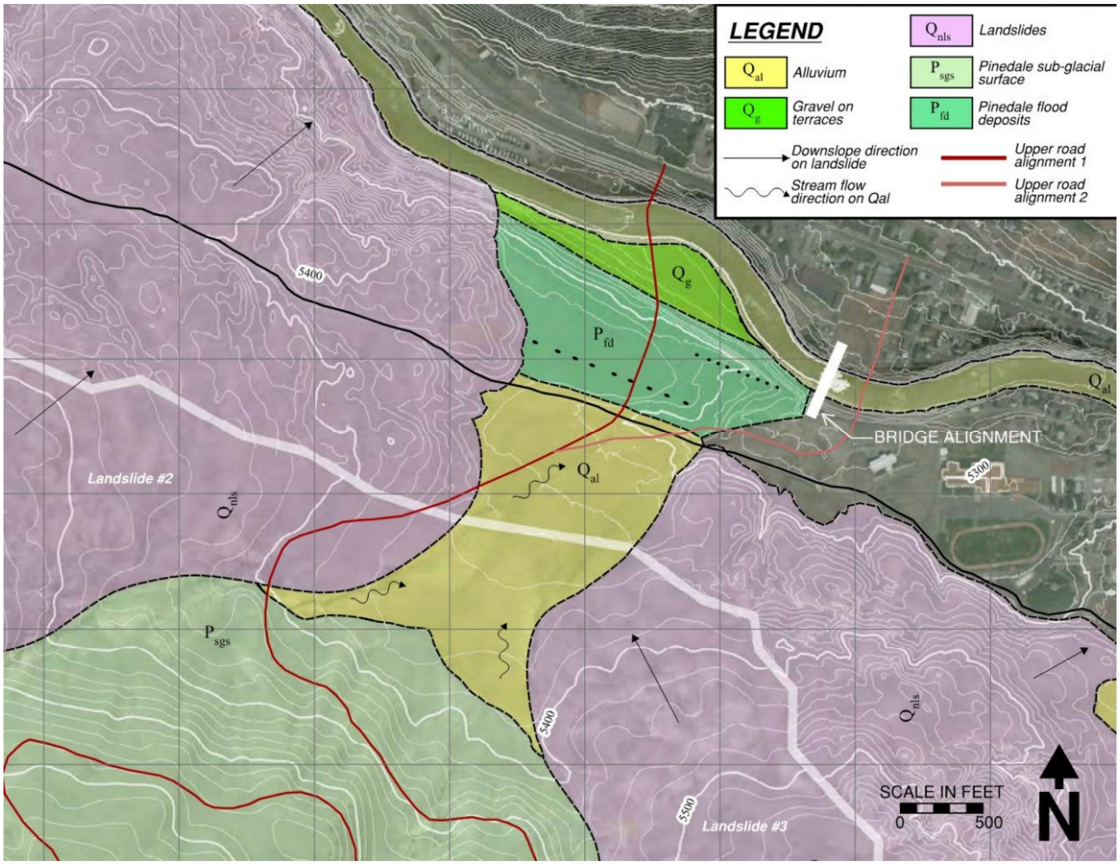


Figure 5. Geologic Map of project area, (Pierce et al., 2018)

Yellowstone Park is a very seismically active region. There are numerous faults mapped in the project vicinity, and these are included in the USGS National Seismic Hazard Mapping project as major faults or as gridded seismicity. The closest Quaternary fault to the site is the East Gallatin-Reese Creek fault system, located about 3.5 miles west of the site. Additionally, there are a series of middle to late Quaternary faults located approximately 6 miles south of the bridge location.

Six major faults are mapped within 50 miles of the site in the USGS National Seismic Hazard Maps. These include Table 1 below.

Table 1. Active Faults Mapped as in the National Seismic Hazard Maps within 50 miles of Gardiner Pedestrian Bridge

Fault Name	Distance from Site (miles)	Length (km)	Dip (degrees)	Dip Direction	Slip Sense
Emigrant Fault	14.7	57	50/65/35	NW	Normal
Hebgen-Red Canyon Fault	25.8	25	50/65/35	SW	Normal
Madison Fault	38.2	111	50/65/35	W	Normal
Eagle Bay Fault	38.3	32	50/65/35	E	Normal
Centennial Fault	44.6	64	50/65/35	N	Normal
East Mount Sheridan Faults	49.8	22	50/65/35	E	Normal

(USGS, 2023)

There are landslides that have been mapped in the area south of the project site. These are presented in the Pierce et al., 2018 map above, as the Landslides north of Sliding Lake landslide (Qnls) deposits. The toe of one of these landslides is mapped within approximately 300 feet of the south abutment. A review of recently acquired InSAR of these landslides shows that some movement may be occurring south of the existing Old Yellowstone trail. This will need to be studied in greater detail during the design stage.

6. Design Criteria

6.1 Multi-Use Trail

For this feasibility study, the multi-use trail on either side of the pedestrian bridge will be classified as a shared use path. Shared use paths are designed primarily for use by bicyclists and pedestrians, including pedestrians with disabilities. A 10-foot wide path with 2 feet of clear space on each side of the path was used to develop the multi-use trail layout and alignment.

- Criteria
  - (Proposed) Public Rights-of-Way Accessibility Guidelines (PROWAG)
  - Architectural Barriers Act (ABA) Standards (2015)
  - AASHTO Guide for the Development of Bicycle Facilities – 2012 Edition
- Slopes
  - Running Slope – 5 percent maximum
  - Cross Slope – 2 percent maximum
- Geometry
  - Centerline radius - Minimum 20 foot
  - Sight distance – 150 feet preferred

6.2 Bridge

For the purpose of this feasibility study, the bridge will be designed for a 14-foot wide trail section. That width is based upon a 10-foot wide path with 2-feet of shy distance on each side of the trail. A concrete deck will be considered for all bridge options. The bridge will include the following design codes and loads:

- Criteria
  - AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges – 2009 Edition with 2015 Interims
  - AASHTO LRFD Bridge Design Specifications – 9th Edition
  - AASHTO Guide Specifications for LRFD Seismic Bridge Design – 2nd Edition
  - FLH PDDM and WFLHD Supplements
  - 75yr Service Life
- Live Load
  - Pedestrian – 90psf
  - Vehicle – H10
- Utilities
  - Gardiner Park County Water and Sewer District
    - Sewer – 10" Diameter (Insulated)
    - Water Main – 8" Diameter (Insulated)
- Wind
  - Design Wind Speed – 115mph
  - Wind Exposure Category – Category D
- Seismic
  - 7% Possibility of Exceedance in 75 years
  - Site Class – D
  - PGA – 0.289g (As – 0.353g)
  - Ss – 0.695g (Sds – 0.864g)
  - S1 – 0.207g (Sd1 – 0.411g)
  - Seismic Design Category – C

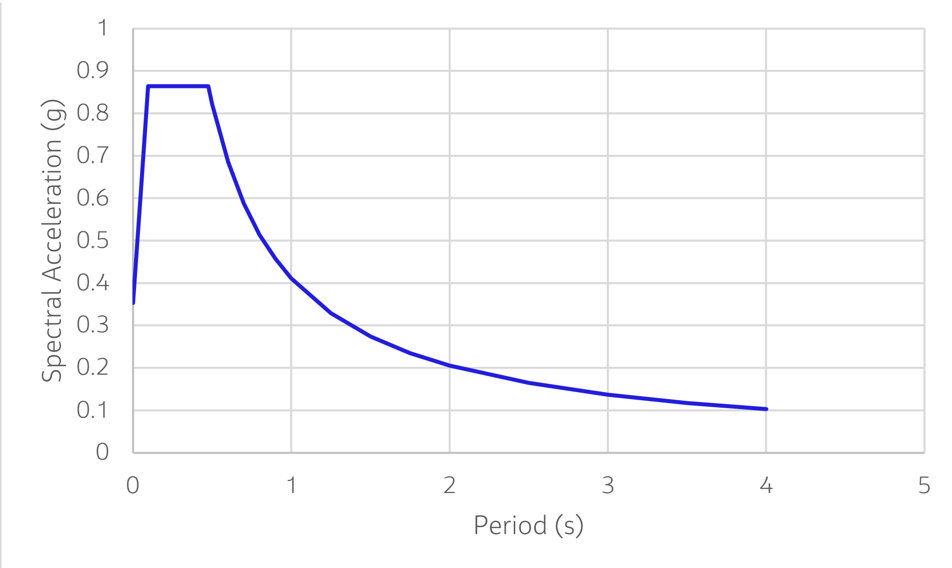


Figure 6: Design Response Spectrum for Gardiner Pedestrian Bridge

7. Multi-Use Trail

In the February 2023 kickoff meeting, the project team visited the proposed bridge site and evaluated multi-use trail alignments on either side of the pedestrian bridge. On the south portion of the multi-use trail, the project team determined the trail would begin near the west end of the YNP stockpile and staging area. A southern connection between the pedestrian bridge and OYTS was not developed as part of this feasibility study. On the north portion of the multi-use trail, the project team identified a trail corridor that would roughly follow the west fence line of the USFS property, then would jog west onto the adjacent property of Delaware North as the trail approaches and eventually connects with US 89. The project team acknowledged ABA design standards would dictate the final alignment of the multi-use trail. Only one trail option was developed as part of this feasibility study; trail alternatives and refinements to be investigated are discussed below.

Figure 7. West fence line of USFS property.

A preliminary trail alignment was evaluated using the design criteria identified above and priorities identified from the field visit. A 10-foot wide path with 2 feet of clear space on each side of the path was used to develop the multi-use trail layout and alignment. A three-inch thick asphalt sidewalk constructed on four inches of bedding material was used as the trail surface for estimating purposes. See Appendix B for conceptual alignment drawings.

7.1 South Multi-Use Trail

7.1.1 Overview

The portion of the multi-use trail south of the pedestrian bridge is a tangent connecting the pedestrian bridge into the west side of the staging and stockpiling area.

7.1.2 Discussion

No major design challenges or controlling features were identified within the south portion of the multi-use trail. The relatively flat grade of the staging and stockpiling areas allows future refinement of the alignment without ABA grade constraints. Vehicle access to the bridge would be achieved through the staging and stockpiling area. Design vehicle turning movements should be incorporated into the final design to confirm efficient access. YNP cultural resources has confirmed that excavation in the old railbed may be performed.

7.2 North Multi-Use Trail

7.2.1 Overview

The portion of the multi-use trail north of the pedestrian bridge, starts at the bridge then meanders and switchbacks north through the existing USFS corral. The meander is required to achieve a running slope of 5%. The existing ground slope within the corral area is approximately 5.5%. The multi-use trail switchbacks twice to maintain grade below the maximum running slope. The multi-use trail crosses into the adjacent property of Delaware North at the northwest corner of the USFS corral. The trail then heads north along the east property line of Delaware North before crossing back over to the USFS property as it connects to US 89.

7.2.2 Discussion

Multiple design challenges and controlling features exist in the north portion of the multi-use trail. The existing grade through the corral area requires the trail to meander more than discussed during the site visit; running parallel to the fence would require additional earthwork or grades exceeding 5%. Grades exceeding 5% are permissible with special consideration, such as the inclusion of periodic resting areas along the alignment. However, a straight path with grades exceeding 5% prompts excessive speed for bicycle traffic, which can be hazardous to pedestrians using the trail.

A significant challenge and controlling feature of the north portion of the trail is the constriction as the trail approaches the southwest corner of USFS staff housing, as shown in figure 8. This was the identified location of where the trail would connect to the adjacent Delaware North property to avoid impacts to the USFS staff housing. The width of the proposed trail would not fit between the existing features and impacts to the USFS staff housing yard were evaluated as part of this feasibility study. Additional design and detailed coordination between the USFS and Delaware North will be required to identify a solution that results in minimal impacts both properties. There are alternative routes feasible through the USFS property but those are not conducive to USFS operations.

Figure 8. South connection to Delaware North Property.

Figure 9. Fence line between USFS and Delaware North.

As shown in Figure 9 additional design would be required as the trail jogs onto the Delaware North property. Providing adequate width of the trail and separation from the traffic movements within the Delaware North property would be required.

Vehicle access to the pedestrian bridge's north approach would be through the existing road on the east side of the USFS property. Access to the lift station would be maintained via the same access and crossing the trail.

8. Bridge Options

As part of the February 2023 site visit, the project team evaluated potential bridge solutions and bridge landing points. The north bank of the Yellowstone River features a steep slope with limited access to the river. Any piers or bank stabilization at the edge of the north riverbank would likely require extensive site preparation and restoration to build access roads to the river. Given the potential classification of the Yellowstone River as a "Wild and Scenic River", the project team discussed the possibility of landing the north abutment of the bridge approximately 10 feet beyond the top of the slope to avoid in-water work. The project team also set a goal of limiting the total disturbance and environmental impact by constructing any potential bridge alternatives from above.

Figure 10. Steep Slope on the North bank of the Yellowstone River.

The South bank of the Yellowstone River features a steep slope to a 60 feet wide lower terrace, then another steep slope to the top of the railroad berm. The lower terrace was evaluated for potential abutment or pier locations. The slope from the river to the lower terrace is currently exhibiting moderate scour due to the 2022 flooding along the Yellowstone River. It was determined that any substructure on the lower terrace needs to be placed far enough away from the scoured slope to allow the natural erosion of the bank. Additionally, given the location of this slope on the outside curve of the river, the possibility for additional scour in future floods must be considered.

Deep foundations will likely be needed due to the potential for scour and the likelihood for bedrock to be 50 feet or more below the riverbed. Due to the boulders and cobbles expected in the deposits above bedrock, driven piles would likely not be practical. Drilled shafts and micropiles are likely the best options for bridge foundations with high axial loads, while ground anchors are likely the best option to resist high tensile loads. Additional foundation considerations are discussed for each bridge type below. Specific foundation options can be developed following a subsurface investigation and determination of design loads.

Figure 11. Noticeable Erosion/Scour on South Bank of the Yellowstone River.

Landing the bridge on the South side on the top of the railroad berm would lead to a significant longitudinal slope along the bridge. The trail would also need to be graded down from the berm, increasing the permanent impacts on the Yellowstone National Park land. The project team discussed the potential for landing the bridge mid-way through the railroad berm. This option requires excavating the existing berm approximately 10-12 feet vertically. This option is preferable and produces a total bridge length of approximately 350-375 feet and an overall longitudinal slope on the bridge below 1% (measured from beginning of bridge to end of bridge). To avoid significant in-water work and avoid the scoured face, a main span over the river of 250-275 feet is required.

Given the spans and total lengths discussed above, multiple bridge types were discussed. Aesthetics are an important factor in any bridge type, as the structure will be easily viewable from US89 and downtown Gardiner. The primary goal for aesthetics is to not disrupt the views of the Roosevelt Arch and blend in with the historic and rustic feel of the town. A structure type with a large cross section at midspan could potentially obscure these views. In particular, when entering the town of Gardiner along US89, drivers have an unobstructed view of the town and the Roosevelt arch. For this reason, structure types with large visual footprints were eliminated from consideration. These types include:

- Through Trusses
- Through Arches (tied and traditional types)
- Cable Stayed and Extradosed Bridges

Additionally, concrete structures (such as segmental box girders or spliced I-girders) were eliminated as they are inefficient for longer span pedestrian structures.

The project team settled on three primary structure types: a steel deck arch bridge, a steel suspension bridge, and a stress ribbon bridge. All options considered can be constructed without in-water work or access roads constructed to reach the riverbank, with the exception of potential scour protection mentioned in Section 5.1. Foundation options for each bridge type are discussed below. Given the limited information regarding geotechnical conditions at the bridge site, specific recommendations on foundation type are not possible. As noted in Section 5.4, there is a high likelihood for subsurface cobbles and boulders. Given that potential, the design team has not considered driven piles a viable option. If future site investigation confirms good driving conditions, driven piles we be evaluated. The three options will be evaluated in detail below.

Table 2. Span Lengths for Bridge Options

Bridge Summary		
Type	Total Length (ft)	Main Span (ft)
Option 1 - Steel Deck Arch	360	265
Option 2 - Steel Suspension Bridge	390	325
Option 3 - Stress Ribbon	360	-

8.1 Traditional Steel Deck Arch

The first option evaluated is a traditional steel deck arch. The arch is one of the oldest structural forms, dating back thousands of years. The arch primarily transfers force through compression. A deck arch sits beneath the riding surface of the bridge. Loads from the deck are sent through spandrel columns to the arch rib, where they are transferred to the arch abutments. Loading on the abutments is comprised primarily of vertical compression loads, and horizontal thrusts.

The site of the Gardiner Pedestrian Bridge is well suited for a traditional deck arch. The North side of the site features a steep bank, which can be excavated to construct an abutment. The South side of the site features a lower terrace where the other abutment can be constructed. The arch would span approximately 265 feet across the Yellowstone River. Short backspans can be constructed to accommodate the site topography. A general rule of thumb for arch geometry is that the arch rise-to-span ratio, measured from low point where the arch meets the abutment to the apex of the arch at midspan, should be between 1:3 and 1:20. A rise-to-span ratio of 1:6 is typically highly efficient. Given the site constraints, the 265 feet span arch has a rise of approximately 16.5 feet. This rise produces a rise-to-span ratio of approximately 1:16. This qualifies the arch as a low-rise arch. That likely means the arch ribs will need to be constructed out of heavier structural sections and the foundation will be larger than a similar span arch with a larger rise. Keeping the arch rise-to-span ratio below 1:20 ensures that arch has the necessary stiffness to prevent live load deflection concerns.

Arches can be constructed of virtually any material, though they are primarily constructed of steel, concrete, and masonry. Pedestrian bridges tend to be constructed of steel to minimize the dead load of the structure. A steel deck arch, utilizing either box-sections or built up I-sections for the arch rib and either rolled or welded plate I-sections for the spandrel columns and deck system is an efficient structure type for the Gardiner Pedestrian Bridge.

Foundations for the arch abutments are required to handle large vertical and lateral loads. As the depth to rock is likely tens of feet below the riverbed a deep foundation system, consisting of drilled shafts or micropiles, is the preferred foundation alternative. The depth of the deep foundation system will be influenced by the depth of scour. The foundations for the backspans support relatively minor vertical and lateral loads, therefore spread footings, with minor over-excavation for ground improvement, are preferrable to deep foundation elements.

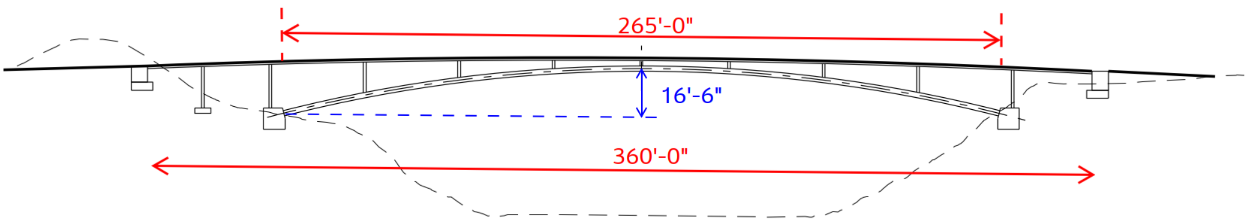


Figure 12. Steel Deck Arch Layout.

8.1.1 Aesthetics

As one of the oldest structural shapes, arches are typically seen by the public as elegant and efficient. As a highly familiar structure type, the structure also inspires confidence amongst the public. The Gardiner Pedestrian Bridge will be a highly visible structure. The structure is noticeable when driving along US89 towards the town of Gardiner, MT. The first look people will have of Yellowstone National Park when headed towards Gardiner is the historic Roosevelt Arch. A large imposing structure may negatively impact this viewshed. A traditional deck steel arch will sit below the Roosevelt Arch in the view line and should complement the view along US89.

Pedestrians will have an open-air feel when approaching and crossing the bridge. Given the arch sits beneath the deck level, the only structural element extending above the deck are the railings. The steel components of the arch can utilize a painted finish or a weathering steel finish. These finishes allow the arch to blend into their background.

8.1.2 Design

Arches are a common structure type amongst engineers in comparison to the other alternatives. Arches are naturally stiff structures, and rarely require geometric nonlinear analysis or dynamic modeling. The design of the arch itself usually requires either the design team perform a standard elastic analysis and utilize amplification factors to accommodate for arch deflection, or the design team can utilize a finite element analysis software package to perform a second-order analysis. Advances in modern software have made performing a second-order analysis relatively simple, and therefore modern arch design is more efficient.

At the time of this study, there is limited information regarding the geotechnical conditions at the site and a hydraulic analysis has not yet been performed on the Yellowstone River. Therefore, the potential for scour and channel migration is unknown at his time. Scour protection, including the use of rip rap, may be required to protect against undermining of the arch abutments.

In comparison to the other alternatives, an arch will typically perform the worst in large seismic events. During a seismic event, spandrel columns will form plastic hinges and therefore could experience permanent deformations which would require strengthen or replacement prior to reopening the bridge for service. Joints and bearings will likely require repair or replacement and minor to moderate damage to the backspan abutment backwalls is likely. The arch will likely handle wind and pedestrian vibrations better than the other alternatives, and typically does not require wind tunnel testing or dynamic vibration studies.

The engineer must pay careful attention to arch geometry during construction and take into account the forces imparted during construction. If the design team does not consider the construction sequencing, it's likely the contractor will need to reevaluate and potentially redesign portions of the arch prior to beginning fabrication. By paying attention to these details, the design team can mitigate the concern of construction delays due to redesign.

A standard 6 to 9 month design schedule, from Type Selection to 100% bridge plans, is common for these types of structures.

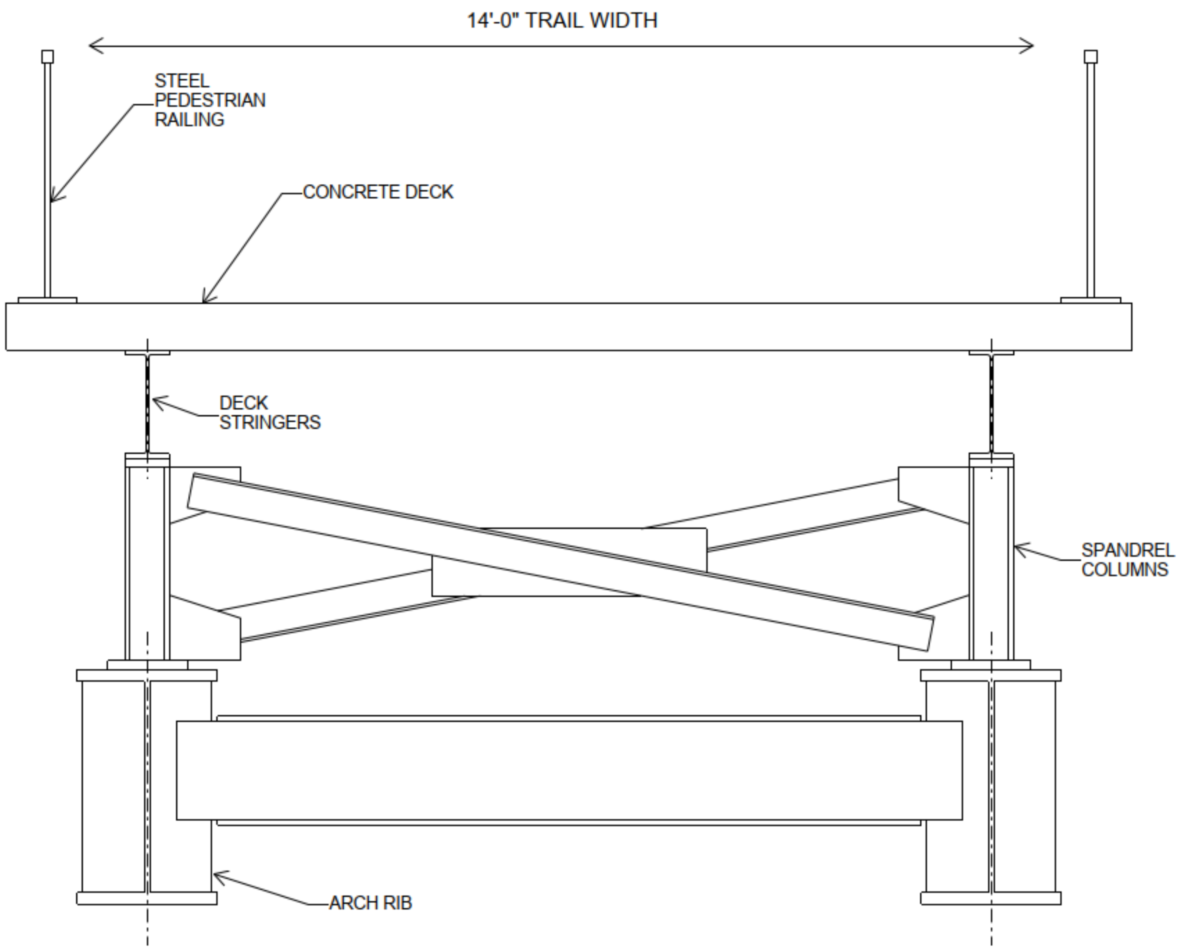


Figure 13: Traditional Steel Deck Arch Cross Section

8.1.3 Construction

Arches can be constructed in a variety of ways. Historically, the most common form of construction was to build falsework beneath the arch. The contractor would then erect the arch on the falsework, and the arch would be reliant on the falsework until the final piece was placed and the arch was stable. This method is expensive and slow. Today, most deck arches are built as cantilevers. The arch is supported by cables that are tied to the backspans or to temporary towers constructed behind the arch. This allows the contractor to work from both sides of the bridge and meet in the middle where the final piece completes the arch, and makes the arch stable. In addition to being more efficient, this method also allows the contractor to work completely from above, without the need to construct access roads below the arch itself. Given the environmental sensitivity of the site, and the limited access to the river, this method would be proposed for the Gardiner Pedestrian Bridge.

Access to the North side of the bridge site would be gained through the Forest Service access road. This road is currently used by Forest Service employees, the contractor will need to accommodate uninterrupted access by the Forest Service throughout the construction of the bridge. A staging area for construction equipment on the North side is required for storage of equipment and materials. Access to the South side of the bridge site would be gained through the existing staging/stockpiling location in

Yellowstone National Park. This area would also service as the primary staging area for the contractor, including housing any construction trailers.

The contractor would begin construction by excavating the North and South arch abutments. Access would primarily be from along the alignment. On the North side, excavation would ramp down to the arch abutment along the alignment, setting slopes back for the access road. A similar approach would be taken on the South side, beginning with the excavation of the historic railroad berm, and cutting an access road down to the South abutment. The abutment and its foundation would be constructed, and the contractor would work backwards, erecting the backspans. A crane would then be placed adjacent to the backspan, and arch segments would be lifted into place. After one or two arch segments are erected, a cable would then be attached to the cantilever and to the backspan or the temporary tower. The cable can be tensioned to meet the desired geometry prior to the next arch segment erection. After the final segment is placed, the cables are then detensioned, and the self-weight of the arch is transferred to the arch itself. Spandrel columns and the deck system are then erected, and the bridge deck and railings are constructed.

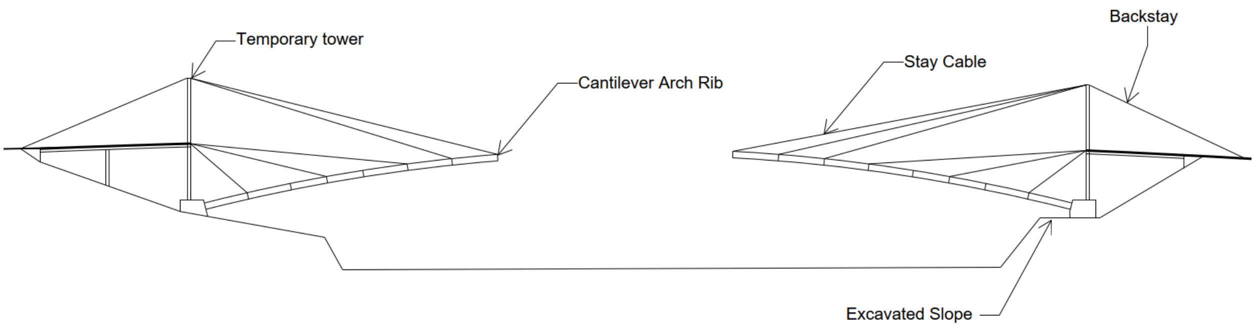


Figure 14. Steel Deck Arch Cantilever Construction.

Given the fabrication time of the all the required steel; the required site preparation and foundation construction; and the deck and approaches, construction of the traditional deck arch is expected to take approximately 18 months. A precast deck system may help expedite construction.

8.1.4 Maintenance

All steel structures exposed to the elements require some form of maintenance. If the steel structure begins to experience significant corrosion, steel replacement or reconstruction may be required. This is expensive and time intensive. The most common form of steel protection is a multi-coat painting system. This typically involves a primer being applied during fabrication, or just after erection and tarping the structure to allow for the sprayed paint coats to be applied. As the structure ages, the paint becomes brittle and begins to crack and peel. This process allows moisture to come into direct contact with the steel and corrode the steel members. To prevent corrosion, the structure typically require sandblasting and repainting every 25 years. An alternative that has becoming increasingly more common is the use of weathering steel. This material features an outer layer of planned corrosion that protects the steel underneath. Weathering steel is commonly used on steel bridges in locations with minimal to moderate corrosion potential. The Gardiner Pedestrian Bridge is in a moderate corrosive environment and the use of weathering steel is recommended over a painting system.

Arches also require joints and bearings to allow thermal expansion and contraction of the deck. These elements must be maintained to avoid runoff from rain or snowmelt coming into contact with the steel superstructure. In recent years, many owners have moved to abutment systems that move the bridge joints behind the abutments. In the event of a joint failure, water will not drain onto the superstructure. A similar system can be utilized on the Gardiner Pedestrian Bridge. A properly detailed and well maintained joint and bearing system should last 25-50 years.

Table 3. Advantages and Disadvantages of Traditional Steel Deck Arch

Option 1 – Traditional Steel Deck Arch	
Advantages	**Disadvantages**
Comparatively common structure type for contractors and erectors	Large excavation
Classic aesthetics	Large equipment
Open air above deck	Seismic performance
Use of weathering steel reduces maintenance	Most expensive alternative
Wind and vibration performance	

8.2 Suspension Bridge

The second option evaluated is a suspension bridge. Historically, suspension bridges have been used to span long distances or used in areas with difficult site access for heavy construction equipment. Suspension bridges work primarily by transferring loads on the deck to the main cables by suspenders. The main cables are passed over towers at either end of the bridge, transferring the vertical loads from the deck down through the towers into foundations. The main cables continue over the towers and are anchored into ground at a large anchorage. A suspension bridge is a lightweight and efficient structure type for pedestrian bridges, as the primary structural element is wire rope, rather than large steel or concrete structural shapes.

A suspension bridge fits the site constraints of the Gardiner Pedestrian Bridge well. The bridge can be constructed with minimal excavation and without the use of extremely large cranes or construction equipment. The bridge spans approximately 325 feet, with one tower being constructed approximately 10 feet behind the edge of the North bank and the other tower being constructed on the lower terrace of the South bank. Towers would rise approximately 35 feet above the deck, for an efficient sag of approximately 1:10. Short backspans would be used to help transition the trail to the bridge deck. The main cables would be anchored behind the bridge. The suspension bridge option is the widest option of the three alternatives. In addition to the 14 feet of trail width and 2 feet allowance for railings, the bridge will need to be at least 4 feet wider to allow for towers, suspenders, and floorbeam extensions.

The primary materials that compose the bridge include steel towers and a steel stiffening truss, made with either weathering steel or painted steel, and galvanized steel wire rope. Careful attention must be paid to locations where galvanized steel interacts with non-galvanized steel, such as at saddles over the towers or the sockets connected to the deck system. If not properly protected, these connection points can lead to decreased corrosion resistance and service life.

Foundations are a critical element for suspension bridges. The towers primarily transmit vertical loads, and would likely require deep foundations, such as drilled shafts or micropiles. Main cable anchorages transfer significant tensile forces into the ground. Two potential solutions for main cable anchorages are ground anchors and a dead-man anchorage. Ground anchors are drilled and grouted anchors that transfer loads into the ground using friction. A dead-man anchorage involves constructing a traditional foundation element, such as a pile cap supported by drilled shafts or battered micropiles, and anchoring the main cables directly to the pile cap. Most pedestrian suspension bridges utilize ground/rock anchors for main cable anchorages; however, if depth of rock and soil capacity limit the ability to utilize these anchors, a dead-man anchorage will be required.

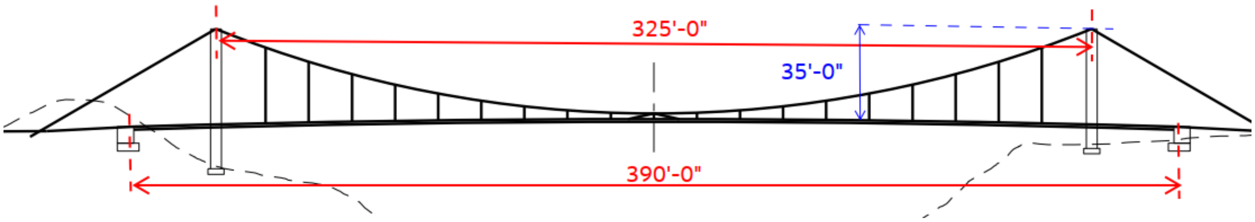


Figure 15. Suspension Bridge Layout.

8.2.1 Aesthetics

Suspension bridge aesthetics are dominated by the large towers at either end of the main span. Towers can be shaped into a variety of orientations; however, they typically consist of two large steel columns. Column members are usually box or I-shapes and feature lateral bracing between the two columns. The deck section is composed of a stiffening truss that can double as the railing system. Given the importance of the viewshed along US89, careful attention must be paid to avoid blocking views of Yellowstone National Park and the Roosevelt Arch. Considering the proposed location of the towers, the bridge should provide relatively unobstructed views of the Roosevelt Arch from US89.

Unlike the deck arch, pedestrians using the bridge will have a slightly enclosed feel. Pedestrians will pass through the towers and the main and suspender cables will drape down alongside the bridge. At midspan the cables will be below the stiffening truss and railing, giving pedestrians an open feeling. If properly detailed the bridge will feel stiff during typical use. However, the bridge may noticeably sway in high wind events.

8.2.2 Design

Pedestrian suspension bridges are unique structure types. The bridges are typically designed using large-deflection theory and thus require more advanced analysis than other standard types of structures. Wind analysis for suspension bridges falls outside the realm of typical AASHTO wind design. Traditionally wind analysis for suspension bridges has required a wind tunnel test to study the effects of aeroelastic flutter or galloping, where the bridge deck twists and bounces in high winds. To prevent these hazardous effects, the deck system for the bridge typically requires stiffening girders or trusses. Vibrations, from pedestrians walking across the bridge, must also be investigated. If vibrations are determined to be problematic, dampers may be required. These additional analyses can lead to longer design engineering timelines, and affect the overall project schedule.

Suspension bridges tend to perform quite well in seismic events. The deck system does not act as a rigid diaphragm, so individual towers are allowed to move independently. The deck system itself is fairly soft and tends to sway slowly in seismic events, limiting total damage. Joints and bearings are likely to experience moderate damage, requiring replacement, and the abutment backwall may experience minor to moderate damage, requiring repair prior to reopening the bridge to public use.

Similar to arches, the design team must pay careful attention to geometry of the structure during construction. Suspension bridges can experience large deformations during construction as cables elongate with each new load placed on the bridge. The design team is typically highly involved with the contractor during construction and may provide updated cable tensioning during construction to account for variations in calculated deformation vs actual measured deformation.

A design schedule between 9 and 12 months is expected for a suspension bridge. That accounts for the time from Type Selection to 100% bridge plans.

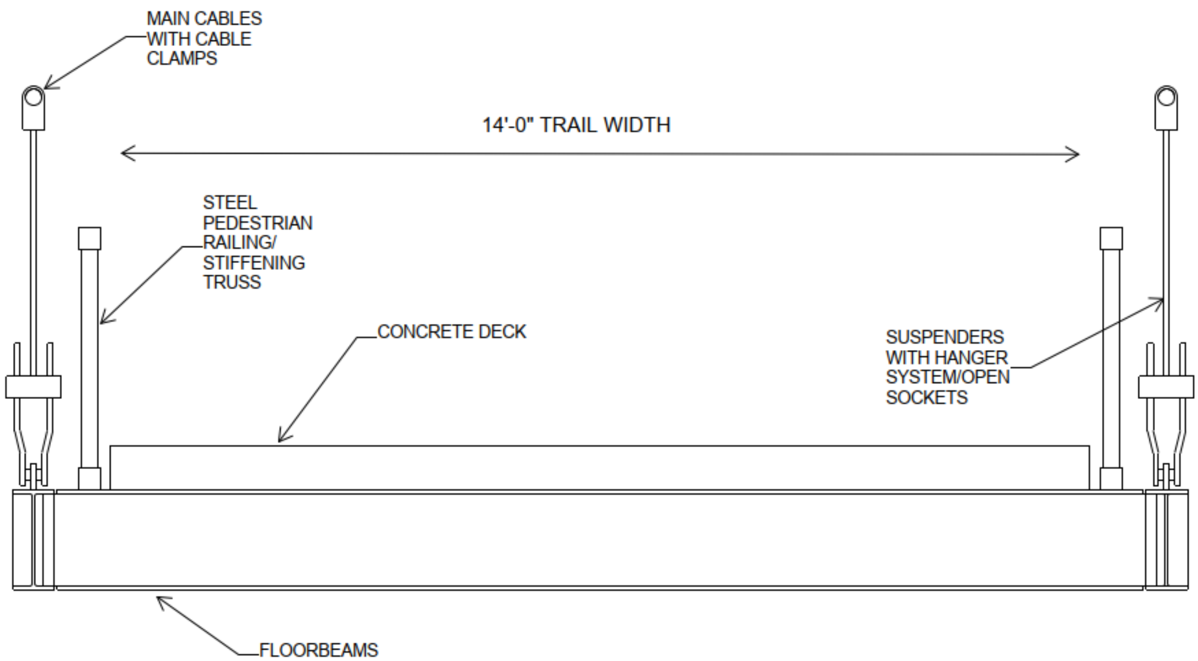


Figure 16: Suspension Bridge Cross Section

8.2.3 Construction

Suspension bridge construction would begin by excavating the railroad berm on the South side of the bridge. The contractor would build an access road down to the lower terrace to construct the foundation for the South tower. The North tower would be constructed at grade, limiting excavation to just deep enough to build the foundation and pile cap. Tower erection will require a crane to lift the individual towers into place, and connect them with lateral bracing. Cable anchorages are also at grade and can be constructed without significant excavation. The largest construction activity is running the main cables across the bridge, over the towers, and attaching them to the anchorages. This activity can be performed via helicopter or through the use of very large cranes. Once the main cables have been secured, construction on the deck and suspenders can proceed from both sides of the bridge. The stiffening truss and deck section can be fabricated in short sections to allow the use of smaller cranes or construction equipment.

Once the stiffening truss and deck section is erected, suspenders and main cables can be re-tensioned to meet the required finished deck geometry.

Similar to the arch option, staging areas are required on either end of the bridge for material and equipment storage. Compared to the arch, less room is required for storage of materials, and smaller equipment is required throughout the full construction of the bridge.

Given the fabrication time of the all the required bridge elements; the foundation construction; and the deck and approaches, construction of the suspension bridge option is expected to take approximately 12-18 months. A precast or integrated deck system may help expedite construction.

8.2.4 Maintenance

The suspension bridge features a number of items requiring regular maintenance. Steel towers are susceptible to corrosion and should employ a corrosion resistance mechanism, such as a painting system or utilizing weathering steel. Weathering steel is preferred as it requires less overall maintenance and upkeep. Galvanized cables are typically used to mitigate corrosion on exposed main and suspender cables. The cable saddles (where main cables are seated above the towers) and cable socket connections (where suspenders are attached to the deck system) require special detailing to prevent pack rust and corrosion due to dissimilar metals. Weathering steel would also be proposed for all steel elements in the deck system and stiffening truss. An alternative to galvanized steel elements is stainless steel. Use of stainless steel would alleviate the concerns regarding dissimilar metals. Stainless steel is quite expensive, especially for custom fabricated steel members, therefore a cost-benefit analysis should be performed prior to recommending its use.

The short backspans of the suspension bridge feature joints and bearings. Similar to the arch option, these can be detailed to avoid deterioration of the bearings and steel superstructure in the event of a joint failure.

Table 4. Advantages and Disadvantages of Steel Suspension Bridge

Option 2 - Steel Suspension Bridge	
Advantages	**Disadvantages**
Minimal excavation compared to alternatives	Large towers may affect viewshed
Small crane for tower and deck erection	May require specialist contractor/erector
Seismic performance	Large amount of exposed steel / maintenance
Fast construction	Wind and pedestrian vibration performance

8.3 Stress Ribbon

The third option evaluated is a stress ribbon bridge. Stress ribbon bridges are catenary-shaped tension structures which share many of the same principles as suspension bridges both in concept and geometry. Stress ribbon bridges consist of slightly draped bearing and prestressed tensioned cables that are embedded in a thin concrete deck slab. The deck itself serves to locally distribute loads and maintain continuity as an inverted concrete arch formed by uplift pressures due to cable tensioning after deck placement. The inverted arch action supplies bending rigidity while the cables transmit tension loads through the deck to the abutments and foundations. As the main supporting mechanism, the cables require a large horizontal force to be anchored by the foundations which can become costly depending on subsurface conditions. Ground anchors, drilled shafts, or micropiles in combination with a concrete abutment shear key are common foundations utilized to address the significant horizontal forces. This structure type has the benefit of not requiring any joints, bearings, dampers, or towers making it optimal for maintenance. Stress ribbon bridges also minimize the amount of material required for bridge construction, thus adding to the environmental and cost savings for this structure type.

Since their initial implementation in the 1960's, stress ribbon bridges have been constructed across the globe and the United States for numerous pedestrian bridge applications. Due to the structural mechanism relying upon the catenary shape of the cables for stiffening and stability, the variable slope of this structure type limits its use for highway application but makes it an excellent option for pedestrian and cyclist traffic. The maximum sag of this characteristic shape can be estimated as roughly 2% of the total span length. For a single span stress ribbon bridge spanning the approximately 360 feet at the proposed site for the Gardiner Pedestrian Bridge, a corresponding maximum sag of around 7 feet can be expected. Depending on the differential elevation of the abutments, the bridge would have an average slope of around 4%. The prestressing forces can be tuned to achieve specific sag and slope requirements;

however, this tuning comes at the cost of increasing the lateral forces being transferred through the foundations and into the soil. With the aforementioned 7 feet of sag, the bridge has a maximum slope of approximately 8% at the abutments. Note that while this exceeds the preferred 5% max slope, the bridge slope transitions under 5% relatively quickly.

The site of the Gardiner Pedestrian Bridge would be well-suited for a single-span stress ribbon structure that, combined with its characteristically slender profile, results in an aesthetically appealing and minimalist structure type that complements the existing viewshed.

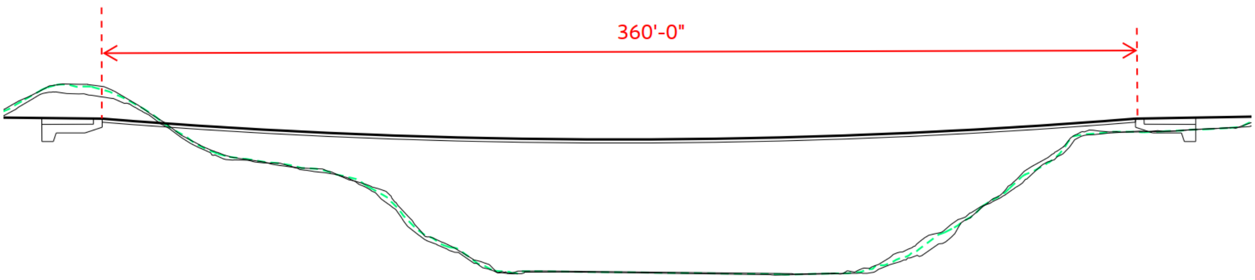


Figure 17. Stress Ribbon Layout.

8.3.1 Aesthetics

Stress ribbon bridges are simple structures with minimalist aesthetic characteristics. They are dominated by the draped deck section, with only the railings extending above the deck. Stress ribbon bridges can span significant lengths without intermediate supports at structural depths of the concrete deck often less than 1'-6". The concrete deck can also be painted diminishing the visual impact of the bridge especially at increased distances as would be the case on US89 approaching Gardiner. Similarly, the railing can be painted or utilize a weathered finish, such as Natina, to blend in or complement the rustic feel of the town. On the bridge an open-air environment is maintained, and the structural system is hidden from public view.

Given the structure type is unique and the section is so slender, public confidence may not be immediate. In the past, similar structures have performed public load tests using heavy equipment and vehicles to demonstrate the structural capacity of bridge prior to opening the structure to the public. While this practice is not typical or in many cases practical, it demonstrates the occasional difficulty in achieving public buy-in.

8.3.2 Design

These structures are considered fairly new, with the Sacramento River Trail bridge being the first U.S. installation in 1990. Their design is not covered in most modern codes (such as AASHTO LRFD Bridge Design Specifications and the AASHTO LRFD Guide Specifications for Pedestrian Bridges). The design team must rely on classical structural theory and best practices. Stress ribbon bridge design relies upon the governing behaviors of cables analysis and borrows many of the same guiding principles as suspension structures.

Both static and dynamic analyses are required for stress ribbon bridges. A static analysis is required for the erection and service stages of the bridge. The structure is analyzed as a flexible cable in the erection stage and as a rigid stress ribbon in the service stage. Stresses in the structure are dependent upon the construction procedure and must be tracked in design from the erection stage analysis to the service stage analysis. The complexity of a stress ribbon bridge is enhanced by the necessity to perform a time-dependent geometrically non-linear analysis to consider the creep and shrinkage effects. The large horizontal prestressing forces also require careful consideration be given to the redistribution of the stresses across all the non-homogeneous materials including the steel cables, precast concrete, and cast-in-place concrete.

Due to the low natural frequency and damping of stress ribbon bridges, a dynamic analysis is required to ensure acceptable resistance and serviceability during pedestrian and wind loadings. A wind tunnel study is likely warranted to better understand the performance in high wind events. Seismic loading needs to also be considered as well; however, the horizontal forces due to the live load on a single span stress ribbon bridges typically control over seismic forces.

For the reasons outlined above, a stress ribbon bridge design is technically complex and an advanced structural analysis software with sophisticated modeling capabilities is necessary for design. Given the additional analysis time, including wind tunnel studies, a longer design period (9 to 12 months) is required.

8.3.3 Construction

The construction of a stress ribbon bridge would begin with the excavation of the railroad berm on the south bank of the Yellowstone River to create a suitable landing point for the south abutment. Next, the abutments, wingwalls, and foundations would be constructed, and the exact procedure would depend on whether ground anchors, drilled shafts, or micropiles are selected based on subsurface conditions. Ground anchors are the preferred foundation type for stress ribbon bridges due to their ability to efficiently resist large tensile forces when competent soil is located within a reasonable distance. The ground anchors require post-tensioning to be performed in two stages to ensure resistance to sliding and to eliminate a variation of stresses. Roughly half of the ground anchors are post-tensioned before the deck erection and the remaining ground anchors are post-tensioned after the deck erection. If a micropile or drilled shaft foundation system is utilized, the contractor must take into account the deformation in the foundation during the construction of the stress ribbon bridge.

The deck would typically be erected in one of two ways; both of which can be done independently from the surrounding terrain using precast deck segments with a relatively small staging area required at both ends of the bridge. The first option for erecting the deck starts with drawing bearing tendons by a winch and tensioning the cables to a prescribed stress. A cable break at the abutment is used to maintain all strands at an equal length. Precast segments are typically 10’ in length and are then erected via a crane at one of the abutments. The segments are then placed under the bearing tendons, so the bottom of the trough is brought in contact with the tendons. Hanger bars are positioned to secure the precast segment to the tendons. The winch is then used to pull the segment into place using an auxiliary rope. This process is repeated for all segments. Post-tensioning ducts are coupled between the segments, and the troughs and closure pours between the segments are cast. Prestressing strands are fed through the PT ducts and tensioned at abutments. To reduce effects such as shrinkage and temperature, the prestressing tendons should be partially stressed as soon as possible and then stressed to the full design level once the minimum specified concrete strength is achieved. Lastly the metal railing is installed and the abutments and wingwall are backfilled.

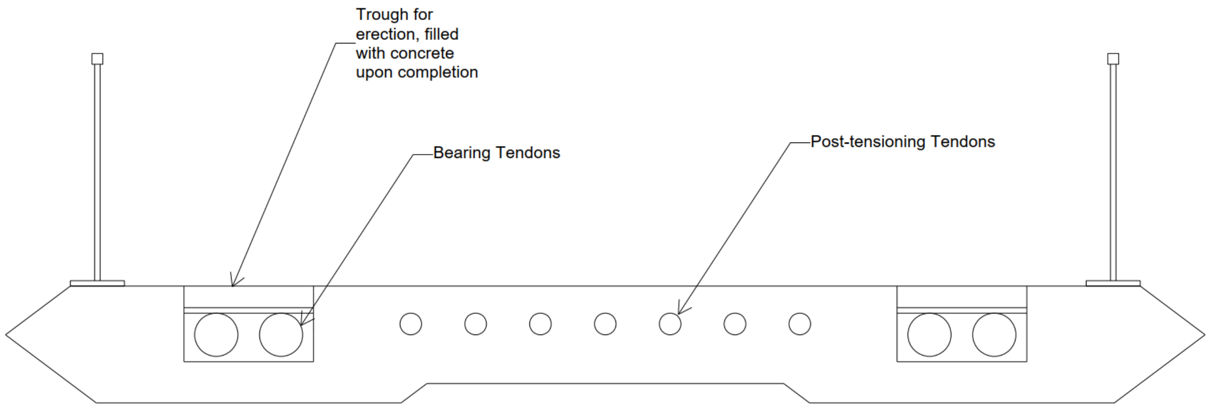


Figure 18. Stress Ribbon Cross Section.

The second alternative for the deck erection is similar to the first with the exception that an erection framework utilizes a trolley and highline cables placed above the future bridge profile to hang the bearing tendon ducts in segments that are then spliced and moved into place. The bearing strands are then pulled through the ducts and stressed. From there the process continues in a similar fashion to the first alternative where hangers are used to secure the deck segments to the bearing tendons. This sequence however allows for closure forms to be easily hung for any additional casting operations not utilizing the precast segments as forms.

A single span stress ribbon bridge located at the proposed site for the Gardiner Pedestrian Bridge can expect to have a 6-month construction duration. A 3-6 month lead time for the precast segments fabrication and material furnishment should also be anticipated.

8.3.4 Maintenance

Stress ribbon bridges have the unique advantage of requiring minimal long-term maintenance. The structure type does not need expansion joints or bearings. The continuous deck slab provides excellent protection of the prestressing steel and corrosion concerns are negligible in mild to moderate environments. With minor exception, maintenance of stress ribbon bridges is isolated to concrete deck or wearing surface repairs, railing repairs or replacement, and re-painting of the aesthetic concrete paint system if applicable.

Table 5. Advantages and Disadvantages of Stress Ribbon Bridge

Option 3 - Stress Ribbon Bridge	
Advantages	**Disadvantages**
Minimal aesthetics	Highly unique structure type
Minimal excavation compared to Arch	May require dampers for wind/vibration control
Small equipment/cranes required	Sag may violate 5% maximum slope for ABA access
Minimal maintenance requirements	Pedestrians may be hesitant given minimal structure
Lowest cost alternative	Cost is sensitive to foundation conditions

9. Cost Assessment

A detailed cost estimate was compiled for the three bridge options and associated approach trail work. Included in this estimate are the following assumptions:

- 30% Contingency
- 10% Mobilization
- 15-20% Preliminary Engineering
- 15% Construction Engineering

Table 6. Cost Summary Table

Cost Summary					
Option	**Construction Cost**	**Preliminary Engineering (Design)**	**Construction Engineering**	**Total Cost To Complete**	**Cost/SQFT**
Traditional Steel Deck Arch	$10,918,000	$1,637,700	$1,637,700	$14,194,000	$1,950
Suspension Bridge	$9,422,000	$1,984,400	$1,413,300	$12,820,000	$1,510
Stress Ribbon Bridge	$7,522,000	$1,604,400	$1,128,300	$10,255,000	$1,306

Option 1 - Steel Deck Arch Bridge					
Item #	Description	Unit	Quantity	Unit Price	Amount
20801-0000	Structural Excavation	CUYD	1900	$170	$323,000
20803-0000	Structure Backfill	CUYD	1100	$190	$209,000
55201-0200	Structural Concrete, Class A (AE) (Substructure)	CUYD	290	$2,800	$812,000
55201-0200	Structural Concrete, Class A (AE) (Superstructure)	CUYD	150	$2,000	$300,000
55235-0000	Expansion Joints (Strip Seal)	LNFT	32	$460	$14,720
55401-2000	Reinforcing Steel, Epoxy Coated	LB	73500	$7	$477,750
55502-0000	Structural Steel, Furnished, Fabricated, and Erected (50ksi)	LB	395000	$10	$3,752,500
55601-0900	Bridge Railing, Steel	LNFT	740	$390	$288,600
56401-0000	Bearing Device, Elastomeric	EA	4	$13,000	$52,000
56501-0600	Drilled Shaft (48-Inch Diameter)	LNFT	800	$1,400	$1,120,000
	Trail and Approach Work	LPSM	1	$285,000	$285,000

	Total	$7,634,570
30% Contingency		$2,519,408
10% Mobilization		$763,457
Area of Bridge to be built	SQFT	5600
Rounded Estimated Cost of Proposed Bridge		$10,918,000
Cost per SQFT of new bridge	$	$1,950

Engineering Costs					
	Description				Amount
	Preliminary Engineering (Design) - 15%				$1,637,700
	Construction Engineering - 15%				$1,637,700
Rounded Total Engineering Costs				$3,276,000	
Total Project Construction				$14,194,000	

Option 2 - Steel Suspension Bridge					
Item #	Description	Unit	Quantity	Unit Price	Amount
20801-0000	Structural Excavation	CUYD	1150	$170	$195,500
25602-0000	Ground Anchor	LNFT	1280	$260	$332,800
20803-0000	Structure Backfill	CUYD	600	$190	$114,000
55201-0200	Structural Concrete, Class A (AE) (Substructure)	CUYD	120	$1,900	$228,000
55201-0200	Structural Concrete, Class A (AE) (Superstructure)	CUYD	165	$2,000	$330,000
55235-0000	Expansion Joints (Strip Seal)	LNFT	32	$460	$14,720
55401-2000	Reinforcing Steel, Epoxy Coated	LB	51000	$7	$331,500
55502-0000	Structural Steel, Furnished, Fabricated, and Erected (50ksi)	LB	110000	$12	$1,320,000
55601-0900	Bridge Railing, Steel	LNFT	740	$390	$288,600
56401-0000	Bearing Device, Elastomeric	EA	8	$1,000	$8,000
56501-0900	Drilled Shaft (72-Inch Diameter)	LNFT	400	$4,100	$1,640,000
58101-1000	Cables and Anchor Components, Main Cable System	LPSM	1	$1,500,000	$1,500,000
	Trail and Approach Work	LPSM	1	$285,000	$285,000
		Total			$6,588,120

30% Contingency		$2,174,080
10% Mobilization		$658,812
Area of Bridge to be built	SQFT	6240
Rounded Estimated Cost of Proposed Bridge		$9,422,000
Cost per SQFT of new bridge	$	$1,510

Engineering Costs					
	Description				Amount
	Preliminary Engineering (Design) - 20%				$1,884,400
	Specialized Wind Tunnel and Vibration Analysis				$100,000
	Construction Engineering - 15%				$1,413,300
Rounded Total Engineering Costs				$3,398,000	
Total Project Construction				$12,820,000	

Option 3 - Stress Ribbon Bridge					
Item #	Description	Unit	Quantity	Unit Price	Amount
20801-0000	Structural Excavation	CUYD	500	$210	$105,000
25602-0000	Ground Anchor	LNFT	3840	$260	$998,400
20803-0000	Structure Backfill	CUYD	100	$270	$27,000
55201-0200	Structural Concrete, Class A (AE) (Substructure)	CUYD	80	$1,700	$136,000
55201-0200	Structural Concrete, Class A (AE) (Superstructure)	CUYD	100	$2,800	$280,000
55210-0000	Precast structural concrete (Deck panels)	CUYD	150	$6,500	$975,000
55401-2000	Reinforcing Steel, Epoxy Coated	LB	65000	$7	$422,500
55601-0900	Bridge Railing, Steel	LNFT	720	$390	$280,800
58701-0000	Post-tensioning system (strands)	LPSM	1	$1,750,000	$1,750,000
	Trail and Approach Work	LPSM	1	$285,000	$285,000

	Total	$5,259,700
30% Contingency		$1,735,701
10% Mobilization		$525,970
Area of Bridge to be built	SQFT	5760
Rounded Estimated Cost of Proposed Bridge		$7,522,000
Cost per SQFT of new bridge	$	$1,306

Engineering Costs					
	Description				Amount
	Preliminary Engineering (Design) - 20%				$1,504,400
	Specialized Wind Tunnel and Vibration Analysis				$100,000
	Construction Engineering - 15%				$1,128,300
Rounded Total Engineering Costs				$2,733,000	
Total Project Construction				$10,255,000	

10. Environmental Considerations and Compliance

The project is expected to have a federal nexus through: (1) potential federal funding from the Federal Highway Administration (FHWA); (2) granting of easements or special use permits for encroachment on National Park Service (NPS) and U.S. Forest Service (USFS) lands; and (3) other federal permits, such as a Clean Water Act Section 404 permit. For these reasons, compliance with the National Environmental Policy Act will be required. A lead federal agency will need to be determined; however, it is expected a Categorical Exclusion (CE) or an Environmental Assessment (EA) will need to be prepared. It is recommended that one document is prepared to satisfy all agencies' NEPA requirements, which would capture efficiencies and best manage project delivery expectations.

The determination of the class of action under NEPA is expected to vary between agencies because of the differing NEPA implementing regulations for FHWA, NPS, and USFS. Based on the scope of the project, WFLHD could comply with NEPA by preparing a CE under 23 CFR § 771.117(c)(3). The NPS and USFS have more limited CEs available to them for this scope of project, and an EA may be warranted to meet their NEPA implementing regulations. The USFS may be able to meet their needs through a case file or decision memo under 36 CFR § 220.6(e)(1), which deals with construction and reconstruction of trails. With that level of documentation, it is reasonable that USFS could use WFLHD's CE to meet their agency's needs. A review of existing Categorical Exclusions for the Department of Interior did not identify CEs available to NPS for the proposed scope of work. It should be noted that each land management agency's determination on class of action will depend on the extent of encroachment and disturbance within their administrative boundaries, as well as the type of decision required by their respective agency (e.g., granting of easement). Any requirements under the Montana Environmental Policy Act could be captured through the NEPA process, and no separate documentation is expected.

Table 7 summarizes potential environmental resource issues and compliance considerations expected with all bridge options, including potential permit requirements. No significant environmental constraints or concerns were identified that would pose significant constructability issues or prove especially burdensome for the schedule and cost of project delivery. With the exception of visual quality, the bridge options do not differ widely from one another when considering environmental constraints and compliance. In addition, when considering project delivery, the permits identified in the table can be obtained through Montana's *Joint Application for Proposed Work in Montana's Streams, Floodplains, and Other Water Bodies* process.

Table 7. Summary of Environmental Resource Considerations

Resource	Constraints/Concerns and Permit Requirements
Air Quality	No constraints or concerns identified. The project is in an attainment area. Short-term impacts may occur during construction, but standard project specifications are expected to be adequate to minimize impacts.
Historic Properties	The project is located in an area that has largely been previously disturbed. The only known historic property in the project area is the railroad bed located on the south side of the river. Based on initial coordination with Tom James, YNP Archaeologist, the railroad is considered eligible for listing on the National Register of Historic Places under Criterion A. Tom James did not note any concerns with potential impacts to the railroad bed that could risk a finding of adverse effect. Further coordination with the YNP Archaeologist and USFS Archaeologist should be conducted to confirm approach to National

Resource	Constraints/Concerns and Permit Requirements
	Historic Preservation Act compliance. Consultation with the Montana State Historic Preservation Office and notification to tribes with interest in the project area will be required.
Farmlands	No constraints or concerns identified. The project would not result in the conversion of farmland of prime, unique, or statewide importance.
Floodplains	According to Federal Emergency Management Administration Flood Insurance Management Rate Map 30067C1600C, the pedestrian bridge would cross Zone A of the Yellowstone River. Encroachment or work within the floodplain would need to adhere to Executive Order 11988, Floodplain Management, and ensure that any proposed activities would not raise the base flood elevation more than one foot. **Permits:** A floodplain permit for any development within the regulated floodplain may be required from Park County. Depending on extent of work within the floodplain, further coordination with the Park County Floodplain Administrator is recommended to determine county requirements.
Hazardous Materials	A review of publicly available Montana Department of Environmental Quality (DEQ) data did not identify any known hazardous material sites within the project area (MDEQ n.d.). However, an abandoned railroad bed is located on the south side of the river, and it is reasonable to assume contaminated soils may be encountered. At a minimum, a Phase 1 Environmental Site Assessment is recommended to determine potential risks.
Land Use	The project is located within the administrative boundaries of Yellowstone National Park and Custer Gallatin National Forest. While minor impacts to existing land use would occur to construct the trail alignment and bridge abutments, based on the scope of the work, the project is anticipated to be consistent with the Yellowstone National Park's Foundation Document (2014) and strategic priorities, and the Custer Gallatin National Forest Land Management Plan (USFS 2022). The USFS plan identifies the project area as located in a Recreation Emphasis Area, which acknowledges the existing recreation use of the area and plan for increased demand for recreation near communities. The project would be consistent with the intent of this designation.
Noise	No constraints or concerns identified. The project is a pedestrian bridge and associated multi-use trail; therefore, no formal noise analysis will be required.

Resource	Constraints/Concerns and Permit Requirements
	However, construction timing restrictions (e.g., no nighttime work) will need to be considered due to the proximity to developed areas within Gardiner to minimize impacts to residents and businesses in the area.
Recreation	The Yellowstone River is used for recreation, including rafting and fishing. While the project is expected to result in long-term benefits to recreation through trail connectivity, it may have short-term adverse impacts during construction by restricting public use of a portion of the river during construction. Outreach to the public, including private rafting or other recreational companies, will be required to ensure public safety during construction.
Section 4(f) Properties	WFLHD is subject to the requirements of 23 CFR Part 774, commonly referred to as Section 4(f). The railroad is the only known historic properties located within the project area that would be considered a Section 4(f) property. The project would also encroach on Yellowstone National Park, which is a significant publicly owned, public park. As defined, the park in and of itself is available for public recreation. Depending on the nature of the construction activity on park land and need for permanent easement, a conversion of park property to a transportation use could occur. Based on the expected limited potential use of park land, and assuming it is determined the project has no adverse effect to the railroad, a *de minimis* finding is likely to satisfy WFLHD's needs under 23 CFR Part 774. The intent to make a *de minimis* finding would require public review for a public park, but this could be conducted concurrent with any NEPA document review or outreach required. SHPO concurrence for a no adverse effect finding would be required to satisfy a *de minimis* finding for the railroad.
Section 6(f) Properties	No constraints or concerns identified. There are no known Section 6(f) properties in the project area.
Social and Economic Resources	As discussed under recreation, short-term adverse impacts to private rafting and other guiding companies may occur during construction due to restricting use of a portion of the river during construction. Advanced notification and coordination with private companies is recommended prior to construction. In the long-term, the project would have benefits to the local community through increased trail connectivity and providing secondary access to the town of Gardiner.
Special Land Use Designations	Within the immediate project area, the Custer Gallatin National Forest Land Management Plan (USFS 2022) identifies the segment of the Yellowstone River as an

Resource	Constraints/Concerns and Permit Requirements
	eligible wild and scenic river. The tentative classification is "Recreational," and the outstandingly remarkable values are identified as Recreation, Scenery, and Heritage. Although not formally designated, USFS manages eligible wild and scenic rivers to ensure that they retain their free-flowing condition and outstandingly remarkable values so that development activities do not preclude a river's potential formal designation. Design of the bridge will need to be coordinated with the USFS to ensure consistency with their wild and scenic river management objectives.
Threatened and Endangered Species; USFS Sensitive Species	No constraints or concerns identified. Based on a review of the U.S. Fish and Wildlife Service Information for Planning and Consultation, Canada lynx, grizzly bear, North American wolverine, monarch butterfly, and whitebark pine have the potential to occur in the project area (USFWS n.d.). Based on the project location, no suitable habitat for these species is expected to occur in the immediate project area other than the potential transient use of the river by bear, lynx, or wolverine. It is expected the project would have *no effect* to federally listed or candidate species. No USFS sensitive species are known to occur in the project area and because of the disturbed nature of the area, it is not expected a Biological Evaluation will be required to meet USFS needs.
General Wildlife and Aquatic Species	Based on the project location and scope of activities, limited impacts to wildlife and aquatic species are expected. Terrestrial species, such as elk, that may be within the project area would temporarily avoid the project site during construction but return upon completion of the project. Wildlife may use the bridge following its construction, and discussion during design should be had with agencies on if wildlife use of the bridge should be deterred. Raptors may nest within the Yellowstone River corridor and, if active nests are located within the project area, considerations such as construction timing may be warranted to avoid impacts during nesting and breeding season. During construction, aquatic species may be impacted by any required in-water work that could result in increased turbidity, noise, and direct fish kills. To minimize impacts, work should be isolated from flowing water and in-water work activities timed to avoid fish spawning.
Vegetation and Noxious Weeds	No constraints or concerns identified. The project is located in an area that has largely been previously

Resource	Constraints/Concerns and Permit Requirements
	disturbed and has limited vegetation. Areas temporarily impacted by the project would be re-seeded. Any ground disturbance has the potential to spread noxious weeds. Standard federal project specifications, as well as standard specifications implemented on Yellowstone National Park projects, are expected to be adequate to address noxious weed concerns.
Visual Quality	Within the project area, views of Yellowstone National Park and the Roosevelt Arch are part of a sensitive viewshed. Users of US 89 can view Roosevelt Arch from the highway, and the pedestrian bridge is within this viewshed and has the potential to disrupt viewer experience and expectations. With that in mind, the suspension bridge option has the highest risk of adversely impacting the viewshed in this area because of the large towers associated with the structure option that could dominant viewers' line of sight. The deck arch and stress ribbon bridge options have more potential to blend with the existing viewshed and not dominant the landscape. Per the USFS Land Management Plan (USFS 2022), the project is located in an area with a Scenic Integrity Objective of Moderate, meaning management activities are noticeable but not visually dominant. Based on this management objective, the deck arch and stress ribbon bridge options are likely more consistent with the USFS plan.
Waters of the U.S.	A review of aerial photography and National Wetland Inventory data identified the Yellowstone River and a potential tributary channel or palustrine emergent wetland on the south side of the river that could be impacted by the project. An aquatic resource delineation in accordance with U.S. Army Corps of Engineers standards should be conducted to identify all potential waters of the U.S. in the project work area and to define the regulatory ordinary high water mark (OHWM) and bed and bank of the Yellowstone River and any other channels identified. **Permits:** If discharge of dredged or fill material below OHWM or within wetlands is required, a Section 404 permit from the U.S. Army Corps of Engineers (USACE) Omaha District will be required. It is expected that wetland impacts are avoidable and limited impacts to the river may occur. Therefore, it is likely the project could be verified under a Nationwide Permit 14, Linear Transportation Projects. Based on Regional Condition 6, a

Resource	Constraints/Concerns and Permit Requirements
	pre-construction notification would be required. The current nationwide permits are valid through March 2026. In addition, if work is required within the bed or bank of the river or any other identified channels, a Stream Protection Act (SPA) 124 permit may be obtained from the Montana Fish, Wildlife & Parks. While this requirement does not technically apply to federal agencies, federal agencies typically comply with SPA 124 requirements as a best practice.
Water Quality	The Yellowstone River is on the 303(d) impaired waters list for Montana for ammonia (total), arsenic, copper, nitrate/nitrite, lead, and sedimentation/siltation (MDEQ n.d.). Water quality should be considered in design. While the bridge would serve pedestrians and bicyclists, if the bridge could serve as a potential source for de-icing salts or other surface treatments that could enter the river and degrade water quality, it may be warranted to assess stormwater collection on the bridge to facilitate treatment prior to entering the river. **Permits:** If a Section 404 permit is required, then a 401 water quality certification will be required from the Montana Department of Environmental Quality (DEQ). Currently, Montana DEQ has conditionally certified most nationwide permits, including NWP 14. In addition, a 318 authorization may be required from the Montana DEQ for activities that may temporarily increase turbidity. If construction disturbs more than one acre, a Montana Pollutant Discharge Elimination System General Permit for Storm Water Discharges Associated with Construction Activities will be required from the Montana DEQ.
Navigable Waters	No constraints or concerns identified. The portion of the river within the project area is not a navigable water per Section 9 of the Rivers and Harbors Act of 1899 and the General Bridge Act of 1946. The Yellowstone River is only considered a navigable water from Emigrant, Montana to its confluence with the Missouri River in North Dakota. Therefore, no Section 10 permit is required from the USACE or Section 9 permit from the U.S. Coast Guard.

11. Risk Assessment

Jacobs conducted a risk assessment for the project, concluding in a risk management plan. The plan includes risk identification, qualitative risk assessment, response actions, and monitoring and control strategies. The Risk Management Register is located in Appendix C and commentary on threats with high impacts is provided below.

Right of Way (Risk 1). This risk is associated with the ability and/or willingness of landowners to grant easements for the project. If such easements cannot be secured, the project would not be constructed. An initial discussion with all involved parties shows a willingness to grant the necessary easements. Mitigation of this risk will involve ongoing conversations with affected parties and developing a trail alignment on the north side of the river that minimizes impacts to USFS property.

External (Risks 6, and 11). These risks are associated with project funding shortfalls. Shortfalls could be due to not securing funds for the project or contractor bids exceeding allocated amounts. Mitigation of this risk involves pursuing multiple funding sources and requesting fund amounts based upon realistic construction cost estimates.

Environment (Risks 18). This risk is associated with encountering contaminated materials in the old railbed, which is quite common in railbeds. Mitigation of this risk involves early site assessments to identify any contamination and developing realistic schedules to accommodate the required remediation.

Appendix A. References

Fraser, G.D., Waldrop, H.A., & Hyden, H.J., (1969), Gardiner Area Park County Montana, Geological Survey Bulletin 1277, United States Government Printing Office, Washington, DC.

Lopez, D.A., & Reiten, J.C., (2003), Preliminary geologic map of Paradise valley, south-central Montana: Montana Bureau of Mines and Geology Open-File Report 480, 22 p., 1 sheet, scale 1:50,000.

MDEQ, no date, Discover DEQ's Data, https://discover-mtdeq.hub.arcgis.com/ (access 03/08/2023).

Nicholas, G.E.. (2018). Landslide Morphology and Its Insight into the Timing and Causes of Slope Failure: Case Study of Post-Glacial Landslides in Yellowstone National Park.

NPS, 2014, Foundation Document Yellowstone National Park. Available at: https://www.nps.gov/yell/learn/management/upload/YELL_FD_508.pdf

NPS, 2023, Water Flow in the Yellowstone River at Corwin Springs, Montana, https://www.nps.gov/articles/000/yellowstone-river-water-flow.htm (accessed 02/27/2023).

Pierce, K.L., Dewey, C.S., & Nicholas, G.E. (2018). Surficial Geologic Map Involving the Roads between Gardiner, Montana, Mammoth, Wyoming. 1:8000. Slickenside Consulting, LLC, Vancouver, WA.

USFS, 2022, Custer Gallatin National Forest Land Management Plan Revision, https://www.fs.usda.gov/detail/custergallatin/landmanagement/planning/?cid=FSEPRD897383 (accessed 03/08/2023).

USGS, 2014, 2014 National Seismic Hazard Maps – Source Parameters, 2014 National Seismic Hazard Maps - Source Parameters (usgs.gov) (accessed 03/02/2023).

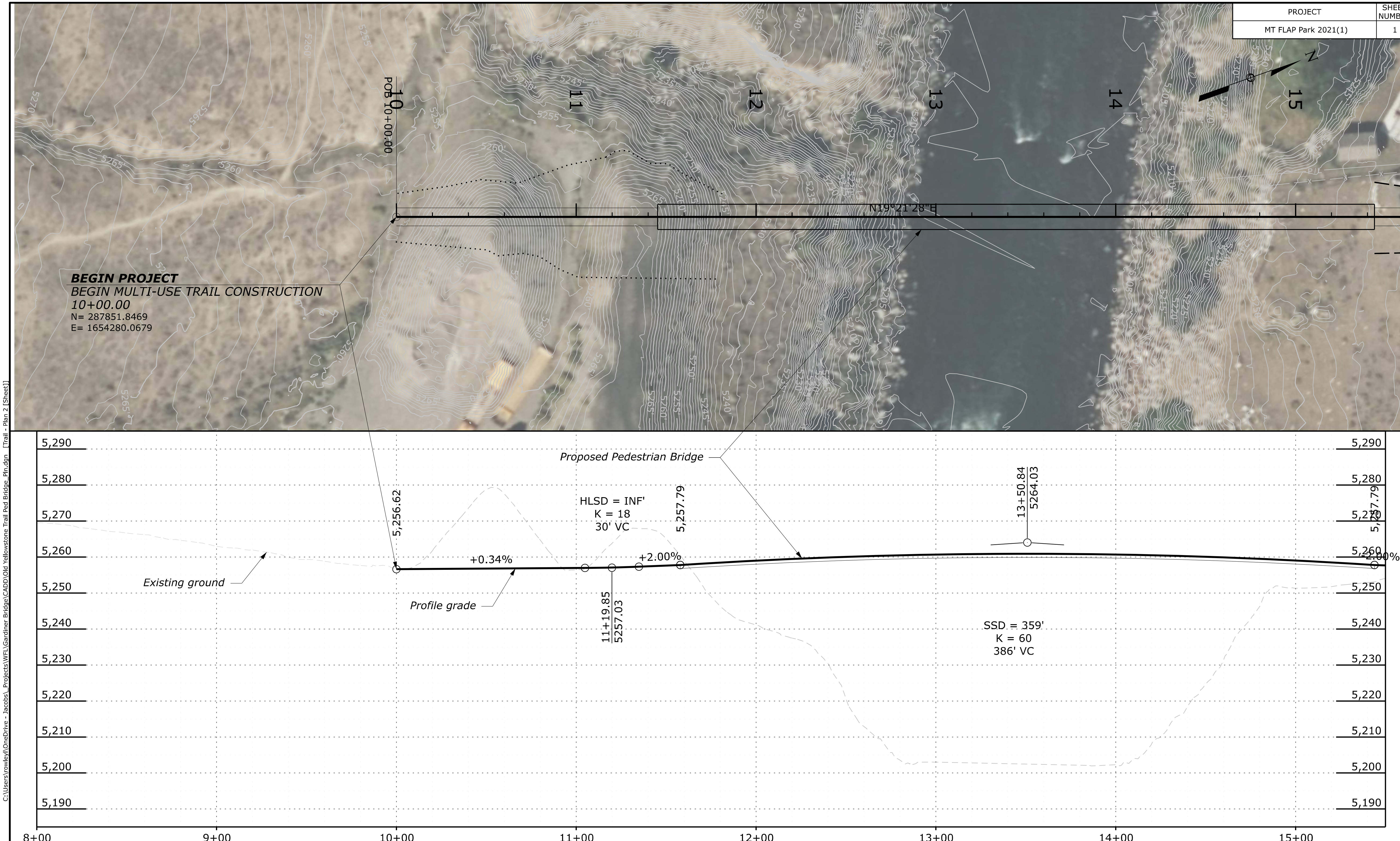
USGS, 2018, U.S. Seismic Design Maps application, https://earthquake.usgs.gov/designmaps/us/application.php (accessed 03/02/2023).

WFLHD, (2020), Old Yellowstone Trail South Corridor Study.

USACE, (2022), USACE Technical Team Damage Assessment and Conceptual Repairs: Gardiner, MT; Park County, MT 2022 Yellowstone River Flooding 12 December 2022

USFWS, no date, IPaC – Information for Planning and Consultation, https://ecos.fws.gov/ipac (accessed 03/08/2023).

Appendix B. Conceptual Alignment Drawings and Renderings



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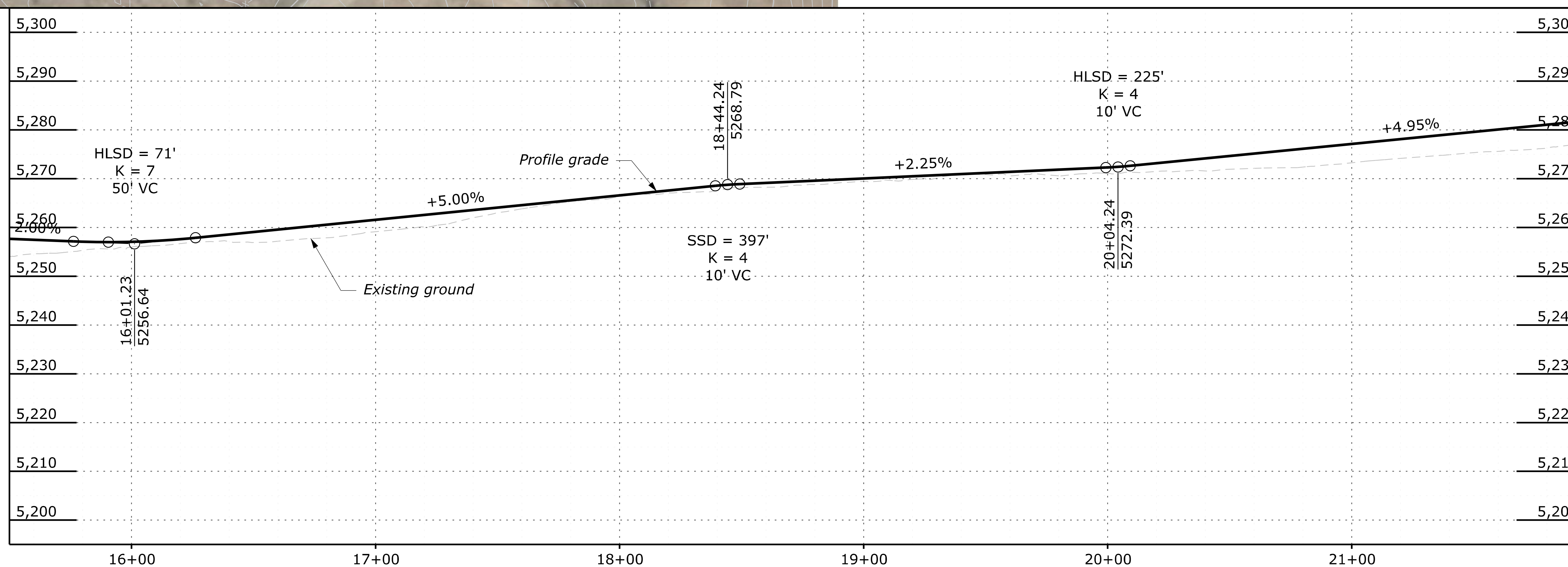
PROJECT	SHEET NUMBER
MT FLAP Park 2021(1)	2

(1) PI 15+86.07
Δ = 50°26'35" (RT)
R = 50.00'
T = 23.55'
L = 44.02'

(2) PI 17+78.02
Δ = 128°48'16" (LT)
R = 30.00'
T = 62.62'
L = 67.44'

(3) PI 19+66.71
Δ = 150°56'14" (RT)
R = 20.00'
T = 77.16'
L = 52.69'

(4) PI 21+33.06
Δ = 151°10'59" (LT)
R = 20.00'
T = 77.85'
L = 52.77'



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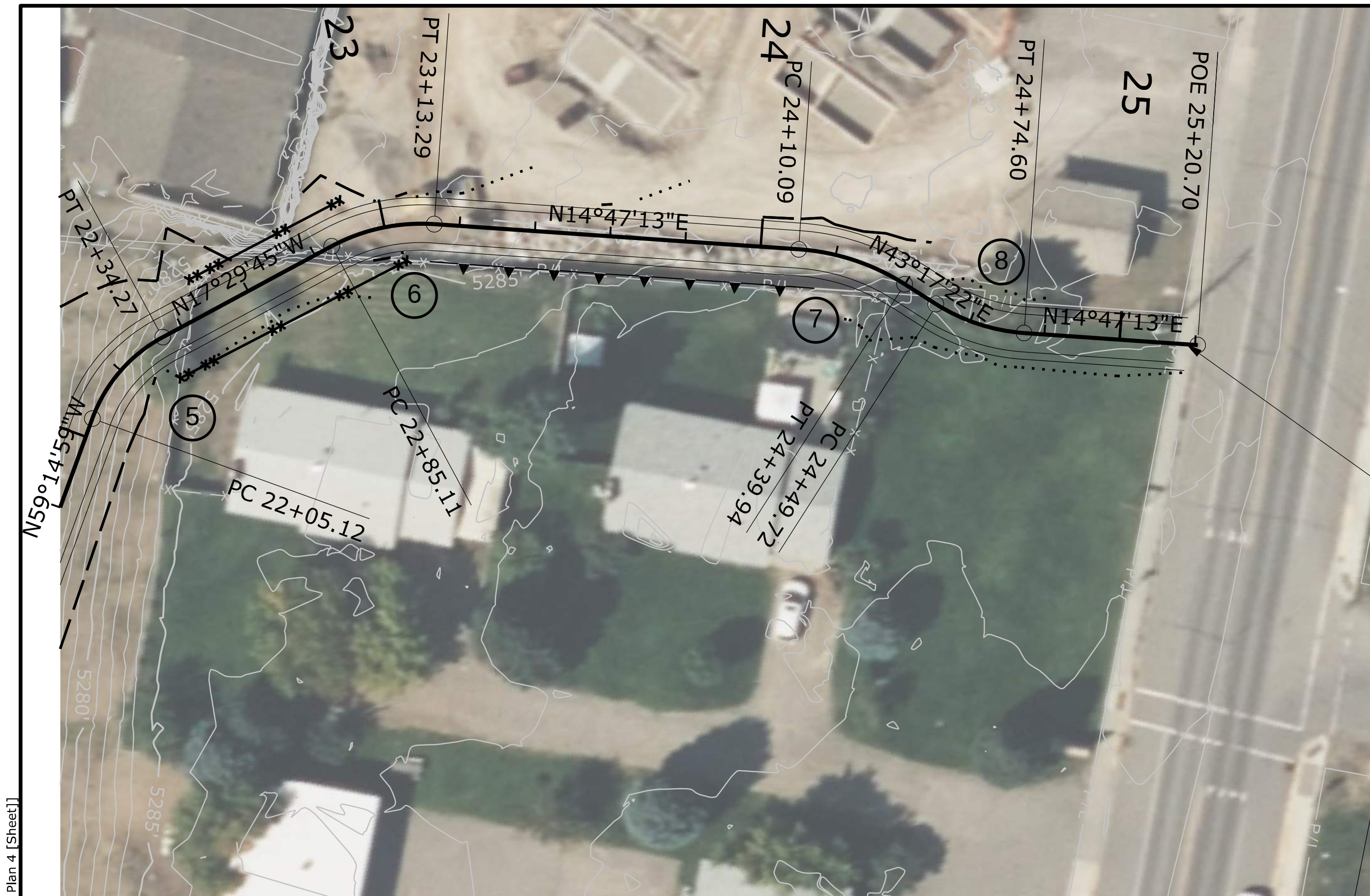
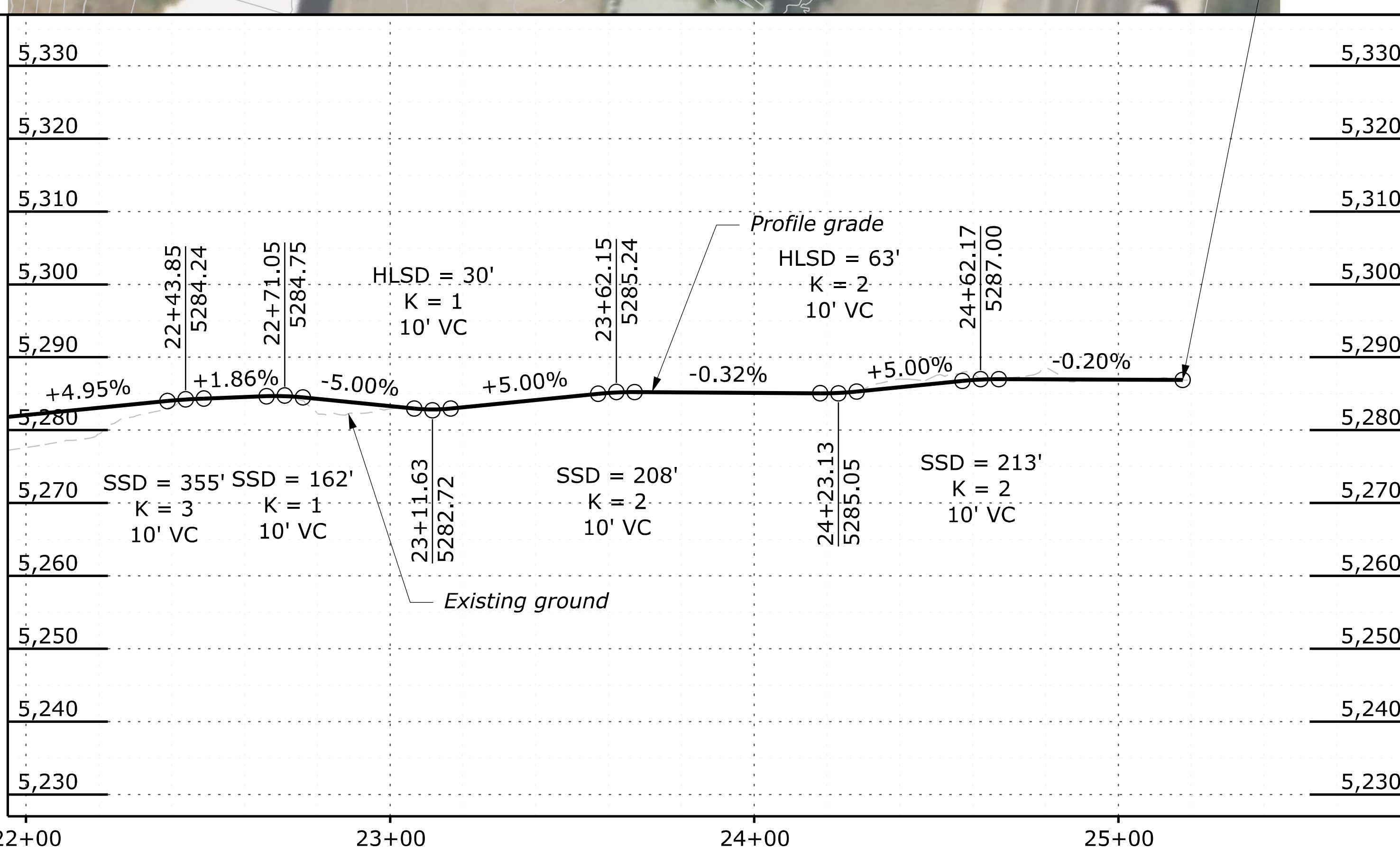
PROJECT	SHEET NUMBER
MT FLAP Park 2021(1)	3



End PROJECT
END MULTI-USE TRAIL CONSTRUCTION
25+17.66
N= 288967.8332
E= 1654598.5939

5	PI 22+20.38	Δ = 41°45'14" (RT)	R = 40.00'	T = 15.26'	L = 29.15'
6	PI 22+99.58	Δ = 32°16'58" (RT)	R = 50.00'	T = 14.47'	L = 28.17'
7	PI 24+25.33	Δ = 28°30'09" (RT)	R = 60.00'	T = 15.24'	L = 29.85'
8	PI 24+62.42	Δ = 28°30'09" (LT)	R = 50.00'	T = 12.70'	L = 24.87'



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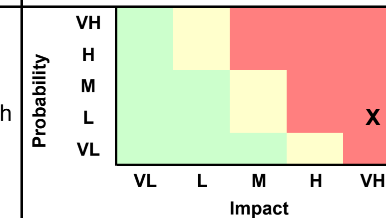
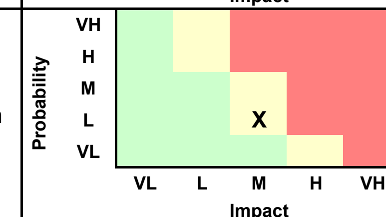
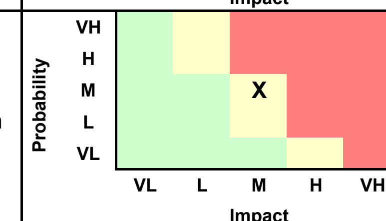
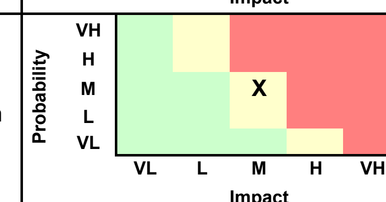
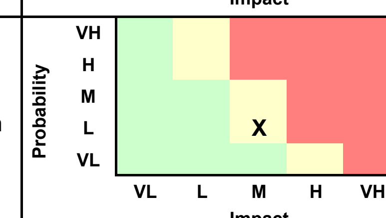
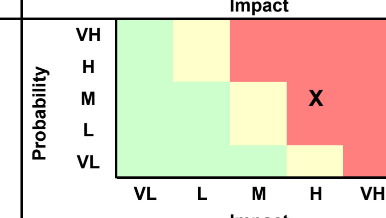
Option 1: Traditional Steel Deck Arch Bridge

Option 2: Suspension Bridge

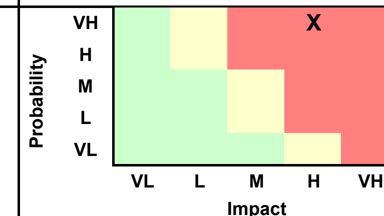
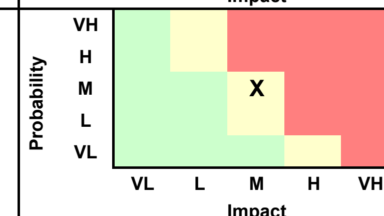
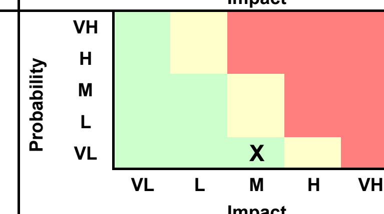
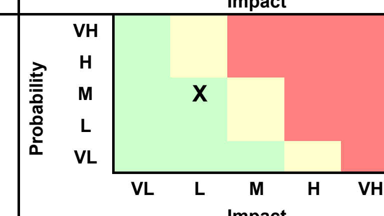
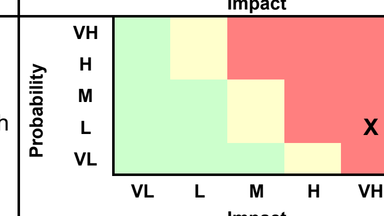
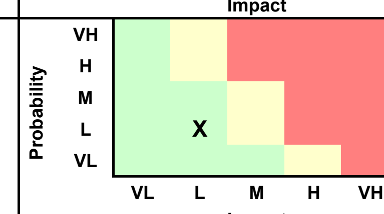
Option 3: Stress Ribbon Bridge

Appendix C. Risk Management Register

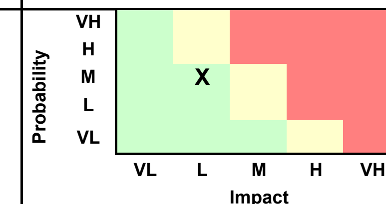
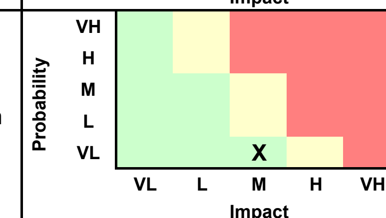
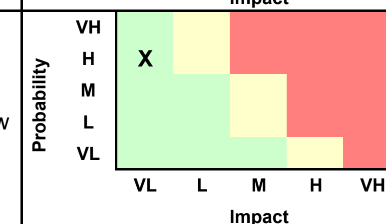
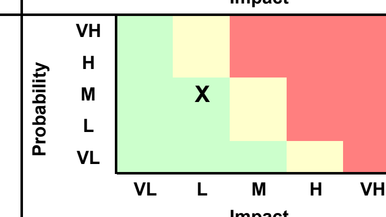
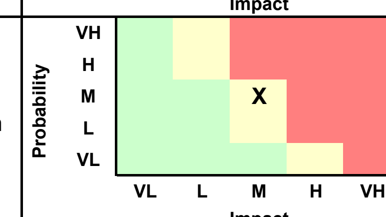
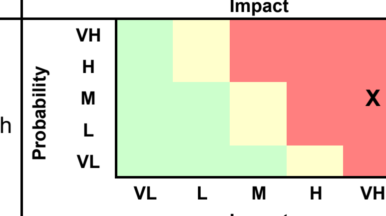
Risk Management Register for MT FLAP Park 2021(1) Gardiner Pedestrian Bridge

Risk Identification								Qualitative Risk Assessment				Risk Response Plan		Monitoring and Control		
#	**RMP No.**	**Status**	**Functional Area**	**Risk Category**	**Cause**	**Effect**	**Threat or Opportunity**	**Primary Objective**	**Probability**	**Impact**	**Risk Matrix**	**Response Strategy**	**Response Actions**	**Responsible Entity**	**Interval or Milestone Check**	**Status: Date and Review Comments**
1	1	Active	Right of Way	Right of Way	USFS, YNP or Delaware North unable / unwilling to grant easement.	Approach trails cannot be constructed and therefore the bridge cannot be accessed by the public. Realistically, bridge should not be constructed.	Threat	Scope	Low	Very High		Mitigate	Conduct early and regular coordination with affected parties about granting the necessary easements.	Project Manager	At each milestone submittal.	
2	2	Active	External	Public opposition	Community opposes the project and does not want it constructed.	Politicians move to cancel the project.	Threat	Scope	Low	Medium		Accept	None / minimal. Accept the risk because the community and politicians currently support the project. Monitor over project lifecycle to see if sentiment changes.	Project Manager	At each milestone submittal.	
3	3	Active	Design	Aesthetic features	Desired level of aesthetic treatment increases after FLAP application.	Enhanced aesthetic treatment increases the estimated construction cost, eventually exceeding the program funding amount.	Threat	Cost	Medium	Medium		Mitigate	Conduct early and regular coordination with stakeholders about the desired aesthetic features and its impact to the budget.	Design Manager	At each milestone submittal.	
4	4	Active	Environment	Wildlife impacts	Wildlife management strategy changes after FLAP application	The strategy to manage wildlife requires project features that increase the estimated construction cost, eventually exceeding the program funding amount.	Threat	Cost	Medium	Medium		Mitigate	Conduct early and regular coordination with wildlife management specialists about the preferred strategy and its impact to the budget.	Design Manager	At each milestone submittal.	
5	5	Active	Environment	Historic or cultural impacts	Resource concerns (namely historic or cultural) limit or prevent excavation on south railbed	Requires bridge alignment and/or profile grade to be adjusted. Changes bridge geometry and could possible violate ABA criteria.	Threat	Scope	Low	Medium		Avoid	Perform consultation with Tom James (YNP) to determine risk of historic or cultural impact.	Project Manager	30% submittal.	
6	6	Active	External	FLAP Funding	Project is not selected as a FLAP project.	Fuds are not available to deliver the project.	Threat	Cost	Medium	High		Mitigate	Support Park County's efforts to secure other funding sources. Involves supplying information for the appropriation application(s).	Project Manager	As requested by Park County	

Risk Management Register for MT FLAP Park 2021(1) Gardiner Pedestrian Bridge

Risk Identification								Qualitative Risk Assessment				Risk Response Plan		Monitoring and Control		
#	RMP No.	Status	Functional Area	Risk Category	Cause	Effect	Threat or Opportunity	Primary Objective	Probability	Impact	Risk Matrix	Response Strategy	Response Actions	Responsible Entity	Interval or Milestone Check	Status: Date and Review Comments
7	7	Retired	Organization	Multiple funding sources	FEMA deadline for utility work can be extended.	Will not have to repair damaged utility lines now and then relocate in just a few years. Best use of federal funds (good stewards).	Opportunity	Cost	Very High	High		Exploit	Request approval to extend deadline by which FEMA funds must be used.	Project Manager	Extension already secured.	
8	8	Active	Design	ABA compliance	ABA-compliant approaches are difficult to obtain.	Approach trails require more switchbacks, which in turn requires more ROW from USFS and NPS.	Threat	Scope	Medium	Medium		Mitigate	Progress approach trail design early to determine the ROW required for an ABA-compliant solution.	Roadway Engineer	By 30% submittal.	
9	9	Active	Design	Bridge design	Specialized bridge design misses a key element.	Requires design change during construction and associated change order for the general contractor.	Threat	Quality	Very Low	Medium		Mitigate	Perform appropriate QA/QC activities with qualified professionals and SME's.	Bridge Engineer	At 70% and 95% submittals.	
10	10	Active	Organization	Program of projects	Mis-alignment with OYTS delivery plan.	OYTS and pedestrian bridge are completed at different times.	Threat	Time	Medium	Low		Accept	None / minimal. Accept the risk because either project can function alone. Completing both at the same time is a "nice to have"	Project Manager	N/a	
11	11	Active	External	Construction cost	General Contractor bids exceed program funding amounts.	Project cannot be awarded due to insufficient funds.	Threat	Cost	Low	Very High		Mitigate	Develop the best construction cost estimate possible using qualified professionals and recent bid data for comparable projects (location and scope).	Design Manager	Feasibility Level (for FLAP application) and updates at regular submittals during design.	
12	12	Active	Construction	Unidentified utility impacts	Unidentified utilities discovered during construction	Additional construction time is required to develop a solution for the utility impact as well as to implement the solution.	Threat	Time	Low	Low		Transfer	Conduct appropriate utility investigation plan during the design phase. Ultimately, contract is response for utility coordination.	Utility Engineer	At each milestone submittal.	

Risk Management Register for MT FLAP Park 2021(1) Gardiner Pedestrian Bridge

Risk Identification								Qualitative Risk Assessment				Risk Response Plan		Monitoring and Control		
#	RMP No.	Status	Functional Area	Risk Category	Cause	Effect	Threat or Opportunity	Primary Objective	Probability	Impact	Risk Matrix	Response Strategy	Response Actions	Responsible Entity	Interval or Milestone Check	Status: Date and Review Comments
13	13	Active	Environment	Permit delays	Permits (401, 404) are delayed.	Construction is delayed.	Threat	Time	Medium	Low		Mitigate	Conduct early and regular coordination with permit agencies.	Environmental Lead	Initiate discussions at 30% level.	
14	14	Active	Design	Landslides	Verify nearby landslide movement.	Additional design time to properly understand and mitigate the hazard.	Threat	Time	Very Low	Medium		Mitigate	Perform InSAR change detection	Geotechnical Engineer	Initiate discussions at 30% level.	
15	15	Active	Design	Geology	Depth to bedrock, unknown soil conditions, likely significant amount of boulders.	Foundation options or design may need to be changed.	Threat	Time	High	Very Low		Mitigate	Perform geotechnical borings at all proposed foundation elements.	Geotechnical Engineer	Initiate discussions at 30% level.	
16	16	Active	Design	Seismicity	Examine nearby active seismic fault.	Additional design time to properly understand and mitigate the hazard	Threat	Time	Medium	Low		Mitigate	Perform a detailed seismic hazard assessment.	Geotechnical Engineer & Bridge Engineer	Initiate discussions at 30% level.	
17	17	Active	Design	Hydraulics	Potential for scour/channel migration.	Impacts to permits, additional in-water work, scour protection.	Threat	Cost	Medium	Medium		Mitigate	Perform a full hydraulic analysis using site specific geotechnical information	Hydraulic Engineer, Geotechnical Engineer, Bridge Engineer	Initiate discussions at 30% level.	
18	18	Active	Environment	Hazardous Materials	Encountering contaminated soils.	Impacts to construction schedule, risk to worker safety, and unexpected cost for remediation.	Threat	Cost	Medium	Very High		Mitigate	Perform Phase I ESA, and possibly Phase II ESA, during project delivery to properly assess risks and account for any materials management and remediation required.	Environmental Lead	Present findings at 30% milestone	