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ENGINEERS/CONSULTANTS/CM

FINAL REPORT

DESIGN MEMORANDUM

ALLEGHENY TUNNEL EXPANSION

Engineering & Construction Management
Hydro • Nuclear • Fossil

Tunnel Engineering

Geotechnical Engineering

Seismic & Structural Engineering

Hydrological & Hydraulic Engineering

Environmental Engineering & Permitting

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PROJECT NO. 12-4747
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1.0 INTRODUCTION

The Pennsylvania Turnpike Commission is currently developing plans for the Allegheny Tunnel Transportation Improvement Project. One of the design concepts is to widen the existing tubes to provide additional lanes and to increase shoulder widths to meet current design standards. This Report presents a summary of the evaluation conducted by Paul C. Rizzo Associates, Inc. (RIZZO) to determine whether widening of the tunnel is a viable option.

This Report contains an evaluation of the existing geological and geotechnical information that is available, an evaluation of the design and construction issues related to tunnel widening, and an evaluation of the costs associated with widening the tunnels. This Report focuses on the civil design issues and does not consider lighting, ventilation, and fire, environmental, permitting, or socioeconomic issues. However, estimated costs for supporting infrastructure including lighting, ventilation, and fire systems developed by others are included in the cost estimate presented in this Report.

2.0 SITE CONDITIONS AND GEOLOGY

RIZZO has reviewed the existing geotechnical information for the Allegheny Tunnel Transportation Improvement Project provided by L.R. Kimball. The following information was reviewed:

- Proposed Allegheny Tunnel No. 2, Pennsylvania Turnpike, Geologic Investigation (Ackenheil and Associates, 1961)
- Engineering Characteristics of the Rocks of Pennsylvania (Geyer and Whilshusen, 1982)
- Analysis of the Potential for Acidic Drainage from the Proposed Brown Cut (Casselberry, 2002)

The primary source of geotechnical information is the 1961 geologic investigation performed to assist in design of the second portal of the existing Allegheny Tunnel. This Section summarizes the geotechnical conditions at the Allegheny Tunnel Site, which have been used to prepare conceptual level designs, and associated budgetary construction estimate for widening the existing tunnels.

2.1 SITE DESCRIPTION

Based on available information, the existing configuration at the Allegheny Tunnel site consists of two 6,070 feet (ft) long tubes, approximately 14 feet high and 30 feet wide with 24 ft wide by 14 foot high traffic portals. The first tube was constructed in 1939, and the second tube was constructed to the south of the original tube and was completed in 1965. Both tubes currently carry two lanes of directional traffic with minimal shoulders/safety lanes outside of the traffic lanes. As shown on Figure 1, the subsurface conditions vary widely from the portal entrances across the tunnel alignment.

The West Portal was constructed through a minimal sandy soil layer with boulders and rock fragments from 9 to 24 ft thick and penetrates massive orthoquartzite sandstone. The slope of the mountain above this portal is much flatter than at the East Portal, resulting in an approximate cut face height of 45 ft.

The East Portal was constructed through a minimal sandy clay soil layer 8 to 10 ft thick and penetrates a mix of sandstone and limestone. These sandstones and limestones also exist in outcrop above the portal entrance, and show solutioning, sculpture, and sinkholes from limestone dissolution where exposed. In addition, it appears that surface runoff charges these features which results in small springs in the area. The cut face was around 80 ft high at the Portal entrance due to the relatively higher mountain surface at the East Portal.

According to the boring logs, the rock along the tunnel alignment away from the East and West Portals is generally massive to slightly fractured, with core drilling recovery higher than 80 percent. The Ackenheil Report suggests that drilling and blasting was used to excavate the new tunnel bore in the 1960s.

2.2 GEOLOGIC FORMATIONS

As shown on ***Figure 1***, the Allegheny Tunnel penetrates the following geologic units from west to east: the Kittanning Sandstone of the Allegheny Group, Pottsville Group, Mauch Chunk, Loyalhanna, and Pocono. The Allegheny and Pottsville formations are Pennsylvanian aged, while the other formations are from the Mississippian period. The formations along the tunnel alignments are gently folded to flat lying sedimentary rocks in alternating layers including sandstone, limestone, claystone, siltstone, and shale formations through Allegheny Mountain. In general, the bedrock dips to the west at about 20 degrees and the water table is around 10 ft above the tunnel alignment.

2.3 ENGINEERING CHARACTERISTICS OF ROCKS

This Section includes a preliminary evaluation of the engineering properties of the rocks along the tunnel alignment and describes each formation. ***Table 2-1*** shows general characteristics of the formations along the tunnel alignment. (Geyer and Wilshusen, 1982.)

TABLE 2-1
ENGINEERING PROPERTIES OF GEOLOGIC UNITS
ALLEGHENY TUNNEL

FORMATION	POROSITY AND PERMEABILITY	EASE OF EXCAVATION	CUT-SLOPE STABILITY	ROCK TEST DATA
Allegheny Group (Kittanning Sandstone)	Porosity moderate in sandstone, low in other rock types. Permeability moderate to low	Difficult in sandstone, moderately easy in weaker fine grained rocks, moderate drilling rates	Fair, undercutting of limestone beds by shale, claystone, underclay, and coal cause rockfalls, slumps, and landslides. Homogenous sandstone units may have good stability	Compressive Strength: 23,000 psi Modulus of Rupture: 28,000 psi Impact Toughness: 6.6 in/in^2 Young's Modulus: $3.57x10^6$ psi Specific Gravity: 2.70 Porosity: 1.4 %
Pottsville Group	Primary and secondary porosity moderate. Permeability moderate	Difficult in highly weathered sandstone and other rocks	Fair, undercutting in shale and coal under thick beds of sandstone and conglomerate causes rockfalls and slumping. Drainage diversion channels may be needed	Not available
Mauch Chunk Formation	Low to moderate porosity in sandstone and siltstone, joints provide abundant secondary porosity in shale, sandstone, and siltstone, effective porosity is high. Moderate to low permeability	Moderately easy to moderately difficult, depending on rock type and fracturing	Good if severe undercutting of resistant beds does not occur	Compressive Strength: 311 to 2,830 tsf (4,319 psi to 39,306 psi)
FORMATION	POROSITY AND PERMEABILITY	EASE OF EXCAVATION	CUT-SLOPE STABILITY	ROCK TEST DATA
Loyalhanna Limestone	This unit possibly a sub-unit of Mauch Chunk			
Pocono	Interstitial porosity and secondary porosity result in a high effective porosity. Moderate to low permeability	Difficult, moderate to slow drilling rate	Good, rockfalls occur where bedding and joints intersect and rock is steeply dipping toward the cut	Not available

The Kittanning Sandstone of the Allegheny series is present in outcrop at the West Portal of the Tunnel. This sandstone consists of fine to coarse grained orthoquartzite sandstone that is very hard and massive where it is not dissected by joints and bedding. Below the massive sandstone, silty sandstone exists that is more susceptible to weathering than the orthoquartzite rock. This formation generally requires drilling and blasting for cost effective excavation.

The Pottsville Series is primarily sandstone with conglomeratic zones interbedded with carbonaceous shale and impure coal seams. This formation generally requires blasting for cost effective excavation. The existence of coal seams and shale beds could present issues with shelving during excavation.

The Mauch Chunk Formation consists of variegated red claystones and silty shales with sandy lenses and calcareous zones. Depending on the actual rock types encountered in the excavation, this formation could be dug mechanically using road headers or an excavator, or excavated using drill and blast operations.

The Loyalhanna Formation is one massive stratum made up of equal parts of sandstone and limestone. This formation generally requires blasting for cost effective excavation.

The Pocono Formation consists mainly of sandstones. The Burgoon Sandstone is one of these sandstones and comprises most of the outcrop at the East Portal. The Burgoon Sandstone is massive but contains large joints and continuous bedding planes. The heavy jointing of this formation makes movement of rock blocks along joints and bedding more likely than in the more massive formations along the tunnel alignment. This formation generally requires blasting for cost effective excavations in more massive areas, but may be broken enough for excavation with heavy mechanical equipment in some areas. Excavation stability is a particular concern in this formation and significant stabilization is expected to be required in this area.

3.0 DESIGN CONSIDERATIONS

This Section describes the items that will need to be considered in the design of the Tunnel Widening. The information in this Section was developed based on the information available for the site during the preparation of this Report.

3.1 TUNNEL DEMOLITION AND MAINTENANCE AND PROTECTION OF TRAFFIC

One of the criteria for the Project is that the existing tubes remain open to traffic for the majority of the time during construction. Intermittent full closures of the tunnel and reductions to one lane may be required during the Project, but these restrictions could be scheduled during off-peak times. Full closures or restrictions to one lane would likely be required during the following times:

- Tunnel Ceiling Removal: The geometry of the tubes may not allow for shield assembly until the false ceiling in the existing tube has been removed. This will depend on the height of the existing tube ceiling, the clearance required for truck traffic, and the design of the tunnel shield. If the false ceiling needs to be removed prior to full assembly of the shield, traffic through the existing tunnel during ceiling removal could not be maintained and bi-directional traffic through the adjacent tube would be required.
- Tunnel Shield Mobilization and Demobilization: Traffic will need to be stopped to assemble and disassemble the shield.
- Blasting: Traffic stoppages of up to 30 minutes should be expected during blasting activities. Traffic would need to be stopped for the blast, and for a period of time after the blast to allow dust and debris to dissipate or be removed. The tube would also need to be checked for hazardous gasses after the blast.

To expedite the construction schedule, each tube could theoretically be excavated starting from both the east and west ends of the West Portal at the same time. However, this approach would likely increase cost substantially, introduce logistical issues for the Contractor, and would require additional traffic stoppages. Therefore, we do not believe that excavating from both sides of each tube is a viable option.

3.2 GROUNDWATER INFLOW

Joints and bedding planes were encountered in each test boring drilled on the East Portal based on the Geologic Investigation performed by A.C. Ackenheil & Associates, Inc. in 1961. This is typical of the geology in the area and indicates that water could flow into the tunnel during construction. Therefore, dewatering will likely be required for expansion of the existing tunnels. If available, the construction records from the tunnel built in the 1960s may provide information on the amount of water encountered, and the dewatering that was required during construction of this tunnel.

An owner/engineer dewatering plan should be developed before construction begins. The owner/engineer dewatering plan will be developed to address dewatering and will need to evolve throughout the project as different ground conditions are encountered. Groundwater can have a significant effect on productivity and schedule and; therefore, could have a significant impact on the cost of the Project. Several options that could be considered for dewatering are discussed below.

3.2.1 Dewatering at the Tunnel Face

One of the most common methods of dewatering is controlling groundwater through dewatering at the tunnel face. This would consist of allowing the water to flow in through the open face of the tunnel and remove it from the construction area using pumps, pipes or other means. This method would likely be viable for this Project based on the anticipated groundwater levels.

3.2.2 Drain Holes

Probe holes ahead of the tunnel face may be drilled to verify the characteristics of the rock and to provide information for machine operation and excavation techniques. In areas where there are known deposits of gas or other contaminants it is common (and recommended) practice to drill one or more probe holes in front of the excavation. These holes could also be used to pre-drain the rock and provide warning of increased volumes of water. The holes would also provide warning of any methane, hydrogen sulfide or any other gas or contaminant that may be present. When such conditions are encountered, the probe holes can alert the construction crew so they can adjust for anticipated increased groundwater flow, increase the frequency of gas readings, increase the volume of ventilation, or to take other steps as required.

3.2.3 Grouting

In order to control groundwater inflow, a series of grout holes could be drilled ahead of the tunnel face to intercept joints and other defects in the rock. The holes would be drilled to approximately a tunnel diameter beyond the tunnel face. The holes would then be grouted, possibly in several phases, to reduce groundwater inflow before advancing the tunnel.

3.3 EXCAVATION OF TUNNEL EXPANSION

Three types of excavation are generally considered for tunnel widening projects: drilling and blasting, road header, or hydraulic hammer. Drilling and blasting is the most common rock excavation technique, and is typically the most efficient and cost effective in hard rock if a Tunnel Boring Machine (TBM) is not feasible. However, drilling and blasting techniques require careful monitoring of adjacent structures and careful planning with regard to the existing rock type and defect pattern to prevent unwanted overbreak or unsafe excavation conditions. Considerations for roadheaders, drilling and blasting, and hydraulic hammer excavation are detailed in the following sections. A discussion of the feasibility of excavation along the tunnel alignment using each of the methods is also included.

3.3.1 Expansion Width

The minimum width of the expanded tubes is a function of the number of additional traffic lanes, minimum lane, and shoulder widths based on Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) standards.

Expanding the tunnel will consist of widening the West Bound tube from two to four lanes and expanding the East Bound tube from two to three lanes. The West Bound Tube expansion would involve increasing the existing traffic lanes widths from 11 to 12 feet, providing new 12-foot-wide traffic lanes, and expanding the shoulder and sidewalk widths to meet current standards (i.e., 3.5 feet on the right and 2.5 feet on the left). The East Bound tube expansion would also involve increasing the existing traffic widths from 11 to 12 feet, providing a new 12-foot-wide traffic lane, and expanding shoulder and sidewalk widths. Details of the proposed East Bound and West Bound tube expansions are shown on ***Figures 3 and 4***. We have included additional space of 2.5 feet per tube for lining the ceiling and walls, over excavation, and other features.

Therefore, the total proposed width for the expanded East and West Bound tubes are 49 feet and 61 feet, respectively.

This excavation option assumes a crescent shape excavation heading to the south for each tunnel. This will require engineering analysis to evaluate the impact of widening the tunnels on the adjacent tunnels.

3.3.2 Roadheader

Roadheaders are rotary tools mounted on excavator or drill jumbo booms that grind away the cut face, and can be very effective in soft to medium hard rock or soil conditions. Strong and/or abrasive rocks can greatly reduce the production rates of road header excavation and greatly increase the amount of maintenance required to keep the machines running due to excessive wear on the header teeth (picks). Advantages associated with roadheaders include minimal overbreak, especially for odd shapes, and minimal disturbance to the surrounding rock mass. Excavation with a roadheader could likely proceed with minimal impacts on traffic if a shield is used in the tunnel.

Most roadheaders have an electric motor and; therefore, would not emit fumes in the tunnel that would need to be considered in the ventilation system design. A roadheader would require a generator on site for power, and step up and step down transformers would likely be required to power the roadheader in the tunnel from the generator located outside the tunnel. For the type of rock and volume of rock that will be excavated for the tunnel expansion, a large roadheader will be required to excavate the rock efficiently. We anticipate that a roadheader with a cutting motor power of approximately 200 – 250 kilowatt (kW) or greater would be required. The Sany EBZ 260H can economically cut rock with an unconfined compressive strength up to approximately 13,000 pounds per square inch (psi). A diagram of a typical roadheader is shown on ***Figure 2***.

Additional equipment required for excavation using a roadheader would likely include a dust suppression unit, ventilation equipment, a laser guided alignment control system, and a cooling unit. A conveyor system or a skidsteer or loader, and haul trucks would also be needed for removal of the excavated material. One roadheader on the side of the tunnel may not be able to reach over and across the traffic shield to excavate rock. An additional roadheader attachment mounted on a 20 to 30 ton excavator could also be used to excavate rock the main roadheader could not reach.

The roadheader could likely reach to a height of approximately 16 ft. Since the new tunnel height is expected to be greater than 20 ft, the roadheader will need to start construction on a platform or pad built up with excavated material. As the construction advances, the pad, or platform can be removed. The roadheader could also potentially excavate the material at the top of the tunnel first then excavate material at the bottom of the tunnel as it progresses.

3.3.3 Mechanical Excavation

Excavation with a hydraulic hammer is generally suitable for rock of all strengths and hardness; however, production rates are generally slow in massive rocks with few fractures. In fractured rocks, production rates are faster because the operator can take advantage of existing defects to speed up breaking out the rock mass. Excavation with a hydraulic hammer will also generally cause minimal disturbance to the surrounding rock mass, but overbreak could be higher than with other methods.

General excavation equipment such as excavators with hydraulic breakers could be utilized for the mechanical excavation in the tunnel. Even though a ventilation system will be supplied in the tunnel, a low sulfur diesel engine or a natural gas engine could be considered to reduce emissions in the tunnel.

3.3.4 Drill and Blast

Drilling and blasting is acceptable for removal of all types of rock. One of the drawbacks with the drilling and blasting is the potential to overshoot the zone or weaken an adjacent area during excavation. Unsafe conditions can be created during blasting when the rock surrounding the tunnel is fractured and disturbed, and blasting can also require creating a larger opening and more supports than would otherwise be needed. There would also be limitations associated with blasting near an operating roadway, including reduced allowable blast energy compared to the allowable energy for new construction and the need to stop traffic for each blast and long enough after a blast to clear harmful gases and verify the roadway is clear. This time frame is assumed to be approximately one half hour.

Blasting control using nonelectric fuse systems should be considered as this would allow for charges to be set prior to stopping traffic and vibration induced velocity should be measured during the initial rounds of blasting. A test section may also be considered to measure the effect of blasting on the rock and surrounding structures. If a cast-in-place concrete liner is used, it may be necessary to allow the concrete liner to cure to a certain strength before blasting is done nearby. A non explosive demolition agent like Da-mite may also be considered for rock removal. Da-mite is a rock splitting mortar that breaks rock or concrete by expanding in pre-drilled holes. The advantages of a non explosive demolition agent could include less overbreak during excavation, a smaller shield, and the elimination or minimization of traffic stoppages.

3.3.4.1 Depths and Quantities

Although current drilling and blasting techniques could yield production rates ranging from 10 to 15 ft along the tunnel alignment per blast, the maximum length of the area of rock removed by each blast will be dictated by the engineering characteristics of the rock (i.e., compressive strength, fracture spacing, etc.), the length and structural capacity of the tunnel shield, and limitations on the blast energy. These factors may limit the amount of rock that can be removed per blast. Possible reduced blasting rates have been considered in the development of the schedule included in this Report.

Overbreak and over excavation can be controlled using the following controlled blasting principles:

- Creating Relief: To effectively fragment the rock, there must be space for the rock fragments created from the blast to move. If adequate space is not provided, then the rock is fractured but not fragmented, and the unstable rock mass will remain in place. Therefore, the geometry of the blast hole array must be designed to allow movement of the rock fragments.
- Delay Sequencing: To optimize the relief, internal free faces must be created during the blasting sequence by utilizing millisecond delay detonators that separate the firing times of the charges.
- Tunnel Blast Specifics: Tunnel blasting differs from surface blasting in that there is usually only one free face that provides relief. An array of blastholes is drilled using drilling equipment that can drill several holes at once. The pattern of drill holes is determined before the blast, taking into account the rock type, the existing discontinuities in the rock (joints, fractures, bedding planes), and the desired final shape of the tunnel. This sequence of firing is called Burn Cut.
- Burn Cut: Since the start of each cut with a solid face has no relief, several extra holes are usually drilled and not loaded with explosives in the immediate area of the initiation point. These burn holes are generally larger than the loaded holes. Many different geometries of burn holes are used to optimize the cut, depending on the rock type and joint patterns in a specific tunnel

geology. These holes are fired first, with enough firing time to allow the creation of a free face for the following holes to expand.

3.3.5 Assessment of Excavation Techniques

The shales, claystones, siltstones, sandstones, and limestones that the tunnel alignment penetrates have widely ranging strengths and structural characteristics. In general, the sandstones and limestones are likely to be hard and massive and at the depths of the tunnel alignment are expected to be slightly too moderately fractured. Excavation in these rock types can be expected to be slow with mechanical excavation techniques. Drill and blast excavation methods could allow for faster production rates, but the limited blast energy required to prevent damage to the surrounding rock formation, existing tunnels, and traffic shield may severely limit production rates using drill and blast methods. In general, the shales, claystones, and siltstones are generally softer than the sandstone and limestone, but may contain comparably hard lenses. These materials will likely allow for better production rates using the mechanical excavation techniques.

Estimates of the excavation volumes in each of the rock types required to widen both tunnels have been developed as described in ***Section 3.3.1***. The volumes are presented in ***Tables 3-1***

TABLE 3-1
SUMMARY OF GEOLOGIC UNITS AND EXCAVATION VOLUMES FOR TUNNEL WIDENING

Station Range		Rock Type	Formation	Description from Boring Log	Rock Excavation (CY) [1]
126200	127005	Sandstone	Allegheny	Light grey, cross-banded, fairly massive, medium grained, with calcareous streaks and silty zones	53380
127005	127146	Shale	Pottsville	Black carbonaceous/argillaceous, with streaks of impure coal	9350
127146	127622	Sandstone	Pottsville	Grey to dark. Grey cross-bedded with many carbonaceous streaks, fine to coarse grained to conglomeratic, with silty zones	31564
127622	128387	Claystone and Siltstone	Pottsville	Massive	50728
128387	128534	Shale	Pottsville	Dark grey, fairly massive, carbonaceous, silty	9748
128534	128716	Sandstone	Pottsville	Light grey, massive, carbonaceous, argillaceous	12069
128716	128993	Claystone	Mauch Chunk	Variegated, red, green, grey, massive, with sandy lenses and calcareous zones	18368
128993	130005	Shale, Siltstone, and Claystone	Mauch Chunk	Variegated, red, green, grey, massive, with sandy lenses and calcareous zones	67107
130005	130422	Limestone	Loyalhanna	Mottled red and grey, argillaceous, with sandy streaks	27652
130422	130845	Claystone	Pocono	Variegated, red, green, grey, massive, with sandy lenses and calcareous zones	28050
130845	132270	Sandstone	Pocono	Light grey, massive, cross-bedded, slightly calcareous, fine grained, orthoquartzite, with hairline carbonaceous and micaceous streaks. Near eastern limits of tunnel friable, stained w/ limonite, conglomeratic, porous	94493
Approximate Total Estimated Excavation Volume (CY):					400000

Approximately 50 percent of the proposed tunnel excavation is in the harder sandstones and limestones and 50 percent is in the softer shales, claystones, and siltstones. The exterior portions of the tunnel alignment generally consist of the harder units, while the softer units make up the interior of the mountain. Site specific strength data and detailed information about the rock quality along the tunnel alignments such as Rock Quality Designation (RQD) values, Unconfined Compressive Strengths, P-Wave or S-Wave velocities, tensile strengths, and

Abrasivity Indices are not included in the existing geotechnical information. These data are critical for determining the most cost effective method for excavating the rock at the Site. Based on the existing information, we believe that it will be possible to widen the tunnel using a roadheader and mechanical methods for most of the geologic units along the existing tunnel alignment. However, drilling and blasting will be required in some sections of the tunnel. In the case of new tunnel construction in moderately hard rock, the use of mechanical excavation methods such as roadheaders or hydraulic hammers are likely to have slower production rates than drill and blast methods. However, for tunnel widening for an odd shape with a shield protecting traffic lanes, drill and blast and mechanical excavation may have comparable production rates due to the limitations of blasting near an operating roadway.

Excavation by drilling and blasting techniques will be required when the rock hardness and structure slows or stops the rate of roadheader or mechanical excavation production to the point that it is not the most economical option. Based on the available geotechnical information summarized in this report, we believe that drilling and blasting will be required in portions of all five of the major rock formations along the tunnel. However, based on the published engineering characteristics of the Kittanning Sandstone of the Allegheny Group (i.e., massive structure and high compressive strength), more of this formation will require blasting than the other rock formations.

Sections of the tunnel where drilling and blasting may be required more frequently include:

- Allegheny Formation: Sta. 126200 to 127005
- Pottsville Formation: Sta. 127146 to 127622
- Pottsville Formation: Sta. 128534 to 128716
- Pocono Formation: Sta. 130845 to 132270
- Loyalhanna Formation: Sta. 130005 to 130422

To reduce the risk associated with tunnel construction, a test section near the existing tunnel could be done to evaluate the effectiveness of a roadheader and mechanical excavation techniques before tunnel construction begins. The test section could help to define excavation rate, pick use, and other key information.

3.4 TUNNEL SHIELD

3.4.1 Description

The tunnel shield required to widen the tunnel while maintaining traffic flow will consist of a top working deck and two supporting walls under the working deck. The supporting walls will rest on rails to allow the whole system to move longitudinally along the length of the tunnel. The working deck will need to be strong enough to protect traffic from falling rocks and debris, including during blasting, and should also be designed to support a CAT 320 excavator or equivalent construction equipment.

The following approximate tunnel shield dimensions summarized in the following paragraph are based in part on the shield used at the Inner Shikishima Tunnel in Japan (Tonon, 2010) as well as our understanding of the requirements for Allegheny Tunnel.

The shield would be approximately 150 to 200 ft long, and would weigh about 350 to 450 tons. The shield will need to be wide enough to span two lanes of traffic in the tunnel and to allow an excavator or similar equipment to work on the top of the shield. The shield will have three segments. The front segment of the shield will be about 30 ft long and will fit inside the existing tunnel to possibly allow demolition of the existing tunnel lining while protecting traffic. The middle segment of the shield will be between 65 ft and 100 ft long and will be made to carry excavation equipment and will need to be designed to resist blasting and falling debris. The rear segment of the shield will be about 50 ft long and will follow behind the active excavation to protect traffic while the lining for the new tunnel is placed.

The shield may also need to include a lift for transporting equipment and material up to and down from the working deck on top of the shield. The shield will require both shop and field fabrication, and will need to be transported to the Site in segments. The shield will likely have a long lead time and will need to be procured well in advance of the start of construction.

Dimensions for the protective shield used at Inner Shikishima Tunnel Project (Tonon, 2010) are provided in ***Table 3-2***. Shield dimensions and weights would likely be similar for widening the Allegheny Tunnel.

TABLE 3-2
DETAILS OF PROTECTION SHIELD

PARAMETER	NAME	VALUE
Total Length		152.6 ft
	Front Segment	32.8 ft
	Middle Segment	65.6 ft
	Rear Segment	54.1 ft
Effective Inside Diameter	Minimum	13.1 ft
	Maximum	23.0 ft
Effective Inside Height		13.1 ft
Outside Width of Segment	Standard at Minimum	17.1 ft
Outside Height of Segment	Standard	15.2 ft
Total Weight		350 tons

3.4.2 Case History Summary

An analysis of case histories for tunnel enlargement projects constructed without restricting traffic resulted in the following conclusions (Tonon, 2010):

1. Original tunnel widths ranged from 7 to 30 ft and the enlarged tunnel widths ranged from 20 to 50 ft.

2. To allow traffic during construction, a protective shield was used to protect traffic from the construction activities.

3. In 80 percent of the projects, small construction equipment was used to work between the shield and the crown of the enlarged tunnel, or in the drifts on either side of the shield.

Details for the shields utilized in two notable tunnel enlargement projects are briefly summarized in the following sections.

3.4.2.1 Nazzano Tunnel, Italy

The shield protecting the road was a self-propelled steel traffic shell. The shield had a total length of 196.9 ft and extended approximately 131.2 ft ahead of the widened face. It consisted of a modular steel structure and was equipped with runner guides, anchors, motors, and sound proof anti-shock panels to absorb the shock of falling blocks of material during excavation. When tunnel widening advanced to the point where the distance between the face and the front end of the shield reached what was considered the minimum safety limit for vehicle traffic, it was moved forward and the various stages repeated in cycles until the whole tunnel had been widened.

3.4.2.2 Shikishima Tunnel

The total length of the movable shield was 152.6 ft and the total weight of the shield was 350 tons. Additional details associated with the shield are provided in ***Table 3-2***. Drilling and blasting was used to excavate the rock to widen the tunnel and only the front segment of the shield was reinforced to resist blast loads.

3.4.3 Allegheny Tunnel Shield

There is a potential to use the existing sidewalls, sidewalks, or barriers (infrastructure) in the tunnel to support the protective shield system. However, engineering analysis would need to be performed to determine if the existing infrastructure can support the loads from the tunnel shield. If the existing infrastructure does not have adequate capacity to resist the loads from the shield, new reinforced concrete infrastructure will need to be designed and constructed to support the shield. This could impact the number of road closures required for the project assuming a closure would be required to remove or enhance the existing tunnel infrastructure and to construct adequate infrastructure.

The shop fabrication work, transportation, and assembly outside the tunnel and inside the tunnel could be performed prior to the allowable construction season, which is assumed to begin on May 2 of each year as described in ***Section 3.7.2***. The shield would be assembled on tracks in the median and then rolled into place on tracks that will be installed inside the tunnel. The tracks inside the tunnel can be installed with one lane closure at night to reduce the impacts on traffic. To move the shield into place and set it up would likely require about 48 hours. It is expected to take approximately 1 day to remove the shield. It is estimated that each tunnel would need to be closed for approximately 30 days to remove the false ceiling, assuming the false ceiling could not be removed while the shield was in place. An estimate of the number of additional days required for road or lane closures for the duration of the project is summarized in ***Tables 3-3 and 3-4***.

TABLE 3-3
ROAD CLOSURES AND RESTRICTIONS WITH ONE ROAD HEADER - WEST PORTAL

SHIELD SET UP/YEAR	DAYS	SHIELD REMOVAL/YEAR	DAYS
2015	2	2015	1
2016	2	2016	1
2017	2	2017	1
2018	2	2018	1
2019	2	2019	1
2020	2	2020	1
2021	2	2021	1
2022	2	2022	1
2023	2	2023	1
2024	2	2024	1
Total	20		10

TABLE 3-4
RAIL SETUP WITH ONE LANE RESTRICTION

RAIL SET UP/YEAR	DAYS	RAIL REMOVAL/YEAR	DAYS
2015	5	2015	2
2016	5	2016	2
2017	5	2017	2
2018	5	2018	2
2019	5	2019	2
2020	5	2020	2
2021	5	2021	2
2022	5	2022	2
2023	5	2023	2
2024	5	2024	2
Total	50		20

3.5 LINING OF NEW TUNNEL

The new tunnel will need to be lined, likely with cast in place concrete or with a segmental concrete lining. The lining will be placed immediately behind the excavation and tunneling as work advances.

3.6 CONSTRUCTION SEQUENCE

An anticipated construction sequence has been developed based on the information available at this stage of the Project. Where information is not currently available, assumptions have been made. This construction sequence was also used to develop the conceptual cost discussed in

Section 4.0. Volumes were estimated assuming the expanded tunnel will follow the existing Tunnel Alignment, that excavation can only be performed south of the existing alignment, (Crescent Shape Construction) and that traffic can only be stopped for brief periods of time during construction.

TABLE 3-5
ANTICIPATED CONSTRUCTION SEQUENCE

Pre-Permitting	Permitting needed to advance the project to the point of construction.
Mobilization	Mobilization for office personnel and required equipment for job startup is expected to be between 12% and 15% of the total cost of the project.
Surveying	Initial surveying will be required to set extents and limits of construction.
Instrumentation Monitoring	Instrumentation monitoring is expected to start before construction and continue well past the completion date.
Erosion and Sedimentation Control	Erosion and Sedimentation Control will need to be put in place before work commences and maintained as construction proceeds.
Dewatering	Dewatering is assumed to start before construction begins in accordance with the Owner/Engineer. Dewatering plan will evolve as the project progresses.
Tunnel Shield	Shop Fabrication, Field Fabrication, and Mobilization of each shield.
Existing Tunnel Demolition	Demolition of the existing tunnel will start after each tunnel shield is mobilized and continue as the shields advance.
Dewatering ahead of Face from Probe Holes	Probe holes will likely be drilled in rock ahead of tunnel to allow for water drainage and detection of any trapped gases.
Grouting	Grouting of Large Joints and Bedding Planes may be required.
Roadheader Excavation	Excavation using roadheaders will advance from each direction. Ventilation, power supply, and excavation spoils removal will also be provided for each direction.
Tunnel Mapping	Tunnel mapping will be completed concurrently with excavation.
Liner Construction	Liner will be installed over the protection shield rear segment while excavation is advancing
Ventilation Installation	Ventilation installation will proceed with liner installation
Lighting Installation	Lighting installation will proceed with liner installation
Tunnel Shield	Tunnel shield will be advanced for the next rock cut
Mechanical Excavation	Mechanical excavation will be done as necessary along with the roadheader excavation and drilling and blasting
Tunnel Mapping	Tunnel mapping will be completed concurrently with excavation.
Liner Construction	Liner will be installed over the protection shield rear segment while excavation is advancing
Ventilation Installation	Ventilation installation will proceed with liner installation
Lighting Installation	Lighting installation will proceed with liner installation
Tunnel Shield	Tunnel shield will be advanced for the next rock cut
Drilling and Blasting	When rock is too massive or too hard for effective excavation using the roadheader, drilling and blasting will be required in each direction.
Tunnel Mapping	Tunnel mapping will be completed concurrently with excavation.
Liner Construction	Liner will be installed over the protection shield rear segment while excavation is advancing
Ventilation Installation	Ventilation installation will proceed with liner installation
Lighting Installation	Lighting installation will proceed with liner installation
Tunnel Shield	Tunnel shield will be advanced for the next rock cut.

3.7 EXCAVATION RATES

Excavation rates will vary based on the type of equipment used, the geological conditions encountered, and the geometry of the section being excavated. As described in ***Section 2.3***, the unconfined compressive strength of the rock encountered is likely to vary from 4,000 psi to 39,000 psi. This data, along with rates of production for similar work and discussions with equipment manufacturers, was used as the basis for the development of the excavation rates in this Section.

3.7.1 Roadheader Excavation Rates

When the roadheader is in use, it is expected that it would be in operation approximately six hours per shift with the remaining time during the shift dedicated to clean up, debris removal, moving the shield, and equipment maintenance. It is assumed that there will be two shifts per day, six days per week during construction. The roadheader is expected to excavate between 10 cubic yards and 15 cubic yards per hour when in operation. The total amount of excavation is 400,000 cubic yards. Assuming 50 percent of the excavation can be done with the roadheader, we estimate the following duration for excavation with the roadheader:

- 400,000 cubic yards x 50 percent using roadheader = 200,000 cubic yards of excavation using roadheader
- 200,000 cubic yards / 13.5 cubic yards per hour = 14,815 hours
- 14,815 hours / 6 hours excavation per shift = 2,469 shifts
- For 2 shifts per day total days worked = 1,235 working days
- Assuming 125 working days a year, 1235 days/125 working days per year = 9.88 years; say 10 years
- For work proceeding from both ends of tunnel, total road header time = 5 years assuming the eastbound and westbound tunnels are not worked on simultaneously

3.7.2 Total Construction Duration

Mechanical excavation and drill and blast excavation will likely proceed at approximately the same rates as the roadheader excavation. We expect that mechanical excavation would be performed for approximately 25 percent of the total volume, and that drill and blast excavation would be performed for the remaining 25 percent of the total volume. For this estimate, we have assumed that excavation can only occur from May 2 to September 30 each year due to environmental issues associated with the Indiana bat hibernaculum located in the South Penn Railroad Tunnel located approximately 60 feet from the West Bound Tube. Therefore, only mobilization and demobilization of equipment can occur between October 1 and May 1 each year when excavation is prohibited. Assuming that all the excavation proceeds at an average rate of 13.5 cubic yards per hour we estimate the following total duration:

- 400,000 cubic yards total excavation / 13.5 cubic yards per hour = 29,630 hours
- 29,630 hours / 6 hours excavation per shift = 4,940 shifts
- For 2 shifts per day, total days worked = 2,470 working days
- Assuming 125 working days a year, 2,470 days/125 working days per year = 19.76 years, say 20 years
- For work proceeding consecutively from one end of each tube, total estimated duration for the west bound tunnel = 12 years and for the east bound tunnel 8 years. This takes into account that the west bound tunnel is scheduled to be widened to 4 lanes and the east bound 3 lanes.

Due to the expected rates of tunnel excavation, construction will likely need to proceed consecutively from one end of each tube. Therefore, two tunnel shields, two roadheaders, and two sets of supporting equipment will be required and are considered in the cost estimate. Assuming construction proceeds in each tunnel at approximately the same rate, excavation is estimated to be completed in approximately 10 years.

4.0 CONCEPTUAL COST ESTIMATE

This Section provides a summary of the items that were considered in the conceptual cost estimate along with the total estimated cost for tunnel widening. A list of the key considerations and items that affect the cost estimate included in this Report are also provided. The Cost estimate is presented in ***Appendix A*** and is summarized in ***Table 4-1*** below.

TABLE 4-1
COST ESTIMATE

DESCRIPTION	VOLUME OF EXCAVATION (cy)	ESTIMATED CIVIL CONSTRUCTION COST (MILLION $)[1]	ESTIMATED SUPPORTING SYSTEMS COST (MILLION $)[2]	ESTIMATED TOTAL COST (MILLION $)
Four lanes Westbound, Three lanes Eastbound	400,000	$330	$368	$698

Notes:

1. The cost estimate presented in ***Appendix A*** has been multiplied by 1.5 to develop the construction costs shown in this column. The 1.5 factor is to account for the shortened construction season due to environmental issues.
2. Estimated supporting Systems Costs provided by Gannett Fleming

A cost estimate has been developed as follows:

1. Initial Tunnel Excavation: $330M
2. Lighting and Ventilation and Portals: $72M x 1.5 = $108M
3. Roadway Improvements: $260M

4.1 COST ESTIMATING SCOPE

The cost estimate for Civil Construction portions of the proposed tube widening includes the following items:

- Mobilization/Demobilization
- Surveying
- Erosion and Sedimentation Control
- Existing Tunnel Removal
- Dewatering including possible:
  - Dewatering at Tunnel Face
  - Drainage ahead of Face from Probe Holes
  - Grouting
- Tunnel Shield
  - Shop Fabrication
  - Transportation and Permitting
  - Field Fabrication
  - Rail Setup
  - Shield Removal and Disposal
- Instrumentation Monitoring
- Excavation by Roadheader
  - Roadheader Purchase
  - Roadheader Equipment
  - Pick (Teeth Replacement)
  - Additional Spare Parts
  - Hydraulic Set Up
  - Hydraulic Consumption
  - Dust Suppression Machine
  - Ventilation Operation
  - Ventilation Equipment
  - Haul Equipment
  - Laser Guided Alignment Control System
  - Cooling System

  - Electrical Issues
- Mechanical Excavation
  - CAT 320 Excavator or Equivalent
  - Roadheader Attachment
  - Teeth Replacement
  - Ventilation Operation
  - Ventilation Equipment
  - Haul Equipment
- Drilling and Blasting
  - Permitting and Monitoring
  - Storage Location and Guard
  - Ventilation Operation
  - Ventilation Equipment
  - Haul Equipment
  - Ventilation Operation
  - Ventilation Equipment
- Work in Progress Ground Treatment
  - Rock Bolts
  - Cast in Place Concrete /Segmental Liner
  - Contact Grout
  - Geologic Mapping

4.2 ASSUMPTIONS

Due to the expected rates of tunnel excavation through moderate to hard rock with limited drill and blasting and continual traffic with a shield, the construction sequence envisions starting at both ends of a given tunnel simultaneously. Excavation work is time constrained due to Environmental issues associated with the bat hibernaculum located in the abandoned tunnel located to the west of the site. The estimated costs for supporting systems, where applicable, have been provided by Gannett Fleming and include construction costs for fire protection systems, roadway improvements, traffic signs, and other appurtenances.

4.3 CONSTRUCTION EQUIPMENT

It will be important to have additional equipment and parts on site for key pieces of equipment like the roadheaders that may impact the schedule if they break down. Additional wear items like roadheader teeth will also be required on site. In addition, any items required for construction that have a long lead time should be identified to prevent delays in construction in event of a breakdown.

We estimate that the roadheader will perform up to 50 percent of the total excavation. Therefore, the excavation contractor will need to keep the roadheader in good working condition using the best maintenance practices during operation and downtime. If a roadheader is nonoperational, it is probably not possible to use manual excavation equipment to take the place of a roadheader since the roadheader machine covers a large area of the tunnel. The following is a list of equipment that requires spare parts:

- Hoses
- Bolts
- Picks (Teeth)
- O-Rings
- Replacement Drum
- Motor
- Conveyor Belt

Additional spare Parts or items needed to operate the Roadheader are listed below:

- Main Bearings
- Bushings
- Electrical Equipment
- Backup Generators
- Additional Ventilation
- Water Supply

The excavation contractor will need readily available spare parts to minimize production down time.

The number of picks used for the roadheader increases with the hardness of the geologic formation. Therefore, several back up picks will need to be on site when one breaks and/or needs replaced.

Depending on which manufacturer supplies the road header, the lead-time for the spare parts described above can vary considerably. Therefore, the construction specifications should require that the Excavation Contractor have a number of spare parts that have a long lead-time on site before excavation can proceed. This should minimize schedule delays due to equipment breakdowns and unavailable spare parts.

Long lead-time items also include the protective shield. The protective shield will need designed, approved, fabricated, and placed before construction excavation can begin.

5.0 SUMMARY AND CONCLUSIONS

This Report presents a summary of the evaluation conducted by RIZZO for widening the existing tubes as part of the Allegheny Tunnel Transportation Improvement Project. A conceptual designs and cost estimate was developed for widening both the East Bound and West Bound tubes. An evaluation of the available geologic and geotechnical information was presented and the suitability of various excavation equipment was evaluated.

Based on the existing information and time constraints imposed on the construction, widening of the existing Allegheny Tunnel is not practical for the following reasons:

The duration of the project is affected by maintenance of traffic, low production rates of excavation, and seasonal restrictions placed on construction activities due to environmental issues associated with the Indiana Bat hibernaculum located in the nearby South Penn Railroad Tunnel. These requirements may extend the construction duration up to 20 years.

Sequential closing of the tubes required for approximately (six) 6 months will result in bi-directional traffic in the tube not under construction. There will also be numerous traffic stoppages associated with blasting with durations up to 30 minutes each. The traffic control measures required for the widening of the existing tubes are not practical due to the interruption of traffic flow, increased accident hazard, and substantial congestion generated by these operations. The contractor will have appropriate safety measures in place; however, due to the nature of the construction activities and confined working space adjacent to traffic, there is an increased accident risk during widening of the existing tubes.

Adequate ventilation is critical and must be provided during construction to ensure appropriate visibility for traffic due to dust created by construction activities occurring within the closed environment of the tunnel. Depending on the method of excavation utilized, this will require close monitoring and could result in possible modifications to proposed construction methods as well as unscheduled closures of the tunnels due to reduced visibility.

The cost associated with widening the tubes of the Allegheny Tunnel and associated roadway improvements is estimated at nearly $700 million, which is likely higher than other engineering alternatives.

Disturbance of the South Penn Railroad Tunnel, directly or indirectly due to construction activities, has the potential to adversely alter the bat hibernaculum, which could be an important environmental issue.

6.0 REFERENCES

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Geyer, Alan R. and Whilshusen, J. Peter, Pennsylvania Geological Survey, "Engineering Characteristics of the Rocks of Pennsylvania," 1982.

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FIGURES

PLOT	DRAWN BY	J.S.S.	CHECKED BY	APPROVED BY	CAD FILE NUMBER
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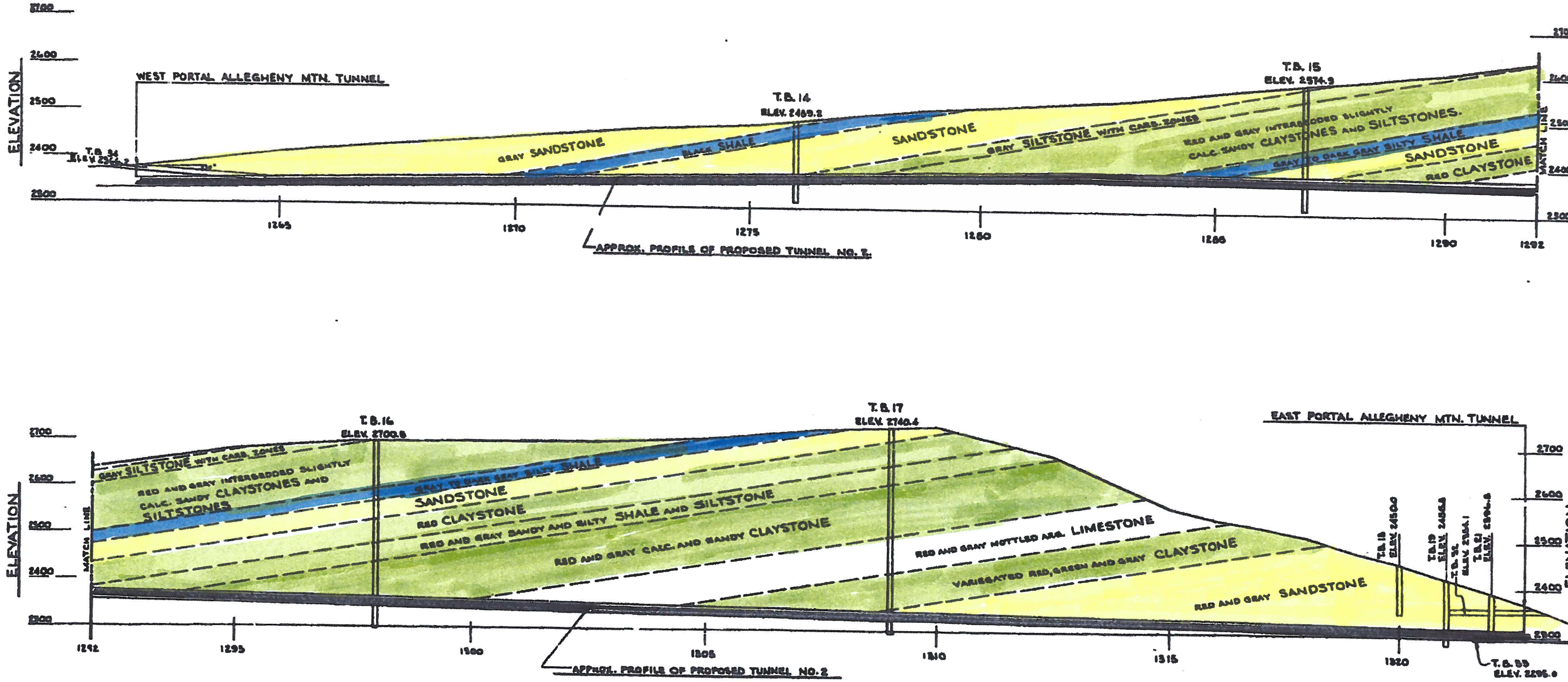


REFERENCE:

A.C. ACKENHEIL & ASSOCIATES, INC.
1961 "PROPOSED ALLEGHENY TUNNEL NO. 2,
PENNSYLVANIA TURNPIKE, GEOLOGIC INVESTIGATION," REPORT
PREPARED FOR THE PENNSYLVANIA TURNPIKE COMMISSION
UNDER MICHAEL BAKER, JR. INC. DESIGN CONSULTANT.

DRAWING NOT TO SCALE

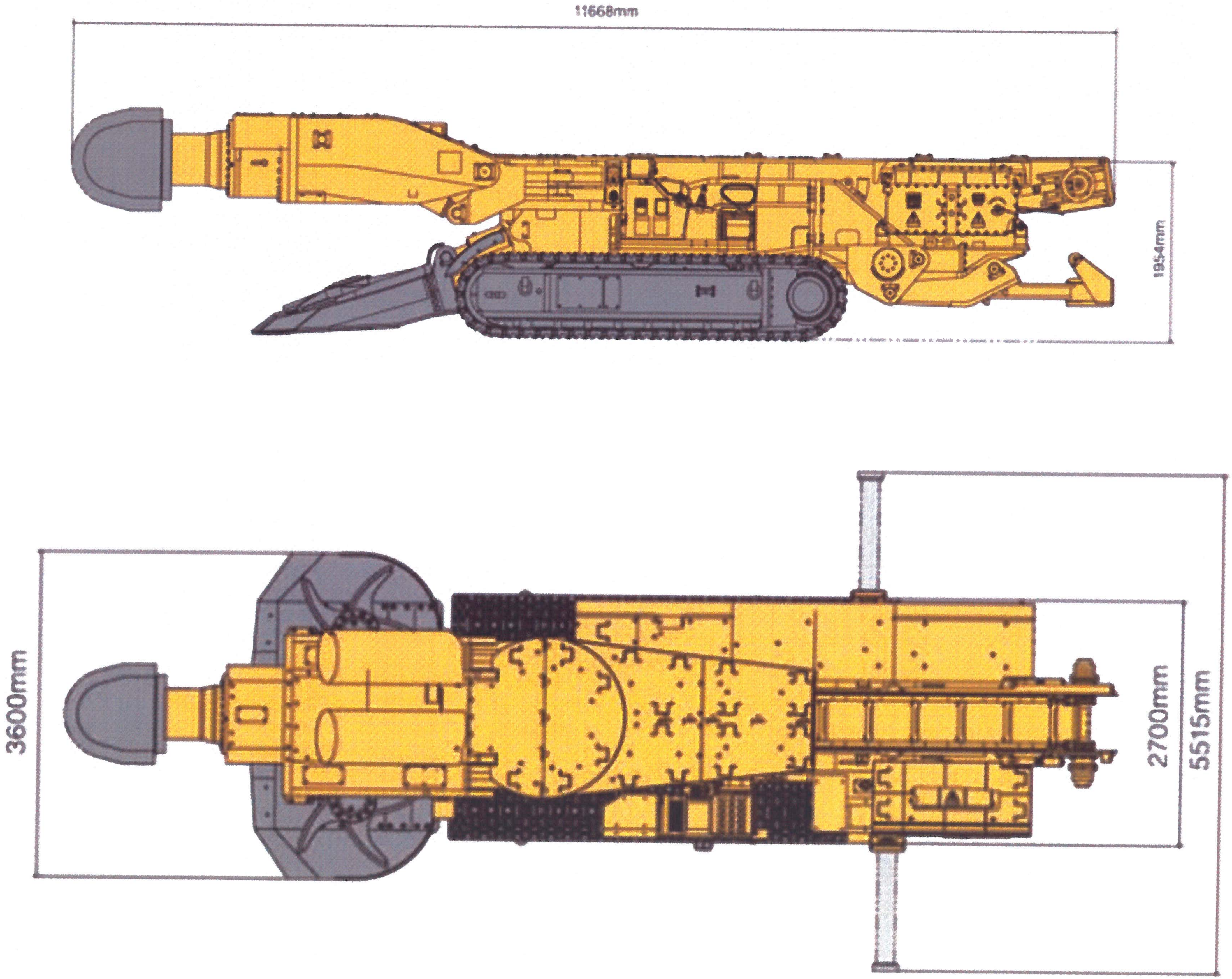
FIGURE 1

GEOLOGIC PROFILE
ALONG TUNNEL ALIGNMENT
ALLEGHENY MOUNTAIN TUNNEL

PREPARED FOR

PA TURNPIKE COMMISSION
SOMERSET, PENNSYLVANIA

Paul C. Rizzo Associates, Inc.
ENGINEERS / CONSULTANTS / CM



DRAWING NOT TO SCALE

FIGURE 2

TYPICAL ROADHEADER DIAGRAM

ALLEGHENY MOUNTAIN TUNNEL

PREPARED FOR

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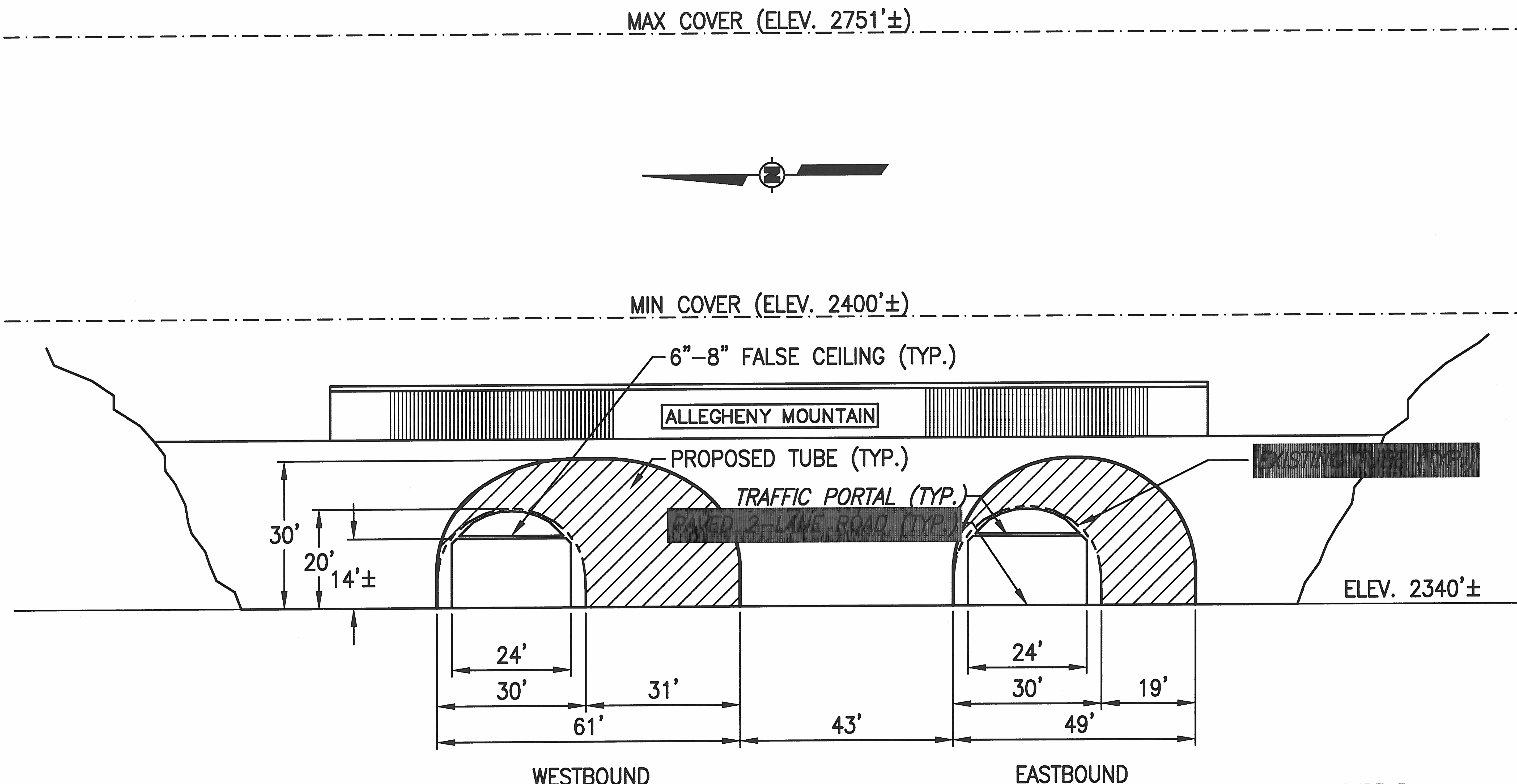

WEST PORTAL ELEVATION

SCALE

20 0 20 FEET

- AREA TO BE EXCAVATED

NOTES:

WESTBOUND: 4 LANES
EASTBOUND: 3 LANES

FIGURE 3

TUBE EXCAVATION OPTION
WEST PORTAL
ALLEGHENY MOUNTAIN TUNNEL

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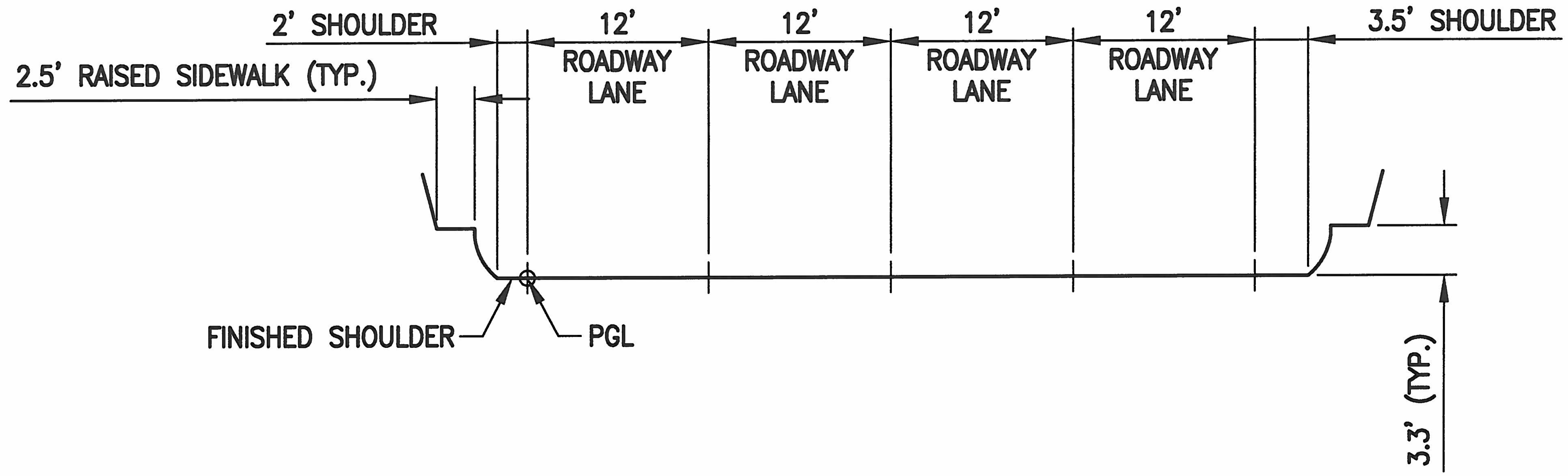
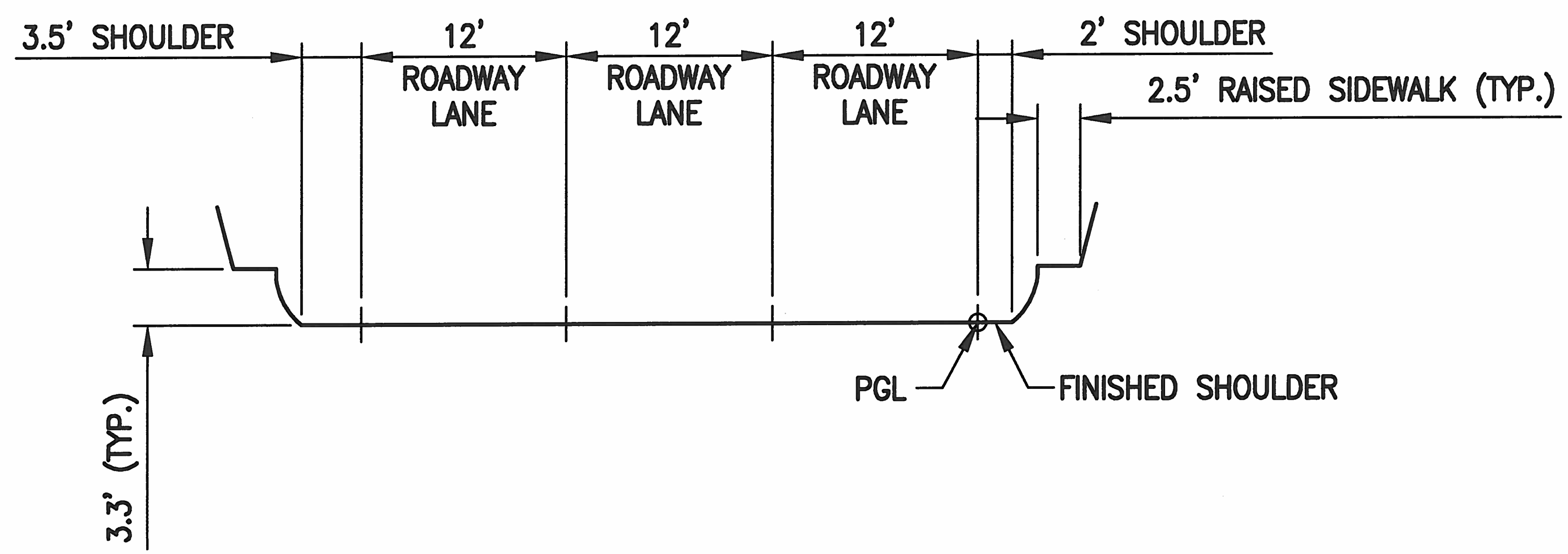


WESTBOUND TYPICAL TUBE ROADWAY
WITH REDUCED SHOULDER WIDTHS



EASTBOUND TYPICAL TUBE ROADWAY
WITH REDUCED SHOULDER WIDTHS

FIGURE 4

TUNNEL ROADWAYS
TUBE EXCAVATION OPTION
ALLEGHENY MOUNTAIN TUNNEL

PREPARED FOR

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APPENDIX A

COST ESTIMATE

ENGINEERS & CONSULTANTS

Allegheny County Tunnel
Conceptual Cost Estimate
Tube Excavation Option

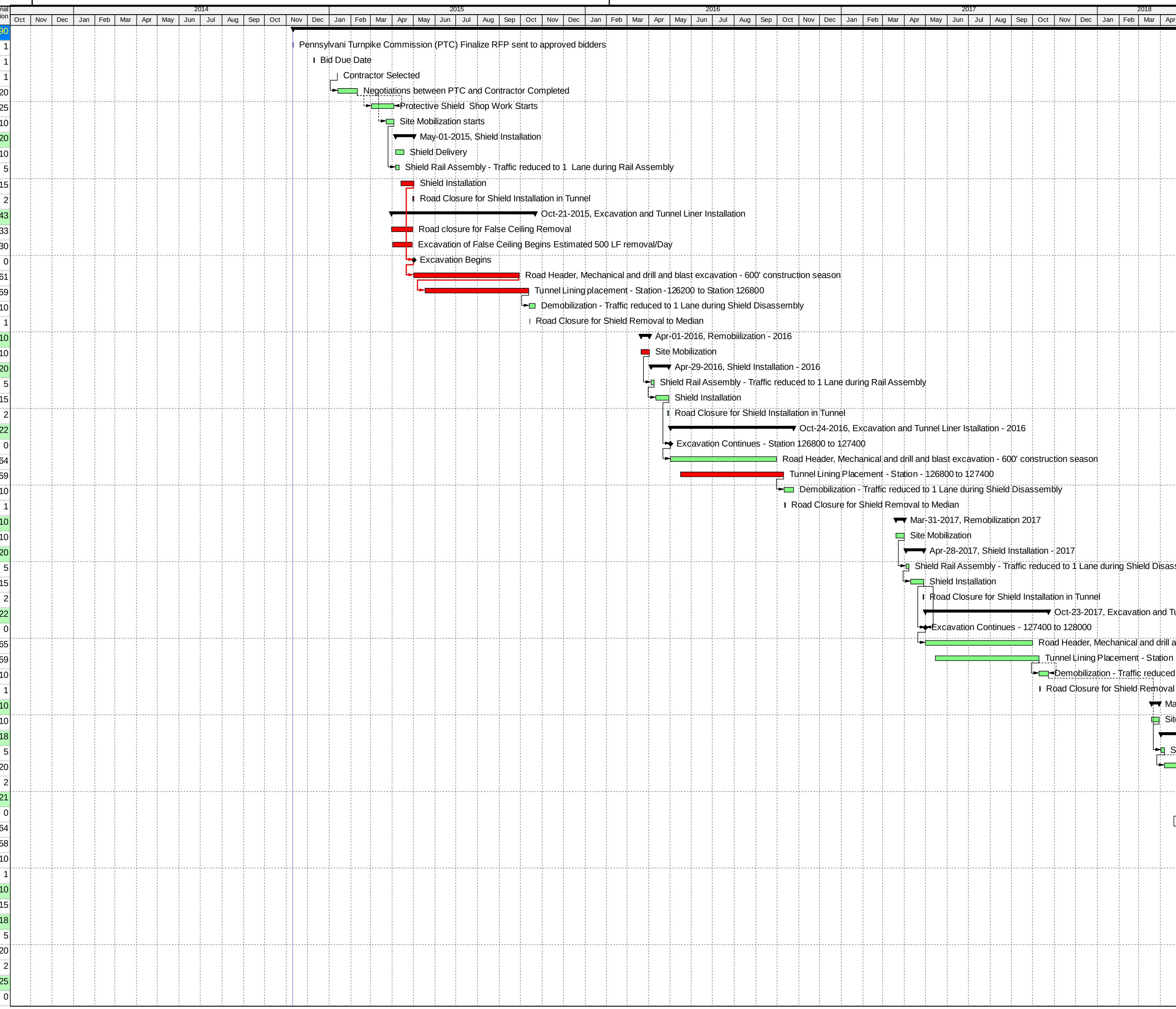
Item	Description	Engineers Estimate Estimated Quantity	Unit of Measure	Unit Cost	Total Estimated Cost
1.0	**Mobilization/Demobilization**				
1.1	Mobilization/Demobilization (15% of cost)	1	Lump Sum		$25,000,000
1.2	Erosion and Sedimentation Control	1	Lump Sum		$1,000,000
1.4	General Costs (Site Office, Overhead, etc)	30	Months	$25,000.00	$750,000
	Sub Total Item 1.0				**$26,750,000**
2.0	**Surveying**				
2.1	Surveying	1	LS	$100,000.00	$100,000
	Sub Total Item 2.0				**$100,000**
3.0	**Excavation Roadheader**				
3.1	Road Header Machine	2	LS	$2,000,000.00	$4,000,000
3.2	Road Header Equipment				$0
3.2A	Road Head Attachment	4	Each	$80,000.00	$320,000
3.2B	Teeth Replacement	104	Week	2,600	$270,400
3.2C	Hydraulic Setup	4	Each	$50,000.00	$200,000
3.2D	Additional Spare Parts	2	LS	$54,080.00	$108,160
3.2E	Hydraulic Consumption		LS	$25,000.00	$25,000
3.3	Dust Suppression Machine	2	Each	$100,000.00	$200,000
3.4	Ventilation Operation	6,000	LF	$250.00	$1,500,000
3.5	Ventilation Equipment	2	Each	$20,000.00	$40,000
3.6	Skidster Loader	24	Month	$5,000.00	$120,000
3.7	Haul Equipment, Trucks Conveyor System	24	Month	$5,000.00	$120,000
3.8	Laser Guided Alignment Control System	2	Each	$75,000.00	$150,000
3.9	Cooling	2	Each	$100,000.00	$200,000
3.10	50 % Excavation option	200,000	CY	$175.00	$35,000,000
3:10A	Initial Platform Construction	2	LS	$50,000.00	$100,000
3.11	Electrical Issues	2	LS	$50,000.00	$100,000
3.111A	Generator Outside	3	LS	$191,877.48	$575,632
3.11B	Step Up Transformer	3	LS	$247,600.00	$742,800
3.11C	Step Down Transformer	3	LS	$247,600.00	$742,800
3:11D	Relocation of Step Down Transformer	20	Days	$2,579.60	$51,592
3.12	Material Excavation	200,000	CY	$15.00	$3,000,000
3.13	Road Header Test Section				
	Sub Total Item 3.0				**$47,566,384**
4.0	**Excavation Mechanical**				
4.1	25% of Excavation	100,000	CY	$175.00	$17,500,000
4.2	CAT 320 Excavator	24	Month	$10,000.00	$240,000
4.2A	Road Head Attachment	4	Each	$80,000.00	$320,000
4.2B	Teeth Replacement	52	Week	2,600	$135,200
4.3	Ventilation Operation	3,000	LF	$250.00	$750,000
4.4	Dust Suppression Machine	1	LS	$50,000.00	$50,000
4.5	Ventilation Equipment	1.00	Each	$20,000.00	$20,000
4.6	Material Removal	100000.00	CY	$15.00	$1,500,000
	Sub Total Item 4.0				**$20,515,200**
5.0	**Drilling and Blasting**				
5.1	25% of Excavation	100,000	CY	$225.00	$22,500,000
5.2	Ventalation Operation	3000	LF	$250.00	$750,000

5.3	Ventilation Equipment	1	Each	$20,000.00	$20,000
5.4	Material Removal	100000	CY	$15.00	$1,500,000
5.5	Permitting and Monitoring	1	LS	$50,000.00	$50,000
5.6	Storage Location of Explosives and Guard	200	Days	$1,000.00	$200,000
5.7	Traffic Patrol and Signs	1	LS	$30,000.00	$30,000
	Sub Total 5.0				**$25,050,000**
6.0	**Ground Treatment**				
6.1	Grouting	20	Days	$12,500.00	$250,000
6.2	Shotcrete				
6.3	Primary Supports	8,000			
6.4	Steel Lattice Girder				
6.5	Rock Bolts	20	Crew/day	$800.00	$16,000
	Sub Total 6.0				**$266,000**
7.0	**Post Ground Treatment**				
7.1	Backfill Grout				
7.2	Contact Grout	12000	LF	$60	$720,000
7.3	Composite Grout				
	Sub Total 7.0				**$720,000**
8.0	**Water Infiltration**				
8.1	Dewatering	1	YR	$5,000,000.00	$5,000,000
	Sub Total 8.0				**$5,000,000**
9.0	**Permitting**				
9.1	Permitting	1	LS	$35,000.00	$35,000
	Sub Total 9.0				**$35,000**
10.0	**Tunnel Shield**				
10.1	Shop Fabrication	2,000,000	LBS	$3.00	$6,000,000
10.2A	Field Fabrication	2	Month	$100,000.00	$200,000
10.2B	Crane Rental	2	Month	$20,000.00	$40,000
10.2C	Crane Rental Crew	50	Days	$1,740.50	$87,025
10.3	Transportation and Permitting	40	Each	$6,000.00	$240,000
10.4	Relocating during Construction	60	Each	$1,500.00	$90,000
10.5	Rail Set up	2	LS	$50,000.00	$100,000
10.6	Maintenance	560	Laboror/Day	$1,200.00	$672,000
10.7	Moving shield to other tunnel and setup	2	LS	$1,200,000.00	$2,400,000
10.8	Shield Removal and Disposal	2	LS	$500,000.00	$1,000,000
10.9	Traffic Setup	20	Days	$3,000.00	$60,000
	Sub Total 10.0		LS		**$10,889,025**
11.0	**Detailed Engineering**				
11.1	Detailed Design, Construction Inspection	1	LS	$15,000,000.00	$15,000,000
	Sub Total 11.0				**$15,000,000**
12.0	**Instrumentation Installation and Monitoring**				
12.1	Inclinometers	1	LS	$100,000.00	$100,000
12.2	Piezometers	1	LS	$80,000.00	$80,000
	Sub Total 12.0				**$180,000**
13.0	**Existing Tunnel Excavation**				
13.1	Concrete Removal	18,225	CY	$300.00	$5,467,500
13.2	Concrete Disposal	18,225	CY	$15.00	$273,375
	Sub Total 13.0				**$5,740,875**
14.0	**Cast in Place Concrete Tunnel Lining**				
	Cast in Place Concrete Tunnel Lining	12,150	LF	$900.00	$10,935,000
				Sub Total	**$168,712,484**
				Contingency (30%)	**$50,613,745**
				Total	**$219,326,230**

APPENDIX B

CONSTRUCTION SCHEDULES

Activity ID	Activity Name	Planned Start	Planned Finish	Original Duration
Allegheny Tunnel		Nov-10-2014	Oct-25-2024	2490
A1000	Pennsylvani Turnpike Commission (PTC) Finalize RFP sent to approved bidd	Nov-10-2014	Nov-10-2014	1
A1010	Bid Due Date	Dec-10-2014	Dec-10-2014	1
A1020	Contractor Selected	Jan-12-2015	Jan-12-2015	1
A1030	Negotiations between PTC and Contractor Completed	Jan-13-2015	Feb-10-2015	20
A1040	Protective Shield Shop Work Starts	Mar-02-2015	Apr-03-2015	25
A1050	Site Mobilization starts	Mar-23-2015	Apr-03-2015	10
Shield Installation		Apr-06-2015	May-01-2015	20
A1060	Shield Delivery	Apr-06-2015	Apr-17-2015	10
A1065	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-06-2015	Apr-10-2015	5
A1070	Shield Installation	Apr-13-2015	May-01-2015	15
A1150	Road Closure for Shield Installation in Tunnel	Apr-30-2015	May-01-2015	2
Excavation and Tunnel Liner Installation		Mar-31-2015	Oct-21-2015	143
A1067	Road closure for False Ceiling Removal	Mar-31-2015	Apr-30-2015	33
A1075	Excavation of False Ceiling Begins Estimated 500 LF removal/Day	Apr-01-2015	Apr-29-2015	30
A1080	Excavation Begins	May-02-2015		0
A1090	Road Header, Mechanical and drill and blast excavation - 600' construction se	May-02-2015	Sep-29-2015	161
A1100	Tunnel Lining placement - Station -126200 to Station 126800	May-18-2015	Oct-12-2015	159
A1110	Demobilization - Traffic reduced to 1 Lane during Shield Disassembly	Oct-13-2015	Oct-21-2015	10
A1770	Road Closure for Shield Removal to Median	Oct-14-2015	Oct-14-2015	1
Remobilization - 2016		Mar-21-2016	Apr-01-2016	10
A1120	Site Mobilization	Mar-21-2016	Apr-01-2016	10
Shield Installation - 2016		Apr-04-2016	Apr-29-2016	20
A1130	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-04-2016	Apr-08-2016	5
A1140	Shield Installation	Apr-11-2016	Apr-29-2016	15
A1350	Road Closure for Shield Installation in Tunnel	Apr-28-2016	Apr-29-2016	2
Excavation and Tunnel Liner Installation - 2016		May-02-2016	Oct-24-2016	122
A1160	Excavation Continues - Station 126800 to 127400	May-02-2016		0
A1170	Road Header, Mechanical and drill and blast excavation - 600' construction se	May-02-2016	Sep-30-2016	164
A1180	Tunnel Lining Placement - Station - 126800 to 127400	May-16-2016	Oct-10-2016	159
A1190	Demobilization - Traffic reduced to 1 Lane during Shield Disassembly	Oct-11-2016	Oct-24-2016	10
A1780	Road Closure for Shield Removal to Median	Oct-12-2016	Oct-12-2016	1
Remobilization 2017		Mar-20-2017	Mar-31-2017	10
A1200	Site Mobilization	Mar-20-2017	Mar-31-2017	10
Shield Installation - 2017		Apr-03-2017	Apr-28-2017	20
A1210	Shield Rail Assembly - Traffic reduced to 1 Lane during Shield Disassembly	Apr-03-2017	Apr-07-2017	5
A1230	Shield Installation	Apr-10-2017	Apr-28-2017	15
A1790	Road Closure for Shield Installation in Tunnel	Apr-27-2017	Apr-28-2017	2
Excavation and Tunnel Liner Installation - 2017		May-01-2017	Oct-23-2017	122
A1220	Excavation Continues - 127400 to 128000	May-01-2017		0
A1240	Road Header, Mechanical and drill and blast excavation - 600' construction se	May-01-2017	Sep-30-2017	165
A1250	Tunnel Lining Placement - Station 127400 to 128000	May-15-2017	Oct-09-2017	159
A1260	Demobilization - Traffic reduced to 1 Lane during Shield Disassembly	Oct-10-2017	Oct-23-2017	10
A1800	Road Closure for Shield Removal to Median	Oct-11-2017	Oct-11-2017	1
Remobilization - 2018		Mar-19-2018	Mar-30-2018	10
A1270	Site Mobilization	Mar-19-2018	Mar-30-2018	10
Shield Installation - 2018		Apr-02-2018	Apr-25-2018	18
A1280	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-02-2018	Apr-06-2018	5
A1290	Shield Installation	Apr-07-2018	Apr-25-2018	20
A1810	Road Closure for Shield Installation in Tunnel	Apr-24-2018	Apr-25-2018	2
Excavation and Tunnel Liner Installation - 2018		May-01-2018	Oct-22-2018	121
A1300	Excavation Continues - 128000 to 128600	May-01-2018		0
A1310	Road Header, Mechanical and drill and blast excavation - 600' construction se	May-01-2018	Sep-29-2018	164
A1320	Tunnel Lining Placement - Station 128000 to 128600	May-15-2018	Oct-08-2018	158
A1330	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-09-2018	Oct-22-2018	10
A1820	Road Closure for Shield Removal to Median	Oct-10-2018	Oct-10-2018	1
Remobilization - 2019		Mar-18-2019	Mar-30-2019	10
A1340	Site Mobilization	Mar-18-2019	Mar-30-2019	15
Shield Installation-2019		Apr-01-2019	Apr-24-2019	18
A1360	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-01-2019	Apr-05-2019	5
A1390	Shield Installation	Apr-06-2019	Apr-24-2019	20
A1830	Road Closure for Shield Installation in Tunnel	Apr-23-2019	Apr-24-2019	2
Excavation and Tunnel Liner Installation - 2019		May-01-2019	Oct-28-2019	125
A1370	Excavation Continues - 128600 to 129200	May-01-2019		0



Actual Work | Critical Remaining Work | Summary
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TASK filter: All Activities

(c) Primavera Systems, Inc.

Activity ID	Activity Name	Planned Start	Planned Finish	Original Duration
A1380	Road Header, Mechanical and drill and blast excavation - 600' construction s	May-01-2019	Oct-01-2019	164
A1400	Tunnel Lining Placement - Station 128600 to 129200	May-15-2019	Oct-14-2019	164
A1410	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-15-2019	Oct-28-2019	10
A1840	Road Closure for Shield Removal to Median	Oct-16-2019	Oct-16-2019	1
Remobilization -2020		Mar-16-2020	Mar-27-2020	10
A1420	Site Mobilization	Mar-16-2020	Mar-27-2020	10
Shield Installation - 2020		Mar-30-2020	May-01-2020	25
A1430	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Mar-30-2020	Apr-03-2020	5
A1440	Shield Installation	Apr-06-2020	May-01-2020	20
A1850	Road Closure for Shield Installation in Tunnel	Apr-30-2020	May-01-2020	2
Excavation and Tunnel Liner Installation - 2020		May-02-2020	Oct-26-2020	122
A1450	Excavation Continues - 129200 to 129800	May-02-2020		0
A1460	Road Header, Mechanical and drill and blast excavation - 600' construction s	May-04-2020	Sep-30-2020	161
A1470	Tunnel Lining Placement - Station 129200 to 129800	May-18-2020	Oct-10-2020	158
A1480	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-13-2020	Oct-26-2020	10
A1860	Road Closure for Shield Removal to Median	Oct-14-2020	Oct-14-2020	1
Remobilization - 2021		Mar-16-2021	Mar-29-2021	10
A1490	Site Mobilization	Mar-16-2021	Mar-29-2021	10
Shield Installation - 2021		Mar-30-2021	Apr-23-2021	19
A1500	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Mar-30-2021	Apr-05-2021	5
A1520	Shield Installation	Apr-06-2021	Apr-23-2021	20
A1870	Road Closure for Shield Installation in Tunnel	Apr-22-2021	Apr-23-2021	2
Excavation and Tunnel Liner Installation - 2021		Apr-30-2021	Oct-25-2021	123
A1510	Excavation Continues - 129800 to 130400	Apr-30-2021		0
A1530	Road Header, Mechanical and drill and blast excavation - 600' construction s	May-01-2021	Sep-30-2021	164
A1540	Tunnel Lining Placement - Station 129800 to 130400	May-17-2021	Oct-11-2021	159
A1550	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-12-2021	Oct-25-2021	10
A1880	Road Closure for Shield Removal to Median	Oct-13-2021	Oct-13-2021	1
Remobilization - 2022		Mar-14-2022	Mar-25-2022	10
A1560	Site Mobilization	Mar-14-2022	Mar-25-2022	10
Shield Installation- 2022		Mar-28-2022	Apr-29-2022	25
A1570	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Mar-28-2022	Apr-01-2022	5
A1590	Shield Installation	Apr-04-2022	Apr-29-2022	20
A1890	Road Closure for Shield Installation in Tunnel	Apr-28-2022	Apr-29-2022	2
Excavation and Tunnel Liner Installation - 2022		May-02-2022	Oct-24-2022	122
A1580	Excavation Continues - 130400 to 131000	May-02-2022		0
A1600	Road Header, Mechanical and drill and blast excavation - 600' construction s	May-02-2022	Sep-30-2022	164
A1610	Tunnel Lining Placement - Station 130400 to 131000	May-16-2022	Oct-10-2022	159
A1620	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-11-2022	Oct-24-2022	10
A1900	Road Closure for Shield Removal to Median	Oct-12-2022	Oct-12-2022	1
Remobilization - 2023		Mar-13-2023	Mar-24-2023	10
A1630	Site Mobilization	Mar-13-2023	Mar-24-2023	10
Shield Installation - 2023		Mar-27-2023	Apr-28-2023	25
A1640	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Mar-27-2023	Mar-31-2023	5
A1660	Shield Installation	Apr-03-2023	Apr-28-2023	20
A1910	Road Closure for Shield Installation in Tunnel	Apr-27-2023	Apr-28-2023	2
Excavation and Tunnel Liner Installation - 2023		May-01-2023	Oct-27-2023	126
A1650	Excavation Continues - 131000 to 131600	May-01-2023		0
A1670	Road Header, Mechanical and drill and blast excavation - 600' construction s	May-01-2023	Sep-30-2023	165
A1680	Tunnel Lining Placement - Station 131000 to 131600	May-15-2023	Oct-14-2023	165
A1690	Demobilization - Traffic Reduced to 1 Lane during Shield Diassembly	Oct-16-2023	Oct-27-2023	10
A1920	Road Closure for Shield Removal to Median	Oct-17-2023	Oct-17-2023	1
Remobilization - 2024		Mar-11-2024	Mar-22-2024	10
A1700	Site Mobilization	Mar-11-2024	Mar-22-2024	10
Shield Installation - 2024		Mar-25-2024	Apr-26-2024	25
A1730	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Mar-25-2024	Mar-29-2024	5
A1740	Shield Installation	Apr-01-2024	Apr-26-2024	20
A1930	Road Closure for Shield Installation in Tunnel	Apr-25-2024	Apr-26-2024	2
Excavation and Tunnel Liner Installation - 2024		May-02-2024	Oct-25-2024	123
A1710	Excavation Continues - 131600 to 132200	May-02-2024		0
A1720	Road Header, Mechanical and drill and blast excavation - 600' construction s	May-02-2024	Sep-30-2024	162
A1750	Tunnel Lining Placement - Station 131600 to 132200	May-10-2024	Oct-10-2024	165
A1760	Demobilization - Traffic Reduced to 1 Lane during Shield Diassembly	Oct-11-2024	Oct-25-2024	10

2014 2015 2016 2017 2018
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May

Actual Work | Critical Remaining Work | Summary
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TASK filter: All Activities

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Activity ID	Activity Name	Planned Start	Planned Finish	Original Duration
A1940	Road Closure for Shield Removal to Median	Oct-12-2024	Oct-12-2024	1

Actual Work
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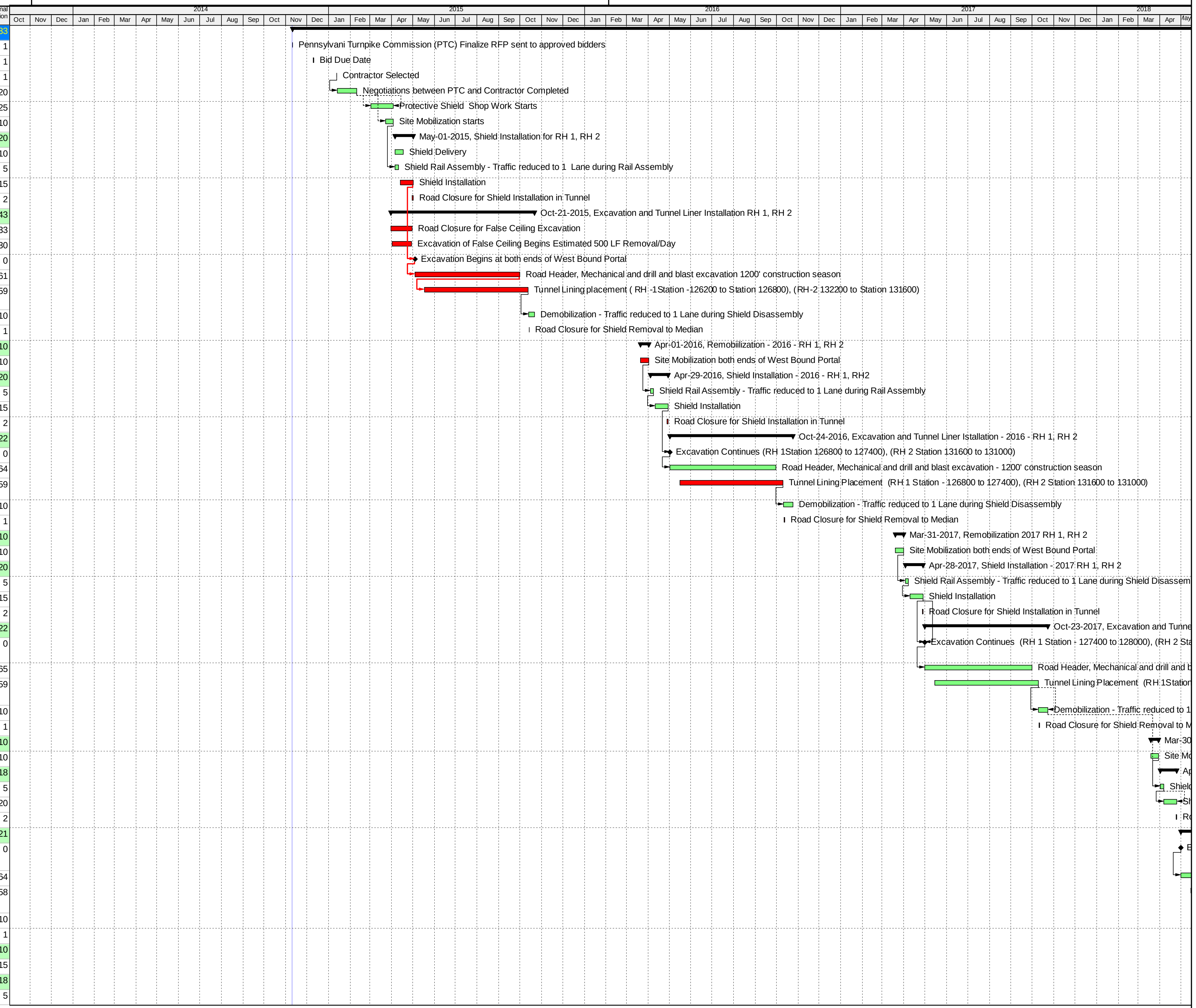
TASK filter: All Activities

(c) Primavera Systems, Inc.

Activity ID	Activity Name	Planned Start	Planned Finish	Original Duration
Allegheny Tunnel - 2 RH		Nov-10-2014	Aug-04-2020	1433
A1000	Pennsylvani Turnpike Commission (PTC) Finalize RFP sent to approved bidd	Nov-10-2014	Nov-10-2014	1
A1010	Bid Due Date	Dec-10-2014	Dec-10-2014	1
A1020	Contractor Selected	Jan-12-2015	Jan-12-2015	1
A1030	Negotiations between PTC and Contractor Completed	Jan-13-2015	Feb-10-2015	20
A1040	Protective Shield Shop Work Starts	Mar-02-2015	Apr-03-2015	25
A1050	Site Mobilization starts	Mar-23-2015	Apr-03-2015	10
Shield Installation for RH 1, RH 2		Apr-06-2015	May-01-2015	20
A1060	Shield Delivery	Apr-06-2015	Apr-17-2015	10
A1065	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-06-2015	Apr-10-2015	5
A1070	Shield Installation	Apr-13-2015	May-01-2015	15
1075	Road Closure for Shield Installation in Tunnel	Apr-30-2015	May-01-2015	2
Excavation and Tunnel Liner Installation RH 1, RH 2		Mar-31-2015	Oct-21-2015	143
A1067	Road Closure for False Ceiling Excavation	Mar-31-2015	Apr-30-2015	33
A1075	Excavation of False Ceiling Begins Estimated 500 LF Removal/Day	Apr-01-2015	Apr-29-2015	30
A1080	Excavation Begins at both ends of West Bound Portal	May-04-2015		0
A1090	Road Header, Mechanical and drill and blast excavation 1200' construction se	May-04-2015	Sep-30-2015	161
A1100	Tunnel Lining placement (RH -1Station -126200 to Station 126800), (RH-2 132200 to Station 131600)	May-18-2015	Oct-12-2015	159
A1110	Demobilization - Traffic reduced to 1 Lane during Shield Disassembly	Oct-13-2015	Oct-21-2015	10
A1770	Road Closure for Shield Removal to Median	Oct-14-2015	Oct-14-2015	1
Remobiilization - 2016 - RH 1, RH 2		Mar-21-2016	Apr-01-2016	10
A1120	Site Mobilization both ends of West Bound Portal	Mar-21-2016	Apr-01-2016	10
Shield Installation - 2016 - RH 1, RH2		Apr-04-2016	Apr-29-2016	20
A1130	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-04-2016	Apr-08-2016	5
A1140	Shield Installation	Apr-11-2016	Apr-29-2016	15
A1780	Road Closure for Shield Installation in Tunnel	Apr-28-2016	Apr-29-2016	2
Excavation and Tunnel Liner Istallation - 2016 - RH 1, RH 2		May-02-2016	Oct-24-2016	122
A1160	Excavation Continues (RH 1Station 126800 to 127400), (RH 2 Station 131600	May-02-2016		0
A1170	Road Header, Mechanical and drill and blast excavation - 1200' construction s	May-02-2016	Sep-30-2016	164
A1180	Tunnel Lining Placement (RH 1 Station - 126800 to 127400), (RH 2 Station 131600 to 131000)	May-16-2016	Oct-10-2016	159
A1190	Demobilization - Traffic reduced to 1 Lane during Shield Disassembly	Oct-11-2016	Oct-24-2016	10
A1790	Road Closure for Shield Removal to Median	Oct-12-2016	Oct-12-2016	1
Remobilization 2017 RH 1, RH 2		Mar-20-2017	Mar-31-2017	10
A1200	Site Mobilization both ends of West Bound Portal	Mar-20-2017	Mar-31-2017	10
Shield Installation - 2017 RH 1, RH 2		Apr-03-2017	Apr-28-2017	20
A1210	Shield Rail Assembly - Traffic reduced to 1 Lane during Shield Disassembly	Apr-03-2017	Apr-07-2017	5
A1230	Shield Installation	Apr-10-2017	Apr-28-2017	15
A1350	Road Closure for Shield Installation in Tunnel	Apr-27-2017	Apr-28-2017	2
Excavation and Tunnel Liner Installation - 2017 RH 1, RH 2		May-01-2017	Oct-23-2017	122
A1220	Excavation Continues (RH 1 Station - 127400 to 128000), (RH 2 Station - 131000 to 130400)	May-01-2017		0
A1240	Road Header, Mechanical and drill and blast excavation - 1200' construction s	May-01-2017	Sep-30-2017	165
A1250	Tunnel Lining Placement (RH 1Station - 127400 to 128000), (RH 2 Station - 131000 to 130400)	May-15-2017	Oct-09-2017	159
A1260	Demobilization - Traffic reduced to 1 Lane during Shield Disassembly	Oct-10-2017	Oct-23-2017	10
A1800	Road Closure for Shield Removal to Median	Oct-11-2017	Oct-11-2017	1
Remobilization - 2018 RH 1, RH 2		Mar-19-2018	Mar-30-2018	10
A1270	Site Mobilization	Mar-19-2018	Mar-30-2018	10
Shield Installation - 2018 RH 1, RH 2		Apr-02-2018	Apr-25-2018	18
A1280	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-02-2018	Apr-06-2018	5
A1290	Shield Installation	Apr-07-2018	Apr-25-2018	20
A1810	Road Closure for Shield Installation in Tunnel	Apr-24-2018	Apr-25-2018	2
Excavation and Tunnel Liner Installation - 2018 RH 1, RH 2		May-01-2018	Oct-22-2018	121
A1300	Excavation Continues (RH 1 Station - 128000 to 128600), (RH 2 Station - 130400 to 129800)	May-01-2018		0
A1310	Road Header, Mechanical and drill and blast excavation - 1200' construction s	May-01-2018	Sep-29-2018	164
A1320	Tunnel Lining Placement (RH 1 Station 128000 to 128600), (RH 2 Station - 130400 to 129800)	May-15-2018	Oct-08-2018	158
A1330	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-09-2018	Oct-22-2018	10
A1820	Road Closure for Shield Removal to Median	Oct-10-2018	Oct-10-2018	1
Remobilization - 2019 RH 1, RH 2		Mar-18-2019	Mar-30-2019	10
A1340	Site Mobilization	Mar-18-2019	Mar-30-2019	15
Shield Installation-2019 RH 1, RH 2		Apr-01-2019	Apr-24-2019	18
A1360	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Apr-01-2019	Apr-05-2019	5



Actual Work	Critical Remaining Work	Summary	
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TASK filter: All Activities

(c) Primavera Systems, Inc.

Activity ID	Activity Name	Planned Start	Planned Finish	Original Duration
A1390	Shield Installation	Apr-06-2019	Apr-24-2019	20
A1830	Road Closure for Shield Installation in Tunnel	Apr-23-2019	Apr-24-2019	2
Excavation and Tunnel Liner Installation - 2019 RH 1, RH 2		May-01-2019	Oct-28-2019	125
A1370	Excavation Continues (RH 1 Station 128600 to 129200), (RH 2 Station 129800 to 129400)	May-01-2019		0
A1380	Road Header, Mechanical and drill and blast excavation - 1000' construction s	May-01-2019	Oct-01-2019	164
A1400	Tunnel Lining Placement (RH 1Station 128600 to 129200), (RH 2 Station 129800 to 129400)	May-15-2019	Oct-14-2019	164
A1410	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Oct-15-2019	Oct-28-2019	10
A1840	Road Closure for Shield Removal to Median	Oct-16-2019	Oct-16-2019	1
Remobilization -2020 RH 1 Only		Mar-16-2020	Mar-27-2020	10
A1420	Site Mobilization	Mar-16-2020	Mar-27-2020	10
Shield Installation - 2020 RH 1 Only		Mar-30-2020	May-01-2020	25
A1430	Shield Rail Assembly - Traffic reduced to 1 Lane during Rail Assembly	Mar-30-2020	Apr-03-2020	5
A1440	Shield Installation	Apr-06-2020	May-01-2020	20
A1850	Road Closure for Shield Installation in Tunnel	Apr-30-2020	May-01-2020	2
Excavation and Tunnel Liner Installation - 2020 RH 1 Only		May-02-2020	Aug-04-2020	65
A1450	Excavation Continues - R H 1 Station 129200 to 129400	May-02-2020		0
A1460	Road Header, Mechanical and drill and blast excavation - 200' construction se	May-04-2020	Jul-07-2020	70
A1470	Tunnel Lining Placement - RH 1 Station 129200 to 129400	May-18-2020	Jul-21-2020	70
A1480	Demobilization - Traffic Reduced to 1 Lane during Shield Disassembly	Jul-22-2020	Aug-04-2020	10
A1860	Road Closure for Shield Removal to Median	Jul-23-2020	Jul-23-2020	1

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