Oregon Department of Transportation – Rail Division

Oregon Rail Study Appendix C

Oregon Rail Tunnel Assessment: Double – Stack Clearance Inventory

Prepared by:

Shannon & Wilson, Inc.

February 2009

Oregon Rail Tunnel Assessment

Double-Stack Clearance Inventory for Oregon Department of Transportation Rail Division

WOC #2 Under PA/ATA # 25184

February 3, 2009

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Oregon Rail Tunnel Assessment

Double-Stack Clearance Inventory for Oregon Department of Transportation Rail Division

WOC #2 Under PA/ATA # 25184

February 3, 2009

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Excellence. Innovation. Service. Value.
Since 1954.

Submitted To:
Oregon Department of Transportation
Rail Division
555 13th NE, Suite 3
Salem, Oregon 97301-4179

By:
Shannon & Wilson, Inc.
3990 SW Collins Way, Suite 203
Lake Oswego, Oregon 97035

24-1-03505-001

OREGON RAIL TUNNEL ASSESSMENT AND DOUBLE-STACK CLEARANCE INVENTORY EXECUTIVE SUMMARY

The Oregon Department of Transportation contracted with Shannon & Wilson, Inc. to evaluate the condition of short line railroad tunnels in Oregon and to provide our opinion of probable construction costs to repair each tunnel to (1) a 20-year life expectancy and, (2) upgrade to accommodate bigger or "double-stack" rail cars. Cost estimates were based on available data during the 4th quarter of 2008, and should be adjusted for inflation. Twenty-four of the 34 short line railroad tunnels in Oregon were evaluated using available data and visual reconnaissance. Central Oregon and Pacific Railroad (CORP) tunnels and 4 Portland & Western Railroad (P&W) tunnels were evaluated. The ten remaining tunnels on the Port of Tillamook Bay Railroad were not included in this evaluation because of storm damage in 2008 that left the line inaccessible and the Port's ongoing evaluation with the Federal Emergency Management Agency.

Evaluation of 24 railroad tunnels on the CORP and P&W indicated that about half of these tunnels should be significantly rehabilitated if they are to provide another 20 years of service and most of these tunnels require some degree of modification to accommodate 20-foot 3-inch-high by 8-foot 6-inch-wide double-stack rail cars that would likely be preferred for freight handling from coastal ports. Twenty five percent of the total tunnel footage evaluated is supported with aging timber lining, amounting to 7,713 feet out of a total 31,144 cumulative feet of tunnels. About 3,919 feet or 51 percent of the timber lining is moderately to highly deteriorated and should be replaced within the next three years. In some cases, the timber is so deteriorated that we recommend that it be reinforced with steel jump-sets, or replaced with steel ribs, shotcrete, and grouted rock dowels immediately, since support failures may occur at any time.

For 20 years of additional service life, we recommend that all of the exposed timber sets be removed and the exposed rock be supported with grouted rock dowels and shotcrete. Periodic inspections of track and tunnel structure combined with proper maintenance of drainage and ballast condition, and timely repair of damaged tunnel portions (i.e., after a derailment, fire, earthquake, extreme weather conditions etc.) can extend the lifespan of rehabilitated and maintained tunnels to over 50 years. Based on observations and previous experience, in an estimated 20 percent of the timber-lined portions of tunnels, the rock mass is likely to be sufficiently weak and fractured to require the additional use of steel set supports.

Eleven of the 24 tunnels require remedial measures to extend their useful lifespan for at least another 20 years, at an estimated cost of approximately $32 million, not including the cost of replacement of fouled ballast, rail and ties, and re-establishing drainage, as shown in the following table. Ballast cleaning and replacement is typically accomplished by railroad maintenance crews, and the drainage is normally re-established along with ballast maintenance. Removal of old rail, ties, and ballast has been estimated by a railroad subcontractor at $400 to $500 per foot of tunnel, including replacement with clean ballast and re-establishing of the drainage.

Nearly 90 % (21 of the 24) of the tunnels evaluated have impediments, with up to 4.5 feet of clearance deficiencies for double-stack cars. Most often, the old timber sets form the clearance impediments for double-stack rail cars. In a few instances, hard bedrock knobs intrude by several feet into the desired double-stack clearance envelope. In addition, about 90 percent of the concrete portal barrels are also clearance impediments for double-stack rail cars. Only the CORP Siskiyou Line Tunnels 2 and 15 and P&W Tunnel 0 are currently in good condition and require no repairs or excavation and relining to satisfy double-stack clearance criteria.

Double-stack clearance can be obtained in all of the tunnels by a combination of track realignment, (vertical and horizontal) grinding of notches in the concrete portal barrels, removal of obstructing timber or steel sets, and lowering the tunnel bottom by undercutting. Enlargement of the tunnel crown or undercutting by more than a few inches will likely require that the existing lining be stabilized and anchored to the bedrock with a combination of grouted steel rock dowels, shotcrete wall/footing extensions, and backfill grouting. Several tunnels on the CORP Siskiyou Line will require arch modification using blasting methods to remove bedrock impediments in excess of more than 2 feet.

Clearance improvement, combined with repair and maintenance of the existing tunnel lining for the 24 tunnels, is estimated to cost on the order of $92 million, if accomplished under "dead-track" conditions. The cost and duration of any repairs accomplished under "live track" conditions will increase substantially and generally in proportion to the amount of rail traffic. Even one train per day could increase overall construction costs by 15 to 25 percent. Multiple daily trains could double or triple construction costs and the duration of tunnel rehabilitation and clearance improvement construction.

The following summary table presents the results of the Rail Tunnel Assessment Project.

SUMMARY TABLE OF RAIL TUNNELS AND OPINION OF IMPROVEMENT COSTS

Tunnel	Railroad	Line	Total Length (ft)	Total Repair Cost (20-year Design Life) ($)	Total Clearance Cost (Double-Stack) ($)
13	CORP	Siskiyou (Roseburg)	3111	0	16,012,000
14	CORP	Siskiyou (Roseburg)	1192	2,569,400	11,503,200
15	CORP	Siskiyou (Roseburg)	258	0	0
9	CORP	Siskiyou	2105	1,976,100	2,113,000
8	CORP	Siskiyou	2819	0	559,100
7	CORP	Siskiyou	128	0	59,000
6	CORP	Siskiyou	516	0	1,442,200
5	CORP	Siskiyou	341	323,500	372,400
4	CORP	Siskiyou	325	0	1,790,038
3	CORP	Siskiyou	435	0	1,518,000
2	CORP	Siskiyou	432	0	0
13	CORP	Coos Bay	2496	6,846,700	9,613,900
14	CORP	Coos Bay	471	0	1,737,600
15	CORP	Coos Bay	2143	5,987,200	10,450,808
16	CORP	Coos Bay	624	0	4,951,100
17	CORP	Coos Bay	1200	2,144,200	9,921,800
18	CORP	Coos Bay	1556	2,806,300	3,566,400
19	CORP	Coos Bay	4202	3,413,600	4,399,900
20	CORP	Coos Bay	874	263,100	2,796,000
21	CORP	Coos Bay	478	0	2,269,500
1	P&W	United	4105	5,004,700	6,262,400
0	P&W	United	471	0	0
3	P&W	Astoria	193	0	64,100
24	P&W	Toledo	669	802,600	802,600
TOTALS			**31,144**	**32,137,400**	**92,205,046**

Notes: More detailed assessments of construction costs are presented in Tables 1 through 29.
CORP = Central Oregon and Pacific Railroad
P&W = Portland & Western Railroad

The opinions and estimated costs presented herein are based on brief site visits combined with review of other available information discussed herein. No exploration through the existing linings or ballast has been performed. Design of repairs and clearance improvements, with appropriate geotechnical explorations will be required before construction. The final costs of the work will be influenced by the results of the design investigations and final design criteria. Opinions of cost presented herein are based on industry experience, discussions with contractor and railroad staff, and are intended to allow comparative evaluations of the future improvements or repairs.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

Page

LIST OF TABLES

Table No.

LIST OF FIGURES

Figure No.

LIST OF PHOTOS

Photo No.

LIST OF APPENDICES

Appendix

OREGON RAIL TUNNEL CONDITION ASSESSMENT AND DOUBLE-STACK CLEARANCE INVENTORY FOR OREGON DEPARTMENT OF TRANSPORTATION RAIL DIVISION WOC # 2 UNDER PA/ATA # 25184

1.0 INTRODUCTION

1.1 Scope of Work

This report presents the results of our preliminary condition assessments and associated repair requirements for a minimum of 20 more years of satisfactory performance with the current freight car clearances and for double-stack clearance improvements for 24 tunnels on the Central Oregon and Pacific Railroad (CORP) and Portland & Western Railroad (P&W) in western Oregon. In the course of this contract, we visited and visually assessed 4 out of 9 tunnels on the Coos Bay Line, all 11 tunnels on the CORP Siskiyou Line, and all 4 tunnels on the P&W Lines. Shannon & Wilson, Inc. has not performed explorations through the lining and ballast, or beneath the wall footings in these tunnels, which would be necessary for complete design of remedial measures and clearance improvements. Our evaluations are based on brief site visits to selected tunnels, our prior work with CORP on several of the tunnels, track charts, tunnel cross section clearance surveys, and published geologic and topographic maps.

This study was accomplished to evaluate the feasible methods for rehabilitation and for achieving double-stack clearance for the tunnels and to provide preliminary estimates of probable construction cost to complete the work.

The 24 tunnels evaluated for this report are listed in Table 1 and the various railroad divisions and tunnel locations are shown in Figures 1 through 25.

1.2 Authorization

The Oregon Department of Transportation (ODOT) Rail Division, authorized this work. The site visits were conducted at various times, depending on the availability of railroad personnel to provide hy-rail access. Visits to the P&W Line were accomplished between August 17 and 26, 2008, by Klaus Winkler of Shannon & Wilson, Inc., accompanied by Mr. Jerry Bachmeier, Track Inspector with P&W, and supporting Shannon & Wilson geologists. Mr. Winkler visited the Siskiyou Division tunnels between September 9 and 12, 2008, and revisited several tunnels October 14 through 16, 2008, with Mr. Robert Robinson, Director of Underground Services, and Mr. Gary Peterson, manager of the Portland Office of Shannon & Wilson, Inc. For our visits to the Siskiyou Division, we were accompanied by Messrs. Danny Paul and Jimmy Sims, Track Inspectors with CORP. Mr. Robinson visited Tunnels 13 and 15 on the Coos Bay Division on September 11, 2008, and was joined by Mr. Winkler on September 12, 2008, to visit Tunnels 17 and 18, accompanied by Mr. Troy Milbrett of CORP.

2.0 GENERAL TUNNEL CONDITION ASSESSMENTS

The ability of the 24 evaluated tunnels to remain stable and safe over the next 20 years is a function of lining types, liner conditions, groundwater seepage, soil/rock conditions, tunnel drainage, and ballast conditions. The conditions of the tunnels were assessed based on visual observations of tunnel liner types, evidence of deterioration of the liner, poor drainage, and fouling of the ballast. Lining deterioration was reflected by the presence of open or offset cracks in shotcrete and concrete, rotting and deterioration of timber sets and lagging, and offsets or bowing of lining components. The conditions of the various tunnels are discussed in Section 6, and are presented on Tables 2, 14, and 24, respectively, for the Siskiyou, Coos Bay, and P&W tunnels.

Most of the tunnels were originally supported with timber sets and wood lagging and rubble and wood back packing. Many of the tunnels are still supported at least partially with timber sets, although in many cases, the most deteriorated of the timber sets were replaced by various owners and operators during several phases of tunnel maintenance and rehabilitation over the last 50 or more years. Nevertheless, over 7,700 feet or 25 percent of the total 31,144 aggregate feet of tunnel is still supported with timber sets. Of the 7,713 feet of timber lining, approximately 3,919 feet or 51 percent show indications of deterioration in the form of through-going cracks, rotting bottoms of posts, severely deteriorated foot blocks, cracked and offset joints, etc.

The anticipated lifespan of cedar and redwood timber tunnel supports is normally on the order of 50 years. Although some of the timber sets may be replacement sets placed in the 1930s or 1940s, any timber sets replaced after 1950 would most likely be replaced with steel sets. Consequently, most of the remaining timber supports in the tunnels have likely been in place for well over 50 years and, therefore, have far exceeded their normal useful lifespan, even under dry conditions.

Where groundwater is seeping from the rock and through the lining, or where the base of the timber set posts are standing in poorly drained and/or muddy drainage ditches or on low concrete footing walls (curbs) where soil debris has accumulated and holds the moisture, the timber supports are in various stages of decay. In some instances, decay is limited to only the timber foot blocks supporting the posts, or to the lower 1 to 5 feet of the posts. Elsewhere, the decay is more pervasive and has penetrated the entire timber lining for several sets in a row. The decay may manifest as splayed or "broomed" butt joints, longitudinal splitting of timber sections, and rotting of the timber, both from the outside inward, and in some cases from the inside out.

Over the years, where the base of timber sets have been exposed to wet conditions and have deteriorated, the sets often settle by a few inches to over a foot, as the deteriorated foot blocks or bottoms of posts disintegrate. Generally, this disintegration occurs in several adjacent sets, and the settlement of horizontal spreader blocks located at about head-height can be observed for several sets relative to the adjacent undecayed and still intact timber sets. In the Coos Bay Division Tunnel 18, settlement of several adjacent posts by about a foot has been accompanied by inward shifting of the posts by 1 to 2 feet toward tunnel centerline. This progressive settlement and inward movement of the base of timber sets is likely a precursor to tunnel collapse, unless the liner is reinforced.

The timber sets also pose a fire hazard, as evidenced by charred and blackened timber in many of the tunnels. In the last 10 years, catastrophic fires have occurred in several of the tunnels, including the nearly complete burn out and partial collapse of Tunnel 13 on the Siskiyou Division and a partial burn out of Tunnel 1 on the P&W Lines.

Therefore, our primary recommendation for extending the life of the tunnels for at least another 20 years is to replace the timber sets and lagging. In stable rock, the timber sets may be removed one at a time and immediately replaced with grouted steel rock dowels, spaced 4 to 6 feet apart, typically with three to five dowels per row in the tunnel crown, and 3 to 4 inches of wire fiber-reinforced shotcrete. In poorer rock that tends to ravel, spall, or fall as blocks, the timber sets should be replaced with steel sets or lattice girders, spaced 3 to 4 feet, and shotcreted or concreted in place.

Many of the tunnels also have very poor drainage, resulting in part from low gradients and also from local blockage of the ditches, infrequent cleaning of the ditches, and poor conveyance of tunnel drainage water out and away from the tunnels.

In a few instances, the portals of some of the tunnels have numerous cracks indicating adverse loading and behavior. These portals should be reinforced with grouted rock dowels, shotcrete, and in at least one case, a reinforced concrete portal cap.

In anticipation that the tunnels will eventually be enlarged for larger train loads such as double-stack containers and tri-level car carriers, any timber replacement should be designed to accommodate eventual clearance improvements for each of the tunnels.

Normal, periodic tunnel maintenance should include cleanout and maintenance of the ditches, replacement of the muddy ballast in many of the tunnels, and inspections of the shotcrete and concrete support for any indications of deterioration.

3.0 DOUBLE-STACK CLEARANCE REQUIREMENTS

The 24 tunnels that were evaluated are currently capable of clearing Plate "F" freight trains that correspond to a single 17-foot-high by 10-foot, 8-inch-wide rectangular box. Our evaluations were directed at determining the requirements for upgrading these tunnels to accommodate double-stack railroad cars. The double-stack clearance envelope used in this study provides 6 inches of additional clearance around the outline of the sides and over the top of a 20-foot, 3-inch-high by 8-foot- 6-inch-wide double-stack car on tangent track as used by the Union Pacific Railroad (UPRR) and BNSF Railway Company. The car dimensions and clearance envelopes used in this study are shown in Figure 26 for double-stack cars.

The swing-in effects were added to the clearance envelope according to the degree of tunnel curvature. There was no correction for the swing-out. For the double-stack car, the swing-in is 1.05 inches for each degree of track curvature. The correction was added to the horizontal dimensions of the clearance envelopes on the inside of the curve. Figure 26, sheets 2 through 7, show the clearance envelopes for the various curvatures utilized. No additional correction has been added in the curved sections related super-elevation of the track.

4.0 CLEARANCE MEASUREMENTS

Tunnel clearance cross sections are presented in Appendix A, for each of the 24 tunnels. Surveyed sections are presented that are spaced roughly 200 feet apart, but vary depending on changes in tunnel configurations and support-type. The appropriate clearance envelope, depending on the degree of track curvature, has been positioned on each corresponding tunnel cross section, and centered on existing track centerline to show the clearance impediment or the available clearance through the tunnels. The sections have been oriented uniformly to look up milepost and up station.

Most of the cross sections were developed using data provided by the railroads that were obtained using a commercial clearance car with a laser scanner. The clearance cross sections are developed relative to track centerline, which may or may not be positioned at tunnel centerline. With the permission of the various railroads we obtained this data from either the UPRR clearance division or from L- Kopia, Inc., a commercial clearance measurement company. Where commercial cross section data was not available we measured tunnel cross sections utilizing a hand-portable Leica DISTO A5 laser distance meter and a reference beam that we constructed to measure selected tunnel dimensions relative to the top-of-rail and center of track.

Tables 2, 14, and 24 summarize tunnel conditions and the additional clearance requirements for the Siskiyou, Coos Bay, and P&W tunnels for double-stack clearance and the recommended remedial support by station interval that is required for the double-stack cars to clear the various tunnels. The indicated required additional clearance is measured in the vertical direction, by extending the sides of the double-stack envelope up to the horizontal top of the clearance envelope. The 6-inch radius curved corners of the double-stack clearance envelope will allow for slightly less excavation in the quarter arch of the tunnels, if notching or arch excavation is selected as the preferred clearance improvement method, as discussed in the following sections.

As shown in Tables 2, 14, and 24, additional clearance requirements vary from 0 to 4.5 feet at various locations in the 24 tunnels. At locations where timber sets have already been removed and the remaining rock has been supported with shotcrete (pneumatically applied minus ⅜ inch gravel and sand concrete) and grouted steel dowels (typically, 1- to 1.25-inch-diameter threadbars, 10 feet long) the tunnel sections are typically clear for double-stack trains, except in some of the tunnels on the Siskiyou line, where the hard, relatively intact rock obstructs the clearances by up to 4.5 feet and will likely require blasting.

5.0 CLEARANCE IMPROVEMENT OPTIONS

Clearance improvements for the Oregon railroad tunnels may by achieved by a variety of means ranging from minor shifts in the track along with minor thinning of the ballast section, which can often accommodate a few inches of clearance improvement. More extreme clearance improvements can be accomplished by modifying or replacing the arch of the tunnels or by undercutting or lowering the invert or floor of the tunnels. Combinations of track realignment, ballast thinning, replacement of wood ties with the thinner steel ties, excavation and replacement of the arch, and/or excavation or undercutting of the invert may all be possible, to reduce costs and impacts. Issues that should be considered in raising the arch or lowering the invert of a tunnel are: additional clearance required, tunnel geology, nature and condition of the tunnel liner, presence of bridges or other structures near the tunnel portals that limit undercutting depths, presence of utilities such as fiber-optic lines, impacts on tunnel drainage, effects on track grade, and frequency of train traffic

It is most cost-effective and efficient to accomplish major clearance improvements without train traffic. Major tunnel rehabilitation projects with frequent train interruptions could double or triple clearance improvement costs. At a minimum, tunnel arch modifications or undercutting require at least 4 hours, and preferably 8- to 12-hour work windows when the track is out of service and large increments of the tunnel can be excavated and safely re-supported.

5.1 Tunnel Arch Modifications

In areas of existing timber sets or timber sets with jump steel sets and gunite (pneumatically applied sanded concrete) and/or shotcrete (pneumatically applied minus ⅜ inch gravel and sand concrete) there are limited options for enlarging clearance by cutting localized notches at the corners of the projected double-stack clearance envelope in the lining. Notches up to 3 to 6 inches deep may be feasible to cut with a roadheader or boom excavator in 2-foot-thick or thicker concrete sections, as occur at most portals without significant additional support. Notches up to 2 inches deep, may be milled where timber or steel sets have been covered with gunite/shotcrete. If the required clearance notching is 1 inch or more, the steel sets would likely have to be completely removed and replaced with new steel sets with a higher arch. Notches up to 4 inches deep may be feasible in good quality timber sets with the addition of shotcrete and/or steel plate reinforcement. In better quality rock, the timber or steel set lining might be removed and replaced with a lining consisting of shotcrete augmented with grouted steel rock dowels to support rock blocks with either pattern dowels or isolated spot dowels.

At various times operators of the rail lines have replaced some of the deteriorated timber sets with steel sets, or placed steel “jump sets” between the deteriorated timber sets, leaving the timber set in place. In most instances these newer steel sets satisfy double-stack clearance criteria. Where steel jump sets are present, we have assumed that the timber lagging and backpacking will be left in place and the steel sets and intervening 2- to 4-foot-wide spacing between sets will be covered with 8 inches of shotcrete. This approach has generally resulted in long-term satisfactory performance of the shotcrete and steel set support already present in many of the tunnels, however, in some cases, grouting of voids behind the liner may be required to anchor the liner to the bedrock if major undercutting is anticipated. Based on observations of timber-lined sections, we assume that about 2 feet of wood and rock rubble filled void is present, on average, continuously behind the existing liner.

In the past, several of the tunnels have experienced tunnel fires, resulting in partially unlined conditions in the various tunnels. To reduce the potential for future fires we have also considered the cost impacts to remove and replace all of the remaining exposed timber sets and associated timber backpacking. As noted earlier, these remaining timber sets are often a clearance impediment. However, in some instances, such as Tunnel 9 on the CORP Siskiyou line, where timber sets apparently are taking loads but do not interfere with the double-stack clearance envelope, we also recommend replacement of timber sets with steel sets and leaving timber cribbing and lagging in place. Steel sets and intervening gaps should be covered with 8 inches of shotcrete in order to protect the remaining timber from fire hazards. We have not considered removing existing good condition shotcrete and steel set support in order to remove the underlying remaining timber lagging and cribbing, since this wood is shielded from train induced sparks and vandalism that could lead to tunnel fires. If there is concern for fire getting into the wood backpacking behind the shotcrete and steel set liner, then fire breaks could be constructed over 10- to 20-foot lengths of tunnel, where all wood would be removed.

In tunnels (such as Coos Bay Tunnels 14, 17, 19, 20, and 21 and Siskiyou Tunnel 13) where the timber lining has been removed from portions of the tunnel, along with the associated timber cribbing and rock rubble, and replaced with a gunite/shotcrete and grouted steel dowels, the remaining clearance of the tunnel is generally sufficient for rail cars requiring the double-stack clearance envelope.

Remaining unlined sections in Tunnels 4, 5, 6, and 8 on the Siskiyou Division, amounting to 3,044 aggregate feet of tunnel, will require significant modifications in the crown and the quarter arches to accommodate double-stack clearance. The unlined segments will need between 2.0 and 4.5 feet of arch excavation in typically hard, intact bedrock. Due to the hard, intact nature of the rock, excavation is likely to be accomplished by utilizing smooth-wall blasting methods.

Adequate clearance in the concrete tunnel portal barrels that range from 30 to 620 feet long may completely or partially be achieved by grinding a notch into the concrete quarter arches with a roadheader. Older concrete is generally unreinforced, making grinding of the notches relatively efficient. The presence of reinforcing steel will slow the notching process and result in more wear and tear on the roadheader. Shallow notches, on the order of 3 to 6 inches deep, generally require little or no auxiliary support, such as grouted rock dowels and grouting, if the concrete portal barrel is at least 18 inches thick.

Deep notches, on the order of 6 to 12 inches, may require excavating the debris backfill over the portal, reinforcing the barrel from the outside (where possible) with concrete and reinforcing steel and then grinding the required notches in the portal barrel with a roadheader. Where the portal barrels are embedded in the bedrock, the existing lining would need to be anchored to the bedrock with grouted steel dowels. A roadheader would likely be used to grind oversized notches into portal concrete barrel quarter arches, followed by the application of steel fiber reinforced shotcrete.

5.2 Undercutting

Undercutting consists of excavating the ballast, subballast, and rock subgrade for a sufficient depth to provide the desired clearance with a lowered track elevation. Undercutting should be sufficient to permit the placement of a minimum of 12 inches of ballast under the ties. The type of remedial work necessary to support the existing tunnel structure for the undercut is dependent upon the depth of the undercut, the location of the bottom of the tunnel concrete curbs or walls and portal barrel footings (where present), and the engineering characteristics of the subgrade material. Deep undercuts, in excess of 1 foot, often require that the tunnel lining be supported before being undercut by supporting and tying back the tunnel sidewalls with shoring and grouted rock anchors. In poor rock conditions, it may be necessary to install additional support for the sidewalls such as shoring piles, invert struts or full reinforced concrete invert slabs. Steel invert struts are present in several hundred feet of Tunnel 9 on the Siskiyou Line, and reflect high wall loads, as indicated by bowing of the shotcreted walls. These high side loads may be the result of very poor rock conditions, possibly associated with local faulting.

Deep undercutting, on the order of 1 to 3 feet, such as may be required in some of the Coos Bay Branch and Siskiyou Division tunnels will have to be performed “dead-track” using conventional excavation equipment and/or blasting. However, the remedial work that may be necessary to support the tunnel walls during the undercut may be completed in advance under “live track” conditions. Track lowering may not be a preferred option if extended periods of “dead track” are not possible and in situations where there are below grade obstructions along the approaches to the tunnel (e.g., culverts or bridges). In general, there appears to be sufficient topographic relief at both ends of most of the tunnels to allow for undercutting and re-establishing and improving the drainage conditions in the tunnels.

Undercutting of the tunnels will also require that the track approach grades be adjusted accordingly to establish an acceptable vertical curve. We have assumed that 1 foot of undercutting at the tunnel portals would require regrading to extend out 500 feet from the portals or ends of the undercut section. An estimate of the regrading costs have been included in our preliminary cost estimate.

5.3 Combined Arch Excavation and Undercutting

For the purposes of the preliminary cost estimates we have considered both excavation of the arch and undercutting alternatives for each of the tunnels, where appropriate. In a couple of the tunnels, bridges or other structures near the portals will limit the ability to undercut, which has been taken into account for the recommended clearance improvement methods. In some tunnels, recognized poor rock conditions, particularly in the tunnel arch, will make undercutting the preferred alternative for improving clearance. A discussion of the approaches to improving clearances for each tunnel is included in Section 6, and is summarized in Tables 2, 14, and 24.

6.0 TUNNEL DESCRIPTIONS AND EXISTING CONDITIONS

Table 1 presents a summary of the locations and geometric properties of the 24 tunnels. The tunnels are listed by railroad division, and then generally from the south to the north borders of Oregon. The table includes the portal milepost, tunnel curvature, length, and type of lining.

The CORP Siskiyou Division is located in southern Oregon, generally west of Interstate 5 (I-5), as shown in Figure 2. Eleven tunnels are in this division, which actually consists of the combined Siskiyou and Roseburg Divisions. The tunnels are identified on the various topographic maps shown for each tunnel in Figures 3 through 12.

The CORP Coos Bay Division starts in the vicinity of I-5 near Eugene and heads in a westerly direction to Florence and then to the south to Coos Bay and Coquille, as shown in Figure 13. Nine tunnels are in this division, and are identified on the topographic maps for each tunnel in Figures 14 through 20.

The P&W tunnels included in this report are located on various branches in northern Oregon, west of I-5, as shown in Figure 21. The four reviewed tunnels are identified in the topographic maps shown for each tunnel in Figures 22 through 25.

6.1 General Excavation and Support History

Based on available documents, the original tunnel construction generally took place in the late 1800s for the Siskiyou tunnels and early 1900s for the Coos Bay tunnels. Two P&W tunnels were constructed prior to 1900 and two were built after 1900. Excavation would have been by drill-and-blast methods, as confirmed by the presence of drilled blast holes observed in the arch of some of the tunnels. The tunnels were generally supported with wood, including timber sets, wood lagging and cribbing, and wood portal structures. Concrete portal structures, were constructed between 1910 and the 1920s for most of the tunnels. Rehabilitation including, in some cases, replacement with steel sets and shotcrete (pneumatically applied and generally chemically accelerated concrete) or gunite (pneumatically applied and generally chemically accelerated sanded concrete mix), or concreting between timber sets, was accomplished in portions of many of the tunnels in the 1950s through 2008, as sections of timber lining deteriorated or were burned out.

In portions of most of the tunnels, steel sets have been installed during various repair phases inside the timber lagging and between the rotting timber sets, and then the timber sets have generally been removed. However, where shotcrete covers the sets, it is possible that some timber sets still remain in place and that much of the timber lagging and cribbing is still present behind the shotcrete. In a few locations, timber sets and lagging have been completely removed and replaced with grouted steel dowels to knit the rock mass together and been covered with shotcrete to provide a fire resistant support system.

6.2 Siskiyou Line

6.2.1 General Conditions

The 11 tunnels on the Siskiyou line were apparently completed in the early 1880s when the line became part of the mainline railroad connecting Portland with the San Francisco Bay area. Today the Siskiyou line connects Eugene with Black Butte in Northern California, crossing the Siskiyou summit in the 3,111-foot-long Tunnel 13 at an elevation of 4,135 feet above sea level. Tunnels 2 through 9 are on the northern branch of the line which is also known as the Roseburg Division (from Eugene to Medford). They are located on a segment located between

Grants Pass in the south and Riddle in the north where the line follows Cow Creek Canyon. Tunnels 13 through 15 are on the southern branch of the Siskiyou line (from Medford to Black Butte) on a steep segment between Ashland and Siskiyou summit featuring tight curves and stretches of sustained grades in excess of 3 percent.

The tunnels were initially supported by timber sets, wood lagging, and timber portal structures or remained unlined where suitable ground conditions were encountered. Timber-lined sections are still present in Tunnels 9 and 14, totaling 994 feet of timber-supported tunnel.

A total of 3,490 feet of unlined sections were observed in Tunnels 4 through 8. Tunnel 8 features the longest unlined section of 2,665 feet. During our field reconnaissance, a Schmidt Hammer (a portable device used to estimate the compressive strength of rock) was used in unlined tunnel sections to evaluate the strengths of the exposed bedrock, consisting of various igneous and metamorphic rock types. The field data collected at selected outcrops in the tunnels indicates medium-high to high-strength rock with estimated unconfined compressive strengths ranging between 13,000 and 25,000 pounds per square inch.

At several tunnels, the concrete portal structures were constructed in the 1920s and 1930s. Both portals of Tunnels 2, 6, 13, 14, and 15; the south portal of Tunnel 5; and the north portal of Tunnel 3 are lined with shotcrete placed over steel sets.

Portions of Tunnels 3, 8, 9, 13, and 14 and all of Tunnel 15 are supported with steel sets installed to replace the timber sets. In most areas, the steel sets have been covered with shotcrete. It is likely that the original wood lagging and cribbing remains in place behind the shotcrete and steel sets.

Portions of Tunnels 2, 3, 9, 13, and 14 were supported with only a thin layer (0.5 to 3 inches) of shotcrete applied to the bedrock after removal of the timber lining and rubble. This represents a total of 2,158 feet of shotcrete and gunite lining – 1,438 feet in Tunnel 13 alone. In Tunnel 13, steel fiber-reinforced shotcrete applied over bedrock was used to support the tunnel after a fire in 2003 destroyed most of the timber sets and partially collapsed portions of the tunnel.

Buried fiber-optic cables (FOC) are present along the ditch line to either side in Tunnels 2 through 9. The FOC has typically been placed on the inside of curves, to minimize the length of the cable and, consequently, the FOC alternates from side to side of the track along the sinuous alignment. A 4-inch-diameter steel conduit typically carries and protects the FOC. Based on observations during our site visits, the fiber-optic line is buried in ballast and the top of the steel conduit is typically located just below the bottom of ties. The FOC may present an obstacle in tunnels where lowering and undercutting of track is recommended in order to accomplish the required double-stack clearance. The FOC can typically be rerouted temporarily along the tunnel walls or over the hill or ridge through which each tunnel was constructed, during clearance improvements.

The Siskiyou Branch mileposts increase from railroad south to north (Black Butte, California, to Eugene). Tunnel cross sections, presented in Appendix A, have been selected on about 200-foot intervals from existing laser car measurements provided by UPRR, and show the tunnel configuration and required double-stack clearance envelope as if looking to the north, up milepost or up station. Table 2 shows tunnel stationing according to increasing mileposts (0+00 at the south portal).

In the following tunnel descriptions, and in Table 2, the "right" and "left" sidewall designations relate to the increasing milepost direction, looking north. Pictures of the tunnels and portals are shown in Photo Plates 1 through 11.

6.2.2 General Geology Along the Alignment

The Siskiyou Line tunnels lie within the Klamath Mountains whose subsurface geology is complex and diverse. The Klamath Mountains typically consist of sedimentary, volcanic and intrusive volcanic Jurassic and Cretaceous Age rocks. The rocks are comprised of pieces of oceanic crust or volcanic island arcs that were accreted to the ancient western coastline of the North American landmass, and welded to the mainland by granitic intrusives. The Jurassic and Cretaceous age rocks that the tunnels run through include the Josephine Ophiolite and the Rogue, Galice, and Dothan Formations. The geologic formation(s) present in each tunnel is listed in Table 2.

The Josephine Ophiolite is in close proximity to Tunnels 6 and 7 and, thus, has been included in this report. The Josephine Ophiolite consists of basalts, gabbros, and ultramafics locally altered and sheared to form the low-grade metamorphic rocks, greenstone and serpentenite.

The Rogue Formation consists of lava flows, flow breccia, and agglomerate as well as some interlayered tuff and tuffaceous sedimentary rocks all of which are commonly metamorphosed to the greenschist facies. In addition, the rocks are typically locally foliated and schistose or gneissic. The rocks are considered to be an accreted volcanic island-arc terrain and are generally assigned to the Galice Formation.

The Galice Formation consists of black and gray mudstones, shales, water-laid tuffs, and fine-grained sediments metamorphosed to phyllite or slate. The area also includes andesite and basalt flows and breccia and metamorphosed Jurassic volcanic rocks of the Rogue Formation.

The Dothan Formation is composed of sandstone, greywacke, mudstone, and some deep water rhythmically banded chert lenses.

In addition, Tunnels 13, 14, and 15, located on the northeastern side of Mt. Ashland, are within the Ashland Plutonic Complex, consisting of tonalite and quartz diorite but also including lesser amounts of other granitoid rocks. The Ashland Pluton is overlain by younger volcanogenic deposits of flows and breccia and also relatively low strength andesitic ash-flow and air-fall tuffs, which comprise the geology in Tunnel 13.

6.2.3 Tunnel 13

The tunnel is 3,111 feet long and on tangent track. More than 2,800 feet of the original timber lining was destroyed during a fire in November 2003. Major cave-ins that extend up to 50 feet above top-of-rail occurred during the fire, which closed the tunnel for 18 months until it was re-opened again in April 2005 after extensive repairs and re-mining of large caved-in tunnel sections were completed. Remedial clearance improvements continued in the tunnel until 2007.

The tunnel is currently supported in alternating sections with either shotcreted steel sets or shotcrete applied over bedrock. About 1,440 feet of the tunnel are supported with shotcreted steel sets that replaced timber sets during prior improvements and maintenance work, and from the latest repairs after the devastating tunnel fire in 2003. Typically, steel fiber-reinforced shotcrete was applied over the installed steel sets. In a few sections of tunnel, steel channel lagging was installed between the steel sets and then backfilled with concrete and/or shotcrete. Based on our observations during our relatively brief involvement in the tunnel rehabilitation, a significant amount of Styrofoam and wood cribbing had been used to backfill voids and overbreak areas and to stabilize the ground behind the steel sets prior to covering the sets with shotcrete. We understand that at a minimum of two locations, between approximately Stations 8+30 and 9+00 and from 28+60 to 29+10, large overbreak caverns were partially backfilled with lightweight grout placed above steel set supports. The partially backfilled overbreak cavity near

Station 29+00 eventually daylighted to form a large sinkhole at ground surface near the north portal.

Bedrock in Tunnel 13 appeared to consist predominantly of weakly consolidated volcanic ash and tuff layers carrying andesitic boulders that reached more than 5 feet in diameter. Due to bedrock conditions, excavation and re-mining of collapsed and caved-in sections of tunnel resulted in caverns that are locally more than 50 feet high. These caverns were supported by an estimated 2 to 3 inches of steel fiber-reinforced shotcrete placed over bedrock.

The tunnel, in general, is in good condition and we anticipate that it will not require significant repairs for at least 20 years, other than normal maintenance of the drains, ballast, and track. However, little time has passed since the tunnel was repaired and re-opened after the fire and, consequently, the behavior of the shotcrete-supported caverns and overbreak sections should be reviewed yearly over the next several years. Minor cracks observed in the shotcreted sidewalls of the steel set-supported south portal should be reviewed during regular annual tunnel inspections.

The tunnel sections supported with shotcrete over bedrock are almost all clear for double-stack cars except for a short, 200-foot-long stretch between Stations 3+60 and 5+60 where the right quarter-arch impedes the clearance envelope by 1 foot. However, none of the steel set-supported sections provide sufficient clearance for double-stack rail cars. Based on our experience during Tunnel 13 repair work between 2006 and 2007, it does not appear to be feasible or safe to achieve over 4 feet of additional clearance by removing existing steel sets and raising the crown and quarter arches of the tunnel. In our opinion, the existing ground conditions are too inconsistent, and the types and amount of materials (wood, Styrofoam, and/or shotcrete) used to support the ground behind the installed steel sets are too inconsistent and, consequently, there would be unpredictably high risks inherent in excavating and replacing the tunnel arch. Therefore, we recommend lowering and undercutting the invert of the tunnel to accomplish the double-stack clearance. Undercutting will require a cautious approach and extensive support measures to stabilize and anchor the sidewalls prior to undercutting. Replacement of the existing tunnel with a new tunnel at an alternate location, while more expensive, would avoid the risks associated with prolonged satisfactory performance of the shotcrete-supported high cavities and undercutting of tunnel walls in the fire-damaged rock.

6.2.4 Tunnel 14

Roughly half of the 1,192-foot-long tunnel is on tangent track and approximately 580 feet of the south end of the tunnel is on a tight, 14-degree right curve. Various liner types were used in the tunnel constructed in relatively competent granitic rocks. The original timber lining is still present over a total length of 571 feet of the tunnel. Due to age and poor drainage conditions, most of the timber lining, particularly the wood foot blocks and bottoms of timber posts, have deteriorated and rotted. Timber sets have sagged locally and individual sets have erratically collapsed into the tunnel over time. Approximately 195 feet of the tunnel is supported with steel sets installed to replace the timber sets, including both portal areas. Seventy-five percent of the steel sets are covered with shotcrete. A 428-foot-long section of the tunnel is supported with a thin, typically less than 1-inch-thick, layer of shotcrete that was applied over bedrock.

To achieve a 20-year design life for the tunnel, timber-lined sections, which already show advanced deterioration over long stretches, should be replaced with rows of grouted rock dowels and shotcrete as timber sets are removed. Pervasive timber decay is related to poor drainage. Consequently, we recommend that proper drainage be re-established in the tunnel. The current drainage conditions in the tunnel are very poor, and muddy. Flooded track was observed at numerous locations. An existing drainage system featuring concrete catchments connected by a drainage pipe located on the left side of the tunnel is apparently plugged.

The entire tunnel will require clearance improvements to accommodate double-stack clearance. Up to 2.5 feet of additional clearance is required in sections supported by steel sets. Lowering/undercutting the tunnel invert presents a feasible and effective alternative to accomplish double-stack clearance. In timber-lined sections, where up to 3.8 feet of additional clearance is required, clearance can be improved by removing the existing timber sets and then supporting exposed bedrock with grouted steel rock dowels and steel fiber-reinforced shotcrete as the timber sets are removed. Some notching in quarter arches and crown may be required locally to achieve the desired clearance.

6.2.5 Tunnel 15

The tunnel is 258 feet long and on a 7-degree left curve. The entire tunnel is supported by steel sets including both portals. The steel sets likely replaced old timber sets and have been shotcreted throughout the tunnel. The tunnel is generally dry, and the current liner is in good condition. We do not anticipate major additional repairs for a 20-year design life.

Approximately 0.3 foot of additional clearance is required in the left quarter arch in order to achieve double-stack clearance. The additional clearance can be accomplished by realigning and shifting the track to the right, toward the outside of the curve.

6.2.6 Tunnel 9

The 2,105-foot-long tunnel is on tangent track. Original timber lining is present over a total length of 423 feet of the tunnel. Vertical cracks in timber posts likely reflect soil and rock loads from the ground above, and will affect the degree of difficulty and effort needed to replace the timber sets. Approximately 70 percent of the tunnel is supported by steel sets that were likely installed to replace the original timber sets. Shotcrete has been applied over the steel sets, except in a 44-foot-long section where concrete arches were formed between the sets. A 182-foot-long section of the tunnel is supported with roughly 1-inch-thick shotcrete placed directly over bedrock. Approximately 25-foot-long cast-in-place concrete barrels support both portals.

Insufficient drainage is evident at several locations throughout the tunnel where standing water covers the ties, and muddy and pumping ballast conditions occur. The poor drainage and muddy conditions are likely related to prior lowering and undercutting of the tunnel invert. The undercutting apparently also prompted the placement of steel invert struts at about 15- to 20-foot intervals to stabilize and support the tunnel sidewalls over a roughly 170-foot-long segment supported with steel sets at the north end of the tunnel. High ground loads on both tunnel sidewalls are indicated in this section by numerous, generally horizontal cracks in the shotcrete applied over the bowed steel sets. The tunnel will need repairs in order to meet the 20-year design life criteria.

Additional repairs are recommended locally in order to improve the structural condition of the tunnel liner. Timber-lined sections should be replaced, which, based on our observations described above, will require the installation of steel "jump" sets (installed between the existing sets) prior to the removal of the original timber sets. To complete the work, we recommend the application of steel fiber reinforced shotcrete over the steel sets. The shotcrete already applied over timber lagging can be left in place as long as it is sealed properly by at least 3 inches of shotcrete to protect the wood against sparks.

In the 170-foot-long section at the north end of the tunnel, where both sidewalls are cracked and slightly bowed, indicating lateral rock or soil loading on the lining, we recommend that borings be drilled at least 20 feet through the lining and into the ground to assess the soil/rock conditions behind the wall and then supporting the sidewalls with the appropriate soil or rock anchors installed between the existing steel sets. Support of the sidewalls with grouted steel dowels replacing the steel invert struts will greatly improve the poor drainage in this section.

We recommend re-establishing drainage to the north and south of the tunnel, due to a grade change roughly midway through the tunnel. Groundwater inflow from crown and quarter arches at various locations was observed in several areas, resulting in muddy, pumping ballast conditions and, locally, in near flooded track. Due to an existing fiber-optic line, drainage will need to be re-established and provided on the left side of the tunnel.

Only minor clearance enlargements are needed in this tunnel to meet the required double-stack envelope. Additional 0.1 foot of required clearance in both quarter arches of the 25-foot-long concrete barrel at the north end of the tunnel can be achieved by notching. Localized notching up to 0.4 foot deep is also required in the crown of a roughly 180-foot-long section of tunnel supported with shotcrete applied over bedrock. Realigning and shifting the track to the left accomplishes the required clearance in a 44-foot-long section supported with steel sets and concrete arches that were formed and poured between the sets.

6.2.7 Tunnel 8

Tunnel 8 is 2,819 feet long and almost 2,600 feet on tangent track, transitioning to a 6-degree right curve at the north end for the remainder of the tunnel. Both portals consist of 25-foot-long, cast-in-place concrete barrels. A 100-foot-long section is supported by shotcreted steel sets at the north end. The remaining 2,669 feet of the tunnel is unlined. Considering that the unlined section has been unsupported since the construction of the tunnel over 100 years ago, it is in good condition and only two relatively small areas were identified with recent rockfall scars and rockfall debris totaling less than ¾ cubic yard in both areas.

The tunnel is in good condition and no additional repairs are needed for a 20-year design life, provided that occasional small rockfalls are acceptable. Rockfall activity in the unlined section should be monitored during regular yearly inspections. Based on current conditions and presently low train traffic, remedial work, in our opinion, is not needed at this point due to the apparently infrequent and small size of rockfalls. If even small rockfalls are unacceptable, then the application of 3 inches of shotcrete will greatly reduce rockfall size and frequency

Clearance improvements are necessary throughout the entire tunnel in order to provide double-stack clearance. The required additional clearance of about 0.4 foot in the quarter arches of both concrete portal barrels can be accomplished by notching. Realigning and shifting the track to the left achieves the required clearance in the section supported with steel sets. The unlined section requires up to 4.5 feet of additional clearance, which can be accomplished by re-mining and raising the tunnel crown, likely using smooth-wall blasting methods in the hard, intact bedrock. If minor infrequent rockfalls are unacceptable, the periodic scaling, followed by the application of 3 to 4 inches of shotcrete, will stabilize the rock surface.

6.2.8 Tunnel 7

The 128-foot-long Tunnel 7 is on a 10-degree right curve. The 22-foot-long north portal barrel and 28-foot-long south portal barrel consist of concrete. The remaining 78 feet of tunnel is unlined. The tunnel is dry and in generally good condition and does not need additional repairs for a 20-year design life. As recommended for all unlined tunnel sections, any rockfall activity should be observed and recorded during regular tunnel inspections. If minor infrequent rockfalls are unacceptable, the periodic scaling, followed by the application of 3 to 4 inches of shotcrete, will stabilize the rock surface.

Up to 0.7 foot of additional clearance is required in the quarter arches of the concrete portal barrels at both portals. Five inches of additional clearance is also needed locally in the unlined portion of the tunnel. The tight areas in the unlined rock are typically located in the quarter arches. In all of the tunnel areas, double-stack clearance can be accomplished by notching.

6.2.9 Tunnel 6

The tunnel is 516 feet long and on a 10-degree left curve. Both 35-foot-long portals are supported by steel sets. Shotcrete was applied over the steel sets. The remaining 481 feet of tunnel is unlined. The tunnel is in good condition and other than regular track maintenance, we do not anticipate any repairs in order to accomplish a 20-year design life. The unlined section should be inspected regularly for rockfall activity. If minor infrequent rockfalls are unacceptable, the periodic scaling, followed by the application of 3 to 4 inches of shotcrete, will stabilize the rock surface.

Current dimensions of the tunnel do not provide double-stack clearance. The required clearance can be accomplished by realigning and shifting the track to the left by 0.6 foot in the steel set-supported section at the south portal. Lowering the track by 0.5 foot is required in the section supported by steel sets at the north portal in order to achieve double-stack clearance. In the unlined portion of the tunnel, up to 3.3 feet of additional clearance is needed in the crown and quarter arches. Blasting is the most likely option to accomplish the clearance improvements. If minor infrequent rockfalls are unacceptable, the periodic scaling, followed by the application of 3 to 4 inches of shotcrete, will stabilize the rock surface.

6.2.10 Tunnel 5

The 341-foot-long tunnel is on a 10-degree right curve. A bridge is located 160 feet north of the tunnel. The south end of the tunnel consists of an 80-foot-long section supported by steel sets. Shotcrete has been applied over the steel sets and timber lagging that was left in place after removal of the original timber sets. A 23-foot-long concrete barrel supports the north portal. The remaining 238 feet of the tunnel is unlined. Evidence of occasional rockfalls with fragments typically less than 18 inches in diameter were observed in this section.

Cracks in the shotcrete around the portal and in the right sidewall of the steel set-supported section at the south portal, appear to be related to rock dilation and sliding observed above the portal. Original timber lagging and cribbing is exposed at ground surface above the crown and quarter arches over a distance of approximately 15 feet from the portal. Partially exposed Styrofoam blocks are present in overburden material on top of the portal structure. The overburden consists of relatively loose rockfall and rock slide debris. A recent rockfall was observed in the slope at the north approach of the tunnel. Ballast conditions are poor inside the tunnel, and muddy and pumping ballast occur at several locations.

Improvements and repairs are needed to accomplish a 20-year design life of the tunnel.

Cracks observed in the shotcrete in the vicinity of the south portal indicate rock loads acting on the right sidewall. We recommend rehabilitating the south entrance to the tunnel as follows:

- Excavate and remove loose rock debris and all foreign materials such as Styrofoam and original timber lagging and cribbing from the top of the portal. The excavation should roughly follow the tunnel alignment over a length of approximately 40 feet starting at the portal. Materials should be removed from the crown to both quarter arches down to the existing liner consisting of steel sets and shotcrete.

- Re-construct the tunnel arch by placing an approximately 3-foot-thick layer of lightweight concrete on top of exposed existing liner.
- Additional scaling in the rock slide area upslope may be necessary, followed by the installation of grouted steel dowel rock anchors and the application of steel fiber-reinforced shotcrete at selected locations, if needed.
- To improve stability, rock dowels should be installed in the right sidewall at the south portal. We anticipate 15-foot-long anchors installed at a 5-foot spacing over a total length of 50 feet, beginning at the tunnel portal. We estimate that three rows of grouted rock dowels spaced 5-foot vertically will be needed for additional support of the sidewall.
- Re-establish drainage and replace fouled ballast to improve track condition.

Both portal sections will need clearance improvements in the quarter arches. The steel set-supported section at the south end of the tunnel requires an additional 1 foot of clearance in the left quarter arch, which can be accomplished by realigning and shifting track to the left. Notching the left quarter arch in the concrete barrel at the north end of the tunnel can achieve the additional clearance of 0.3 foot necessary in this section. In the unlined portion, up to 3.5 feet of additional clearance is required. This can be accomplished by raising the crown and both quarter arches throughout the section using blasting methods. If minor infrequent rockfalls are unacceptable, the periodic scaling, followed by the application of 3 to 4 inches of shotcrete will stabilize the rock surface.

6.2.11 Tunnel 4

Tunnel 4 is 325 feet long and on a relatively tight 12-degree right curve. Both portals of the tunnel are supported by steel sets and shotcrete representing a total length of 262 feet of tunnel. A 63-foot-long portion of the tunnel is unlined. The tunnel appears to be dry and in good condition overall. No improvement work is anticipated for the 20-year design life of the tunnel. If minor infrequent rockfalls are unacceptable, then periodic scaling, followed by the application of 3 to 4 inches of shotcrete, will stabilize the rock surface.

Both portals require about 9 inches of additional clearance in the right quarter arch. The shotcrete and steel set lined sections at both ends will require lowering and undercutting the track in order to accomplish double-stack clearance. This effort could be combined with realigning and shifting track to the left, which can accomplish up to 0.2 foot of additional clearance where needed in addition to the undercutting. The unlined portion requires up to 3.5 feet of additional clearance, which can be achieved by raising the roof of the tunnel throughout the section using smooth-wall blasting methods. If minor infrequent rockfalls are unacceptable, then periodic scaling, followed by the application of 3 to 4 inches of shotcrete, will stabilize the rock surface.

6.2.12 Tunnel 3

Tunnel 3 is 435 feet long and on a 10-degree right curve. The south portal consists of a 60-foot-long concrete barrel, followed by a 150-foot-long section supported by shotcreted steel sets, and then a 65-foot-long unlined portion supported with 1 to 2 inches of shotcrete placed over bedrock. The north portal barrel is supported with steel sets and shotcrete over a length of 160 feet. An 8-inch-diameter corrugated drain pipe buried in ballast was observed throughout the tunnel in the right side ditch. In general, the tunnel is in good condition and drainage appears to be adequate. We do not foresee additional repairs needed for the 20-year design life of the tunnel.

The only areas in the tunnel that require clearance improvements are the right quarter arches in the sections supported by steel sets. Additional clearance of up to 0.4 foot can be accomplished by realigning the track and lowering and undercutting the track by 0 to 0.3 foot. Drainage should be re-established to the north of the tunnel after clearance improvements are completed.

6.2.13 Tunnel 2

Tunnel 2 is 432 feet long and on a 10-degree left curve. A total of 387 feet, including both tunnel portals, are supported by steel sets. Shotcrete was applied over and between sets, probably also over original timber lagging and cribbing that was left in place when timber sets were replaced by steel sets. Approximately midway through the tunnel, a 45-foot-long portion is lined with less than 1.5-inch-thick shotcrete on bedrock. A bridge is located approximately 200 feet north of the tunnel. The tunnel is in good condition overall and does not require improvements in order to meet the 20-year design life criteria.

The tunnel requires only minor clearance improvements in the sections supported by steel sets. The additional clearance is typically needed in the left quarter arch and can be accomplished by realigning and shifting track to the right by 1 foot or less.

6.3 Coos Bay Line

6.3.1 General Conditions

The tunnels on the Coos Bay Line were initially supported with timber sets, wood lagging, and timber portal structures and were constructed between 1913 and 1916. Concrete portal structures were constructed later in the 1920s and 1930s. The south portal barrel of Tunnel 14 and the north portal barrels of Tunnels 18 and 19 are lined with shotcrete placed over steel and timber sets.

Portions of Tunnels 13, 14, 15, 17, 18, 19, and 20, and nearly all of Tunnel 16, are supported with steel sets installed to replace the timber sets. In most areas the steel sets have been covered with shotcrete.

Portions of Tunnel 13, and most of the lengths of Tunnels 14, 19, 20, and 21 were supported with only a thin layer (0.5 to 3 inches) of shotcrete after the removal of the timber lining and rubble. It appears that the timber lining in Tunnel 21 was removed more recently, possibly after a tunnel fire, and steel fiber-reinforced shotcrete was used to support the tunnel. At present, approximately 1,207 feet of timber lining remains in place in Tunnel 13, 1,100 feet in Tunnel 15, 417 feet in Tunnel 17, and 622 feet in Tunnel 18. This represents a total of 3,346 feet of timber lining or about 25 percent of the cumulative Coos Bay tunnel lengths of 14,077 feet.

The Coos Bay Branch mileposts increase from north to south (Eugene to Coos Bay). Tunnel cross sections, presented in Appendix A, have been selected at about 200-foot intervals, and show the tunnel configuration and required double-stack clearance envelope as if looking to the south, up milepost or up station. Table 14 shows tunnel stationing according to increasing mileposts (0+00 at the north portal).

In the following tunnel descriptions, and in Table 14, the right and left sidewalls correspond to the increasing milepost direction, looking railroad south. Pictures of the tunnels and portals are shown in Photo Plates 12 through 20.

6.3.2 General Geology Along the Alignment

The subsurface geology in the vicinity of the tunnels is made up primarily of Eocene Age sedimentary rocks. These rocks are comprised of sediment that was eroded from the existing continent and transported to a forearc basin (Orr et al., 1992). The Eocene Age sedimentary rocks that the tunnels run through include the Coaledo Formation, the Flourney Formation, and the Tyee Formation. The geologic formation applicable to each tunnel is listed in Table 14.

The Flourney Formation consists of thick sequences of massive, rhythmically bedded, micaceous sandstone and minor siltstone, impermeable except for infiltration along joints and faults. This formation is very similar to the overlying Tyee Formation.

The Coaledo Formation consists of coarse to fine-grained, hard, deltaic sandstone with interbeds of softer siltstone and coal. It lays unconformably over the Flourney Formation.

The Tyee Formation consists of a thick sequence of massive, rhythmically bedded sandstone and siltstone. The sandstone is grey green, micaceous, fine-grained, and generally harder than the siltstone. The siltstone is softer, and failures and landslides tend to occur in siltstone beds.

The coastal areas are covered by dune sand, typically unconsolidated sand, mixed with silt, and stratified with layers of gravel. The dune sand forms beaches, spits, and bars. The railroad only crosses dune sands south of Lakeside.

In addition to the sedimentary rocks, the railroad crosses intrusive igneous rocks. These are composed of gabbro and diorite that were intruded into the Eocene sedimentary rocks after the sedimentary rocks were deposited. None of the tunnels are apparently located in these igneous rocks, although the timber and shotcrete lining obscures the rock in several of the tunnels.

The most common geological features in the study area are gentle anticlines and synclines. There are faults in the area, and faults with small offsets were observed at two locations during the tunnel survey. No mapped faults cross the tunnels according to the geologic maps, but mapped faults cross the railroad at several points. Tunnel surveys identified a fault in Tunnel 13. A suspected fault likely contributed to the cave-in experienced during rehabilitation work in Tunnel 15. There are suspected faults in other tunnels, but these were covered by steel sets and timber lagging or shotcrete lining. All of the bedrock is jointed, with through-going, planar fractures, which in some cases are coated with clay gouge or slickensided (smoothed and grooved by geologic movements across the fractures).

6.3.3 Tunnel 13

Tunnel 13 is 2,496 feet long on an 8-degree left curve for approximately 720 feet at the north end, transitioning to tangent for the remainder of the tunnel. Approximately 1,207 feet of the tunnel is supported with timber sets, 739 feet is supported with steel sets covered with shotcrete, and 475 feet is supported with steel sets but with no shotcrete cover over the exposed timber lagging. Approximately 115 feet of the tunnel is unlined. Adjacent to the unlined sections, timber cribbing can be observed extending for 2 to 3 feet above the timber or steel sets. In some areas, soil and water in the blocked drainage ditches has caused the timber foot blocks and base of the timber sets to rot, resulting in the sets dropping by 6 to 12 inches. Approximately 65-foot-long concrete barrels support both portals. Just inside the south portal barrel, the lagging has a burnt and blackened appearance, and periodic small rockfalls have occurred through the lagging. We estimated the depth of the concrete footing wall near the south portal at about 2 feet below top-of-rail.

To prolong the useful lifespan of Tunnel 13 for another 20 years, the approximately 1,207 feet of timber set support should be replaced with grouted steel rock dowels and 3 to 4 inches of shotcrete. Approximately 123 feet of the tunnel is unlined and has experienced rockfalls. These unlined sections of tunnel should also be supported with grouted rock dowels and shotcrete. Lastly, approximately 134 feet of the tunnel is supported by steel sets and rotting timber lagging, which has locally fallen into the tunnel along with some rockfall. Shotcrete, 6 to 8 inches thick, should be placed in these sections to seal and stabilize the deteriorating timber lagging, to prevent future rockfalls, and to stabilize and anchor the steel sets.

Tunnel 13 requires up to 1.9 feet of additional clearance, with the largest improvements required on the inside of the 8-degree curve in the northern 720 feet of the tunnel. Up to 1.2 feet of additional clearance can be achieved by shifting the track away from the inside of the curve. At the north and south portals, 0.5 to 1 foot of clearance can be achieved by notching, in combination with reinforcing the portal barrels. Additional clearance improvement will require that the tunnel either be undercut by about 0.9 foot or the arch excavated and replaced over the north 700 feet of the tunnel, of which about 400 feet consists of steel sets, with and without shotcrete. The southern 1,780 feet of the tunnel is generally clear for double-stack, but will require timber set replacement with grouted rock dowels and shotcreting, and up to 20 percent of the length will likely consist of poor quality rock and will be supported with steel sets and shotcrete. The south portal requires 1.1 feet of additional clearance, after centering the track. Approximately 0.5 foot of clearance can be achieved in the concrete portal barrel by notching.

An additional 0.6 foot of clearance may be accomplished with undercutting. The northern 700 feet of tunnel could be cleared with a combination of track realignment, undercutting, and arch excavation and replacement.

6.3.4 Tunnel 14

The 471-foot-long tunnel is on an 8-degree right curve. The 50-foot-long north portal barrel is concrete. The 20-foot-long south portal barrel consists of steel sets covered with shotcrete instead of the typical curved arch. Approximately 211 feet of the tunnel is unlined, except for a thin coating of shotcrete. Minor rockfalls of a few cubic feet to a couple of cubic yards and shotcrete spalls have occurred periodically in the unlined and lightly shotcreted sections of tunnel; however, overall the rock appears to be relatively massive and stable. A steel girder bridge is present about 100 feet north of the north portal and will limit the potential for undercutting or lowering tunnel invert in order to gain additional clearance.

While Tunnel 14 is in relatively good condition and contains no timber sets, some repairs are needed to prolong its useful lifespan for another 20 years. The 401 feet of gunited bedrock has experienced several rockfalls due to insufficient gunite thicknesses of 0.5 to 1 inch. The existing gunite should be thoroughly cleaned with high pressure water and grit, and recoated with 3 to 4 inches of steel fiber-reinforced shotcrete extending across the arch and down to tunnel invert.

The unlined sections of the tunnel can accommodate double-stack cars. The north portal requires an increased clearance of 2.2 feet, mostly on the inside of the curve, and the south portal requires an additional 0.75 foot, all on the inside of the curve. The bridge adjacent to the north portal limits any undercutting at this end of the tunnel. The bedrock over the portals appears to be competent; consequently, one alternative is to excavate and replace the 50-foot-long concrete north portal barrel, and shift the track at the steel set-supported 20-foot-long south portal to the outside of the curve, and undercut/lower the track by approximately 0.5 foot.

6.3.5 Tunnel 15

Tunnel 15 is 2,143 feet long on tangent track. Concrete footings or curbs were built in this tunnel for a distance of about 1,400 feet (Stations 1+47 to 15+65). There is a culvert located approximately 150 feet from the 26-foot-long concrete north portal barrel. The 83-foot-long south concrete portal barrel has horizontal cracks running along both sidewalls, below the springline. In the last 35 feet of the portal, the crack is 6 feet above tunnel invert and the wall is bulging. At about Station 7+00, a series of steel jump sets were installed. Several of the timber arch segments have deteriorated and collapsed into the tunnel and been removed. Several sections of moderately to highly deteriorated timber sets, totaling over 150 feet of tunnel, are in desperate need of immediate repair, with splayed or crushed butt joints. The remaining 877 feet of timber set-supported tunnel appears to be in fair to good condition, but will eventually require replacement with steel sets or grouted rock dowels and shotcrete.

Between November 2006 and January 2007, major repairs were done in Tunnel 15. Steel jump sets were installed in between timber sets. In one area (Station 4+80) while incrementally removing and replacing timber sets with steel sets over a length of 12 feet of tunnel, there was a collapse that extended to about 30 feet above the tunnel arch. The resulting muck pile extended far into the caved-in area above the tunnel and was grouted from the original crown of the tunnel and above, and then reinforced with grouted steel dowel spiling drilled into the arch as a protective canopy over a top heading that was advanced in 3- to 4-foot increments through the muck pile. Steel arch sets were installed and shotcreted in place at a 3- to 4-foot spacing as the top heading advanced, leaving the lower portion of the muck pile in place to support the tunnel and also serving as a work bench. Once the arch section was completed, the remaining bench was excavated in 3- to 4-foot increments, and steel posts installed and shotcreted in place. The void above the tunnel was backfilled with lightweight concrete to prevent the cavity from eventually progressing to the ground surface.

To prolong the useful lifespan of Tunnel 15 for another 20 years, the approximately 1,068 feet of timber set support should be replaced. We have assumed that 80 percent or 854 feet consists of relatively stable rock that will be supported with grouted steel rock dowels and 3 to 4 inches of shotcrete. The remaining 20 percent is assumed to be poor quality rock and will be supported with steel sets and 8 inches of shotcrete. The drainage ditches throughout the tunnel should be re-established and the drainage should be improved away from both portals.

The north portal clears for double-stack cars. Approximately 1,068 feet of the tunnel is supported with timber sets and lagging that restrict clearance. Removal and replacement of these sets will likely result in sufficient clearance. Minor realigning and centering of the track will generally be sufficient to provide adequate clearance in the steel set-supported portions of the tunnel. Clearance of the southern 700 feet of the tunnel can be accomplished by undercutting the tunnel by a progressively larger amount with a maximum of 0.8 foot at the south portal, in combination with 0.5-foot-deep notches cut into the quarter arches of the 83-foot-long concrete portal barrel.

6.3.6 Tunnel 16

The 624-foot-long Tunnel 16 is on a 7-degree right curve. The 55-foot-long north portal concrete barrel has a longitudinal crack located 10 feet above invert. Bottom of concrete footing was measured at approximately 1.2 feet below top-of-rail. Steel sets have been installed to replace most of the timber sets and then covered with shotcrete throughout the tunnel except in the 55-foot-long concrete portal barrels. It is likely that the timber lagging and cribbing were left in place behind the shotcreted steel sets throughout the tunnel.

Tunnel 16 is in relatively good condition and contains no timber sets, and the 523 feet of steel set and shotcrete-supported tunnel appears to be sound, with very minor cracking in the arch and localized drips. No major repairs are envisioned to maintain this tunnel for an additional 20 years of service.

Clearance impediments of 0.8 to 1.8 feet for double-stack cars occur throughout the tunnel, with the largest impediments occurring on the inside of the curve. Shifting of the track by an average of 0.5 foot towards the outside of the curve will increase clearances by approximately 0.5 foot, with the remaining 0.9 to 1.3 feet of required clearance improvement to be accomplished by undercutting/lowering the track by 0.7 to 0.9 foot and notching the north and south portals by 0.5 foot.

6.3.7 Tunnel 17

Tunnel 17 is 1,200 feet long, with a 2-degree right curve for approximately the first 850 feet and then tangent alignment for the remaining 350 feet. The tunnel has very poor drainage that has caused wet and muddy conditions almost throughout. Due to the wet, muddy invert conditions, approximately 324 feet of the timber lining has been replaced with shotcrete over steel sets. Approximately 417 feet of the tunnel is still timber set-supported. Approximately 185 feet of the tunnel is unlined, except for a thin (<1 inch) coating of shotcrete.

Tunnel 17 will require replacement of timber support and re-establishment of drainage inside and outside of the tunnel for another 20 years of satisfactory tunnel performance. The poor drainage and resulting very muddy ballast and clogged ditches has contributed to replacement of about half of the timber sets with steel sets and shotcrete; however, the remaining

417 feet of timber set lining should be replaced. We have assumed that 80 percent or 334 feet consists of relatively stable rock and the timber sets will be replaced with grouted steel rock dowels and 3 to 4 inches of shotcrete. The remaining 20 percent of timber set-supported tunnel is assumed to be in poor quality rock and will be replaced with steel sets and 8 inches of shotcrete.

Clearance is impeded for double-stack cars by up to 1.2 feet over the northern 300 feet of tunnel and by up to 1.5 feet over the southern 200 feet of tunnel. Clearance in the 128-foot-long north concrete portal barrel will likely be accomplished by a combination of 0.5 foot deep notching, and 1 foot of undercutting/track lowering that should extend for about 100 feet into the steel set-supported tunnel and then taper to zero over the next 500 feet. The 55-foot-long south concrete portal barrel will also require a minor shift in the track by 0.5 foot, notching to a depth of 0.5 foot, and undercutting by 0.6 foot.

6.3.8 Tunnel 18

The 1,556-foot-long tunnel is on a tangent alignment and the track centerline is offset from tunnel centerline by about 10 inches. The north portal has no well-defined barrel, but consists of 905 feet of steel, and possibly some timber, sets covered with shotcrete, with the sets founded on a concrete curb footing. The south portal has a 53-foot-long concrete barrel. The remainder of the tunnel, approximately 622 feet, consists of timber sets, variously on wood foot blocks and concrete curbs. There is a rail spur located north of the north portal.

Many of the timber sets have posts that are out of plumb and in places the wood foot blocks at the base of the posts are rotted and crushed, allowing the timber sets to settle by up to 12 inches. Rehabilitation work in Tunnel 18 in 2007 reinforced the posts of eight timber sets that had kicked into the tunnel by 1 to 2 feet. Grouted steel dowel rock anchors and steel straps were installed into the sidewalls to restrain horizontal movement of the posts.

Tunnel 18 will require replacement of timber support and re-establishing of drainage inside and outside of the tunnel, for another 20 years of satisfactory tunnel performance. The poor drainage and resulting locally muddy ballast and clogged ditches has contributed to replacement of nearly two-thirds of the timber sets with steel sets and shotcrete; however, the remaining 622 feet of timber set lining should be replaced. We have assumed that 80 percent or 498 feet consists of relatively stable rock and will be replaced with grouted steel rock dowels and

3 to 4 inches of shotcrete. The remaining 20 percent is assumed to be in poor quality rock and will be replaced with steel sets and 8 inches of shotcrete.

The steel set-supported northern 905 feet of the tunnel is generally clear for double-stack cars, with minor realignment of the tracks satisfying the clearance needs. The remaining 622 feet of the tunnel interior is supported with timber sets that locally impede clearance by up to 1 foot. Many of the timber sets are severely deteriorated, deformed, and impede clearance, and should be replaced with a combination of grouted rock dowels and shotcrete, augmented with steel sets, as needed, to both improve clearance and provide a stable tunnel support. The 53-foot-long south portal concrete barrel will require an additional 1 foot of clearance after minor realignment of the track by 0.5 foot. Approximately 0.5 foot of additional clearance will be accommodated by grinding notches in the quarter arch of the concrete barrel and the remaining 0.5 foot of required clearance is assumed to be accommodated by undercutting/lowering the track.

6.3.9 Tunnel 19

Tunnel 19 is 4,202 feet long on a 6-degree left curve that transitions to tangent track. The north portal barrel consists of 50 feet of steel sets covered with 6 inches of shotcrete. The south portal consists of a 54-foot-long concrete barrel. The remainder of the tunnel, approximately 4,097 feet, is in sandstone bedrock covered with less than 2 inches of shotcrete. Locally, there have been rockfalls of a few cubic feet to over a cubic yard, in part due to the thin shotcrete support, and possibly due to seepage through the rock. Groundwater seepage has also contributed to the muddy ballast present throughout much of the tunnel. Blacks Creek crosses over the tunnel and may be contributing to the water infiltration in the tunnel.

While Tunnel 19 is in relatively good condition and contains no timber sets, some repairs are needed to prolong its useful lifespan for another 20 years. The 4,097 feet of gunited bedrock has experienced several small rockfalls due to insufficient gunite thicknesses of 0.5 to 1 inch. Minor slabbing will likely continue over time, but will not likely impact the overall integrity of the tunnel, although such rockfalls will pose a safety risk to passing trains. A conservative, safe approach would be to reinforce the rock sections by thoroughly cleaning the gunite with high pressure water and grit, and recoating the tunnel with 3 inches of steel fiber-reinforced shotcrete extending across the arch and down to tunnel invert. Poor drainage in the tunnel has resulted in very muddy ballast throughout. Consequently, improvement of drainage inside the tunnel and outside both portals as well as ballast replacement will be needed.

The two portals present the only clearance impediments for double-stack rail car clearance. The north portal has only about 0.2 foot of clearance impediment, which can be corrected by shifting the track 0.25 foot toward the outside of the 6-degree curve. However, the south portal has 1.4 feet of clearance impediment in both quarter arches. Clearance at the south portal can be achieved by notching (6 to 12 inches deep) preceded by grouted rock dowel reinforcement of the concrete barrel, combined with undercutting/track lowering (5 to 11 inches) followed by underpinning of the concrete lining with shotcrete. Undercutting will require an undercutting transition extending 250 to 500 feet south of the south portal. The thin shotcrete and occasional rockfalls along the 4,097 feet of gunite-lined tunnel will be improved by the placement of 3 inches of steel fiber-reinforced shotcrete in the arch of the tunnel.

6.3.10 Tunnel 20

Tunnel 20 is 874 feet long and is all on a 2-degree right curve. The north and south portals include 54-foot-long concrete barrels. The tunnel has three segments totaling 603 feet (or 70 percent of the tunnel) in which the timber sets have been removed and the remaining stable rock has been supported with thin gunite, generally less than 0.5 inch over bedrock. At Stations 7+25 and 7+60, rockfalls have occurred through the shotcrete lining. There is a large spall on the left wall at Station 6+50. Only two sections of steel and timber sets remain, totaling about 64 feet of tunnel. The Black Arm of North Tenmile Lake and a bridge are located about 250 feet north of the north end of the tunnel.

While Tunnel 20 is in relatively good condition and contains no timber sets, some repairs are needed to prolong its useful lifespan for another 20 years. The 603-foot-long gunite-supported tunnel sections consisting of gunited bedrock have experienced several small rockfalls due to insufficient gunite thicknesses of 0.5 to 1 inch. Minor slabbing will likely continue over time, but will not likely impact the integrity of the tunnel, although such rockfalls will pose a safety risk to passing trains. A conservative, safe approach would be to reinforce the rock sections by thoroughly cleaning the gunite with high pressure water and grit, and recoating the tunnel with 3 to 4 inches of steel fiber-reinforced shotcrete extending across the arch and down to tunnel invert.

The portal barrels and steel set sections are clearance impediments for double-stack rail car clearance. The north portal is tight by 2.1 vertical feet, the shotcrete/steel set section is tight by up to 1.5 feet, and the south portal is tight by up to 1.8 feet. The remaining 380 feet of shotcrete-supported rock tunnel appears to have sufficient clearance for double-stack cars.

Realigning the track by 0.8 to 1.1 feet towards the outside of the 2-degree curve will reduce the clearance impediments to a more manageable 1.5 feet at the north portal, 0.4 foot in the steel set section, and 1.6 feet in the south portal. Undercutting/track lowering is limited by the presence of a bridge 250 feet north of the north portal. Rock conditions appear to be fairly good at the portals and, consequently, deep notching in coordination with reinforcement of the portals and undercutting/track lowering by 0.6 foot will be sufficient for double-stack clearance throughout the tunnel.

6.3.11 Tunnel 21

Tunnel 21 is 478 feet long on a 4-degree right curve. The north and south ends of the tunnel are lined with approximately 55-foot-long concrete portal barrels. The sandstone observed in the lower sidewalls has weathered and turned into loose sand that accumulates on the sidewalls and blocks the ditches. The right side ditch has ponding water. The burned out timber sets have been replaced with up to 4 inches of steel fiber-reinforced shotcrete for a distance of 308 feet (or 65 percent of the tunnel). The remaining 61 feet of the tunnel is supported with steel sets covered with 1 to 4 inches of shotcrete. North Tenmile Lake is located at the north end of the tunnel. A bridge is located approximately 500 feet north of the north portal.

While Tunnel 21 is in relatively good condition and contains no timber sets, some repairs are needed to prolong its useful lifespan for another 20 years. About 308 feet of the tunnel is supported with wire fiber-reinforced shotcrete over bedrock. The shotcrete was not extended all the way down the sidewalls, and the underlying exposed sandstone continues to degrade and slough into the drainage ditches. A conservative, safe approach would be to reinforce the rock sections by cleaning the exposed rock surface and lower few feet of shotcrete with high pressure water and grit, and recoating the lower 6 feet of the tunnel sidewalls with 3 to 4 inches of steel fiber-reinforced shotcrete extending into the ditch line.

The portal barrels and steel set sections are clearance impediments for double-stack rail car clearance. The north portal is tight by 2.2 vertical feet, the shotcrete/steel set section is tight by up to 0.8 foot, and the south portal is tight by up to 1.7 feet. The remaining 308 feet of shotcrete supported rock tunnel appears to have sufficient clearance for double-stack cars. Realigning the track by 0.2 to 0.8 foot towards the outside of the 4-degree curve will reduce the clearance impediments to a more manageable 1.3 feet at the north portal, 0.8 foot in the steel set section, and 1.5 feet in the south portal. Undercutting/track lowering is limited by the presence of a bridge 500 feet north of the north portal. Rock conditions appear to be fairly good at the portals and, consequently, deep notching in concert with reinforcement of the portals, and undercutting/track lowering by 0.6 foot will be sufficient for double-stack clearance throughout the tunnel.

6.4 Portland & Western Railroad (P&W) Lines

6.4.1 General Conditions

The four P&W tunnels reviewed in this report are located on three different lines: Tunnels 0 and 1 are on the United Railways District, Tunnel 3 is on the Astoria District, and Tunnel 24 is located on the Toledo District. The Astoria and Toledo Districts connect Portland and Albany, respectively, with the Oregon Coast. The United Line branches off the Astoria Line just west of Portland and connects to Banks, located in the coastal mountain range, where it subsequently serves as the interchange point with the Port of Tillamook Bay Railroad Line.

Except Tunnel 0, which is a relatively new cut–and-cover structure underneath Highway 30, the construction of the tunnels on the P&W Lines was apparently completed between the 1880s and 1910s. Initial support consisted of timber sets, wood lagging, and timber portal structures. Tunnel 3 apparently has remained unlined since its construction.

Like tunnels on the CORP Coos Bay and Siskiyou Divisions, several of the tunnels on the P&W Lines received improvements in previous years by replacing timber sets with steel sets and shotcrete/gunite, or – such as in Tunnel 1– by casting rebar reinforced concrete arches between timber sets.

The mileposts on the P&W Lines increase from east to west. Tunnel cross sections, presented in Appendix A, generally have been collected on about 200-foot intervals, and show the tunnel configuration and required double-stack clearance envelope as if looking to the west, up milepost or up station. Shorter intervals between some cross sections were selected due to variations in liner types and their subsequent impact on the double-stack clearance requirements. Table 24 shows tunnel stationing according to increasing mileposts (0+00 at the east portal). Pictures of the tunnels and portals are shown in Photo Plates 21 through 24.

6.4.2 General Geology Along the Alignments

Based on the Geologic Map of Oregon, P&W Tunnels 0 and 3 are generally located in Columbia River Basalt, which was confirmed by observations of exposed bedrock at the tunnel portals and in unlined sections during the field reconnaissance. According to geologic maps, Tunnel 1 begins also in Columbia River Basalt on the north, but then passes through sedimentary rocks consisting of semi-consolidated volcanic ash and palagonitic sedimentary rocks in the middle section, and emerges on the south in Columbia River Basalt. During field reconnaissance of the tunnel alignment, Columbia River Basalt was the only unit observed at exposures in the tunnel and the tunnel portals.

P&W Tunnel 24 is located within the middle-Miocene Tyee Formation (see Section 6.3.2), a very thick sequence of rhythmically bedded sandstones and siltstones. During field reconnaissance, slightly tilted, interbedded sandstones and shales, typically in 2- to 5-foot-thick beds, were observed within the tunnel and the tunnel portals.

6.4.3 Tunnel 0

The 471-foot-long tunnel is on 4-degree right curve. The tunnel passes under Highway 30 and is located at the beginning of the United Railways Line. The box-shaped tunnel is concrete-lined and it appears that the underpass was constructed by utilizing cut-and-cover method. A 3-foot-wide concrete lined drainage ditch following the general tunnel grade is located on the south side of the tunnel. Based on our observations, the tunnel does not need any improvements for a 20-year design life.

The tunnel has sufficient clearance for double-stack rail cars.

6.4.4 Tunnel 1

The 4,105-foot-long tunnel at the Cornelius Pass summit, also known as "Cornelius Pass Tunnel," is located on the United Railways Line. The first 260 feet at the east end of the tunnel is on a 4-degree right curve, the remaining tunnel is tangent. Tunnel construction began in 1909 and was completed in February 1911. Concrete portal structures were added later, in the mid-1920s. Today, the tunnel has kept most of its original timber lining. Later, concrete arches were poured between the existing timber sets throughout the entire tunnel. The steel rebar-reinforced concrete arches were placed over existing timber lagging that were installed as part of the original timber tunnel liner.

In general, the tunnel appears to be dry and the liner is in overall good condition. However, exposed timber sets present a serious fire hazard, which became evident in 2005 when a fire broke out near the west portal of the tunnel. The fire destroyed exposed timber sets at the west end of the tunnel over a length of more than 1,000 feet. The fire reached behind the existing concrete liner where it ignited timber lagging and wood cribbing. Fire break locations, where the entire liner including timber sets and concrete arches were removed and bedrock was exposed in order to prevent the fire from extending farther into the tunnel, were established during the fire at around Stations 25+70 and 30+00. The section that was affected by the fire has not yet been repaired. Burnt-out timber sets left 12-inch-wide gaps in the concrete liner, which has resulted in rubble and debris falling through the liner. This will continue to present a considerable hazard if it is not repaired. Consequently, the following improvements will be needed to maintain a 20-year operational life of the tunnel.

Repairs are recommended at the west end of the tunnel in the area affected by the fire in 2005, during which essentially all timber sets were destroyed in this tunnel section (see also paragraph above). Open gaps left in the 12- to 14-inch-thick liner between the concrete arches due to burnt out timber sets should be backfilled and remaining timber sets should be removed and replaced with steel fiber-reinforced shotcrete. The shotcrete should be applied flush with the surrounding concrete arches. We recommend that the shotcrete used to fill these gaps should be at least 6 inches thick. Due to the 12- to 14-inch-depth of the gaps in the liner and large voids observed behind the liner, expanded mesh may be used to “back-form” the proposed backfill area in order to control shotcrete amounts and improve the shotcrete application process. Similar repairs are required between Stations 9+18 and 13+00, and between Stations 21+71 and 29+93, where timber sets partially collapsed into the tunnel.

We recommend the replacement of all existing timber sets in the remaining portions of the tunnel in order to reduce future fire hazards. Timber sets surrounded by concrete or shotcrete have been excavated on other projects with a roadheader. However, sparks from the milling process may potentially ignite dry timber. Consequently, continuous wetting of the timber will be an essential safety precaution. After timber sets are removed, the gaps should be backfilled with shotcrete, similar to the repair process described in the prior paragraph.

To achieve double-stack clearance, clearance improvements in both quarter arches are required throughout the tunnel. This could be accomplished by notching and realigning track which appears to be 1 to 3 inches off-center, in general.

To further improve long-term stability of the tunnel support, voids and open space between the existing liner and bedrock surface, which were observed at numerous locations and which are anticipated to exist throughout the tunnel, should be filled with light-weight grout backfill to fill voids between the tunnel liner and the bedrock. Due to indicated inconsistencies in dimensions and locations of voids it is impractical to estimate concrete volumes and cost for this operation at this point in time and further investigation, such as a series of probe holes, will be needed to evaluate the estimated grout volumes.

6.4.5 Tunnel 3

The 193-foot-long tunnel is located on the Astoria line. The line connecting Portland with Astoria located on the coast was established in the late 1890s. The tunnel is on a 2-degree left curve and unlined. Observed bedrock exposures in the tunnel consist of Columbia River basalt with lattice work-like joints and fractures (instead of the more typical column-like appearance). The unsupported basalt appears to be relatively stable with no indications of recent rockfalls or overbreaks. The current tunnel conditions are good for a 20-year operational life. Any rockfall activity should be observed and recorded during regular tunnel inspections.

The tunnel does not provide double-stack clearance under current conditions. Crown and quarter arches will need notching up to 12 inches locally in order to accomplish the required clearance.

6.4.6 Tunnel 24

The 669-foot-long tunnel is located in the Toledo District, which was completed in the 1880s as part of the original line connecting Albany with Yaquina Bay. The east 269 feet of the tunnel is on a 10-degree left curve, and the west 400 feet of the tunnel is on a tangent alignment. Timber trestles are located approximately 640 feet east and 25 feet west of the tunnel.

Existing tunnel liner types include shotcreted steel sets, shotcrete over bedrock, and original timber sets with timber lagging. Timber sets rest on wood foot blocks that are typically covered with ballast and debris. The timber-lined section appears to be relatively old and shows signs of rotting and advanced deterioration at many locations. Timber set segments have fallen out of the quarter arches and crown at several locations. An 80-foot-long section consisting of steel sets that replaced the original timber sets had been prepared for shotcrete by placing steel mesh over the existing timber lagging, but the work was never carried out. It appears that the tunnel has been undercut, which may have resulted in drainage problems and extremely muddy, fouled ballast, particularly at the west end of the tunnel. Undercutting of the tunnel may have also contributed to the poor condition of the bridge abutment 25 feet west of the tunnel.

To accomplish 20-year operational life of the tunnel, the timber-lined sections will need to be replaced, likely with pattern-grouted rock dowels and a shotcrete cover as timber sets are removed. In addition, tunnel portions supported with non-shotcreted steel sets should be encased in a layer of 8-inch-thick shotcrete in order to shield the timber lagging left in place behind the sets from fire hazard. Grade improvements are necessary to re-establish drainage, and fouled ballast should be replaced to improve track condition. Adjustments and reconstruction of the bridge abutment adjacent to the west portal may be necessary to accomplish suggested grade and track improvement.

The curved section and the timber-lined section of the tunnel currently do not satisfy double-stack clearance requirements. Realignment and shifting the track to the right can accomplish the required clearance in the curved portion of the tunnel. Double-stack clearance in the timber-lined section will require the removal of the entire existing timber liner and replacement with rock dowels and steel fiber-reinforced shotcrete and/or steel sets and shotcrete in poor quality rock.

7.0 PRELIMINARY OPINION OF PROBABLE CONSTRUCTION COST

Our opinion of the preliminary construction cost estimate is based on average unit prices observed on similar construction projects, and on our experience. Tables 3 through 28 present our opinion of probable construction costs by tunnel. Table 29 is a summary of our opinion of probable construction costs to 1) extend the reliable and safe operation of these tunnels for another 20 years without improving clearance and, alternatively, 2) the rehabilitation along with improvements to double-stack clearances for the 24 tunnels. Our cost estimate includes costs for removal of rail, ties, and ballast, where rock undercutting is required, but does not include costs for re-establishing drainage, sub-ballast, ballast, track, and ties and for temporarily relocating and then replacing FOCs, where present. We understand from discussions with railroad subcontractors that the cost to remove the old ballast, ties, and track from a tunnel, and place new ballast and shape the drainage ditch may range from $400 to $500 per foot of tunnel. The placement of rail and ties is typically accomplished by railroad personnel. From this preliminary assessment of double-stack clearance improvement, it appears that a combination of track realignment, notching, timber set replacement, and partial undercutting will be the most cost-effective approach.

Higher clearance improvement costs would likely occur if clearance improvements are accomplished under "live track" conditions with limited work windows, which could further limit the cost-effectiveness of track removal and undercutting.

At bid time, costs could be higher or lower than anticipated, depending on many factors out of our control. We have included in our estimate a contingency of 10 percent of the total cost. To develop this cost estimate, we have made a number of assumptions on the scope of final design. However, as the design is developed with new information, the assumptions made at this time may change and have a direct impact on the estimated cost.

8.0 ADDITIONAL EXPLORATIONS AND DESIGN FOR CONSTRUCTION

For either raising the arch or lowering the invert of the various tunnels to gain the additional necessary clearance, as well as for repairing deteriorated or fire-prone timber linings, additional exploration and design work will be required. Our evaluations of the conditions of the 24 tunnels have thus far only involved assessment of existing clearance constraints and logging of the visible conditions in the tunnels. Additional information will be required for each tunnel in order to develop designs, plans, and specifications for tunnel rehabilitation and clearance improvements. The additional surveying and explorations needed to advance the design and develop construction documents is likely to be on the order of 1 to 2 percent of the estimated construction costs.

Track grades and curvatures inside the tunnels were obtained from track charts provided by the railroads and information provided by ODOT. The data will need to be verified by actual field measurements and surveys. Clearance car surveys of all tunnels should be accomplished with composite sections spaced 20 feet apart to assess tight spots, length of clearance impediments, and changes in liner type. Track centerline surveys should be implemented to confirm total length of tunnels, degree of curvature, lengths of various liner support systems, and grade of the tunnels.

Lowering of the tunnel invert, at a minimum, should be preceded by exploration of the thickness of ballast, depth of curbs, footings, or walls below top-of-rail, presence and depth of FOCs and other utilities below the drainage ditches, effectiveness of the drainage system, and options for improving and redirecting drainage. Probes and geophysics through the ballast and along the wall footing should be performed every 50 to 100 feet throughout the tunnels. Where FOCs are suspected to be present, the owners should be contacted and a coordinated site visit should be arranged and the FOCs should be carefully exposed at 100- to 200-foot intervals throughout the tunnel to determine if its presence will impact undercutting/lowering of the track.

Enlargement of the tunnel arch should be preceded by exploration with probe holes, rock coring, and geophysics to assess the thickness of the liner, presence of voids, depth of rubble fill, depth to solid rock, and general condition and characteristics of the rock.

Chemical contamination residue from engine stack gasses likely exist on all tunnel surfaces and should be sampled to determine the variety and concentration of various contaminants in order to assess the necessary safety precautions for construction workers, and the appropriate disposal measures for excavated wood, concrete, and ballast.

9.0 LIMITATIONS

The analyses, conclusions, and recommendations presented in this report are based on site conditions as observed during our various site visits in summer and fall of 2008, the information contained in our files and the clearance section files provided by ODOT, CORP, and P&W. We have not performed probes through the tunnel liner or borings to determine subsurface conditions. Given the variable and somewhat unpredictable nature of naturally fractured rock, and the unknown thicknesses of the rock rubble and cribbing over the tunnel liners, it is likely that subsurface conditions different from those anticipated will be encountered in future explorations or appear to be present during construction. If significant variations in ground or liner conditions are encountered, we should be advised at once so that we can review those conditions and reconsider our recommendations. If there is a substantial lapse of time between submission of our report and the start of work at the tunnels, or if conditions have changed because of natural forces or human activity, or if conditions appear to be different from those described in our report, we recommend that we review this report to determine the applicability of the conclusions and recommendations.

This report was prepared for use by ODOT to make a preliminary evaluation of the feasibility and cost-effectiveness of remedial repairs to extend the useful lifespan of the 24 short line railroad tunnels and the required tunnel enlargements to accommodate double-stack car clearances. Due to this report's preliminary nature, and lack of in depth explorations, it should not be made available to prospective contractors.

Unanticipated conditions are commonly encountered and cannot be fully determined by merely taking rock samples or visually logging the condition of the tunnels. Such unexpected conditions frequently require additional services to achieve a properly constructed project. For conceptual or preliminary level design assessments a 20 to 25 percent contingency fund is relatively common.

The scope of our services did not include environmental assessments or evaluations regarding the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below the site, or for the evaluation and disposal of contaminated soils or groundwater, should any be encountered. However, we do have experienced personnel on staff who can address environmental issues should they arise.

Shannon & Wilson has prepared and included in Appendix B, "Important Information About Your Geotechnical/Environmental Report," as an integral part of this report to assist you and others in understanding its use and limitations.

SHANNON & WILSON, INC.

Klaus G. Winkler
Principal Engineering Geologist

Robert A. (Red) Robinson
Senior Vice President
Director of Underground Services

REGISTERED PROFESSIONAL ENGINEER 66833PE OREGON ROBERTO JOSE GUARDIA 1/29/09
RENEWAL DATE 06/30/09

Roberto J. Guardia, P.E.
Vice President

CERTIFIED OREGON GARY L. PETERSON E 845 ENGINEERING GEOLOGIST
Renews April 2009

Gary Peterson, C.E.G.
Vice President

Geotechnical design recommendations were prepared under the direction supervision of Roberto J. Guardia, P.E. Geologic interpretation and subsurface explorations were prepared under the direct supervision of Gary Peterson, C.E.G.

KGW:RAR:RJG:GP/kgw

10.0 REFERENCES

American Railway Engineering and Maintenance Right-of-Way Association (AREMA), 2007, Manual for railway engineering, Chapter 28 – Clearances, page 28-2-9, Plate F.

Orr, Elizabeth L., Orr, William N., and Baldwin, Ewart M., 1992, Geology of Oregon: Fourth Edition: Dubuque, Iowa, Kendall/Hunt.

Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey.

Winkler, K.G., Robinson, R.A., and Guardia, R.J., 2009, Tunnel inventory – Coos Bay Subdivision, Oregon: Prepared for Rail America Operations West.

11.0 GLOSSARY OF TERMS

Arch – The curved or segmented ceiling of a tunnel.

Back Packing – Material, such as timber, rock debris, or Styrofoam used to fill the space between the timber lagging and bedrock surface.

Clearance Improvement – Enlarging a tunnel or structure by a combination of undercutting and arch excavation or notching to provide additional space for the unobstructed passage of various rail car configurations.

Cribbing – Wood blocks stacked in an orderly fashion between the sets and rock surface.

Curb – Low concrete footing walls, typically 2 to 3 feet high and about 1 foot thick that run along the walls of some tunnels and provide support for timber or steel sets.

Double-Stack Cars – Specialized flat-bed railcars with two-high stacked freight containers that can be readily transferred to ships and flat-bed trucks.

Double-Stack Clearance Envelope – The clear or unobstructed opening needed to allow passage of a train of double-stack rail cars.

Foot Block – Timber (typically) block, approximately 1 to 2 feet thick, by 1.5 to 2 feet square, placed on the ground to support the vertical posts of the timber or steel sets.

Grout – Neat cement slurry or a mix of cement, sand, water and other additives that may be pumped into voids as a filler, or injected in to drilled holes to anchor steel rock dowels.

Gunite – Sprayed concrete, with sand aggregate, and conveyed through a hose and pneumatically projected at high velocity at a surface. Gunite may contain chemical accelerators to reduce set time, 1- to 2-inch-long steel or polypropylene fibers for reinforcement, and other additives to enhance strength, reduce permeability, and reduce water content.

Invert – The bottom or floor of a tunnel.

Jump Sets –Additional set (timber or steel) placed between existing sets to provide additional tunnel support.

Lagging – Longitudinal timber boards placed around the circumference of the tunnel between and behind the sets to retain backfill rock and cribbing.

Lattice Girder – An open, relatively light-weight, pre-assembled girder, consisting of reinforcing steel bars joined and braced together by intersecting diagonal bars.

Notching – The cutting of a shallow, usually 1- to 12-inch-deep notch or furrow in concrete, shotcrete or bedrock to enhance clearance for a rail car. Notching is most commonly accomplished with a roadheader, but also by controlled smooth-wall blasting and chipping with a backhoe mounted “hoe-ram.”

Pattern Dowels – The installation of a grouted steel rock dowel in borehole drilled on a regular pattern around the tunnel perimeter.

Portal – The normally reinforced entrance to either end of a railroad tunnel.

Quarter Arch – A point on a horseshoe-shaped or arched tunnel that is midway between the springline and centerline of the arch.

Roadheader – A crawler-track mounted, mobile machine fitted with an adjustable boom on which is mounted a rotary cutting head with ripping- or milling-type carbide tipped teeth.

Rock Block – A block of intact rock bounded by natural or man-made fractures.

Rock Dowels – An untensioned steel reinforcing rod or dowel embedded in a grout-filled hole in the rock mass to knit or anchor adjacent rock blocks together.

Set – An arched or segmented individual steel or wood frame used in tunnels to support the excavation at discrete intervals, typically spaced 2 to 5 feet apart, depending on the condition of the ground.

Shoring – Various support systems for stabilizing and supporting the tunnel sidewalls during and following undercutting/lowering of the invert.

Shoring Piles – Drilled piles spaced along and just inside the tunnel sidewalls to provide lateral and vertical support for the tunnel walls.

Shotcrete – Sprayed concrete, with aggregate graded up to minus ⅜ inch, and conveyed through a hose and pneumatically projected at high velocity at a surface. Shotcrete may contain chemical accelerators to reduce set time, 1- to 2-inch-long steel or polypropylene fibers for reinforcement, and other additives to enhance strength, reduce permeability, enhance pumpability, and reduce water content.

Sidewall – Near-vertical sides of a tunnel. Sidewalls meet the arch at the springline.

Spiles – Steel dowels shoved into holes drilled sub-horizontally above and ahead of an advancing excavation to provide a canopy of reinforced rock for temporary support.

Spot Dowels –The installation of rock dowels in localized areas of potentially unstable rock, as determined during excavation or based on field mapping of rock falls.

Springline – The point where the curved or inclined portion of the arch or roof meets the top of the near vertical sidewall.

Struts – A piece of wood or steel inserted between each pair of sidewall support legs to resist buckling of the sidewalls due to lateral earth pressures.

Tri-Level Rack Auto Carriers – Specialized piece of railroad rolling stock used to transport new automobiles and light trucks from the factories to automotive distributors.

Undercutting – The act of excavating and lowering the invert elevation of a tunnel to provide more vertical clearance.

Unlined – An essentially unsupported section of tunnel where the bedrock is either exposed, or to which a thin, less than 1 inch, coating of gunite or shotcrete has been applied.