APPENDIX J

Draft Snow Shed Concepts

Little Cottonwood Canyon ENVIRONMENTAL IMPACT STATEMENT
S.R. 210 | Wasatch Blvd. to Alta

Draft Snow Shed Concepts

Little Cottonwood Canyon Environmental Impact Statement S.R. 210 - Wasatch Boulevard to Alta

Lead agency:
Utah Department of Transportation

May 11, 2020

Contents

Tables

Figures

Appendixes

1.0 Introduction

This technical memorandum describes applicable special design codes, standards, guidance, and recommended practices for snow sheds and lists site-specific design considerations as the Utah Department of Transportation (UDOT) evaluates snow sheds as passive avalanche mitigation for the more active avalanche paths along State Route (S.R.) 210 in Little Cottonwood Canyon. This memorandum also presents a conceptual structural design for snow sheds and summarizes planning-level cost estimates.

2.0 Background

HDR, Inc., is working with UDOT on the Little Cottonwood Canyon (S.R. 210) Environmental Impact Statement. Dynamic Avalanche Consulting, Ltd. (Dynamic), has been engaged to assess the current avalanche hazards and to evaluate hazard-mitigation options to protect the traveling public on S.R. 210.

What is the main reference for special design considerations for snow sheds?

The main reference is the standard NFPA 502 from the National Fire Protection Association. This memorandum references NFPA 502 and other applicable references.

Dynamic worked closely with UDOT personnel to understand the current conditions. Dynamic conceptually evaluated several passive avalanche-risk-mitigation options. The most feasible and practical option for reducing the avalanche hazard in Little Cottonwood Canyon appears to be snow sheds covering S.R. 210 through three avalanche paths on which avalanches occur most frequently.[1] Therefore, UDOT asked HDR to evaluate and conceptually design the snow sheds and provide planning-level cost estimates.

In its National Tunnel Inspection Standards, the Federal Highway Administration (FHWA) defines a *tunnel*[2] as "an enclosed roadway for motor vehicle traffic with vehicle access limited to portals, regardless of type of structure or method of construction, that requires, based on the owner's determination, special design considerations to include lighting, ventilation, fire protection systems, and emergency egress capacity." The American Association of State Highway and Transportation Officials (AASHTO) echoes that definition. In addition, the National Fire Protection Association (NFPA) defines a *road tunnel* as "an enclosed roadway for motor vehicles with vehicle access that is limited to portals." [3]

What are portals?

As used in this memorandum, *portal* refers to the entrance and exit points of a snow shed.

The references mentioned above are not a comprehensive list and, in fact, the code and manuals HDR reviewed list other applicable references. Not all of these references were reviewed in preparing this memorandum. However, HDR's subject-matter experts for fire and life safety and tunnel inspections were consulted, and this memorandum provides UDOT with general information about the additional requirements and considerations for constructing these snow sheds and the major cost implications.

[1] *Snow Avalanche Hazard Baseline Report* (Phase 1), Dynamic, July 2018.

[2] 23 Code of Federal Regulations (CFR) Part 650, *Bridges, Structures, and Hydraulics*, Subpart E, *National Tunnel Inspection Standard*, Section 505, *Definitions*

[3] NFPA 502, *Standards for Road Tunnels and Other Limited Access Highways*, 2017 Edition

NFPA 502 is the main reference for special design considerations for snow sheds (road tunnels). NFPA 502 requires a holistic, multidisciplinary engineering analysis of the fire protection and life safety requirements for a road tunnel regardless of the length of the tunnel.[4] See Appendix A, NFPA 502, which is an excerpt from NFPA 502 with the requirements for the engineering analysis of show sheds.

Per NFPA 502, where a roadway is not fully enclosed, the decision by the “authority having jurisdiction” to consider the roadway as a road tunnel shall be made after an engineering analysis is performed.[5] The “authority having jurisdiction” is a broad term, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is a primary consideration, the authority having jurisdiction might be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority.[6] In the context of Little Cottonwood Canyon, the authority(ies) having jurisdiction could include UDOT, the U.S. Forest Service, the Unified Fire Authority, and others. FHWA also gives owners flexibility regarding whether to consider rock sheds, snow sheds, and other three-sided structures as highway tunnels as they relate to the inspection requirements in the National Tunnel Inspection Standards.[7]

[4] NFPA 502, Section 4.3.1

[5] NFPA 502, Section 7.2.1

[6] NFPA 502, Annex A, *Explanatory Material*, Section A3.2.2

[7] FHWA, Informational Memorandum, *Guidance on Structures Subject to the National Tunnel Inspection Standards*, October 2015

3.0 Snow Shed Design

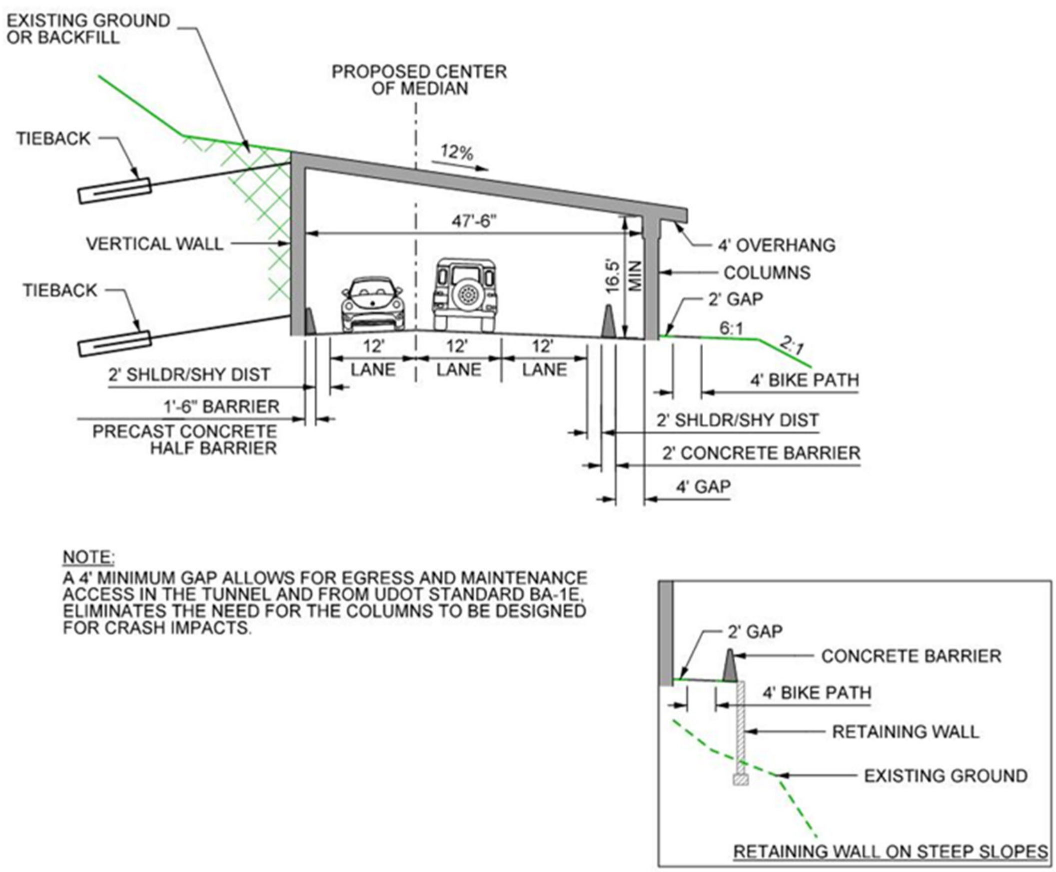
3.1 Cross-section

The preliminary snow shed cross-section is shown in Figure 3-1. FHWA recommends a barrier to protect the vertical wall of the snow shed, and a minimum of a 2-foot shoulder/shy distance to the barrier is common.[8] As stated in the note in Figure 3-1, UDOT's standards require a barrier and 4-foot gap to protect snow shed's columns from the high-impact force of a vehicle striking the column. The snow sheds were designed to match the existing three-lane roadway on S.R. 210 at the locations of the proposed snow sheds. With standard 12-foot-wide travel lanes, the total roadway span for the snow shed evaluated by HDR is 47 feet 6 inches.

What is a shoulder/shy distance?

A shoulder/shy distance is buffer to increase roadside safety when roadside barriers, walls or other vertical elements are present in the roadway.

Figure 3-1. Cross-section for Three-lane Snow Shed



[8] FHWA, *Technical Manual for Design of Road Tunnels – Civil Elements*, 2009

Note that UDOT's Maintenance Division prefers placing the barrier adjacent to the columns because snow would accumulate in the gap between the barrier and columns. Moving the barrier would result in a 4-foot shoulder/shy distance from the edge of the travel lane to the barriers and maintain a 47-foot internal span. Note, however, that HDR did not design the columns to resist vehicle impacts.

3.2 Structure

HDR consulted with geotechnical firm Gerhart Cole to determine the potential foundation and structural elements for the snow sheds. Gerhart Cole performed a feasibility-level geologic and geotechnical assessment of the S.R. 210 corridor in August 2018.[9] Gerhart Cole reviewed existing literature and performed a field reconnaissance; no geotechnical borings were taken or subsurface investigations performed. No detailed hillside or fill slope stability, seismic stability, rock fall risk, hydrologic and hydraulic, or debris hazard analyses were performed. The approximate location of bedrock was based on limited field visits and literature search only.

Dynamic modeled the avalanche paths to approximate the required snow shed locations. Dynamic estimated the structural loads for the show shed for the White Pine Chutes 1–4 avalanche paths. Dynamic modeled an avalanche flowing over previous avalanche deposits and snow cover to determine the roof and lateral loads for the White Pine Chutes 1–4 snow shed as follows:

- Normal (vertical load) of 790 pounds per square foot (psf)
- Lateral (parallel) load of 120 psf

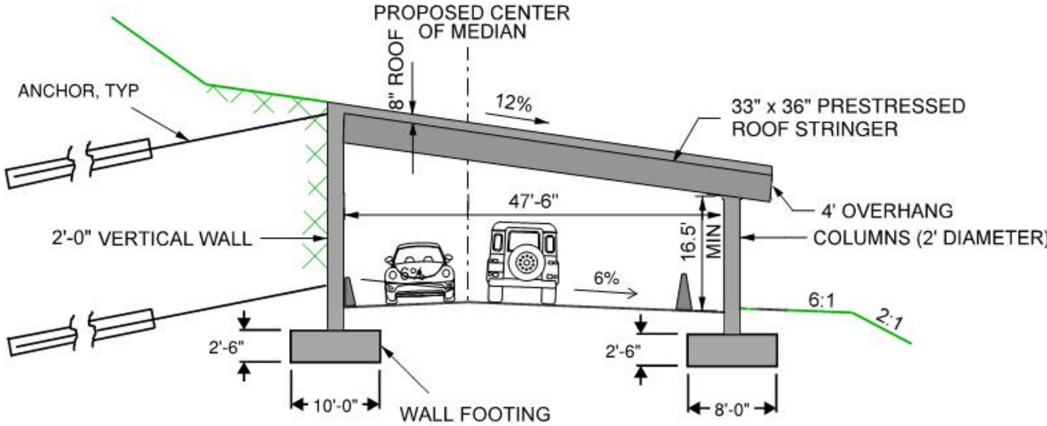
According to Dynamic, these loads assume an approximate 100-year return frequency (that is, a 1% chance of occurring in a given year) but do not include engineering safety factors.[10] As mentioned, these loads were calculated for the White Pine Chutes 1–4 snow shed only; the loading for the other snow sheds might vary. HDR applied a load factor of 1.5 to the snow loads listed above for preliminary structural design calculations.

HDR determined that the avalanche design loads for the White Pine Chutes 1–4 snow shed could be supported by an 8-inch-thick, cast-in-place (CIP) concrete slab roof supported by 33-inch-deep, prestressed concrete roof box beams at about 10-foot spacing. These beams are AASHTO Type BII-36 box beams, which are common. There would also need to be a 2-foot-thick CIP retaining wall on the mountain side founded on a 2.5-foot-thick, 10-foot-wide spread footing. On the other (stream) side, 2-foot-diameter concrete columns would need to be spaced every 10 feet and would bear on 2.5-foot-thick, 8-foot-wide spread footings. Figure 3-2 shows these dimensions.

[9] Gerhart Cole Technical Memorandum, Little Cottonwood Canyon EIS, August 8, 2018

[10] Email from Jordy Henrikx to Terry Warner, August 29, 2018

Figure 3-2. Preliminary Design of Three-lane Snow Shed



Note that this basic preliminary design was assumed by HDR to apply to all snow sheds. However, avalanche loading could be different for the White Pine and/or Little Pine snow shed.

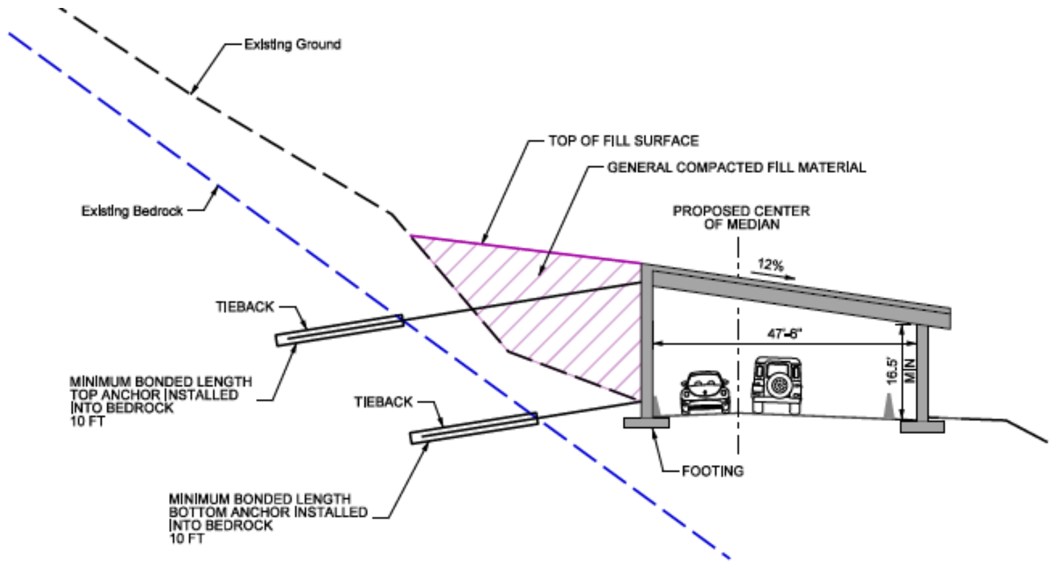
3.3 Anchoring Options

To resist the lateral loads, the show shed must be anchored to the mountain. Gerhart Cole estimated that two rows of tie-backs (one near the top and one about 20 feet below the top of the wall) would be required about every 6 feet, as shown above in Figure 3-2. HDR and Gerhart Cole evaluated two options for constructing anchors: (1) anchors in bedrock and (2) anchors in imported fill.

3.3.1 Option 1: Anchors in Bedrock

In areas where the snow sheds would be located close to the mountainside, primarily at White Pine Chutes 1–4, HDR assumed that rock excavation would be required at limited areas only and that the tie-back anchors could be drilled and secured into the underlying bedrock. The area behind the snow shed walls would then be backfilled with free-draining aggregate to fill in the space between the tie-backs and to allow water to drain from behind the snow shed retaining wall. The shed roof slope of 12% would be continued into the hillside to maintain the flow of snow over the top of the shed. The configuration for option 1 is shown in Figure 3-3. As shown in Figure 3-3, about 10 feet of bonded anchors secured into bedrock at the end of each steel strand would be needed to resist lateral loads.

Figure 3-3. Option 1: Anchors in Bedrock



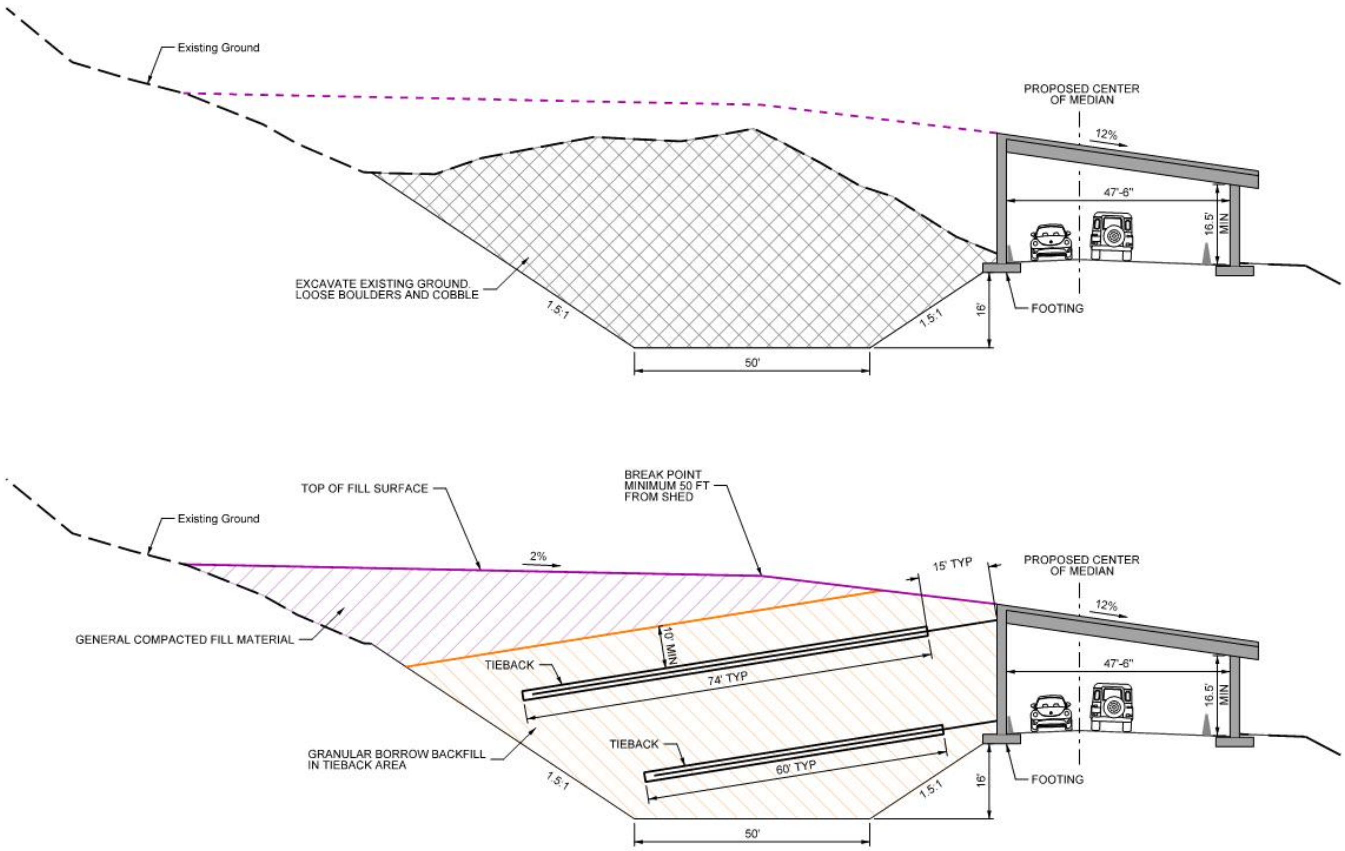
3.3.2 Option 2: Anchors in Imported Fill

Along some of the snow shed areas, primarily at White Pine and Little Pine, the roadway is inside the avalanche run-out zone, but the road is located away from the mountainside and in gently sloping rubble and talus fields. In these areas, in order to maintain the avalanche flow across the top of the sheds and to avoid avalanche flows being blocked by the shed, large quantities of fill would be placed on the mountain side of the shed to maintain a slope extending from the roof of the shed to the mountain. The top of the snow sheds with the required interior clearance would be above much of the surrounding terrain, and fill behind the snow shed would tie into the mountainside several hundred feet away. Therefore, the length of the steel strands that connect to the anchor that actually bonds to the bedrock would also be long, over about 100 to 150 feet.

HDR assumes that the existing boulder and talus material on the mountain side of the snow shed in these areas contains large boulders of various sizes. The large boulders and voids between the boulders would make drilling anchors extremely difficult. In addition, with unknown bedrock conditions at each anchor, construction could result in poor grouting and bonding or involve many ineffective attempts at anchoring the steel cables into the mountainside. Therefore, HDR and Gerhart Cole evaluated the feasibility of importing a granular fill material (or manufacturing a suitable fill from on-site material) and anchoring the snow sheds into the imported granular fill. With this method, UDOT would control the fill quality, and this fill would then become the anchoring medium for the snow shed.

The construction approach for anchoring option 2 would excavate a 16-foot-deep zone behind the snow shed. Suitable granular fill borrow material would be placed in the tie-back zone. Gerhart Cole estimated that bonded lengths of anchors of about 74 feet (top anchors) and 60 feet (bottom anchors) in the granular fill would be needed to resist the lateral avalanche loads. The approximate excavation and required anchor lengths for option 2 are shown in Figure 3-4.

Figure 3-4. Option 2: Anchors in Imported Manufactured Fill



In the area above the anchors, a more general fill material could be used to save cost. The roof fill slope of 12% would be continued into the mountainside to maintain the flow of snow over the shed, but, at about 50 feet from the shed, the slope could be reduced to 2% or less to reduce the amount of additional fill required.

3.4 Snow Shed Lengths

Dynamic provided approximate lengths for the snow sheds that would serve as passive avalanche mitigation measures for the paths that have the largest effect on the AHI calculation (Table 3-1 and Figure 3-5). At these lengths, the White Pine and Little Pine snow sheds would need guiding earthen berms running up the mountain on the north side to help minimize the lateral spread of the avalanches and keep the flow on the snow sheds.

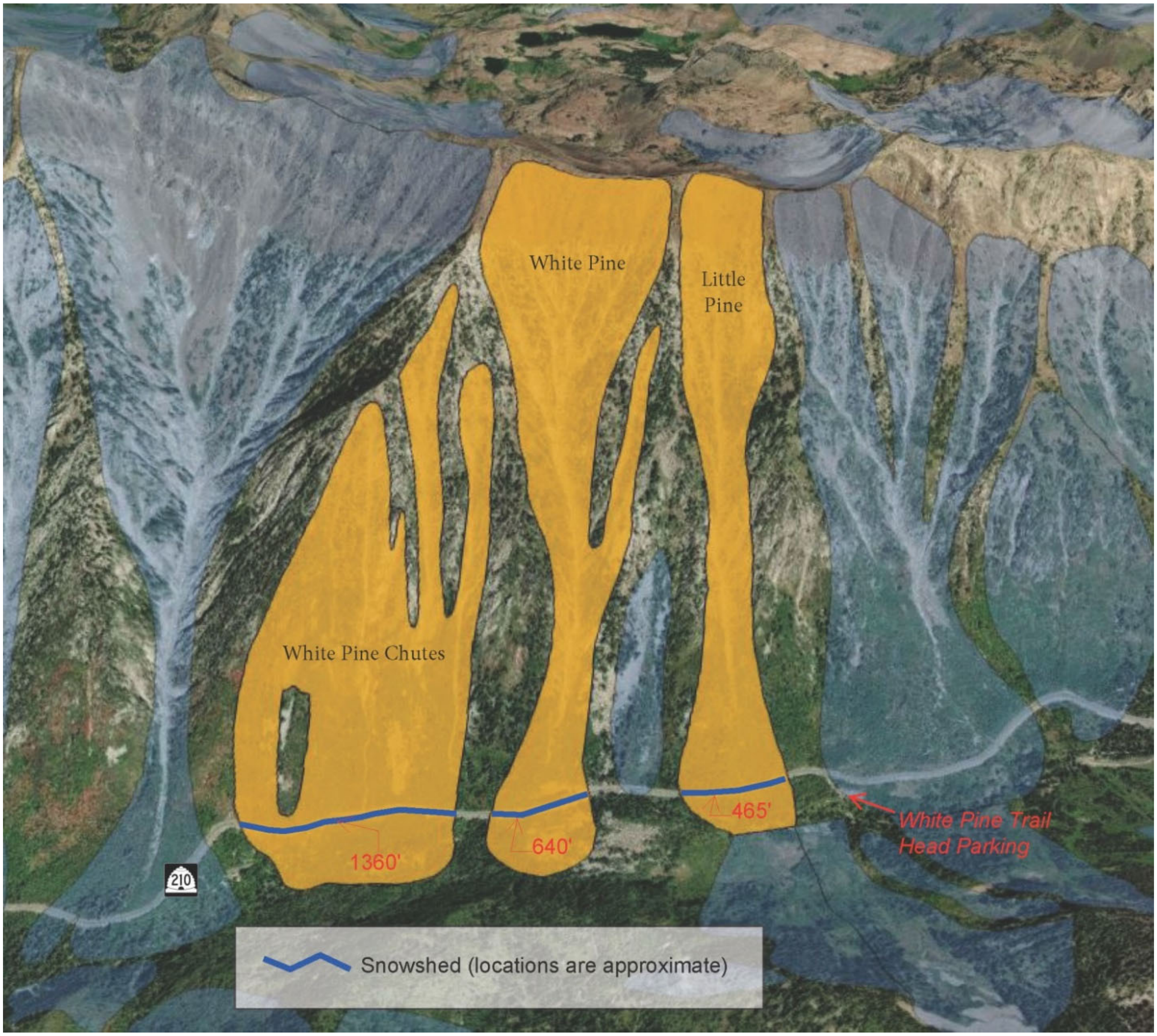
Table 3-1. Approximate Snow Shed Lengths

Avalanche Path	Approximate Length (feet)[a]
White Pine Chutes 1–4	1,360
White Pine	640[b]
Little Pine	465[b]

[a] Snow shed lengths were provided by Dynamic Avalanche on August 28, 2018. They are preliminary and are subject to change.

[b] The snow shed length assumes a guiding berm earthen 10 to 20 feet high and about 300 feet long on the mountain side of the shed at the portals.

Figure 3-5. Approximate Snow Shed Locations and Lengths



4.0 Snow Shed Concepts

HDR evaluated the following three conceptual snow shed layouts in order to compare their environmental footprints (which will be evaluated in a separate report) and to allow HDR to estimate their costs. The snow shed cross-section and structure (Sections 3.1 and 3.2) would be the same for all of them. The anchoring option (Section 3.3) used for each snow shed would depend on more-detailed geotechnical investigation.

- Concept 1: No Berms
- Concept 2: Earthen Berms
- Concept 3: No Berms, Realign Road

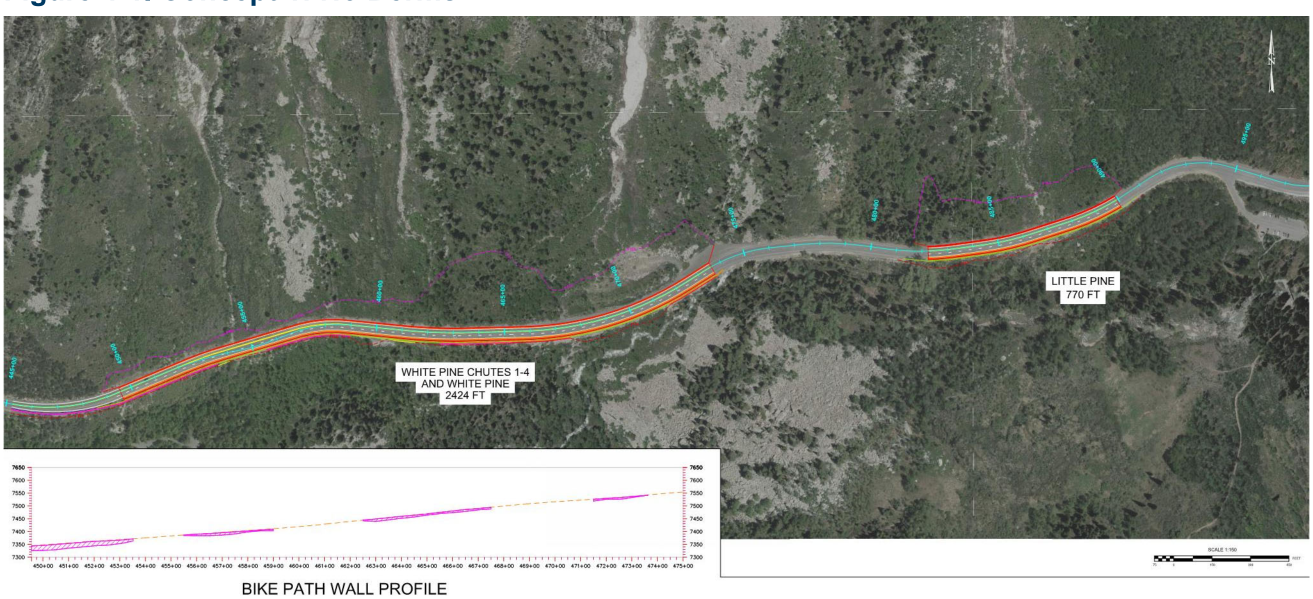
4.1 Concept 1: No Berms

This concept assumes that snow sheds are built along the existing roadway alignment, both horizontal and vertical alignments, and that no earthen avalanche-guiding berms are used to limit the length of the snow sheds. Without guiding berms, the overall length of the sheds needs to be long enough to cover enough of the avalanche run-out area to be effective.

With Concept 1, the preliminary snow shed length at White Pine results in a gap between the White Pine and White Pine Chutes 1–4 snow sheds of about 200 feet. This short distance presents several safety and driving issues. One issue is that a driver's eyes would need to adjust to the light difference as the vehicle exits one shed and enters the next. The sheds could possibly have lighting at the portals as a standard design element to minimize the "black hole effect" (the snow shed portal appearing like the entrance to a dark cave) and help with visibility, but the short transition distance might not be the safest option. For example, if vehicles are traveling at 35 miles per hour (mph), there would be a travel time of only about 4 seconds between these two sheds. Given this short distance, HDR recommends combining these two sheds into one continuous snow shed.

The length of the combined White Pine and White Pine Chutes 1–4 shed would be about 2,424 feet. The length of the Little Pine shed without berms would be about 770 feet. Figure 4-1 shows a plan view of this layout.

Figure 4-1. Concept 1: No Berms



4.2 Concept 2: Earthen Berms

This concept includes separate snow sheds for White Pine Chutes 1–4 and White Pine. Dynamic recommended using earthen guiding berms at Little Pine and White Pine as a way to reduce the required length of the snow shed and potentially reduce costs. These guiding berms would be about 300 feet long. They would be constructed up the mountain side from the tops of the shed portals and would extend along the avalanche paths to help direct avalanche flows across the tops of the sheds. The berm geometry was assumed to be 20 feet high and 10 feet wide at the top, with 1.5:1 (horizontal:vertical) side slopes. The recommended lengths of sheds with earthen berms was approximated by Dynamic and is shown in Table 3-1 above.

To allow a comparison to Concept 1, Concept 2 would also be built along the existing roadway. Figure 4-2 shows a plan view of this layout, and Figure 4-3 shows a typical cross-section of the guiding berm.

Figure 4-2. Concept 2: Earthen Berms

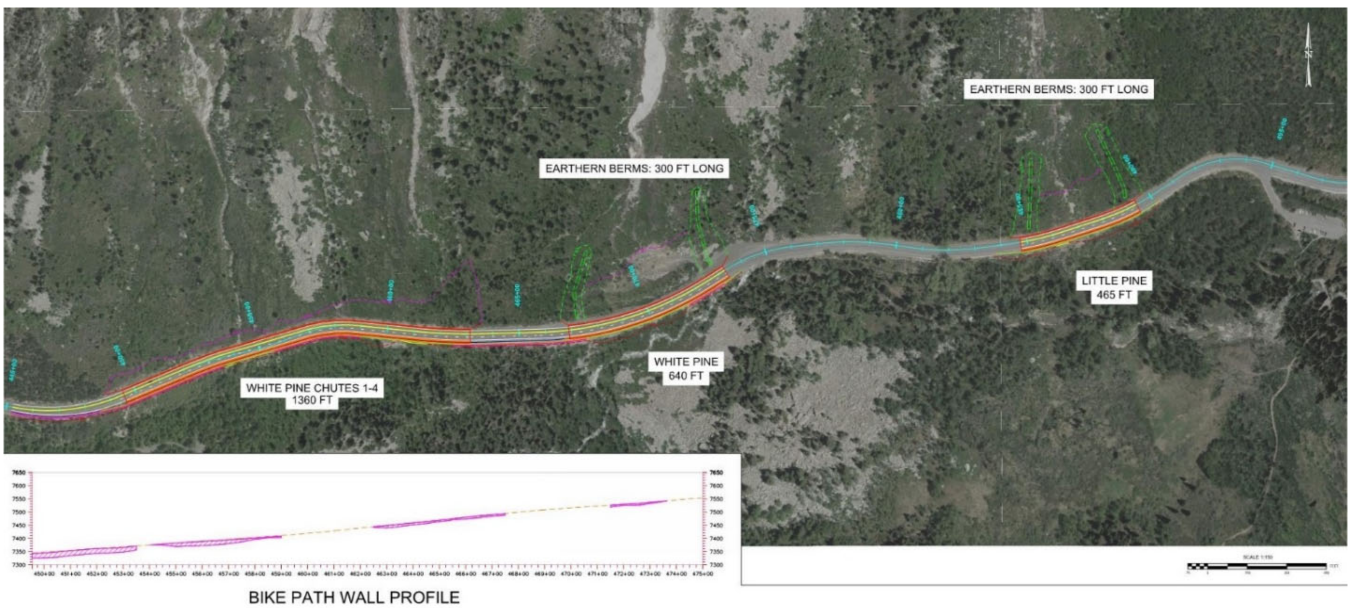
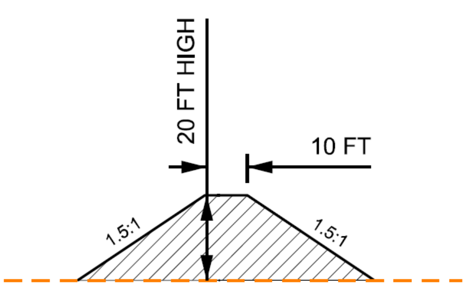


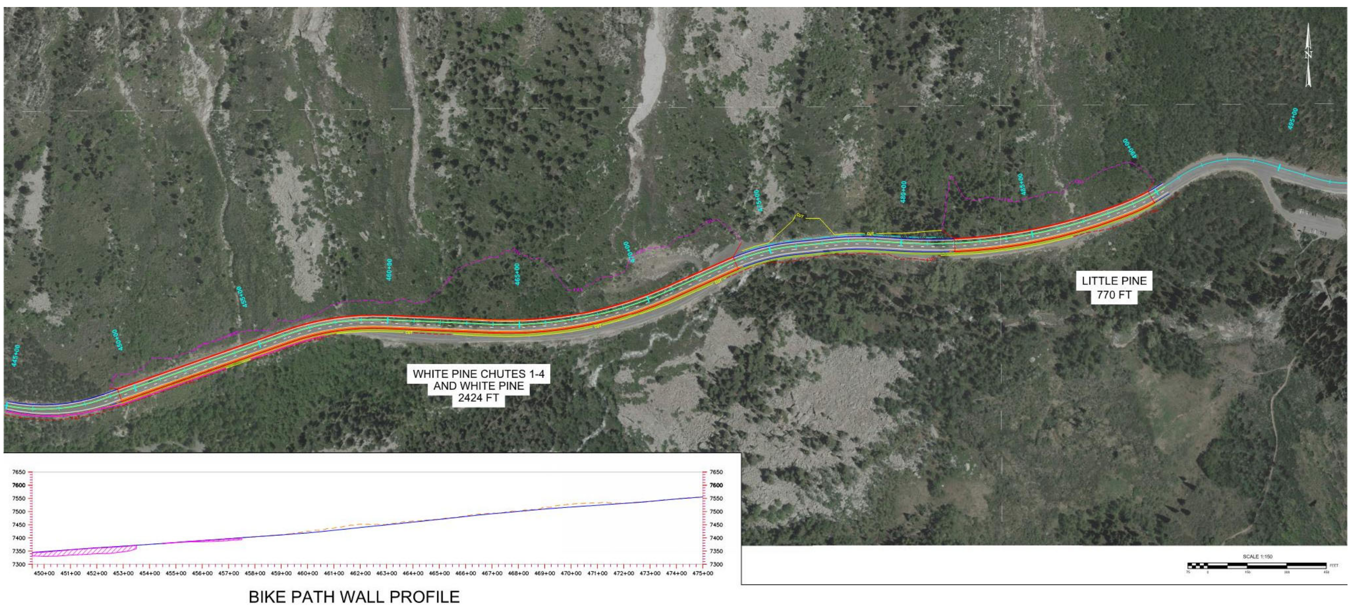
Figure 4-3. Earthen Berm Cross-section



4.3 Concept 3: No Berms, Realign Road

For this concept, HDR used the same snow shed lengths and considerations as for Concept 1 (a continuous snow shed for White Pine Chutes 1–4 and White Pine). HDR looked at realigning the existing roadway to be closer to the mountain side in order to potentially reduce the amounts of fill needed behind the snow sheds as well as to improve curve radii and sight distances inside the snow sheds. The sight distances on the existing alignment inside the sheds would be suitable for a 30-mph design speed. The realigned road with snow sheds would be suitable for a 35-mph design speed.[11] Concept 3 would, however, require UDOT to fully reconstruct the roadway cross-section and potentially relocate all utilities in the project area, including between the sheds and along the roadway leading up to the snow shed zone. Figure 4-4 shows a plan view of this layout.

Figure 4-4. Concept 3: No Berms, Realign Road



Moving the road and widening it toward the mountain side would also reduce the amount of fill or walls required on the downhill or stream side for the widened road and the bicycle lane that would be outside the sheds. The geotechnical composition and bedrock locations of the new roadway area were not evaluated.

[11] Based on AASHTO stopping sight distance requirements

4.4 Cost Estimates for Snow Shed Concepts

HDR estimated the major material quantities for snow sheds on a per-linear-foot basis and applied this unit cost to the lengths of all snow sheds per concept. We included the site-specific needs, which were a new water line from Snowbird for fire suppression and sewer and utility relocations under the sheds. We also included special design criteria features for roadway tunnels (standpipe, fire suppression, alarm, communications, and lighting systems), which were estimated based on a per-square-foot unit cost.

HDR prepared an engineer's estimate of probable bid costs, which includes estimates for the contractor's markup, administration, and mobilization. Estimates also include values for mobilization, traffic control, and maintenance of traffic. The bid estimates prepared do not include any right-of-way or inflation. HDR added contingencies and professional services (design and construction engineering, geotechnical analysis, and insurance, incentives, and stipends).

Table 4-1 summarizes the cost estimate for each of the concepts described in this memorandum. The bid cost derivation is provided as Appendix B, Bid Cost Estimate.

Table 4-1. Planning-level Cost Estimate Summary

Category	Contingencies and Markups	Snow Shed Concept (cost in $)		
		Concept 1 – No Berms	Concept 2 – Earthen Berms	Concept 3 – No Berms, Realign Road
Total bid estimate	—	65,772,696	53,327,810	63,211,016
Other items not estimated	4%	2,630,908	2,133,112	2,528,441
Subtotal		**68,403,604**	**55,460,922**	**65,739,457**
Contingency	10%	6,840,360	5,546,092	6,573,946
Construction subtotal		**75,243,964**	**61,007,015**	**72,313,402**
Environmental clearances and permits	4.0%	3,009,759	2,440,281	2,892,536
PM, geotechnical, PE, and procurement	5.0%	3,762,198	3,050,351	3,615,670
Geotechnical, and final design	3.0%	2,257,319	1,830,210	2,169,402
Construction engineering	3.0%	2,257,319	1,830,210	2,169,402
Environmental mitigation	2.0%	1,504,879	1,220,140	1,446,268
Insurance, incentives, and stipends	1.5%	1,128,659	915,105	1,084,701
Total		**89,164,098**	**72,293,312**	**85,691,382**

PE = preliminary engineering, PM = project management

A planning-level construction cost estimate for three-lane snow shed is about $23,000 to $25,000 per linear foot of structure. Adding professional services, geotechnical explorations, an allowance for environmental mitigation, and contractor insurance, incentives, and stipends at the percentages shown in Table 4-1 above, the budgetary cost estimate is $27,000 to $29,000 per linear foot of structure.

The planning-level cost estimate for Concept 1 (three-lane snow sheds without guiding berms and no roadway realignment) is about $89 million.

The planning-level cost estimate for Concepts 1 and 3 (no guiding berms but with roadway realignment) are similar. Concept 3 moves the new alignment closer to the mountainside, which decreases the amount of fill required in the flatter areas but increases the amount of roadway excavation and reconstruction work needed. Concept 3 provides improved sight distance inside the tunnels and requires fewer retaining walls on the stream side of the snow sheds for a new bicycle path. The planning-level cost estimate for Concept 3 is about $86 million.

Concept 2 (with guiding berms and no roadway alignment) has a lower planning-level cost estimate ($72 million) than either Concept 1 (no guiding berms) or Concept 3 (no guiding berms but with roadway realignment). The cost of the snow sheds and the amount of fill is driving the cost estimates. With Concept 2, the three separate snow sheds would overall be about 660 feet shorter than with either Concept 1 or Concept 3.

5.0 Design Considerations

A detailed engineering analysis would confirm or eliminate some of the following design considerations and might introduce other fire and life safety considerations.

5.1 Design Considerations for Road Tunnels

For the preliminary feasibility analysis presented in this memorandum, HDR assumed that the snow sheds are road tunnels and that the minimum requirements in NFPA 502 are applicable. The minimum requirements (provisions) are classified as (1) "mandatory requirements," which are prefaced with the word *shall*, meaning that they are the standards, and (2) "conditionally mandatory requirements," which are requirements, but confirmation is based on the results of an engineering analysis.[12]

The minimum requirements based on tunnel length are as follows. In the following requirements, underlining indicates the minimum provision for each length category.

- **Category X (L < 300 feet)** – Where the tunnel length (L) is less than 300 feet, an engineering analysis shall be performed for fire protection and life safety requirements, an evaluation of the protection of structural elements shall be conducted, and traffic control systems shall be installed.
- **Category A (L ≥ 300 feet)** – Where the tunnel length (L) is equal to or greater than 300 feet, an engineering analysis shall be performed for fire protection and life safety requirements, an evaluation of the protection of structural elements shall be conducted, and traffic control systems shall be installed. In addition, a water supply and standpipe system shall be installed.
- **Category B (L ≥ 800 feet)** – Where the tunnel length (L) is equal to or greater than 800 feet and the maximum distance from any point within the tunnel to a point of safety exceeds 400 feet, all provisions of NFPA 502 shall apply unless noted otherwise.
- **Category C (L ≥ 1,000 feet)** – Where the tunnel length (L) is equal to or greater than 1,000 feet, all provisions of NFPA 502 shall apply unless noted otherwise.
- **Category D (L ≥ 3,280 feet)** – Where the tunnel length (L) is equal to or greater than 3,280 feet, all provisions of NFPA 502 shall apply.

[12] NFPA 502, Section 3.3.39

A description of the minimum provisions of NFPA 502 is provided below. In summary, the design considerations for snow sheds in Little Cottonwood Canyon are the following:

- Traffic-control devices at the approaches to the snow sheds and within the snow sheds
- Fire-detection and alarm systems (minimum requirement is a manual system)
- Two-way communications
- A water connection to local water infrastructure
- Dry pipeline and dry standpipes in the snow sheds
- Portable fire extinguishers
- Fixed water-based fire-fighting systems
- Tunnel drainage systems
- Means of egress
- Electrical systems and emergency power

The following sections provide more information regarding these design considerations.

5.1.1 Protection of Structural Elements

Regardless of tunnel length, acceptable means shall be included within the design of the tunnel to prevent progressive collapse of primary structural elements in accordance with this standard to achieve the following functional requirements (in addition to life safety): support fire fighter accessibility, minimize economic impact, and mitigate structural damage. As part of the engineering analysis, modeling (for example, using Fire Dynamics Simulator or Computer Fluid Dynamics) of the approved design fire shall be performed to determine the protective measures needed to prevent progressive structural collapse and mitigation of structural damage.

5.1.2 Fire Alarm and Detection

Road tunnels equal to or greater than 800 feet (Category B, C, and D) shall have at least one manual means of identifying and locating a fire. This would require installing manual fire boxes at approved intervals and locations accessible to the public and tunnel personnel. Tunnels without 24-hour supervision shall include automatic fire-detection systems. Closed-circuit television systems can be used to identify and locate fires.

5.1.3 Emergency Communication Systems

Two-way radio communication enhancement systems shall be installed in new and existing tunnels and ancillary facilities where required by the authority having jurisdiction or by other applicable governing laws, codes, or standards. Inclusion of a communication system is a conditionally mandatory requirement for all tunnel lengths.

5.1.4 Tunnel Closure and Traffic Control

All road tunnels shall be provided with a means to stop approaching traffic. Road tunnels longer than 800 feet (Category B, C, and D) shall be provided with a means to stop traffic from entering the direct approaches to the tunnel, to control traffic within the tunnel, and to clear traffic downstream of the fire site following activation of a fire alarm within the tunnel. An important consideration is a means to expedite the flow of vehicles from the tunnel, downstream of the incident site, in all traffic conditions. If expeditious traffic flow is not possible, then a fixed water-based fire-fighting system shall be installed to establish a tenable environment for safe evacuation and emergency service access.[13] Also see the discussion under Fire Protection below.

5.1.5 Fire Protection

NFPA 502 groups many of its provisions under a broad fire-protection category. As described above in the introduction to Section 5.1, some of the provisions are classified as mandatory requirements and some as conditionally mandatory requirements, implementation of which are all based on the results of an engineering analysis. The minimum provisions based on the length of snow sheds are provided below.

Fire Apparatus. A fire apparatus is a piece of mobile fire-fighting equipment suitable for fighting fires within the tunnels that should be available within the general facility area to allow a rapid response to a fire emergency. Such apparatus should be equipped to deal effectively with flammable-liquid and hazardous-material fires. NFPA 502 does not mandate that an apparatus be at the tunnel site. Unified Fire Station 113 is about 1 mile from the proposed Little Pine snow shed. Therefore, HDR assumes that no additional apparatus or expanded facilities would be needed. However, the final determination would be made after a detailed analysis of the emergency response and the needs for fire and life safety systems.

Standpipe, Fire Hydrants, and Water Supply. A water supply and standpipes shall be provided in road tunnels for all lengths greater than 300 feet. A standpipe is a vertical pipe extending from a water supply main. Because the water lines would be subject to freezing conditions, and to eliminate the need to circulate the water and to install heat tracing tape and insulation, we assume that a dry standpipe system could be used. With a dry system, water is turned on at a source and shall be delivered to all hose connections in 10 minutes or less. A municipal source—Salt Lake County Service Area #3 (Canyon Water), a government water and sewer district—might be available. Canyon Water's rights are restricted to delivering water within its defined service area, which is outside the proposed snow shed area. An agreement with the Salt Lake City Department of Public Utilities would be required to deliver water to the snow sheds. Canyon Water believes it has adequate storage capacity and infrastructure to supply fire flows (1,000 gallons per minute for about 2 hours) to the snow sheds.[14] Assuming a connection near Snowbird Entry 1, a 1.75-mile-long water line would be needed to supply water to the sheds. To fill the line in 10 minutes or less, about a 4- to 6-inch water line would be required. A detailed hydraulic analysis would be required to define the fire flows, size the water main and standpipe systems (and/or sprinklers), and confirm the existing system's capacity.

Portable Fire Extinguishers. Portable fire extinguishers that are less than 20 pounds shall be placed in cabinets at intervals of not more than 300 feet.

Fixed Water-Based Fire-Fighting Systems. These systems include equipment that is permanently attached to a road tunnel that, when operated, has the intended effect of reducing the heat release and fire growth rates and is able to spread an extinguishing agent in all or part of the tunnel using a network of pipes and nozzles. These systems are conditionally mandatory in Category C (≥ 1,000 feet) and Category D (≥ 3,280 feet) tunnels. A detailed engineering analysis would need to be performed to determine the

[13] NFPA 502, Section 7.6.2(3)

[14] Terry Warner, telephone conversation with Keith Hanson of Canyon Water, August 29, 2018

effectiveness (for both fire and life safety and for structure protection) and impact on other safety measures.[15] The proposed snow shed protecting the road from the avalanche path for White Pine Chutes 1–4 would be about 1,360 feet long, which meets the length category for a conditionally mandatory provision. NFPA acknowledges that fixed water-based firefighting systems are highly regarded by fire protection professionals and fire fighters and can be effective in controlling a fuel based fire by actually limiting the spread of the fire and protecting the structure. Because we assume that all of the snow sheds would be treated as one system from the standpoint of fire detection and alarm and traffic control, for cost estimating purposes, we assume that a fixed water-based fire-fighting system would be incorporated in all snow sheds.

Emergency Ventilation. Emergency ventilation is a conditionally mandatory requirement in road tunnels longer than 800 feet. However, NFPA 502 states that emergency ventilation is not required in tunnels less than 3,280 feet long, where it can be shown by an engineering analysis that the level of safety provided by a mechanical ventilation system can be equaled or exceeded by enhancing the means of egress, the use of natural ventilation, or the use of smoke storage, and shall be permitted only where approved by the authority having jurisdiction.[16] Our initial structural analysis assumes that the snow sheds have one side (the south side) open between roof support columns to provide natural ventilation and to facilitate emergency egress from the travel lanes and the snow sheds. Therefore, we assume that the smoke and gases from a fire can be evacuated adequately, that a tenable environment can be maintained along the egress paths, and that no supplemental or emergency ventilation would be required. As mentioned in Section 5.1.1, a detailed computer model, prepared as part of the engineering analysis, would be needed to prove that a tenable environment can be achieved using natural ventilation.

Tunnel Drainage Systems. A tunnel drainage system is required, and it should be designed to capture spills of hazardous or flammable liquids so that they cannot spread or cause flame propagation.[17] The tunnel drainage system shall be provided with an oil and fuel separator and a storage capacity sufficient for the design spill rate for hazardous liquids, the size of which is a function of the size of hazardous or flammable transport vehicles. A tunnel drainage system should be considered given the proximity of Little Cottonwood Creek. The drainage and storage system can introduce additional requirements associated with hazardous locations (confined space) and require hydrocarbon detection. These items were not evaluated. For cost estimates, we assume 12-inch-diameter concrete pipe and standard catch basins.

5.1.6 Means of Egress

NFPA 502 includes egress requirements as mandatory requirements for road tunnels. NFPA 502 also cross-references the requirements of NFPA 101, *Life Safety Code*, Chapter 7, for the means of egress requirements for all road tunnels. This reference was not reviewed for this preliminary evaluation of snow sheds. The applicable egress requirements of NFPA 502 are summarized as follows: add reflective or lighted direction signs, incorporate slip-resistant surfaces, and be continuously maintained. For the preliminary analysis, we assume a snow shed cross-section that includes a barrier and a 4-foot gap between the barrier and the support columns. The gap exceeds the minimum clear pathway of 3.7 feet required by NFPA 502. From an egress perspective, if the barrier were placed adjacent to the columns or if, in the

[15] NFPA 502, Section 9.6 and Annex E

[16] NFPA 502, Section 11.1.1

[17] FHWA, *Technical Manual for Design of Road Tunnels – Civil Elements*, 2009

winter, snow fills the gap, NFPA allows the roadway tunnel surface to be considered as part of the egress pathway. The required detailed engineering analysis and emergency response planning efforts (see Section 5.3) would define the required means of egress.

5.1.7 Electrical Systems

Power is needed to support life safety operations, fire emergency operations, and normal operations, that latter of which includes communications, illuminating the signs and traffic-control devices, monitoring, and lighting the snow sheds. Lighting is an important design element to assist drivers in identifying hazards and disabled vehicles and to minimize the contrast between the portals and the interior of the snow shed. Power needs were not determined. We assume that existing power is a reliable power source (for example, the power source has not experienced any shutdowns longer than 4 continuous hours during 1 year). We also assume that the existing power line that runs under the roadway is adequate to supply power and, although the existing line might need to be relocated, UDOT would not need to install a newer, higher-capacity power cable along the length of the canyon.

5.2 Site-specific Considerations

An existing 10-inch-diameter sewer line runs near the westbound edge of the pavement through the snow shed zone. This sewer line might need to be relocated outside the snow shed footprint or outside the snow shed foundations (Little Pine to White Pine Chute 4). This sewer line might need to be relocated for a potential total distance of about 4,200 feet (assuming that the line needs to be relocated in the space between the snow sheds). Other utilities that might also need to be relocated include power and gas, the locations of which are not currently known.

5.3 Operations, Maintenance, Inspections, and Evaluation Overview

The operating requirements for the snow sheds would be defined by the level of traffic, the availability of emergency responders, and other conditions specific to the snow shed locations and their ultimate design. UDOT needs to employ the appropriate personnel to operate the tunnels safely and provide reliable levels of service.[18] Emergency response plans are required for all road tunnel lengths and shall be submitted for acceptance and approval by the authority having jurisdiction.[19] The outcome of preparing and reviewing the emergency response plan, which will include coordinating with many participating agencies, will define the required snow shed staff, their roles and qualifications, and their ongoing training needs. It will also determine whether a stand-alone operations and control center near the snow sheds is needed or whether remote monitoring is feasible.

An effective maintenance program helps reduce costs, decrease the number of tunnel closures, increase public safety, and ensure adequate levels of service.[20] Maintenance activities include routine activities such as removing snow, ice, and debris; regularly scheduled preventative maintenance such as checking portable

[18] FHWA, *Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual*, 2015

[19] NFPA 502, Chapter 13, *Emergency Response*

[20] FHWA, *Technical Manual for Design of Road Tunnels – Civil Elements*, 2009

fire extinguishers, washing tunnel surfaces, flushing drain systems, and servicing equipment; and corrective maintenance such as repairing pavement or addressing the sudden failure of functional equipment.

FHWA developed the National Tunnel Inspection Standards; the *Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual*; and the Specifications for National Tunnel Inventory to help safeguard tunnels and to ensure reliable levels of service on all public roads. The general requirements of these programs are as follows:[21]

- Performing regularly scheduled tunnel inspections:
  - Routine inspections every 24 months
  - In-depth inspections at a frequency determined by the program manager[22]
  - Damage inspection after a seismic event, fire, collision, avalanche, rockslide, etc.
- Maintaining tunnel records and inventories
- Submitting tunnel inventory and inspection data to FHWA
- Reporting critical findings and responding to safety and/or structural concerns
- Maintaining current load ratings on all applicable tunnel structures
- Developing and maintaining a quality control and quality assurance program
- Establishing responsibilities for the tunnel inspection organization and qualifications for tunnel inspection personnel
- Training and national certification of tunnel inspectors

A tunnel evaluation should be performed after an inspection to evaluate risks and prioritize repairs. In addition, we suggest periodically reviewing the fire and life safety engineering analysis and the emergency response plan. Lessons learned from the training exercises and drills should also be considered and plans updated accordingly.

[21] FHWA, *Technical Manual for Design of Road Tunnels – Civil Elements*, 2009

[22] The individual in charge of tunnel inspections in Utah.

Appendix A. NFPA 502

4.3.1* Regardless of the length of the facility, at a minimum, the following factors shall be considered as part of a holistic multidisciplinary engineering analysis of the fire protection and life safety requirements for the facilities covered by this standard:

(1) New facility or alteration of a facility
(2) Transportation modes using the facility
(3) Anticipated traffic mix and volume
(4) Restricted vehicle access and egress
(5) Fire emergencies ranging from minor incidents to major catastrophes
(6) Potential fire emergencies including but not limited to the following:
  (a) At one or more locations inside or on the facility
  (b) In close proximity to the facility
  (c) At facilities a long distance from emergency response facilities
(7) Exposure of emergency systems and structures to elevated temperatures
(8) Traffic congestion and control requirements during emergencies
(9) Fire protection features, including but not limited to the following:
  (a) Fire alarm and detection systems
  (b) Standpipe systems
  (c) Water-based fire-fighting systems
  (d) Ventilation systems
  (e) Emergency communications systems
  (f) Protection of structural elements
(10) Facility components, including emergency systems
(11) Evacuation and rescue requirements
(12) Emergency response time
(13) Emergency vehicle access points
(14) Emergency communications to appropriate agencies
(15) Facility location such as urban or rural (risk level and response capacity)
(16) Physical dimensions, number of traffic lanes, and roadway geometry
(17) Natural factors, including prevailing wind and pressure conditions
(18) Anticipated cargo
(19) Impact to buildings or landmarks near the facility
(20) Impacts to facility from external conditions and/or incidents
(21) Traffic operating mode (unidirectional, bidirectional, switchable, or reversible)

Appendix B. Bid Cost Estimate

18-034-ALT#1 Little Cottonw ALT #1 No berms old align Young, Stephen Archiblald 05/11/2020 1:31 PM

BID PROPOSAL

Biditem	Description	Quantity	Units	Unit Price	Bid Total
10	Mobilization	1.000	LS	5,589,251.91	5,589,251.91
20	Traffic Control	1.000	LS	727,164.53	727,164.53
30	Maintenance of Traffic	1.000	LS	321,557.17	321,557.17
40	Dust Control and Watering	9,858.000	MGAL	19.09	188,189.22
50	Borrow (Plan Quantity)	208,905.000	CY	31.13	6,503,212.65
60	Granular Borrow (Plan Quantity)	5,360.000	CY	28.08	150,508.80
70	Clearing and Grubbing	1.000	LS	71,003.22	71,003.22
90	Untreated Base Course (Plan Quantity)	4,538.000	CY	32.78	148,755.64
100	Micro-Surfacing	20,795.000	SY	12.05	250,579.75
110	HMA - 1/2 Inch	8,817.000	TON	99.95	881,259.15
130	Remove Asphalt Paving	19,388.000	SY	9.53	184,767.64
140	Pavement Marking Paint	164.000	GALL	280.06	45,929.84
150	Precast Concrete Barrier - 32 Inch (New Jersey Sha	8,500.000	LF	77.46	658,410.00
200	Concrete Drainage Structure 5 ft to 7 ft deep - CB	9.000	EA	4,588.19	41,293.71
210	Retaining Wall	18,510.000	SF	59.59	1,103,010.90
220	White Pine Chutes + White Pine	2,424.000	LF	13,785.39	33,415,785.36
230	Little Pine	770.000	LF	12,775.74	9,837,319.80
280	10" Sewer Line Relocation	3,194.000	LF	84.60	270,212.40
285	4' Manhole Standard	5.000	EA	5,720.34	28,601.70
286	4" Gas Relocation	4,200.000	LF	178.76	750,792.00
290	Electrical	4,200.000	L;F	31.70	133,140.00
300	Lighting	3,194.000	LF	55.97	178,768.18
310	Communications	4,200.000	LF	35.47	148,974.00
320	Signing	11.000	EACH	1,625.10	17,876.10
330	4" Waterline	8,450.000	LF	65.38	552,461.00
340	Fixed Water Based Suppression	151,715.000	SF	14.30	2,169,524.50
350	Fire Alarm System	151,715.000	SF	7.75	1,175,791.25
360	Water Standpipes	12.000	EA	3,147.15	37,765.80
370	Portable Fire Extinguishers and Cabinets	12.000	EA	417.11	5,005.32
380	12" Conc. Drain	3,194.000	LF	58.10	185,571.40
	Bid Total				**$65,772,482.94**

18-034-ALT#2 Little Cottnwood Canyon ALT # 2 w/berms Young, Stephen Archiblald 05/11/2020 1:36 PM

BID PROPOSAL

Biditem	Description	Quantity	Units	Unit Price	Bid Total
10	Mobilization	1.000	LS	4,978,440.26	4,978,440.26
20	Traffic Control	1.000	LS	724,988.51	724,988.51
30	Maintenance of Traffic	1.000	LS	320,594.92	320,594.92
40	Dust Control and Watering	8,859.000	MGAL	19.03	168,586.77
50	Borrow (Plan Quantity)	187,050.000	CY	31.04	5,806,032.00
60	Granular Borrow (Plan Quantity)	5,186.000	CY	28.00	145,208.00
70	Clearing and Grubbing	1.000	LS	70,790.75	70,790.75
90	Untreated Base Course (Plan Quantity)	4,388.000	CY	32.68	143,399.84
100	Micro-Surfacing	20,102.000	SY	12.01	241,425.02
110	HMA - 1/2 Inch	8,527.000	TON	99.65	849,715.55
130	Remove Asphalt Pavement	18,483.333	SY	9.51	175,776.50
140	Pavement Marking Paint	158.000	GAL	279.22	44,116.76
150	Precast Concrete Barrier - 32 Inch (New Jersey Sha	7,100.000	LF	77.23	548,333.00
200	Concrete Drainage Structure 5 ft to 7 ft deep - CB	9.000	EA	4,574.46	41,170.14
210	Retaining Wall	15,700.000	SF	59.41	932,737.00
220	White Pine Chutes	1,360.000	LF	13,744.27	18,692,207.20
230	White Pine	640.000	LF	13,743.42	8,795,788.80
240	Little Pine	465.000	LF	12,740.14	5,924,165.10
290	10" Sewer Line Relocation	2,465.000	LF	84.35	207,922.75
295	4' Manhole Standard	5.000	EA	5,703.22	28,516.10
296	4" Gas Relocation	4,200.000	LF	178.23	748,566.00
300	Electrical	4,200.000	LF	31.61	132,762.00
310	Lighting	2,465.000	LF	55.67	137,226.55
320	Communications	4,200.000	LF	35.36	148,512.00
330	Signing	11.000	EA	1,620.24	17,822.64
340	4" Water Line	8,450.000	LF	65.17	550,686.50
350	Fixed Water Based Suppression	117,088.000	SF	14.26	1,669,674.88
360	Fire Alarm System	117,088.000	SF	7.72	903,919.36
370	Water Standpipes	10.000	EA	3,136.93	31,369.30
380	Portable Fire Extinguishers and Cabinets	10.000	EA	415.86	4,158.60
390	12" Concrete Drain	2,465.000	LF	57.93	142,797.45
	Bid Total				**$53,327,410.25**

18-034-ALT#3 Little Cottnwood ALT#3 w/o berms n align Young, Stephen Archiblald 05/11/2020 2:01 PM

BID PROPOSAL

Biditem	Description	Quantity	Units	Unit Price	Bid Total
10	Mobilization	1.000	LS	5,270,952.25	5,270,952.25
20	Traffic Control	1.000	LS	724,365.83	724,365.83
30	Maintenance of Traffic	1.000	LS	320,319.56	320,319.56
40	Dust Control and Watering	6,419.000	MGAL	19.02	122,089.38
50	Borrow (Plan Quantity)	129,914.000	CY	31.01	4,028,633.14
60	Granular Borrow (Plan Quantity)	6,726.000	CY	27.97	188,126.22
70	Clearing and Grubbing	1.000	LS	70,729.94	70,729.94
80	Roadway Excavation (Plan Quantity)	12,986.000	CY	22.16	287,769.76
90	Untreated Base Course (Plan Quantity)	5,690.000	CY	32.65	185,778.50
100	Micro-Surfacing	26,065.000	SY	12.00	312,780.00
110	HMA - 1/2 Inch	11,060.000	TON	99.57	1,101,244.20
130	Remove Asphalt Pavement	23,923.000	SY	9.50	227,268.50
140	Pavement Marking Paint	204.000	GAL	278.98	56,911.92
150	Precast Concrete Barrier - 32 Inch (New Jersey Sha	7,800.000	LF	77.16	601,848.00
200	Concrete Drainage Structure 5 ft to 7 ft deep - CB	11.000	EA	4,570.53	50,275.83
210	Retaining Wall	13,145.000	SF	59.36	780,287.20
220	White Pine Chutes + White Pine	2,424.000	LF	13,732.33	33,287,167.92
230	Little Pine	770.000	LF	12,726.57	9,799,458.90
280	10" Sewer Line Relocation	4,200.000	LF	84.28	353,976.00
285	4' Manhole Standard	9.000	EA	5,698.33	51,284.97
286	4" Gas Line Relocation	4,200.000	LF	178.07	747,894.00
290	Electrical	4,200.000	LF	31.58	132,636.00
300	Lighting	3,194.000	LF	72.48	231,501.12
310	Communications	4,200.000	LF	35.33	148,386.00
320	Signing	11.000	EA	1,618.85	17,807.35
330	4" Water line	8,450.000	LF	65.12	550,264.00
340	Fixed Water Based Fire Suppression	151,715.000	SF	14.25	2,161,938.75
350	Fire Alarm System	151,715.000	SF	7.72	1,171,239.80
360	Water Standpipes	12.000	EA	3,135.14	37,621.68
370	Portable Fire Extinguishers with Cabinets	12.000	EA	415.50	4,986.00
380	12" Conctete Drain Line	3,194.000	LF	57.88	184,868.72
	Bid Total				**$63,210,411.44**