Rehabilitation of the Heroes (West Rock) Tunnel State Project No. 167-103

Heroes Tunnel Alternative Construction Options Study Final Report – *Supplement*

Prepared for:

Connecticut Department of Transportation

September 1, 2016

Prepared by:

CDM Smith

Executive Summary

CDM Smith together with CTDOT prepared an extensive analysis of the Heroes Tunnel conditions in a 2008 study and then in the November 2014 Alternative Construction Options Study, developed several permanent solutions to the tunnel deterioration. This supplement to the 2014 Study evaluates an additional alternative that has not yet been investigated and therefore, provides a final evaluation of the potential options for rehabilitation of the tunnels. This option includes a potential Construction Bypass Tunnel, a temporary tunnel to be constructed roughly parallel to the existing tunnels.

The purpose of this study supplement is to provide the Connecticut Department of Transportation (CTDOT) with a comprehensive evaluation of an additional construction and rehabilitation option for improvements to the Heroes Tunnel, similar to the efforts under the November 2014 Study. This option presented in this supplement is conceptual in nature and the recommendations are intended to assist CTDOT in evaluating the alternatives for the tunnel rehabilitation and subsequent Preliminary Design.

This Alternative Construction Options Study Supplement presents a new option that was identified by CTDOT for CDM Smith to evaluate involving a Construction Bypass Alternative, a temporary tunnel running roughly parallel and astride of the existing northbound tunnel for diverting traffic into during enlargement of the existing tunnel barrels. After review of this alternative, two variations were developed, Option 6 with a steeper grade and shortened tunnel length (versus the existing tunnels) and Option 7, with similar grade and length as existing tunnels. The use of the temporary tunnel post construction has not been determined nor evaluated. It is expected that the Department will consider the potential uses as part of the forthcoming public outreach process.

The construction bypass tunnel Alternative with two Options is summarized below.

Description of Construction Alternative to Rehabilitate Heroes Tunnel

Option #	Name	Approach	Highway Modifications	Traffic Impact
6	Construction Bypass Tunnel (temporary)	Build a two-lane northbound only tunnel with 4% vertical grade astride existing northbound tunnel, divert traffic into tunnel for each existing tunnel enlargement.	New approaches to be constructed to access the temporary tunnel, significant grading, retaining crossovers. Shorter tunnel length.	This will have the minimalist impact of all the Options on traffic flow.
7	Construction Bypass Tunnel (temporary)	Build a two-lane northbound only tunnel with 3% grade (same as existing tunnels) astride existing northbound tunnel, divert traffic into tunnel for each existing tunnel enlargement	New approaches to be constructed to access the temporary tunnel, significant grading, retaining crossovers.	This will have the minimalist impact of all the Options on traffic flow.

The construction bypass tunnel can be constructed in similar fashion as the previous options, however the significant advantage to the other options is that it will allow the complete closure of one barrel at a time to rehabilitate and enlarge the tunnel without significant impacts to traffic flow.

The construction bypass tunnel will require additional and significant approach roadway work than some of the options although the work will be similar to the permanent option of a new barrel. In addition, Option 6 of the alternative will require steeper approach and departure grades while providing an overall shorter tunnel length.

The construction bypass tunnel will satisfy all applicable tunnel standards and as proposed, provide minimum 8 foot shoulders.

The construction bypass tunnel can employ a curved geometry (versus straight barrel section) in the previous alternatives.

The construction bypass tunnel will avoid a direct impact to the CTDOT District III salt shed and reduce the potentially significant impacts to Wintergreen Brook and West Rock Nature Center on the north portal under the previous options.

The construction bypass tunnel Option 6 can be shorter in length and higher in grade than the other options to reduce the significance of regrading the sloped areas at both portals. The higher grade option will require impacts to West Rock Ridge State Park roadway and parking area.

The construction cost is estimated to be $240 million for the construction bypass tunnel and enlargement of the existing tunnels, of which approximately $83 million for the bypass tunnel and approach work.

The construction bypass tunnel will be constructed in accordance with international and national standards, providing a significant longer service life than typical temporary construction methods. As an example, the tunnel lighting will be designed as permanent lighting in according with lighting standards.

Given the complex, unique and unprecedented (since 1949 original tunnel construction) construction methods required for this project in Connecticut, alternative construction project delivery methods should be considered aside from traditional Design/Bid/Build. These may include Design Build (D-B), Construction Manager/General Contractor (CM/CG) methods as well as other potential considerations to best serve the Department in ensuring the risk of complexities of construction are addressed and the Department retains tunnel construction expertise for the project.

Finally, the CDM Smith can provide the Department with other Transportation agency contacts with recent tunnel construction projects to gain additional knowledge of tunnel construction. A scan tour of a similar project should be considered and CDM Smith can facilitate this tour for pertinent Department personnel.

Table of Contents

Appendices

Section 1
Introduction

1.1 Supplement Objective

The purpose of this study is to provide the Connecticut Department of Transportation (CTDOT) a comprehensive evaluation of an additional construction and rehabilitation option for improvements to the Heroes Tunnel. This option presented in this supplement is conceptual in nature and the recommendations are intended to assist CTDOT in evaluating the alternatives for the tunnel rehabilitation and subsequent Preliminary Design.

1.2 Background

CDM Smith together with CTDOT prepared an extensive analysis of the Heroes Tunnel conditions in a 2008 study and then in the November 2014 Alternative Construction Options Study, developed several permanent solutions to the tunnel deterioration. This supplement to the 2014 Study evaluates an additional alternative that has not yet been investigated and therefore, provides a final evaluation of the potential options for rehabilitation of the tunnels. This option includes a potential Construction Bypass Tunnel, a temporary tunnel to be constructed roughly parallel to the existing tunnels with two variations: Option 6 with a steeper grade (4%) and shorter tunnel length than the existing tunnel barrels; and Option 7 which follows similar path as Option 6, however with the same grade (3%) as the existing tunnels and similar length.

1.4 Purpose and Need

CTDOT's review of the 2008 inspection report and recommended rehabilitation approach raised concerns regarding the significant impact and delays on the traffic passing through the tunnel during rehabilitation. CTDOT requested CDM Smith to explore several different construction options, which were summarized in the aforementioned November 2014 Study.

In collaboration, CTDOT and CDM Smith identified five alternative construction options to rehabilitate the tunnel. The overarching goal of examining alternative construction options was to reduce the impact of rehabilitation on traffic, by maintaining three to four lanes of traffic open at all times. These options were reviewed in extensive detail.

This Alternative Construction Options Study Supplement presents two variations of an option that was identified by CTDOT for CDM Smith to evaluate in addition to the previous five options. This latest option involves a Construction Bypass Alternative, a temporary tunnel running roughly parallel and astride of the existing northbound tunnel for diverting traffic into during enlargement of the existing tunnel barrels. This alternative includes two variations, Option 6 with a steeper grade (than existing tunnels) and shorter tunnel length and Option 7, with similar grade and length as existing tunnels. It should be noted that the use of the temporary tunnel facility post construction has not been determined nor evaluated as part of this effort. It is recommended however, that the Department fully vet the potential options for either dismantling/removing the Construction Bypass Tunnel post-completion of the tunnel work or use of the tunnel for other options into the future. This could include consideration for incorporating tunnel into the plans for the Exit 59 interchange long term improvement project now underway. Finally, it is fully expected that the public outreach efforts to be conducted will provide direction and input on any and all alternatives, including the construction bypass tunnel as well as post construction use of the tunnel.

1.5 Scope of Work

The intent of this Supplemental Study is to evaluate the relative impacts resulting from the Construction Bypass Tunnel option. The following criteria were used to evaluate the temporary tunnel option):

1. Impact on traffic – Expected to be minimal with this option
2. Construction cost – Updated from 2014 Study
3. Construction duration and sequencing
4. Construction complexity

1.5.1 Scope of Construction Cost Estimates

Using the conceptual design and layout for Construction Bypass Tunnel option, the previous construction item quantities were updated and used to create construction, rights-of-way (ROW), and engineering cost estimates.

1.5.2 Construction Duration

The duration estimated only includes duration of the construction time. The estimated duration time does not include the time from notice to proceed to close-out of the project nor does it include down time for weather-related or seasonal shut-down.

1.6 Overview of Construction Options #1-7

The seven alternatives for the tunnel improvement constructability and traffic impacts are summarized in **Table 1.1** with Options 6 and 7 summarized in this supplement as the Construction Bypass Tunnel alternative (two variations).

Table 1.1: Description of Seven Construction Alternatives to Rehabilitate Heroes Tunnel

Option #	Name	Approach	Highway Modifications	Traffic Impact
1	New Single Barrel Tunnel one lane – Permanent	Construction of a new permanent one lane tunnel adjacent to the existing tunnel.	Requires new alignment along Route 15 – realignment of the entrance ramp just to the west of the tunnels is necessary. Additionally, enhanced crossovers must be constructed to shift traffic during construction.	Options 1, 2 and 3 do not have a major impact on traffic flow along Route 15 as all existing lanes of travel will be retained during construction. Therefore, the traffic and delay cost impacts of options 1, 2, and 3 are not directly analyzed in this report.
2	New Single Barrel Tunnel for two lanes – Permanent	Construction of a new permanent two lane tunnel adjacent to the existing tunnel.	Requires new alignment along Route 15 – realignment of the entrance ramp just to the west of the tunnels is necessary. Additionally, enhanced crossovers must	

Table 1.1: Description of Seven Construction Alternatives to Rehabilitate Heroes Tunnel

Option #	Name	Approach	Highway Modifications	Traffic Impact
			be constructed to shift traffic during construction.	
3	Enlargement of Existing Tunnel	Enlargement of the existing tunnel for installation of new tunnel lining and drainage system while the traffic is passing through the tunnel under protective shield.	Does not require new alignment, but requires enhanced crossovers to shift traffic during construction.	
4	Proposed Rehabilitation Method – Complete shutdown of one barrel	This option includes rehabilitation of civil-drainage systems and structural systems during complete shutdown of one barrel at a time. The details of this option were submitted to Connecticut Department of Transportation in 'Heroes (West Rock) Tunnel Inspection and Rehabilitation Recommendations" report dated July 2010.	No alignment work or crossovers required.	Option 4 requires a detour route since Route 15will be closed in the northbound direction. The detour will divert northbound Route 15 traffic at the tunnel along regional and local detours. In order to minimize impact to travel as much as possible, construction operations for this option will be limited to weekend operations only.
5	Proposed Rehabilitation Method – Partial shutdown of one barrel	This option includes rehabilitation of civil-drainage systems and structural systems similar to option #4 but involves closure of only one-lane per barrel during the allocated construction/closure period. Likewise, details of this option were submitted in the 2010 report.	No alignment work or crossovers required.	Option 5 will not require a detour route. For this option, construction will be assumed to be conducted overnight on weekdays.
6	**Construction Bypass Tunnel (temporary)**	**Build a two-lane northbound only tunnel astride existing northbound tunnel, divert traffic into tunnel for each existing tunnel enlargement.**	**New approaches to be constructed to access the temporary tunnel, significant grading, retaining crossovers.**	**This will have the minimalist impact of all the Options on traffic flow.**
7	**Construction Bypass Tunnel (temporary)**	**Build a two-lane northbound only tunnel with 3% grade (same as existing tunnels) astride existing northbound tunnel, divert traffic into tunnel for each existing tunnel enlargement**	**New approaches to be constructed to access the temporary tunnel, significant grading, retaining crossovers.**	**This will have the minimalist impact of all the Options on traffic flow.**

1.7 Organization of this Supplement

In **Sections 2** through **5** of this supplement, the Construction Bypass Tunnel alternative is presented with the following organization:

- Temporary tunnel guidelines
- Alignment
- Method of Construction/Sequencing/Duration
- Geotechnical Plan
- Construction cost

In addition, the Appendix contains the Cost Estimate (updated for this option), Construction Bypass Tunnel details and Highway Plans showing the alignment of the approaches to the temporary tunnel, geotechnical staging area and an elevation of the proposed tunnel at the South Portal.

Section 2

Tunnel Guidelines | Standards Review for Design and Construction of Temporary Highway Tunnels

To present the findings of reviewing various guidelines/standards in regard to design and construction requirements for temporary highway tunnels in comparison to permanent tunnel design and construction requirements. This review is being conducted as part of additional study for rehabilitation of Heroes Tunnel. This additional study consists of a review of the construction of a new two-lane northbound temporary tunnel (Construction Bypass Tunnel) with two variations (Options 6 and 7) and enlarging the existing tunnel northbound and south bound tunnels.

Introduction

CDM Smith has been directed by Connecticut Department of Transportation (CTDOT) to study another alternative for rehabilitation of Heroes Tunnel in addition to the numerous alternatives identified in the November 2014 Alternative Options Study Final Report. This temporary alternative envisions the construction of a new temporary northbound two lane tunnel and enlarging/rehabilitating the existing tunnels. In order to construct the new temporary tunnel, it is essential to investigate whether there are design and construction requirements for temporary applications as well as determine if there are additional requirements to be considered such as less stringent guidelines given the temporary use. For this study a comprehensive review of different guidelines from various sources and other agencies outside of the USA for design and construction of tunnels has been conducted.

Although numerous guidelines for design and construction of highway are prepared by various regulatory agencies in different countries across the world, for this review the following documents have been reviewed. The main objective for selecting these documents is due to the frequent application of these guidelines and documents for the design and construction of large number of tunnels across the world. It should be noted that there is no universal guideline or documents for the design and construction of highway tunnels which covers all aspects of tunnel and in many cases it could be necessary to refer to various documents or guidelines.

1) Standard for Road Tunnels, Bridges, and Other Limited Access Highways, NFPA 502, 2014 Edition

2) Technical Manual for Design and Construction of Road Tunnels-Civil Elements; U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-NHI-10-034;
http://www.fhwa.dot.gov/bridge/Tunnel/pubs/nhi09010/tunnel_manual.pdf

3) Handbook of Tunnel Engineering Volume I and II, written based on German tunneling Committee (DAUB, http://www.daub-ita.de/en/start/), by Bernhard Maidl, Markus Thewes, and Ulrich Maidl
4) Recommendations published by French Tunneling Association and Underground Space(AFTES); http://www.aftes.asso.fr/publications_recommandations.html
5) Recommendations published by British Tunnel Society; https://www.britishtunnelling.org.uk/?sitecontentid=219DD9DA-DF4D-4FB7-B724-4CD6BEB8924F
6) Arnold Dix (2004), Safety Standards for Road and Rail Tunnels, A Comparative Analysis. International Conference on Tunnel Safety and Ventilation, pp. 272-278.
7) Road Tunnels Manual, v1.1 October 2015, published by World Road Association-PIARC
8) 2015 International Building Code, published by International Code Council; Section 108 "temporary Structures and Uses"
9) American Concrete Institute (ACI) Guidelines and Reports on Concrete Design; https://www.concrete.org/publications/mcponline/mcpsearch.aspx

The following will present the findings from reviewing the above materials.

Findings

The design and construction of highway tunnels consists of several facets of engineering and construction. For simplistic understanding, the following general categories are considered:

- Structural design of the tunnel;
  - Design of tunnel excavation, temporary support system such as rock bolts, wire mesh and shotcrete, final support such as steel ribs/lattice girder and steel fiber reinforced shotcrete; steel ribs and conventional steel bars and concrete.
- Waterproofing system;
  - Tunnel waterproofing systems used to prevent into an underground opening. They consist of various materials and elements. The design of a waterproofing system is based on understanding of the ground and geohydrological conditions, geometry and layout of the tunnel and construction method to be used. A waterproofing system should always be an integrated system that takes into account intermediate construction stages, final condition of tunnel, and the ultimate stage including maintenance and operations.
- Tunnel Safety; this is mainly related to fire safety of tunnel which consists of:
  - Effective fire suppression (i.e. standpipe, fire hydrants, water supply, portable fire extinguisher, fixed water base fire-fighting system)
  - Protection of structural Elements

  - Fire detection
  - Communication systems
  - Traffic control
  - Tunnel drainage system
  - Emergency egress
  - Smoke detector and ventilation system
  - Electric, and
  - Emergency response plan
- Other requirements such as lighting, drainage system and SCADA (Supervisory Control And Data Acquisition

A review of the above materials revealed that temporary highway tunnels have not been considered in preparation of these guidelines and manuals. There are no specific references in these materials for provisions for constructing temporary tunnels in all but one of the documents reviewed. This is likely due to highway tunnels having to meet specific design requirements regarding road and operational safety to create a higher standard of care for safe passage for the tunnel users than non-tunnel roadways.

In addition, at any relaxation in standards and guidelines for design and construction of a tunnel would result in a tunnel structure with low quality and shorter service life and high cost of maintenance if to be used in the future.

The only document which discusses the design of temporary structure is Section 3103 of International Building Code (IBC). The provision of this section applies to structures erected for the period of less than 180 days. This does not apply to this project because the temporary tunnel to be constructed as part of Heroes Tunnel rehabilitation work will be in service for a longer period than 180 days. Therefore, provisions of the IBC for temporary structures cannot be applied to the temporary tunnel alternative.

Based upon this document review, the applicable design and construction standards and requirements for permanent tunnels must be considered in the design and construction of the temporary highway tunnels. This is highlighted by the fact that the temporary tunnel alternative will likely be in service for a couple of years at a minimum during the rehabilitation work on the existing tunnels for Heroes Tunnel.

In summary, the temporary tunnel alternatives Options 6 and 7 must be considered as permanent tunnels in the study and development of preliminary design plans. CDM Smith can review the potential opportunities for special design criteria for the temporary tunnel which applies specifically to this project.

Section 3

Construction Bypass Tunnel Location | Alignment

The Construction Bypass Tunnel alternative is considered by CTDOT to be a temporary tunnel alternative that allows the work on each of the other two existing tunnels to be conducted without significant impacts to traffic flow such as closing lanes and/or diversion of traffic on a long term basis.

Alignment Alternative

CDM Smith developed an initial layout of the temporary alignment of the Construction Bypass Tunnel Options based upon CTDOT direction to consider a temporary alternative to bypass the construction involved with the enlargement of the existing tunnels. The intent was to investigate the flexibility of a temporary alternative in terms of standards and guidelines, as well as consider a horizontally curved tunnel as well as review previous approach and departure geometries to potentially reduce impacts. These potential impacts included the CTDOT District III Salt Shed at the south portal, on the northbound approach, as well as the City of New Haven West Rock Nature Center on the north portal, also on the northbound approach. In addition, exploring the vertical gradient of the approaches was also suggested in an effort to possibly reduce the length of the construction bypass tunnel and thereby lower costs and potential impacts.

Options

Two options were considered for the Construction Bypass Tunnel, Option 6 with a proposed 4% grade for the northbound approach and Option 7 utilizing the existing 3% grade for the northbound approach. Both Options carry the grades through the tunnel before cresting just outside of the north portal. Both options start in the same vicinity north of the Exit 59 interchange, commencing at the end of the planned interchange improvement project and terminating north of Wintergreen Avenue beyond the north portal.

These options are conceptually drawn on the Highway Plans in Appendix C and include a proposed profile plan for Option 6 with the 4% grade. Of note, Option 6 provides a reduced tunnel length with the steeper 4% grade.

In addition, a cross section sketch of the south portal is provided for both options showing the relationship between the existing tunnels, enlarged tunnels and proposed construction bypass tunnel. The spacing between the proposed tunnel and enlarged tunnels is proposed as one tunnel diameter or 60 feet. This spacing will be adjusted upon completion of geotechnical investigations and better understanding of the rock properties.

The construction bypass tunnel is projected to be 50 feet in width, and 29 feet in height, sufficient for two travel lanes, standard shoulders and escape walks. Both options meet or exceed CTDOT's design requirements for expressways such as the Wilbur Cross Parkway.

Section 4

Method of Construction | Sequencing | Duration

To present the construction sequence/technique, construction complexity, construction duration, anticipated useful life, for the proposed alternative consisting of the construction of a new two lane construction bypass tunnel parallel and adjacent to the existing northbound tunnel and enlarging the existing northbound and southbound tunnels.

Introduction

CDM Smith has been directed by Connecticut Department of Transportation (CTDOT) to study another alternative for rehabilitation of Heroes Tunnel in addition to the numerous alternatives identified in the November 2014 Alternative Options Study Final Report. This construction bypass tunnel alternative envisions the construction of a new temporary northbound two lane tunnel and enlarging/rehabilitating the existing tunnels. The main objective of this study is to investigate possible merits such as reducing construction cost by constructing a shorter tunnel and for temporary application.

Construction Method and Sequence

Construction of the bypass tunnel and the enlarging/rehabilitation of the existing tunnels depending on uniaxial compressive strength (UCS) of the rock could be conducted either by drill-and-blast method or road header combined with wire mesh, rock bolts/dowels, steel fiber reinforced shotcrete, and lattice girder or steel ribs. If the UCS of the host rock is greater than 23,000 psi (150 MPa) then the drill-and-blast will be the proffered excavation option for the construction of the new tunnel and enlarging the existing tunnels. It could be necessary to use controlled blasting technique to minimize the risk of damaging the existing tunnel structure and the temporary shotcrete support. Figure 1 presents the cross section of the construction bypass tunnel with geometry based on recommendation of Technical manual for Design and Construction of Road Tunnels/Civil Elements (FHWA-NHI-10-034.

The construction sequences will be as follow:

1. Construction of the bypass tunnel with two lanes and cross overs;
2. Directing the traffic from northbound tunnel to the construction bypass tunnel
3. Remove the soil and rock above the existing northbound tunnel and enlarge/rehabilitate the tunnel as shown in Figure 2.
4. Direct the traffic from southbound tunnel to northbound tunnel and repeat step 3 for southbound tunnel.

Construction Duration

The bypass tunnel is projected to require up to 43 months for construction of the two lane tunnel. Subsequent to the bypass tunnel completion, the existing tunnels will be widened. The revised total construction duration is expected to be 86 months (43 months per barrel) for enlarging/rehabilitation of the existing tunnels Therefore, the total construction duration for this alternative is projected to be 129 months.

The duration of this work suggests splitting the work into separate contracts can encourage competitive bidding and lower the overall cost and potentially reduce the schedule.

Construction Schedule

The preliminary construction schedule for temporary tunnel is not limited by work hour restrictions as four lanes of traffic will be maintained at all times. Under the drill-and-blast and roadheader methods, two crews are anticipated to work simultaneously at opposite ends of the new tunnel over two 10 hour shifts per day five days per week. Upon completion of the new tunnel, enlarging/rehabilitation of the two existing tunnels would begin.

Four lanes of traffic will be maintained during the widening of the tunnel side shift. Two crews can work simultaneously at either end of the side shift expansion. The crews will work one 10-hour shift per day five days per week (no weekends). During the expansion of the existing tunnel, the two crews can be working together using two vehicle shields in order to have the least impact on traffic.

Current state law prohibits blasting for rock at night time. A review of the blasting requirements will be conducted to ensure tunnel blasting is compliant with State law. Blasting will be scheduled during reduced traffic demand periods. Traffic will have to be slowed down during blasts for approximately 5 minutes; using the "rolling lane closure method."

Upon completion of the enlarged tunnel, enlargement/rehabilitation of the other existing barrel would begin. No work hour restrictions would be enforced during this phase as four lanes of traffic would be maintained within the enlarged barrel at all times. Two crews are anticipated to work simultaneously over one 10-hour shift per day five days per week.

Shift lengths assumed represent the maximum length of productive daily time. Increasing shift durations would not increase productivity. Reductions in construction duration would only be achievable through the scheduling of additional shifts during currently unscheduled work periods. 24-Hour work over seven days per week may require additional contractors or escalated labor rates, however, increasing the anticipated construction cost.

When necessary, traffic will be reduced to one lane during off peak periods through the use of the cross over areas on each portal to allow for complete shutdown of one tunnel barrel as needed for the proposed work.

Construction Cost

The preliminary construction cost for the recommended alternative is the summation of construction cost for enlargement/rehabilitation of the two existing tunnels (2×$46,500,000=$93,000,000) and the construction cost for a new two lane temporary tunnel ($41,050,000). The length of the temporary bypass tunnel is approximately 1070 LF under Option 6. The construction cost for enlargement/rehabilitation of the two existing tunnels has been revised, eliminating the use of protective shield which would reduce the cost and the duration. The construction cost includes the cost for regrading the soil on top of the cut-and-cover section, electrical, ventilation, lighting, etc.

Construction Complexity

With respect to construction complexity, each alternative has advantages and disadvantages, which are outlined in previous sections. On a scale of 1 to 10, with 1 representing low construction complexity and 10 very high complexities, the complexity rating for this alternative is 8. This relatively high complexity rating is related to risks of employing drill and blast techniques in close vicinity of the existing tunnel and difficulty in drilling holes for explosives due to the height of the drill and blast area.

Anticipated Useful Life

Since the enlarged tunnels and the temporary tunnel are new tunnels conforming to permanent tunnel standards, a 100-year useful life of the expanded tunnels is achievable. The criterion of 100 years of useful life is that the tunnel will be operational with no serious damage or deteriorations to tunnel elements, resulting in major construction work and rehabilitation work during its designed service life. The 100-year useful life is achievable if the tunnel will be periodically inspected and maintained as described by FHW Highway and Rail Transit Tunnel Maintenance and Rehabilitation Manual, version 2005.

As indicated previously, the use of the temporary tunnel post construction has not been evaluated but should be considered by the Department as well as likely during the public outreach efforts for the project.

Section 5

Geotechnical Plan

To present the Geotechnical Field and Laboratory Investigation Plan in support of the Construction Bypass Tunnel alternative for rehabilitation of Heroes Tunnel. This alternative consists of construction of a new two lane northbound construction bypass tunnel which will allow the enlargement of the existing northbound and south bound tunnels to add a third lane in each.

This information is based upon the construction bypass tunnel alternatives shown on the attached plans.

Introduction

The construction of the construction bypass tunnel and enlargement of the existing tunnels require additional geotechnical field and laboratory investigations to ascertain the major properties of the host environment. The use of a Tunnel Boring Machine (TBM) was deemed uneconomical in the November 2014 Study which means traditional rock excavation and controlled blasting will be used for any of the tunnel options indicated. The design and construction of this project requires thought processes and procedures that are in many ways different from other design and construction projects, because the principal construction material is the rock mass itself rather than an engineered material. While there is information available in the original 1947 as built West Rock Tunnel Plans, there are uncertainties in the properties of the rock materials and in the way the rock mass and the groundwater will behave when subject to blasting. These uncertainties must be determined by sound, flexible design and redundancies and safeguards during construction. More than for any other type of structure, the design of tunnels must involve selection or anticipation of methods of construction. In tunnels excavated in jointed rock masses at relatively shallow depth, the most common types of failure of the supporting rock are those involving wedges falling from the roof or sliding out of the sidewalls of the openings. Performing an extensive geotechnical investigation will provide information to identify potential wedges which are susceptible to failure and prepare mitigation approach to stabilize such rock wedges.

Geotechnical Investigation Program

In general, the geotechnical investigation program for any tunnel project consists of field (subsurface) investigation and laboratory tests. Geotechnical field investigation consists of drilling and sampling of rock or samples and conducting in-situ tests. Subsurface investigation for a tunnel project must consider the unique needs for different tunneling methods, i.e. drill-and-blast, roadheader, as summarized in the November 2014 Study. As an example, for tunnel construction using drill-and-blast methods, the geotechnical investigation must provide data required to predict stand-up time for the size and orientation of tunnel. Laboratory tests are also necessary to determine rock/soil properties for design and selection of construction techniques. These geotechnical investigations provide factual information about the distribution and engineering characteristics of rock/soil and possibly groundwater at the site. This would provide an understanding of the existing conditions sufficient for developing an economical design, determining a reliable construction cost estimate, and reducing the risks of construction. The specific scope and extent of the investigation must be appropriate for the size of the project and the complexity of the existing geologic conditions; must consider project budget; and must be consistent with the level of risk considered acceptable to the client/owner. To ensure the collected data can be analyzed correctly throughout the project, the project coordinate system and vertical datum should be established early on in the field and the boring and testing locations must be surveyed. Photographs of the locations should be maintained as well. The following sections summarize the suggested Geotechnical field and laboratory investigations for the rehabilitation alternative.

Recommended Geotechnical Investigations

Considering the project site constraints such as impact on traffic due to equipment placement, logistics for performing vertical borings from the top of the tunnel, and available space for laydown and staging area there are options regarding both the phasing of the exploration and methods of performing these explorations to mitigate some of these constraints.

Throughout the project development, the final alignment and profile often deviates from those originally anticipated. As a result, phasing of the geotechnical investigations provides an economical and rational approach for adjusting to these anticipated changes in project. Subsurface investigations are typically concentrated in the preliminary design phase of the project. However, because of the concern of traffic delays resulting in more unique methods of performing the geotechnical explorations this overall investigation could be conducted in two different ways from a phasing point of view.

Drilling Phases

I. Conducting all geotechnical investigation in one phase; the main advantage of this is that the cost of mobilization and demobilization and the interruption to the traffic will be reduced. The risk with this one phase approach is if there are any changes in the alignment after the drilling is completed.

II. Perform a two phase program with approximately 30% to 40% of the vertical borings at present time and conducting the rest of the investigation at the time when there is better understanding of technical issues and final alignment of the tunnel. The main advantage of this method is that the location of the later borings can be established during the next phase of the investigation or even the some of the borings can be eliminated based on updated tunnel alignment. The main disadvantage of this method is the additional cost for mobilization and demobilization of equipment and the multiple interruption for performing vertical drilling.

III. Performing the horizontal boring first and then based on the information gathered from this boring decide on the number and location of vertical boring required for the existing tunnel. This approach will be two phase approach. The main advantage of this arrangement is that the geotechnical investigation program can be modified and the number and location of vertical borings can be modified based on the findings from horizontal borings. The other advantage of this method to minimize the traffic interruption by conducting necessary vertical borings.

Drilling Methods

Two goals of the drilling program include performing the work while mitigating delays to the traffic; and obtaining as many rock cores within the zone of the tunnels as possible within reasonable project budgeting. The first goal is achieved by reducing the time a drill rig set up interferes with the traffic. The second goal can be achieved by taking advantage of the more recent technology regarding the ability of drilling boreholes from angles that produce more drill footage within the zone of the tunnel. If suitable locations can be found, a horizontal hole should be drilled so that most of the core foot is within a target zone of the tunnel horizon, whereas a conventional vertical borehole includes drilling through overburden to get to the target zone.

Horizontal Drilling

Figure 1 *LM 90 Boart Longyear Horizontal Drilling Rig*

Horizontal boreholes along tunnel alignments provide a continuous record of ground conditions and information which is directly relevant to the tunnel alignment. Although the horizontal drilling and coring cost per linear feet may be much higher than conventional vertical/inclined borings, a horizontal boring can be more economical, especially for investigating a deep mountainous alignment, since one horizontal boring can replace many deep vertical conventional boreholes and avoid unnecessary drilling of overburden materials and disruption to the ground surface activities, local communities. Performing horizontal boring, for this option a drilling rig which combines the horizontal directional drilling technology with conventional drilling technique would be used. The rock cores will be extracted and preserved in core boxes for further laboratory tests. This method has been used in projects such Louisville Bridges East End Tunnel Geotechnical Exploration. Figure 1 presents an LM 90 Boart Longyear horizontal drill rig. The required space for drilling platform and equipment is approximately 20 ft×20 ft. There is a need for additional staging area (laydown yard) which will be used for a portable office, storage containers, and storage of materials/equipment. Total staging area required could be contained within a half-acre area or less.

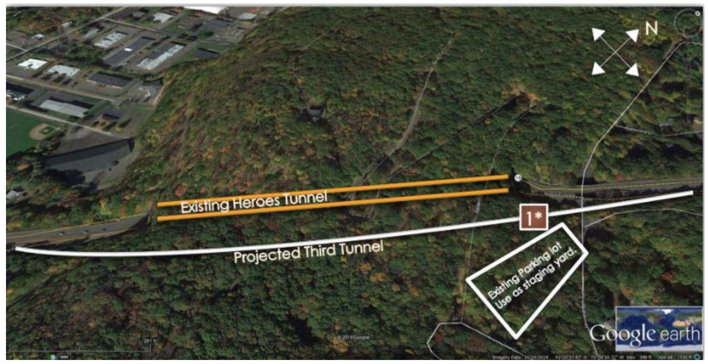


Figure 2 *Horizontal Directional Drilling Layout Option*

Figure 2 presents one possible arrangement for performing horizontal directional drilling along the new tunnel. For this option the existing parking lot located on the northeastern side of the project along the Wintergreen Avenue could be used as laydown area and storage space. The exact location and configuration of drilling platform and staging rea and possible access road between drilling platform and staging area shall be developed by the selected drilling contractor. This location will require permission from the CTDEEP for the work within the West Rock Ridge State Park as well as relocation of parking area. Potential permitting issues will need to be reviewed due to the proximity of the Wintergreen Brook less than 100 feet away. The boreholes shall be NQ size (3 inches nominal).

In addition, the attached concept plan also depicts suggested staging areas for the horizontal boring locations including a potential south portal staging area. This area would utilize the CTDOT District III rear maintenance area for access but require significant temporary regrading of the area adjacent to the existing south (west) portal. This regrading is highlighted on the plans showing the construction bypass tunnel alternative and the revised contours necessary for the 5 foot contours shown on the steep adjacent slope.

This regrading could be utilized for the eventual construction of the construction bypass tunnel or other permanent alternatives while minimizing potential impacts to CT DEEP state park lands.

Figure 3 *Drilling equipment to be used for vertical and sub-vertical boreholes*

Vertical Roof Drilling

This will involve performing vertical borings from inside the existing tunnels with a detour of traffic from the tunnel during this time. The geotechnical field investigation can be performed from inside the existing tunnel through the roof using equipment as shown in **Figure 3**. To perform this type of vertical drilling from inside the tunnel it is necessary to consider traffic maintenance during drilling operation. The advantage to this is that each boring hole is only about 30 to 40 feet in length (from the roof of the tunnel) whereas drilling conventionally from the ground surface above the tunnels within the CTDEEP West Rock Ridge State Park will require drilling of longer boreholes.

Based upon documented field observations of the terrain on top of the tunnels with significant grades and rock fields on the slopes, it will be very difficult to mobilize the drilling rig. Discussing the potential vertical borings with drilling contractors reveals it may be possible to use only one lane for performing vertical drilling. This will need to be evaluated further to understand the limitations of the equipment to work within a single lane of traffic. One benefit of this method is the potential to reduce the cost of the maintenance and protection of traffic and avoid shutting one barrel down and crossing over traffic. Vertical drilling can be conducted up to 40 ft. For each tunnel it is recommended to have at least 10 borings spaced at approximately 100 ft. The boreholes configuration can be in a staggered manner at 12.0 o'clock, 2.0 o'clock, and 10.0 o'clock for each three consecutive boreholes along the tunnel as shown in Figure 4. After completion of each borehole in-situ tests described for horizontal boring should be performed. These borings are shown on the construction bypass tunnel alternative plans.

Testing

Both in-situ field testing and laboratory testing of selected rock cores are recommended.

In-Situ File Testing

After completion of drilling operation in-situ field tests will be performed in the borehole. These include:

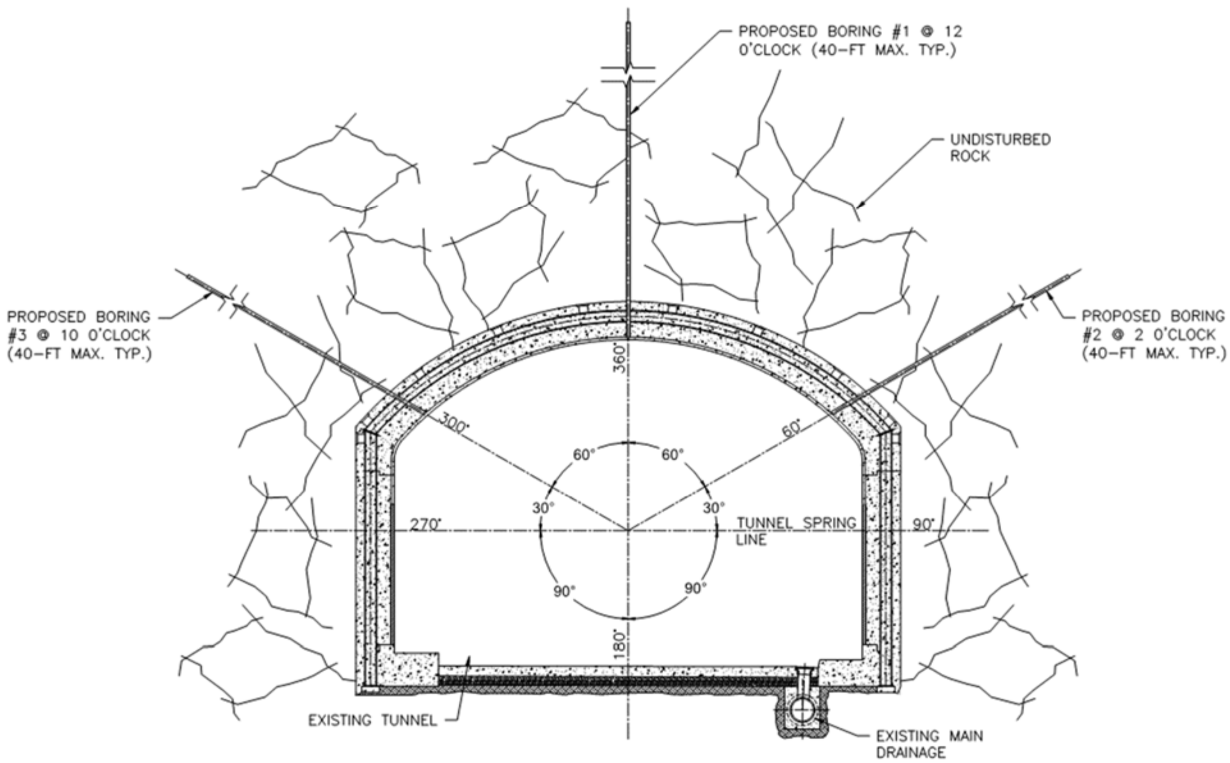


Figure 4 Staggered configuration for vertical borehole along the tunnel

a) Packer tests to calculate the permeability of host rock. It is recommended to perform the packer test at 10-foot spacing.

b) Borehole televiewer (either acoustic or optical) logging to obtain oriented images of borehole core. The resulting data offers the unique ability to present the core either as a wrapped image, showing an external view of the core as if it were laying on its side; or as an unwrapped image, looking out from the center of the borehole. One popular visual data display option is the projection of features onto an imaginary core that can be rotated and viewed from any orientation. Further analysis allows void and joint data to be presented in terms of depth, direction of dip (with respect to north), dip angle, and strike. Results of televiewer tests can be used for:

- Fracture identification
- Stratigraphic studies
- Core orientation

c) Performing pressure meter tests in order to obtain engineering properties i.e. undrained shear strength, secant shear modulus from an unload-reload cycle, and limit pressure. The spacing between each test depends on capability of equipment.

The following laboratory tests are suggested as part of geotechnical program for Heroes Tunnel for this alternative:

- Unconfined Compressive Strength (UCS) of rock; this test is critical in making decision on using drill-and-blast or roadheader for excavation of the tunnel. A minimum number of this test shall be provided in bid document package for selecting the contractor.
- Brazilian Tensile Strength of rock; this test is also critical in making decision on using drill-and-blast or roadheader for excavation of the tunnel. The minimum number of this test shall be provided in bid document package for selecting the contractor.
- Elastic modulus of intact rock from Unconfined Compressive Strength (UCS) tests. The minimum number of this test shall be provided in bid document package for selecting the contractor.
- Triaxial tests to determine engineering properties of the rock mass such as elastic modulus, cohesion, and internal friction angle at various confining pressures. The minimum number of this test shall be provided in bid document package for selecting the contractor.
- Cerchar Abrasivity Index (CAI) test and drillability tests such Drilling Rate Index (DRI), Bit Wear Index (BWI), and Cutter Life Index (CLI). The main purpose of these tests are to determine the abrasivity of the rock and to estimate the life of the cutting tools. The minimum number of these tests shall be provided in bid document package for selecting the contractor.

Summary

The recommended geotechnical field exploration and laboratory testing program is provided above to for the construction bypass tunnel parallel to the northbound tunnel and enlargement/rehabilitation of the existing northbound and southbound tunnels. Horizontal borehole drilling is recommended for the new bypass tunnels with options for accessing either the north or south portals of the tunnel. Geotechnical investigations are recommended for the existing tunnels using vertical borehole drilling.

Appendix A

Cost Estimate

HEROES TUNNEL CONSTRUCTION SCENARIO
1070' CONSTRUCTION BYPASS TUNNEL - OPTION 6

CONCEPTUAL COST ESTIMATE

Construction Scenario Description:

Construct 1,070' new 2 lane northbound construction bypass barrel. Enlarge the existing northbound and southbound barrels to 3 lane configurations. Construction duration: 43 Months.

New Tunnel Construction Method:

Drill-and-Blast

Existing Tunnel Rehabilitation Method:

Enlarged Barrel:
Drill-and-Blast

Construction Duration:
43 Months per Barrel

Construction Duration

129 Months

TOTAL COST SUMMARY

CONTRACT ITEMS	ESTIMATED COST					
	NEW 2 LANE TUNNEL		ENLARGED 3 LANE NORTHBOUND TUNNEL	ENLARGED 3 LANE SOUTHBOUND TUNNEL	HIGHWAY MODIFICATIONS CONSTRUCTION	RIGHT OF WAY
NEW 2 LANE TUNNEL						
NEW 2 LANE TUNNEL	$23,771,740.00					
ABANDON VENT SHAFT		$200,000.00				
ENLARGED 3 LANE TUNNEL						
ENLARGED 3 LANE TUNNEL			$26,939,150.00	$26,939,150.00		
HIGHWAY MODIFICATIONS CONSTRUCTION						
ROADWAY FEATURES (OUTSIDE OF TUNNEL)					$6,790,000.00	
RIGHT OF WAY						
ROW ACQUISITIONS						$2,101,449.28
TOTAL CONTRACT ITEMS	**$23,771,740.00**	**$200,000.00**	**$26,939,150.00**	**$26,939,150.00**	**$6,790,000.00**	**$2,101,449.28**
MINOR ITEM ALLOWANCE (20%)	$6,890,359.42	$57,971.01	$7,808,449.28	$7,808,449.28	$1,968,115.94	NA
MAINTENANCE & PROTECTION OF TRAFFIC (4%)	NA	NA	NA	NA	NA	NA
CLEARING AND GRUBBING (3%)	$1,033,553.91	$8,695.65	$1,171,267.39	$1,171,267.39	$295,217.39	NA
CONSTRUCTION STAKING (1%)	$344,517.97	$2,898.55	$390,422.46	$390,422.46	$98,405.80	NA
MOBILIZATION (7%)	$2,411,625.80	$20,289.86	$2,732,957.25	$2,732,957.25	$688,840.58	NA
BASE ESTIMATE	**$34,451,797.10**	**$289,855.07**	**$39,042,246.38**	**$39,042,246.38**	**$9,840,579.71**	**$2,101,449.28**
CONTINGENCY (30%)	$10,335,539.13	$86,956.52	$11,712,673.91	$11,712,673.91	$2,952,173.91	NA
INCIDENTALS (15%)	$5,167,769.57	$43,478.26	$5,856,336.96	$5,856,336.96	$1,476,086.96	NA
SUBTOTAL	**$49,955,105.80**	**$420,289.86**	**$56,611,257.25**	**$56,611,257.25**	**$14,268,840.58**	**$2,101,449.28**
INFLATION (5 YEARS @ 4%)	$9,991,021.16	$84,057.97	$11,322,251.45	$11,322,251.45	$2,853,768.12	$420,289.86
ITEM TOTAL	**$59,946,126.96**	**$504,347.83**	**$67,933,508.70**	**$67,933,508.70**	**$17,122,608.70**	**$2,521,739.14**
NEW 2 LANE TUNNEL TOTAL		**$60,450,474.78**				
ENLARGED 3 LANE TUNNEL			**$67,933,508.70**	**$67,933,508.70**		
HIGHWAY MODIFICATIONS CONSTRUCTION					**$17,122,608.70**	
RIGHT OF WAY TOTAL						**$2,521,739.14**
CONSTRUCTION TOTAL	**$215,961,840.01**					
ENGINEERING TOTAL	**$20,000,000.00**					
PROJECT TOTAL	**$235,961,840.01**					

Note: NA denotes Maintenance & Protection of Traffic already included in cost calculation.

HEROES TUNNEL CONSTRUCTION SCENARIO
1200' CONSTRUCTION BYPASS TUNNEL - OPTION 7

CONCEPTUAL COST ESTIMATE

Construction Scenario Description:

Construct 1,200' new 2 lane northbound construction bypass barrel. Enlarge the existing northbound and southbound barrels to 3 lane configurations. Construction duration: 48 Months.

New Tunnel Construction Method:

Drill-and-Blast

Existing Tunnel Rehabilitation Method:

Enlarged Barrel:
Drill-and-Blast

Construction Duration:
43 Months per Barrel

Construction Duration

134 Months

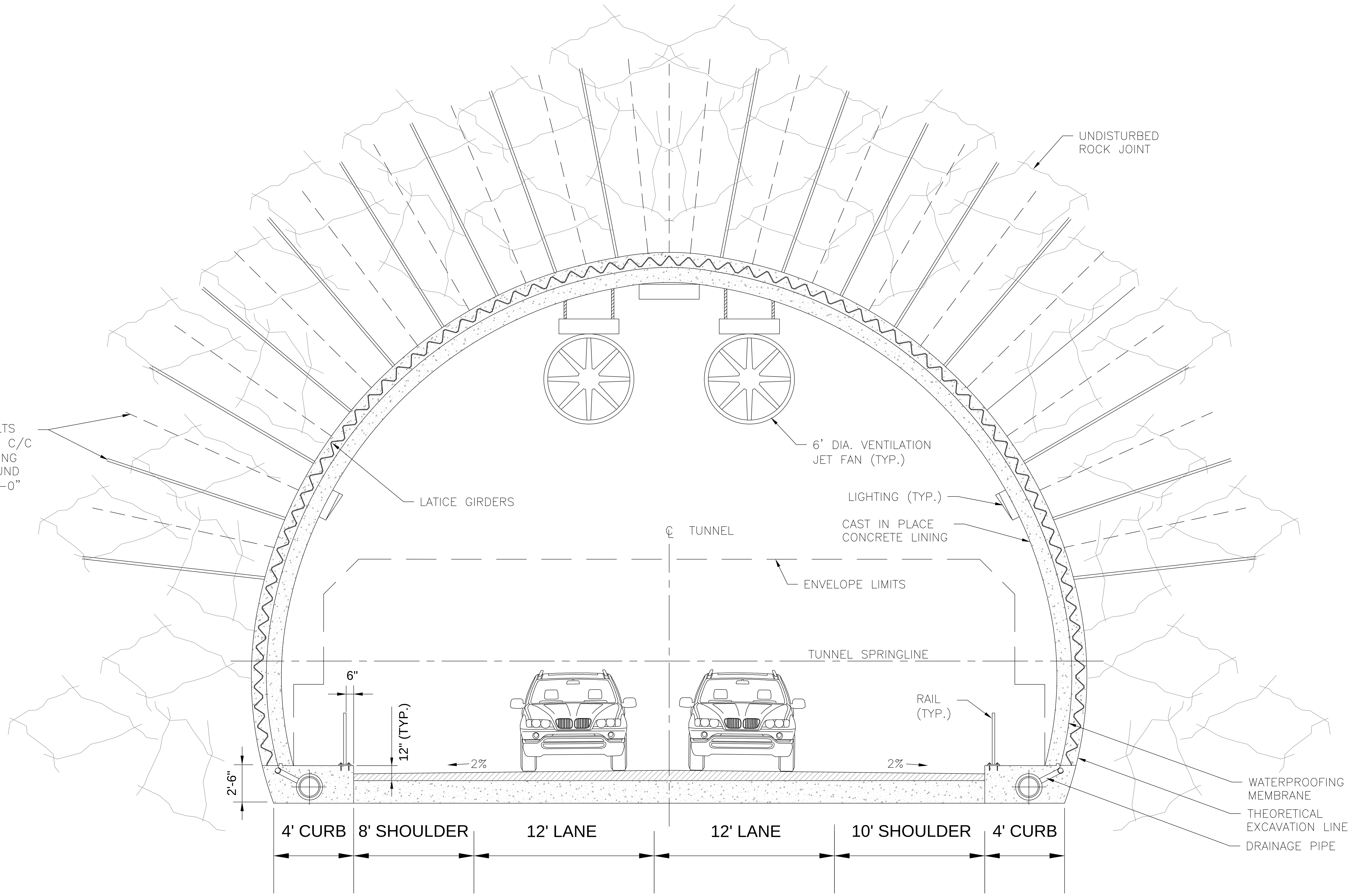
TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**					
	NEW 2 LANE TUNNEL		**ENLARGED 3 LANE NORTHBOUND TUNNEL**	**ENLARGED 3 LANE SOUTHBOUND TUNNEL**	**HIGHWAY MODIFICATIONS CONSTRUCTION**	**RIGHT OF WAY**
NEW 2 LANE TUNNEL						
NEW 2 LANE TUNNEL	$25,538,514.00					
ABANDON VENT SHAFT		$200,000.00				
ENLARGED 3 LANE TUNNEL						
ENLARGED 3 LANE TUNNEL			$26,939,150.00	$26,939,150.00		
HIGHWAY MODIFICATIONS CONSTRUCTION						
ROADWAY FEATURES (OUTSIDE OF TUNNEL)					$6,790,000.00	
RIGHT OF WAY						
ROW ACQUISITIONS						$2,101,449.28
TOTAL CONTRACT ITEMS	**$25,538,514.00**	**$200,000.00**	**$26,939,150.00**	**$26,939,150.00**	**$6,790,000.00**	**$2,101,449.28**
MINOR ITEM ALLOWANCE (20%)	$7,402,467.83	$57,971.01	$7,808,449.28	$7,808,449.28	$1,968,115.94	NA
MAINTENANCE & PROTECTION OF TRAFFIC (4%)	NA	NA	NA	NA	NA	NA
CLEARING AND GRUBBING (3%)	$1,110,370.17	$8,695.65	$1,171,267.39	$1,171,267.39	$295,217.39	NA
CONSTRUCTION STAKING (1%)	$370,123.39	$2,898.55	$390,422.46	$390,422.46	$98,405.80	NA
MOBILIZATION (7%)	$2,590,863.74	$20,289.86	$2,732,957.25	$2,732,957.25	$688,840.58	NA
BASE ESTIMATE	**$37,012,339.13**	**$289,855.07**	**$39,042,246.38**	**$39,042,246.38**	**$9,840,579.71**	**$2,101,449.28**
CONTINGENCY (30%)	$11,103,701.74	$86,956.52	$11,712,673.91	$11,712,673.91	$2,952,173.91	NA
INCIDENTALS (15%)	$5,551,850.87	$43,478.26	$5,856,336.96	$5,856,336.96	$1,476,086.96	NA
SUBTOTAL	**$53,667,891.74**	**$420,289.86**	**$56,611,257.25**	**$56,611,257.25**	**$14,268,840.58**	**$2,101,449.28**
INFLATION (5 YEARS @ 4%)	$10,733,578.35	$84,057.97	$11,322,251.45	$11,322,251.45	$2,853,768.12	$420,289.86
ITEM TOTAL	**$64,401,470.09**	**$504,347.83**	**$67,933,508.70**	**$67,933,508.70**	**$17,122,608.70**	**$2,521,739.14**
NEW 2 LANE TUNNEL TOTAL		**$64,905,817.91**				
ENLARGED 3 LANE TUNNEL			**$67,933,508.70**	**$67,933,508.70**		
HIGHWAY MODIFICATIONS CONSTRUCTION					**$17,122,608.70**	
RIGHT OF WAY TOTAL						**$2,521,739.14**
CONSTRUCTION TOTAL	**$220,417,183.14**					
ENGINEERING TOTAL	**$20,000,000.00**					
PROJECT TOTAL	**$240,417,183.14**					

Note: NA denotes Maintenance & Protection of Traffic already included in cost calculation.

Appendix B

Construction Bypass Tunnel



TWO LANE CONFIGURATION

Figure 1 Cross Section of New temporary Two lane Tunnel

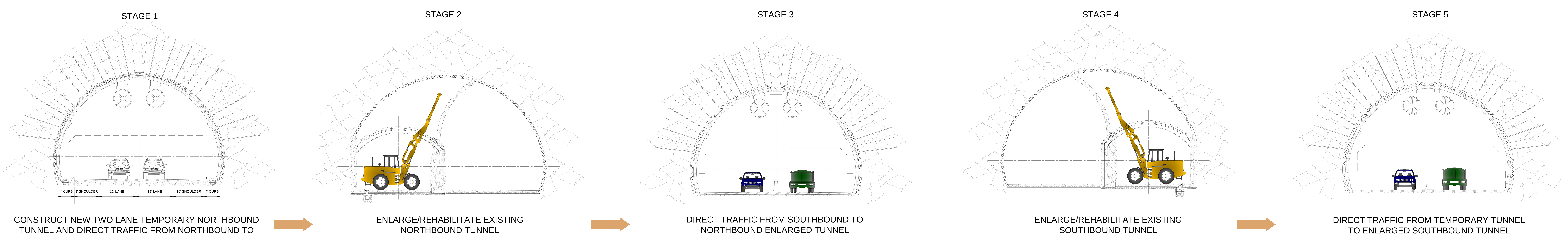
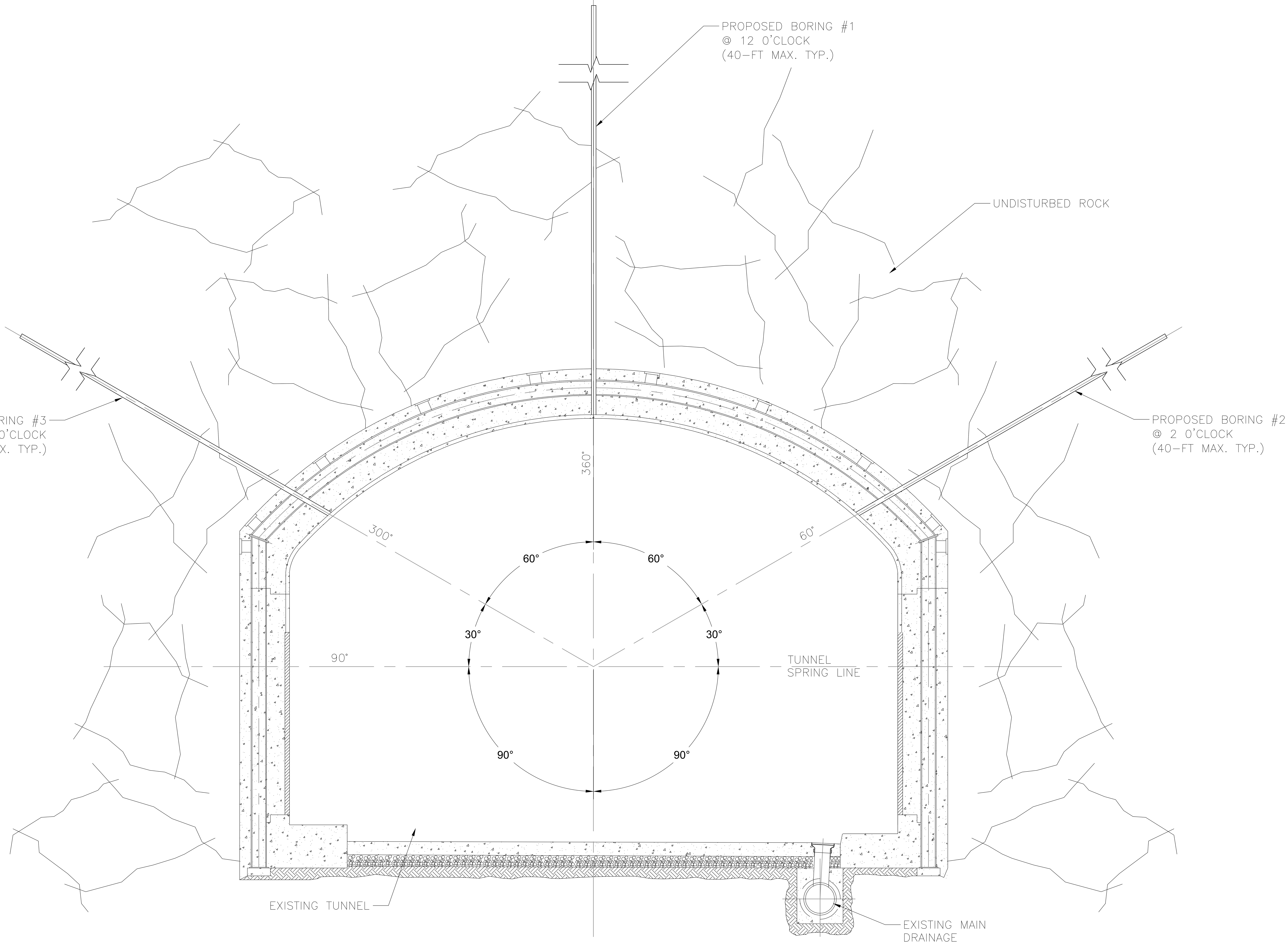
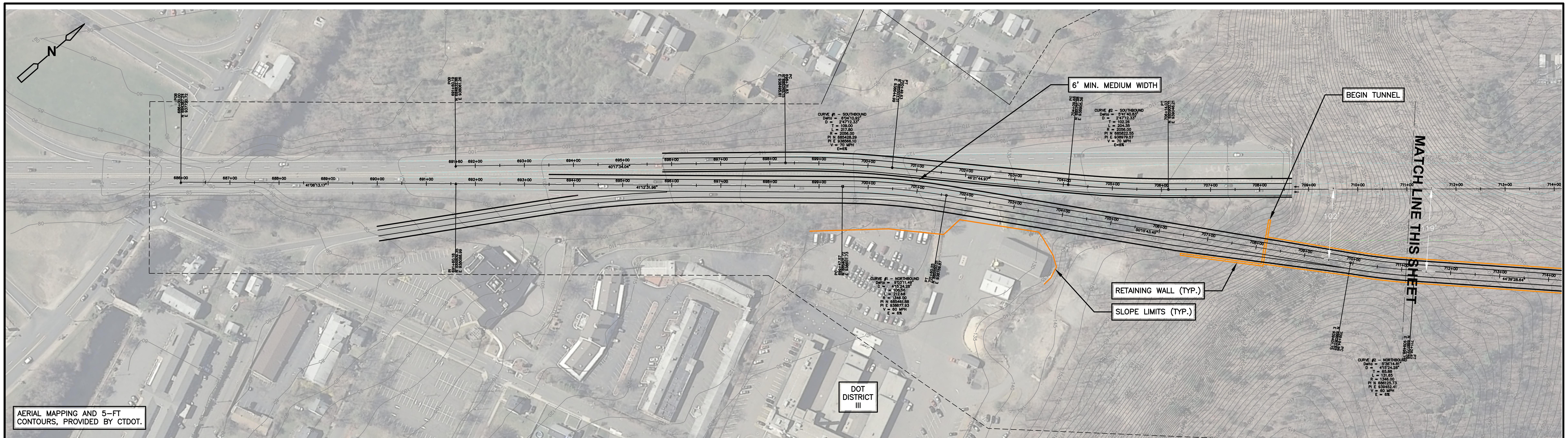


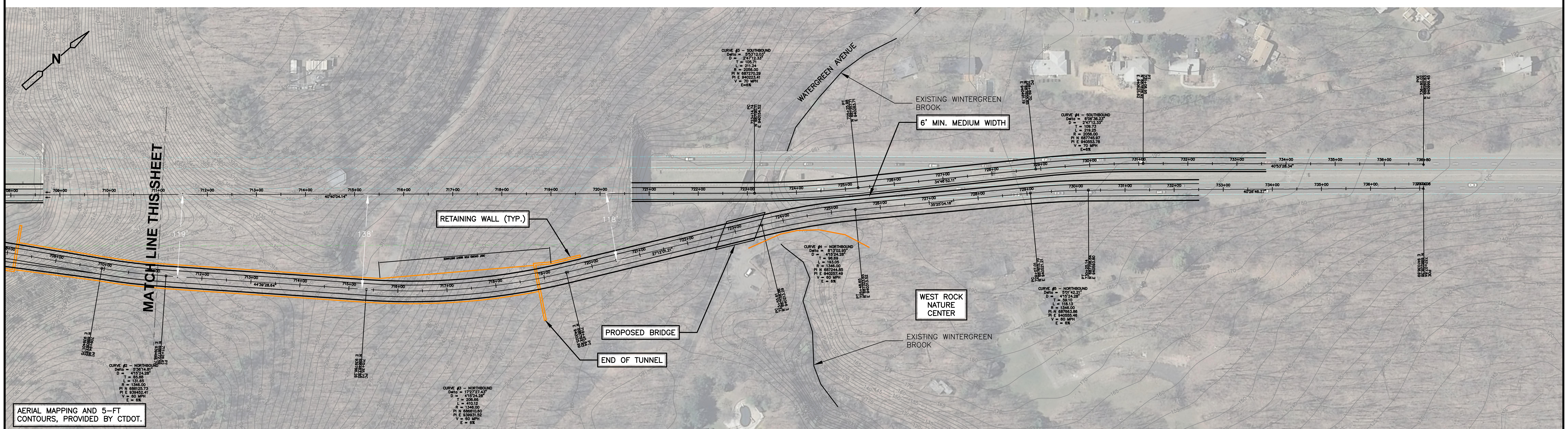
Figure 2
CONSTRUCTION SEQUENCES


PROPOSED BORING #1
@ 12 O'CLOCK
(40-FT MAX. TYP.)
UNDISTURBED ROCK
PROPOSED BORING #3
@ 10 O'CLOCK
(40-FT MAX. TYP.)
PROPOSED BORING #2
@ 2 O'CLOCK
(40-FT MAX. TYP.)
360°
300°
60°
60°
60°
30°
30°
90°
TUNNEL
SPRING LINE
90°
90°
EXISTING TUNNEL
EXISTING MAIN
DRAINAGE

Appendix C

Highway Design





REV.	DATE	REVISION DESCRIPTION	SHEET NO.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE CONDITIONS OF ACTUAL QUANTITIES OF WORK WHICH WILL BE REQUIRED.

Plotted Date: 6/7/2016

DESIGNER/DRAFTER: JGC/WGS

CHECKED BY: JCB

SCALE 1" = 100'

100 50 0 100

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: ...\Exports\Option 4 Sheet 1.dgn

SIGNATURE/
BLOCK:

PROJECT TITLE:
HEROES TUNNEL (ROUTE 15) STUDY
CONSTRUCTION BYPASS TUNNEL
STATE PROJECT NO. 167-108

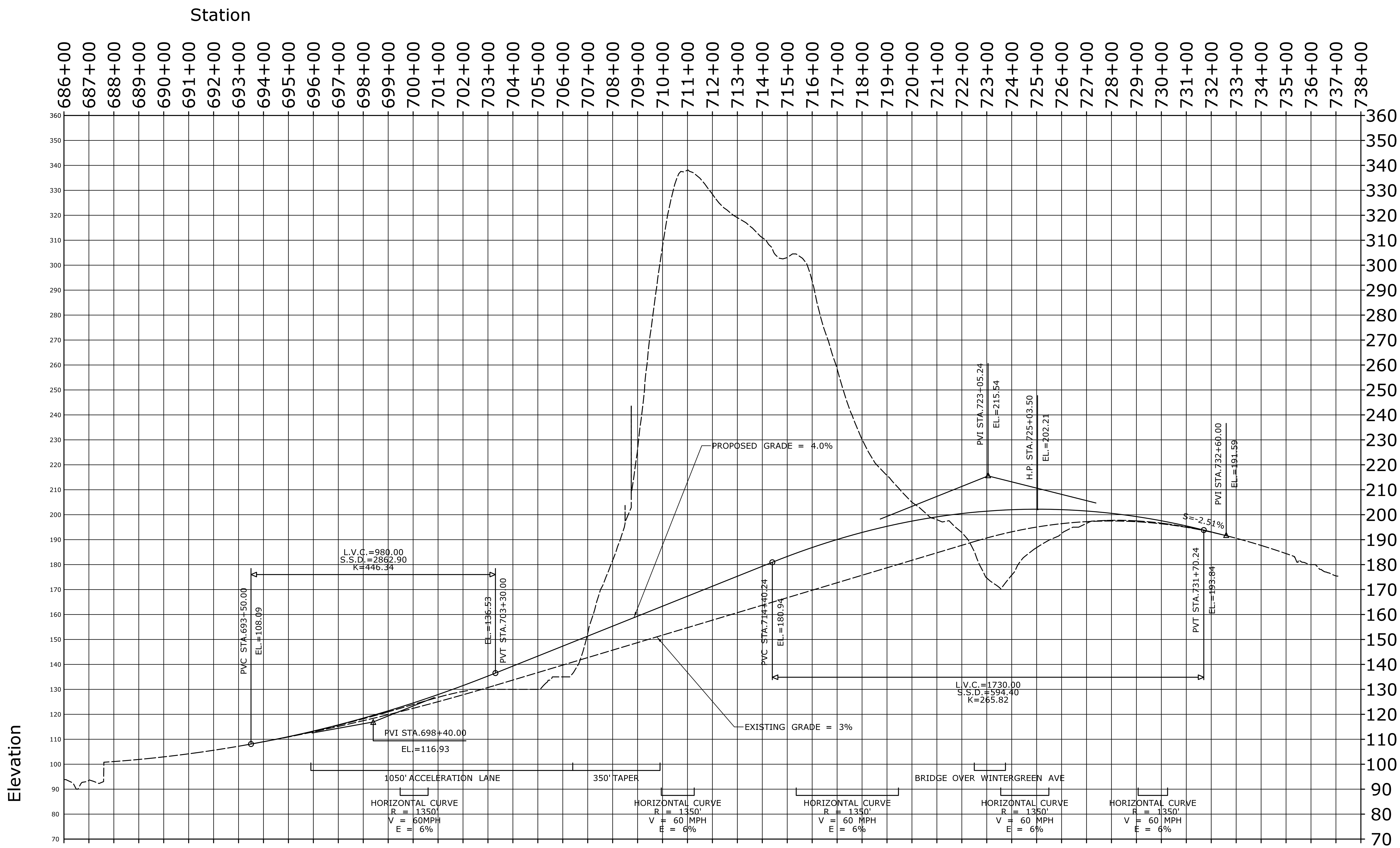
TOWN:
HAMDEN, NEW HAVEN
AND WOODBRIDGE

DRAWING TITLE:
OPTION 6
4% GRADE

PROJECT NO.
167-108

DRAWING NO.
PLN-01

SHEET NO.
1



REV.	DATE	REVISION DESCRIPTION	SHEET NO.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE CONDITIONS OF ACTUAL QUANTITIES OF WORK WHICH WILL BE REQUIRED.

Plotted Date: 6/7/2016

DESIGNER/DRAFTER: WGS
CHECKED BY: JCB
HORIZ. SCALE IN FEET 0 200 400
VERT. SCALE IN FEET 0 20 40

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: ...\Exports\Option 4 Design.dgn

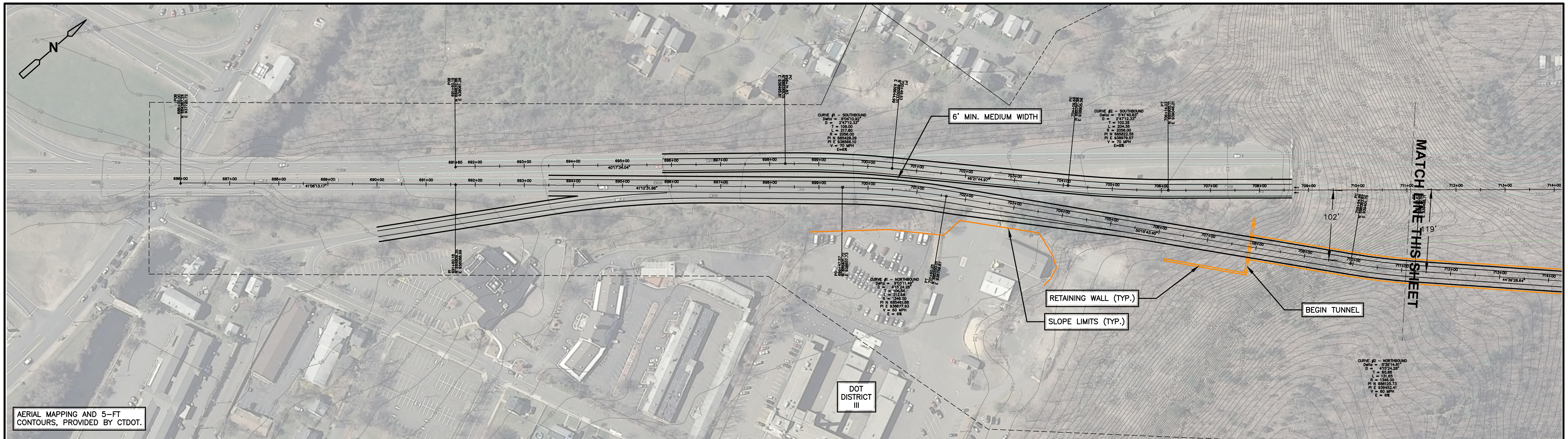
SIGNATURE/BLOCK:

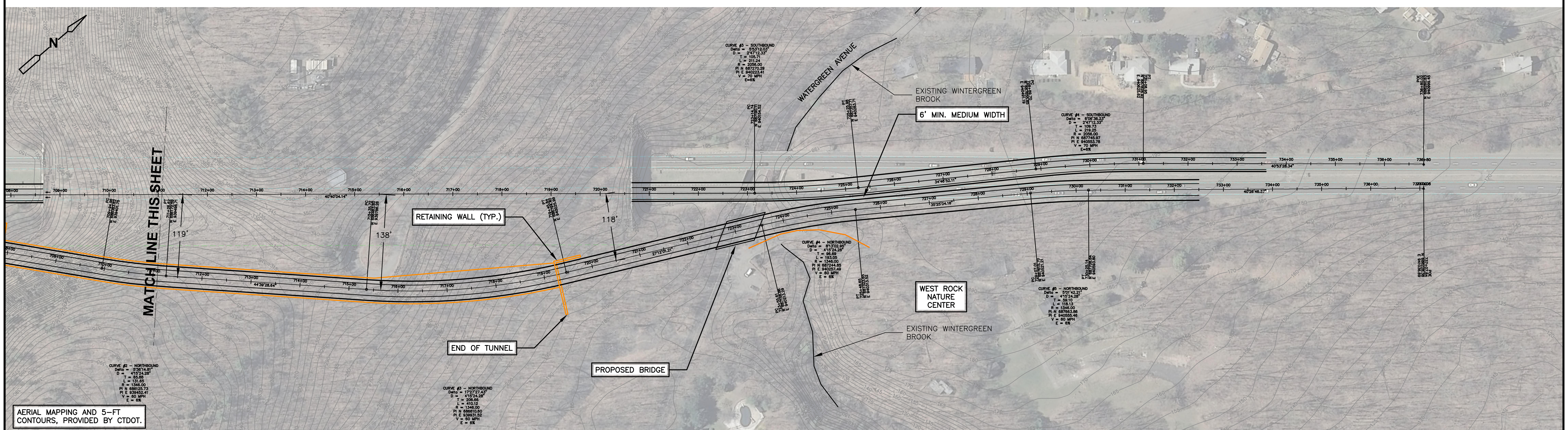
PROJECT TITLE:
HEROES TUNNEL (ROUTE 15) STUDY
CONSTRUCTION BYPASS TUNNEL
STATE PROJECT NO. 167-108

TOWN: HAMDEN, NEW HAVEN AND WOODBRIDGE

DRAWING TITLE: OPTION 6 PROFILE 4% GRADE

PROJECT NO. 100381
DRAWING NO. PRF-01
SHEET NO. 2





REV.	DATE	REVISION DESCRIPTION	SHEET NO.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE CONDITIONS OF ACTUAL QUANTITIES OF WORK WHICH WILL BE REQUIRED.

Plotted Date: 6/7/2016

DESIGNER/DRAFTER: JGC/WGS

CHECKED BY: JCB

SCALE 1" = 100'

100 50 0 100

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: ...\Exports\Option 4 Sheet 1.dgn

SIGNATURE/ BLOCK:

PROJECT TITLE:

HEROES TUNNEL (ROUTE 15) STUDY
CONSTRUCTION BYPASS TUNNEL
STATE PROJECT NO. 167-108

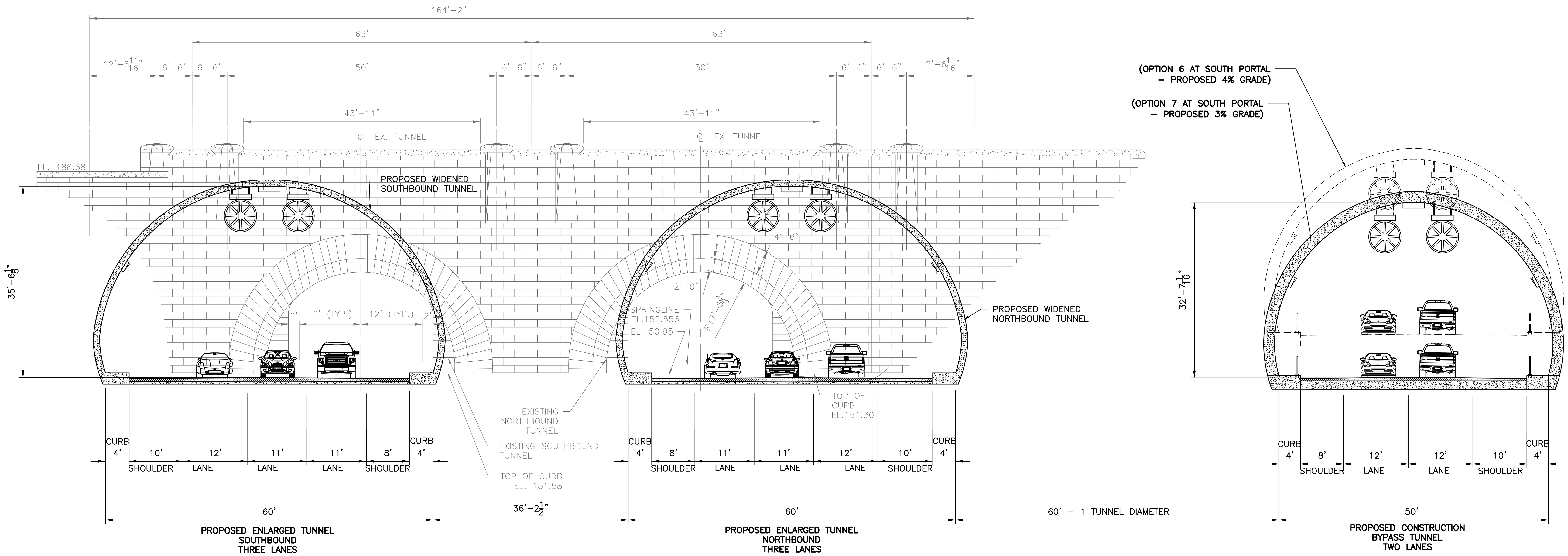
TOWN: **HAMDEN, NEW HAVEN AND WOODBRIDGE**

DRAWING TITLE: **OPTION 7**
3% GRADE

PROJECT NO. **167-108**

DRAWING NO. **PLN-02**

SHEET NO. **3**



REV.	DATE	REVISION DESCRIPTION	SHEET NO.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE CONDITIONS OF ACTUAL QUANTITIES OF WORK WHICH WILL BE REQUIRED.

Plotted Date: 05/24/2016

DESIGNER/DRAFTER: JGC
CHECKED BY: MRJ/JCB
SCALE IN FEET 8 0 8 16
SCALE 3/32"=1'

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

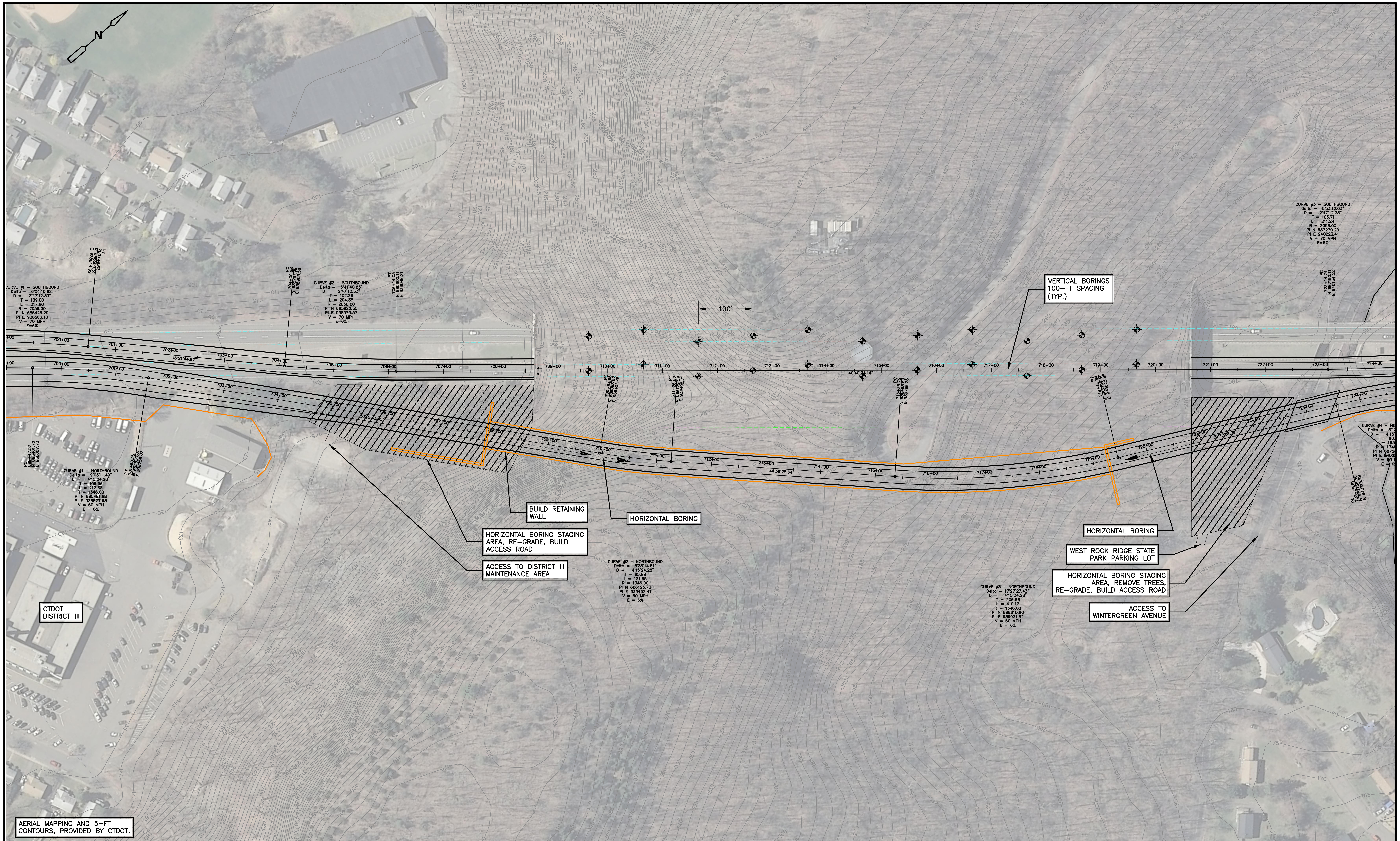
Filename: ...\alt 5 at 3%.dwg

SIGNATURE/BLOCK: OFFICE OF ENGINEERING
APPROVED BY:

PROJECT TITLE:
HEROES TUNNEL (ROUTE 15) STUDY
CONSTRUCTION BYPASS TUNNEL
STATE PROJECT NO. 167-108

TOWN: HAMDEN, NEW HAVEN AND WOODBRIDGE
DRAWING TITLE: SOUTH PORTAL (WOODBRIDGE)

PROJECT NO. 100381
DRAWING NO. ST-01
SHEET NO. 04



REV.	DATE	REVISION DESCRIPTION	SHEET NO.

THE INFORMATION, INCLUDING ESTIMATED QUANTITIES OF WORK, SHOWN ON THESE SHEETS IS BASED ON LIMITED INVESTIGATIONS BY THE STATE AND IS IN NO WAY WARRANTED TO INDICATE THE CONDITIONS OF ACTUAL QUANTITIES OF WORK WHICH WILL BE REQUIRED.

Plotted Date: 6/7/2016

DESIGNER/DRAFTER: JGC

CHECKED BY: JCB

SCALE 1" = 100'

100 50 0 100

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: ...\Exports\Option 4 Sheet 1.dgn

SIGNATURE/BLOCK:

PROJECT TITLE:
HEROES TUNNEL (ROUTE 15) STUDY CONSTRUCTION BYPASS TUNNEL STATE PROJECT NO. 167-108

TOWN: **HAMDEN, NEW HAVEN AND WOODBRIDGE**

DRAWING TITLE: **GEOTECHNICAL BORING CONCEPT**

PROJECT NO. **167-108**

DRAWING NO. **GPLN-01**

SHEET NO. **5**