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Technical Memorandum

Appendix 3

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Subject	**New Bridges Technical Memorandum**
Project Name	Palisades Trolley Trail Feasibility Study
Date	December 6, 2019

1. Overview

The District of Columbia (DC) Department of Transportation (the District) is performing a project feasibility study to convert a portion of the former Georgetown/Glen Echo Trolley alignment between Georgetown University and Arizona Avenue NE into a multi-use trail. This portion of the trail has four bridge crossings at Maddox Branch, Reservoir Road NW, Clark Place NW, and at Foundry Branch Valley Park. Trolley service was discontinued in the mid-1960s. In the mid-1980s a 78-inch Crosstown Watermain (assumed 96 inches outside diameter) was constructed in the DC right-of-way along the original alignment of the trolley from north of Arizona Avenue NW to south of Clark Place NW. As part of the construction of the Watermain, the bridges at Maddox Branch, Reservoir Road NW, and Clark Place NW were demolished hence new bridges at all three locations will be required for a trail. Right-of-way constraints and challenging terrain produce a constrained environment for all three crossings, creating potential conflicts with utilities and the possible need for temporary or permanent easements. Selected as-built plans for the Crosstown Watermain at the location of the three bridges are included in Attachment 1.

2. Bridge Locations

This section describes the locations and physical features at the three proposed bridge locations. Figure 1 provides a map depicting the location of the three proposed bridges.

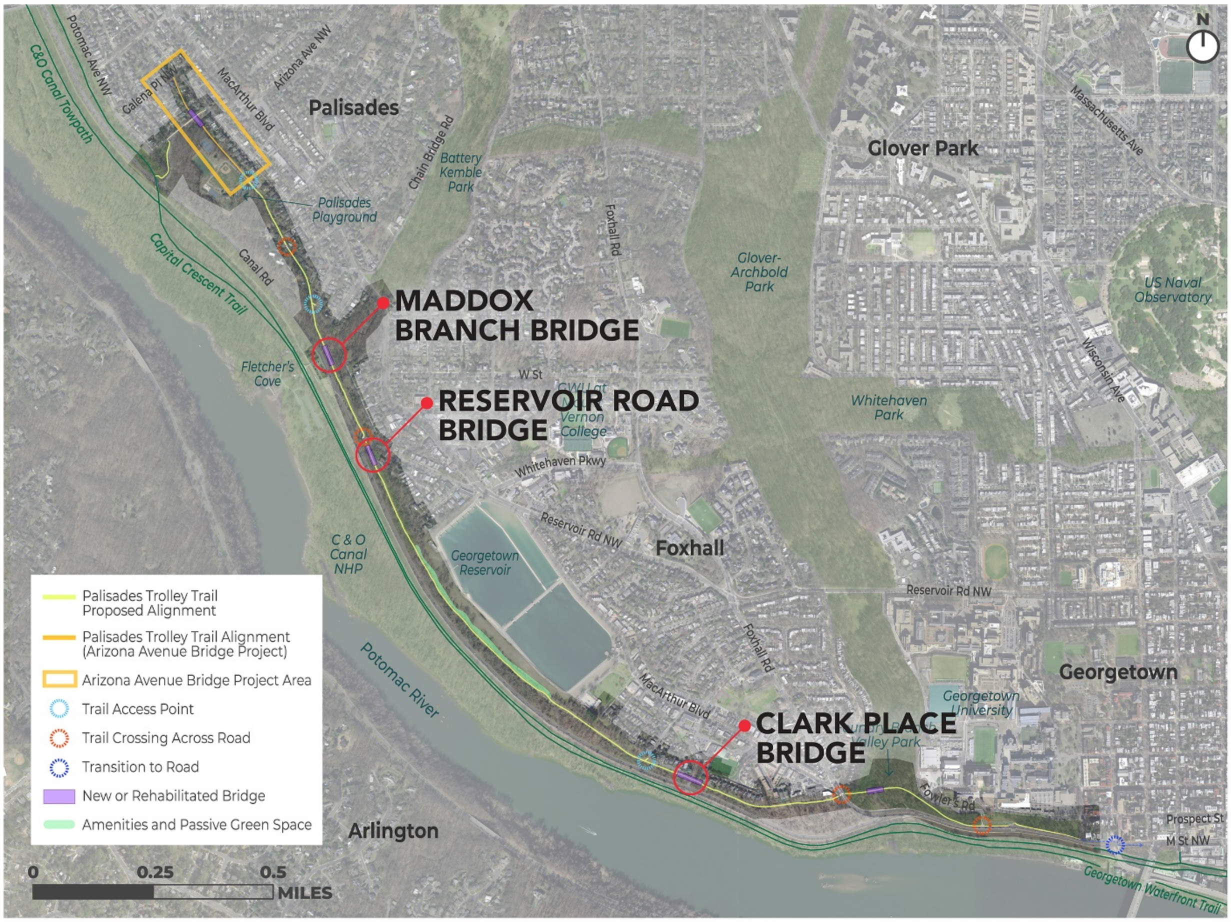

Figure 1. Location of the Proposed Bridges

2.1 Clark Place NW Bridge

Approximately 1/2 mile north on Canal Road NW from the intersection of Canal Road NW and Foxhall Road NW, Clark Place NW intersects Canal Road. Directly adjacent to this intersection of Canal Road NW and Clark Place NW, is where the former Trolley Line crossed over Clark Place NW and is the proposed location for the new Clark Place NW Bridge. The elevation of the proposed Trolley Trail directly adjacent to Clark Place NW is approximately 95 feet. The elevation of Clark Place NW at the proposed crossing location is approximately 53 feet, placing the trail surface approximately 42 feet above Clark Place NW at the proposed crossing with very steep embankments on both sides of Clark Place NW.

On the northern side of Clark Place NW, the DC right-of-way width for the trail is approximately 28 feet, 3 inches, and is bound on the east by a public street, Potomac Avenue NW, and is bound on the west by National Park Service (NPS) property. The 78-inch Crosstown Watermain is located almost centered in the DC right-of-way for the trail. The as-built records show that the watermain is approximately 3 feet below grade. There are PEPCO overhead powerlines that run along the western edge of the DC right-of-way for the trail. The pole supporting these lines is approximately 125 feet north of the steep slope adjacent to Clark Place NW.

On the southern side of Clark Place NW, the DC right-of-way width for the trail is approximately 28 feet, 5 inches, and is bound on the east by private landowners and on the west by NPS property. The 78-inch Crosstown Watermain is located almost centered in the DC right-of-way for the trail. The as-built records show that the watermain is approximately 3 feet below grade. There are PEPCO overhead powerlines that run along the western edge of the DC right-of-way for the trail. The pole supporting these lines is approximately 15 feet south of the steep slope adjacent to Clark Place NW. Additionally, there is a

PEPCO overhead line and an unidentified communication overhead line that runs along the bottom of the slope on the southern side of Clark Place NW.

2.2 Reservoir Road NW Bridge

Approximately 1/4 mile north on Reservoir Road NW from the intersection of Reservoir Road NW and MacArthur Boulevard NW, the proposed trail crosses Reservoir Road NW at-grade. Adjacent to the south of this at-grade crossing, a bridge is proposed to cross an unnamed channel that is the result on an outfall from beneath Reservoir Road. The bottom of this channel is approximately 25 feet below the proposed trail elevation, based on the existing grades of the unimproved trail.

On the northern side of the unnamed channel, the DC right-of-way width for the trail is approximately 30 feet wide and is bound on the east and west sides by NPS property. The 78-inch Crosstown Watermain is located just outside of the DC right-of-way to the west, presumably to avoid the retaining wall supporting Reservoir Road NW adjacent to the channel. There are PEPCO overhead powerlines that run along the western edge of the DC right-of-way for the trail. The pole supporting these lines is approximately 55 feet north of the top of the slope adjacent to the channel and is located along the west side Reservoir Road NW. Additionally, there are overhead communication lines that run adjacent to the west side of Reservoir Road NW as well.

On the southern side of the unnamed channel, the DC right-of-way width for the trail is approximately 30 feet wide and is bound on the eastern side by NPS and private property, and on the west sides by NPS property. The center of the 78-inch Crosstown Watermain is located approximately 9 feet from the eastern limit of the DC right-of-way. There are PEPCO overhead powerlines that run along the western edge of the DC right-of-way for the trail. The pole supporting these lines is at of the top of the slope adjacent to the channel and is located along the western side Reservoir Road NW.

2.3 Maddox Branch Bridge

Approximately 1,000 feet north along the proposed trail from the at grade crossing of Reservoir Road NW, a bridge is proposed to cross Maddox Branch. The bottom of Maddox Branch is approximately 38 feet below the proposed trail elevation based on the existing grades of the unimproved trail.

On the northern side of Maddox Branch, the DC right-of-way width for the trail is approximately 30 feet wide and is bound on the eastern and western sides by NPS property. The center of the 78-inch Crosstown Watermain is located approximately 10 feet from the eastern limit of the DC right-of-way. The center of a 21-inch sanitary sewer (SS) is located approximately 7 feet west of the watermain. There are PEPCO overhead powerlines that run along the western edge of the DC right-of-way for the trail. The pole supporting these lines is approximately 15 feet north of the top of the slope adjacent to Maddox Branch.

On the southern side of Maddox Branch, the DC right-of-way width for the trail is over 70 feet wide as it is bound on the east by NPS property but extends to Canal Road to the west. Because of the steep slope along the west side, adjacent to Canal Road, the practical, usable right-of-way width is approximately 30 feet. The center of the 78-inch Crosstown Watermain is located approximately 8 feet from the eastern limit of the DC right-of-way. There are PEPCO overhead powerlines that run along the western edge of the unimproved trail. The pole supporting these lines is at the top of the slope adjacent to Maddox Branch.

3. Bridge Alignment and Layout Options

The alignment options for the three new bridges were developed with following criteria; stay within the existing DC right-of-way for the trail, avoid any utility conflicts that would result in a utility relocation that would be impractical to perform such as relocating the 78-inch Crosstown Watermain, maintain a 12 foot trail width on the bridge, bridges must be on a tangential alignment, and minimize number of substructures units needed. With a right-of-way width of approximately 30 feet at all three locations, a trail width on the bridge of 12 feet and an underground Crosstown Watermain within the right-of-way at all three locations, the alignment options for the each of the bridges were very limited.

3.1 Clark Place NW Bridge

For the proposed bridge at Clark Place NW, the DC right-of-way is approximately 28 feet, 3 inches, as described previously and the 78-inch Crosstown Watermain runs approximately down the center of that right-of-way. This location provided no opportunity to move the bridge alignment to one side of the DC right-of-way and the alignment was set for this study to be centered directly above the watermain. This placement allows the substructure foundations to straddle the watermain to obtain maximum clearance from the watermain without impacting the adjacent right-of-way.

3.2 Reservoir Road NW Bridge

For the proposed bridge at Reservoir Road NW, the DC right-of-way is approximately 30 feet wide, as described previously and the 78-inch Crosstown Watermain runs along the eastern 1/3 of the right-of-way on the southern side of the channel and is outside of the right-of-way on the northern side of the channel. This constrained the alignment on the southern side of the channel because the only viable option to avoid a conflict and to stay within DC right-of-way is to align the bridge between the watermain and the west right-of-way boundary. On the northern side of the channel, there are multiple options for aligning the trail that would stay within the right-of-way and avoid significant conflict. The chosen alignment for this study was approximately the center of the DC right-of-way because a natural outcropping in the center provides a good location for the north abutment. However, this alignment on the north should be studied in more detail in future phases in conjunction with the at-grade crossing location of Reservoir Road NW.

3.3 Maddox Branch Bridge

For the proposed bridge at Maddox Branch, the DC right-of-way is approximately 30 feet wide as described previously. On the northern side of Maddox Branch the 78-inch Crosstown Watermain and the 21-inch SS line run slightly east of the center of the right-of-way. To avoid conflicts and right-of-way impacts, the only feasible option on the northern side is to straddle the alignment of the trail and bridge over the underground utilities. On the southern side, the usable right-of-way is approximately 30 feet wide and the watermain is aligned close to the eastern boundary of the right-of-way. The only practical option on the southern side is to align the bridge and trail between the watermain and slope adjacent to Canal Road. The alignment on the south could be shifted further west to avoid the watermain to the maximum extent but that would require a retaining wall and stabilization of a 35-foot tall slope embankment. The concept alignment developed does align the trail close to the slope. A railing to protect trail users will have to be considered at the end of the bridge for some distance along the trial to protect that hazard.

4. Bridge Foundation Options

Bridge foundation options depend on subsurface conditions, bridge loading, site spaces and constraints among others. At this stage, loading and subsurface information is limited to make a complete assessment and decision on feasibility. Consequently, this section focuses on what will need to be considered and evaluated during the next design stage, to determine the best possible foundation alternative. This section also provides a qualitative assessment on the foundation alternatives based on the limited information available at this stage. Recommendations in this section should be considered preliminary in nature and will need to be validated as the design progresses. In addition to the bridge foundation design, the global stability of the existing slopes under the new bridge abutment loads will need to be evaluated during the next design stage to confirm that adequate factor of safety can be obtained.

Shallow foundations are generally the most economic option when feasible. However, the use of shallow foundations to support the proposed three bridges must be carefully evaluated because of the presence of the 78-inch watermain at shallow depths in all the three locations, tight easement spaces, and the existing terrain. The geometry and size of the shallow foundation elements that need to transfer the load to the ground will depend on the bridge loading and subsurface conditions. Given the tight spaces and other site constraints, the size of a shallow foundation will have to be substantially limited so that it can be installed within the available space and minimize the impact on existing utilities. In addition, the shallow foundation will need to be set as far as possible from the existing watermain and the base will need to be set at an elevation that is at or lower than the invert of the existing watermain, to reduce the risk of transferring loading to this pipe. Given the narrow width of the easement, it may not be possible to set the shallow foundations far enough away to avoid impacting the existing watermain. Even if the design of the shallow foundation manages to not transfer load to the 78-inch watermain, the shallow foundation configuration could potentially induce settlement and cause movement of this utility. Therefore, all these aspects will need to be evaluated in more detail during detail design. It is possible that some of these aspects may prevent a shallow foundation option from being technically feasible.

Deep foundations will provide the best option for reducing the risk of impacting the existing watermain from bridge loading and settlement. Also, deep foundations will likely have the advantage of carrying higher lateral and axial loads as compared to shallow foundations. While driven piles are typically the most economical deep foundation, use of driven piles could be problematic because of the following:

- Presence of shallow rock. A subsurface investigation has not been performed yet for these bridges; however, the presence of rock at the ground surface indicates the possibility of having shallow rocks, boulder obstacles, or shallow bedrock in the area of the proposed bridges. A subsurface investigation will need to be performed in future design phase of the project to confirm such observations.
- Proximity of existing adjacent structures. Vibrations because of pile driving operations could cause cracking or unacceptable settlements in nearby structures.
- Presence of the aforementioned 78-inch Crosstown Watermain is directly adjacent to the proposed foundations for the three proposed bridges. Driving pile adjacent to this watermain could have detrimental impacts to the watermain, which need to be avoided at all costs. Preliminary drilling options may be necessary to reduce the risk of vibration-induced damage, which would be an added cost.
- Presence of overhead power lines which place limitations on driven pile installation equipment in areas with low overhead room.

Drilled-in types of deep foundation may be the most appropriate choice for these bridges. Drilled-in deep foundation options include auger-cast-in-place (ACIP) piles, drilled shafts and micropiles. Subsurface conditions might not be ideal for the use of ACIP piles as these are generally not suitable in hard, boulder-ground conditions and shallow bedrock. A subsurface investigation will be performed in future phases of the project, to investigate if ground conditions for this technique are favorable.

Drilled shafts are versatile and can be installed in multiple ground conditions. High vertical and lateral loads can be carried by a single drilled shaft. In addition, drilled shafts installation does not generate excessive vibrations, making it a very attractive technique when nearby structures are present. A challenge for using drilled shafts is the limited access to site and small maneuvering area onsite. An additional challenge is the presence of the 78-inch Crosstown Watermain, which may limit the ability of using drilled shafts because of the typical heavy weights of the drilled shaft rigs. The weight impact of the drilled shaft rig on this watermain or any other utility will need to be assessed to prevent damage to the utility. Additionally, the bridges' abutments are adjacent to steep slopes. Using heavy machinery right next to steep slope will need to be carefully evaluated to confirm that the stability of the existing slope is not adversely impacted. The electric overhead lines may also present a challenge for using drilled shafts and low headroom equipment will likely be required for construction of the drilled shafts. Although such low headroom drilled shaft rigs are available, the use of this technique will need to be carefully evaluated to make sure there is sufficient height not only for the drilling equipment, but also to erect the steel reinforcement without conflict.

Although expensive, micropiles may be the best foundation support alternative because of their small diameter, speed of installation, minimized footprint for installation and ability to handle unforeseen subsurface conditions including rocky fill and boulders. Micropiles can be installed in very restrictive environments and are constructed by methods that cause minimal disturbance to adjacent structures. Micropiles are generally less than 14 inches in diameter. Structural reinforcement of a micropile consists of a steel casing that is installed during drilling, as well as a single steel threaded rebar installed after grouting, which can be spliced with a mechanical coupler (allowing for a short erecting segment of rebar). The steel casing and rebar can be of high yield strength to provide adequate lateral load resistance. In addition, the micropiles could be installed in a battered configuration to resist the lateral loading. It is very likely that a group of micropiles will be necessary at each abutment.

Table 1 summarizes the deep foundation options discussed above. All options, with the exception of driven piles, are considered feasible at this stage. Driven piles may be feasible, however additional testing would need to be performed to confirm feasibility.

Table 1. Deep Foundation System Comparisons

System	Advantage	Disadvantage
Driven Piles	1. Not specialized. 2. Typically most cost-effective alternative. 3. Fast installation. 4. Pile group provides redundancy in the system.	1. Vibration impacts to adjacent utilities and structures. 2. Very noisy for adjacent public. 3. Hard subsurface will cause driving issues.
ACIP Piles	1. Minimal vibration. 2. Pile group provides redundancy in the system.	1. Specialized contractor is required. 2. Quality control is difficult. 3. Technique has limitations with respect to the ground conditions that can be installed in. Ground conditions may not be favorable for this alternative.
Drilled Shafts	1. Minimal Vibration. 2. Versatile and for any ground conditions. 3. High vertical and lateral load capacity.	1. Specialized contractor is required. 2. Extensive (relatively) quality control will be required. 3. Large and heavy drilling rig is required (high mobilization cost). The weight of the equipment can have an adverse impact on existing utilities. 4. Drilled shafts can be installed in low overhead. However, low overhead installation will make it difficult to work with a full-length temporary casing if needed and may also require splicing of the rebar cages.
Micropiles	1. Low headroom installation. 2. Very small diameter piles with minimal vibration during installation 3. Require less space for construction staging area 4. Can be drilled to relatively significant depth. 5. Micropiles can penetrate through obstacles with relative ease. 6. Can be more easily relocated in the field as needed to avoid conflicts	1. Specialized contractor is required. 2. Expensive. 3. Need for a pile group and a relatively large pile cap. Space limitations could be a problem for construction of the pile cap. 4. Due to the small diameter, unbraced lengths are not favorable and could significantly reduce the pile capacity. 5. Micropiles are typically used to underpin existing bridges, but the use of micropiles as foundation support for new bridges has increased recently.

5. Geotechnical Investigation

As previously mentioned, a geotechnical investigation is required before commencing the design process of the bridges' foundations. Geotechnical investigation of the subsurface conditions, including laboratory and field testing are required to be performed to describe the features of the soil and rocks as well as measuring the groundwater level. The investigation should be adequate to determine the subsurface profile, shear strength parameters, compressibility parameters and unit weights of each of the soil layers. In addition, rock coring and laboratory testing will be needed to determine the characteristics of the rock masses. Geologic mapping including orientation and characteristics of rock discontinuities may be necessary if bedrock is shallow to properly assess the stability of the existing slopes under the new bridge abutment loads.

6. Bridge Superstructure and Material Options

For all three locations, the bridge lengths required are suitable for single-span bridges. Piers are an option even with these shorter spans, as they would allow for smaller, lighter superstructure elements. However, piers would introduce additional environmental impacts and/or constructability challenges given the locations where they would be installed. Therefore, this feasibility study focused on single spans for each of the three proposed bridges.

6.1 Main Superstructure

For pedestrian bridge superstructure, there are generally two types of bridges, prefabricated trusses and girder bridges; and two types of primary materials, steel and concrete. Prefabricated trusses are steel only while girders can be steel or concrete and the concrete can be conventionally reinforced or prestressed. Conventionally reinforced is not a consideration for these bridges because of the required span lengths. Table 2 summarizes the advantages and disadvantages of each.

Table 2. Superstructure Type and Material Comparison

System	Advantage	Disadvantage
Prefabricated Steel Box Truss	1. Smallest member sizes can make it lighter and cheaper than other prefabricated options 2. Shallowest bridge from walking surface to low chord – good for underpass clearance requirements. 3. Very stable during construction 4. Longest span lengths, over 200 feet.	1. Pedestrians can feel enclosed in the bridge. 2. Sight lines for pedestrians are through the truss. 3. Has a more industrial look and feel that can be unappealing aesthetically to many. 4. Deck installation and maintenance difficult due to overhead members.
Prefabricated Steel H Truss	1. More open feel than the box truss. 2. Pedestrians have sight lines over the top chord. 3. Deck installation simpler.	1. Less protection for users since they are not fully enclosed. 2. Larger members can give a bulkier feel. 3. Walking surface to low chord is deeper than box truss.
Prefabricated Steel Bow String Arch Truss	1. More open feel than the box truss. 2. Deck installation simpler. 3. Arch shape can be more aesthetically pleasing. 4. Member sizes can be reduced due to depth of arch.	1. Less protection for users since they are not fully enclosed. 2. Walking surface to low chord is deeper than box truss. 3. Depth of arch can block sight lines for pedestrians.
Steel Girder Bridge	1. Very open feel for pedestrians. 2. Deck installation simpler. 3. Smaller members, smaller construction equipment. Girders can be spliced. 4. Frequently a lower cost option. 5. Lower maintenance.	1. Longer construction time. 2. Very simple and typical aesthetically. 3. Deeper section from walking surface to low steel than truss alternatives.
Prestressed Concrete Girder Bridge	1. Very open feel for pedestrians. 2. Deck installation simpler. 3. Frequently a lower cost option. 4. Lower maintenance.	1. Longer construction time. 2. Very simple and typical aesthetically. 3. Girders can be very deep and heavy, making them impractical at longer lengths.

From the five types of superstructures listed in Table 2, only three were carried forward for concept development and presentation to the public. The main advantages of the Box Truss over the other types of prefabricated trusses are its shallow depth for vertical clearance, ease for creating an enclosed environment and long span length range. For these three bridges locations, none of those criteria governed as the bridges have ample vertical clearance, will not be enclosed, and all span lengths are less than 200 feet. Therefore, the Box Truss was eliminated from further consideration. Also, for conventional girder bridges, the prestressed concrete option was eliminated because of constructability concerns given the weight and length required for the Maddox Branch bridge in particular.

For the three superstructure options carried forward, Prefabricated Steel H Truss, Prefabricated Steel Bow String Arch Truss, and Steel Girder concepts for each were investigated. It is recommended that further consideration be given to each of the three options should the project move forward as each option is considered feasible. Additional input should be gathered from the public and stakeholders before moving forward with an option for final design. Sample images of these three types of bridges can be seen in Figure 2.

Figure 2. Sample Bridges

6.2 Finishing Options for Steel Superstructure

As previously discussed, the three feasible options studied for the three proposed bridges are all steel. For steel bridges, particularly prefabricated trusses, there are generally three finishing options: uncoated weathering steel, painted, and galvanized. Figure 3 provides examples of these three finishing options. In order of cost, galvanized is the most expensive of the three finishes, then painted, and then uncoated weathering steel, which is the most cost effective. A galvanized bridge will require very little to no maintenance for many years; however, it is very expensive, and the grey/silver galvanized finish creates an appearance that may not be suitable from a context sensitive standpoint for certain areas. Painting a steel bridge will provide a protective coating for the steel and can be used to achieve desired aesthetic enhancements since paints come in many colors. The disadvantage is that painting is expensive and will require future maintenance and recoating. The final option is uncoated weathering steel. Uncoated weathering steel will naturally weather to form a brown-colored protective coating on the surface of the steel. The disadvantages of weathering steel are that the protective weather coating can be ineffective and the steel can corrode if frequently or continuously exposed to a wet environment. There is only one color option, brown, and anything below the bridge, such as concrete substructures, may be subject to the brown rust staining if water runs off the weathering steel and onto the concrete. For the purposes of this feasibility study and estimate, uncoated weathering steel was considered the preferred option because of its low cost, low maintenance, and the brown color blends well with the surrounding environment.

Figure 3. Sample Finishes

6.3 Deck Material Options

The final material consideration for the superstructure of the three proposed bridges is the deck, or the walking and riding surface. Three options were discussed for the deck surface: concrete, wood and fiber reinforced polymer (FRP) panels and pictures of each of these options are shown in Figure 4. Of the three options, wood is the least expensive and FRP is the most expensive. Concrete is the heaviest option with wood and FRP being substantially lighter, which will be a major contributing factor for the size of the steel superstructure members, substructures, and foundations. A heavier deck will require larger superstructure, substructure, and foundations to carry the additional weight. All three options are feasible and were discussed with the District. For the purposes of this feasibility study, the concrete deck was considered the preferred option. The wood deck was less preferred because of its slick surface when wet and because it is a noisier surface for adjacent residents when bicyclists pass over the deck. The FRP was least preferred because of long term maintenance and durability concerns with this fairly new product.

Figure 4. Deck Material Options

7. Constructability

As described in Section 3, Bridge Alignment and Layout Options, the sites for all three proposed bridge locations are highly constrained with an approximately 30 foot wide DC right-of-way width for the trail. In addition to the narrow width, the sites at all three locations have access challenges and multiple underground and overhead utilities that present potential conflicts. In addition, it should be noted that temporary access and construction easements may be required at all three locations and there may be the need to clear vegetation and trees adjacent to the trail to avoid conflicts with bridge erection. A discussion on the constructability, risks, and mitigations for each location is presented herein.

7.1 Clark Place NW Bridge

For the construction of the foundations and abutments, there is very good access to the north abutment from Potomac Avenue NW. This should not pose any issues for equipment access. For the south abutment, equipment would need to access the trail from Foxhall Road NW and traverse for trail for approximately 1/2 mile. While this poses a nuisance for access, the equipment required should not have any issues accessing the south abutment site to construction the foundations and abutment. For erection of the bridge itself, the superstructure can be staged on or adjacent to Potomac Avenue NW or parallel along the trail adjacent to Potomac Avenue NW. A crane could set up directly behind the north abutment and pick up the superstructure and swing it to the east to set it over Clark Place NW. The crane would not be able to swing to the west because of the overhead power lines. Clark Place would need to be temporarily closed during this operation and the overhead power lines de-energized. An alternate method to erect the superstructure would be to set up a crane on Clark Place and assemble the bridge on Clark Place before lifting into place. This would require a longer closure and detour of Clark Place, which would be feasible over a weekend. The more significant construction risks and mitigations are summarized as follows:

- Risk #1 – Foundation conflict with the 78-inch watermain. DC Water has commented that a forthcoming standard will require 4 feet of horizontal clearance.
  - Mitigation – Continue coordination with DC Water and apply for a waiver if needed. If the 4 feet clearance becomes absolutely mandatory, it should still be feasible to construct the foundations; however, it may require a small permanent easement or acquisition.
- Risk #2 – Additional temporary construction loading on the 78-inch watermain.
  - Mitigation – Determine maximum permissible loading and use matting to ensure the loading is uniformly distributed or use matting to span over the watermain and ensure construction loading is not directly applied to the watermain.
- Risk #3 – Conflicts and de-energizing overhead powerlines.
  - Mitigation – Construction may need to be timed for the Spring or Fall, when power demands are lower so that de-energizing can occur. Additionally, there is an overhead secondary powerline that runs adjacent to the southern side of Clark Place. The elevation of that line will need to be surveyed to ensure adequate clearance from the underside of the bridge to the power line. If the clearance is insufficient, the line may need to be lowered or buried in the vicinity of the bridge to avoid conflict.

7.2 Reservoir Road NW Bridge

For the construction of the foundations and abutments, there is good access to the north abutment from Reservoir Road NW; however, the area for equipment and material laydown is very limited and lane closures or temporary closures of Reservoir Road NW would be required to construct the foundations and abutment. For the south abutment, equipment would likely need to access the trail from Potomac Avenue NW and traverse the trail for approximately 1 mile, to access the south abutment to construct the foundations and abutment. For erection of the bridge itself, the most feasible option would be a temporary weekend shut down of Reservoir Road NW. The superstructure would be assembled and staged on Reservoir Road NW along with the cranes, which would swing the bridge into place from Reservoir Road NW. An alternative method would be to construct the bridge on the trail behind the south abutment and swing the bridge around to set it. This would be challenging because of the overhead powerlines on one side of the trail and the residential property and building on the other side.

This site has very similar risks to the three previously identified for Clark Place NW and has the same mitigation strategies. The significant additional construction risks and mitigations for this site are as follows:

- Risk #4 – Multiple overhead power and communication lines along both sides of Reservoir Road NW and crossing over Reservoir Road NW that will conflict with the cranes.
  - Mitigation – Positively identify all overhead communication utilities potentially in conflict. Develop a detailed construction sequence including crane sizes and placements. Determine required relocations of the power and communication lines in conflict. All overhead lines in conflict would need to be relocated to the east side of Reservoir Road NW in the vicinity of this bridge. An alternate mitigation strategy would be to develop an erection procedure, such as launching, that would not require large cranes to swing and set the superstructure. The superstructure would be assembled on the ground with smaller equipment and launched (or pushed) into place along the ground using specialty hardware.
- Risk #5 – South Abutment conflict with overhead power pole
  - Mitigation – Coordinate with PEPCO to relocate the pole to the south to avoid conflict.

7.3 Maddox Branch Bridge

For the construction of the foundations and abutments, there is good access to the north abutment from Sherier Road NW; however, there is a fire hydrant that may require relocation to allow for access to the site. For the south abutment, equipment would likely need to access the trail from Reservoir Road NW and traverse for trail for approximately 1/8 mile to access the south abutment to construct the foundations and abutment. For erection of the bridge itself, there is an option to stage, assemble, and erect the bridge from Canal Road NW; however, that would require the relocation of overhead power and communication lines along Canal Road NW and relocation of the power lines along the trail. A more likely scenario would be to assemble the bridge north of the north abutment along the trail. The bridge could be launched (pushed/rolled) into place or erected with a large crane or multiple cranes. Because of the span length and weight of the superstructure, a temporary support would likely be needed in Maddox Branch, to allow the crane to swing the bridge partially into position and then reconfigure it to attach a second crane to lift and place the bridge into its final position. This site has very similar risks to Risks #1, #2, #3 and #5 that were previously identified and the same mitigation measures should be implemented.

8. Concept Design Summary

Concept designs were performed for the three bridge types, Prefabricated Steel H Truss, Prefabricated Steel Bow String Arch Truss, and Steel Girder, for each of the three bridge locations: Clark Place, Reservoir Road, and Maddox Branch. The alignment and layout for each of the locations is described in detail in section 3, Bridge Alignment and Layout Options, above and the current concepts at all three locations stay within the DC right-of-way limits. For all options and locations, the deck width on the bridge for the trail is 12 feet as agreed with the District through biweekly coordination meetings. Pedestrian railing is proposed on both sides to meet Americans with Disabilities Act and other requirements for pedestrian and bicyclist safety.

Micropiles are the assumed foundation type for all bridges and locations. Where the 78-inch diameter watermain is present at an abutment location, the abutment is proposed to straddle the watermain or be shifted to one side to avoid conflict. Where the abutment or portion of the abutment is proposed to be above the watermain, a minimum clearance of 18 inches is proposed and that space is proposed to be filled with expanded polystyrene (EPS), which is a very lightweight material that is compressible and will rebound to its original shape. This EPS will ensure that minimal load is transferred from the bridge abutment to the Watermain. At the approaches to the bridges, additional fill up to 5 feet deep is proposed. This fill is proposed to be a lightweight material, such as low density cementitious fill, to minimize additional loading to the Watermain. It may also be necessary to remove existing normal weight fill in these areas and replace it with lightweight fill to help balance the weight of the additional lightweight fill.

8.1 Clark Place NW Bridge

The concept design for the proposed Clark Place Bridge is a single-span, 156-foot-long bridge over Clark Place NW. The bridge will have over 30 feet of vertical clearance over Clark Place NW, easily satisfying the 17-foot, 6-inch minimum requirement. The abutments will be simple, short shelf abutment with a small backwall and wingwalls to retain the additional fill behind the abutments. The abutments will be supported by micropile foundations that will straddle the watermain with a minimum horizontal clearance of 3 feet, 3 inches to the watermain which may require a waiver from DC Water. Figure 5 shows a rendering of the proposed Clark Place NW prefabricated steel H truss bridge.

Figure 5. Rendering of the Proposed Clark Place NW Prefabricated Steel H Truss Bridge

8.2 Reservoir Road NW Bridge

The concept design for the proposed bridge adjacent to Reservoir Road NW is a single-span, 128-foot-long bridge over the unnamed drainage outfall and ravine. The bridge will have approximately 25 feet of vertical clearance over the ravine and hydraulics will not be an issue as no substructure units are proposed in the ravine. The abutments will be simple, short shelf abutment with a small backwall and wingwalls to retain the additional fill behind the abutments. The abutments will be supported by micropile foundations. There are no conflicts with underground utilities for the north abutment. The south abutment will be adjacent to the watermain with a proposed minimum horizontal clearance of 3 feet, 3 inches from the foundation, to the watermain which may require a waiver from DC Water. The shelf abutment will have a small cantilever on one side to avoid conflict with the watermain. Figure 6 shows a rendering of the proposed bridge adjacent to Reservoir Road NW as a prefabricated steel H truss.

Figure 6. Rendering of the Proposed Bridge Adjacent to Reservoir Road NW as a Prefabricated Steel H Truss

8.3 Maddox Branch NW Bridge

The concept design for the proposed bridge over Maddox Branch is a single-span, 171-foot-long bridge. The bridge will have approximately 35 feet of vertical clearance over Maddox Branch and hydraulics will not be an issue as no substructure units are proposed in or adjacent to Maddox Branch. The abutments will be simple, short shelf abutment with a small backwall and wingwalls to retain the additional fill behind the abutments. The abutments will be supported by micropile foundations. The north abutment will be located over the 78-inch watermain and a 21-inch SS pipe. The micropile foundation will be placed outside the limits of the Waterman and SS. A 2-foot, 6-inch minimum horizontal clearance is proposed to the Watermain and a 1-foot, 6-inch minimum horizontal clearance is proposed to the SS. The south abutment will be adjacent to the Watermain with a proposed minimum horizontal clearance of 3 feet, 3 inches from the foundation to the watermain and the shelf abutment will have a small cantilever on one side to avoid conflict with the watermain. A waiver may be required from DC Water for the clearances proposed in the concept designs. Figure 7 shows a rendering of the proposed prefabricated steel H truss bridge over Maddox Branch.

Figure 7. Rendering of the Proposed Prefabricated Steel H Truss Bridge over Maddox Branch

9. Order of Magnitude Cost Estimate

A planning-level order of magnitude cost estimate was completed for the three proposed bridges in accordance with a Class 5 estimate as defined by the Association for the Advancement of Cost Engineering (AACE). The estimates presented herein have a range of accuracy, as defined by AACE and estimator judgment, of -20 percent to +50 percent based on level of project definition and other factors such as project timing. The assumed superstrate type for the estimates is a prefabricated steel H truss with uncoated weathering steel and a concrete deck. The order of magnitude cost estimate for each bridge is as follows:

- Clark Place Bridge - $1,767,000
- Reservoir Road Bridge - $1,588,000
- Maddox Branch Bridge - $2,089,000