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

Heroes Tunnel Alternative Construction Options Study Final Report

Prepared for:

Connecticut Department of Transportation

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Executive Summary

ES.1 Background and Overview

Heroes Tunnel is located in the State of Connecticut within the Town of Woodbridge and the City of New Haven near the Hamden border. The quarter mile long tunnel is part of the Wilbur Cross Parkway (Route 15), a vital roadway within the State transportation infrastructure which connects New York to the Hartford area and serves as an alternate expressway route to I-95 and I-91. In the vicinity of Heroes Tunnel, Route 15 carries approximately 71,000 vehicles daily. The tunnel consists of two existing tunnel barrels, each with two lanes of traffic.

Structural and drainage deficiencies have been identified within Heroes Tunnel. The general deterioration necessitates either rehabilitation or replacement and is discussed in this report in more detail. In addition to the deteriorating condition of the tunnel, other characteristics are substandard, which would be upgraded or improved through the rehabilitation or replacement of the existing tunnel.

CTDOT has begun a managed approach to responsibly manage the risk and financial implications of when to undertake the repairs necessary to rehabilitate the tunnel. The first step was a field inspection conducted by CDM Smith in 2008 in which rehabilitation steps were recommended for different elements of the tunnel including structural, electrical, and mechanical elements. Subsequently CTDOT requested CDM Smith to explore several different rehabilitation options, some of which include construction of new tunnels or expansion of the existing tunnels. Evaluation of the rehabilitation and construction options is the basis of this report.

ES.2 Overview of Construction Options #1-5

In collaboration, CTDOT and CDM Smith identified five alternative construction options. The initial proposal to rehabilitate the tunnel with complete shutdown of the tunnel remains option 4 in this report. Since this option would result in severe traffic delays, four other alternative construction options are examined that would reduce the impact of rehabilitation on traffic, by maintaining three to four lanes of traffic open at all times. Option 5 provides for rehabilitation of the tunnel with partial shutdown of the tunnel (one lane). Options 1 through 3 take a different track, by first either constructing a new one-lane or two-lane tunnel (options 1 and 2, respectively), or widening one of the existing tunnels (option 3) prior to rehabilitation of the existing tunnels. Thus, options 1 through 3 offer an ancillary benefit – providing excess tunnel capacity in the future.

The following criteria were used to evaluate the five options, ranked in order of importance (starting with the most important):

1. Impact on traffic.
2. Construction cost.
3. Construction duration and sequencing.
4. Construction complexity.

In addition, the anticipated useful life of each option was evaluated, along with the highway redesign required, and road user costs associated with the traffic delays. The report also presents the concept design of a proposed interchange between Route 15 and Route 40, which would provide for some traffic relief on Route 15 during construction of options 4 or 5. The report also includes a literature review of state-of-the-art vehicle height warning systems and traffic data collection systems that could be used at the Heroes Tunnel site. The flow of the report is presented in **Section 1**.

ES.3 How the Five (5) Construction Options Would Be Combined for Six (6) Construction Sequencing Scenarios

The five alternative construction and rehabilitation options are described in **Sections 2 through 8**. In order to achieve the goal of providing at least three traffic lanes through the existing or new tunnels, the following construction scenarios are possible, which combine some of the options described:

Construction Scenario A	Construct a new single barrel tunnel (Option 1) and subsequently rehabilitate both existing barrels in a staggered approach (minimal traffic impact). This results in 5 lanes in the future.
Construction Scenario B1	Construct a new double lane single barrel tunnel (Option 2) and subsequently rehabilitate one of the two existing barrels (minimal traffic impact); abandon non-rehabilitated barrel. This results in 4 lanes in the future plus a non-rehabilitated 2-lane tunnel that could potentially be used for storage by installing bulkheads at each portal to prevent access of pedestrians and traffic through the tunnel.
Construction Scenario B2	Construct a new double lane single barrel tunnel (Option 2) and subsequently rehabilitate both of the two existing barrels (minimal traffic impact). This results in 6 lanes in the future.
Construction Scenario C	Enlarge one barrel of the existing tunnel (Option 3) and subsequently rehabilitate the other existing barrel (minimal traffic impact). This results in 5 lanes in the future.
Construction Scenario D	Rehabilitate both of the existing barrels with a complete shutdown of one barrel, followed by a complete shutdown of the other barrel (Option 4). This results in 4 lanes in the future.
Construction Scenario E	Rehabilitate both of the existing barrels with a partial shutdown of one barrel, followed by a partial shutdown of the other barrel (Option 5). This results in 4 lanes in the future.

Table ES.1 summarizes the costs and benefits of each of the construction sequencing scenarios.

Table ES.1 Costs and benefits of each of the construction sequencing scenarios

Construction Scenario	Cost estimate(million $2019)[1]	Duration (months)	Monetized Benefits	Non-Monetized Benefits
A[2]	106	37	Avoid $1-800 million in delay costs associated with Options 4 and 5	Avoid complex construction; Additional capacity in the future; Minimal traffic disruption
B1[3]	108	28	Avoid $1-800 million in delay costs associated with Options 4 and 5	Avoid complex construction; Minimal traffic disruption
B2[4]	120	40	Avoid $1-800 million in delay costs associated with Options 4 and 5	Avoid complex construction; Additional capacity in the future; Minimal traffic disruption
C[5]	91	65	Avoid $1-800 million in delay costs associated with Options 4 and 5	Additional capacity in the future; Minor traffic disruption
D[6]	30	24	Lowest construction/rehabilitation cost of any of the options (but extremely high traffic impacts and associated delay costs)	Avoid complex construction
E[7]	31	20	Avoid $2-800 million in delay costs associated with Option 4	Avoid significant traffic disruption

[1] Here, the "cost estimate" includes construction, engineering, and ROW costs. This value does not include delay costs.
[2] The cost of this scenario includes the construction, engineering, and ROW costs of option 1 ($50 million) plus the construction, engineering, and ROW costs of option 4 ($26 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[3] The cost of this scenario includes the construction, engineering, and ROW costs of option 2 ($60 million) plus half of the construction, engineering, and ROW costs of option 4 ($13 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[4] The cost of this scenario includes the construction, engineering, and ROW costs of option 2 ($60 million) plus the construction, engineering, and ROW costs of option 4 ($26 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[5] The cost of this scenario includes the construction, engineering, and ROW costs of option 3 ($67 million) plus half of the construction, engineering, and ROW costs of option 4 ($13 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[6] The cost of this scenario includes the construction, engineering, and ROW costs of option 4 ($26 million). The duration is the duration estimated for option 4 (24 months).
[7] The cost of this scenario includes the construction, engineering, and ROW costs of option 5 ($28 million). The duration is the duration estimated for option 5 (20 months).

The five construction sequencing scenarios are rated in **Table ES.2** against the criteria identified in the scope of work.

Table ES.2 Non-cost impacts of each of the construction options. (Green indicates preferable conditions, yellow indicates moderate conditions, and red indicates negative conditions.)

Construction Sequencing Scenario	Impact on traffic	Cost estimate[1]	Construction duration	Construction complexity	Anticipated Useful Life	Number of lanes open at project completion
A	[green]	[yellow]	[yellow]	[green]	[green]	5
B1	[green]	[yellow]	[yellow]	[green]	[green]	4
B2	[green]	[red]	[yellow]	[green]	[green]	6
C	[green]	[yellow]	[red]	[red]	[green]	5
D	[red]	[green]	[green]	[green]	[green]	4
E	[yellow]	[green]	[green]	[red]	[green]	4

[1] Here, the "cost estimate" includes construction, engineering, and ROW costs. This value does not include delay costs.

Scenario D is not viable because of major traffic impacts and high delay costs. Scenario C is not viable because of very high construction cost, duration, and complexity.

Scenarios A, B1, and B2 have higher cost than scenario E, but scenarios A, B1, and B2 may be viable since they offer lower traffic impacts and lower complexity than Scenario E. Scenarios A and B2 provide the ancillary benefit of additional capacity in the future. Although scenario B1 represents cost and duration savings compared to scenario A or B2 since only one of the existing tunnels will be rehabilitated, scenario B1 has a disadvantage compared to scenario A and B2 in that one tunnel is abandoned in a state of deterioration, whereas both tunnels are rehabilitated in scenarios A and B2. This disadvantage can be addressed by planning for scheduled inspection and maintenance of the abandoned tunnel. To prevent any access of pedestrians and the traffic into the abandoned tunnel, bulkhead with access doors for CTDOT staff can be installed at both portals.

Scenario B2 provides a new two barrel tunnel and rehabilitation of both existing tunnels. This would increase the capacity of the tunnel for future and in case of any future maintenance work there would be no impact on traffic. However, the cost is higher than all other options excepting Scenario C. A drawback to the additional capacity provided by scenario B2 is that the configuration results in three two-lane tunnels. Since the middle tunnel cannot be split down the middle to allow traffic to travel in both directions due to safety, the result would be 4 lanes of traffic in one direction and 2 lanes of traffic in the other direction. This setup would be valuable in highly urbanized areas with unidirectional traffic loads during rush hour, but this is not the reality in the vicinity of the Heroes Tunnel. Thus, the excess capacity under scenario B2 might not be very valuable in terms of providing regional traffic relief.

It should be noted that regardless of the selected scenario, the final design of each scenario would require execution of a comprehensive geotechnical field investigation and laboratory tests in order to ascertain the rockmass properties such as intact rock strength, joint direction, joint condition, permeability, etc.

ES.4 Recommended Approach

CDM Smith recommends further consideration of two of the construction scenarios: scenarios A and E. Scenario E achieves the main objective of the project (tunnel rehabilitation) at a low cost. Scenario A meets the objective of the project while also providing a new tunnel with one lane of extra capacity in the future.

Alternately, CTDOT may consider construction alternatives not originally identified by CTDOT at the outset of this study. Ongoing discussions with CTDOT have identified the following additional construction alternative:

Alternative Construction Scenario	Construct new 2 or 3 lane northbound barrel. Enlarge the southbound barrel to a 2 or 3 lane configuration. Rehabilitate the existing northbound barrel for use as a service tunnel.

The direction and refinement of this alternative will depend on the Interchange 59 Study determinations, future traffic projections and needs, as well as a cost/benefit analysis. The rehabilitation of the existing northbound barrel may be included as an alternate construction bid proposal. Based on the conceptual cost estimates developed above, CDM Smith estimates this construction alternative will cost a minimum of $170,000,000.

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Section 1

Introduction

1.1 Project Objective

The purpose of this study is to provide the Connecticut Department of Transportation (CTDOT) a comprehensive evaluation of alternative construction and rehabilitation options for improvements to the Heroes Tunnel. The options presented in this report are conceptual in nature. The recommendations in this report are intended to assist CTDOT in moving forward to plan one or two specific approaches for final design.

1.2 Background

1.2.1 Location and Importance

Heroes Tunnel is located in the State of Connecticut within the Town of Woodbridge and the City of New Haven near the Hamden border (shown in **Figures 1.1 through 1.3**).

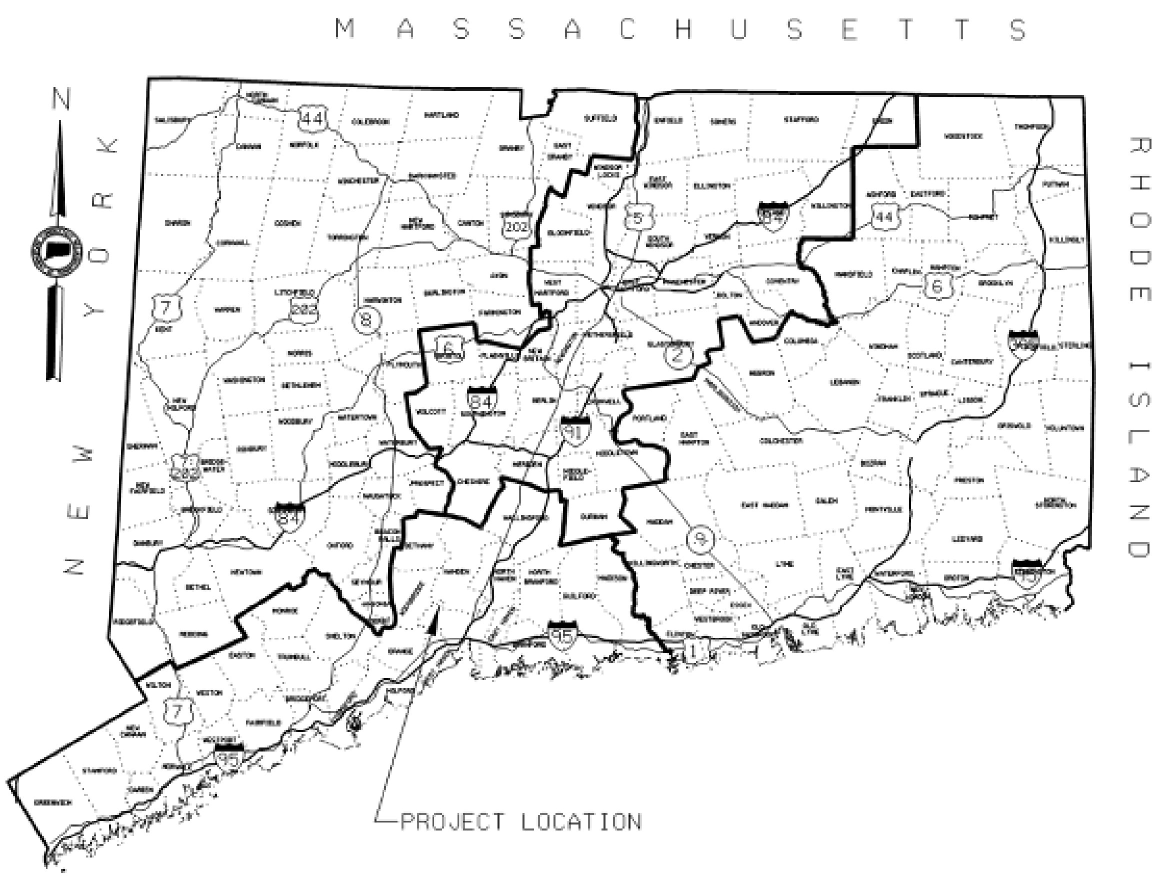
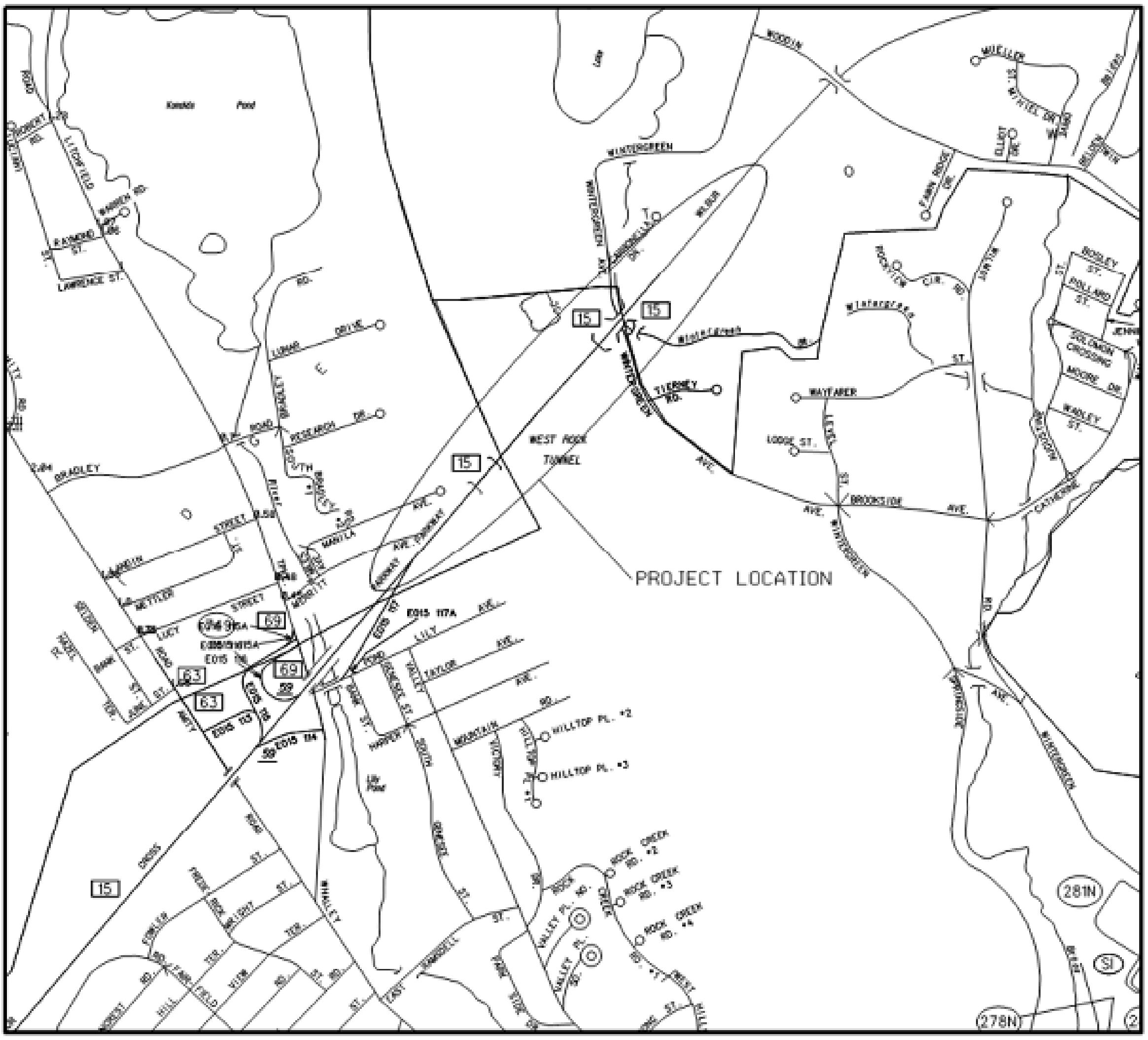


Figure 1.1 Project Location: State of Connecticut



LOCATION PLAN

NOT TO SCALE

Figure 1.2 Project Location: Location of Tunnel on Route 15

a) Topographic View of Site

b) Satellite View of Site

Figure 1.3: Tunnel Location and Topography

Heroes Tunnel is the only highway tunnel in the State of Connecticut. The tunnel is part of the Wilbur Cross Parkway (Route 15), seen in Figure 1.2; a scenic connection between Hartford and New York. Originally constructed and opened to traffic in 1949, the tunneled portion of the parkway passes through the West Rock Ridge. The tunnel was originally named West Rock Tunnel, but was redesignated as Heroes Tunnel in 2003. Route 15 is a vital roadway within the State transportation infrastructure. In the vicinity of Heroes Tunnel, Route 15 carries approximately 71,000 vehicles daily. Locally, Route 15 provides access to residences, shopping centers, and points of interest, as well as other state roadways. Regionally, Route 15 connects New York to the Hartford area and serves as an alternate expressway route to I-95 and I-91.

The tunnel is approximately one quarter mile long and passes through the West Rock Ridge. West Rock Ridge, or West Rock of south-central Connecticut with a high point of 700 feet, is a 7-mile long rock ridge located on the west side of New Haven. The ridge forms a continuous line of exposed cliff visible from New Haven. West Rock Ridge is located in the municipalities of New Haven, Hamden, Woodbridge, and Bethany, Connecticut. The Ridge is 1 mile wide at its widest point, although steepness of the terrain makes the actual square mileage much larger. Notable peaks on the ridge include the high point, alternately called High Rock or York Mountain, approximately 700 feet at the north terminus of the ridge, and the southern prominence, usually referred to as West Rock, 400 feet.

The West Rock Ridge is an important aquifer. The ridge is bordered on the west by property owned by the South Central Connecticut Regional Water Authority; reservoirs include Lake Dawson and Lake Watrous. Konolds Pond, which is not used as a water source, is located just north of Route 15 in an industrial area. West Rock Ridge is within the limits of West Rock Park, which is controlled by the Connecticut Department of Energy and Environmental Protection. The main body of water inside the park is Lake Wintergreen, 44 acres, located east of the ridge. There is also a small fishing pond located near Mountain Road, and a flood control pond located at the north end of the park. Route 15 passes through the south-central side of the ridge in Heroes Tunnel.

A network of suburban streets abuts the mountain on all sides and a seasonal paved park road climbs to the crest of the ridge and along its length. Several communications towers are located along the ridge crest. Baldwin Drive traverses the park and crosses the tunnel several times. This is a typical side slope park road with steep grades and sharp horizontal curves.

1.2.2 Tunnel Description

The tunnel consists of two existing tunnel barrels, each with two lanes of traffic. Each barrel is 1,200 feet long and approximately 28 feet wide, 19 feet high, with two 11-foot lanes, 6-inch wide shoulders on each side, and 26-inch wide raised walkways on each side. The roadway slopes at a 2.08 percent cross-slope toward the right shoulder inside each barrel and rises from the southwest to the northeast at a consistent grade of 3.0 percent through the entire tunnel barrel including the approaches for approximately 300 feet on either end of the barrels.

1.2.3 Current Problems

Structural and drainage deficiencies have been identified within Heroes Tunnel. The general deterioration necessitates either rehabilitation or replacement and is discussed below in more detail. In addition to the deteriorating condition of the tunnel, other relative characteristics are substandard, which would be upgraded or improved through the rehabilitation or replacement of the existing tunnel.

1.2.3.1 Deterioration

CTDOT recognized the risk involved with general aging of the infrastructure that is compounded by potential safety issues to the vehicular traffic caused by groundwater and New England winter weather. The existing drainage system has been modified extensively since its original construction, which likely impacted its intent to provide conveyance of both surface runoff from the roadway, and hydrostatic pressure behind the tunnel lining. The presence of groundwater entrapment behind the tunnel liner appears to be the root cause of the ongoing deterioration of the concrete liner. During the winter temperatures, ice build-up occurs, forming icicles that drop and create icy patches on the traveled way. Frequent freeze thaw cycles at joints and cracks would also accelerate the concrete lining deterioration.

1.2.3.2 Congestion

Vehicles currently reduce speed under peak flow conditions, creating congestion at the tunnel. Contributing factors include narrow shoulders and sidewalls causing driver discomfort.

1.2.3.3 Emergency Response

The current roadway dimensions within the tunnel severely constrain emergency response and management. There are no auxiliary or breakdown lanes to clear vehicles involved in a crash. Crossovers in the vicinity of the tunnel are in poor condition, making access difficult for emergency responders and are inefficient for use in incident management.

1.2.3.4 Ventilation

The ventilation system including exhaust fans and subsequent control system is in serious condition. The ventilation shafts are not currently operational, and the outlets at the bottom of the shafts into the main tunnels have been closed with steel doors. Access into the shafts is possible from within the ventilation structure atop West Rock Ridge. A visual inspection performed inside the ventilation structure indicated minor surface corrosion on the structural steel roof beams and the center support column. The concrete surfaces appear to be in good condition with no apparent deterioration. Groundwater seeps into the tunnel through space between the shaft structure and the host ground.

1.3 Past Studies

CTDOT has begun a managed approach to responsibly manage the risk and financial implications of when to undertake the repairs necessary to rehabilitate the tunnel. The first step was a field inspection conducted by CDM Smith in 2008. The comprehensive report titled "Heroes (West Rock) Tunnel Inspection and Rehabilitation Recommendations" (2008) presents the inspection results for different elements of the tunnel including structural, electrical, and mechanical elements. Since the main source of the tunnel deterioration was identified as the direct contact of groundwater with the reinforced concrete tunnel lining and water infiltration through the tunnel lining, this report also provided various alternatives for structural and water management. The proposed alternatives for rehabilitation of the tunnels required the closure of the barrel of the tunnel and diverting the traffic into the other barrel resulting in decrease of traffic lanes from the existing four lanes to two lanes.

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 are the basis of this report.

In collaboration, CTDOT and CDM Smith identified five alternative construction options, which are presented in **Section 1.5**. The initial proposal to rehabilitate the tunnel with complete shutdown of the tunnel remains option 4 in this report. The overarching goal of examining alternative construction options is to reduce the impact of rehabilitation on traffic, by maintaining three to four lanes of traffic open at all times. Option 5 provides for rehabilitation of the tunnel with partial shutdown of the tunnel (one lane). Options 1 through 3 take a different tack, by first either constructing a new one-lane or two-lane tunnel (options 1 and 2, respectively), or widening one of the existing tunnels (option 3) prior to rehabilitation of the existing tunnels. Thus, options 1 through 3 offer an ancillary benefit – providing excess tunnel capacity in the future.

This report presents all of the viable options that were identified by CTDOT and CDM Smith (i.e., options 1 through 5). No additional options were identified.

1.5 Scope of Work

The intent of this analysis is to evaluate the relative impacts resulting from the five tunnel rehabilitation and construction options. The following criteria were used to evaluate the five options, ranked in order of importance (starting with the most important):

1. Impact on traffic.
2. Construction cost.
3. Construction duration and sequencing.
4. Construction complexity.

In addition, the anticipated useful life of each option was evaluated, along with the road user costs associated with the traffic delays.

1.5.1 Scope of Construction Cost Estimates

Using the conceptual designs and layouts for each rehabilitation and construction option, construction item quantities were developed and used to create construction, rights-of-way (ROW), and engineering cost estimates.

1.5.1.1 Construction Costs

The cost estimate for each construction option includes a conceptual construction cost. These conceptual costs include maintenance and protection of traffic; additional electrical, mechanical, and hydraulics engineering design work; and drainage costs. The cost estimate includes the civil work such as regrading as required for option 3. Highway realignment work as required for options 1 and 2 are considered separately.

The conceptual construction cost estimate was derived from the scope of work provided by CTDOT and from drawings and cross-sections developed by CDM Smith. The quantities, crews, and production values used in creating the estimate were taken from the CCI Timberline database.

The cost estimates are based on 2014 Labor and Equipment rates; with an escalation for labor for 5 years to April 2019 (mid-construction) at 4 percent per year. The estimates are also tied to the Engineering News Record Construction Cost Index for May 2014.

1.5.1.2 Engineering Costs

Engineering costs were estimated as 10 percent of the construction cost estimates.

1.5.1.3 Right-of-Way Costs

ROW costs were estimated for construction options 1, 2, and 3 separately during highway design estimates.

1.5.2 Construction Duration

The durations estimated for each construction option 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 #1-5

The five alternatives for the tunnel constructability and traffic impacts are summarized in **Table 1.1**.

Table 1.1: Description of Five 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 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.	

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

Option #	Name	Approach	Highway Modifications	Traffic Impact
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.

1.7 Organization of the Report

In **Sections 2** through **5** of this report, each of the five alternative construction and rehabilitation options are presented with the following organization:

- State of the art methods and techniques
- Duration
- Schedule
- Construction cost
- Construction complexity
- Traffic impacts
- Anticipated useful life

In addition, since traffic impacts would be significant under options 4 and 5, **Section 6** evaluates traffic impacts and **Section 7** evaluates delay costs associated with these options. Since options 1 through 3 do not have a major impact on traffic flow along Route 15 as all existing lanes of travel will be retained during construction, traffic and delay costs were not evaluated for these options. Traffic impact associated with staging is assumed to be the same for all options and is not estimated.

The five construction options analyzed during this study require slightly different highway design solutions, which are described in **Section 8**. Section 8 also presents the concept design of a proposed interchange between Route 15 and Route 40, which would provide for some traffic relief on Route 15 during construction of options 4 or 5.

Section 9 includes a literature review of state-of-the-art vehicle height warning systems and traffic data collection systems that could be used at the Heroes Tunnel site.

Section 10 concludes the report, by combining various options for actual construction sequence scenarios that provide for a combination of construction, expansion, and rehabilitation stages. These construction sequencing scenarios are then evaluated against the criteria identified in Section 1.4.

In summary, this report consists of the following sections as described in **Table 1.2**.

Table 1.2: Sections of this Report

Report Section	Title	Description
1	Introduction	• Overview of the report
2	Construction Options 1 and 2: Construction of New Tunnels	• State-of-the-art methods for a range of tunneling techniques and recommended excavation method for new tunnel(s) • Construction duration of various tunneling techniques • Construction schedule of various tunneling techniques • Cost of various tunneling techniques • Construction complexity • Overview of traffic impacts (discussed in detail in Section 6) • Anticipated useful life • Summary
3	Construction Option 3: Widening of the Existing Tunnels	• State-of-the-art methods for enlarging transportation tunnels while maintaining current traffic capacity during construction & recommendation • Construction duration of various tunnel enlargement techniques • Construction schedule of various tunnel enlargement techniques • Cost of various tunnel enlargement techniques • Construction complexity • Overview of traffic impacts (discussed in detail in Section 6) • Anticipated useful life • Summary
4	Construction Option 4: Rehabilitation of the Existing Tunnel by Complete Shutdown of One Barrel	• Brief summary of the rehabilitation measures to civil-drainage systems and structural systems • Construction duration of complete shutdown rehabilitation • Construction schedule of complete shutdown rehabilitation • Cost of complete shutdown rehabilitation • Construction complexity • Overview of traffic impacts (discussed in detail in Section 6) • Anticipated useful life • Summary

Table 1.2: Sections of this Report

Report Section	Title	Description
5	Construction Option 5: Rehabilitation of the Existing Tunnel by Partial Shutdown of One Barrel	• Unique challenges that would be associated with partial shutdown of one barrel to accomplish the rehabilitation measures described in section 4. • Construction duration of partial rehabilitation • Construction schedule of partial shutdown rehabilitation • Cost of partial shutdown rehabilitation • Construction complexity • Overview of traffic impacts (discussed in detail in Section 6) • Anticipated useful life • Summary
6	Traffic Impacts	• Traffic impacts for options 4 and 5
7	Evaluation of Delay Costs	• Estimate of delay costs for options 4 and 5
8	Highway Design	• Highway design solutions near Heroes Tunnel on Route 15 that are required by the five construction options • Conceptual design of a proposed interchange between Route 15 and Route 40 • Endangered species assessment
9	Evaluation of Vehicle Height Warning Systems	• Literature review of state-of-the-art vehicle height warning systems and traffic data collection systems that could be used at the Heroes Tunnel site
10	Conclusions	• Description of how the various construction options would be combined for construction sequencing scenarios • Cost-benefit analysis for the construction sequencing scenarios • Summary of the overall evaluation of the construction sequencing scenarios • Recommended approach
11	References	• References for citations throughout the report
Appendices		
A	Tunnel Boring Machines	• Tunnel Boring Machine Classifications and Support Systems
B	Traffic modeling	• Traffic modeling details for construction options 4 and 5
C	Highway design	• Plan and profile views of highway designs required for options 1-3 and for the proposed interchange between Route 15 and Route 40 • Maps showing that the project location is within areas designated as a "State and Federal Listed Species & Significant Natural Communities" area and a critical habitat area as designated by the Connecticut Department of Energy and Environmental Protection (DEEP).
D	Vehicle height warning systems – system specifications	• System specifications for optoelectric sensors used in vehicle height warning systems
E	Advanced traffic data collection systems	• Description of the technologies available for advanced traffic data collection.
F	Cost estimates	• Construction and right-of-way (ROW) cost estimates

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Section 2

Construction Options 1 and 2: Construction of New Tunnels

2.1 Introduction

As described in Section 1, the construction alternatives for Heroes Tunnel include construction of one-lane and two-lane tunnels (options 1 and 2, respectively). This section will explore various tunneling techniques and equipment for the construction of these tunneling alternatives along with the advantages and disadvantages of each method identified (Sections 2.2-2.5). Finally, the construction sequencing, cost, duration, construction complexity rating, and anticipated useful life of various tunneling options are presented (Sections 2.6-2.9).

2.1.1 Geotechnical Assessment

A geotechnical field investigation consisting of 21 borings was made before construction of the tunnel in 1941 to investigate the subsurface condition of the site. These borings were drilled along both north and south bound tunnel alignments, having depths that varied from 15 feet to 236 feet. The geological profile along the tunnel indicated that the subsurface ground consists of four major strata of loam, sand and gravel, sandstone, and diabase (locally known as trap rock). The geological profile also indicates that the north and south portals have been constructed through soil formations.

The trap rock is typically dark green, fine-grained, hard igneous rock, and very homogeneous throughout with a few exceptions noted hereafter. The geological term for trap rock is "diabase" or "dolerite," and the main minerals forming this rock are plagioclase, feldspar, and augite. It is hard, having a hardness of 6 on the Mohs Hardness Scale, or slightly softer than quartz. The trap rock forming the West Rock Ridge was molten lava under high pressure that forced its way between layers of sedimentary sandstone (brownstone). The erosion of the softer sandstone leaves the trap rock exposed as a ridge. The trap rock had a number of fine seams due to shrinkage, cooling, and shearing caused by fault movements.

Subsequent normal faulting caused the beddings to dip eastward 15° to 30° from the horizontal; hence the west faces of these ridges are steep while the east faces have gentle slopes. These seams are thin and sometimes filled with calcite (calcium carbonate). The thickest seam observed was 1/4 inch; however, there were few places of seam concentration where within a short vertical distance there were so many seams that the core could not be retrieved. The report dated 1941 on the borings for Heroes Tunnel stated that the seam concentration, open fissures, and weathering are local deficiencies, and as far as it could be established do not affect the general excellent condition of the rock, which was characterized by the high recovery and state of most samples. This report indicated that measured recovery (core retrieved as a percentage of core length drilled) for rock samples were above 90 percent with an average of 95 percent. Considering the equipment used for coring at the time this tunnel was designed this is an indication of very good rock.

The unconfined compressive strength (UCS) tests performed on three samples indicated a range of strength ranging between 3100 to 8200 pounds per square inch (psi). Recent information from the tunnel under design in Hartford, which may be in the same or similar geologic formation for Heroes Tunnel, have been reported to have compressive strength between 27,000±9 psi (for Hampton basalt formation) to 32,000±14 psi (for Holyoke basalt formation). The Hartford values of UCS of diabase are within published ranges of this rock type whereas the strength of the Hero's tunnel are low and probably are indicative of the strength of the joints within the rock rather than the intact rock. Further sampling and unconfined compressive strength tests are required for final design.

Based on historical data collected for the borings in close vicinity of the tunnel's north portal, the groundwater table is approximately 3 to 5 feet below ground surface. This data showed a high groundwater table between stations 718+65 and 720+65. The stationing used here is the same shown on the available drawings and measured in feet. The high groundwater levels relative to the tunnel required the installation of a drainage system behind the tunnel and portal wall to lower the groundwater table. Currently there is no updated information on the groundwater table along the tunnel alignment since the tunnels were constructed.

2.2 Tunneling Methods

2.2.1 Overview of Tunneling Construction Techniques

The techniques to construct these new tunnels can be summarized as:

1. Construction using sequential excavation method (SEM) using a mechanized excavator.
2. Full face or sequential excavation using drill and blast technique.
3. Construction by Tunnel Boring Machine (TBM) using either closed-face and open mode machines. For this size and length of tunnel conventional tunneling using a TBM is not considered feasible with regards to either schedule or cost and therefore discussion of the technique is limited in this report

This chapter covers the construction of one and two lane tunnels using different types of TBMs for circular tunnels and drill-and-blast technique for non-circular tunnels.

2.2.2 Factors Considered when Selecting Tunneling Method

When choosing the method for penetrating rock, the geological characteristics, tunnel dimensions, the length of the TBM relative to length of the tunnel, schedule, availability of equipment, availability and level of skilled labor, and costs are primary considerations. The cost issue is also related to the length of the tunnel. There is an excavation cost per unit of tunnel length and a lump sum cost for purchase and mobilization of the TBM. This later cost is divided by the length of the tunnel and added to the excavation cost. Any one factor or combination of factors can be the deciding factor when selecting the method.

2.2.3 TBM Construction

A TBM is a complex system that is essentially a moving factory consisting of a main body and other supporting mechanisms for excavating rock and installing a lining system. The separate activities consist of:

- Breaking the rock
- Advancing the TBM
- Steering the TBM
- Providing a means of stabilizing the machine so a thrust can be applied to break the rock
- Provide a shield for worker safety
- Providing means to perform exploratory drilling to confirm the need for additional ground control and support
- Lining erection
- Spoil (muck) removal
- Ventilation and power supply

Since the application of TBM is not viable option for Heroes Tunnel, the details of different types of machines and the advantages and disadvantages of each machine are shown in Appendix A**.**

2.2.3.1 Minimum Required Diameter of TBM for Construction of Tunnel

The estimation of required diameter for TBM is based on the specified dimensions as follows:

- 12-foot wide lane for cars
- 8- to 11-foot wide sidewalks
- 14.5-foot clearance measured from top of the road
- Space for ventilation of jet fan, lighting, fire hydrants (approximately 4 to 6 feet), etc.
- Thickness of lining (approximately 1.5 to 2.0 feet)

Figures 2.1 and 2.2 present the minimum required diameter for TBM for construction of one-lane and two-lane new tunnels, respectively. As can be seen, the minimum diameter for TBM for one-lane and two-lane circular tunnels are 34 feet and 47 feet, respectively.

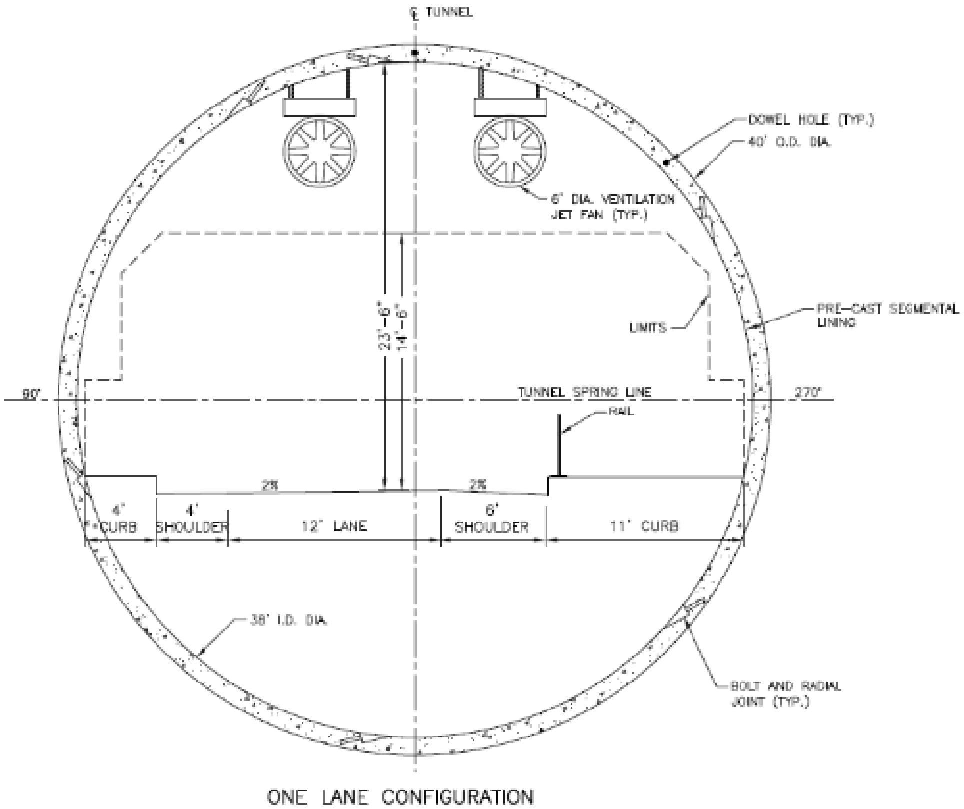


Figure 2.1: Tunnel Configuration for One Lane

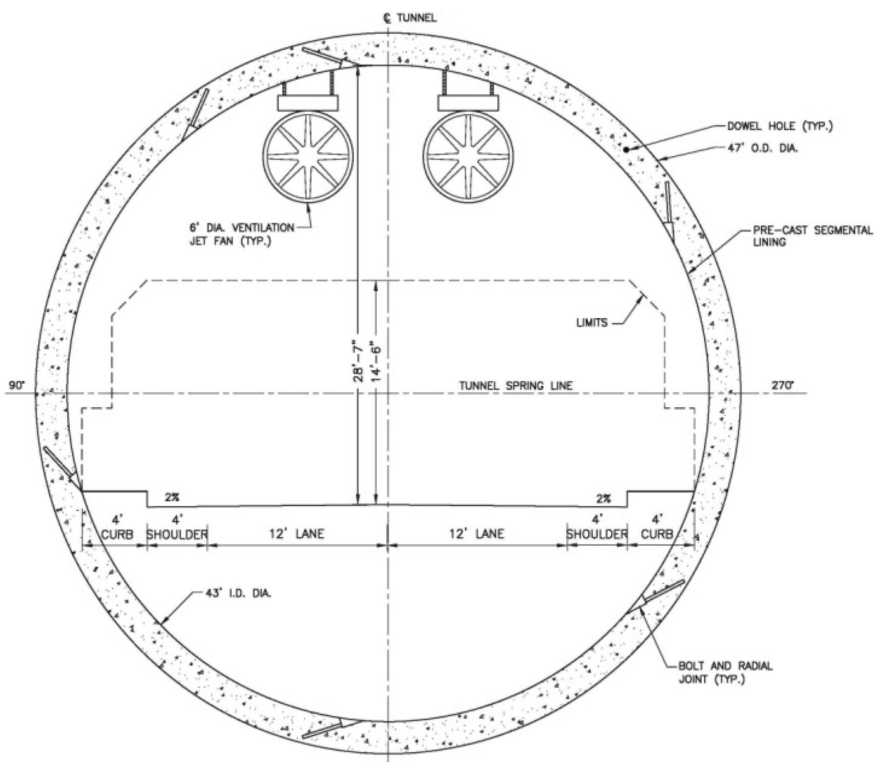


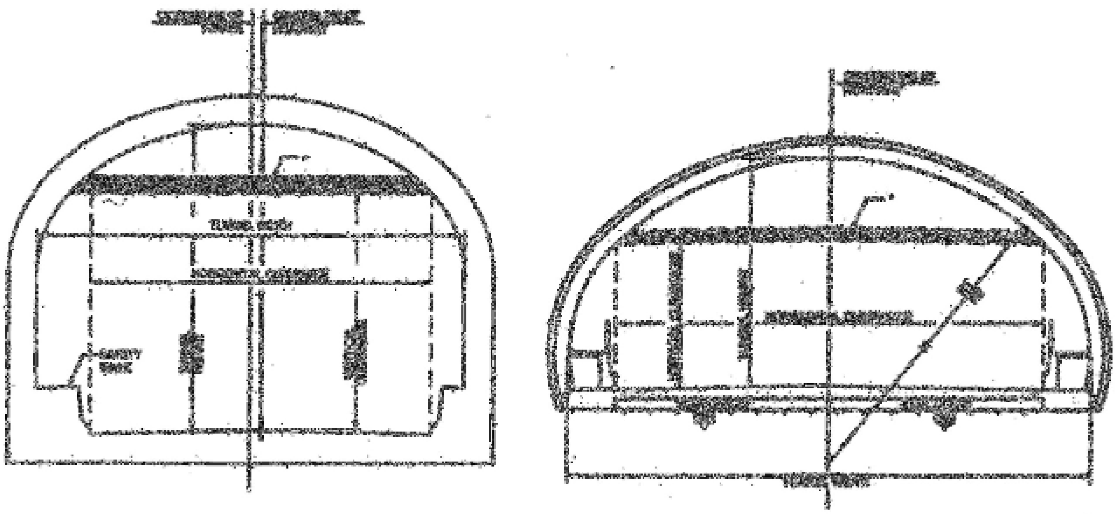
Figure 2.2: Tunnel Configuration for Two Lanes

2.2.4 Construction of Non-Circular New Tunnels

2.2.4.1 Non-Circular Mechanized Tunneling

The non-circular tunnel configurations consist of the horseshoe configuration and the oval configuration as shown in **Figure 2.3**.

Horseshoe configuration tunnels are generally constructed using drill and blast in rock or by following the SEM, also known as New Austrian Tunneling Method. These methods will be discussed in following sections.



* Alternate Ceiling Slab that Provides Space for Air Plenum and Utilities Above

Figure 2.3: Horseshoe and Curvilinear Tunnel Configurations (Reference 1)

2.2.4.2 Non-Circular Cross-Sections for Heroes Tunnel

Figure 2.4 presents a typical non-circular tunnel section for highway tunnel. The tunnel should accommodate the required number of car lanes, shoulders, adequate clearance, space for lighting, and ventilation equipment.

The designed cross-section areas for one-lane and two lane tunnels for Heroes Tunnel are shown in **Figure 2.5 and 2.6**, respectively. The tunnel support consists of rock bolts, initial shotcrete (containing steel fibers), lattice girders, and the final lining.

The following section provides the method of excavation for non-circular tunnel cross-sections.

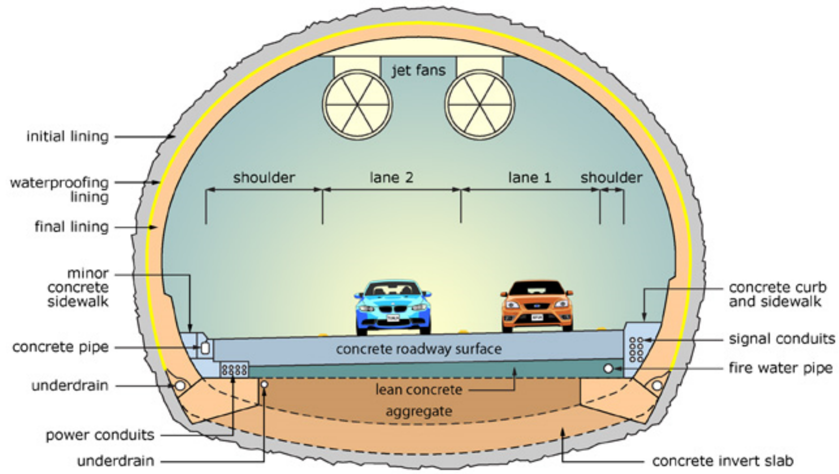


Figure 2.4: Typical Cross-Section of Non-Circular Highway Tunnel (Reference 1)

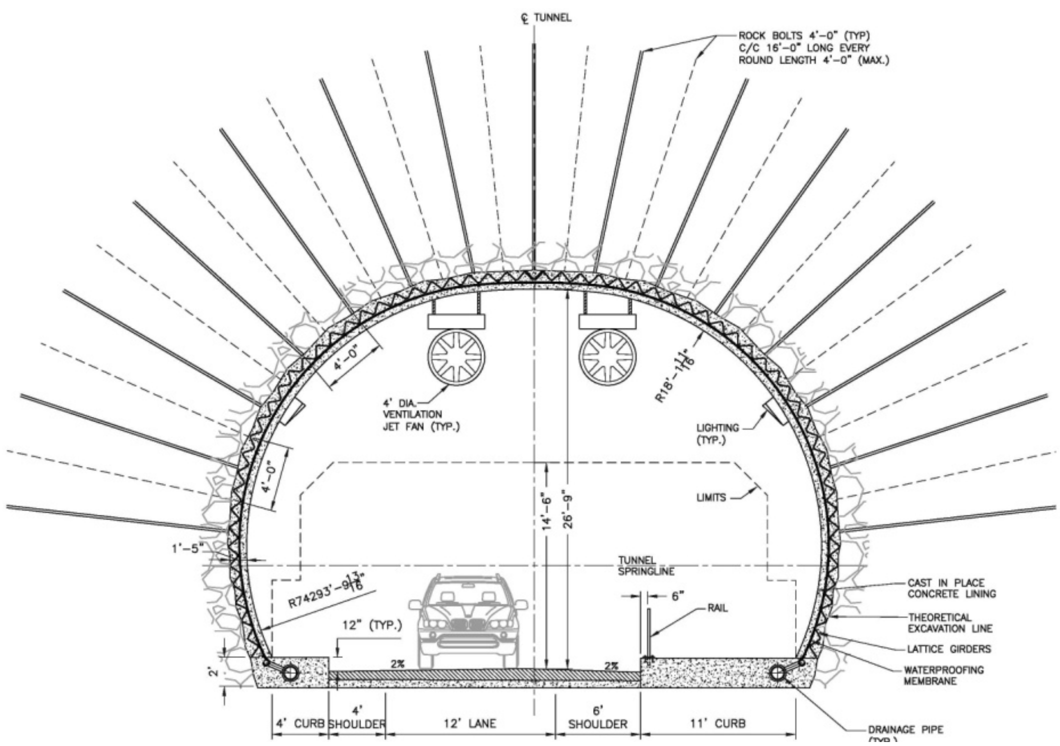


Figure 2.5: Non-Circular One-Lane Tunnel Configuration

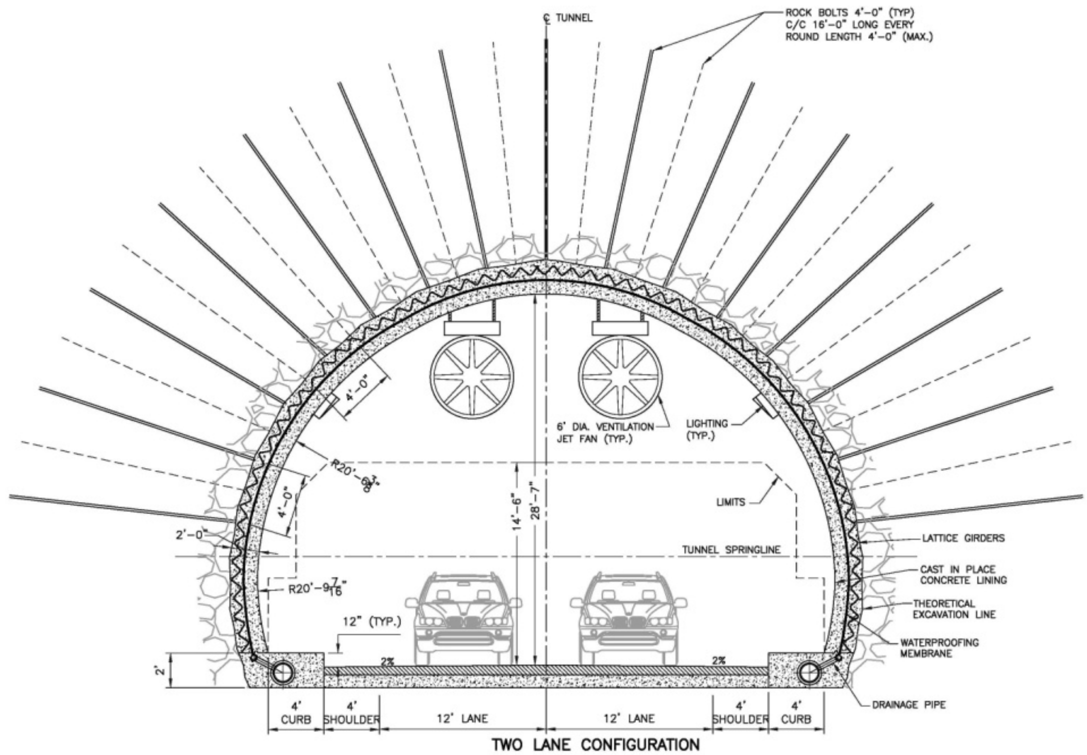


Figure 2.6: Non-Circular Two-Lane Tunnel Configuration

2.2.4.3 Excavation Methods for Non-Circular Tunnels

Non-Circular Tunneling by Roadheaders

One tunnel excavation method that maximizes the efficiency of an excavated tunnel is by using a roadheader. The basic cutting tool for a roadheader is a very large milling head mounted on a boom, which in turn is mounted on tracks or within a shield. **Figure 2.7** shows a large size roadheader.

There are two roadheader cutting approaches—axial and transverse. The axial approach can be referred to as milling, radial auger, or inline. For inline roadheader the cutterhead rotates around the boom axis and, applying the cutter forces sideways, reduces the utilization of the machine's weight in the cutting process. However, it provides the optimum position for maximizing cutting force forward. Because of lower cutting speeds, there is less pick consumption. The axial roadheader throws the muck to the side, making gathering it to the apron a little more difficult. It is best suited for tunnels up to 10 feet in diameter.

Figure 2.7: A Typical Roadheader during Excavation of a Tunnel (Reference 2)

The transverse approach is often referred to as "ripping" where the cutterhead rotates perpendicular to the boom axis. The ripping principle is adapted from continuous mining machines. Its best cutting performance is in the weak rocks. The slewing force is at a right angle to the circumferential force. Cutting in the direction of the face makes it more stable. It is more adaptable to a wider range of conditions. It is less affected by changing rock conditions, including hard rock bands, and it is highly maneuverable. The transverse roadheader can cut large cross-sections; a large machine can cut 650 square feet. Figure 2.8 shows a large size transverse roadheader. A single roadheader can cut variable or odd shapes that otherwise would require TBM excavation in combination with drill and blast or drill and blast itself. Because of their adaptability, availability (a few months rather than a year or longer), and lower purchasing cost (approximately 20 percent, and can vary by 10 percent, depending on the size of the roadheader and the TBM), roadheaders also are the method of choice for relatively short tunnels, say less than one mile in length. Roadheaders are often available for renting, which makes it ideal for small projects. The roadheader is relatively easily mobilized. The delivery time is less than half of a TBM and it can be put into operation as soon as it arrives at the site.

The muck collection and transport system for roadheaders have also undergone major improvements, increasing attainable production rates. The loading apron can now be manufactured as an extendable piece providing for more mobility and flexibility. The machine can be equipped with rock bolting and automatic dust suppression equipment to enhance the safety of personnel working at the heading. They can also be fitted with laser-guided alignment control systems, computer profile controlling, and remote control systems allowing for reduced operator sensitivity coupled with increased efficiency and productivity. A loading device on the front of the machine then gathers the cut rock bits, called spoil, onto a conveyer belt to be moved out of the tunnel for disposal.

Rock and machine parameters are factors that affect machine performance. The rock parameters include intact properties, rock mass properties, and the environment. The intact properties are strength, cutting ability/resistance, impact resistance, abrasiveness, and thermal properties. Strength is quantified by using the Unconfined Compressive Strength (UCS) and is one of the most important parameters in penetrating rock. The rock strength is used for the determination of the ability and capacity of the roadheader. Tensile and shear strengths of the rock indicate the toughness of the rock fabric. The density or specific gravity provides an indication of the muck and ability of the excavator.

Cutting ability is the property that indicates if the rock can be effectively drilled. Stronger rock results in lower penetration rates. Impact resistance describes the resistance of the rock to penetration. This can be obtained from the point load test results. Abrasiveness of the rock is the most important indicator of bit wear and life. Young's modulus and Poisson's ratio indicate the competence and brittleness of the rock. The ultrasonicpulse velocity (acoustic velocity) indicates the competency of the rock and its brittleness, which strongly affects its resistance to excavation. Abrasion provides a strong indication to bit wear, which can be determined by Cerchar Abrasivity Index (CAI) test. Rock mass properties such as joints, joint spacing, joint condition, and joint orientation could affect the production rate of the roadheader. **Figure 2.8** presents roadheader performance relative to cutting performance.

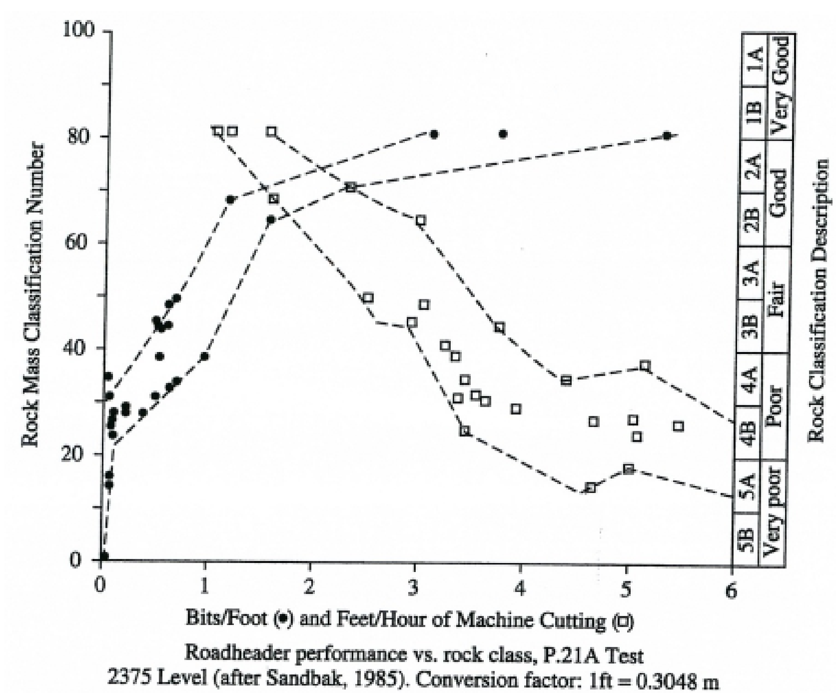


Figure 2.8: Roadheader Performance versus Rock Class (Reference 3)

The most powerful roadheaders can cut rock up to 23,000 psi UCS if favorable jointing or bedding is present with low Rock Quality Designation (RQD) values. **Table 2.1** presents various classes of roadheaders. The silica content is still a major consideration when using a roadheader. The silica content may reach a level such that the cost of bit wear makes using a roadheader uneconomical. The UCS/T (ratio of unconfined compressive strength to tensile strength) indicates the toughness of the rock fabric. A low UCS/T means a high tensile strength relative to compressive strength of rock. Thus, the rock is harder to penetrate. Generally, the use of a roadheader is not recommended if UCS/T is less than 10.

Table 2.1: Classes of Roadheaders (Reference 3)

Roadheader Class	Maximum UCS (psi)	Weight (tons)
Light duty	8,700 – 11,600	40
Medium duty	10,000 – 14,500	80
Heavy	14,500 – 17,500	100
Extra heavy	17,500 – 21,700	120

Recent information from the tunnel under design in Hartford, which may be in the same or similar geologic formation for Heroes Tunnel, have been reported to have compressive strength between 27,000±9 psi (for Hampton basalt formation) to 32,000±14 psi (for Holyoke basalt formation). The 1941 report had UCS at 3100 to 8200 psi…Therefore, it is probable that a combination of roadheader and drill and blast could be used for construction of non-circular tunnel using a roadheader.

The main advantages of using a roadheader are:

- Excavation of wide range of face configuration
- The need for ground support can be reduced by 40 percent of that required for blasting because of minimal disturbance
- There would be significant reduction of noise or vibration compared to blasting
- Can change directions at any time and is able to make 90° or more turn
- Multiple activities can be performed while excavating; in some cases ground support can be installed while the roadheader is operating
- More accurate system of providing line and grade than blasting can be utilized
- Increase in production rates by 50 percent greater than blasting can be achieved if the rock is conducive to this method of excavation

The following is a general list when roadheaders may be considered:

- Rock strength below about 24,000 psi
- Short runs. Less than 2,000 lf
- Odd, non-circular shapes
- Connections, cross passages, etc.
- Low to moderate abrasivity
- Preferably self-supporting rock
- Nominal water pressure

Non-Circular Tunneling by Hydraulic Impact Hammer

Although the hydraulic impact hammer by itself rarely has been used for excavation of the entire length of a non-circular tunnel, for Heroes Tunnel the hydraulic impact hammer should be considered for demolishing the existing tunnel lining system, especially for enlarging tunnel option.

Hydraulic impact hammer is usually equipped with a chisel impact tool that fractures the rock. Breaker hammering and boom movements are carried out by hydraulic power. The machine is either mounted on a track undercarriage or as backhoe attachment. Operating similar to pneumatic pavement breaker used for breaking up sidewalks, the hydraulic impact hammer strikes with an impact tool having the power to break hard rocks *in situ*. The hydraulic impact hammer works on the same principle as a hammer hitting chisel. The chisel receives energy from blows from the hammer. The chisel of the impact hammer receives energy to break the rock from the movement of a hydraulic piston in the impact hammer as shown in **Figure 2.9**.

Figure 2.9: A Hydraulic Impact Hammer during Excavation (Reference 4)

Figure 2.10 presents the hydraulic impact hammer during tunnel excavation.

Figure 2.10: A Hydraulic Impact Hammer during Tunnel Excavation (Reference 4)

Hydraulic impact hammers eliminate the difficulties of blasting by not requiring drilling, explosives are not used, and thus hazards and vibration are reduced. In medium or large tunnels it allows mucking operation to be performed simultaneously. Unlike blasting, secondary fragmentation can be done immediately. That is, if a fragmented rock is too large to be efficiently mucked out, the impact hammer can immediately break it. If this occurs with blasting, the rock has to be drilled and blasted, or, if small enough, additional equipment will be required to break it up.

The properties of the rock to be fragmented will determine the success of using and impact hammer. The efficiency of primary breakage is determined by the rock intact properties. Secondary breakage depends on the rock mass properties. Intact rock properties are related to the strength and toughness of the rock. These include UCS, tensile strength, total hardness, and sonic velocity. All of these characteristics are related to the strength of the rock mass and its ability to resist breakage.

Where primary breakage depends on intact rock strength, secondary breakage is dependent on the rock mass properties. These properties are related to rock discontinuities and their properties and consequently usually have lower strength parameter values. The information required to evaluate secondary breakage includes the nature of the discontinuities, the spacing, distance between them, the orientation, strike and dip, and RQD. The RQD will provide an indication of the condition of the mass; that is, how fractured it is. The seismic velocity is the best indicator of the toughness and resistance of the rock mass to excavation by an impact hammer. **Figure 2.11** presents a typical relationship between net breaking rate and the rock compressive strength for a given RQD value and power of hydraulic impact hammer.

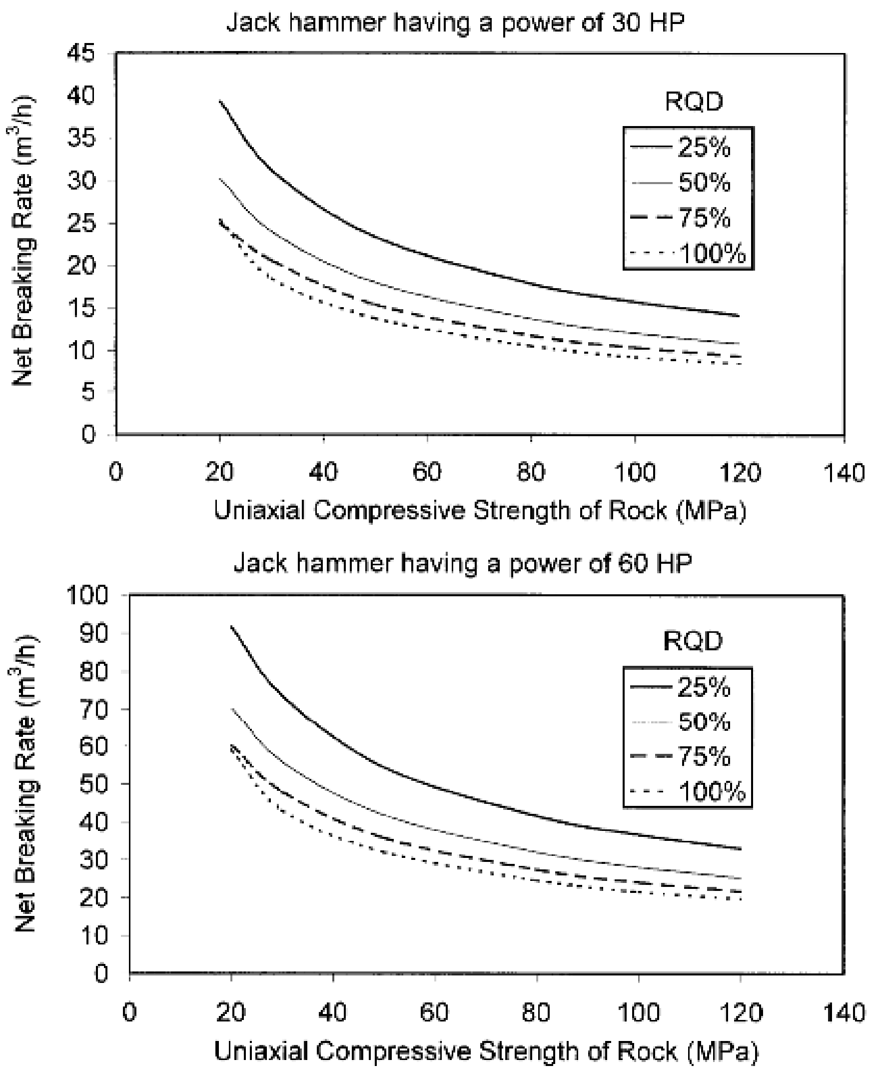


Figure 2.11: Relationship between Rock Compressive Strength and the Breaking Rate of Hydraulic Impact Hammer for a Given RQD and the Power of the Hammer (Reference 5)

Generally, hydraulic impact breakers are readily available and mobilization is similar to other heavy construction equipment. There is considerable flexibility to different shapes for headings and these are adaptable to various rock types. Because of its flexibility, the impact hammer can work in mixed rock conditions. Being self-contained, the hydraulic impact breaker can be introduced to any equipment mix on the job. The overbreak is minimized, and there is no break in the progress of the tunnel to blast and the rock excavation cycle can be continuous because of the ability to muck while excavating.

When precise excavation lines are required, the hydraulic impact hammer can excavate to those lines without blasting or special equipment. Hydraulic impact hammers are much slower than blasting. However, if blasting is prohibited, using the hydraulic impact hammer to excavate can be the most efficient and cost-effective replacement for blasting.

Non-Circular Tunneling by Drill-and-Blast

As mentioned above, drill-and-blast technique is mainly used in rock tunnels for non-circular tunnel configurations either for full face excavation or sequential excavation. The basic approach is to drill a pattern of small holes, load them with explosives, and then detonate those explosives, thereby creating an opening in the rock. The blasted and broken rock (muck) is then removed and the rock surface is supported so that the whole process can be repeated as many times as necessary to advance the desired opening in the rock. The steps associated with a drill-and-blast technique are shown in **Figure 2.12**. By its nature, the drill-and-blast technique leaves a rock surface fractured and disturbed. The disturbance typically extends 3 to 6.5 feet (1 to 2 m) into the rock and can be the initiator of wedge failure, which is the falling block of rock created by intersecting joints in rock mass. As a minimum this usually results in an opening larger than needed (over excavation) for its service requirement and in the need to install more supports than would be needed if the opening could be made with fewer disturbances. **Figure 2.13** presents the tunnel surface after excavation by drill-and-blast technique.

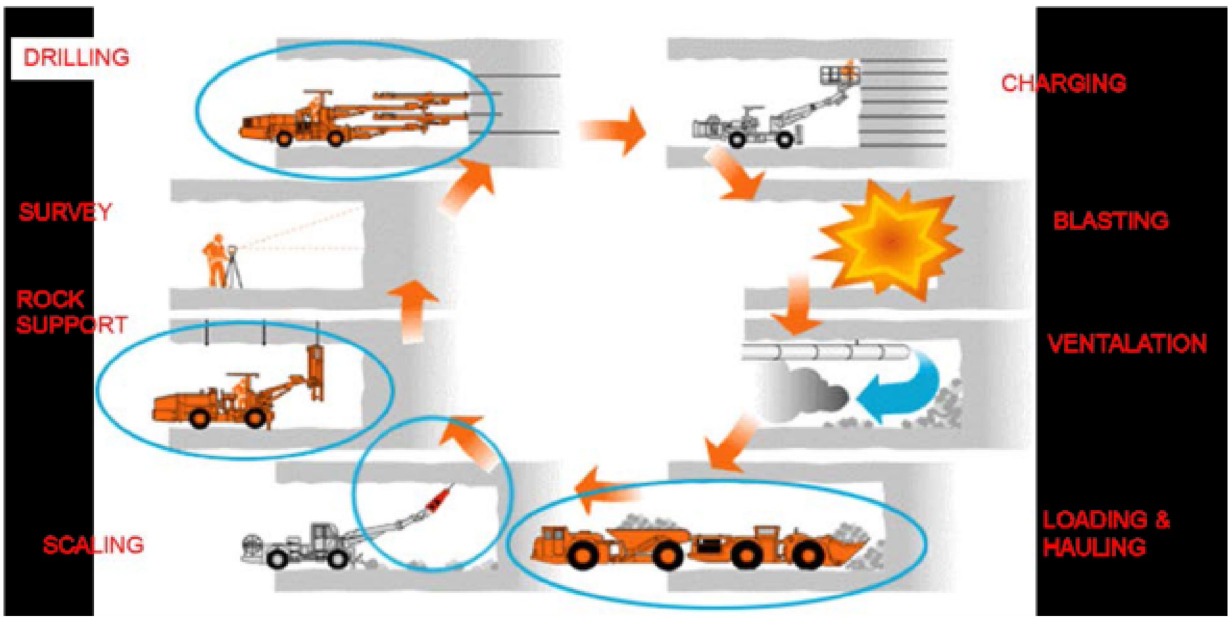


Figure 2.12: Drill-and-Blast Activities (Reference 6)

Figure 2.13: Tunnel Surface Excavated by Drill-and-Blast Technique (Reference 7)

To reduce the disturbance, a controlled blasting technique can be applied. The drill-and-blast technique can be used for full face excavation or sequential excavation. It is predicted that the excavation of new tunnels either using mechanized techniques or drill-and-blast method could be done for full face. For further information on sequential excavation method please refer to Chapter 9 of FHW Technical Manual for Design and Construction of Road Tunnels.

2.2.5 Tunnel Lining for Non-TBM Tunneling

2.2.5.1 Initial Support

The purpose of an initial support (sometimes called temporary lining, or temporary support of excavation) in rock tunneling is to keep the opening open, stable, and safe until the final lining is installed and construction is complete. As a consequence the initial support system in a rock tunnel can be one or a combination of a number of options:

- Rock reinforcement (i.e., rock dowels, rock bolts, rock anchors, etc.)
- Steel ribs
- Wood or other lagging
- Lattice girders
- Shotcrete
- Spiles or forepoling
- Concrete

- Re-steel mats
- Steel mats
- Cables
- Precast concrete segments
- Others

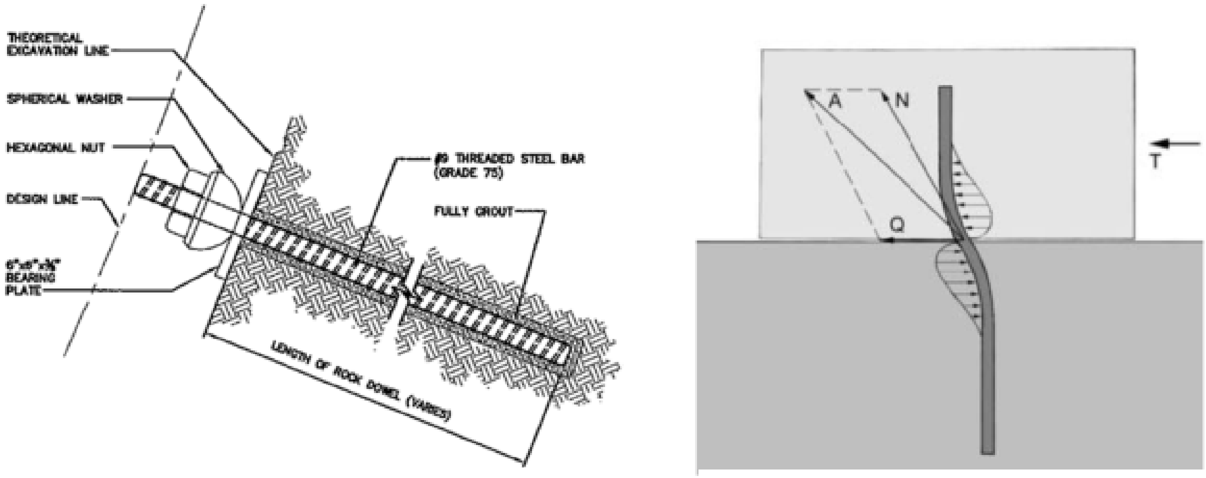
The first five above are the most common on U.S. projects, and of those, a combination of rock bolts or dowels and shotcrete is the single most common. Especially in good (or better) rock tunnels, modern rock bolting machines provide rapid and adjustable "support" close to the heading by knitting and holding the rock (ground) arch in place, thus taking maximum advantage of the rock's ability to support itself. Preferably, shotcrete is added (if needed) a diameter or so behind the face where dust, grit, and flying aggregate is not the problem for both workers and equipment than it is at the heading. Where there is a concern with smaller pieces of rock falling, the system can be easily modified by adding shotcrete closer to the face, or more usually, by embedding any of a number of types of steel mats in the shotcrete.

Where the rock quality is lower there is currently a movement toward replacing steel ribs by lattice girders—perhaps somewhat more so in Europe than in the U.S. Like steel ribs, the lattice girders form a template of sorts for the shotcrete and for spiling. However, the lattice girders are lighter and can be erected faster. To provide the same support capacity, the lattice girder system may require nominally more shotcrete (e.g., an additional ½ to 1 inch) but that is more than compensated for by the easier and faster erection. A second new trend is the use of steel fiber reinforced shotcrete. The fiber doesn't change the compressive strength significantly but does produce a significant increase in the toughness or ductility of the shotcrete.

The following sections will cover the most common support system used for initial support for rock tunneling.

Rock Reinforcement

Rock reinforcement causes the binding of the rock to prevent it from falling and moving into the cavity. The mechanical properties of rock in terms of stiffness and strength can be improved by the installation of various types of reinforcement. Steel bars can be fixed at their ends and pre-tensioned against the rock. In this way, the surrounding rock is compressed and, as a consequence, its stiffness and its strength increases. Such reinforcing bars are called anchors or bolts. An alternative type of reinforcement consists of bars that are connected with surrounding rock over their entire length, e.g., grout. Such bars are not pre-tensioned and are called nails. Rock with nails is a composite material; its stiffness is increased as compared to the original rock. A third action of reinforcement is given when a steel bar (dowel) inhibits the relative slip of two adjacent rock blocks. In this case the bar is loaded by transverse forces and acts as a plug. The usage of names, stated here (anchor, bolt, dowel), is, however, not unique and they are often interchanged. **Figure 2.14** presents a rock dowel and the forces acting on it.



(a) (b)

Figure 2.14: a) Temporary Rock Dowel; b) Forces Acting Upon and Within a Dowel (Reference 3)

There are three methods for securing the rock bolt in the borehole—mechanically anchored, friction anchored, and grouted bars. **Figure 2.15** presents various types of rock bolts.

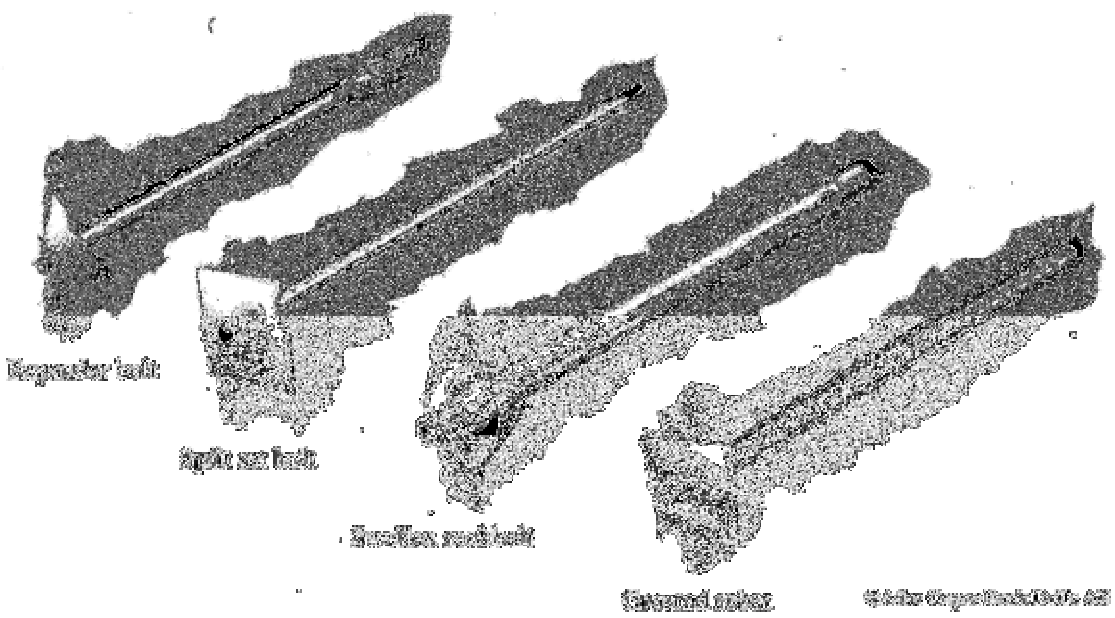


Figure 2.15: Types of Bolts (Courtesy of Atlas Copco) (Reference 3)

Mechanical

The expansion shell anchored rock bolt is the most common form of mechanically anchored rock bolt. A wedge attached to the bolt shank is pulled into a conical expansion shell as the bolt is rotated, forcing the shell to expand against the wall of the borehole. Once the bolt is rotated and the threads have forced the ridge on the wedge into the borehole wall rock, the support is in place. As the bolt is rotated, a torque is applied to the bolt head and tension accumulates in the bolt, permitting installation and tensioning in one step. It is relatively inexpensive method of support but its use is limited to moderately hard to hard rock. In hard rock conditions it is a versatile system of rock reinforcement and can achieve high bolt loads. Some bolts are hollow and can be grouted. With an expansion shell approach, the grout acts more as corrosion protection because the bolt is already tensioned prior to the grout being added. **Table 2.2** shows the expansion shell rock bolts and its characteristics.

Table 2.2: Types of Rock Bolts and Their Characteristics (Reference 1)

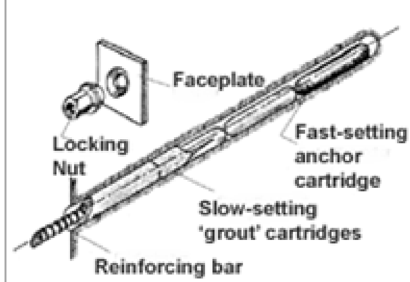
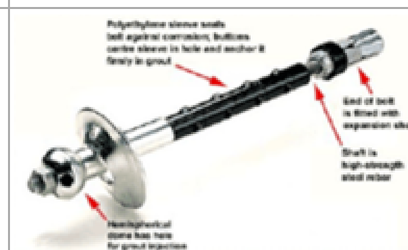
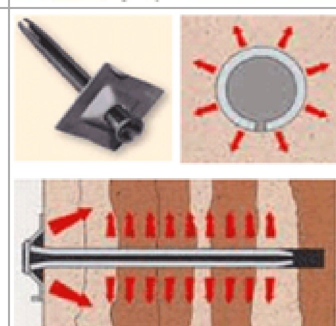
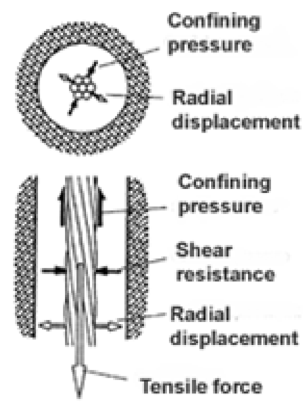
Type	Description	Illustration
Resin Grouted Rock Bolt	• Additional capacity due to side friction develops after setting of the second resin • Good for soft and hard rocks • Withstands blasting vibrations	
Expansion shell rock bolt	• Post grouted expansive bolt • Good for relatively good rocks • Fully grouted • Corrosion protection	
Split set stabilizers	• Slotted bolt is inserted into a slightly smaller diameter hole • Induced radial stress anchors the system in place by friction • Mainly for mining, and under mild rock burst conditions • It slips instead of suddenly failing • Limited load handling	
Swellex®	• Length up to 12 m (40 ft) • Hole diameter = 32-52 mm (1.25-2 in.) • Tensile load = 100 -240 kN (11-30 tons) • Inflation pressure ≈ 30 Mpa (300 ton/ft^2) • Instant full load bearing capacity • Fast application • Not sensitive to blasting • Elongation range: 20-30%	

Table 2.2: Types of Rock Bolts and Their Characteristics (Reference 1)

Type	Description	Illustration
Self Drilling Anchor	• Drilling, installation, and injection in one single operational step • No pre-drilling of a borehole by using a casing tube and extension rods with subsequent anchor installation necessary • Minor space requirement for anchor installation • Optimized machinery and manpower requirements	
Cablebolt reinforcement	• Primarily used to support large underground structures, i.e., mining applications, underground power caverns etc. • Can handle high loads • Tendons are grouted with concrete mix • At very high loads the governing parameter is most often the bond between the tendon and the grout • Cable capacity is confining stress dependent	

Friction

Friction rock bolts (split set) are rock stabilizers that rely on the friction between the bolt and the rock as support (see Table 2.2 and Figure 2.15). They consist of a high strength steel tube that is slotted along its length a matching domed bearing plate. One end has a welded ring flange to hold the bearing plate and the other end is tapered for easy insertion into a drill hole. Once the bearing plate is in place, the tube is driven into slightly smaller hole using the same percussion drill that created the hole. Radial pressure is exerted against the rock over its full contact length because as the rock bolt slides into the hole the full length of the slot narrows. The rigidity of metal being forced against the side of the hole as it is pushed into causes a radial load against the rock, resulting in friction between the wall of the hole and the bolt. The bolt provides an immediate plate load support while exerting a radial pressure against the rock over the entire contact length. Friction bolts are easy to install and therefore save labor and money. They have hangers to which welded wire mesh can be attached, facilitating mesh installation. Because of their ease of installation, shorter ones are often used with a hanger attachment in tunnels for hanging utilities. The bolts are short, 18 to 24 inches, and are not used for ground support.

Swellex® bolts function on the same principles as split-set bolts; that is, by the friction of the bolt against the rock. Where the split-set bolt uses the stiffness of the metal to provide friction, the Swellex® bolt uses the deformation of the bolt caused by high-pressure water. The Swellex® bolt is made from a folded thin wall tube of steel. Bushings on both ends of the bolt are sealed by welding. High pressure water is injected through a small hole in the lower bushing to expand the bolt. As it expands, the Swellex® bolt compresses the rock surrounding the hole and adapts its shape to fit the irregularities of the borehole. **Figure 2.16** presents the Swellex® bolt installation sequence. **Figure 2.17** presents the installation of Swellex® bolt in the field.

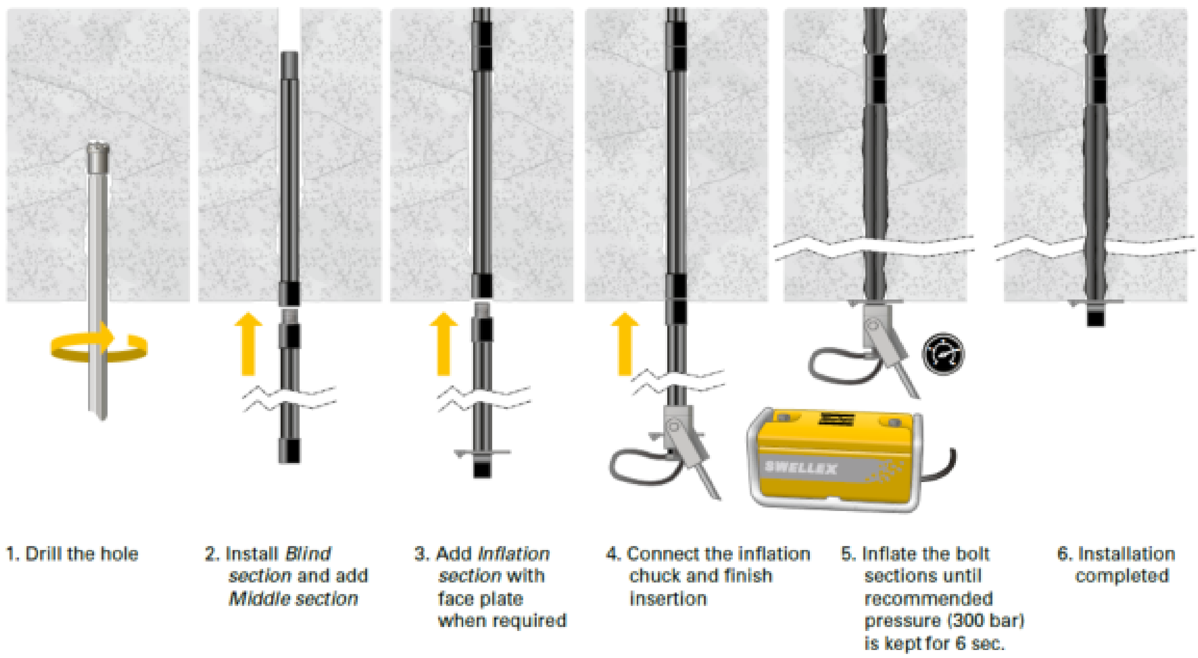


Figure 2.16: Swellex® Bolt Installation Sequence (Reference 8)

Figure 2.17: Swellex® Bolt Installation (Reference 8)

CDM Smith

There are two versions of the Swellex® bolt—the Swellex® Premium line, which is a relatively stiff rock bolt used for tunneling and mining in moderate stress conditions, and the Swellex® Manganese line, which is a highly deformable rock bolt for large rock deformation. The Swellex® strengthens the rock mass by a combination of mechanical interlock at the rock and bolt interface and friction. The Swellex® bolts are less sensitive to blasting or slight rock movements than mechanical bolts. The Swellex® bolts have the ability to deform to adjust to the direction of the load. The Swellex® bolts are best used in tensile strength situations. Due to the thin wall, the bolt has little strength in shear. As with other bolts, wire mesh and other surface protection can be attached to the Swellex® bolts. Table 2.2 presents typical rock bolts and their characteristics.

Grouted Rock Bolts

Tensioned bolts are used to prevent movement along the axis of the bolt, i.e., normal to the rock surface. The anchorage of rock bolt is very important since it permits the tensioning of the rod or cable. If the anchorage fails, the main purpose of tensioned rock bolt would not be accomplished because the ground reinforcement is based on the element being tensioned, and thus tensile strength is required. Most commonly used grouted rock bolt is the fully grouted rebar or threaded rebar made of steel. Cement grout or resin is used as the grouting agent individually or in combination. Rebar used with resin creates a system commonly used for tensioned rock bolts. Rebar or threaded bar with cement grout can also be used for untensioned bolts. Both systems are used for temporary as well as permanent support under various rock conditions. Threaded rock bolt is mainly used in civil engineering applications for permanent installation. **Figure 2.18** presents schematics of a pre-tensioned rock bolt.

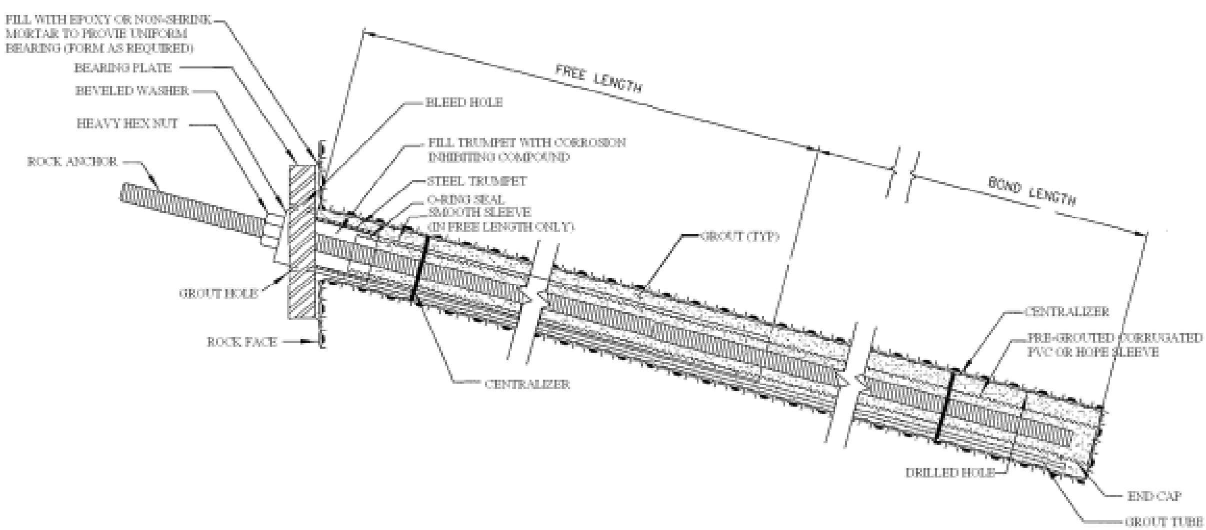


Figure 2.18: Schematics of a Pre-Tensioned Rock Bolt (Reference 1)

Figure 2.19 shows a rock cavern excavation and the rock bolt installation.

Figure 2.19: Rock Tunnel Excavation and Rock Bolt Installation (Reference 9)

Shotcrete

The initial shotcrete lining is the layer of shotcrete applied to support the ground following excavation. It has a thickness ranging generally from 4 to 16 inches (100 to 400 mm) mainly depending on the ground conditions and size of the tunnel opening. It is reinforced by either welded wire fabric or steel fibers; the latter have generally replaced the traditional welded wire fabric over the last 10 to 15 years.

Occasionally structural plastic fibers are used in lieu of steel fibers. This is the case where the shotcrete lining is expected to undergo high deformations and ductility post cracking is of importance. Where the shotcrete lining is greater than about 6 inches (150 mm) it further includes lattice girders. Depending on loading conditions and purpose, rolled steel sets may replace lattice girders or act in combination.

Lattice Girder

Lattice girders are support members made up of steel reinforcement bars laced together (usually) in a triangular pattern as shown on **Figure 2.20,** and rolled to match the shape of the opening. Because their area is typically very small compared to surrounding shotcrete, lattice girders do not, by themselves, add greatly to the total support of an opening. However, they do provide two significant benefits:

1. They are typically spaced similarly to rock bolts, thus they quickly provide temporary support to blocks having an immediate tendency to loosen and fall.

2. They provide a ready template for assuring that a sufficient thickness of shotcrete is being applied.

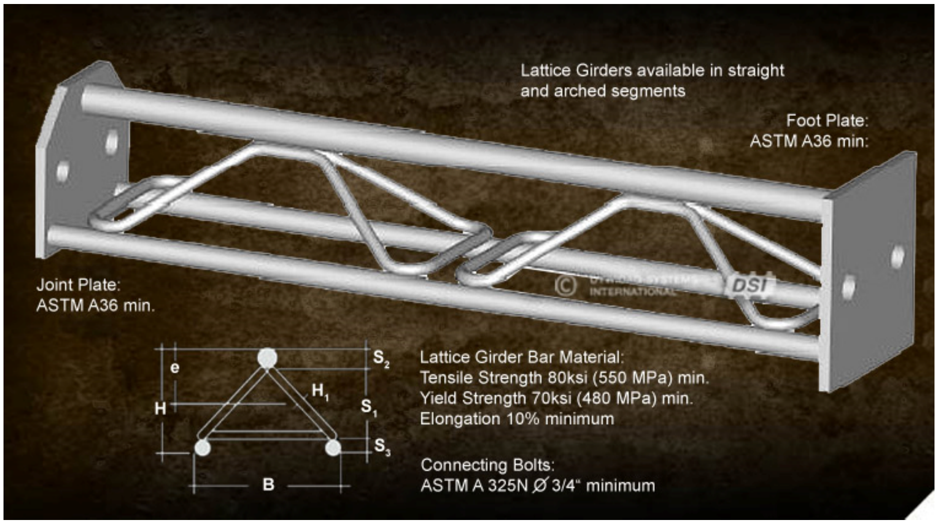


Figure 2.20: A Typical Three-Bar Lattice Girder (Reference 10)

Generally, lattice girders are used much more frequently in tunnels driven by sequential excavation method.

Figure 2.21 presents the initial tunnel support comprising of wire mesh, lattice girders, rock bolts and shotcrete.

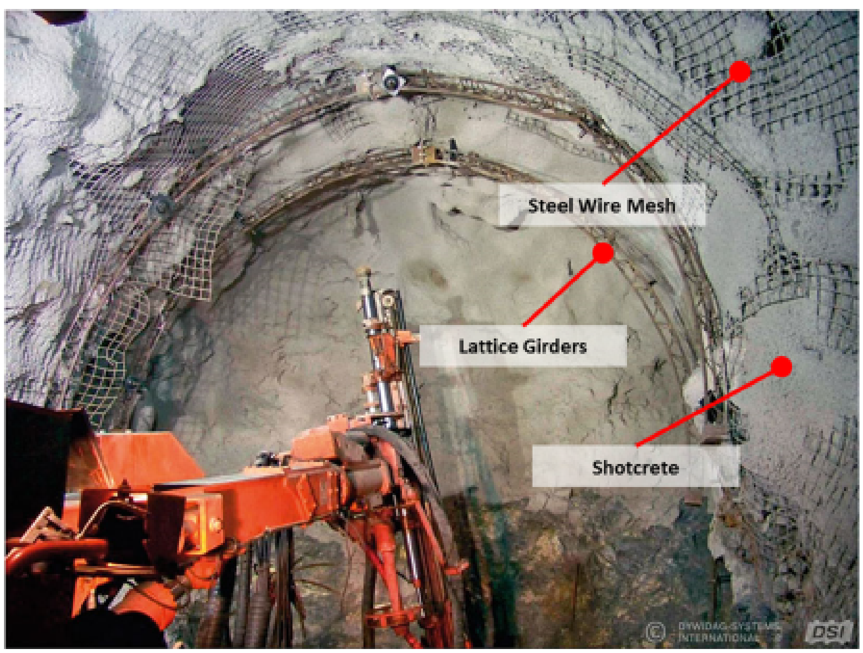


Figure 2.21: Initial Tunnel Support System (Reference 11)

2.2.5.2 Waterproofing

The SEM uses flexible, continuous membranes for tunnel waterproofing. Most frequently PVC membranes are used at thicknesses of 80 to 120 mil (2.0 to 3.0 mm) depending on the size of the tunnel. Only in special circumstances, for example when contaminated ground water is present, are special membranes are applied using hydrocarbon resistant polyolefin or very low density polyethylene (VLDPE) membranes. To provide a drained condition behind the tunnel a dimpled waterproofing membrane shall be used. This type of waterproofing membrane will discharge the water very fast resulting in possible water freezing behind the tunnel lining during winter time. **Figure 2.22** presents the dimpled waterproofing membrane.

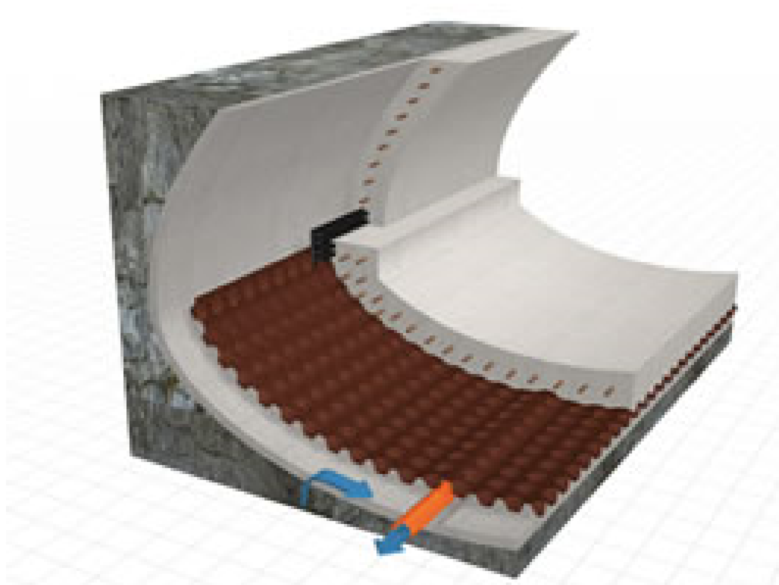


Figure 2.22: Dimpled Waterproofing Membrane Manufactured by DELTA® (Reference 12)

The impermeable membrane is backed by a geotextile that also acts as a protection layer, and in drained systems as a drainage layer behind the membrane. This waterproofing system is placed against the initial lining and prior to installation of the final lining. Prior to waterproofing system installation all tunnel deformations must have ceased.

In drained system applications water is collected behind the membrane and conducted to perforated sidewall drainage pipes located at tunnel invert elevation on each side of the tunnel. From there collected water is conveyed via transverse, non-perforated pipes to the tunnel's main roadway drain. In undrained systems the membrane and geotextile wrap around the entire tunnel envelope and prevent water seepage into the tunnel, thereby subjecting it to hydrostatic pressures. If this is the case the tunnel invert geometry and structural design must be adapted to accommodate for the hydrostatic head.

Over the past decades a so called "compartmentalization system" has been developed and currently supplements the installation of flexible membrane based waterproofing systems. The purpose of this compartmentalization is to provide repair capability in case of leakage. In particular, when the tunnel is not drained and the waterproofing has to withstand long-term hydrostatic pressures, installation of such systems provides a cost-effective back-up and assures a dry tunnel interior. Compartmentalization refers to the concept of subdividing the waterproofing membrane into individual areas of self-contained grids (compartments) by means of base seal water barriers. These water barriers are specifically formulated for the purpose of creating these compartments. They feature ribs of 1.3-inch (30 mm) minimum height to properly key into the final lining, which is cast (or sprayed) against the waterproofing. In case of water leakage the water infiltration is limited to the individual compartment thus preventing uncontrolled water migration over long distances behind the final lining. Within each compartment control and grouting pipes are installed. These pipes penetrate through the final lining and are in contact with the membrane. **Figure 2.23** displays an installed PVC waterproofing system with compartments, control and grouting pipes, and hoses prior to final lining installation. Control and grouting pipes serve a twofold purpose; should leakage occur then water would find its path to these pipes and exit there thus signaling a breach within the compartment. Once detected, the same pipes may be used for injection of low viscosity, typically hydro-active grouts into the compartments. The injection of grout is limited to leaking compartment(s) and once cured provides a secondary waterproofing layer in the form of a membrane that acts as a remedial waterproofing layer.

Figure 2.23: Waterproofing System and Compartmentalization (Reference 1)

To provide a suitable surface for the installation of the waterproofing system, all shotcrete surfaces to which the membrane is to be applied must meet certain smoothness criteria. These are expressed in the waviness of the shotcrete surface to which the waterproofing system will be applied. The waviness is measured with a straight edge laid on the surface in the longitudinal direction. The maximum depth to wavelength ratio should be generally 1:5 or smoother. The surface has to be inspected prior to installation of the waterproofing system and all projections should be removed or covered by an additional plain shotcrete layer that meets the smoothness criteria. The SEM design documents will address required smoothness criteria and set those in relation to the waterproofing system to be used.

2.2.5.3 Final Tunnel Support

The final permanent lining for a SEM tunnel may consist of CIP concrete or shotcrete. CIP concrete can be unreinforced or reinforced. Shotcrete is generally fiber reinforced. The following addresses design and construction considerations specifically for SEM application.

Cast-in-Place Concrete Final Lining

The traditional final lining consists of CIP concrete at a thickness of generally 12 inches for two-lane road tunnels. While the lining may generally remain unreinforced, structural design considerations and project design criteria will dictate the need for and amount of reinforcement. The Lehigh Tunnel (Pennsylvania) and Cumberland Gap Tunnels (Kentucky/Tennessee) are the first road tunnels built in the U.S. in the late '80s and early '90s using SEM construction methods. Both feature unreinforced, 12-inch thick CIP concrete final linings. The flexible membrane based waterproofing is in particular beneficial in unreinforced CIP concrete lining applications in that it acts as a de-bonding layer between the initial and final linings and therefore reduces shrinkage cracking in the final lining.

To ensure a contact between the initial and final linings, contact grouting is performed as early as the final lining has achieved its 28-day design compressive strength. With this grouting the contact is established between the initial lining and final tunnel support. Any deterioration or weakening of the initial support will lead to an increased loading of the final support by the increment not being supported by the initial lining. The loads can be directly transferred radially due to the direct contact between initial and final linings.

CIP final concrete linings (concrete arch placed on sidewall footings) are frequently installed in pour lengths not exceeding 30 feet (10 m). This restriction is important to limit surface cracking in general and becomes mandatory if unreinforced concrete linings are used. A 30 foot (10 m) long section in a typical two-lane highway tunnel is also practical in terms of formwork installation and sequencing and duration of concrete placement.

Adjacent concrete pours feature construction joints that are true lining separators designed as contraction joints. The inside face at joint location shall be laid out with a trapezoidal shaped joint. A continuous reinforcement is not desired in construction joints to allow their relative movement in particular for thermal deformation effects.

Water Impermeable Concrete Final Lining

Use of water impermeable CIP concrete linings as an alternative to membranes is generally not considered due to the high demands on construction quality and exposure to freeze thaw conditions in cold climates. Elaborate measures are needed to prevent cracking. Detailed arrangement of construction joints is needed as well as complex concrete mix designs to suppress excessive hydration heat. The curing requires elaborate procedures. These aspects generally do not render water impermeable concrete practical in road tunnels. If selected these construction aspects have to be addressed in detail in specifications and working procedures and they have to be rigidly enforced.

Shotcrete Final Lining

Shotcrete represents a structurally and qualitatively equal alternative to CIP concrete linings. When shotcrete is utilized as a final lining in dual lining applications it will be applied against a waterproofing membrane. The lining thickness will be generally 12 inches (300 mm) or more and its application must be carried out in layers with a time lag between layer applications to allow for shotcrete setting and hardening. To ensure a final lining that behaves close to monolithically from a structural point of view it is important to limit the time lag between layer applications and assure that the shotcrete surface to which the next layer is applied is clean and free of any dust or dirt films that could create a de-bonding feature between the individual layers. It is typical to limit the application between the layers to 24 hours. Shotcrete final linings are applied onto a carrier system that is composed of lattice girders and welded wire fabric mounted to lattice girders toward the waterproofing membrane side. This carrier system also acts fully or partially as structural reinforcement of the finished lining. The remainder of the required structural reinforcing may be accomplished by rebars or mats or by steel or plastic fibers. The final shotcrete layer allows for addition of micro poly propylene (PP) fibers that enhance fire resistance of the final lining.

Unlike the hydrostatic pressure of CIP concrete during installation, the shotcrete application does not develop pressure against the waterproofing membrane and the initial lining and therefore one must ensure that any gap between waterproofing system and initial lining and final shotcrete lining be filled with contact grout. Shotcrete final lining surface appearance can be tailored to the desired project goals. It may remain of a rough, sprayer type shotcrete finish, but may have a quality comparable to cast concrete when trowel finish is specified. Shotcrete as a final lining is typically utilized when the following conditions are encountered:

- The tunnels are relatively short in length and the cross-section is relatively large and therefore investment in formwork is not warranted, i.e., tunnels of less than 300-800 feet (100-250 m) in length and larger than about 25-40 feet (8-12 m) in springline diameter.
- The access is difficult and staging of formwork installation and concrete delivery is problematic.
- The tunnel geometry is complex and customized formwork would be required. Tunnel intersections, as well as bifurcations, qualify in this area. Bifurcations are associated with tunnel widenings and would otherwise be constructed in the form of a stepped lining configuration and increase cost of excavated material.

Figure 2.24 displays a typical shotcrete final lining section with waterproofing system, welded wire fabric (WWF), lattice girder, grouting hoses for contact grouting, and a final shotcrete layer with PP fiber addition.

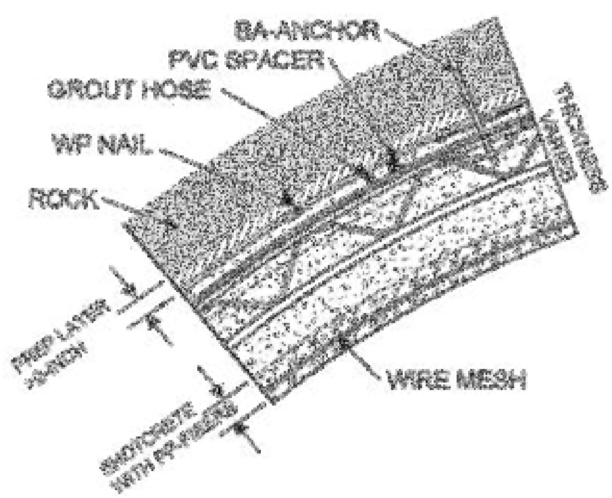


Figure 2.24: Typical Shotcrete Final Lining Detail (Reference 1)

The most important factor that will influence the quality of shotcrete final lining application is workmanship. While the skill of shotcrete applying nozzlemen (by hand or robot) is at the core of this workmanship, it is important to address all aspects of the shotcreting process in a method statement. This method statement becomes the basis for the application procedures, and the applicator's and the supervisor's quality assurance/quality control (QA/QC) program. Minimum requirements to be addressed in the method statement are as follows:

- Execution of work (installation of reinforcement, sequence of operations, spray sections, time lag)
- Survey control and survey method
- Mix design and specifications
- QA/QC procedures and forms
- Qualifications of personnel
- Grouting procedures

The origins of the NATM lie in the alpine tunnel engineering in the early 1960s. In 1948, Ladislaus von Rabcewicz applied for a patent for the use of a dual lining system with the initial lining being allowed to deform.

Single Pass Lining

Under special circumstances the initial shotcrete lining alone, or with an additional shotcrete layer designed to withstand long-term loads, may be used as a single support lining for the long term. Although labeled "single pass" this final shotcrete lining may be applied in multiple shotcrete application cycles. Use of a single pass lining will generally be limited to conditions where the groundwater inflow is not of concern and deterioration of the shotcrete product over the lifetime of the tunnel lining can be excluded or partially tolerated. In multiple layer applications the shotcrete surface to which additional layers will be applied must be sufficiently clean and free of any layer that may cause de-bonding over the long term. Specially detailed construction joints and high quality shotcrete must be required to assure water tightness and long-term integrity.

2.2.5.4 Ground Classification and SEM Excavation Support Classes

Rock Mass Classification Systems

A series of qualitative and quantitative rock mass classification systems have been developed over the years and are implemented on tunneling projects worldwide. The most commonly used rock mass classification systems include Terzaghi's qualitative classification, and quantitative systems such as the Rock Structure Rating (RSR), Q system, and the Rock Mass Rating (RMR) system. Descriptions of these rating systems are presented in Reference 1.

Rock mass classification systems aid in the assessment of the ground behavior and ultimately lead to the definition of the support required to stabilize the tunnel opening. While the above quantitative classification systems lead to a numerical rating system that results in suggestions for tunnel support requirements , these systems cannot replace a thorough design of the excavation and support system by experienced tunnel engineers. Different classification systems place different emphases on the various parameters, and it is recommended that at least two methods to be used at any site during the early stage of a project. **Table 2.3** presents Terzaghi's qualitative descriptions of rock classes.

Table 2.3: Terzaghi's Rock Classification System (Reference 1)

Rock Condition	Descriptions
Intact rock	Contains neither joints nor hair cracks. Hence, if it breaks, it breaks across sound rock. On account of the injury to the rock due to blasting, spalls may drop off the roof several hours or days after blasting. This is known as a spalling condition. Hard, intact rock may also be encountered in the popping condition involving the spontaneous and violent detachment of rock slabs from the sides or roof
Stratified rock	Consists of individual strata with little or no resistance against separation along the boundaries between the strata. The strata may or may not be weakened by transverse joints. In such rock the spalling condition is quite common
Moderately jointed rock	Contains joints and hair cracks, but the blocks between joints are locally grown together or so intimately interlocked that vertical walls do not require lateral support. In rocks of this type, both spalling and popping conditions may be encountered
Blocky and seamy rock	Consists of chemically intact or almost intact rock fragments which are entirely separated from each other and imperfectly interlocked. In such rock, vertical walls may require lateral support
Crushed but chemically intact rock	Consists of chemically intact or almost intact rock fragments which are entirely separated from each other and imperfectly interlocked. In such rock, vertical walls may require lateral support
Squeezing rock	Slowly advances into the tunnel without perceptible volume increase. A prerequisite for squeeze is a high percentage of microscopic and sub-microscopic particles of micaceous minerals or clay minerals with a low swelling capacity
Swelling rock	Advances into the tunnel chiefly on account of expansion. The capacity to swell seems to be limited to those rocks that contain clay minerals such as montmorillonite, with a high swelling capacity

Table 2.4 presents the elements used of most common initial support measures, along with excavation and support installation sequencing associated with SEM road tunnels for rock.

Table 2.4: Elements of Commonly Used Excavation and Support Classes (ESC) in Rock (Reference 1)

Ground Mass Quality - Rock	Excavation Sequence	Rock Reinforce-ment	Initial Shotcrete Lining	Installation Location	Pre-Support	Support Installation Influences Progress	Remarks
Intact Rock	Full face or large top heading & bench	Spot bolting (fully grouted dowels, Swellex ®)	Patches to seal surface in localized fractured areas	Typically Several rounds behind face or directly near face to secure isolated blocks/slabs/ wedges	None	No	
Stratified Rock	Top heading & bench	Systematic doweling or bolting in crown considering strata orientation (fully grouted dowels, Swellex®, rock bolts)	Thin shell (fiber reinforced) typically 4 in (100 mm) to bridge between rock reinforcement in top heading; alternatively chain link mesh; installed with the rock reinforcement.	Two to three rounds behind face	None	No or eventually	

Table 2.4: Elements of Commonly Used Excavation and Support Classes (ESC) in Rock (Reference 1)

Ground Mass Quality - Rock	Excavation Sequence	Rock Reinforce-ment	Initial Shotcrete Lining	Installation Location	Pre-Support	Support Installation Influences Progress	Remarks
Moderately Jointed Rock	Top heading & bench	Systematic doweling or bolting in top heading considering joint spacing (fully grouted dowels, Swellex®, rock bolts)	Systematic shell with reinforcement (welded wire fabric or fibers) in top heading and potentially bench; dependent on tunnel size thickness of 6 in (150 mm) to 8 in (200mm); installed with the rock reinforcement.	One to two rounds behind face	Locally to limit over break	Yes	
Blocky and Seamy Rock	Top heading &bench	Systematic doweling or bolting in top heading & bench considering joint spacing	Systematic shell with reinforcement (welded wire fabric or fibers) in top heading & bench; depending on tunnel size thickness 8 in (200 mm) to 12 in (300 mm)	At the face or maximum one round behind face	Systematic spiling in tunnel roof or parts of it	Yes	
Crushed, but Chemically Intact Rock	Top heading, bench, invert	N/A	Systematic shell with reinforcement (welded wire fabric or fibers) and ring closure in invert; dependent on tunnel size thickness 12 in (300 mm) and more; for initial stabilization and to prevent desiccation, a layer of flashcrete may be required	After each round	Systematic grouted pipe spiling or pipe arch canopy	Support installation dictates progress	If water is present, groundwater draw down or ground improvement is required
Squeezing Rock	Top heading, bench, invert	Systematic doweling or bolting in top heading & bench considering joint spacing; extended length	Systematic shell with reinforcement (welded wire fabric or fibers) and ring closure in invert; dependent on tunnel size thickness 12 in (300 mm) and more; potential use for yield elements; for initial stabilization and to prevent desiccation, a layer of flashcrete may be required	After each round	Systematic grouted pipe spiling or pipe arch canopy	Support installation dictates progress	

Table 2.4: Elements of Commonly Used Excavation and Support Classes (ESC) in Rock (Reference 1)

Ground Mass Quality - Rock	Excavation Sequence	Rock Reinforce-ment	Initial Shotcrete Lining	Installation Location	Pre-Support	Support Installation Influences Progress	Remarks
Swelling Rock	Top heading, bench, invert	Systematic doweling or bolting in top heading & bench considering joint spacing; extended length	Systematic shell with reinforcement (welded wire fabric or fibers) and ring closure in invert; dependent on tunnel size thickness 12 in (300 mm) and more; potential use for yield elements	After each round	Systematic grouted pipe spiling or pipe arch canopy may be required depending on degree of fracturing	Support installation dictates progress	Deepened invert for additional curvature

Figure 2.25 outlines tunnel constructions in three different characteristic rock mass types ranging from intact to fractured rock. The examples have rock mass reinforcement as a common element of initial support while systematic shotcrete support is used in stratified and fractured rock.

Application of rock classification systems in selection of tunnel support requires detailed input about rock mass, including the strength of rock mass, joint configuration and orientation, joint spacing, joint fillings, etc. Conducting a geotechnical investigation program for obtaining rock mass information will be an integral component of final design.

2.2.6 Proposed Excavation Sequence and Support System for Heroes Tunnel

The existing Heroes Tunnel was built by drill-and-blast technique; therefore, the preferred method of excavation for non-circular new tunnels would be drill-and-blast in the form of either top heading and bench or full face. However, the mechanized excavation using a roadheader could be considered based on the actual rock strength. The choice between full face excavation and sequential excavation shall be finalized after gathering geotechnical information for rock strength and the rock mass properties and features such as number of joints, joint spacing, joint condition, and water table.

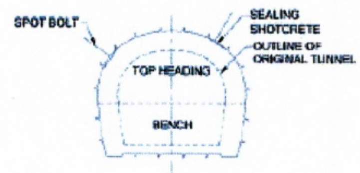
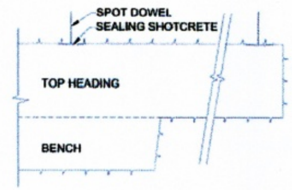
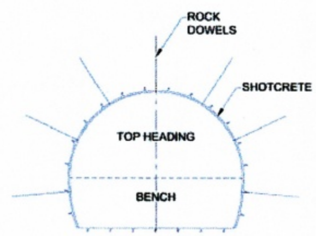
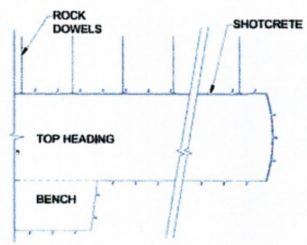
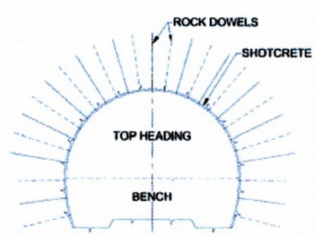
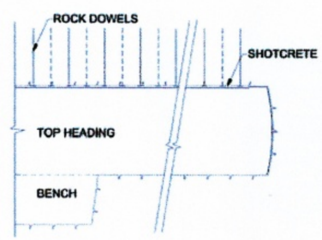
Description	Cross Section	Longitudinal Section	Photo
Intact Rock: ▪ Spot bolting ▪ Occasional sealing shotcrete ▪ Full face or top heading/bench excavation ▪ Round Length Top Heading: 8'-12" (2.5-3.7 m) Bench: Up to 16'-0" (4. 9 m) ▪ Dimensions Height: 20'-0" (6 m) Width: 29'-0" (8.8 m) **Example:** Bergen Tunnels, NJ			
Stratified Rock: ▪ Systematic rock doweling ▪ Systematic shotcrete initial lining ▪ Top heading excavation ▪ Bench excavation follows distant ▪ Round Length Top Heading: 6'-6" (2 m) Bench: 6'-6" (2 m) ▪ Dimensions Height: 29'-6" (9 m) Width: 36'-0" (11 m) **Example:** Zederhaus, Austria			
Fractured Rock: ▪ Systematic rock doweling ▪ Systematic shotcrete initial lining ▪ Top heading excavation ▪ Bench excavation follows any time ▪ Round Length Top Heading: 7'-2" (2.2 m) Bench: 13'-0" (4.0 m) ▪ Dimensions Height: 28'-0" (8.5 m) Width: 36'-5" (11.1 m) **Example:** Devil's Slide Tunnels, CA			

Figure 2.25 Example of SEM Excavation and Support Classes in Rock (Reference 1)

2.3 Construction Duration

Table 2.5 presents the duration for construction of new tunnels using different tunnel construction methods.

2.4 Construction Schedule

The preliminary construction schedules for Option 1 and Option 2 are not limited by work hour restrictions as four lanes of traffic will be maintained at all times.

Under the TBM method, there would be one crew per shift working two 10 hour shifts five days per week. This work period will allow for maximum production while leaving weekends for maintenance and unaffected traffic flow during the week ends.

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, rehabilitation would begin but is not included in the duration estimates. See **Section 10** for construction scenarios that lay out how rehabilitation would be combined with Options 1 and 2.

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 crews 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.

2.5 Construction Cost

Table 2.5 presents the construction cost for construction of new tunnels using different tunnel construction methods. It should be noted the construction cost excludes the cost of lighting, mechanical, electrical, and ventilation systems.

The provided cost and duration for tunnels to be constructed by roadheader is based on the assumption that the UCS of the rock is in the range of roadheader cutting capacity.

Table 2.5: Cost and Duration

	Construction Method	Cost ($ 2019)	Duration (months)
New one-lane tunnel (Option 1)	Closed Face TBM	$110,000,000	5*
	Main Beam TBM	$110,000,000	6*
	Drill-and-blast	$50,000,000	12.5[1]
	Roadheader	$58,000,000	3.5[1]
New two-lane tunnel (Option 2)	Closed Face TBM	$130,000,000	7*
	Main Beam TBM	$131,000,000	8*
	Drill-and-blast	$60,000,000	16[1]
	Roadheader	$87,000,000	5.5[1]

* Excludes mobilization and demobilization time

1 Two crews working simultaneously at opposite ends and working two 10-hour shifts per day 5 days per week

Note that the duration and cost provided for roadheader option is valid if the compressive strength of the excavated rock is within the roadheader capacity; otherwise the duration and the cost will increase dramatically. The duration of rehabilitation of the existing tunnels must be added to the durations for construction of the new tunnels as described in **Section 10**.

2.6 Construction Complexity

With respect to construction complexity, each alternative has advantages and disadvantages which are outlined in sections 2.2 to 2.5 and can include factors such as traffic impact, equipment capacity etc. On a scale of 1 to 10, with 1 representing low construction complexity and 10 very high complexity, construction using TBM would have a rating of 3, whereas construction using drill and blast would have a rating of 4. Since the drill-and-blast technique is a viable option for construction of the new tunnels, the complexity rating considers the risks associated with blasting method such as falling of loose wedges, specialized crew for drilling and blasting operation.

2.7 Traffic

Option 1, the construction of a one lane tunnel, is not anticipated to majorly impact traffic flow along Route 15 as all existing lanes of travel would be retained during construction. The intent is to shift the right lane of northbound traffic to the new tunnel along a new alignment, while maintaining southbound traffic through the existing southbound tunnel. The contractor will rehabilitate the existing northbound tunnel with one lane of traffic maintained. Upon completion of the northbound tunnel, the left lane of southbound traffic will be shifted through a newly constructed crossover north of the tunnel to travel through the northbound tunnel and again shifted through a second newly constructed crossover south of the tunnel back to the southbound mainline. During this sequence, one lane of southbound traffic and one lane of northbound traffic will travel simultaneously through the northbound tunnel. A second lane of northbound traffic will travel through the newly constructed one lane tunnel. During construction, the one lane tunnel is designed to accommodate two lanes of traffic, if necessary, during emergencies or to accommodate unique construction needs.

Option 2, the construction of a two lane tunnel, is not anticipated to majorly impact traffic flow along Route 15 as well, as all existing lanes of travel would likewise be retained during construction. Northbound traffic will be shifted to the new tunnel along a new alignment, while maintaining southbound traffic through the existing southbound tunnel. The contractor will rehabilitate the existing northbound tunnel with all lanes closed to traffic. Upon completion, the southbound traffic will be shifted through a newly constructed crossover north of the tunnel through the northbound tunnel and shifted back to the southbound mainline through a second newly constructed crossover south of the tunnel. Northbound traffic would be maintained through the newly constructed two lane tunnel.

Section 6 further defines the traffic impacts associated with each construction option.

2.8 Anticipated Useful Life

A 100-year useful life of newly constructed tunnels is achievable.

For the existing tunnels the useful life of the rehabilitated tunnel/tunnels depends on thickness and design load for final protective tunnel lining to be installed over the waterproofing membrane. If the protective final lining is being designed for full load of the tunnel load, then a 100 year of useful life is achievable. However, if the final protective liner is designed for fraction of total loads, then the useful life of the rehabilitated tunnel would be in the range of 15 to 20 years. The design of final lining system for both conditions will reduce the tunnel clearance; however, the reduction in tunnel clearance for 100 years of useful life is larger compared to the 15 to 20 years of useful life condition. The reduction in tunnel clearance for 100 years of useful life could be in the range of 1.5 to 2.0 feet.

2.9 Summary and Conclusion

This section provided various techniques and methods for the construction of one-lane and two-lane circular and non-circular tunnels. The method to be used is the function of geological condition, schedule, cost, availability of equipment and personnel, duration of interruption to the traffic, etc. For this study, due to very limited detailed geotechnical investigation, a basic method of construction should be considered and only as additional data is collected can a more sophisticated construction method be considered. A geotechnical investigation program will be planned for final design if the construction of new tunnels is selected as the final option.

In reviewing the cost and duration of the various construction technologies (Table 2.5), drill-and-blast and mechanized excavation using roadheader are the most viable options. It should be noted that the cost and duration of the roadheader option would be dramatically higher if the compressive strength of the excavated rock exceeds the roadheader capacity.

Since these options are not expected to result in any lane closures, there are no anticipated traffic impacts or associated delay costs. However, both option 1 and 2 require new alignment along Route 15, which is described in **Section 8**.

2.10 References

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TAB PAGE

Section 3

Construction Option 3: Widening of the Existing Tunnels

3.1 Introduction

Enlarging the cross-sectional area of one barrel of the existing highway tunnels is another option to be considered (option 3). This type of work is challenging because it is necessary to maintain traffic flow during construction; therefore, the work space is limited to protect both the workers and the public traffic through the work site in tight spaces. As a result, special considerations have to be made to mitigate these issues:

1. Ensure necessary safety level for tunnel users.
2. To the extent possible allow for uninterrupted traffic through the tunnel during the construction and limit disruptions within an acceptable threshold.
3. Develop a scheme that supports the ground that takes into account the present *in situ* state of stress of the rock.
4. Estimate the required materials and tools required for the project so that adequate staging area can be obtained.

The success of a tunnel rehabilitation project is different for all concerned parties. To achieve a success for the owner, designer, and contractor requires that these entities work together. Initially this communication is between the owner and engineer to establish contractor qualifications, issues regarding obtaining available land and how much is required, and for what duration. Once in construction, the contractor is involved with these discussions also to provide input on means and methods to achieve success. There are several common goals to all parties in the project that if achieved can result in a successful project.

Tonon (2010) presented a comprehensive review of various techniques for tunnel enlargement based on 40 case histories of tunnel enlargement projects that allow for traffic flow during tunnel enlargement construction operation. The analyses of these case histories indicated that:

- The original tunnel widths were in the range of 2 to 9 m (6.5 feet to 29.5 feet), whereas the enlarged cross-section were in the range of 6 m to 15 m (19.5 feet to 49 feet). Maximum length was 330 m (1082 feet).
- To maintain traffic flow through the tunnel during active construction, a protective shield, covered with soundproofing and anti-shock material similar to the one shown in **Figure 3.1** was used along the entire tunnel between the traffic and the construction activities. The other benefit to this shield was it eliminated "rubber necking" by the vehicular traffic and accompanying accidents.

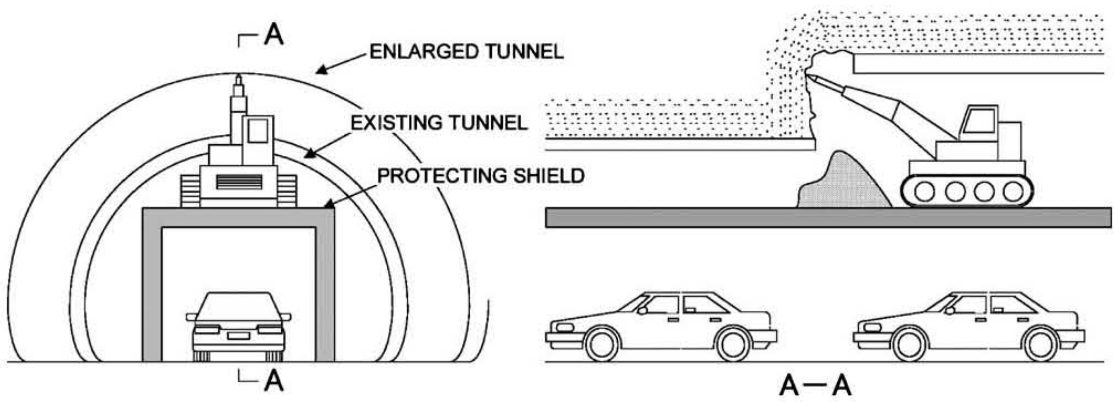

Figure 3.1: Typical Tunnel Enlargement Layout (Tonon 2010)

- In most the projects (80 percent) small equipment was used to fit either between the shield and crown of the enlarged tunnel, or in the drift on each side of the shield.

The results of the analyses performed on these case histories indicated the following challenges, unique to the limited construction space, had to be resolved:

- The narrow work space creates a working environment similar to work cycle for a new tunnel construction, including excavation, mucking, and installation of tunnel support. This requires a work plan similar to a new tunnel excavation working plan.
- There was a need for construction methods that do not require restriction of traffic because the social cost would increase with increasing construction time.

3.2 Enlargement Techniques

The availability of at least three operational lanes of traffic during the rehabilitation activities is the most important requirement for any rehabilitation technique to be used for Heroes Tunnel. As previously mentioned, enlargement of one barrel of the existing tunnels is one of the alternatives to be investigated in this study. The enlargement of the existing tunnel should provide a three-lane tunnel and shoulders with total width of 52 feet. Due to the existing control room and the ventilation shaft located between two adjacent tunnels the enlargement of the existing tunnel should performed from one side to avoid any destruction to these structures and any damage to the adjacent tunnels.

Since 1990 new construction techniques have been developed and used to overcome the challenges associated with enlarging tunnels while keeping the tunnels operational. These main characteristics of these techniques are summarized in **Table 3.1** and the description of each technique will be provided in following sections.

3.2.1 Hybrid Tunnel Work Station (TWS) Method

This technique combines a door shaped excavator for enlarging the tunnel and a movable shield as shown in **Figure 3.2**. In addition, this method is able to enlarge tunnel longer than 1,000 m (3,280 feet), which was difficult in the past.

Table 3.1: Construction Techniques Available for Tunnel Enlargement (Reference 1)

Method	Classification	Traffic lane	Excavation Equipment	Excavation Type	Shield	Direction of enlargement	Ground type	Length of enlarged tunnel
Hybrid TWS method	Purpose-built excavator door type (mechanical excavator)	One lane control	Purpose-built machine	Mechanical excavator	Movable shield	Both sides	Soft rock—medium to hard rock	Medium--long
Napoleon hat-type stage method	Purpose-built excavator, combination of purpose-built and standard excavator door type (blasting excavation)	Two lanes	Purpose-built machine, standard machine	Blasting excavation	Movable shield	Both sides	Sand—hard rock	Short--long
Crescent cross section method	Semi-purpose-built excavation type (mechanical excavation)	One lane control	Semi-purpose-built machine	Mechanical excavator	Movable shield	One side	Up to medium-hard rock	Short--long
Arch-cut method	Purpose-built excavator using pre-existing lining (mechanical excavation)	Two lanes	Purpose-built machine	Mechanical excavator	Use existing lining	Both sides	Up to soft rock	Medium--long
Two-sided enlargement method with two sidewall drifts	standard excavator using pre-existing lining (mechanical excavation)	Two lanes	Standard machine	Mechanical excavator	Use existing lining	Both sides	Up to medium-hard rock	Short--medium
Nonshield enlargement method using the existing lining	standard excavator using pre-existing lining (mechanical excavation)	Two lanes	Standard machine	Mechanical excavator	Use existing lining	One side	Up to medium-hard rock	Short--medium
π stage method	standard excavator movable deck (mechanical excavation)	One lane control	Standard machine	Mechanical excavator	Movable shield	Both sides	Soft rock	Short--medium
Flat deck method	standard excavator movable deck (mechanical excavation)	Two lanes	Standard machine	Mechanical excavator	Use existing lining+fixed type (simple protector)	Both sides	Soft rock	Short--medium

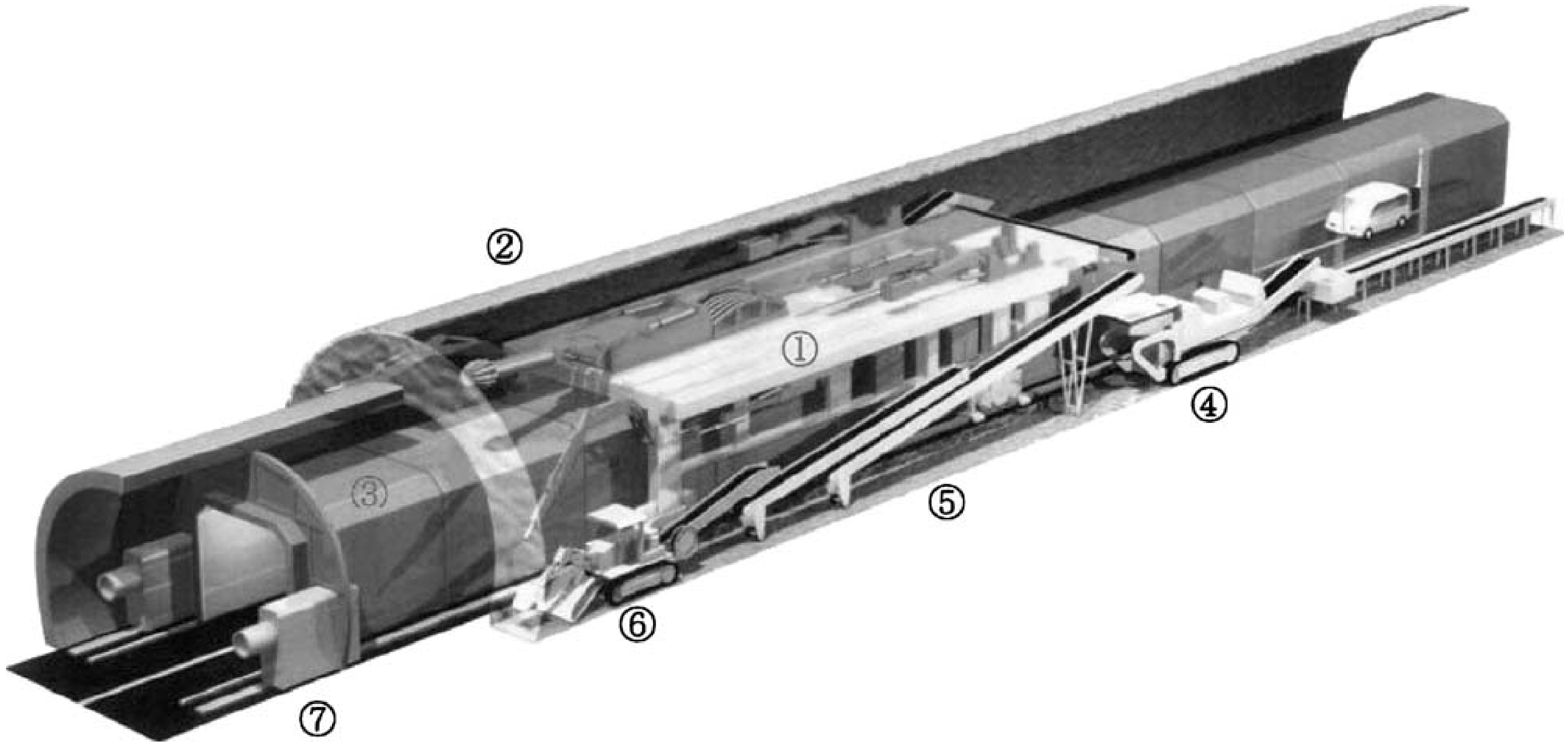

Figure 3.2: Hybrid TWS Method: 1) Door-Shaped Excavator; 2) Free Surface Excavation; 3) Moveable Shield; 4) Crusher; 5) Belt Conveyor; 6) Muck Loader; and 7) Dust Collector Fans (Reference 1**)**

The main characteristics of this technique are as follow:

- The ground may consist of soft rock to mid-hard rock. For hard rock application, a partial face mechanical excavation system attached to the door-shaped excavator is used.
- Since the door-shaped excavator (for enlarging the tunnel) is combined with a movable shield for protecting traffic, the excavation and lining placement activities do not interfere with each. This would allow using this technique for long tunnels.
- There is no waste of time to rotate, move, and prepare the equipment because excavation, mucking, a support installation are accomplished using an integrated machine to the door-shaped excavator.
- The excavation area and the tunnel environment remains clean by means of dust fans and conveyor belts transporting the muck, therefore eradicating the dust and exhaust gases.

3.2.2 Napoleon Hat Staged Method

This method utilizes a sliding deck (Napoleon hat shaped shield), which can provide a larger and wider working space as shown in **Figure 3.3**. The method of excavation is drill and blast. The main characteristics of this technique are:

1. This method can used in wide range of geological formations including hard rock since it employs the drill and blast technique.
2. Two lanes of traffic can remain operational if the original (existing) tunnel is large.
3. The construction sequence from excavation to installation of support system can be performed by using specialized machine located on the wide working deck. Because of that reason, construction duration and cost can be reduced significantly in tunnels longer than 1,000 m (3,280 feet).

3.2.3 Crescent Cross-Section Method

This method provides sufficient working space since enlargement takes place only on one side of the shield. All operations from excavation to tunnel support installation can be performed using a large size multipurpose excavator as shown in **Figure 3.4**. The main characteristics of this technique can be summarized as:

1. A multifunction excavator may remove the existing lining, place shotcrete, install rock bolts, erect tunnel support, and remove muck. Using the multipurpose excavator will reduce the construction time significantly compared to scenario where multiple equipment should work on site..
2. This method uses part of the existing tunnel support system for the enlarged tunnel and therefore it is not necessary to remove the entire existing tunnel support system. This would reduce the consumption of construction material compared to condition in which the entire support system should be removed and constructed..
3. Shield cost is less because different stiffness and strength are used along the shield length which is approximately 130 m (430 feet).

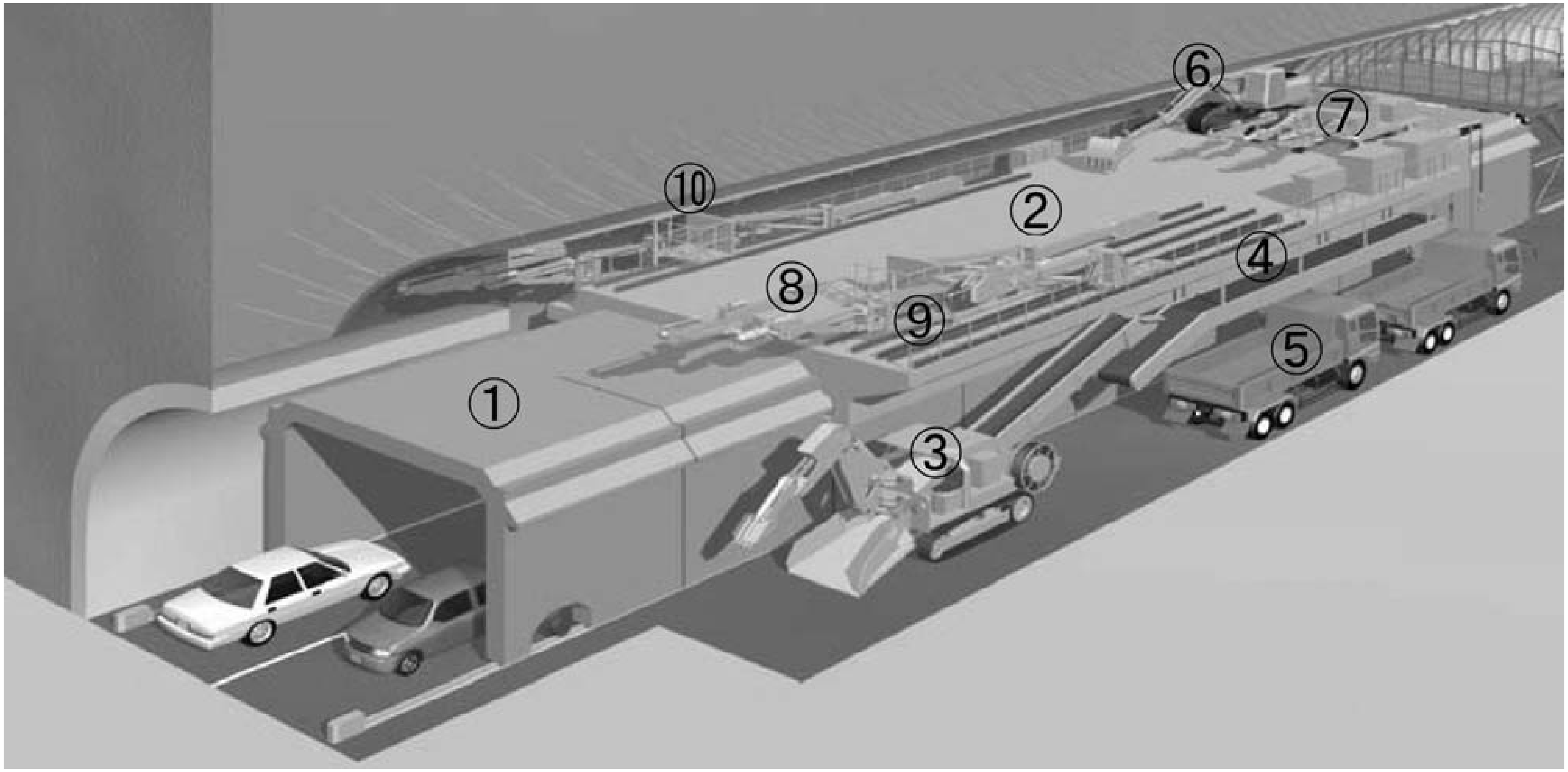

Figure 3.3: Napoleon Hat Type Staged Method; 1) Movable Shield; 2) Sliding TWS; 3) Muck Loader; 4) Belt Conveyor; 5) Dump Trucks; 6) Back-Hoe Excavator; 7) Boom Jumbos; 8) Drilling Unit; 9) Rails; and 10) Cage For Shotcrete (Reference 1**)**

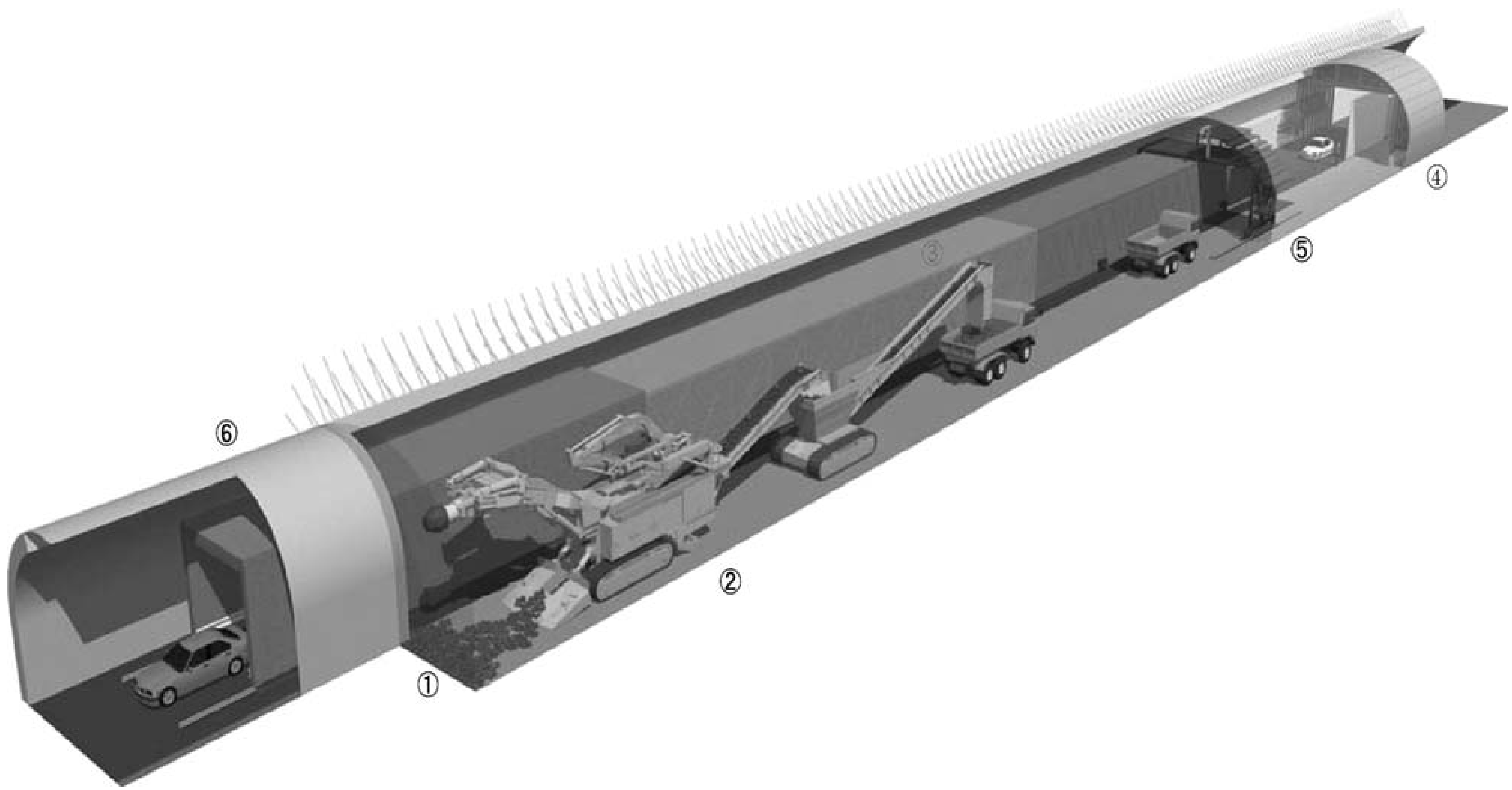

Figure 3.4: Crescent Cross Section Method: 1) Crescent Enlarged Excavation; 2) Multipurpose Excavator; 3) Movable Shield with Different Strength; 4) Concrete Form; 5) Frame for Installation of Sheet Membrane; and 6) Existing Tunnel (Reference 1**)**

3.2.4 Arch-Cut Method

Enlarging is made by excavating side drifts and using the old lining as a protection shield. When the old lining is demolished, a movable shield is installed to ensure traffic safety. In this case, the enlarging excavation is done with a special arch-shaped machine which can excavate and place the new lining (see **Figure 3.5**). This method is mainly used in soft rock and probably not viable for this project due to rock strength.

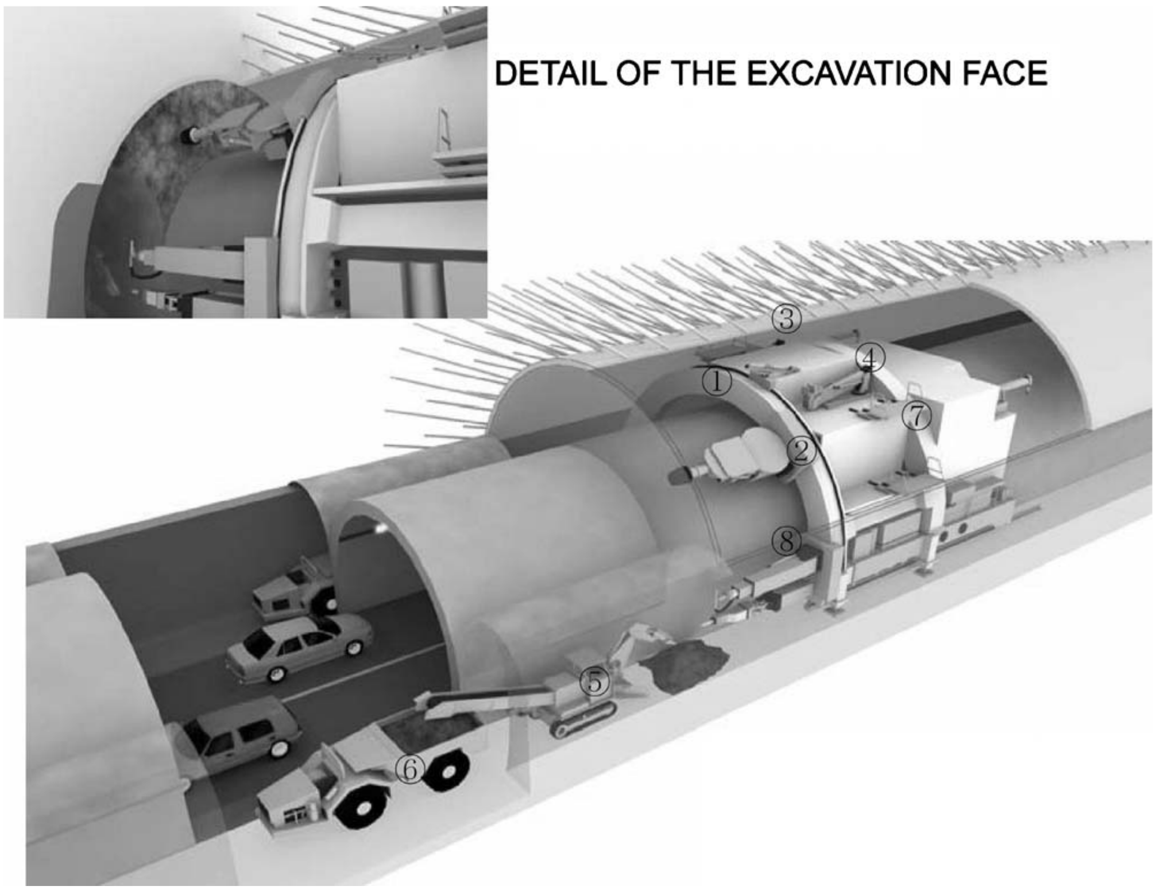

Figure 3.5: Arch Cut Method: 1) Arch Cut Excavator; 2) Road-Header; 3) Bolter; 4) Steel Set Erector; 5) Muck Loader; 6) Dump Truck; 7) Working Platform; and 8) Shotcrete Nozzle (Reference 1)

3.2.4.1 π Stage Method

Construction consists of a wide π shaped shelter with anti-shock material under which traffic runs. Above the shelter, construction takes place following a number of steps composed of: ground improvement, rock bolting, excavation, demolition of the old lining and erection of new lining as shown on **Figure 3.6.** This method is mainly used in soft rock and probably not viable for this project due to rock strength.

3.2.4.2 Flat Deck Method

This method utilizes a simple shield to isolate vehicles from construction equipment as shown in **Figure 3.7**. The movable working deck (flat stage) can also be sued as a working platform for the excavator. This method depending on fracture pattern is mainly used in soft rock and probably not viable for this project due to rock strength.

3.2.4.3 Two-Sided Enlargement Method with Two Sidewall Drifts

This method consists of excavation of drifts on each side of the tunnel as shown in **Figure 3.8**. The existing tunnel is used as a protective shield between traffic and construction operations, and a deck is used to support the construction equipment with the following features:

- Both drift excavation and the enlargement excavation are performed by the same standard excavator. This method is applicable to medium-hard rock.
- This method is efficient because muck can be disposed of in the advancing direction of the face through the excavated drifts.
- When the existing lining is removed, a simple movable shield is installed to ensure traffic safety.

3.2.4.4 Nonshield Enlargement Method Using the Existing Lining

This method depending on rock quality may consist of installation of forepoling system as temporary support, excavation of a drift on only one side of the tunnel using a roadheader or mechanized hammer, and using the existing lining as a shield during construction (see **Figure 3.9-a and b**). Depending on the design the final tunnel support can be cast-in-place concrete combined with rock bolts or combination of rock bolts, wire mesh, lattice girder and shotcrete. It should be noted that a protective shield would be required during stage 2 and 3 to protect and separate the passing traffic from construction activities. This option will provide four lane as temporary condition as shown in stage 4 and three lanes for permanent condition.

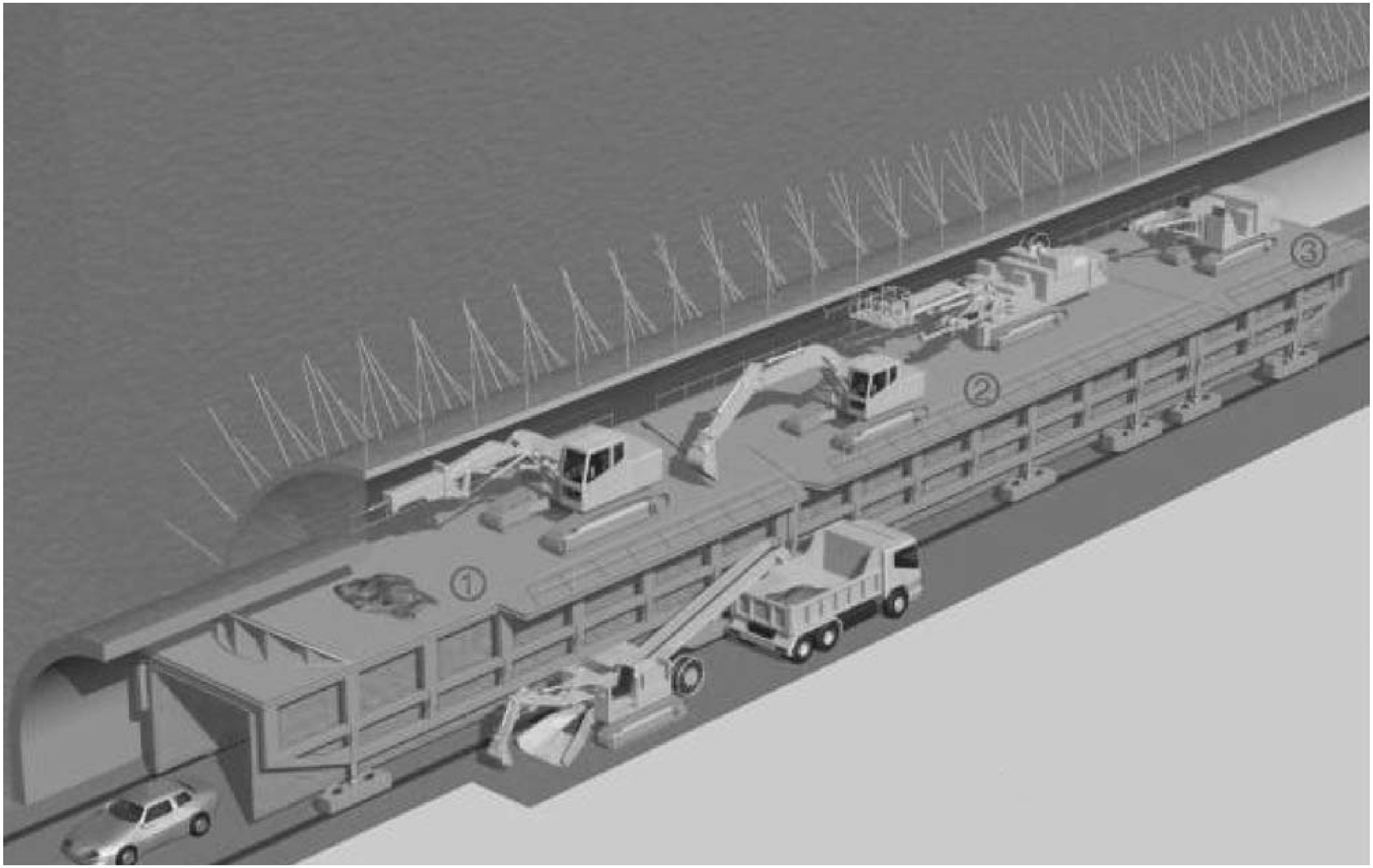

Figure 3.6: π-Deck Method: 1) Fixed Shield; 2) First Deck; and 3) Second Deck (Reference 1**)**

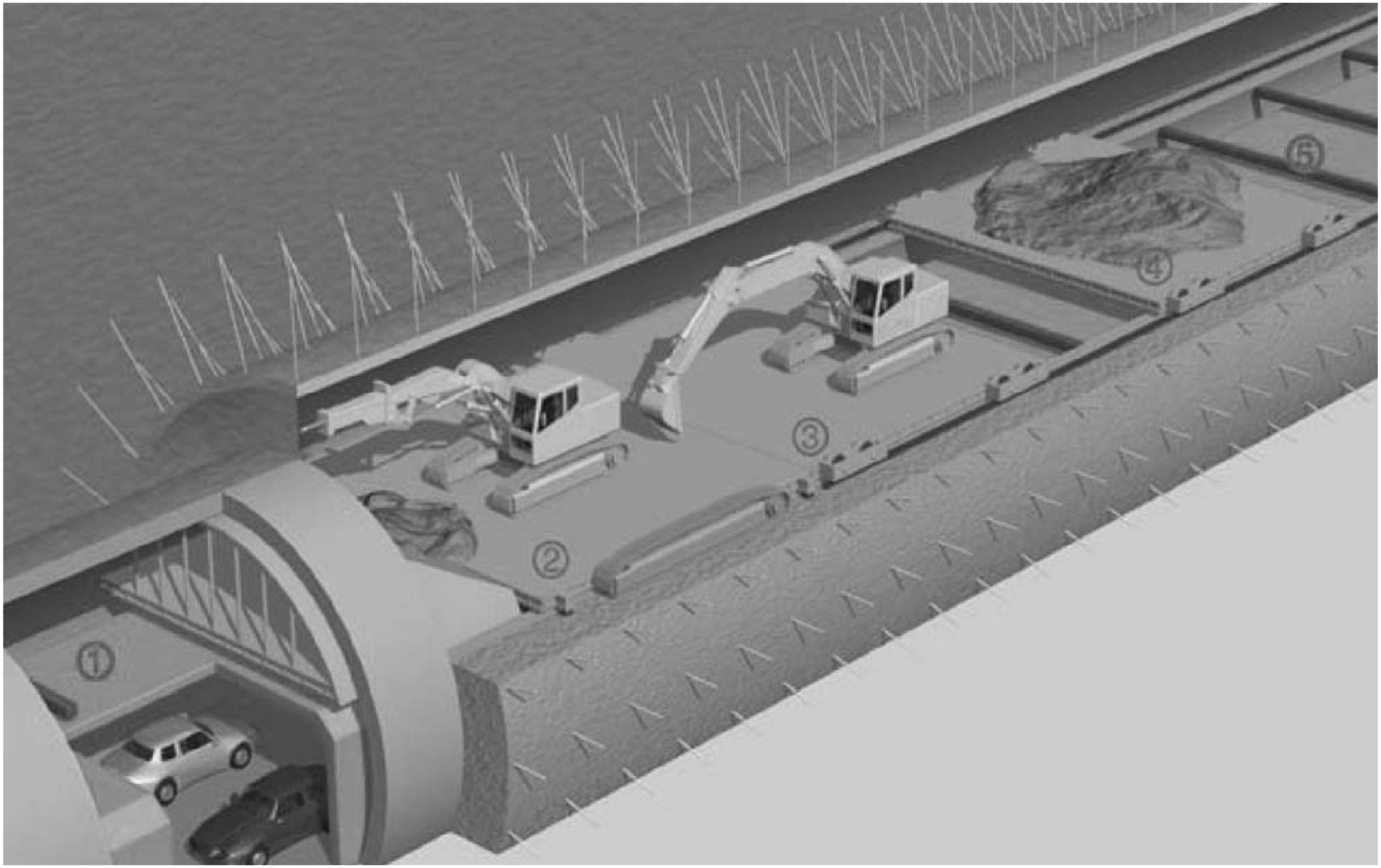

Figure 3.7: Flat Deck Method: 1) Fixed Shield; 2) First Deck; 3) Second Deck; 4) Third Deck; and 5) Strut (Reference 1**)**

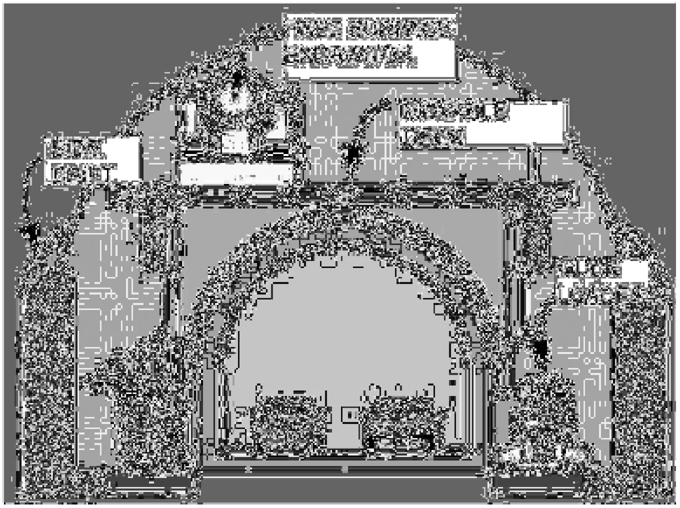

Figure 3.8: Two-Sided Enlargement Method with Two Sidewall Drifts (Reference 1**)**

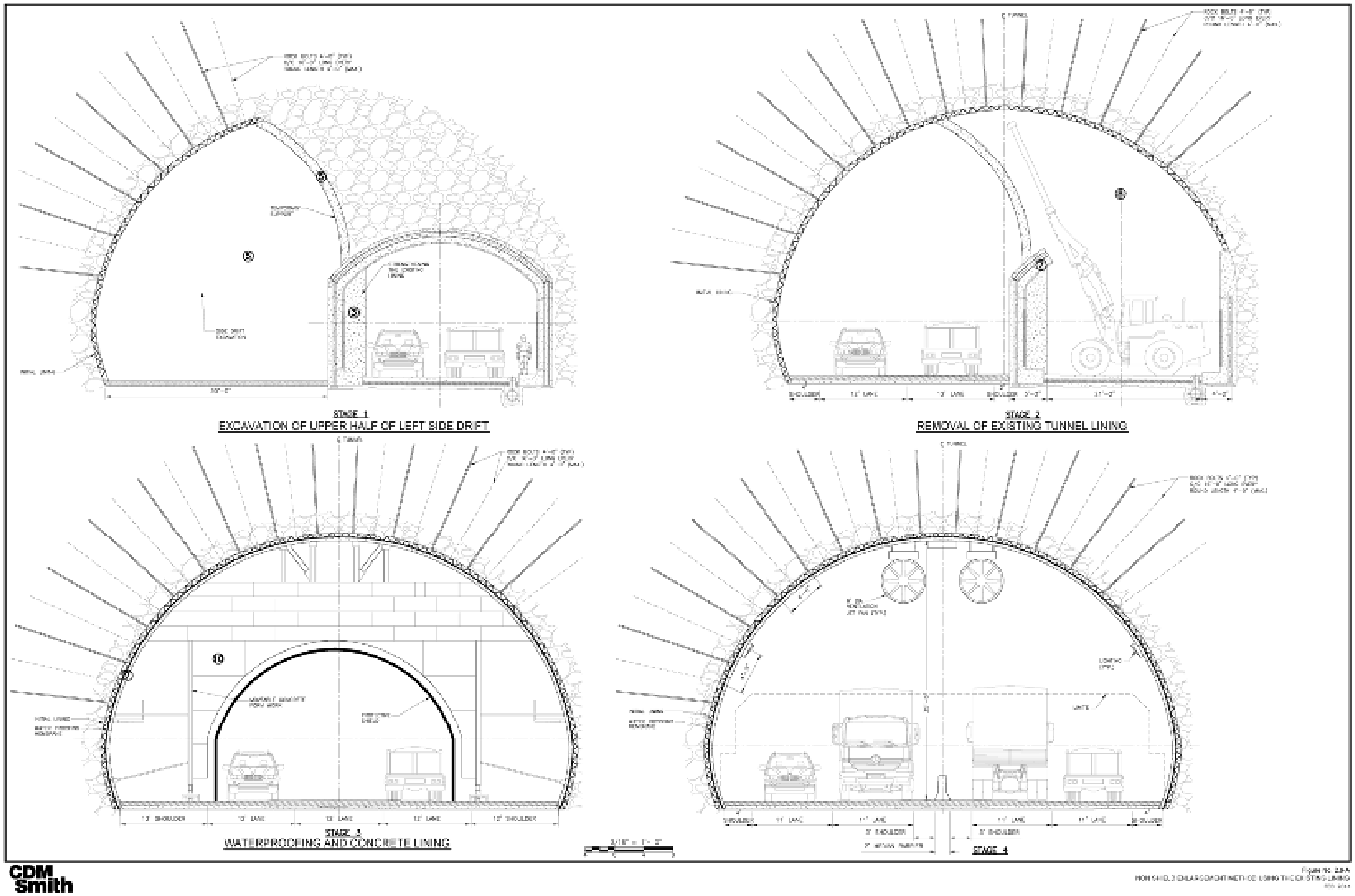

Figure 3.9a: Nonshield Enlargement Method Using the Existing Lining

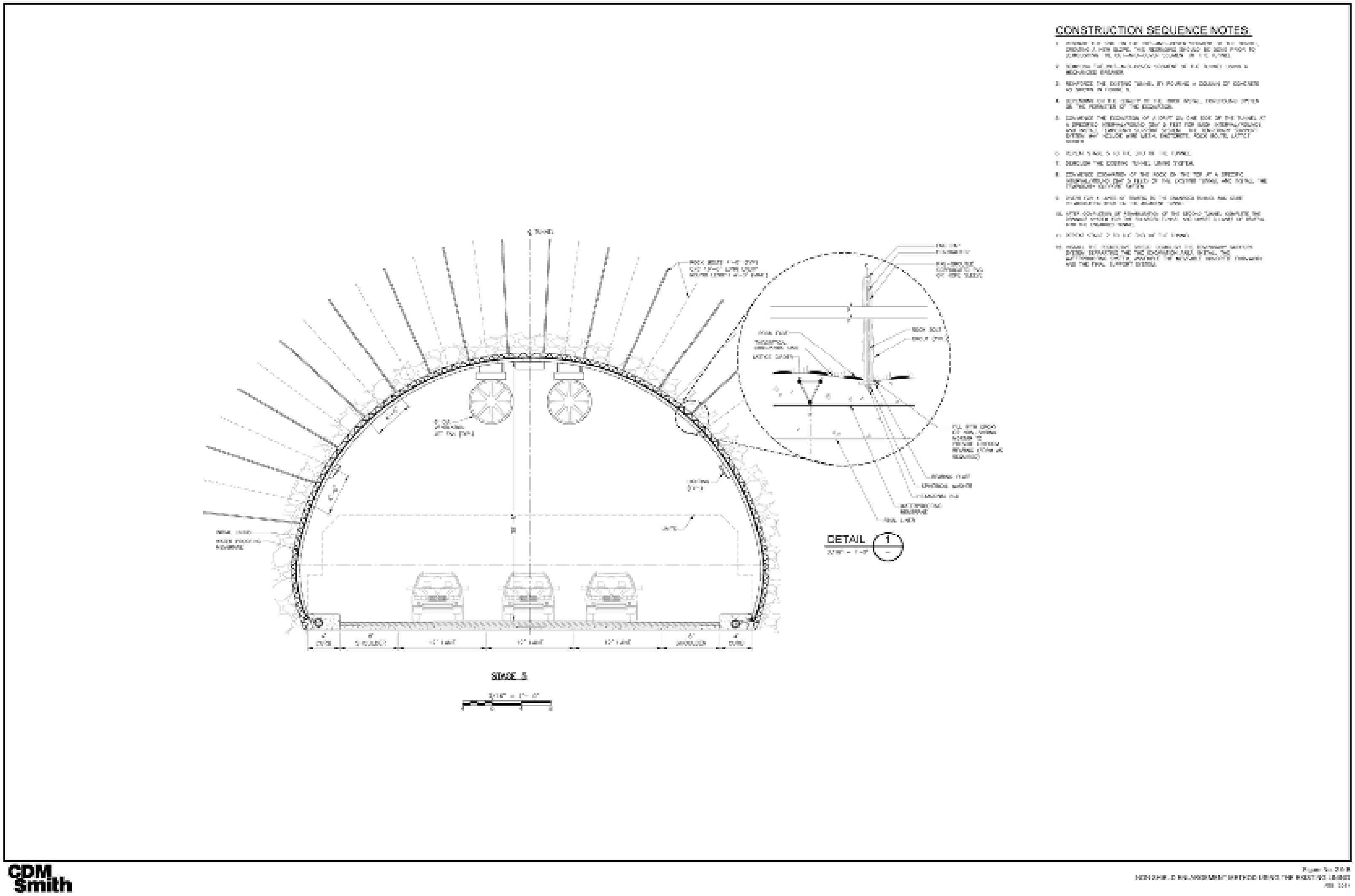

Figure 3.9b: Nonshield Enlargement Method Using the Existing Lining

Figure 3.10 presents a movable concrete formwork for CIP concrete. **Figure 3.11** presents a movable frame for sprayed shotcrete. **Figure 3.12** presents the shotcreting operation using remote control robotic arm. The tunnel support system consisting of rock bolts, wire mesh, and shotcrete is shown on **Figure 3.13. Figure 3.14** presents a roadheader. As presented in Section 2, the basic cutting tool for a roadheader is a very large milling head mounted on a boom, which boom, in turn, is mounted on tracks or within a shield. Using a roadheader corners must be cut to the curvature of the milling head, but the rest of the walls, crown and invert can be cut to almost any desired shape. In addition and in contrast to a TBM, a single roadheader can cut variable or odd shapes that otherwise would require TBM excavation in combination with drill and blast or drill and blast itself. Because of their adaptability, availability (a few months rather than a year or longer), and lower cost, roadheaders also are the method of choice for relatively short tunnels, less than 2,000 lf. Hero's tunnels are both 1250 lf. Section 2 discusses in detail the various excavation methods for construction of new tunnels and the different tunnel support system.

In general the construction sequence for these techniques consists of:

1. Regrade the soil on the cut-and-cover segment of the tunnel, creating a new slope. This regarding should be done prior to demolishing the cut-and-cover segment of the tunnel.

2. Demolish the cut-and-cover segment of the tunnel using a mechanized breaker.

3. Reinforce the existing tunnel by pouring a column of concrete as shown in Figure 3.9-a.

4. Depending on the quality of the rock install forepoling system on the perimeter of the excavation.

5. Commence the excavation of a drift on one side of the tunnel at a specified interval/round (say 5 feet for each interval/round) and install temporary support system. The temporary support system may include wire mesh, shotcrete, rock bolts, and lattice girder.

6. Repeat stage 5 to the end of the tunnel.

7. Demolish the existing tunnel lining system.

8. Commence excavation of the rock on the top at a specific interval/round (say 5 feet) of the existing tunnel and install the temporary support system.

9. Repeat stage 7 to the end of the tunnel.

10. Install the protective shield, demolish the temporary support system separating the two excavation area, install the waterproofing system, assemble the moveable concrete formwork and the final support system.

This method provides a wide working space for construction activities. The main features of this method are:

- This method can be applied to medium-hard rock condition by using general purpose equipment.

- Safety of traffic in the tunnel is ensured by constructing a partition wall between the tunnel and the enlarged part of the tunnel and a protective shield during final lining installation.

Figure 3.10: Movable Formwork for Cast-in-Place Concrete (Source: Reference 2)

Figure 3.11: Movable Frame for Installation of Waterproofing Membrane and Sprayed Shotcrete (Reference 3)

Figure 3.12: Shotcrete Installation Using Remote Control Robotic Arm (Reference 4)

Figure 3.13: Support System Consisting of Rock Bolts, Wire Mesh, and Shotcrete (Reference 5)

Figure 3.14: A Roadheader During the Tunnel Excavation (Reference 6)

3.2.5 Commercial Tunnel Enlargement Machine

There are also commercial tunnel enlargement machines mainly used to enlarge railroad tunnels. **Figures 3.15 and 3.16** present the schematics and also the real machine during the construction work manufactured by GTA Maschinensysteme GmbH, respectively.

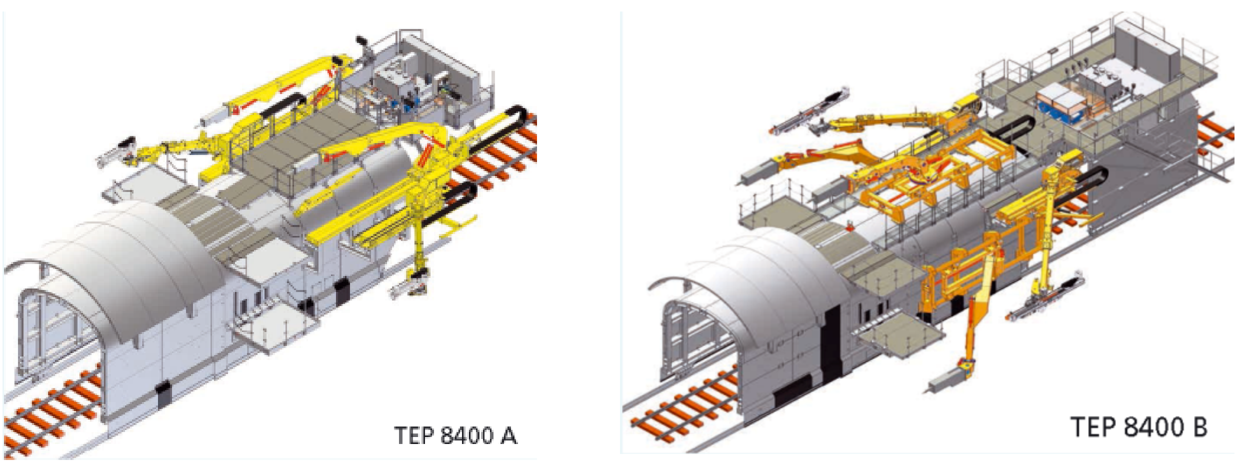

**Figure 3.15: Schematics for Tunnel Enlargement Machine used for Railway Tunnels –
A) Blasting method is used for excavation in gantry TIP 8400A Model;
B) Ripping Method is used for excavation in gantry TIP 8400B Model (Reference 7)**

Figure 3.16: Railway Tunnel Enlargement Machine (Reference 9)

3.2.6 Recommendation

Various techniques were introduced for enlarging the existing tunnel. These techniques can be classified as enlarging the tunnel using a) protective shield and b) nonshield enlargement method using the existing lining as part of protective shield. In comparing these two methods, the cost and lack of specialists in this country to perform of shielded techniques are key reasons that we recommend to use the non-shield technique presented in Figure 3.9 for the enlargement of the Heroes Tunnel.

Drill-and-blast method shall be used for excavation and enlarging the tunnel assuming that the compressive strength of the rock is higher than the capacity of roadheader machine. It could be necessary to used controlled blasting technique to minimize the risk of damaging the existing tunnel structure and the temporary shotcrete support.

3.3 Construction Duration

The duration for the recommended enlargement method is 53 months based on the construction schedule described below. This duration does not account for weather or seasonal shutdowns.

3.4 Construction Schedule

Four lanes of traffic will be maintained during the widening of the tunnel side shift. There will be two crews working 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 will be working together using two vehicle shields in order to least impact on traffic.

Blasting will be scheduled during overnight or 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, 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.

The duration for rehabilitation of the existing tunnels must be added to the durations for widening the existing tunnel as provided in **Section 10**.

3.5 Construction Cost

The preliminary construction cost for the recommended enlargement method is $70,000,000. The construction cost includes the cost for regrading the soil on top of the cut-and-cover section, electrical, ventilation, lighting, etc.

3.6 Construction Complexity

With respect to construction complexity, each alternative has advantages and disadvantages, which are outlined in Sections 3.2 to 3.6. On a scale of 1 to 10, with 1 representing low construction complexity and 10 very high complexity, the complexity rating for option 3 is 7. 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. The recommended method requires construction of protective shields to provide safe passage for passing cars during the construction.

3.7 Traffic

Option 3 presents state-of-the-art methods for enlarging transportation tunnels while maintaining current traffic capacity during construction. Under Stage 1 of construction, two lanes of traffic will be maintained in the existing tunnel while the adjacent earth is excavated. During Stage 2, traffic will be shifted to the recently excavated portion to allow for the removal of the existing tunnel lining. A protective shield will be introduced under Stage 3 to allow for safe passage of two lanes of traffic while waterproofing and concrete lining are installed. Under Stage 4, the opposite direction of Route 15 traffic will be shifted into the enlarged tunnel via a newly constructed crossover to allow rehabilitation of the other tunnel. At this point, four lanes of traffic will be travelling through the enlarged tunnel.

It should be noted that the drill and blast widening method has been recommended under this option. Traffic will have to be held during blasts for approximately 5 minutes; using the "rolling lane closure method." These blasts should be scheduled for off-peak times to minimize traffic impacts. The intermittent stoppages during blasting sequences will be very short in duration. The traffic impacts and associated delay costs of option 3, therefore, are considered negligible. This topic is also discussed in Section 6.

3.8 Anticipated Useful Life

Since the expanded tunnel is a new tunnel, 100 years of useful life of expanded tunnel 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 years 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.

For the existing tunnels the useful life of the rehabilitated tunnel or tunnels depends on thickness and design load for final protective tunnel lining to be installed over the waterproofing membrane. If the protective final lining is being designed for full load of the tunnel load, then a 100 year of useful life is achievable. However, if the final protective liner is designed for fraction of total loads, then the useful life of the rehabilitated tunnel would be in the range of 15 to 20 years. The design of final lining system for both conditions will reduce the tunnel clearance; however, the reduction in tunnel clearance for 100 years of useful life is larger compared to the 15 to 20 years of useful life condition. The reduction in tunnel clearance for 100 years of useful life could be in the range of 1.5 to 2.0 feet.

3.9 References

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Section 4

Construction Option 4: Rehabilitation of the Existing Tunnel by Complete Shutdown of One Barrel

4.1 Introduction

Option 4 includes rehabilitation of the existing tunnels. The rehabilitation process includes a complete shutdown of one tunnel with northbound traffic diverted by local and regional detours. In this section we are presenting a summary of proposed tunnel rehabilitation work, which applies to both option 4 as well as option 5, which is further discussed in **Section 5**.

The objectives of rehabilitation measures are to:

- Provide a means to collect trapped water between tunnel lining and *in situ* ground
- Provide path for groundwater above tunnel to the tunnel main drainage system
- Reduce the adverse effect of groundwater acting on tunnel lining
- Reduce the hydrostatic pressure behind the portal walls due to clogging or non-functioning drainage system
- Eliminate of the adverse effect of freeze and thaw of groundwater on tunnel lining and elimination of icicles during cold weather
- Present a dry and pleasant appearance of tunnel

The alternative rehabilitation option includes only closing one lane in one tunnel at a time (option 5), which is described in Section 5 of this report.

The main advantages and disadvantages of option 4 (compared to option 5) are as follows.

Advantages

- Less storage space for equipment is required to close a tunnel than is required to allow through traffic in the tunnel during rehabilitation.
- With additional work space the estimated construction time will be 20 months which are 4 months less than the single lane closure option.
- Estimated construction cost is $1,500,000 less than the single lane closure option.
- Less risk to the public traveling through the tunnel and workers in the tunnel with the tunnel closed.

Disadvantages

- Traffic will have significant delays to reduce to one lane in each direction to pass through the other tunnel.

Since this option investigates the feasibility of rehabilitating one barrel at a time, completely closing the barrel to traffic, significant traffic detours will be necessary. Traffic detours and the associated delays for this option are presented in **Section 6** of this report. The associated delay costs are presented in **Section 7** of this report. This option does not require any roadway work. All detours are analyzed on existing roadway networks.

4.2 Proposed Rehabilitation Method

This section includes a summary of proposed tunnel rehabilitation work, which options 4 and 5. This summary is taken from a detailed rehabilitation report submitted to Connecticut Department of Transportation in "Heroes (West Rock) Tunnel Inspection and Rehabilitation Recommendations" dated July 2010. The design and construction to rehabilitate the tunnel would be required to satisfy the requirements of NFPA 502; "Standard for Road Tunnels, Bridges, and other limited Access Highways".

4.2.1 Recommended Rehabilitation of Civil-Drainage Systems

It was recommended in the 2010 report that the drainage troughs (gutters) above the North and South Portals be cleaned of debris so as to allow for free flow of drainage of surface runoff water.

It was also recommended that the roadway drainage system be replaced as a part of the tunnel rehabilitation. The existing catch basins and piping would be designed to accommodate surface runoff drainage and also drainage from the vent shaft that currently discharges into main drainage system.

The existing vegetation behind the North and South Portals would also be removed. The purpose of removing this vegetation is to prevent any root system from adversely affecting the tunnel portal structure.

If in the future the drainage system within the tunnel is modified, consideration should be given to the handling of spill of contaminated or hazardous materials.

4.2.2 Recommended Rehabilitation of Structural Systems

4.2.2.1 Concrete Surface Repairs

Geophysical surveys were performed on both tunnels as part of the initial CDM Smith investigation performed in 2010. The sonic/ultrasonic and GPR results of those surveys indicated areas of cracked and/or weakened concrete. In general, these areas were verified during the structural inspection visually and by hammer sounding. It was recommended that in the future, concrete cores be extracted from selected areas to perform petrographic analysis. Petrographic analyses would be used to determine whether chemical attack (along with water infiltration) is a potential contributing factor in the deterioration observed. Compression tests can also be performed on the extracted cores to verify the concrete strengths as estimated by the sonic/ultrasonic non-destructive testing results.

The inspection noted numerous hollow areas on the ceiling of each tunnel. Many of these areas were noted previously in the CTDOT's last inspection dated October 2007. Many of these areas appeared to have increased in size, but do not appear to be severe enough at this time to require a safety critical repair. However, at a minimum, it was recommended that the CDOT continue to monitor these areas for apparent signs of cracking or loosening of the concrete during the next inspection cycle. If observed, any loose concrete in danger of falling onto the roadway surface should be removed and the area repaired to a condition that is safe to the public.

Furthermore, to provide a suitable substrate for installation of a proposed waterproofing system, all concrete surface defects including all spalls, hollow areas, patch failures, and moderate to severe cracks were to be repaired. The methods of repair were presented in Section 5 of the July 2010 report.

4.2.2.2 Groundwater Management and Tunnel Waterproofing by Installing Deep Fan Drains, Tunnel Drainage Membrane, and Insulating Liner System

The rehabilitation technique to manage the groundwater inflow as recommended in the July 2010 report is presented in **Figure 4.1** and consists of:

1. Concrete surface repairs including repair of spalls, hollow areas, patch failures, joints, and severe cracks.
2. Installation of new deep fan drains by drilling through the existing drainage system at the tunnel crown and side walls from inside the tunnel. This fan drain system will allow groundwater to drain through the liner and directly to a waterproofing membrane / drainage layer.
3. Installation of a waterproofing membrane/drainage layer.
4. Installation of a new longitudinal drainage system on each side of the tunnel to direct the collected groundwater catch basins or other system outside the tunnel.
5. Installation of new insulation panels.

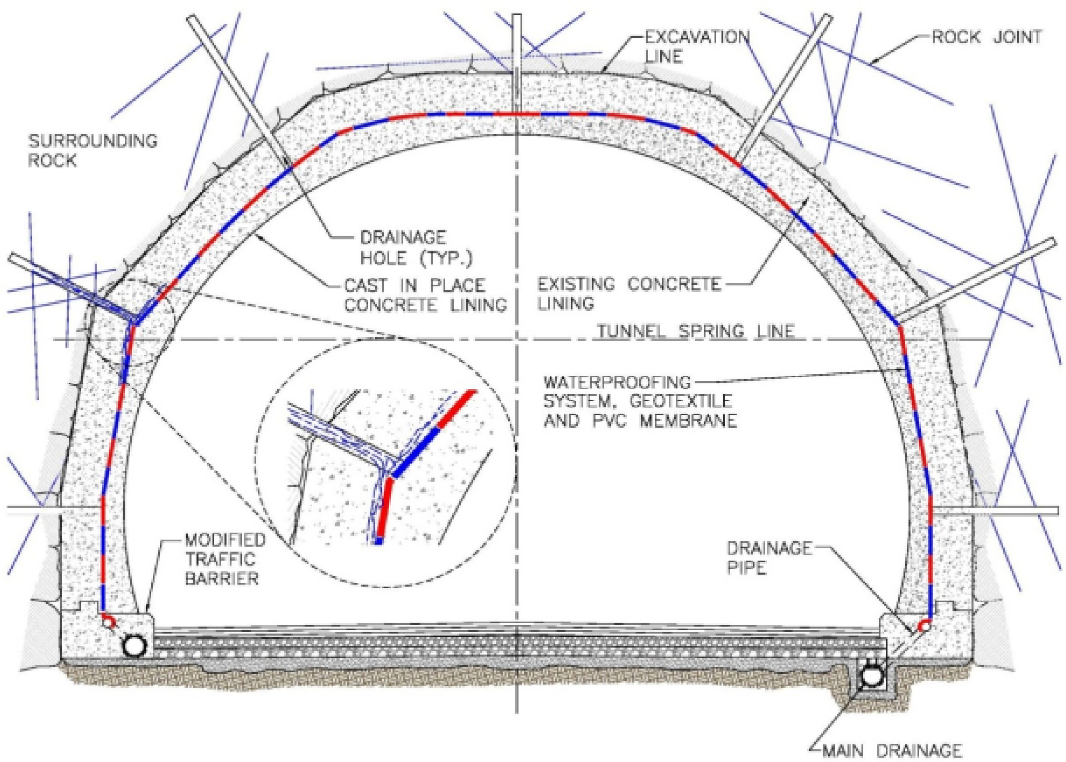

Figure 4.1: Proposed Rehabilitation Method

4.3 Construction Duration

The estimated rehabilitation duration for option 4 which employs complete shutdown of one tunnel with northbound traffic diverted by local and regional detours is 24 months.

4.4 Construction Schedule

The construction cost and duration are estimated based on continuous working hours of 8 PM on Friday to 6 AM on Sunday, amounting to 34 hours of work time per week. The working hour restriction has been identified in order to avoid peak weekday commuting traffic periods while providing longer uninterrupted work periods in the closed tunnel. In case of two crews working from both ends working three 10-hour shifts, the duration will be 24 months.

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 work periods, which is not possible in this scenario since it requires complete closure of one tunnel. The work restrictions were defined, however, to minimize impacts to traffic.

4.5 Construction Cost

The estimated rehabilitation construction cost for option 4 is $27,000,000.

4.6 Construction Complexity

On a scale of 1 to 10, with 1 representing low construction complexity and 10 very high complexity, the complexity rating for option 4 is 3. The rating is due to adequate space for contractor to execute different stages of the rehabilitation work without risk to the passing cars or multiple mobilization and demobilizations.

4.7 Traffic

Based on discussions with CTDOT, option 4 will require diverting northbound Route 15 traffic at the tunnel along a regional or local detour. The regional detour will divert vehicles destined for I-91 via Route 15 along the Milford Parkway to I-95 northbound and finally I-91 northbound in New Haven. The local detour will divert vehicles destined for local Route 15 Exits 60-67 to Route 69 & 63 (Whalley Avenue) via Exit 59 to Route 10 (Fitch Street, Arch Street, and Dixwell Avenue) and returning to Route 15 at Exit 60. Graphics depicting these routes are included in Appendix B3. In order to minimize impact to travel as much as possible, construction operations for this scenario will be limited to weekend operations only.

Section 6 discusses the traffic impacts associated with the Regional and Local Detours during construction in detail.

4.8 Anticipated Useful Life

For option 4 the useful life of a rehabilitated tunnel depends on thickness and design methodology for final protective lining to be installed over the waterproofing membrane. If the protective final lining is being designed for full load of the tunnel load, then a 100-year useful life is achievable. However, if the final protective liner is designed for fraction of total loads, then the useful life of the rehabilitated tunnel would be in the range of 15 to 20 years. The design of final lining system for both conditions will reduce the tunnel clearance; however, the reduction in tunnel clearance for 100-year useful life is larger compared to a 15- to 20-year useful life condition. The reduction in tunnel clearance for a 100-year useful life could be in the range of 18 to 24 inches by approximately 1.5 to 2.0 feet.

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Section 5

Construction Option 5: Rehabilitation of the Existing Tunnel by Partial Shutdown of One Barrel

5.1 Introduction

In this section we are presenting a summary of an alternative rehabilitation method that involves closing a lane of the tunnel during the construction period (option 5). The work would be performed in one tunnel at a time and therefore three lanes of traffic would remain open during the construction period.

As mentioned in Section 4, the details of the rehabilitation methods were submitted CTDOT in "Heroes (West Rock) Tunnel Inspection and Rehabilitation Recommendations" report dated July 2010.

5.2 Proposed Rehabilitation Method

5.2.1 Recommended Rehabilitation of Civil-Drainage Systems

The rehabilitation of the civil-drainage systems in the two tunnels will be same as for the alternative that involves closing the tunnel that is being rehabilitated (option 4) and discussed in Section 4.

5.2.2 Recommended Rehabilitation of Structural Systems

5.2.2.1 Concrete Surface Repairs

The concrete surface repairs summarized in Section 4 of this report and described in detail in the July 2010 Report will be the same for this alternative.

5.2.2.2 Groundwater Management and Tunnel Waterproofing by Installing Deep Fan Drains, Tunnel Drainage Membrane, and Insulating Liner System

This rehabilitation technique as described in Section 4 and in the July 2010 Report will be used for this alternative.

5.3 Construction Duration

The duration of option 5 is 43 months for one crew or 20 months for two crews, as described in Section 5.4.

5.4 Construction Schedule

This evaluation is based on one crew and night working hours of 7 PM to 5 AM each day Sunday through Thursday. The working hour restriction has been identified in order to minimize impacts to traffic based on an evaluation of hourly traffic volumes along Route 15. During construction, three lanes of traffic will be maintained at all times. Two lanes of traffic will be maintained through the second tunnel while one lane is maintained between Jersey barriers using tow vehicle shields in the tunnel being rehabilitated.

In case of two crews working 10-hour shifts per day and 5 days a week, working from both ends of the tunnel utilizing two vehicle shields, the construction time of option 5 will reduce to 20 months.

5.5 Construction Cost

The construction cost of option 5 is $28,000,000.

5.6 Construction Complexity

On a scale of 1 to 10, with 1 representing low construction complexity and 10 very high complexity, the complexity rating for option 5 is 8 to 9. This is the highest complexity rating of any of the construction options reviewed in this study. The complexity is high due to the partial closure of the tunnel, frequent mobilization and demobilization, and limited working area.

5.7 Traffic

The additional requirement of maintaining three lanes in operation at all times during the rehabilitation work will require special construction sequence and traffic flow arrangement. The proposed constriction sequence will require installation of temporary removable safety barrier walls in the middle of the tunnel to mitigate hazards to the vehicular traffic passing through the tunnel as the rehabilitation work is ongoing. This ongoing work will consist of concrete surface repair and drilling the fan shape drainage holes through the concrete lining. Once these two tasks are complete, a moveable formwork combined with a moveable protective shield will be used to install the waterproofing system and the final lining of the tunnel as shown in **Figures 5.1** and **5.2**.

As shown in these two figures, the available working space becomes more confined for the workers than for the tunnel closure alternative (option 4). Also the ability to move construction equipment becomes more restricted similar to work in a linear fashion as required for tunnel construction. As a result there is less efficiency during the construction and the duration will be extended.

Also there is significantly more equipment required to maintain through traffic. Mobilization, assembly, and demobilization of this equipment will also take up additional storage yard space than the other rehabilitation alternative (option 4).

This option, depending on method and sequence of construction and feasible closure time to be obtained from the results of impact analyses, would require closure of only one lane per barrel during the allocated construction/closure period, which would be at night. One lane will be kept open between Jersey barriers using tow vehicle shields. Two lanes will be open in the adjacent tunnel. As one lane of traffic is completely shut down, this option is anticipated to have quantifiable traffic impacts. Traffic delays for this option are estimated in **Section 6** of this report. The associated delay costs are presented in **Section 7** of this report. This option does not require any roadway work. All detours are analyzed on existing roadway networks.

Figure 5.1: Movable Formwork for Cast-in-Place Concrete (Reference 1)

Figure 5.2: Movable Frame for Installation of Waterproofing Membrane and Sprayed Shotcrete (Reference 2)

5.8 Anticipated Useful Life

Similar to option 4 the useful life of a rehabilitated tunnel depends on thickness and design load for final protective tunnel lining to be installed over the waterproofing membrane. If the protective final lining is being designed for full load of the tunnel load, then a 100 year of useful life is achievable. However, if the final protective liner is designed for fraction of total loads, then the useful life of the rehabilitated tunnel would be in the range of 15 to 20 years. The design of final lining system for both conditions will reduce the tunnel clearance; however, the reduction in tunnel clearance for 100 years of useful life is larger compared to the 15 to 20 years of useful life condition. The reduction in tunnel clearance for 100 years of useful life could be in the range of 1.5 to 2.0 feet.

5.9 References

1) http://www.bfs-co.com/Products/Tunnelformworksystem.aspx

2) http://www.bfs-co.com/Products/Tunnelformworksystem.aspx

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Section 6

Traffic Impacts (Options #4-5)

6.1 Introduction

The purpose of the Traffic Impacts section is to evaluate and document the anticipated traffic impacts associated with the various alternative construction options for the Heroes Tunnel. This section also summarizes the analysis methodology, findings, and corresponding evaluation of each alternative construction option. The topics included in the Traffic Impacts section are summarized as follows:

- Introduction
  - Provides an overview of the study areas associated with the construction options and the methodology followed to evaluate the respective traffic impacts.
- Existing Conditions
  - Discusses the data used to establish existing conditions models and the evaluation of existing conditions relative to each study area.
- Future Conditions Without Construction
  - Describes the development of future conditions models without construction and the evaluation of the forecasted future conditions relative to each study area.
- Regional and Local Detours
  - Describes the Regional and Local Detour routes proposed under construction option 4 and the methodology used to forecast traffic volume networks under detour conditions.
- Future Conditions During Construction
  - Evaluates the forecasted future conditions during construction relative to each construction option.
- Alternative Construction Option Evaluation
  - Compares and ranks each construction option based on forecasted traffic impacts.
- Other Recommendations
  - Discusses means to reduce traffic impacts.

6.1.1 Traffic Impacts of Construction Options

The five construction options to remediate or replace the existing tunnel barrels have the following traffic impacts:

- **Option 1 - New Single Barrel Tunnel for one lane – Permanent:** This option investigates the feasibility of constructing a new permanent one-lane tunnel adjacent to the existing tunnel. Option 1 does not majorly impact traffic flow along Route 15 as all existing lanes of travel would be retained during construction. The intent is to shift the right lane of northbound traffic to the new tunnel and new alignment, while maintaining southbound traffic through the existing southbound tunnel. The contractor will rehabilitate the existing northbound tunnel with one lane of traffic maintained. During construction, the one lane tunnel is designed to accommodate two lanes of traffic, if necessary, during emergencies or to accommodate unique construction needs. A detailed description of traffic management during construction is included in Section 2.

- **Option 2 - New Single Barrel Tunnel for two lanes – Permanent:** This option investigates the feasibility of constructing a new permanent two-lane tunnel adjacent to the existing tunnel. Option 2 does not majorly impact traffic flow along Route 15 as all existing lanes of travel would be retained during construction. A detailed description of traffic management during construction is included in Section 2.

- **Option 3 - Enlargement of Existing Tunnel:** This option investigates the feasibility of enlarging the existing tunnel for installation of a new tunnel lining and drainage system while the traffic is passing through the tunnel under protective shield. This option also presents the state-of-the-art methods for enlarging transportation tunnels while maintaining current traffic capacity during construction. It should be noted that the drill and blast widening method has been recommended under this option. Traffic will have to be held during blasts for approximately 5 minutes, using "rolling lane closure method." These blasts should be scheduled for off-peak times to minimize traffic impacts. A detailed description of traffic management during construction is included in Section 3.

- **Option 4 - Proposed Rehabilitation Method – Complete shutdown of one barrel:** This option investigates the feasibility of rehabilitating one barrel at a time, completely closing the barrel to traffic. Traffic detours will be necessary. A detailed description of traffic management during construction is included in this section.

- **Option 5 - Proposed Rehabilitation Method – Partial shutdown of one barrel:** This option, depending on method and sequence of construction and feasible closure time to be obtained from the results of impact analyses, would require closure of only one lane per barrel during the allocated construction/closure period. The construction activities during the allocated closure period will be developed in a manner to minimize both the impacts associated with construction activities and construction duration by an effective coordination between various construction disciplines.

As indicated above, options 1 and 2 do not majorly impact traffic flow along Route 15 as all existing lanes of travel will be retained during construction. Therefore, traffic impacts of options 1 and 2 are not analyzed. Similarly, option 3 does not consistently impact traffic flow along Route 15, as all existing lanes of travel will be retained during construction. The intermittent stoppages during blasting sequences will be very short in duration; therefore, traffic impacts of option 3 were not analyzed. Options 4 and 5 represent the construction options with the greatest impact to traffic and are detailed in the following narrative. Traffic impact associated with staging is assumed to be the same for all options and is not estimated.

6.1.2 Study Area

Heroes Tunnel is located along Route 15 between Exit 59 and Exit 60 on the Hamden/New Haven Town Lines. The study areas analyzed under the critical Construction Options are as follows:

- **Option 4 - Proposed Rehabilitation Method – Complete shutdown of one barrel:** Based on discussions with CTDOT, Option 4 will require diverting northbound Route 15 traffic at the tunnel along a regional or local detour. The regional detour will divert vehicles destined for I-91 via Route 15 along the Milford Parkway to I-95 northbound and finally I-91 northbound in New

Haven. The local detour will divert vehicles destined for local Route 15 Exits 60-67 to Route 69 and 63 (Whalley Avenue) via Exit 59 to Route 10 (Fitch Street, Arch Street, and Dixwell Avenue) and returning to Route 15 at Exit 60. Graphics depicting these routes are included in Appendix B3. In order to minimize impact to travel as much as possible, construction operations for this scenario will be limited to weekend operations only. The specific study areas for each detour, as agreed upon with CTDOT, are detailed below and depicted graphically on **Figures 1 and 2**:

- Regional Detour – Expressways and Interchanges
  - Route 15 – Exits 54-59
  - Route 15/Milford Parkway/I-95 Interchanges

- Local Detour – Local Intersections
  - Route 69 at Pond Lily Avenue
  - Route 63 at Route 69
  - Route 15 northbound off-ramp at Route 69
  - Route 69 at Pond Lily Avenue Route 10 (Dixwell Avenue) at Arch Street
  - Route 10 (Dixwell Avenue) at Putnam Avenue/Circular Avenue
  - Route 10 at Route 63 (Whalley Avenue)
  - Route 15 northbound ramps at Route 10 (Dixwell Avenue)

Initially, the study area included the interchanges of I-95 at I-91 in New Haven and I-91 at Route 15 in Meriden. CTDOT agreed, however, to exclude the I-95/I-91 and I-91/Route 15 interchanges. CTDOT reasoned that the current construction planned at the I-95/I-91 interchange will increase interchange capacity to accommodate some construction traffic. No additional improvements would be made, however, to fully accommodate construction traffic. Relative to the I-91/Route 15 interchange, the Regional detour reduces Route 15 traffic merging onto I-91, thereby reducing merging conflicts and congestion.

In addition, CDM Smith drafted conceptual designs of a new interchange at Route 40 along Route 15. The purpose was to utilize a Route 40 interchange as part of a regional detour during tunnel closures to the southbound Route 15 traffic. However, based on discussions with CTDOT, as traffic volumes along Route 15 are slightly higher overall in the southbound direction, construction option 4 will not close the tunnel to southbound Route 15 traffic. The conceptual Route 40 interchange includes a proposed on ramp to Route 15 northbound from Route 40 northbound. As this connection does not allow vehicles travelling northbound along Route 15 to bypass the closed tunnel, it does not facilitate the regional detour and is not evaluated.

- **Option 5 - Proposed Rehabilitation Method – Partial shutdown of one barrel:** For this option, the study area consists of the Exit 59 and 60 interchanges and the stretch of Route 15 between them.

6.1.3 Evaluation Methodology

The traffic impact evaluation of the alternative construction options required performing the following tasks:

- Obtained existing traffic volume data including CTDOT 24-hour expressway traffic counts at available locations and Saturday Midday Peak Period Turning Movement Counts at local intersections.
- Developed Existing Conditions traffic volume networks for each construction option study period.
- Developed traffic analysis networks for the option 4 and option 5 expressway study areas with Vissim 5.40.09 software. Developed traffic analysis network for option 4 local intersection study area with Synchro 8 software.
- Developed Future Conditions traffic volumes for each construction option based on a 0.5 percent annual growth rate (construction anticipated in 2019) and existing traffic volumes.
- Redistributed Future Conditions traffic volumes for the Saturday Midday peak hour period based on the routes specified under the Regional and Local Detours.
- Developed Future Construction Conditions traffic volumes for option 4 based on the Future Conditions traffic volumes and the redistribution of traffic volumes anticipated under the Regional and Local detours.
- Developed Future Conditions traffic analysis networks with and without construction for the option 4 and option 5 expressway study areas with Vissim 5.40.09 software. Developed traffic analysis network for option 4 local intersection study area with Synchro 8 software.
- Conducted capacity and measures of effectiveness (MOEs) analyses for the Existing and Future Conditions with and without construction.
- Evaluated each alternative construction option based on the completed analysis.
- Provided additional recommendations for CTDOT consideration.

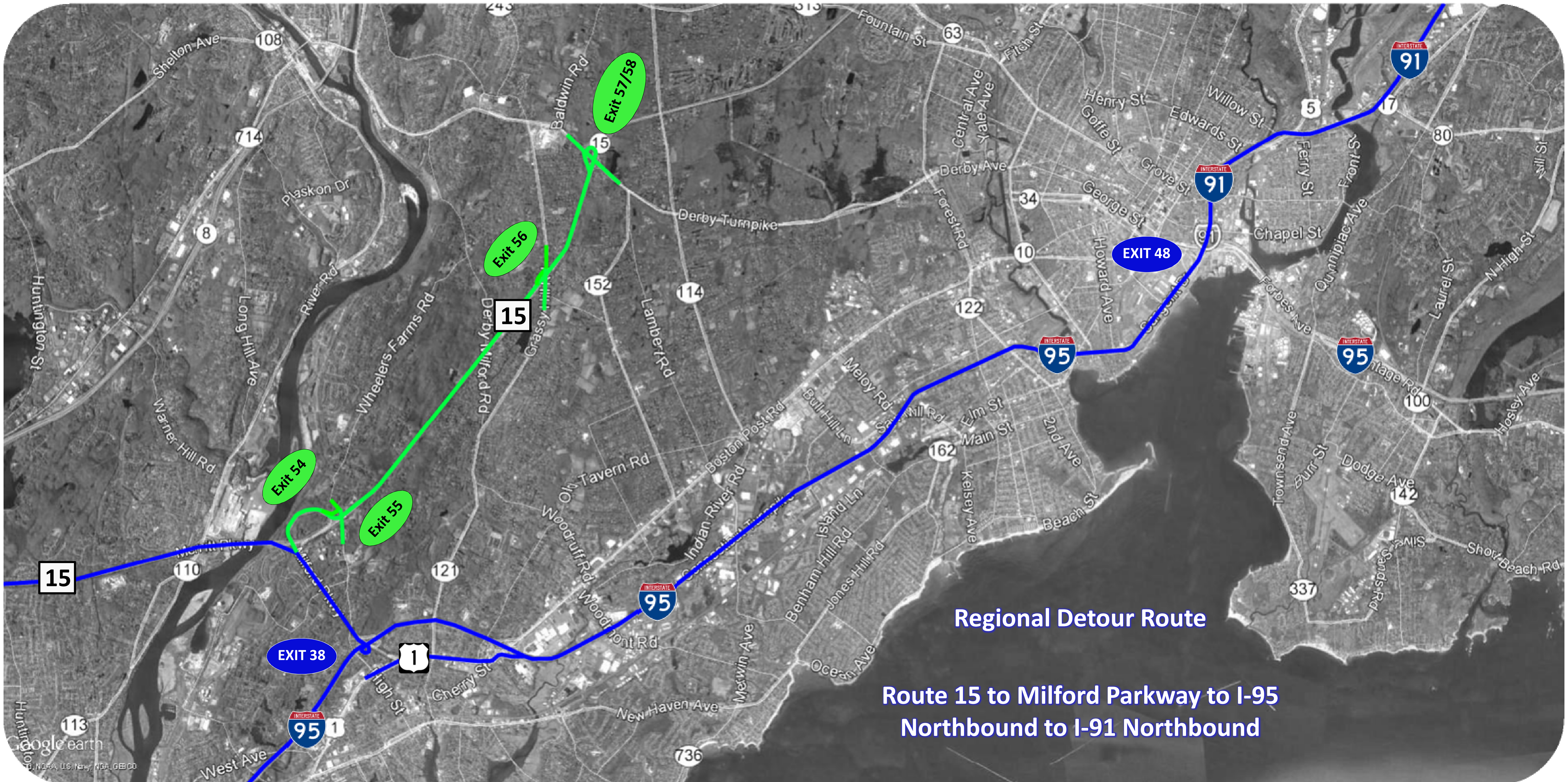
6.2 Existing Conditions

The traffic data collection program was developed based on discussions with the CTDOT Division of Traffic Engineering staff considering the type and extent of traffic analysis required for the project effort.

6.2.1 Construction Option Data Requirements

In general, CDM Smith received the following information from CTDOT:

- Bi-directional Automated Traffic Recorder (ATR) traffic volume data from the Permanent Count Station located on Route 15 north of Heroes Tunnel.
- CTDOT Planning Department weekday 24-hour ATR traffic volume counts
  - Route 15 Exit 54-67 on- and off-ramps
  - Milford Parkway on- and off-ramps



REGIONAL DETOUR ROUTES

N

Not to Scale

XX ROUTE 15 SOUTHBOUND

XX REGIONAL NORTHBOUND

FIGURE 6.1
OPTION 4 STUDY AREA
REGIONAL CONSTRUCTION DETOUR

FIGURE 6.2
OPTION 4 STUDY AREA
LOCAL CONSTRUCTION DETOUR

CDM Smith

CDM Smith also acquired the CTDOT approved traffic volume network produced for State Project #63-676 (I-95 Value Pricing Study). Data utilized included weekday traffic volume and speed data for Route 15 Interchanges 54-59 and I-95 Interchanges 37 and 38.

Based on a review of the Permanent Count Station data as well as the traffic volume network for State Project #63-676, CDM Smith determined that, under option 4, the weekend time period with the heaviest vehicle demand along critical roadways is the Saturday midday period from 11 AM to 3 PM; therefore, CDM Smith acquired Turning Movement Count (TMC) traffic volume data for the Saturday midday peak period between 11 AM and 3 PM at the following local intersections:

- Route 69 at Pond Lily Avenue
- Route 63 at Route 69
- Route 15 northbound off-ramp at Route 69
- Route 69 at Pond Lily Avenue Route 10 (Dixwell Avenue) at Arch Street
- Route 10 (Dixwell Avenue) at Putnam Avenue/Circular Avenue
- Route 10 at Route 63 (Whalley Avenue)
- Route 15 northbound ramps at Route 10 (Dixwell Avenue)

After discussion with CTDOT regarding the need for Saturday expressway and ramp traffic volume data, CTDOT directed CDM Smith to develop Saturday traffic volume estimates based on a comparison of Route 15 Permanent Count Station data for Weekdays and Saturdays. Therefore, CDM Smith did not acquire new Saturday traffic volume data for Route 15, Milford Parkway, or I-95 mainline or ramp locations.

6.2.2 Traffic Volume Network Development

Due to the schedules and anticipated impacts of the construction operations for each construction alternative, the data required to develop a traffic volume network for each option differs substantially. The methodology used to develop each traffic network is discussed here separately.

6.2.2.1 Alternative Construction Option 4

Relative to option 4, as mentioned previously, CTDOT directed CDM Smith to develop Saturday traffic volume estimates based on a comparison of Route 15 Permanent Count Station data for weekdays and Saturdays.

In general, the Saturday Midday Peak Traffic Volume Networks were developed in four stages:

- CDM Smith compared existing weekday traffic volume data along Route 15 at Heroes Tunnel versus Saturday traffic volume data in order to generate an approximate conversion factor for weekday traffic volumes to Saturday traffic volumes for the study corridor.

- CDM Smith then created a base 2014 Balanced Weekday Midday Off-Peak Profiles for Route 15 from Exit 54 to Exit 67 (northbound Route 15 only between Exits 61 and 67), the Milford Parkway from Route 15 to Route 1, and the I-95 interchange at the Milford Parkway based on traffic volumes taken from the following sources:

  - CTDOT Planning Department weekday 24-hour ATR traffic volume counts

  - The CTDOT approved traffic volume network produced for State Project #63-676 (I-95 Value Pricing Study).

- The weekday to Saturday conversion factor established under the first task was applied to each 2014 Balanced Weekday Midday Off-Peak Profile to develop a 2014 Balanced Saturday Midday Peak Profile.

Development of Weekday to Saturday Conversion Factor

Based on seasonal adjustment factors calculated by CTDOT for Route 15, a typical average weekday traffic condition occurs in March and a typical Saturday traffic condition occurs in May. CDM Smith reviewed the CTDOT continuous count data at Heroes Tunnel along the Route 15 mainline for typical weekdays in March to obtain data sets similar in vehicle count and directionality to that of the CTDOT approved traffic profile developed for State Project #63-676 (I-95 Value Pricing Study). CDM Smith determined that Thursday, March 15, 2012 exhibited very similar vehicle counts and directionality to the I-95 Value Pricing Study Network. This exercise verified the applicability of the I-95 Value Pricing Study data set as representative of average weekday traffic conditions along Route 15. CDM Smith then examined Saturdays in May to obtain data sets similar in vehicle count and overall cumulative directionality to that of the I-95 Value Pricing Study Network and the March 15 data. Saturday, May 12, 2012, exhibited very similar counts and cumulative directionality and was chosen to represent a typical Saturday condition along Route 15.

In order to develop a weekday to Saturday traffic volume conversion factor, CDM Smith first determined the peak Saturday time period. Based on the typical Saturday data, the time period between 11:00 AM and 3:00 PM represents peak Saturday volume conditions. We then reviewed the traffic volume characteristics of the I-95 Value Pricing Study Network weekday traffic data to determine the most similar period to the Saturday midday peak period. The following characteristics were found:

- The weekday morning and afternoon peaks exhibited high directionality bias not exhibited in the Saturday midday peak period.
- The weekday evening off-peak period exhibited a rapid decline in traffic counts dissimilar to the more steady volume found during the Saturday midday peak period.
- The weekday midday off-peak (specifically 11:00 AM to 3:00 PM) period exhibited the least fluctuation in vehicle count as well as a similar directionality to that of the Saturday midday peak period count.

Therefore, CDM Smith determined that the most appropriate comparative data would be between the weekday midday off-peak (11:00 AM to 3:00 PM) and the Saturday midday peak (11:00 AM to 3:00 PM) periods. Based on the reviewed data, and as shown in **Table 6.1** below, the average conversion rate from weekday to Saturday traffic volumes for northbound and southbound vehicles along Route 15 is 1.33 and 1.40, respectively. CDM Smith utilized these rates for directional conversions at all study locations.

Table 6.1: Route 15 Conversion Rates by Direction

Time Period	Southbound	Northbound	Total
11 AM	1.48	1.42	1.45
12 PM	1.44	1.43	1.44
1 PM	1.40	1.31	1.36
2 PM	1.26	1.17	1.21
Average	1.40	1.33	1.36

Development of 2014 Balanced Weekday Midday Off-Peak Profiles

CDM Smith developed a base model network for the study area based on existing conditions data for weekday midday off-peak from 11:00 AM to 3:00 PM from the following sources (respective data used as shown):

- CTDOT approved Balanced Network Profile from State Project #63-676 (I-95 Value Pricing Study)
  - Route 15 mainline and ramps for Exits 54-59
  - I-95 mainline and ramps
- Raw 24-hour traffic counts taken by CTDOT Bureau of Policy and Planning
  - Route 15 ramps for Exits 60-67
  - Route 1 ramps at Milford Parkway
  - Milford Parkway on- and off-ramps from Wellington Road

The study area includes the following locations:

- Route 15 from Exit 54 to Exit 67 (northbound Route 15 only between Exits 61 and 67)
- Milford Parkway from Route 15 to Route 1
- I-95 at Exits 37 and 38 (Milford Parkway)

The Milford Parkway lies between Route 15 and Route 1. The only entrances and exits along the Milford Parkway are those to Route 15, Wellington Road, I-95, and Route 1. Therefore, the vehicles entering and exiting the Milford Parkway at Route 15 and Wellington Road must balance with those vehicles entering and exiting at I-95 and Route 1. As the Network Profile from the I-95 Value Pricing Study has been fully balanced and previously approved by CTDOT, CDM Smith utilized the data in this network as the base off of which the data at other locations would be balanced.

CDM Smith began by determining the mainline volumes along Milford Parkway by summing the vehicles entering and exiting the Milford Parkway onto Route 15 or Wellington Road at the Route 15/Milford Parkway interchange. CDM Smith supplemented the Route 15 at Milford Parkway interchange data included in the I-95 Value Pricing Study with the Milford Parkway on- and off-ramp from Wellington Road data recorded by CTDOT Bureau of Policy and Planning.

Based on the established mainline Milford Parkway traffic volumes, the I-95 and Route 1 on- and off-ramp traffic volumes were adjusted proportionately to balance with the mainline traffic volumes.

I-95 mainline traffic volumes from the I-95 Value Pricing Study were adjusted based on the adjusted on- and off-ramp traffic volumes.

The resulting balanced traffic volumes represent the 2014 Balanced Weekday Midday Off-Peak Profiles for each study corridor/interchange during the hours of 11:00 AM to 3:00 PM.

Development of 2014 Balanced Saturday Midday Peak Profiles

CDM Smith applied the directional weekday to Saturday conversion rate at all locations of the base model network. All locations were again balanced for completeness. The resulting balanced traffic volumes represent the 2014 Balanced Saturday Midday Peak Profiles for each study corridor/ interchange during the hours of 11:00 AM to 3:00 PM. These profiles are included in the Appendix.

6.2.2.2 Alternative Construction Option 5

CDM Smith developed the 2014 Existing Conditions Traffic Volume Network for alternative construction option 5 considered the following weekday overnight data.

Table 6.2: Route 15 Hourly Traffic Data

Data Location	Source
Northbound and Southbound Mainline – South of Exit 59	Balanced corridor profile data approved under State Project #63-676 – I-95 Value Pricing Study
Exit 59 On- and Off-Ramps	Balanced corridor profile data approved under State Project #63-676 – I-95 Value Pricing Study
Exit 60 On- and Off-Ramps	Raw count data sent by CTDOT Bureau of Policy and Planning

For the purpose of model evaluation, the 4-hour period between 7 PM and 11 PM represented the most conservative 4-hour overnight period coinciding with the intended overnight construction operations.

It should be noted that the data acquired for Exits 59 and 60 have different sources. The mainline and Exit 59 traffic volumes were extracted from the CTDOT approved balanced profile developed for the I-95 Value Pricing Study (State Project #63-676). CDM Smith used the raw traffic count data provided by CTDOT for the Exit 60 on- and off-ramps. These ramp counts were conducted by CTDOT in September 2012. Despite being conducted in 2012, CDM Smith did not apply a seasonal factor or growth rate factor to the Exit 60 traffic counts. Upon reviewing data developed for the I-95 Value Pricing Study, CTDOT raw traffic counts were typically higher than the final balanced profile traffic volumes. Therefore, we considered the Exit 60 raw traffic counts taken in 2012 to be conservative with respect to the other network traffic volumes.

The Route 15 northbound and southbound mainline traffic volumes depicted between the Exit 59 on- and off-ramps and all points north of Exit 59 were derived by balancing the mainline traffic volumes south of Exit 59 with the on- and off-ramp traffic volumes at Exits 59 and 60. CDM Smith compared the balanced mainline traffic volumes at Heroes Tunnel with the daily data provided by the CTDOT continuous count station at Heroes Tunnel. The balanced traffic volumes depicted in the 2014 Weekday Off-Peak Traffic Volume Network appear indicative of average to above average vehicle counts at the tunnel. Therefore, it is our opinion that the balanced 2014 Existing Conditions Weekday Off-Peak Traffic Volume Network figure accurately depicts the current travel flow characteristics along Route 15 at Exits 59 and 60. This profile is included in the Appendix.

6.2.3 Traffic Network Model Development

Three existing conditions traffic network models were developed for evaluation. Under option 4, separate expressway and local intersection models were created based on project scope. Under option 5, one expressway model was developed. The methodology used to develop each traffic network model is discussed here separately.

6.2.3.1 Alternative Construction Option 4

Relative to option 4, as mentioned previously, this option will require diverting northbound Route 15 traffic at the tunnel along either a regional or a local detour under future conditions during construction.

Vissim Model Development

A Vissim model was developed for the approximate 9-mile corridor along Route 15 encompassing Exits 54-59 as well as the Milford Parkway and I-95 Exit 37-38 Interchanges with the mainline and ramp locations. Aerial mapping was used as a base for developing the model network. The mainline and ramp segments were coded as "freeway" links. Existing traffic volumes were entered based on the developed Traffic Volume Network.

<u>Model Calibration</u>

Model calibration is important to match the model conditions with actual field conditions. This process involves adjusting driver behavior and traffic flow in the model with the local field conditions. It is an iterative process in which the model is run several times unless a reasonable level of acceptance (typically within 10 percent of values). In this case, the calibration was based on traffic volumes and travel speed.

<u>Volume Calibration</u>

The volume calibration process involves checking segment volumes along the corridors in the VISSIM model compared to the field counts. The calibration output data is included in the Appendix. The traffic volumes are within the acceptable 10 percent range of values.

In addition, the output data was evaluated for empirical validity via GEH Statistic compliance. The GEH Statistic reduces the effect the magnitude of the value has on the range of acceptable value. In effect, the GEH Statistic accounts for inherent lower accuracy simulated in lower traffic volumes due to the random generation of the model data. Again, the traffic volumes are within the acceptable 5 GEH tolerance. Therefore, the volume calibration meets target values.

<u>Travel Speed Calibration</u>

The travel speed calibration process involves checking segment travel speeds in the VISSIM model compared to the speeds measured in the field by INRIX under State Project #63-676. In general, the average travel speeds in the VISSIM model were within 10 percent of values of the field data. Therefore, the travel speed calibration meets target values.

Synchro Model Development

A Synchro model was developed for the seven major local intersections identified along the Local Detour Route. Existing traffic volumes were entered based on the developed Traffic Volume Network. Lane configurations were verified by field assessment and aerial imagery. Traffic control signal operations were input based on the most recent traffic control signal plans provided by CTDOT, the City of New Haven, and the Town of Hamden.

6.2.3.2 Alternative Construction Option 5

Relative to option 5, this option would require closure of only one-lane per barrel during the allocated construction/closure period. For this option, the study area consists of the Exit 59 and 60 interchanges and the stretch of Route 15 between them.

Vissim Model Development

A Vissim model was developed for the Route 15 segment including Exits 59 and 60 ramps. Aerial mapping was used as a base for developing the model network. The mainline and ramp segments were coded as "freeway" links. Existing traffic volumes were entered based on the developed Traffic Volume Network.

<u>Model Calibration</u>

As with the option 4 model, the model calibration was again based on traffic volumes and travel speed.

<u>Volume Calibration</u>

The segment and ramp volumes along the corridors in the VISSIM model were compared to the field counts. The traffic volumes are within the acceptable 10 percent range of values and 5 GEH Statistic tolerance. Therefore, the volume calibration meets target values. The calibration output data is included in the Appendix.

<u>Travel Speed Calibration</u>

The VISSIM model speeds were again compared to the speeds measured in the field under State Project #63-676. In general, the average travel speeds in the VISSIM model were within 10 percent of values of the field data. Therefore, the travel speed calibration meets target values.

6.2.4 Existing Conditions Evaluation

The three Existing Conditions traffic network models were utilized to perform traffic operational analysis of the Existing Conditions along the study roadway networks. This section summarizes the metrics of evaluation as well as the evaluation findings.

6.2.4.1 Analysis Parameters

Traffic performance measures are metrics that are used to determine the effectiveness of the infrastructure to process the vehicle demand. Vissim and Synchro were utilized to evaluate different performance measures and are discussed separately below.

Vissim Performance Measures

Critical performance measures evaluated for study area expressways using Vissim include:

- Throughput Volume (in vehicles) – The number of vehicles processed by the model. A higher value correlates with a more efficient infrastructure with fewer speed reductions.
- Average Delay Time per Vehicle (in seconds) – The delay time is the additional time incurred by a vehicle when the travel speed drops below the free-flow speed of the facility. When the delay time is averaged over the number of vehicles in the roadway system, the average delay time is computed. A lower average delay time is considered as good, as it means the vehicles are not experiencing frequent speed reductions.

- Average Speed (in miles per hour) – Travel speed averaged over all vehicles that completed their trips in the designated time period. This is measured for the entire network (and includes when drivers are stopped at signals and stop signs). A higher speed is considered good, as it means vehicles are moving efficiently through the intersections and along the corridor. In the model, the maximum speed a vehicle can achieve on any portion of the corridor is the desired speed. The desired speed is a function of the posted speed limit and varies for each vehicle based on driver comfort and travel conditions.
- Total Distance Traveled (in miles) – The total distance traveled by all vehicles that completed their trips in the designated time period. This is measured for the entire network. A higher value is considered good, as it means that drivers are able to travel further within a given period of time.
- Number of Stops – The total number of stops experienced by vehicles traveling on a facility. Fewer stops are good as vehicles travel unimpeded.
- Total Stopped Delay (in hours) – Total stopped time of all active and arrived vehicles. Stopped delay is the time vehicles spend standing (speed is zero).
- Total Travel Time (in hours) – The total travel time experienced by all vehicles that completed their trips in the designated time period. This is measured for the entire network. A lower VHT is considered good, as it means drivers are spending less time waiting at signals/stop signs and there is less stop-and-go driving.
- Average Hourly Delay (in hours) – The average amount of cumulative hours of delay experienced by all vehicles simulated by the network model for one hour.
- Total Annual Delay (in hours) – The forecasted average amount of cumulative hours of delay experienced by all vehicles simulated by the network model over the course of one year of assumed work periods.

Synchro Performance Measures

Critical performance measures evaluated for study area intersections using Synchro include:

- Level of Service (Definition Below)
- Volume to Capacity Ratio (v/c)
- Delay (in seconds)
- 50th Percentile Queue Length (in feet)
- 95th Percentile Queue Length (in feet)

Level of Service (LOS) analysis provides a measurement of the delay experienced at an intersection as a result of traffic operations at that intersection. In general, there are six levels of service; Level of Service A to Level of Service F.

- Level of Service A describes a condition of free flow, with low volumes and high speeds.
- Level of Service B represents a stable traffic flow with operating speeds beginning to be restricted somewhat by traffic conditions.

- Level of Service C, which is normally utilized for design purposes, describes a stable condition of traffic operation. It entails moderately restricted movements due to higher traffic volumes, but traffic conditions are not objectionable to motorists.
- Level of Service D reflects a condition of more restrictive movements for motorists and influence of congestion becomes more noticeable.
- Level of Service E is representative of the actual capacity of the roadway or intersection and involves delay to all motorists due to congestion.
- Level of Service F, is described as force flow and is characterized by volumes greater than the theoretical roadway capacity. Complete congestion occurs, and in extreme cases, the volume passing a given point drops to zero. This is considered as an unacceptable traffic operating condition.

6.2.4.2 Alternative Construction Option 4

Relative to option 4, as mentioned previously, this option will require diverting northbound Route 15 traffic at the tunnel along either a regional or a local detour under Future Conditions during weekend only construction operations. As such, analysis evaluates peak weekend travel conditions along study roadways.

Expressway Analysis

Under Existing Conditions, the Route 15/Milford Parkway/I-95 study area experiences moderate delays per vehicle. **Table 6.3** indicates that, on average, vehicles experience approximately 44 seconds of delay traveling through the network. While typical speeds along Route 15 and I-95 are in the 60-65 miles per hour (mph) range, the I-95 northbound weave at Interchange 38 (Milford Parkway) creates the majority of network delays and reduces the overall network average speed to 55 mph. Over the course of a year, cumulative weekend delay in the study area is approximately 354,000 hours. Total Annual Delay is an important measure of the overall impact of construction as the construction duration of each respective Alternative Construction Option varies from approximately one year up to several years.

Table 6.3: Option 4 Existing Conditions Expressway Performance Measures

Performance Measure	Unit	Value
Throughput Volume	ea	80,619
Average Delay Time Per Vehicle	sec	44.1
Average Speed	mph	55.4
Total Distance Traveled	mi	335,332
Number of Stops	ea	109,123
Total Stopped Delay	h	125.8
Total Travel Time	h	6,048.40
Average Hourly Delay	h	141.9
Total Annual Delay	h	354,167.6

Local Intersection Analysis

Table 6.4 displays the Existing Conditions performance measures for the local intersections along the proposed Local Detour. As shown on Table 6.4, there are several intersections currently operating at near or above capacity. The signalized intersection of Whalley Avenue at Fitch Street operates at LOS E under Existing Conditions. The signalized intersection of Dixwell Avenue at Putnam Avenue operates at LOS F under Existing Conditions. The unsignalized intersection of Whalley Avenue at the Route 15 northbound off-ramp allows free flow movement along Whalley Avenue and stop control for the off-ramp approach. As shown in the table, off-ramp vehicles experience long delays and excessive queue lengths waiting for an acceptable gap along Whalley Avenue to enter the traffic stream.

Table 6.4: Option 4 Existing Conditions Local Intersection Performance Measures

Intersection	Lane Group		2013 Existing Conditions						
			V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.
Dixwell Ave.@ Rte.15 NB On-/Off-Ramps	EB	L	0.66	36.4	D	C	B	105	140
		R	0.55	23.6	C			103	148
	NB	T	0.71	16.4	B	B		275	382
		R	0.36	2.3	A			0	41
	SB	L	0.56	46.0	D	B		60	117
		T	0.70	16.4	B			218	415
Dixwell Ave. @ Putnam Ave./Circular Ave./Helen St.	SEB	LTR	0.50	32.2	C	C	F	75	92
	NW	L	0.42	35.8	D	D		80	117
		T	0.90	65.0	E			189	356
		R	0.44	7.8	A			0	58
	NB	L	1.76	402.8	F	F		165	293
		T	0.89	45.6	D			227	339
		R	0.17	2.4	A			0	8
	SB	L	1.57	314.5	F	F		205	350
		TR	0.84	39.6	D			227	332
Dixwell Ave. @ Arch St./Morse St.	EB	L	0.73	33.7	C	C	B	122	155
		LTR	0.67	29.0	C			114	201
	WB	T	0.08	31.4	C	C		4	13
		R	0.13	20.2	C			1	17
	NB	L	0.22	9.8	A	B		12	29
		TR	0.44	17.2	B			69	135
	SB	L	0.33	10.9	B	B		20	57
		T	0.63	22.6	C			109	240
		R	0.29	1.1	A			0	7
Whalley Ave. @ Fitch St./Edgewood Park Dr.	SEB	L	1.25	145.7	F	F	E	595	81
		TR	0.33	5.3	A			63	121
	NWB	LTR	1.08	86.3	F	F		268	374
	NEB	LTR	0.04	18.8	B	B		4	3
	SWB	LTR	0.76	35.8	D	D		117	14

Table 6.4: Option 4 Existing Conditions Local Intersection Performance Measures

Intersection	Lane Group		2013 Existing Conditions						
			V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.
(Rte. 69) Whalley Ave.@Amity Rd. (Rte.63)/Wright Ave./Whalley Commons	SEB	L	0.44	46.4	D	C	C	31	59
		TR	0.67	20.7	C			183	271
	WB	L	0.64	57.6	E	D		42	80
		TR	0.75	50.9	D			46	53
	NWB	LT	0.32	37.1	D	C		197	308
		TR	0.60	9.9	D			108	165
	SB	L	0.45	39.5	D	D		34	64
		TR	0.91	41.2	D			172	314
Rte. 69 @ Rte.15 Off-Ramp	WB	L	2.25	593.9	F	F	N/A	N/A	1606
		R	2.25	593.9	F			N/A	1606
	NB	T	0.36	0.0	A	A		N/A	0
	SB	T	0.41	0.0	A	A		N/A	0
Rte. 69 @ Pond Lily Ave.	WB	LR	0.56	16.1	B	B	B	22	43
	NB	TR	0.83	20.7	C	C		129	250
	SB	L	0.65	16.7	B	A		41	117
		T	0.52	6.5	A			79	174

6.2.4.3 Alternative Construction Option 5

For the option 5 study area (Exit 59, Exit 60, and the Route 15 mainline), drivers experience relatively free flow during the weekday off-peak period. **Table 6.5** indicates that delay time per vehicle is very low during the study period, resulting in an annual total delay of approximately 20,934 cumulative hours for all vehicles traveling through the network.

Table 6.5: Option 5 Existing Conditions Expressway Performance Measures

Performance Measure	Unit	Value
Throughput Volume	ea	*12,077*
Average Delay Time Per Vehicle	sec	*9.6*
Average Speed	mph	*64.5*
Total Distance Traveled	mi	*64,767*
Number of Stops	ea	*1,391*
Total Stopped Delay	h	*1.4*
Total Travel Time	h	*1,004.50*
Average Hourly Delay	h	8.1
Total Annual Delay	h	20933.5

6.3 Future Conditions without Construction

The commencement of construction activities for Heroes Tunnel is preliminary anticipated for the year 2019. The forecasted traffic operations along study roadways during the 2019 Future Conditions without Construction provide a baseline comparison for the forecasted traffic operations during construction. This section discusses the traffic volume network development and network model development methodology and findings for the 2019 Future Conditions without Construction.

6.3.1 Traffic Volume Network Development

As mentioned, CDM Smith assumed a 5-year project planning horizon to the year 2019. In addition, CTDOT recommended a 0.5 percent per year annual growth rate. CDM Smith applied the 0.5 percent annual growth rate per year to each 2014 Balanced Traffic Volume Profile for options 4 and 5. All locations were again balanced for completeness. The resulting balanced traffic volumes represent the 2019 Balanced Traffic Volume Profiles for each study corridor/interchange. These profiles are included in the Appendix.

6.3.2 Traffic Network Model Development

The Future Conditions without Construction analysis models were developed by updating the calibrated Existing Conditions models with the 2019 Traffic Volume Profiles. No other calibrations or adjustments were made in order to provide a direct comparison.

6.3.3 Future Conditions Evaluation

6.3.3.1 Alternative Construction Option 4

Relative to option 4, as mentioned previously, this option will require diverting northbound Route 15 traffic at the tunnel along either a regional or a local detour under Future Conditions during construction. Expressways and Local intersections were modeled separately.

Expressway Analysis

Under 2019 Future Conditions without Construction, regional traffic volume increases along the study corridors result in slightly increased delays and reduced speeds. In general, as shown in **Table 6.6**, vehicles within the study area are anticipated to experience an average increase in delay of approximately 5 seconds per vehicle. This increase in delay is minimal and would most likely be unnoticeable. Over the course of a year, cumulative weekend delay would increase by approximately 50,192 hours.

Table 6.6: Option 4 Expressway Performance Measures

Performance Measure	Existing Conditions		2019 Future Conditions Without Construction	
	Unit	Value	Unit	Value
Throughput Volume	ea	80,619	ea	82,169
Average Delay Time Per Vehicle	sec	44.1	sec	49.4
Average Speed	mph	55.4	mph	54.3
Total Distance Traveled	mi	335,332	mi	341,526
Number of Stops	ea	109,123	ea	126,357
Total Stopped Delay	h	125.8	h	155.9
Total Travel Time	h	6,048.40	h	6,286.10
Average Hourly Delay	h	141.9	h	162.0
Total Annual Delay	h	354,167.6		404,359.6

Local Intersection Analysis

Under 2019 Future Conditions without Construction, regional traffic volume increases along the local study roadways result in slightly increased delays and queue lengths at local intersections. As shown in **Table 6.8** on the following page, the intersection of Whalley Avenue at Fitch Street degrades from LOS E under Existing Conditions to LOS F under Future Conditions. However, it should be noted that the actual delay increase is less than 13 percent and increases in queue length are typically less than one vehicle length. All other intersections are anticipated to maintain the same LOS during Existing and Future Conditions without Construction.

6.3.3.2 Alternative Construction Option 5

Under 2019 Future Conditions without Construction, the study area is anticipated to show nearly negligible increases in delay and speed reduction. **Table 6.7**shows the minimal change anticipated along Route 15 in the vicinity of Heroes Tunnel between today and 2019.

Table 6.7: Option 5 Expressway Performance Measures

Performance Measure	Existing Conditions		2019 Future Conditions Without Construction	
	Unit	Value	Unit	Value
Throughput Volume	ea	12,077	ea	12,334
Average Delay Time Per Vehicle	sec	9.6	sec	9.8
Average Speed	mph	64.5	mph	64.4
Total Distance Traveled	mi	64,767	mi	65,908
Number of Stops	ea	1,391	ea	1,461
Total Stopped Delay	h	1.4	h	1.4
Total Travel Time	h	1,004.50	h	1,023.00
Total Annual Hours	h	2600	h	2600
Total Hourly Delay	h	8.1	h	8.4
Total Annual Delay	h	20933.5	h	21824.3

6.4 Regional and Local Detours

Based on discussions with CTDOT, alternative construction option 4 will require diverting northbound Route 15 traffic at the tunnel along a regional or local detour once the northbound tunnel is closed. This section clarifies the proposed detour routes and describes the methodology utilized to develop a redistributed traffic volume network based on the directional diversions of each detour.

Alternative construction option 5 will not require a traffic detour; however, an alternate travel route has been developed. The alternate route follows the same path as the detour route. Proposed signage to implement the alternate route is included in Appendix B3.

Table 6.8: Option 4 Local Intersection Performance Measures

Intersection	Lane Group		2013 Existing Conditions							2019 Future Conditions Without Construction						
			V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.	V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.
Dixwell Ave.@ Rte.15 NB On-/Off-Ramps	EB	L	0.66	36.4	D	C	B	105	140	0.67	36.8	D	C	B	109	143
		R	0.55	23.6	C			103	148	0.56	24.2	C			108	152
	NB	T	0.71	16.4	B	B		275	382	0.73	17.0	B	B		292	402
		R	0.36	2.3	A			0	41	0.37	2.3	A			0	42
	SB	L	0.56	46.0	D	B		60	117	0.58	47.4	D	B		63	120
		T	0.70	16.4	B			218	415	0.71	16.9	B			230	434
Dixwell Ave. @ Putnam Ave./Circular Ave./Helen St.	SEB	LTR	0.50	32.2	C	C	F	75	92	0.51	32.4	C	C	F	76	94
	NW	L	0.42	35.8	D	D		80	117	0.43	36.1	D	D		83	120
		T	0.90	65.0	E			189	356	0.93	70.2	E			196	369
		R	0.44	7.8	A			0	58	0.45	7.8	A			0	59
	NB	L	1.76	402.8	F	F		165	293	1.80	426.6	F	F		171	300
		T	0.89	45.6	D			227	339	0.90	47.1	D			234	352
		R	0.17	2.4	A			0	8	0.17	2.3	A			0	8
	SB	L	1.57	314.5	F	F		205	350	1.62	335.8	F	F		213	360
		TR	0.84	39.6	D			227	332	0.85	40.5	D			234	344
Dixwell Ave. @ Arch St./Morse St.	EB	L	0.73	33.7	C	C	B	122	155	0.75	35.3	D	C	C	128	160
		LTR	0.67	29.0	C			114	201	0.69	30.1	C			121	220
	WB	T	0.08	31.4	C	C		4	13	0.08	31.4	C	C		4	13
		R	0.13	20.2	C			1	17	0.13	20.2	C			1	17
	NB	L	0.22	9.8	A	B		12	29	0.23	9.9	A	B		12	29
		TR	0.44	17.2	B			69	135	0.45	17.2	B			71	138
	SB	L	0.33	10.9	B	B		20	57	0.34	10.9	B	B		21	58
		T	0.63	22.6	C			109	240	0.64	22.9	C			113	247
		R	0.29	1.1	A			0	7	0.29	1.1	A			0	15
Whalley Ave. @ Fitch St./Edgewood Park Dr.	SEB	L	1.25	145.7	F	F	E	595	81	1.29	164.1	F	F	F	631	87
		TR	0.33	5.3	A			63	121	0.34	5.5	A			68	128
	NWB	LTR	1.08	86.3	F	F		268	374	1.10	95.5	F	F		281	387
	NEB	LTR	0.04	18.8	B	B		4	3	0.04	18.5	B	B		4	3
	SWB	LTR	0.76	35.8	D	D		117	14	0.77	36.5	D	D		122	16
(Rte. 69) Whalley Ave.@Amity Rd. (Rte.63)/Wright Ave./Whalley Commons	SEB	L	0.44	46.4	D	C	C	31	59	0.45	47.3	D	C	C	32	60
		TR	0.67	20.7	C			183	271	0.68	21.2	C			190	281
	WB	L	0.64	57.6	E	D		42	80	0.65	58.9	E	E		44	85
		TR	0.75	50.9	D			46	53	0.77	52.7	D			48	55
	NWB	LT	0.32	37.1	D	C		197	308	0.82	38.0	D	C		204	316
		TR	0.60	9.9	A			108	165	0.56	10.2	B			113	172
	SB	L	0.45	39.5	D	D		34	64	0.47	40.8	D	D		35	65
		TR	0.91	41.2	D			172	314	0.93	45.2	D			180	327
Rte. 69 @ Rte.15 Off-Ramp	WB	L	2.25	593.9	F	F	N/A	N/A	1606	2.37	649.8	F	F	N/A	N/A	1704
		R	2.25	593.9	F			N/A	1606	2.37	649.8	F			N/A	1704
	NB	T	0.36	0.0	A	A		N/A	0	0.37	0.0	A	A		N/A	0
	SB	T	0.41	0.0	A	A		N/A	0	0.42	0.0	A	A		N/A	0
Rte. 69 @ Pond Lily Ave.	WB	LR	0.56	16.1	B	B	B	22	43	0.56	16.2	B	B	B	23	43
	NB	TR	0.83	20.7	C	C		129	250	0.85	22.1	C	C		135	263
	SB	L	0.65	16.7	B	A		41	117	0.67	17.7	B	B		50	125
		T	0.52	6.5	A			79	174	0.54	6.7	A			82	183

6.4.1 Redistributed Traffic Volume Network Development

6.4.1.1 Regional Detour

The regional detour will divert vehicles destined for I-91 via Route 15 along the Milford Parkway to I-95 northbound and finally I-91northbound in New Haven. A graphic depicting the Regional Detour and proposed signage is included in Appendix B3.

CDM Smith evaluated regional and local travel patterns for the Route 15 corridor and the Milford Connector during a weekday PM peak hour. Based on this evaluation, CDM Smith assessed the assumptions and critical data points necessary to create a detour network model for a Saturday peak period. A summary of these assumptions and conclusions follows:

- Establish Route 15 mainline traffic volumes prior to Exit 55 to include vehicles entering Route 15 from Milford Connector. The difference between this volume and the summation of all off-ramp volumes for Exits 55-59 represents a conservative estimate of vehicles reaching Heroes Tunnel from the Route 15 Exit 54 interchange. Approximately 58 percent of vehicles from the Route 15 Exit 54 Interchange reach Heroes Tunnel.

- Apply diverge percentages observed at Exits 60-67 to remaining 58 percent of vehicles.

- The remaining 20 percent of vehicles are anticipated to travel regionally from the Route 15 Exit 54 Interchange to I-91.

Alternately, as a means of substantiation, CDM Smith also evaluated the Route 15 corridor travel patterns by examining the ratio of exiting vehicles to mainline traveling vehicles at each exit from Exit 54 to Exit 67. By applying this ratio iteratively for each exit, CDM Smith estimated the regional travel along this portion of Route 15 to be approximately 22.5 percent.

Based on these evaluations and consideration of expected regional travel, CDM Smith defined the following travel compositions along Route 15:

- 45 percent of vehicles exit prior to Heroes Tunnel

- 30 percent of vehicles exit north of Heroes Tunnel but prior to I-91
  - These vehicles will comprise the vehicles travelling along the Local Detour

- 25 percent of vehicles reach I-91
  - These vehicles will comprise the vehicles travelling along the Regional Detour

In order to develop a redistributed traffic volume network, the Regional Detour Vehicle Composition Rate was applied to the traffic volumes entering Route 15 northbound from Route 15 and Milford Parkway at Exit 54. These vehicles are assumed to travel along the Regional Detour. CDM Smith also applied the Regional Detour Vehicle Composition Rate to the vehicles entering northbound Route 15 at Exits 55-58. These vehicles are also assumed to travel along the Regional Detour. The 45 percent of vehicles assumed to not travel along either the Regional or Local Detour will exit Route 15 via Exits 55-59 as they normally would. For those vehicles entering northbound Route 15 at Exits 55-58, 45 percent were assumed to find alternate routes and not enter the network at all. The remaining 30 percent comprise those vehicles traveling along the Local Detour.

A graphic depicting the Regional Detour Redistributed Traffic Volumes is included in Appendix B3.

6.4.1.2 Local Detour

The local detour will divert vehicles destined for local Route 15 Exits 60-67 to Route 69 and 63 (Whalley Avenue) via Exit 59 to Route 10 (Fitch Street, Arch Street, and Dixwell Avenue) and returning to Route 15 at Exit 60. A graphic depicting the Local Detour and proposed signage is included in Appendix B3.

As mentioned previously, approximately 30 percent of Route 15 northbound traffic will follow the Local Detour. In addition, those vehicles entering Route 15 northbound via the Exit 59 on-ramp will be required to access Route 15 at Exit 60 as well. The vehicle demand at this on-ramp was evaluated in order to determine origination percentages. Based on the Existing Condition traffic volumes, 41 percent of vehicles entering the Exit 59 northbound on-ramp originated from the north and 59 percent originated from the south. These vehicles were redistributed along the Local Detour based on their directional origination. Specifically, vehicles from the north were diverted to continue south along Route 69. Vehicles from the south accessed the Local Detour directly at Fitch Street from Whalley Avenue to the south. A graphic depicting the Local Detour Redistributed Traffic Volumes is included in Appendix B3.

6.5 Future Conditions during Construction

The forecasted traffic operations along study roadways during the 2019 Future Conditions without Construction provide a baseline comparison for the forecasted traffic operations during construction. This section discusses the development of the full Future Conditions during Construction Traffic Volume Network and network model. A full evaluation of the anticipated traffic operations for the 2019 Future Conditions during Construction is included.

6.5.1 Traffic Volume Network Development

In order to develop the Future Conditions during Construction Traffic Volume Network for option 4, CDM Smith applied the redistribution of traffic volumes for the Regional and Local Detour to the 2019 Future Conditions Balanced Traffic Volume Profiles. These network profiles are included in the Appendix.

As there is no proposed diversion of traffic under option 5, the 2019 Balanced Traffic Volume Profile created for the Future Conditions without Construction also represents the traffic volumes for the 2019 Future Conditions during Construction Balanced Traffic Volume Profile. This network profile is included in the Appendix.

6.5.2 Traffic Network Model Development

6.5.2.1 Alternative Construction Option 4

Relative to the network model, no infrastructure changes are proposed under Construction Conditions. The Future Conditions during Construction network model utilizes the Future Conditions without Construction network model and incorporates the anticipated redistribution of traffic volumes, ensuring that all vehicles either find alternatives to the study network routes, follow the Regional Detour, or follow the Local Detour.

Upon updating the Vissim expressway model, two segments required further calibration. The Route 15 northbound mainline and Exit 54 off-ramp area as well as the I-95 northbound Exit 38 interchange area were initially unable to process the change in demand directionality. Adjustment of driver behavior eliminated these errors caused by the intense shift in demand.

6.5.2.2 Alternative Construction Option 5

Relative to the network model, Construction Conditions entail the closure of one lane in either direction. The Future Conditions during Construction network model incorporates the anticipated roadway closures but maintains the anticipated future traffic demand along Route 15.

6.5.3 Future Conditions Evaluation

6.5.3.1 Alternative Construction Option 4

Expressway Analysis

As shown in **Table 6.9**, the regional detour during construction operations is anticipated to severely impact study roadways. Average vehicle delay increases by 145 percent while average speeds along the expressways decrease by 21 percent. Vehicles cumulatively spend approximately 34 additional hours in a stopped position during a peak hour. The throughput volume and total distance traveled within the model decrease as the network becomes too congested to process the vehicles already in the network. These conditions are forecast to increase annual delay during construction by approximately 508,000 hours over the no construction condition.

Table 6.9: Option 4 Expressway Performance Measures

Performance Measure	Unit	Existing Conditions Value	2019 Future Conditions Without Construction Value	2019 Future Conditions During Construction Value
Throughput Volume	ea	80,619	82,169	75,495
Average Delay Time Per Vehicle	sec	44.1	49.4	121.3
Average Speed	mph	55.4	54.3	42.7
Total Distance Traveled	mi	335,332	341,526	312,305
Number of Stops	ea	109,123	126,357	275,233
Total Stopped Delay	h	125.8	155.9	292.9
Total Travel Time	h	6,048.40	6,286.10	7,313.25
Total Annual Hours	h	2496	2496	2496
Total Period Delay	h	987.6	1,127.5	2543.8
Average Hourly Delay	h	141.9	162.0	365.5
Total Annual Delay	h	354,167.6	404,359.6	912,245.7
Increase in Annual Delay	h	--	50,192.0	507,886.1

Local Intersection Analysis

In addition to the congestion noted on the expressways, the Local Detour is anticipated to detrimentally impact local intersections as well. As shown in **Table 6.10**, volume to capacity ratios, delay, and queue lengths along the Local Detour increase substantially at all locations with increased traffic demand. 50th Percentile queue lengths along the detour are anticipated to exceed 1,000 feet at many of the critical approaches to the intersection. Delay at multiple intersections is anticipated to exceed 10 minutes of waiting time. These anticipated performance measures reflect unacceptable driving conditions and leads to a complete failure of the local street network.

Table 6.10: Option 4 Local Intersection Performance Measures

Intersection	Lane Group		2013 Existing Conditions							2019 Future Conditions Without Construction							2019 Future Conditions During Construction						
			V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.	V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.	V/C	Delay	Mov. LOS	App. LOS	Int. LOS	50th% QUE.	95th% QUE.
Dixwell Ave.@ Rte.15 NB On-/Off-Ramps	EB	L	0.66	36.4	D	C	B	105	140	0.67	36.8	D	C	B	109	143	0.69	37.9	D	C	F	109	143
		R	0.55	23.6	C			103	148	0.56	24.2	C			108	152	0.58	25.0	C			108	152
	NB	T	0.71	16.4	B	B		275	382	0.73	17.0	B	B		292	402	0.72	16.7	B	***F***		292	402
		R	0.36	2.3	A			0	41	0.37	2.3	A			0	42	***1.58***	***282.7***	***F***			***1349***	***1709***
	SB	L	0.56	46.0	D	B		60	117	0.58	47.4	D	B		63	120	0.61	48.9	D	B		63	120
		T	0.70	16.4	B			218	415	0.71	16.9	B			230	434	0.69	16.4	B			230	434
Dixwell Ave. @ Putnam Ave./Circular Ave./Helen St.	SEB	LTR	0.50	32.2	C	C	F	75	92	0.51	32.4	C	C	F	76	94	0.51	32.5	C	C	F	76	94
	NW	L	0.42	35.8	D	D		80	117	0.43	36.1	D	D		83	120	0.44	36.2	D	D		83	120
		T	0.90	65.0	E			189	356	0.93	70.2	E			196	369	0.94	71.4	E			196	369
		R	0.44	7.8	A			0	58	0.45	7.8	A			0	59	0.45	7.8	A			0	59
	NB	L	1.76	402.8	F	F		165	293	1.80	426.6	F	F		171	300	1.82	431.1	F	***F***		171	300
		T	0.89	45.6	D			227	339	0.90	47.1	D			234	352	***2.80***	***829.0***	***F***			***1307***	***1444***
		R	0.17	2.4	A			0	8	0.17	2.3	A			0	8	0.17	3.1	A			3	12
	SB	L	1.57	314.5	F	F		205	350	1.62	335.8	F	F		213	360	1.63	340.4	F	F		213	360
		TR	0.84	39.6	D			227	332	0.85	40.5	D			234	344	0.84	39.6	D			234	344
Dixwell Ave. @ Arch St./Morse St.	EB	L	0.73	33.7	C	C	B	122	155	0.75	35.3	D	C	C	128	160	***3.35***	***N/A***	***F***	***F***	F	***1162***	***1056***
		LTR	0.67	29.0	C			114	201	0.69	30.1	C			121	220	***3.09***	***960.7***	***F***			***1164***	***1371***
	WB	T	0.08	31.4	C	C		4	13	0.08	31.4	C	C		4	13	0.08	31.4	C	C		4	13
		R	0.13	20.2	C			1	17	0.13	20.2	C			1	17	0.13	20.2	C			1	17
	NB	L	0.22	9.8	A	B		12	29	0.23	9.9	A	B		12	29	0.23	9.9	A	B		12	29
		TR	0.44	17.2	B			69	135	0.45	17.2	B			71	138	0.45	17.2	B			71	138
	SB	L	0.33	10.9	B	B		20	57	0.34	10.9	B	B		21	58	0.34	10.9	B	B		21	58
		T	0.63	22.6	C			109	240	0.64	22.9	C			113	247	0.64	22.9	C			113	247
		R	0.29	1.1	A			0	7	0.29	1.1	A			0	15	0.29	1.1	A			0	7
Whalley Ave. @ Fitch St./Edgewood Park Dr.	SEB	L	1.25	145.7	F	F	E	595	81	1.29	164.1	F	F	F	631	87	***7.70***	***N/A***	***F***	***F***	F	***6384***	***1530***
		TR	0.33	5.3	A			63	121	0.34	5.5	A			68	128	0.34	5.5	A			68	128
	NWB	LTR	1.08	86.3	F	F		268	374	1.10	95.5	F	F		281	387	0.97	38.3	D	D		168	294
	NEB	LTR	0.04	18.8	B	B		4	3	0.04	18.5	B	B		4	3	0.04	18.5	B	B		4	3
	SWB	LTR	0.76	35.8	D	D		117	14	0.77	36.5	D	D		122	16	0.77	36.5	D	D		122	16
(Rte. 69) Whalley Ave.@Amity Rd. (Rte.63)/Wright Ave./Whalley Commons	SEB	L	0.44	46.4	D	C	C	31	59	0.45	47.3	D	C	C	32	60	0.45	46.4	D	C	F	32	60
		TR	0.67	20.7	C			183	271	0.68	21.2	C			190	281	0.69	21.7	C			190	281
	WB	L	0.64	57.6	E	D		42	80	0.65	58.9	E	E		44	85	0.65	57.4	E	D		43	85
		TR	0.75	50.9	D			46	53	0.77	52.7	D			48	55	0.76	51.3	D			47	55
	NWB	LT	0.32	37.1	D	C		197	308	0.82	38.0	D	C		204	316	0.85	40.9	D	C		204	317
		TR	0.60	9.9	A			108	165	0.56	10.2	B			113	172	0.14	2.9	A			7	23
	SB	L	0.45	39.5	D	D		34	64	0.47	40.8	D	D		35	65	0.33	32.8	C	***F***		33	61
		TR	0.91	41.2	D			172	314	0.93	45.2	D			180	327	***2.32***	***618.9***	***F***			***879***	***1119***
Rte. 69 @ Rte.15 Off Ramp	WB	L	2.25	593.9	F	F	N/A	N/A	1606	2.37	649.8	F	F	N/A	N/A	1704	***6.49***	***N/A***	***F***	***F***	N/A	***N/A***	***N/A***
		R	2.25	593.9	F			N/A	1606	2.37	649.8	F			N/A	1704	***6.49***	***N/A***	***F***			***N/A***	***N/A***
	NB	T	0.36	0.0	A	A		N/A	0	0.37	0.0	A	N/A		N/A	0	0.14	0.0	A	N/A		0	0
	SB	T	0.41	0.0	A	A		N/A	0	0.42	0.0	A	N/A		N/A	0	0.57	0.0	A	N/A		0	0
Rte. 69 @ Pond Lily Ave.	WB	LR	0.56	16.1	B	B	B	22	43	0.56	16.2	B	B	B	23	43	0.56	16.2	B	B	B	23	43
	NB	TR	0.83	20.7	C	C		129	250	0.85	22.1	C	C		135	263	0.56	16.3	B	B		90	147
	SB	L	0.65	16.7	B	A		41	117	0.83	20.7	C	C		129	250	0.11	4.1	A	B		6	17
		T	0.52	6.5	A			79	174	0.65	16.7	B	A		41	117	0.74	11.2	B			147	338

Performance Measures for intersection movements along Local Detour shown in red ***bold italics*** under 2019 Future Conditions during Construction

6.5.3.2 Alternative Construction Option 5

Under option 5, the model data reflects a very minor impact to drivers during construction. **Table 6.11** indicates that the average vehicle delay shows a slight increase of approximately 5 seconds per vehicle (9.8 seconds without construction to 14.4 seconds during construction). Average vehicle speed reduces only slightly, increasing the cumulative travel time through the network for all vehicles by approximately 1.6 percent. This correlates to a cumulative annual increase in delay of approximately 10,148 hours.

Table 6.11: Option 5 Expressway Performance Measures

Performance Measure	Unit	Existing Conditions Value	2019 Future Conditions Without Construction Value	2019 Future Conditions During Construction Value
Throughput Volume	ea	12,077	12,334	12,340
Average Delay Time Per Vehicle	sec	9.6	9.8	14.35
Average Speed	mph	64.5	64.4	63.4
Total Distance Traveled	mi	64,767	65,908	65,945
Number of Stops	ea	1,391	1,461	2,527
Total Stopped Delay	h	1.4	1.4	2.466
Total Travel Time	h	1,004.50	1,023.00	1,039.68
Total Annual Hours	h	2600	2600	2600
Total Hourly Delay	h	8.1	8.4	12.3
Total Annual Delay	h	20933.5	21824.3	31972.6
Increase in Annual Delay	h	--	890.9	10,148.3

6.6 Alternative Construction Option Evaluation

This section provides a comprehensive comparative evaluation and summary of the analysis findings for the alternative construction options.

6.6.1 Alternative Construction Option Comparison

Section 6.5 discussed the individual analysis findings for alternative construction options 4 and 5. Expressway and local intersection analysis was performed separately under option 4, while option 5 only required expressway evaluation. **Table 6.12** provides a direct comparison of the expressway analysis findings for options 4 and 5.

Table 6.12: Alternative Construction Option Comparison
2019 Future Conditions during Construction Expressway Performance Measures

Performance Measure	Unit	Option 4 Proposed Rehabilitation – Complete Barrel Shutdown Value	Option 5 Proposed Rehabilitation – Partial Barrel Shutdown Value
Throughput Volume	ea	75,495	12,340
Average Delay Time Per Vehicle	sec	121.3	14.35
Average Speed	mph	42.7	63.4
Total Distance Traveled	mi	312,305	65,945
Number of Stops	ea	275,233	2,527
Total Stopped Delay	h	292.9	2.466
Total Travel Time	h	7,313.25	1,039.68
Total Annual Hours	h	2496	2600
Total Hourly Delay	h	365.5	12.3
Total Annual Delay	h	912,245.7	31,972.6
Increase in Annual Delay	h	507,886.1	10,148.3

As shown in Table 6.12, the anticipated Average Delay Time per Vehicle is nearly nine times larger under option 4. Additionally, the Average Speed for vehicle travelling through the respective study networks is more than 20 mph slower under option 4. Based on the throughput volume, the average number of stops anticipated for each vehicle travelling through each network during construction is approximately 3.65 under option 4 and only 0.2 under option 5. These numbers reveal a very large disparity in anticipated traffic impacts during construction. Option 4 clearly has the greatest detriment to the expressway system during construction.

However, option 4 also detrimentally impacts the local intersections along Routes 69 and 10 in New Haven and Hamden along the Local Detour. As discussed in Section 5, utilization of the Local Detour as proposed under option 4 would result in the complete failure of the local street network.

Alternative construction option 5 will provide the least impact to the expressways and local intersections based on the comparison.

6.6.2 Evaluation Matrix

An Evaluation Matrix has been developed in order to rank each alternative construction option based on the performance measures evaluated during analysis. However, due to the closely linked correlation of the traffic analysis performance measures, evaluating the construction options based on each measure would result in redundancy. CDM Smith identified Annual Delay Impacts as the measure most indicative of the overall traffic impacts and Delay Cost as a unique measure associating the traffic impacts over the duration of construction to the cost of transportation for the region. It should be noted that CDM Smith prepared a separate evaluation of Delay Cost for this State Project. That memorandum provides the basis for the evaluation used in this report.

Table 6.13 represents the Evaluation Matrix developed based on the analysis findings discussed in this report and the Delay Cost memorandum. As shown in the Evaluation Matrix, options 1, 2, and 3 are not anticipated to have appreciable impacts to traffic along Route 15 or other nearby roadways. Relative to traffic impacts, options 1, 2, and 3 are ideal construction scenarios. Option 4 has unacceptable impacts to traffic based on all evaluation criteria. Based on the traffic impacts and delay costs associated with option 4, CDM Smith recommends that, in order to consider this option further, alternative means and methods should be employed. **Section 6.7** discusses such options. Relative to option 5, there are quantifiable impacts to the evaluation parameters associated with the proposed construction operations. However, CDM Smith considers those impacts minimal and acceptable. **Table 6.13** ranks the construction options based on their traffic impact from least to greatest.

Table 6.13 Alternative Construction Options Evaluation Matrix

Evaluation Parameter	Option 1 New One Lane Single Barrel Tunnel	Option 2 New Two Lane Single Barrel Tunnel	Option 3 Enlargement of Existing Tunnel	Option 4 Proposed Rehabilitation – Complete Barrel Shutdown	Option 5 Proposed Rehabilitation – Partial Barrel Shutdown
Increase in Annual Delay	No Impact			2	1
Delay Cost				2	1

6.7 Other Recommendations

6.7.1 Traffic Demand Reduction

As noted in the Evaluation Matrix, alternative construction option 4 is anticipated to result in unacceptable impacts to traffic in the study area. CDM Smith has considered means to reduce the impact of option 4 as currently defined. Two considerations include the prominent implementation of Intelligent Transportation Systems (ITS) applications as well as revised Limitations of Construction Operations.

6.7.1.1 Intelligent Transportation Systems

ITS applications integrate advanced communications technologies into the transportation infrastructure as a means to improve safety and mobility. According to the United States Department of Transportation Research and Innovative Technology Administration[1], implementation of ITS applications has been shown to divert up to 15 percent of traffic onto detour routes. Proper placement of ITS applications in New York and other gateway access points to Route 15 can potentially decrease the traffic demand along study roadways by diverting vehicles along I-684 to I-84 or directly to I-95 (in order to bypass the Route 15/Milford Parkway interchange). During discussions with CTDOT, it was indicated that a typical 20 percent reduction in traffic is realized by implementing advance ITS signage. Preliminary analysis shows that if similar rates can be attained, delays attributed to construction under option 4 would reduce significantly to approximately 60 seconds average delay per vehicle. This alternate analysis is included in the Appendix. However, the positive effect of detour diversion is highest under short duration. As option 4 is currently estimated at 24 months, a full 15 to 20 percent diversion reduction may not be realized for the duration of construction. This means of traffic impact reduction warrants further exploration.

[1] www.its.dot.gov/press/2009/road_construction_tech.htm

6.7.1.2 Limitations of Construction Operations

An alternate means to improve the viability of construction option 4 entails reconsidering the Limitations of Construction Operations. The unacceptable traffic impacts forecast by traffic analysis reveal that weekend travel demand along the study corridors is too high to accommodate the closure of the northbound or southbound barrel of Heroes Tunnel. Restricting work hours to weekday and weekend overnight periods may extend the construction duration, but would considerably reduce the traffic impact. The feasibility of this consideration is contingent upon the temporary traffic control mobilization and demobilization times for the Regional and Local Detours. This means of traffic impact reduction also warrants further exploration.

TAB PAGE

Section 7

Evaluation of Delay Costs (Options #4-5)

7.1 Marginal External Costs for Congestion

7.1.1 Overview of Delay Costs

Delay costs (also called work zone road user costs) – both monetized and non-monetized – are the impacts borne by the community at large and affected motorists as a result of work zone activity. **Figure 7.1** illustrates categories of work zone road user costs.

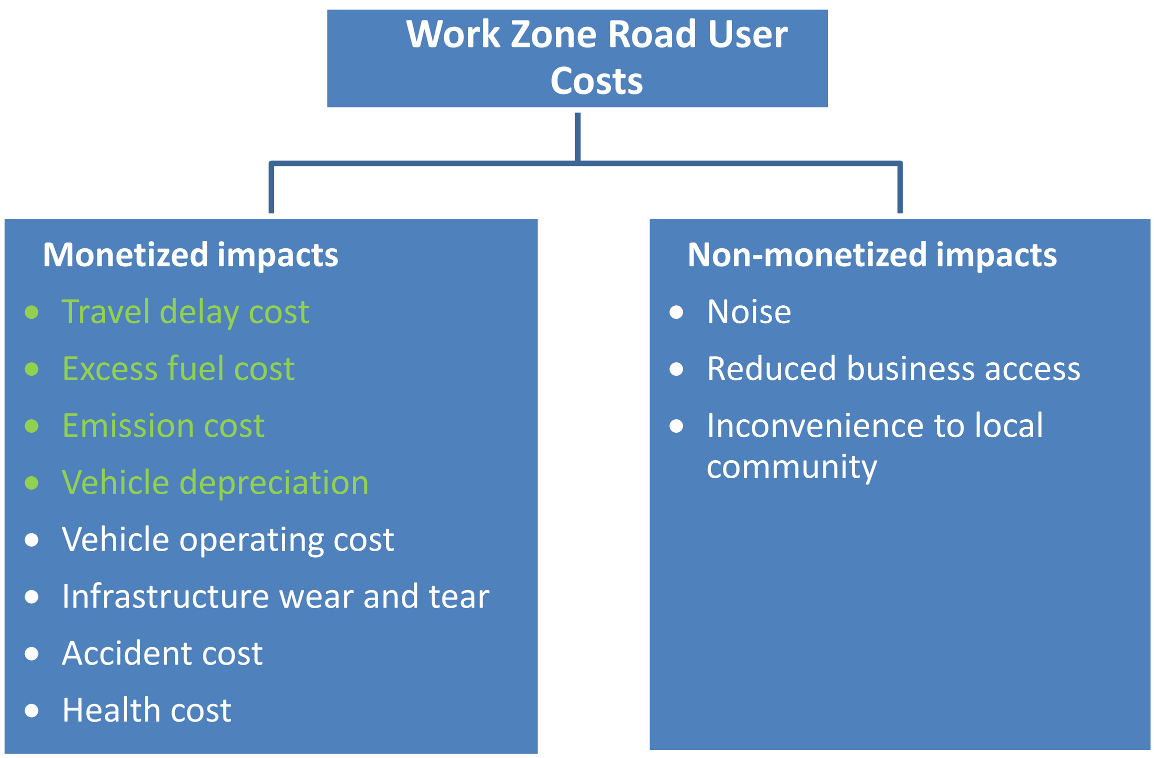


Figure 7.1: Work Zone Road User Cost Components
(Adapted from Mallela and Sadasivam, 2011 and Schrank et al, 2012).
Components estimated in this cost estimate for the Heroes Tunnel project are highlighted in green.

To compute costs associated with the various construction options for the Heroes Tunnel project, three cost estimation methodologies were compared – the Federal Highway Administration (FHWA) Work Zones Cost Report (Mallela and Sadasivam, 2011), the Texas A&M Transportation Institute (TTI) highly referenced annual Urban Mobility Report (Schrank et al., 2012), and Transport Canada's Cost of Urban Congestion in Canada (Transport Canada, 2006). **Table 7.1** presents a comparison of costs that are calculated in these three methodologies. The final column on the right indicates whether a given parameter is estimated for the Heroes Tunnel construction work.

Table 7.1: Marginal External Costs for Congestion (green indicates the item was estimated by the study and red indicates the item was not estimated by the study)

Cost Category	Description	Approach 1: FHWA	Approach 2: TTI	Approach 3: Transport Canada	Estimated for Heroes Tunnel?
Delay	Time lost during congestion	[green]	[green]	[green]	Yes
Excess fuel consumption	Excess fuel wasted due to congestion	[green]	[green]	[green]	Yes
CO_2 emissions	CO_2	[green]	[green]	[green]	Yes
Other air pollution emissions	CO, HC, NOx, SOx, particulate matter	[green]	[red]	[green]	Yes
Vehicle depreciation	Depreciation of vehicles as a function of aging and usage over time	[green]	[red]	[red]	Yes
Vehicle operating cost	Expenses incurred by road users as a result of vehicle use (mileage dependent)	[green]	[red]	[red]	No – not a large portion of overall costs; additionally, existing models are outdated and do not take into account current vehicle standards
Accidents	Increase/decrease in accident risk (frequency and severity)	[green]	[red]	[red]	No – difficult to estimate without detailed existing crash rate and crash cost data
Infrastructure	Wear and tear on infrastructure from increased vehicle miles	[red]	[red]	[red]	No – difficult to estimate incremental additional wear and tear on detour streets
Health	Stress, disability adjusted life years (DALYs) lost due to lowered air quality and accidents	[red]	[red]	[red]	No – difficult to estimate
Noise	Nuisance cost due to noise pollution	[red]	[red]	[red]	No – considered qualitative
Reduced business accessibility	Temporary loss of customers or decrease in property values	[red]	[red]	[red]	No – difficult to estimate

Note: Adapted from Grant-Muller and Laird (2006) and Transport Canada (2006)

In summary, the following costs are estimated for construction Options 4 and 5 for the Heroes Tunnel construction:

- Delay cost
- Excess fuel consumption cost
- Criteria pollutants and greenhouse gas (GHG) emissions
- Vehicle depreciation

The following sections describe how each of these three congestion costs is computed for the Heroes Tunnel construction. The FHWA method was chosen as the basis for these calculations as it is the most conservative methodology. For instance, the FHWA has a higher per person estimate of the monetary value of travel time based on prevailing median household income, whereas the TTI method uses a lower estimated value of time according to literature, rather than the average or prevailing wage rate. Furthermore, the TTI method does not calculate the cost of air pollutants other than CO_2 and does not factor in vehicle depreciation costs. In addition, the FHWA method carries the authority of being published by the federal agency.

Many of the remainder of the costs in Table 7.1 that are not estimated for the Heroes Tunnel construction are externalities to the travel market; there is no direct market price associated with them. While economists have offered estimates for several of these trickier parameters, the estimates are highly site specific and rely on a number of assumptions, making it difficult to quantify them in a meaningful way. For instance, researchers have found that congestion tends to increase crash rates, but those crashes tend to be less severe, resulting in fewer injuries and deaths (Zhou and Sisiopiku, 1997). Therefore, it is recommended that these cost parameters be acknowledged with regards to the Heroes Tunnel project but not quantified.

In addition to congestion costs, there are a range of indices that can be computed to give a fuller picture of the impacts of congestion, including: total peak period travel time, travel time index, commuter stress index, planning time index, roadway congestion index, and percent of daily and peak travel in congested conditions. These indices are not addressed in this memo.

7.1.2 Usage of Delay Costs

Estimating delay costs provides an additional way to measure the public impact of options under consideration (Mallela and Sadasivam, 2011). This methodology can be applied at various stages of a transportation program's life cycle; from planning, design, construction, operations, and preservation. Rarely are delay costs compared directly with construction costs numerically. Rather, they are intended to estimate relative impacts of various options.

Delay cost estimates can be used to:

- Compare alternative approaches qualitatively
- Compare bids on a project so that a proposal is being evaluated for its construction cost plus the overall public impact, as reflected in delay costs
- Derive cost incentives for on-time delivery of construction for contractors that can be added to contract terms

7.2 Estimating Congestion Costs

For the purposes of the Heroes Tunnel construction project, the total cost of congestion can be estimated with the following formula:

$$\begin{aligned}&Total\ congestion\ cost\\&\qquad = (delay) + (fuel\ consumption) + \ (air\ pollution) + \ (vehicle\ depreciation)\end{aligned}$$

Traffic models representing the critical interchanges and corridors were created as part of the Traffic Impact project task for the following scenarios:

- 2014 existing conditions
- 2019 future conditions without construction
- 2019 future conditions during construction

Table 7.2 summarizes the inputs to the calculations that follow, based on the model output for two construction options, examining the difference between 2019 future conditions with and without construction.

Table 7.2: Parameters Used for Estimating Congestion Costs for Two Construction Options for Heroes Tunnel

Parameter	Unit	Option 4[1]	Option 5[2]
Project duration	months	24	20
Impacts on expressways (due to delayed and detoured vehicles)			
Excess Distance Traveled (Total Annual)	miles	4,788,175	0
Average difference in speed (relative to no construction)	mph	-12	Negligible
Excess Stopped Delay (Total Annual)	vehicle hours	49,131	678
Excess Delay (Total Annual)	vehicle hours	507,886	10,148
Excess Fuel Consumption (Total Annual)	gallons	1,000,549	233,005
Impacts at local intersections (due to detoured vehicles)			
Excess Distance Traveled (Per Vehicle)	miles	2.08	N/A
Annual Vehicles Along Detour	#	2,099,791	N/A
Excess Distance Traveled (Total Annual)	miles	4,367,565	N/A
Average difference in speed (relative to no construction)	mph	-32	N/A
Excess Delay (Total Annual)	vehicle hours	10,269,864	N/A
Excess Fuel Consumption (Total Annual)	gallons	7,966,736	N/A

[1] Option 4 involves full northbound tunnel closure during Friday night and Saturday midday peak period with detours
[2] Option 5 involves partial tunnel closure during weekday overnight off-peak period

7.2.1 Delay Cost

The delay cost is an estimate of the value of lost time in passenger vehicles in congestion and can be calculated using the following formula (Schrank et al., 2012):

$$
\begin{aligned}
&\textit{Annual delay cost} \\
&\qquad = [\textit{Total delay}] \\
&\qquad \times \{[(\textit{Proportion of vehicles on personal travel}: \textit{local and intercity}) \\
&\qquad \times (\textit{Monetary value of personal travel time}) \\
&\qquad \times (\textit{AVO of vehicles on personal travel})] \\
&\qquad + [(\textit{Proportion of vehicles on business travel}: \textit{local and intercity}) \\
&\qquad \times (\textit{Monetary value of business travel time}) \\
&\qquad \times (\textit{AVO of vehicles on business travel})]\}
\end{aligned}
$$

Where:

$$AVO = \textit{average vehicle occupancy}$$

Table 7.3 presents the assumed values for the parameters in the above formula, which were presented in the FHWA methodology (Mallela and Sadasivam, 2011).

Table 7.3. Parameter Values Used in Calculating Annual Delay Costs ($2013)

Parameter	Value	Explanation
Proportion of vehicles on personal travel	94%	National average – 2009 data from the National Household Transportation Survey (NHTS) and the Nationwide Personal Transportation Survey (NPTS) as reported by Mallela and Sadasivam, 2011.
Proportion of vehicles on business travel	6%	As above.
AVO of vehicles on personal travel	1.7 (local travel); 2.3 (intercity travel)	As above.
AVO of vehicles on business travel	1.2 (local or intercity travel)	As above.
Proportion of vehicles on local travel	75%	Value determined in traffic modeling.
Proportion of vehicles on intercity travel	25%	Value determined in traffic modeling.
Monetary value of personal travel time on local travel	$14.96/hr	Calculated as 50% of the median annual household income on an hourly basis for New Haven County ($62,224 @ 2,080 hours), per Mallela and Sadasivam, 2011.
Monetary value of personal travel time on intercity travel	$20.94/hr	Calculated as 70% of the median annual household income on an hourly basis for New Haven County ($62,224 @ 2,080 hours), per Mallela and Sadasivam, 2011.
Monetary value of business travel time on local travel	$29.63/hr	Calculated as 100% of the national average total compensation (wages and benefits) cost per hour based on data from the Bureau of Labor Statistics for December 2013, per Mallela and Sadasivam, 2011.
Monetary value of business travel time on intercity travel	$29.63/hr	Calculated as 100% of the national average total compensation (wages and benefits) cost per hour based on data from the Bureau of Labor Statistics for December 2013, per Mallela and Sadasivam, 2011.

Transport Canada estimated delay cost similarly to the method provided above used by the FHWA methodology. The 2012 TTI report uses an AVO of 1.25 persons per vehicle (for all types of travel) and an average monetary value of travel time of $17.40/hour (in 2013$) (likewise for all types of travel), which is based on an estimated national value of time according to literature, rather than the average or prevailing wage rate (Schrank et al, 2012). For completeness, it is recommended that the FHWA approach be adopted. The delay cost estimate produced by the FHWA method using the parameter values presented in Table 7.3 is shown in **Table 7.4**. An estimate produced by the TTI method using the parameter values mentioned in this paragraph results in a lower estimate than the FHWA method. As a result, only the FHWA method is presented here, to employ the most conservative estimate.

Table 7.4. Annual Delay Cost Estimated by the FHWA Method for Two Construction Options for Heroes Tunnel ($2013)

Cost Component	Unit	Option 4	Option 5
Impacts on expressways (due to delayed and detoured vehicles)			
Delay cost – personal travel	$/yr	14,853,268	296,781
Delay cost – business travel	$/yr	1,083,504	21,649
Impacts at local intersections (due to detoured vehicles)			
Delay cost – personal travel	$/yr	232,989,431	N/A
Delay cost – business travel	$/yr	16,995,916	N/A
Total impacts			
Total annual delay cost	$/yr	265,922,119	318,430

Option 4 results in far higher annual delay cost since local detours result in longer delays than expressway delays.

7.2.2 Excess Fuel Consumption Cost

Excess fuel consumption for this project was estimated through the utilization of a microsimulation traffic modeling software, Vissim 5.40.09. Microsimulation software individually simulates each vehicle in the model, thereby considering all relevant properties, including fuel consumption.

Fuel consumption data output by the 2019 Future Conditions models were compared to determine increases in fuel consumption due to construction. It should be noted that under Alternative Construction Option 4, construction detours will be implemented. The fuel consumption associated with vehicle travel along detour roadways outside of the simulation model was estimated based on additional miles traveled and average fuel efficiency for free flow highway conditions output by the model.

Based on the simulation model data, **Table 7.5** presents the estimate for excess fuel consumption costs for the two construction options that have a major impact on traffic. The average cost for fuel was taken to be $ 3.81/gallon, which is the average annual (2013) cost for fuel in the Connecticut, based on data from the American Automobile Association (AAA) and the U.S. Energy Information Administration. This average fuel cost was determined by comparing an instantaneous average fuel cost in Connecticut for June 13, 2014 for regular grade gasoline (http://fuelgaugereport.aaa.com/todays-gas-prices/ $3.921) to the current (as of 6/9/14) Petroleum Administration for Defense District (PADD) price reported by EIA for the New England Region (PADD1A) (http://www.eia.gov/dnav/pet/pet_pri_gnd_a_epmr_pte_dpgal_w.htm $3.723) to determine a comparison factor of 1.053. This factor was then applied to the 2013 EIA annual average for PADD1A of $3.615 to get $3.81.

Table 7.5. Excess Fuel Consumption Cost for Two Construction Options for Heroes Tunnel ($2013)

Cost component	Unit	Option 4	Option 5
Impacts on expressways (due to delayed and detoured vehicles)			
Excess fuel consumption cost	$/yr	3,812,092	887,749
Impacts at local intersections (due to detoured vehicles)			
Excess fuel consumption cost	$/yr	30,353,265	N/A
Total impacts			
Total annual excess fuel consumption cost	$/yr	34,165,357	887,749

Option 4 results in far higher excess fuel consumption cost since local detours result in far higher fuel consumption than expressway delays.

7.2.3 Cost of Air Pollution

The United States Environmental Protection Agency's (EPA's) Motor Vehicle Emission Simulator (MOVES), Version 2010b (October 30, 2012) was used to estimate vehicle emission factors for carbon monoxide (CO), nitrogen dioxide (NO_2), volatile organic compounds (VOC), inhalable and fine particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), and carbon dioxide (CO_2). The national default database with default allocation factors for New Haven County was used to calculate 2019 distance based emission rates for vehicles traveling at less than 2.5 miles per hour (mph) and vehicles traveling at various speed ranges (22.5-27.5 mph, 42.5-47.5 mph, and 52.5-57.5 mph). A weighted average emission factor was calculated based on MOVES default vehicle distribution for motorcycles, passenger cars, and passenger trucks. Haul and light commercial trucks were not included in this analysis. Estimated change in distance traveled by vehicles with and without the project in the study area was multiplied by distance based emission rates in the appropriate speed range for moving vehicles. The emission rates for vehicles traveling at less than 2.5 mph were multiplied by 2.5 mph to convert to time based emission rates and used to calculate emissions from vehicle delay due to signals, railroad crossing, and congestion. Distances traveled and delay times were calculated using the VISSIM2007 model.

Emission rates were then multiplied by published value of damages to infrastructure and/or human health due to pollution. Emission damage values for NO_2, VOC, $PM_{2.5}$, and SO_2 from the National Highway Traffic Safety Administration's 2010 regulatory impact analysis of the Corporate Average Fuel Economy were used (NHTSA, 2010). The values (in 2013 dollars) are $5,954, $1,460, $325,777, and $34,824 per ton of emissions, respectively. There are no damage/benefit values for CO or PM_{10}. The EPA Social Cost of Carbon estimates for the construction year 2019 range from about $13 to $70 for every metric ton of CO_2 (in 2013 dollars), depending on assumptions made in the models used (EPA, 2013). The higher end of this range was used for this CO_2 emission cost estimate ($70/metric ton) for a conservative cost estimate.

Table 7.6 summarizes the annual excess emissions and cost of CO, NO2, VOC, PM10, PM2.5, SO2, and CO2.

Table 7.6: Annual Excess Emissions and Cost ($2013) for Two Construction Options for Heroes Tunnel

Cost Component	Unit	Option 4	Option 5
Impacts on expressways (due to delayed and detoured vehicles)			
CO	kg/yr	11,625	12
NO_2	kg/yr	161	0
VOC	kg/yr	383	1
PM_{10}	kg/yr	170	1
$PM_{2.5}$	kg/yr	92	0
SO_2	kg/yr	26	0
CO_2	kg/yr	1,772,334	3,188

Table 7.6: Annual Excess Emissions and Cost ($2013) for Two Construction Options for Heroes Tunnel

Cost Component	Unit	Option 4	Option 5
Impacts at local intersections (due to detoured vehicles)			
CO	kg/yr	194,183	N/A
NO_2	kg/yr	1,837	N/A
VOC	kg/yr	17,205	N/A
PM_{10}	kg/yr	8,132	N/A
$PM_{2.5}$	kg/yr	2,881	N/A
SO_2	kg/yr	743	N/A
CO_2	kg/yr	52,317,307	N/A
Total impacts			
CO	kg/yr	205,808	12
NO_2	kg/yr	1,997	0
VOC	kg/yr	17,588	1
PM_{10}	kg/yr	8,302	1
$PM_{2.5}$	kg/yr	2,973	0
SO_2	kg/yr	769	0
CO_2	kg/yr	52,317,307	3,188
CO	$/yr	No estimate	No estimate
NO_2	$/yr	13,107	0.75
VOC	$/yr	28,312	1.75
PM_{10}	$/yr	No estimate	No estimate
$PM_{2.5}$	$/yr	1,067,513	65
SO_2	$/yr	29,513	2
CO_2	$/yr	4,063,927	248
Total annual excess emission cost	**$/yr**	**5,202,372**	**317**

Option 4 results in far higher emissions cost since local detours result in far higher air pollution emissions than expressway delays.

7.2.4 Vehicle Depreciation

The cost of vehicle depreciation accounts for the cost of vehicle usage and aging over time. Total vehicle depreciation includes mileage-related and time-related vehicle depreciation costs. The formula to calculate total vehicle depreciation is shown below:

$$\begin{aligned}&Total\ depreciation\ cost\\&\quad = [time\ related\ depreciation\ rate \times total\ vehicle\ delay]\\&\quad + [mileage\ related\ depreciation\ rate\ \times excess\ distance\ traveled]\end{aligned}$$

Table 7.7 shows the parameter values used to calculate the total depreciation cost. Total vehicle delay and excess distance traveled were presented in Table 7.2. The values shown are for passenger vehicles, based on 1995 data provided in the FHWA Highway Economic Requirements System-State Version Technical Report (FHWA, 2005). The 1995 dollar values were adjusted to current year dollars using the Producer Price Index for passenger vehicles.

Table 7.7. Parameter Values Used in Calculating Total Vehicle Depreciation ($2013)

Parameter	Value
Mileage-related depreciation rate	$0.106/mi
Time-related depreciation rate	$1.06/hr

Table 7.8 presents the annual depreciation costs for each of the three scenarios.

Table 7.8. Annual Total Vehicle Depreciation Cost for Two Construction Options for Heroes Tunnel ($2013)

Cost component	Unit	Option 4	Option 5
Total vehicle depreciation cost	$/yr	11,930,617	10,756

7.2.5 Total Annual Congestion Cost – FHWA Method

Table 7.9 presents a summary of the annual costs for options 4 and 5.

Table 7.9: Annual Total Congestion Cost for Two Construction Options for Heroes Tunnel ($2013)

Cost component	Unit	Option 4	Option 5
Total annual delay cost (from Table 5)	$/yr	265,922,119	318,430
Total annual excess fuel consumption cost (from Table 6)	$/yr	34,165,357	887,749
Total annual excess emission cost (from Table 7)	$/yr	5,202,372	317
Total vehicle depreciation cost (from Table 9)	$/yr	11,930,617	10,756
Total annual congestion cost (rounded)	**$/yr**	320,000,000	1,200,000

Option 4 results in far higher emissions cost than Option 5 since local detours result in far longer delays than expressway delays. Although there is a detour, the mileage-related depreciation cost only makes up about 4 percent of the total vehicle depreciation cost for Option 4 – the time-related depreciation cost is the dominant factor.

7.2.6 Total Annual Congestion Cost – Rule-of-Thumb Method

FHWA presents a number of example case studies that illustrate the usage of delay costs (Mallela and Sadasivam, 2011). In some of these case studies, a rule of thumb value per day of construction is provided as an alternative to calculating the line items presented in Section 7.2 of this report. The values used in the case study range from $2,000 to $3,500 per day and notes that these values are specified by the contracting agency, but does not give a basis for these estimates. Using the lower value ($2,000 in delay costs per construction day), a rough estimate of $730,000 per year for any option can be used as a point of reference. This value is similar in magnitude to the rigorously calculated annual delay costs for Option 5, as presented in Table 7.9. This rule of thumb does not take into consideration any of the project-specific aspects noted in this report, such as significant detours and other impacts. Therefore it is presented only for comparison as a lower limit.

7.3 Summary

Table 7.10 presents a summary of the total congestion costs for each of the four options over the project duration based on the FHWA methodology (Mallela and Sadasivam, 2011). Total congestion costs include delay, excess fuel consumption, excess emission, and vehicle depreciation costs. Projection to 2019 dollars was done using an average 4 percent inflation rate.

Table 7.10: Annual Total Congestion Cost for Two Construction Options for Heroes Tunnel ($2013, $2014, and $2017)

	Unit	Option 4[1]	Option 5[1]
Project duration	mo	24	20
Project duration	yr	2.0	1.7
Total annual congestion cost	$million/yr	0.7 – 320	0.7 – 1.2
Total congestion cost ($2013)	**$million/project**	1.4 – 640	1.2 – 2
Total congestion cost ($2014)	**$million/project**	1.5 – 665	1.3 – 2.1
Total congestion cost ($2019)	**$million/project**	1.8 – 810	1.5 – 2.5

[1] Ranges represent the rule-of-thumb method presented in Section 7.2.6 (lower end of range) and the rigorously calculated estimate based on the FHWA method presented in sections 7.2.1-7.2.5 (upper end of range).

Option 4 results in the highest congestion costs, at $1.5 to 665 million (in 2014) over the 2-year project duration (or $1.8 to 810 million in 2019). Option 5 estimated congestion costs are $2.1 million ($2014) over the 1.7-year project duration (or $1.5 to 2.5 million in $2019). The overall congestion costs calculated using the FHWA method for Option 5 are far lower (two orders of magnitude) than Option 4 because of the avoided need for local detours, which increase delays significantly. For each of the options evaluated, travel delay and excess fuel consumption costs made up the greatest portion of the overall congestion costs; excess emissions and vehicle depreciation contributed relatively little to the overall costs estimated by the FHWA method.

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Section 8

Highway Design Components

The five construction alternatives analyzed during this study require slightly different highway design solutions. In the subsequent paragraphs, the different strategies necessary are discussed, followed by a tabulation of the design standards that were selected for each.

8.1 Option 1 – New One-Lane Tunnel

Option 1 requires new alignment along Route 15 (see **Table 8.1** and **Table 8.2** for design standards). This can be seen in **Appendix C1** (Option 1 Geometry) and **Appendix C2** (Option 1 Profile). As part of the new alignment, a realignment of the entrance ramp just to the west of the tunnels is necessary. Additionally, enhanced crossovers must be constructed to shift traffic in accordance with the following sequence of construction and these can also be seen in Appendix C1.

Proposed sequence of construction:

1. Maintain traffic in existing tunnels, construct new tunnel, new tunnel alignment, and new enhanced crossovers.
2. Shift right lane of northbound traffic to new tunnel and new alignment, maintain southbound traffic in existing southbound tunnel, close one lane of existing northbound tunnel, and rehabilitate existing northbound tunnel with one lane of traffic maintained. During construction, the one-lane tunnel is designed to accommodate two lanes of traffic if necessary during emergencies or to accommodate unique construction needs.
3. Shift one lane of southbound traffic to newly rehabilitated northbound tunnel via newly constructed crossovers maintaining one lane of traffic in existing southbound tunnel and one lane in each direction in newly rehabilitated northbound tunnel and maintaining one lane of traffic in new tunnel. Rehabilitate southbound tunnel with one lane of traffic maintained.
4. Shift northbound and southbound traffic back to their respective newly rehabilitated tunnels, maintain one-lane tunnel as the entrance ramp, bringing traffic into mainline after the tunnel. Put bikeway through new tunnel.

This option involves right-of-way (ROW) impacts to three properties. The three properties are owned by the State of Connecticut (approximately 200,00 square feet that does not affect acquisition cost), the City of New Haven Park (approximately 50,000 square feet), and the City of New Haven Nature Center, which is geographically located within the Town of Hamden's borders (approximately 200,000 square feet) totaling approximately 450,000 square feet. Assuming an estimated cost of $4 per square foot for the 250,000 square feet not owned by the state, this results in property acquisition costs of approximately $1 million, and includes a new bridge, reconstruction of a salt storage facility for CTDOT, and rebuilding an access road for the City of New Haven Nature Center. This acquisition cost does not include construction staging and laydown area, which has not yet been quantified. The construction cost of this option is $8,267,974 (**Appendix F1**) not including the tunnel.

8.2 Option 2 – New Two-Lane Tunnel

Option 2 requires new alignment along Route 15 (See **Table 8.1** and **Table 8.3** for design standards). This can be seen in **Appendix C3** (Option 2 Geometry) and **Appendix C4** (Option 2 Profile). As part of the new alignment, a realignment of the entrance ramp just to the west of the tunnels is necessary. Additionally, enhanced crossovers must be constructed to shift traffic in accordance with the following sequence of construction and these can also be seen in Appendix C3.

Proposed sequence of construction:

1. Maintain traffic in existing tunnels, construct new tunnel, new tunnel alignment, and new enhanced crossovers.
2. Shift northbound traffic to new tunnel and new alignment, maintain southbound traffic in existing southbound tunnel, close existing northbound tunnel, and rehabilitate existing northbound tunnel.
3. Shift southbound traffic to newly rehabilitated northbound tunnel via newly constructed crossovers maintaining northbound traffic in new tunnel. Rehabilitate southbound.
4. Shift northbound and southbound traffic back to their respective newly rehabilitated tunnels, maintain new tunnel as the entrance ramp, bringing traffic into mainline after the tunnel. Put bikeway through new tunnel.

This option involves ROW impacts to three properties. The three properties are owned by the State of Connecticut (approximately 200,00 square feet that does not affect acquisition cost), the City of New Haven Park (approximately 50,000 square feet), and the City of New Haven Nature Center, which is geographically located within the Town of Hamden's borders (approximately 200,000 square feet) totaling approximately 450,000 square feet. Assuming an estimated cost of $4 per square foot for the 250,000 square feet not owned by the state, this results in property acquisition costs of approximately $1 million, and includes a new bridge, reconstruction of a salt storage facility for CTDOT, and rebuilding an access road for the City of New Haven Nature Center. This acquisition cost does not include construction staging and laydown area, which has not yet been quantified. The construction cost for this option is $10,793,029 (**Appendix F2**) not including the tunnel.

8.3 Option 3 – Widen Existing Tunnel

This option does not require new alignment, but requires shifting traffic in order to widen the existing tunnels. In order to shift traffic, the enhanced crossovers discussed in Options 1 and 2 will be constructed to serve this function.

8.4 Option 4 – Close One Existing Tunnel and Detour

This option does not require any roadway work. All detours are analyzed on existing roadway networks.

8.5 Option 5 – Close One Lane in Existing Tunnel

This option does not require any roadway work. This option assumes reduced capacity through the tunnel as a result of lane closures.

8.6 Route 40 / 15 Interchange

As part of this study, a concept sketch of a proposed interchange between Route 15 and Route 40 was analyzed. The concept is to provide access from northbound Route 40 to eastbound Route 15 and from westbound Route 15 to southbound Route 40. This concept sketch can be seen in **Appendices C5** and **C6** and the design standards are shown in **Table 8.4**.

This interchange concept will result in impacts to six residential properties, one of which is a total take, consisting of approximately 80,000 square feet at $4 per square foot totaling $320,000.

8.7 Design Standards

Roadway design standards and proposed dimensions used in the development of alignments for crossovers, new tunnel barrel approaches, roadway conditions within the proposed tunnels, and the conceptual interchange between Route 40 and Route 15 are developed in accordance with the "Connecticut Department of Transportation's Guidelines for Highway Design Manual, 2003 Edition," supplemented by AASHTO's "A Policy on Geometric Design of Highways and Streets, 2011."

Table 8.1: Route 15 –New Tunnel Approaches and Crossovers

Description	Design Standard	Proposed
Design Classification	Rural Freeway	
Design Speed	70 MPH	70 MPH
Minimum Allowable Radius for Classification	2050'	5000'
Maximum Grade	4%	2.7%
Maximum Superelevation	6.0%	4.0%
Superelevation runoff (L)	111'	111'
Tangent Runout	60'	60'
Minimum distance between PT and PC on Reverse Curves	270'	270'
Lane Width	12'	12'
Shoulder Width	Right: 10' Left: 8' (4' paved , 4' graded)	Right: 10' Left: 8'
Minimum Length of Auxiliary Lane Merging Taper	840'	900'

Table 8.2: Route 15 –Option 1 – One-Lane Tunnel (Inside Tunnel in the Final Condition)

Description	Design Standard	Proposed
Design Classification	Rural Freeway	
Design Speed	70 MPH	70 MPH
Minimum Allowable Radius for Classification	2050'	NA – On tangent
Maximum Grade	4%	2.7%
Maximum Superelevation	6.0%	NA – On Tangent
Lane Width	12'	12'
Shoulder Width	Right: 10' Left: 8' (4' paved , 4' graded)	Right: 6' * Left: 4' *
Elevated Curb / Safety Walk	Right: 4' Left: 4'	Right: 11' (10' w/ 1' for rail) Left: 4'
Overhead Clearance	14'-6" (per Figure 9-4 of the CTDOT Highway Design Manual)	Varies but at all times greater than 14'-6"

* TBM diameter necessitates narrower shoulders inside tunnel

Table 8.3: Route 15 –Option 2 – Two-Lane Tunnel (Inside Tunnel in the Final Condition)

Description	Design Standard	Proposed
Design Classification	Rural Freeway	
Design Speed	70 MPH	70 MPH
Minimum Allowable Radius for Classification	2050'	NA – On tangent
Maximum Grade	4%	2.7%
Maximum Superelevation	6.0%	NA – On Tangent
Lane Width	12'	12'
Shoulder Width	Right: 10' Left: 8' (4' paved , 4' graded)	Right: 4' * Left: 4' *
Elevated Curb / Safety Walk	Right: 4' Left: 4'	Right: 4' Left: 4'
Overhead Clearance	14'-6" (per Figure 9-4 of the CTDOT Highway Design Manual)	Varies but at all times greater than 14'-6"

* TBM diameter necessitates narrower shoulders inside tunnel

Table 8.4: Route 15 and Route 40 Interchange

Description	Design Standard	Proposed
Design Classification	Rural Freeway	
Design Speed	70 MPH	70 MPH
Entrance Ramp to Freeway Transition radius for outer connection	510'	510'
Entrance Ramp to Freeway Transition radius for loop	150'	150'
Design speed for direct ramp	60 MPH	60 MPH
Minimum radius of direct ramp	1340'	1340'
Max Superelevation	6%	6%
Design Speed of Loop Ramp	25 MPH	25 MPH
Radius of loop	145' min	145'
Radius of transition curve = 1.5 x Loop Radius	217.5'	217.5'
Length of Transition Curve	48' min 68' upper range	68'
Grade Range on Loop Ramp	6-8% max	3.3% upgrade
Grade Range on Direct Ramp	3-5% max	2.5% downgrade
Loop Ramp Decel Lane Length	495'	495'
Loop Ramp Accel Lane Length	852'	852'
Direct Ramp Decel Lane Length	340'	340'
Direct Ramp Accel Lane Length	580'	580'

8.8 Endangered Species

The Heroes Tunnel location (West Rock Park) is within a "State and Federal Listed Species & Significant Natural Communities" area as designated by the Connecticut Department of Energy and Environmental Protection (DEEP). A map (**Appendix C7**) shows the general locations of State and Federal Listed Species and Significant Natural Communities in the New Haven and Hamden, Connecticut areas. The shading over the Heroes Tunnel area shows that there may be a potential conflict with a listed species.

The area around the Heroes Tunnel is also listed as a critical habitat by DEEP. The area includes Dry Subacidic Forest (DSF) and Subacidic Rocky Summit Outcrop (SubRSO) designations, which are two of twenty-five rare and specialized wildlife habitats in the state. **Appendix C8** shows these critical habitat locations within the project area.

During design stage, further investigation would be required to ensure that project work is in compliance with all DEEP and federal regulations regarding listed species and critical habitats.

TAB PAGE

Section 9

Evaluation of Vehicle Height Warning Systems

Beyond basic signage indicating the heights of upcoming bridges and tunnels, there are a range of devices that have been implemented to enhance safety and avoid collisions from over-height vehicles impacting bridges and tunnels. The most basic over-height vehicle detection systems are described in this memo, along with more advanced detection and warning systems that can be integrated with other traffic sensors to collect traffic data.

9.1 Basic Over-height Vehicle Detection Systems

9.1.1 Rigid Passive Overhead Device

Immovable rigid crossbeams, sometimes called "headache bars," set across the road at the clearance height are a basic way of warning trucks of their over-height condition when the truck strikes the crossbeam. A clear disadvantage is the damage this causes trucks, with ensuing danger to following vehicles. In some cases rigid passive devices are installed an additional measure of security to supplement an active over-height detection system.

9.1.2 Nonrigid Passive Overhead Device

The most common form of nonrigid passive overhead devices is a set of hanging chains or signs suspended from a span wire or beam. However, a range of anecdotal reports in the literature suggest that this type of system does not result in fewer overhead collisions. This is likely because drivers may not hear the chains or sign contacting the vehicle over the background engine noise, or they may not identify the meaning of the noise if detected. Active devices that alert drivers and give an opportunity to bypass the hazard or turn around have had far more success.

9.2 Active Vehicle Height Detection and Warning Systems

9.2.1 System Overview

Active vehicle height detection and warning systems are comprised of two main features – a detection device, often employing infrared beams, that identify when an over-height vehicle is approaching the tunnel or bridge, and a warning system that can include audible bells or projected warnings, as well as flashing beacons (**Figure 9.1**). The most effective systems are located sufficiently far away from the bridge or tunnel so that a message is delivered early enough for the driver to see it and make a decision. Furthermore, the most effective systems also include signage to direct the driver to a turnoff after being alerted to the hazard ahead yet well in advance of the bridge or tunnel. In the context of the Heroes Tunnel, this would mean that a warning system would need to be located in advance of the last acceptable turn-off as well as at the ramps entering Route 15 in each direction just prior to the tunnel.

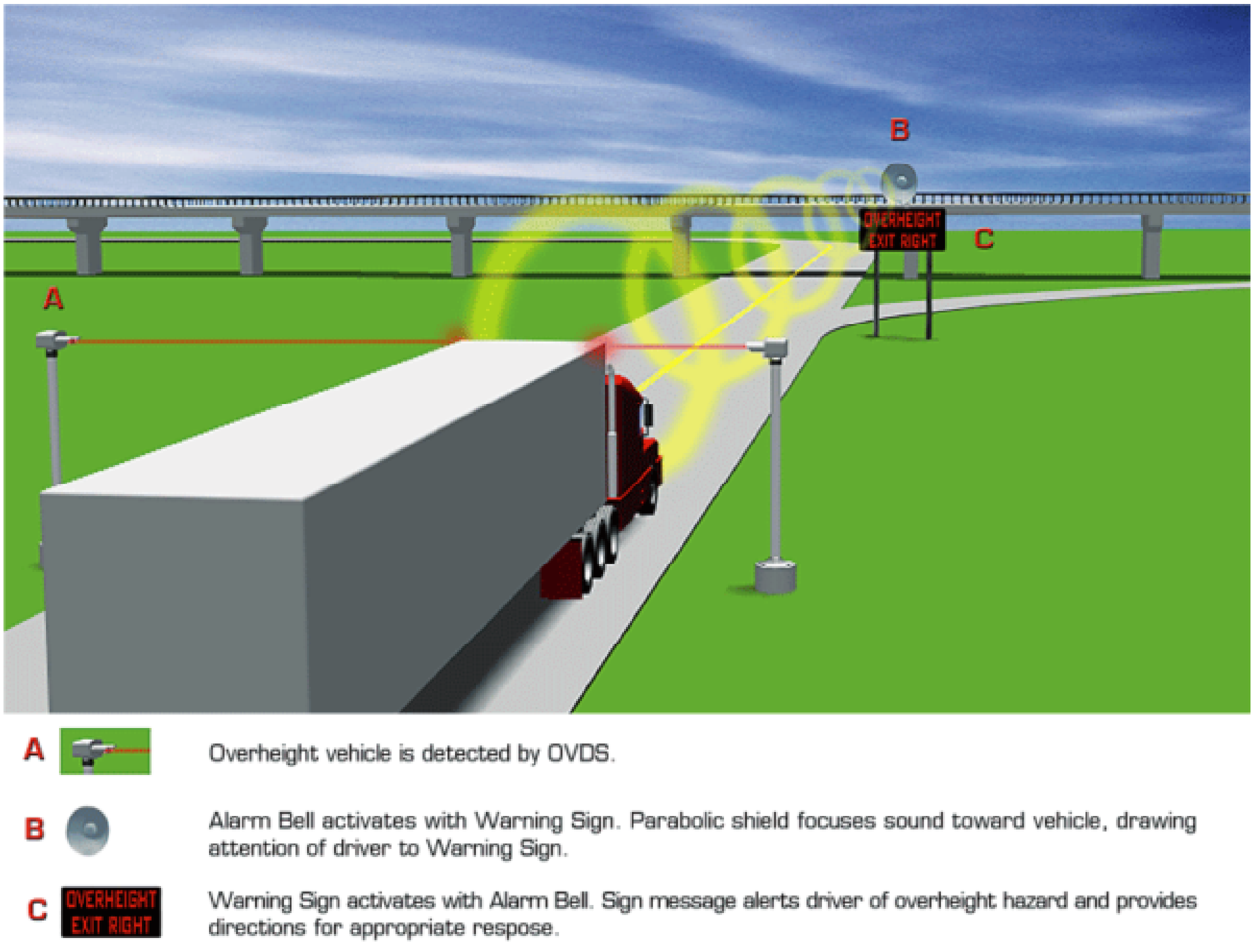

Figure 9.1: Typical Installed Configuration of an Active Detection System
[Photo credit: Trigg Industries; OVDS = over-height vehicle detection system, used with permission]

9.2.2 Sensing Mechanisms

Active overhead vehicle sensing systems can use a range of sensing mechanisms, which are summarized in **Table 9.1**. Optoelectric sensors use the emission and interruption of a beam of light, whereas ultrasonic sensors use sound waves to assess height.

Table 9.1. Sensing Mechanisms for Active Overhead Vehicle Sensing Systems (adapted from Sinfield, 2010)

Sensing approach	Types	Configuration	How it works	Pros	Cons
Ultrasonic	Overhead profiling	Emitters and detectors are mounted above roadway	All vehicles interrupt an ultrasound wave and are measured for height	Perform well in a range of weather conditions. Can be easily setup compared to optoelectric systems	May not detect small protruding vehicle parts that may collide with bridge or tunnel; rarely deployed
Optoelectric	Visible beam	Emitters and detectors are mounted on sides of roadway	Over-height vehicles interrupt a beam of visible light at a predefined height threshold	Low cost	Low performance – influenced by ambient light and weather
Optoelectric	Infrared beam	Emitters and detectors are mounted on sides of roadway	Over-height vehicles interrupt a light beam or laser beam in the infrared spectrum emitted at a predefined height threshold	Perform well in a range of weather conditions and are longer-range than visible beam-based systems[2]	Line of sight could be an issue under poor weather conditions

In general, the most robust systems appear to be infrared based optoelectric sensors that are configured in an opposed dual mode or "Z" beam pattern, where two pairs of aligned infrared emitters and receivers are installed on opposite sides of the roadway (Sinfield, 2010). This configuration minimizes environmental interference.

The key factors that differentiate various systems and likewise impact cost include:

- Range of allowable vehicle speeds
- Transmitter / receiver configuration - directional sensitivity
- Optical transmission / detection range
- Video capability
- False positive check
- Warning system sophistication, including back-up system
- Power requirements
- Environmental robustness
- Installation requirements and simplicity

Systems using the infrared beam perform better than the ultrasonic and the visible beam mechanisms when considering the above factors. A video monitoring system can be installed to compliment any of the systems for security reasons. Systems are available that can be monitored from a remote control center.

The main suppliers of overhead detection and warning systems are:

- ASTI Transportation Systems (USA) – infrared based sensors
- Banner Engineering (USA) – optical based sensors in the red visible spectrum
- Coeval Group (UK) – infrared based sensors
- International Road Dynamics Inc. (Canada) – supplies Trigg Industries' infrared-based sensors

- Measurement Devices Ltd. (Scotland)
- Peter Berghaus GmbH (Germany)
- Schuh & Co. GmbH (Germany)
- Sick-Maihak (USA) – infrared laser-based sensors
- Trigg Industries Inc. (USA) – infrared-based sensors
- Laser Tech – infrared laser-based sensors

The specifications of some of the major optoelectric sensors is provided in Sinfield (2010) and reproduced in Appendix Table A1. The two lead manufacturers are ASTI Transportation Systems and Trigg Industries Inc.

9.2.3 Success Rates

There is no quantitative data in the peer-reviewed literature assessing the comparative performance of the range of systems described in this memo. Reports of the impacts of such systems tend to be anecdotal. A researcher from the University of Texas conducted a survey of departments of transportation (DOTs) to find that, out of 29 DOTs that responded, 9 states have implemented active detection and warning systems. All of these DOT respondents felt that the systems reduced over-height impacts, though data to demonstrate this effect was not available (Mattingly, 2003).

9.2.4 Summary of Over-height Vehicle Detection Technologies

Table 9.2 summarizes the features of technologies that can be used to detect over-height vehicles to avoid infrastructure collisions, which were described in Sections 1 and 2.

Table 9.2 Comparison of Strategies to Reduce Over-height Infrastructure Collisions (adapted from Mattingly, 2003) – red indicates that a technology does not perform the function indicated, yellow is partial performance, and green is good performance

Solution	Power required?	Substantially reduces collisions	Provides additional traffic data	Cost[1]
Warning signs and lights	Yes			$
Rigid passive overhead device	No			$ to $$
Nonrigid passive overhead device	No			$ to $$
Active detection and warning systems[2]	Yes			$$ to $$$

[1] Cost ranges are represented as follows: $ - thousands of dollars, $$ - thousands to tens of thousands, and $$$tens of thousands and higher.

[2] Category includes visible acoustic sensors, light beam sensors, and infrared sensors.

9.3 Advanced Traffic Data Collection Systems

Vehicle height detection and warnings can also be integrated into intelligent transportation systems (ITS) that provide a wider range of transportation data. ITS can include vehicle detection and surveillance technologies that measure the speed, presence, count, gap, headway, height, classification, and weight of vehicles as well as lane occupancy. It is important to note that all of the vendors interviewed for this memo stressed that to capture both over-height vehicle detection as well as traffic data, it is necessary to integrate a dedicated active vehicle height detection and warning system with a dedicated traffic data collection system. There is not one technology that is designed to do both. While a limited number of traffic data collection systems can capture some vehicle height information for classification purposes, the detectors in these systems are not suitable for over-height detection, since over-height detection applications require a near zero-false negative result in real-time.

Traffic data collection systems contain three basic components – a transducer that detects the presence of a vehicle, a signal processing device, and a data processing device. **Table 9.3** compares the method of operation, advantages and disadvantages, types of data collected, and cost of different advanced traffic data collection technologies. Appendix D includes a detailed description of each of the technologies.

9.4 Systems that Integrate Multiple Technologies

Technologies can be used together to generate a suite of data. For example, the TDC3 system by ADEC technologies measures vehicle speed, length and height in each lane by combining radar, passive infrared, and ultrasonic detectors (roadtraffic-technology.com, N.D.). It is important to note that this system alone would have to be additionally integrated with an over-height detection system, as the height captured by the TDC3 system is merely for classification purposes and could not be relied upon for real-time exact height measurement. To accomplish this, the ADEC system would have to be connected to an over-height vehicle detection system that is equipped with a programmable serial (RS 485 or RS 232) port to retrieve the traffic data.

The Measure-in-Motion® Vehicle Detector by Betamont incorporates infrared and optical sensors to measure vehicle height, cameras to recognize vehicle number plates, and inductive loops and weight sensors installed in the roadbed to measure speed and weight (Betamont, N.D.). Like the ADEC system, the Betamont system is not designed for real-time over-height vehicle detection but could be integrated with a dedicated system for that purpose.

International Road Dynamics (IRD) specializes in the design and manufacturing of electronics and custom software to integrate both in-roadway and over-roadway technologies with over-height detection. IRD typically uses a Trigg infrared-based over-height detector with weigh-in-motion piezoelectric-based in-roadway technology for the type of application in the Heroes Tunnel case. IRD can also integrate over-roadway traffic counter/classifiers such as radar-based or Doppler based sensors with over-height detectors.

Table 9.3: Comparison of Advanced Traffic Data Collection System Technologies (adapted from Leduc, 2008 and Mimbela and Klein, 2007)

Category	Sensor Type	How it works	Pros	Cons	Data collected						Cost[1]
					Vehicle Weight	Vehicle Count	Vehicle Speed	Vehicle Classification	Lane Occupancy	Vehicle Height	
In-roadway	Pneumatic road tube	Air pressure pulse	Inexpensive	Not designed for long-term use or on highways		Yes	Yes	Yes			$
	Inductive loop detectors	Change of inductance of a loop embedded in the roadway	Proven technology	Susceptible to wear and tear of traffic and weather		Yes	Yes	Yes	Yes		$$
	Magnetic sensors	Change the magnetic field of a sensor embedded in the roadway		Susceptible to wear and tear of traffic and weather		Yes	Yes		Yes		$$
	Piezoelectric sensors	Material deflection (piezoelectric)	Higher speed range (up to 70 mph) than other weigh-in-motion (WIM) systems	Lower accuracy than other WIM systems; wear-and-tear	Yes	Yes	Yes[2]	Yes[2]	Yes		$$-$$$
	Bending plate sensors	Plate deflection (physical)	More accurate than piezoelectric WIM systems	More expensive than piezoelectric systems	Yes	Yes	Yes[2]	Yes[2]	Yes		$$$
	Load cell	Hydraulic scale	More accurate than piezoelectric WIM systems	Most expensive WIM system	Yes	Yes	Yes[2]	Yes[2]	Yes		$$$
	Capacitance mat	Compression of sandwiched metal sheets		Less accurate than other WIM systems; high cost	Yes	Yes	Yes[2]	Yes[2]	Yes		$$$

Table 9.3: Comparison of Advanced Traffic Data Collection System Technologies (adapted from Leduc, 2008 and Mimbela and Klein, 2007)

Category	Sensor Type	How it works	Pros	Cons	Data collected						Cost[1]
					Vehicle Weight	Vehicle Count	Vehicle Speed	Vehicle Classification	Lane Occupancy	Vehicle Height	
Over-roadway	Video image processing	Video data is processed and interpreted by software	Does not disrupt traffic in installation	Vulnerable to obstructions and weather		Yes	Yes	Yes	Yes		$
	Microwave radar	Reflection of microwave beams	Insensitive to weather; robust; requires a single emitter/detector			Yes	Yes		Yes		$
	Passive infrared	Detect energy emitted by passing objects		Low accuracy		Yes	Yes[3]	Yes[3]	Yes[3]		$
	Active infrared	Detect interruption of an emitted infrared beam	Established technology	Can be sensitive to weather; requires multiple emitter/detectors		Yes	Yes[3]	Yes[3]	Yes[3]	Yes[4]	$$
	Ultrasonic	Transmission of and detection of reflected sound waves		Sensitive to weather; best at low speeds		Yes	Yes[3]		Yes	Yes	$
	Passive acoustic	Detection of sound of passing objects		Sensitive to weather; low accuracy		Yes	Yes[3]		Yes		$-$$

1 Cost ranges are represented as follows: $ - thousands of dollars, $$ - thousands to tens of thousands, and $$$ - tens of thousands and higher.
2 When integrated with an inductive loop sensor.
3 When multiple elements are integrated as an array.
4 Only if the system includes a dedicated infrared sensor for over-height detection, along with additional infrared sensors for traffic data.

ASIM Technologies (part of Xtralis) manufactures a traffic detector that combines passive infrared, microwave radar, and ultrasonic detectors in one overhead-mounted device. The passive infrared detector is used to detect vehicle presence which then activates the ultrasonic and radar emitters to deploy, which helps to prolong the life of the transmitters. The ultrasonic transmitter then determines the height of the vehicle and the microwave radar transmitter detects vehicle speed. The three technologies are mounted in a single device, pointed at different angles along the lane. This device works at highway speeds of up to 150 mph.

9.5 Recommended Technologies

If no traffic data is required, an advanced over-height detection system based on infrared sensors would be recommended (Option A). Option A would provide a robust method to detect over-height vehicles and warn the drivers to exit the highway.

To provide additional traffic data, the type of system used in Option A would need to be supplemented with an additional dedicated traffic data detector system. There is not a single sensor that can both accurately detect over-height vehicles and collect traffic data simultaneously. The most robust over-height detection systems are infrared-based sensors, so the recommendation would be to combine that type of system with a video image processing traffic data collection system (Option B). **Table 9.4** summarizes the two options that are recommended in the Heroes Tunnel context.

Table 9.4. Options for Heroes Tunnel Over-height Vehicle Detection plus Traffic Data Collection

Option	Sensor Type	Provides additional traffic data	Cost[1]
A	Infrared based over-height detection and warning system alone		$$$
B	Infrared based over-height detection and warning system plus a video image processing traffic data system		$$$ to $$$$

[1] Cost ranges are represented as follows: $ - hundreds of dollars, $$ - thousands of dollars, $$$ - $10,000, and $$$$ - $100,000 or more.

Further evaluation of specific vendors and system configurations could be conducted based on client feedback on the specific type of traffic data that would be valuable to collect at this location.

9.6 Resources Searched

The following databases and literature sources were searched to prepare this write-up:

- American Society of Civil Engineers online library http://ascelibrary.org/
- Engineering Village http://www.engineeringvillage.com
- Science Direct http://www.sciencedirect.com
- TRID transportation database http://trid.trb.org/
- EU transportation research portal http://www.intransport.eu/search/index.php
- Knovel online library http://app.knovel.com/web/
- Web searches using Google and Google Scholar
- Vendor interviews: ADEC Technologies, ASIM Technologies (part of Xtralis), ASTI Transportation Systems, Banner Engineering, Coeval Group, International Road Dynamics (IRD), Sick-Maihak Trigg Industries Inc., Wavetronix

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Section 10
Conclusions

Table 10.1 summarizes the costs of each of the construction options described in **Sections 2-5, 7,** and **8**. The methods used to develop the costs are outlined in **Sections 1, 7,** and **8**.

Table 10.1 Costs of Each of the Construction Options ($2019)

Construction Option	Estimated Costs (million $2019)					
	New tunnel construction or tunnel widening	Tunnel rehabilitation	Highway modifications construction	Engineering	ROW	Delay[3]
1	55[1]	N/A	13	7	2	0
2	65[1]	N/A	17	8	2	0
3	70[2]	N/A	1	7	0	0
4	N/A	27	0	3	0	2-800
5	N/A	28	0	3	0	1-3

[1] For drill-and-blast excavation method, as recommended in Section 2.5. Includes abandonment of existing vent shaft and demolition of CTDOT District 3 Maintenance storage building.
[2] For drill-and-blast excavation and enlargement method, as recommended in Section 3.5.
[3] Ranges represent the rule-of-thumb method presented in Section 7.2.6 (lower end of range) and the rigorously calculated estimate based on the FHWA method presented in sections 7.2.1-7.2.5 (upper end of range). Values have been rounded.

Table 10.2 summarizes the non-cost impacts of each of the construction options described in Sections 2-6.

Table 10.2 Non-cost Impacts of Each of the Construction Options

Construction Option	Non-Cost Impacts				
	Construction complexity rating[1]	Traffic impact rating[2]	Construction duration (months)	Anticipated Useful Life (years)	
				New Tunnel	Existing Tunnel
1	3 to 4	0	12.5[3]	100[4]	N/A
2	3 to 4	0	16[3]	100[4]	N/A
3	7	0	53[3]	100[4]	N/A
4	3	10	24	-	100[5]
5	8 to 9	5	20	-	100[5]

[1] Rating system: 1 is low complexity, 10 is very high complexity.
[2] Rating system: 0 is no traffic impact, 10 is very high traffic impact.
[3] For drill-and-blast excavation method.
[4] For new tunnels, the anticipated useful life is estimated to be 100 years.
[5] There are two estimates for anticipated useful life for rehabilitation of the existing tunnel, which depend on the concrete lining designed. If the new protection lining is designed to carry the full load the useful life is 100 years. If the new protection lining is designed for a fraction design load, the useful life is approximately 15 to 20 years.

10.1 How the Five (5) Construction Options would be Combined for Six (6) Construction Sequencing Scenarios

The five alternative construction and rehabilitation options were described in Sections 2 through 5. In order to achieve the goal of providing at least three traffic lanes through the existing or new tunnels, the following construction scenarios are possible, which combine some of the options described:

Construction Scenario A	Construct a new single barrel tunnel (Option 1) and subsequently rehabilitate both existing barrels in a staggered approach (minimal traffic impact). This results in 5 lanes in the future.
Construction Scenario B1	Construct a new double lane single barrel tunnel (Option 2) and subsequently rehabilitate one of the two existing barrels (minimal traffic impact); abandon non-rehabilitated barrel. This results in 4 lanes in the future plus a non-rehabilitated 2-lane tunnel that could potentially be used for storage by installing bulkheads at each portal to prevent access of pedestrians and traffic through the tunnel.
Construction Scenario B2	Construct a new double lane single barrel tunnel (Option 2) and subsequently rehabilitate both of the two existing barrels (minimal traffic impact). This results in 6 lanes in the future.
Construction Scenario C	Enlarge one barrel of the existing tunnel (Option 3) and subsequently rehabilitate the other existing barrel (minimal traffic impact). This results in 5 lanes in the future.
Construction Scenario D	Rehabilitate both of the existing barrels with a complete shutdown of one barrel, followed by a complete shutdown of the other barrel (Option 4). This results in 4 lanes in the future.
Construction Scenario E	Rehabilitate both of the existing barrels with a partial shutdown of one barrel, followed by a partial shutdown of the other barrel (Option 5). This results in 4 lanes in the future.

10.2 Cost-benefit Analysis for the Construction Sequencing Scenarios

Table 10.3 summarizes the costs and benefits of each of the construction sequencing scenarios.

Table 10.3 Costs and Benefits of Each of the Construction Sequencing Scenarios

Construction Scenario	Cost estimate(million $2019)[1]	Duration (months)	Monetized Benefits	Non-Monetized Benefits
A[2]	106	37	Avoid $1-800 million in delay costs associated with Options 4 and 5	Avoid complex construction; Additional capacity in the future; Minimal traffic disruption
B1[3]	108	28	Avoid $1-800 million in delay costs associated with Options 4 and 5	Avoid complex construction; Minimal traffic disruption
B2[4]	120	40	Avoid $1-800 million in delay costs associated with Options 4 and 5	Avoid complex construction; Additional capacity in the future; Minimal traffic disruption
C[5]	91	65	Avoid $1-800 million in delay costs associated with Options 4 and 5	Additional capacity in the future; Minor traffic disruption
D[6]	30	24	Lowest construction/rehabilitation cost of any of the options (but extremely high traffic impacts and associated delay costs)	Avoid complex construction
E[7]	31	20	Avoid $2-800 million in delay costs associated with Option 4	Avoid significant traffic disruption

[1] Here, the "cost estimate" includes construction, engineering, and ROW costs. This value does not include delay costs.
[2] The cost of this scenario includes the construction, engineering, and ROW costs of option 1 ($50 million) plus the construction, engineering, and ROW costs of option 4 ($26 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[3] The cost of this scenario includes the construction, engineering, and ROW costs of option 2 ($60 million) plus half of the construction, engineering, and ROW costs of option 4 ($13 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[4] The cost of this scenario includes the construction, engineering, and ROW costs of option 2 ($60 million) plus the construction, engineering, and ROW costs of option 4 ($26 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[5] The cost of this scenario includes the construction, engineering, and ROW costs of option 3 ($67 million) plus half of the construction, engineering, and ROW costs of option 4 ($13 million). The cost of option 4 is reduced by the cost of the proposed detour which would be unnecessary in this scenario. The duration is calculated similarly.
[6] The cost of this scenario includes the construction, engineering, and ROW costs of option 4 ($26 million). The duration is the duration estimated for option 4 (24 months).
[7] The cost of this scenario includes the construction, engineering, and ROW costs of option 5 ($28 million). The duration is the duration estimated for option 5 (20 months).

10.3 Summary of the Overall Evaluation of the Construction Sequencing Scenarios

The five construction sequencing scenarios are rated in **Table 10.4** against the criteria identified in the scope of work.

Table 10.4 Non-cost Impacts of each of the Construction Options. (Green indicates preferable conditions, yellow indicates moderate conditions, and red indicates negative conditions.)

Construction Sequencing Scenario	Impact on traffic	Cost estimate[1]	Construction duration	Construction complexity	Anticipated Useful Life	Number of lanes open at project completion
A	Green	Yellow	Yellow	Green	Green	5
B1	Green	Yellow	Yellow	Green	Green	4
B2	Green	Red	Yellow	Green	Green	6
C	Green	Yellow	Red	Red	Green	5
D	Red	Green	Green	Green	Green	4
E	Yellow	Green	Green	Red	Green	4

[1] Here, the "cost estimate" includes construction, engineering, and ROW costs. This value does not include delay costs.

Scenario D is not viable due to major traffic impacts and high delay costs. Scenario C is not viable because of higher construction cost, duration, and complexity.

Scenarios A, B1, and B2 have higher cost than scenario E, but scenarios A, B1, and B2 may be viable since they offer lower traffic impacts and lower complexity than Scenario E. Scenarios A and B2 provide the ancillary benefit of additional capacity in the future. Although scenario B1 represents cost and duration savings compared to scenario A or B2 since only one of the existing tunnels will be rehabilitated, scenario B1 has a disadvantage compared to scenario A and B2 in that one tunnel is abandoned in a state of deterioration, whereas both tunnels are rehabilitated in scenarios A and B2. This disadvantage can be addressed by planning for scheduled inspection and maintenance of the abandoned tunnel. To prevent any access of pedestrians and the traffic into the abandoned tunnel, bulkhead with access doors for CTDOT staff can be installed at both portals.

Scenario B2 provides a new two barrel tunnel and rehabilitation of both existing tunnels. This would increase the capacity of the tunnel for future and in case of any future maintenance work there would be no impact on traffic. However, the cost and duration are higher than all other options excepting Scenario C. A drawback to the additional capacity provided by scenario B2 is that the configuration results in three two-lane tunnels. Since the middle tunnel cannot be split down the middle to allow traffic to travel in both directions due to safety, the result would be 4 lanes of traffic in one direction and 2 lanes of traffic in the other direction. This setup would be valuable in highly urbanized areas with unidirectional traffic loads during rush hour, but this is not the reality in the vicinity of the Heroes Tunnel. Thus, the excess capacity under scenario B2 might not be very valuable in terms of providing regional traffic relief.

10.4 Recommended Approach

CDM Smith recommends further consideration of two of the construction scenarios: scenarios A and E. Scenario E achieves the main objective of the project (tunnel rehabilitation) at the lowest cost. Scenario A meets the objective of the project while also providing a new tunnel with one lane of extra capacity in the future.

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Section 11
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Appendix A

Tunnel Boring Machines

Appendix A

Tunnel Boring Machines and Tunnel Support for Construction of New Tunnels

A.1 Introduction

This section will cover some basic information about various types of rock tunnel boring machines (TBM) and various tunnel support systems.

A.2 TBM Classification

Figure 1 shows a general classification of various types of TBMs for hard rock and soft ground.

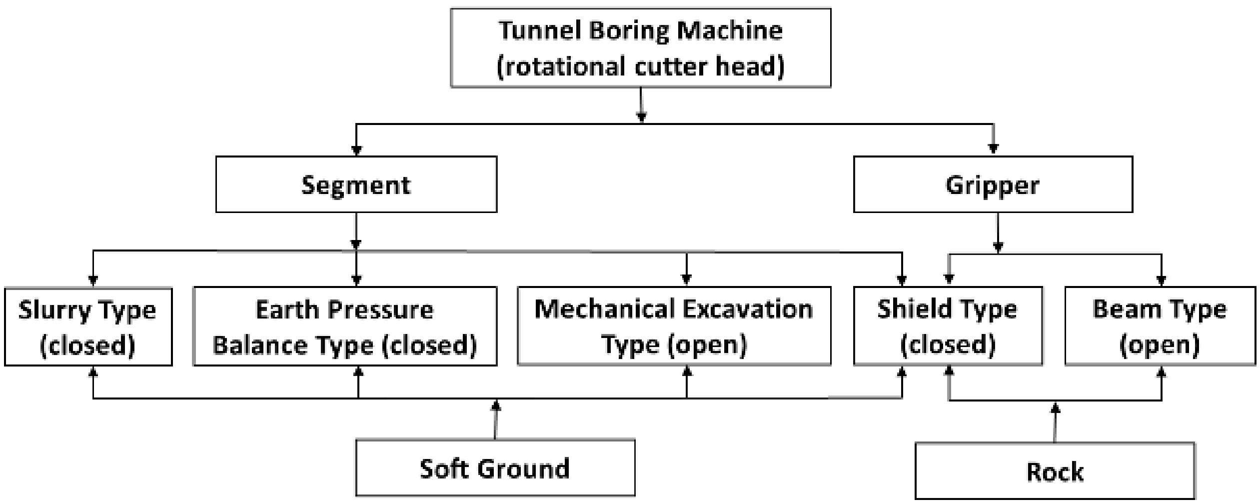


Figure 1: Classification of Tunnel Boring Machines

As shown on Figure 1 there are a variety of TBMs that can be classified as: a) closed-face TBMs and b) open mode TBMs. Since the subsurface condition for Heroes Tunnel consists of basalt rock, we only focus on TBMs suitable for tunneling in medium to hard strength rocks.

A.2.1 Closed-Face TBM

The two most appropriate closed-face TBMs for tunneling in medium to hard rock formations are:

1. Single shield TBM
2. Double shield TBM

Single shield TBMs have an unpressurized face and can efficiently excavate brittle rock. The TBM is protected within a shield and is advanced by hydraulic thrust cylinders pushing off the last completed reinforced concrete segmental lining . The rock is broken at the face by the rotating cutter head and spoil is collected and placed in a conveyor for transfer out of the tunnel.

When tunneling with a single shield TBM, a rotating cutterhead equipped with disc cutters is pressed against the tunnel face with a pressure of up to 30 tonnes per disc. Due to the rolling movement of the discs, single pieces, called chips, are broken out of the rock. Water jets can cool the cutting tools and reduce dust formation. Buckets installed at the cutterhead take up the excavated material. Due tothe gravity, it slides to the center of the machine through integrated muck chutes while the cutterhead rotates and then falls through the funnel-shaped mucking ring onto the machine belt. At the end of the machine belt, the rock chips are passed on to belt conveyors or transport vehicles and removed from the tunnel. **Figure 2** presents the details of the single shield TBM.

The single shield machine is capable of tunneling in soft rock to brittle rock to hard basalt. The machine diameter ranges from 5 feet to 50 feet. The main advantages of this machine are:

- High advance rates can be achieved depending on the characteristics of the rock and consistency of those same characteristics along the length of the tunnel alignment
- Optimum tunneling safety in brittle, non-stable rock formations
- Usable in groundwater bearing geologies with prior soil conditioning

The main disadvantages of this tunneling method are:

- The high cost of renting or buying a machine for a short tunnel (less than a mile)
- Requires a large working area (between 3 to 4 acres)
- Requires skilled crews for operation of the machine compared to open face machine (main beam)
- The machine mobilization and demobilization are time-consuming compared to open face machine
- Large amount of wasted volume of excavation because the top of road is close to the tunnel springline

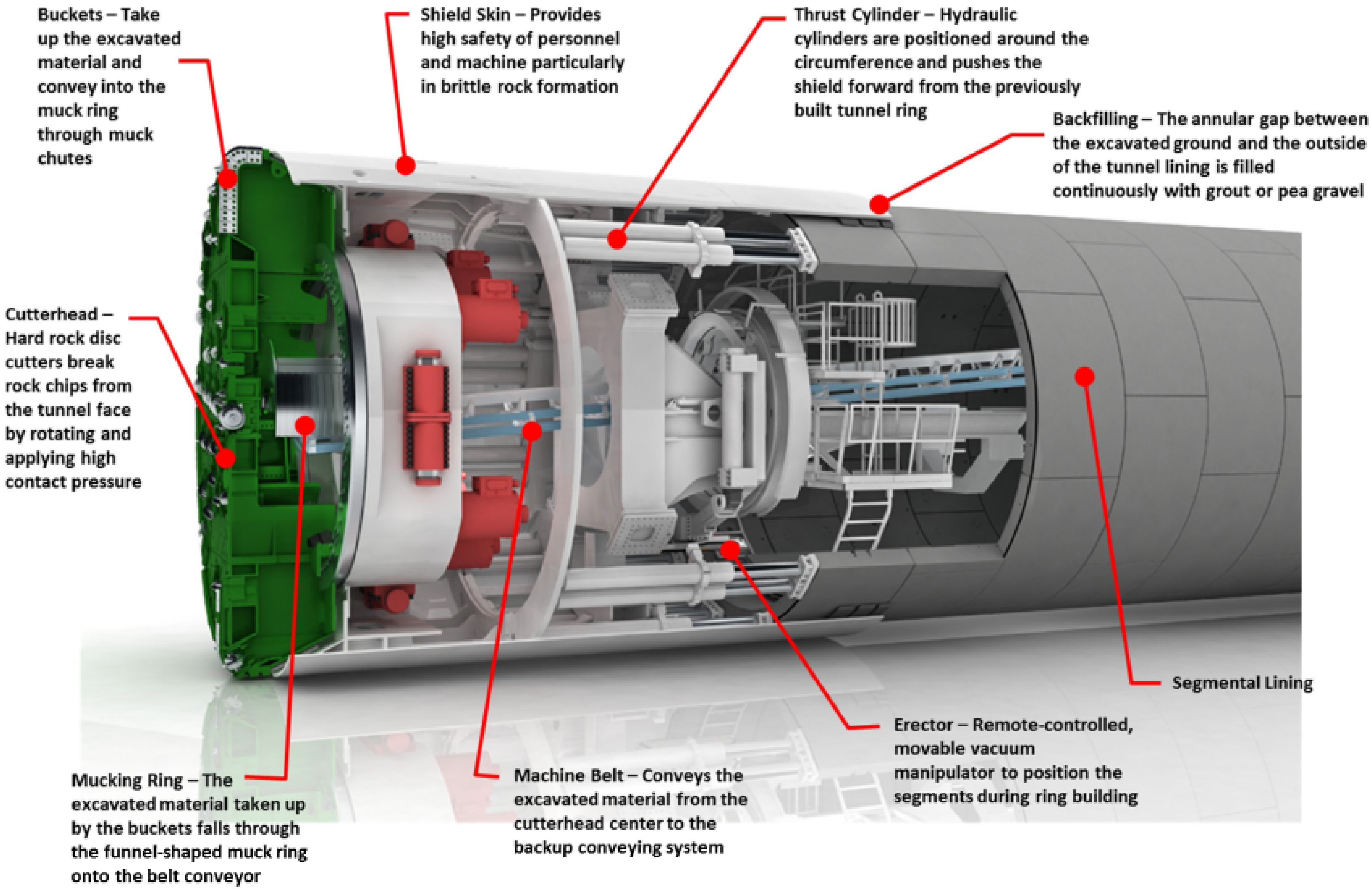


Figure 2. A Typical Single Shield Segmental Lining Machine Manufactured by Herrenknecht (diameter 29.5 feet) (Source http://www.herrenknecht.com/en/products/core-products/tunnelling-pipelines/single-shield-tbm.html)

Double shield TBMs are among the most technically sophisticated TBMs used for tunnel excavation. These machines have distinct modes of operation depending on ground conditions. When operated in double shielded mode, in favorable ground conditions, the design of these machines combines the gripper principle and installation of the segments into one combined process. The machine grips against the tunnel wall rock to advance boring concurrently with installation of segmental lining. In this manner high rates of advance are attained with elimination of sequential operation.

Double shield TBMs can easily be adapted to particular geological conditions of any tunnel alignment. This type of machine is ideally suited for boring long tunnels in hard rock with alternating sections of fractured and competent rock. They unify the functional principles of gripper and single shield TBMs in one machine. This combination of methods allows for the installation of concrete segments parallel to tunneling, achieving very high tunneling performances. A double shield TBM (**Figures 3 and 4**) consists of a rotating cutterhead mounted to the cutterhead support, followed by three shields—a telescopic shield (a smaller diameter inner shield that slides within the larger outer shield), a gripper shield, and a tail shield. Figure 2.5 presents the details of a movable telescopic shield.

In double shield mode, the gripper shoes are energized, pushing against the exposed rock walls to engage the rock and provide the resistance to the thrust applied to the tunnel face just like the open gripper TBM. The main propel cylinders are then extended to push the cutterhead support and cutterhead forward. The rotating cutterhead cuts the rock. The telescopic shield extends as the machine advances keeping everything in the machine under cover and protected from the ground surrounding it.

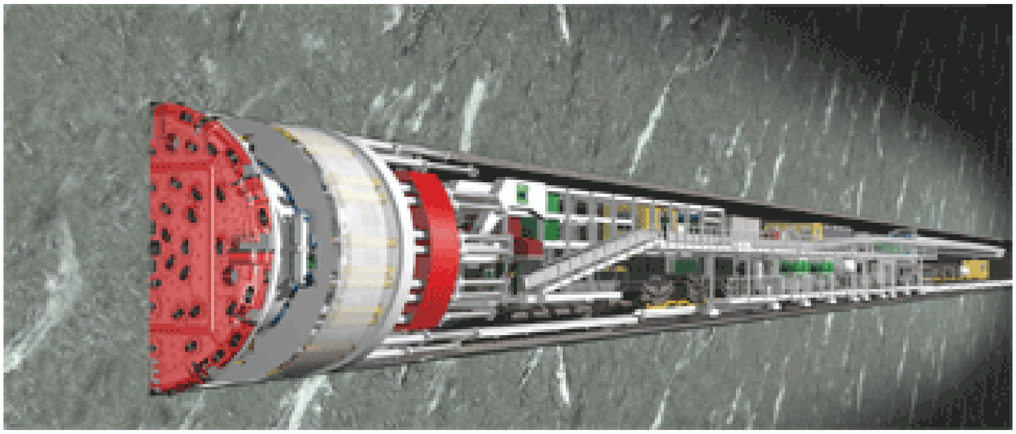


Figure 3: Overview of a Double Shield TBM with Trailing Gear (Herrenknecht) (Source http://www.herrenknecht.com/en/products/core-products/tunnelling)-pipelines/single-shield-tbm.html

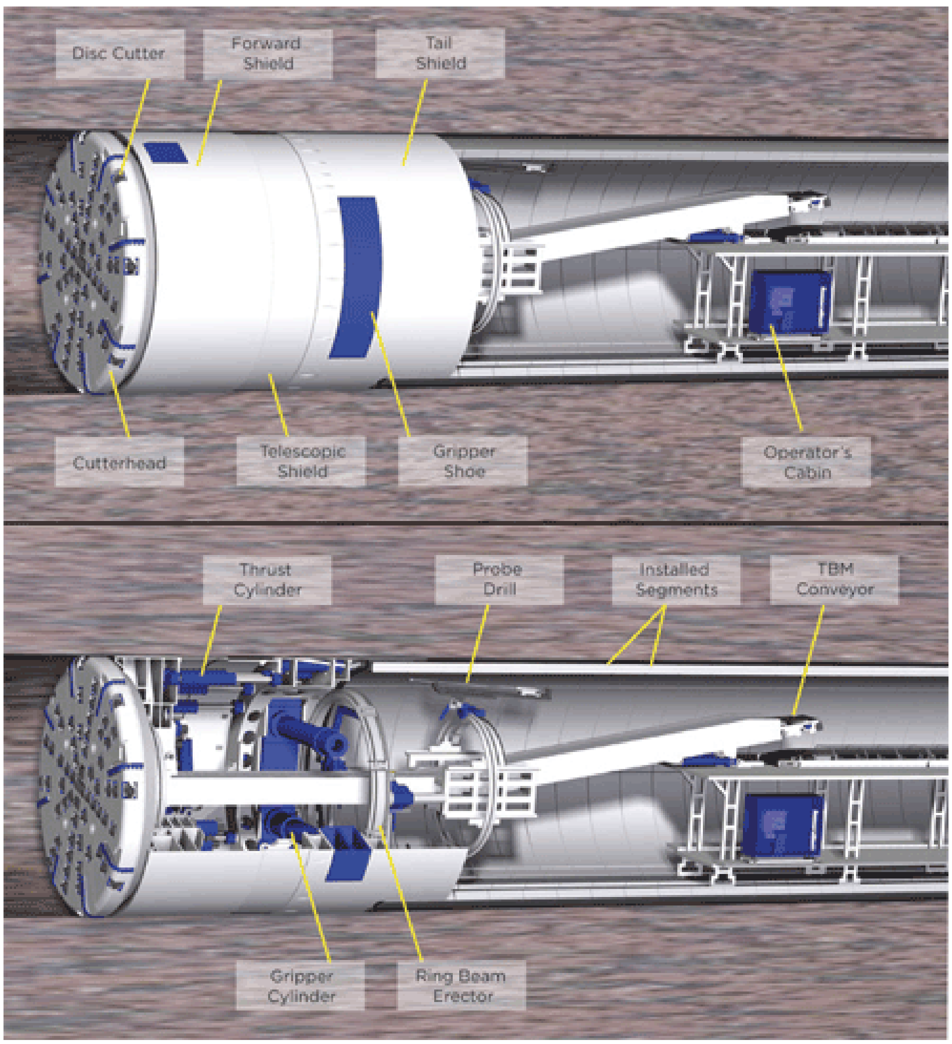


Figure 4: Typical Diagram of a Double Shield TBM (Robbins) (Source http://www.therobbinscompany.com/en/our-products/tunnel-boring-machines/double-shield/

The gripper shield remains stationary during boring. A segment erector is fixed to the gripper shield allowing precast concrete tunnel lining segments to be erected while the machine is boring. The segments are erected within the safety of the tail shield. It is the double shield's ability to erect the tunnel lining simultaneously with boring that allows it to achieve such high performance rates. The completely enclosed shielded design provides the safe working environment.

Additional details on double shield TBM can be found in Technical Manual for Design and Construction of Road Tunnels – Appendix D; Tunnel Boring Machines.

The double shield TBM is capable of tunneling in all kinds of stable and unstable rocks with excavation diameter ranging from 10 feet to 50 feet. The main advantages of this machine are:

- High advance rates in stable rock due to continuous tunneling operation
- Flexible use in all kinds of rock
- High level of work safety for the machine personnel in geological fault zones

The main disadvantages of this tunneling method are:

- For a short tunnel (less than a mile), the high cost of renting or buying a machine make using a TBM economically unviable
- Requires a large working area (between 3 to 4 acres)
- Assembling and disassembling the TBM is time-consuming
- Requires specialty crews for operation and maintenance of the machine
- Large amount of wasted volume of excavation because the top of road is close to the tunnel springline

A.2.2 Gripper TBM (Open TBM)

The gripper TBM, often widely described as main beam rock TBM, is the classic form of TBM. The area of application is in rock with medium to high stand-up time. It can be most economically used if the rock does not need constant support with rock anchors, steel arches, or even shotcrete. Gripper TBMs are open-mode TBMs and do not have a closed shield skin. Therefore, the tunneling performance depends on the time required to secure the rock. In difficult geological formations, gripper TBMs allow for comprehensive measures to temporarily secure the rock right behind the cutterhead using rock anchors, steel mats, and steel arches. Probing and, if necessary, rock conditioning ahead of the machine are possible using additional drilling rigs. Water escaping from the rock is pumped away via a drainage system in the invert section of the machine. The excavated tunnel diameter is permanently supported with shotcrete in the back-up area. All necessary supply facilities are installed there. This often includes, in addition to the installation of permanent shotcrete, the installation of invert segments (see **Figure 5**).

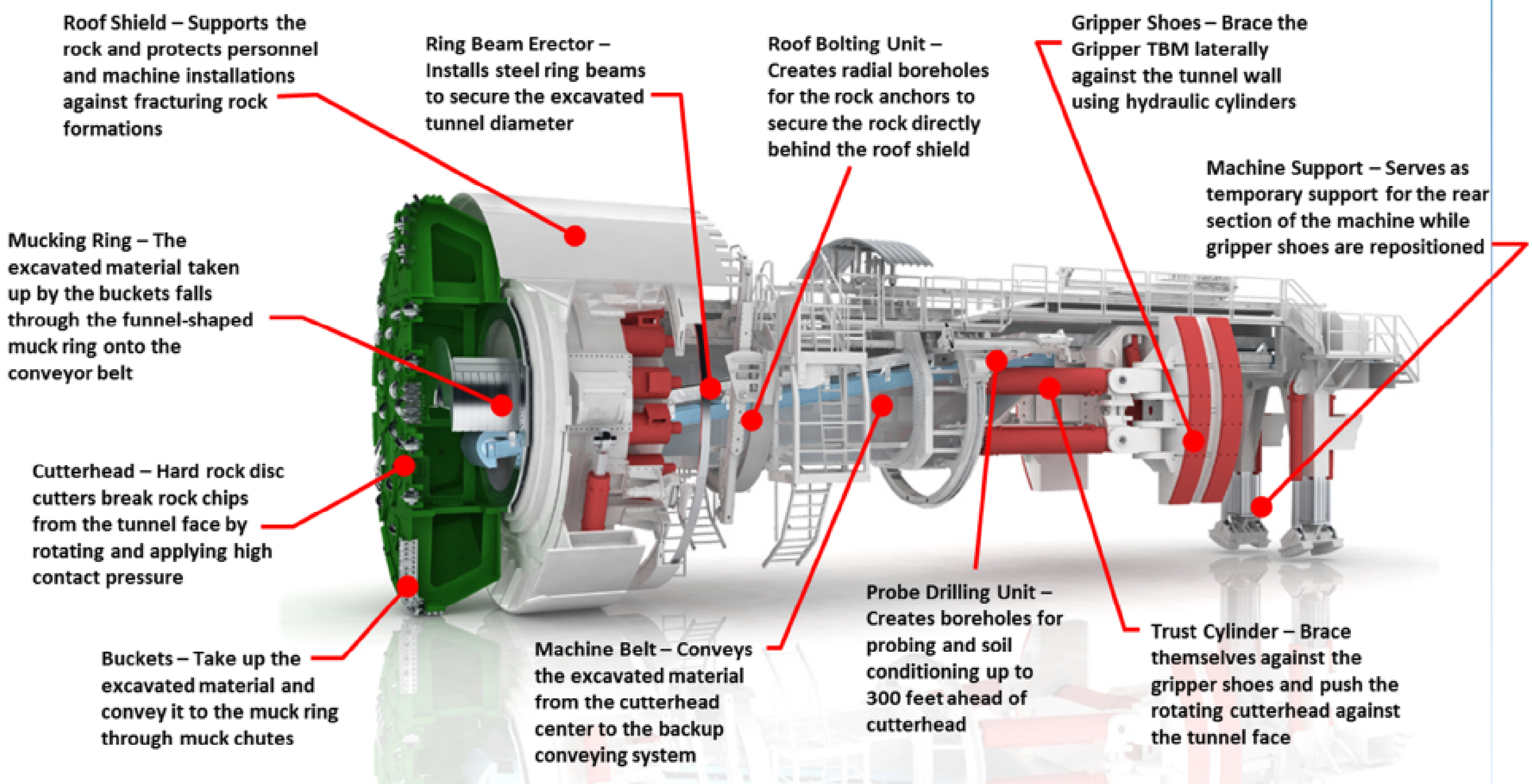


Figure 5: A Typical Gripper TBM (diameter 28 feet) (Source http://www.herrenknecht.com/en/products/core-products/tunnelling-pipelines/gripper-tbm.htm)

The gripper TBM can be used in hard and stable rocks such as granite, gneiss, and basalt. The machine diameter ranges from 10 feet to 50 feet. The main advantages of this machine are:

- High and constant tunneling performances and highly precise excavation in stable rock formations
- Contingency measures to be considered in advance to secure the rock increase safety for personnel and machine in fault zones

The main disadvantages of gripper TBM are:

- Possible inflow of water into the tunnel resulting in interruption of tunnel excavation work or possible surface settlement
- Machine can only be used in stable ground
- Large amount of wasted volume of excavation because the top of road is close to the tunnel springline

A.3 Support System for Circular Tunnels (Precast Segmental Lining)

Precast segmental linings are used in circular tunnels that are mined using a TBM. They can be used in both soft and hard ground. Several curved precast elements or segments are assembled inside the tail of the TBM to form a complete circle. The number of segments used to form the ring is a function of the ring diameter and to a certain respect, contractor's preferences. The segments are relatively thin; 8 to 12 inches (20 to 30 cm) and typically 40 to 60 inches (1 to 1.5 m) wide measured along the length of the tunnel. **Figure 6** presents the main specifics of the segmental lining.

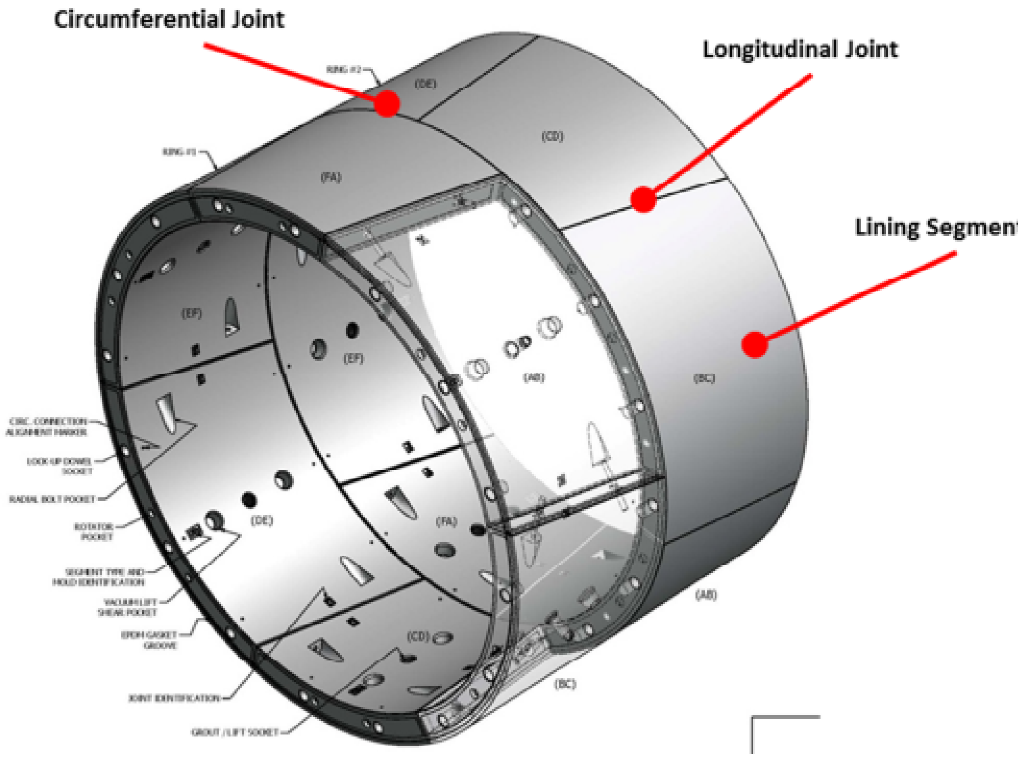


Figure 6: Isometric View of Segmental Lining Ring

Precast segmental linings can be used to serve as both the initial ground support and final lining (the "one-pass" system) straight out of the tail of the TBM. Segments used as initial linings are generally lightly reinforced, erected without bolting them together, and have no waterproofing. The segments are erected inside the tail of the TBM. The TBM pushes against the segments to advance the tunnel excavation. Once the shield of the TBM has passed the completed ring, the ring is jacked apart (expanded) at the crown or near the springline. Jacking the segments helps fill the annular space that was occupied by the shield of the TBM. After jacking, contact grouting may be used to finish filling the annular space and to ensure complete contact between the segments and the surrounding ground. A waterproofing membrane is installed over the initial lining and the final concrete lining is cast in place against the waterproofing membrane. Horizontal and vertical curvature in the tunnel alignment is created by using tapered rings. The curvature is approximated by a series of short chords. **Figure 7** presents the assembly process of the ring.

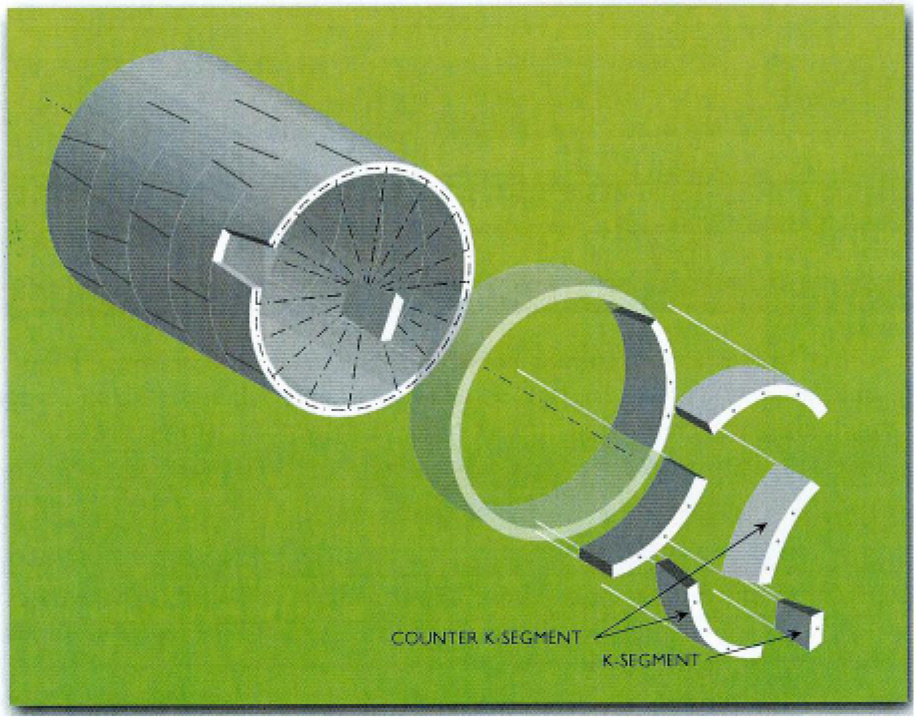


Figure 7: Assembly Process of the Ring

Figure 8 presents the relationship between internal diameter of the ring and the thickness of the segment based on various projects.

Precast segmental linings used as both initial support and final lining are built to high tolerances and quality. They are typically heavily reinforced, fitted with gaskets on all faces for waterproofing and bolted together to compress the gaskets after the ring is completed but prior to advancing the TBM. As the completed ring leaves the tail of the shield of the TBM, contact grouting is performed to fill the annular space that was occupied by the shield. This provides continuous contact between the ring and the surrounding ground and prevents the ring from dropping into the annular space. Bolting is often performed only in the circumferential direction. The shove of the TBM is usually sufficient to compress the gaskets in the longitudinal direction. Friction between the ground and the segments hold the segment in place, maintaining compression on the gasket. When first introduced into the United States in the mid-1970s, segmental linings were fabricated in a honeycomb shape that allowed for bolting in both the longitudinal and circumferential directions.

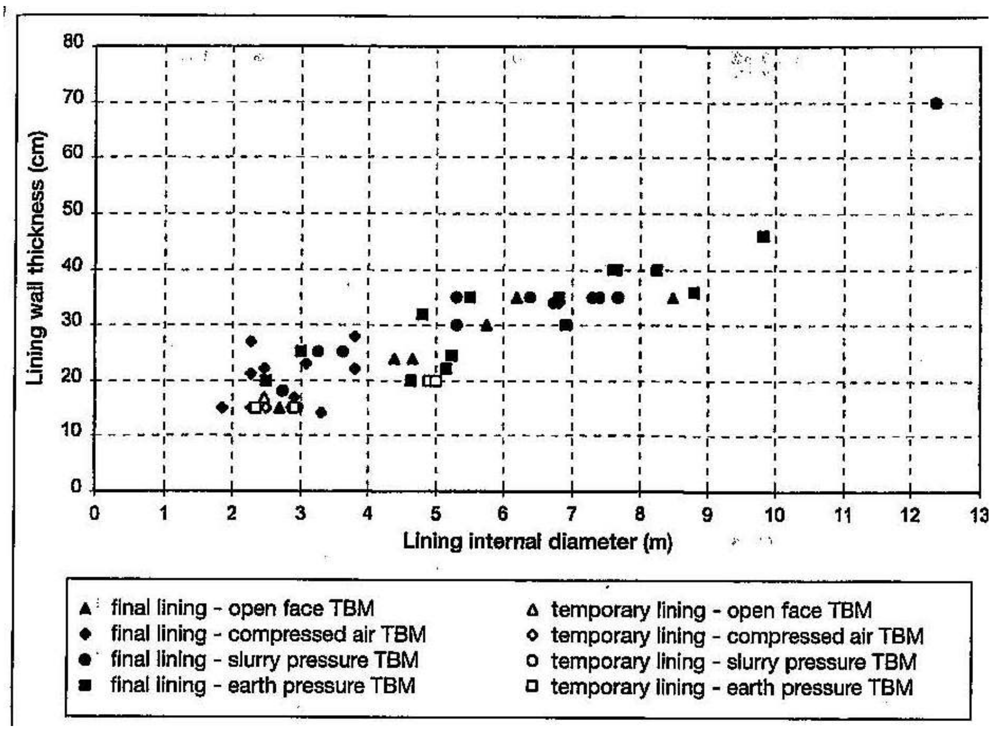


Figure 8: Segmental Lining Wall Thickness with Respect to the Tunnel Internal Diameter (After AFTES; AFTES Recommendations for The Design, Sizing and Construction of Precast Concrete Segments Installed at the area of Tunnel Boring Machine; Version 1, 1997, translated in 1999.)

Recent lining designs have eliminated the longitudinal bolting and the complex forming and reinforcing patterns that were required to accommodate the longitudinal bolts. Segments are generally stored in a stacked arrangement, with one stack containing the segments required to construct a single ring inside the tunnel. As with segments used for initial lining, horizontal and vertical tunnel alignment is achieved through the use of tapered segments. **Figure 9** shows the segments stacked in the storage yard awaiting transport into the tunnel. **Figure 10** shows the trial ring assembly of the segmental lining.

Advantages of a precast segmental lining are as follows:

- Provides complete stable ground support that is ready for follow-on work
- Can be used to serve as both the initial and final support
- Prevention of water flow into the tunnel by installing a lining which is immediately impermeable
- Ensured longitudinal thrust resistance to the TBM during excavation
- Ensured support for the TBM back-up equipment
- Materials are easily transported and handled inside the tunnel
- No additional work such as forming and curing is required prior to use
- Provides a regular sound foundation for tunnel finishes
- Provides a durable low maintenance structure

Figure 9: Segment Stockpile

Figure 10: Trial Ring Assembly

Disadvantages of a precast segmental lining are as follows:

- Segments must be fabricated to very tight tolerances
- Reinforcing steel must be fabricated and placed to very tight tolerances
- Storage space for segments is required at the job site
- Segments can be damaged if mishandled
- Spalls, cracked and damaged edges can result from mishandling and over jacking
- Gasketed segments must be installed to high tolerances to assure that gaskets perform as designed
- Reinforcement when used is subject to corrosion and resulting deterioration of the concrete
- Cracking that allows water infiltration can reduce the life of the lining
- Chemical attack in certain soils can reduce lining life

A.4 Support System for Circular Tunnels (Cast-in-Place Concrete)

Cast-in-place (CIP) concrete linings are generally installed sometime after the initial ground support (two-pass system). CIP concrete linings are used in both soft ground and hard rock tunnels and can be constructed of either reinforced or plain concrete. CIP concrete linings can take on any geometric shape, with the shape being determined by the use, mining method, and ground conditions. CIP concrete lining can be used as the final lining system in rock tunnels using main beam type TBM and when the rock is reasonably stable. The main advantages of using CIP concrete lining are:

- They are cheaper compared to segmental lining
- They would not require storage space
- They would not require very tight tolerances compared to segmental lining
- No need for gaskets for watertightness
- Can be used for tunnels with various geometric shape

The main disadvantages of using CIP concrete lining are:

- The construction process is slower compared to precast segmental lining due to additional work such as forming and curing is required prior to use
- Requires installation of initial support
- Quality of the concrete depends on the workmanship
- Requires waterproofing system

Appendix B

Traffic Modeling

B1. Existing Conditions

B1a. Balanced Traffic Volume Profiles

Station Name:
Site ID:000000000061
Station Num:000000009017
Description:CT 15 - AT BENHAM ROAD UNDERPASS
City:HAMDEN
County:NEW HAVEN
Start Date/Time:03-15-2012 00:00
End Date/Time:03-15-2012 23:59

	Lane 1 (North)	Lane 2 (North)	NB	Lane 3 (South)	Lane 4 (South)	SB	All Lanes
00:00	229	75	304	133	45	178	482
01:00	96	27	123	78	19	97	220
02:00	68	13	81	44	11	55	136
03:00	69	20	89	47	15	62	151
04:00	103	32	135	141	54	195	330
05:00	268	132	400	430	314	744	1144
06:00	719	572	1291	855	1032	1887	3178
07:00	1303	1469	2772	1337	1938	3275	6047
08:00	1317	1549	2866	1293	1734	3027	5893
09:00	981	768	1749	984	962	1946	3695
10:00	924	562	1486	841	644	1485	2971
11:00	918	584	1502	872	625	1497	2999
12:00	1013	667	1680	918	680	1598	3278
13:00	1073	754	1827	928	748	1676	3503
14:00	1194	1031	2225	1105	1085	2190	4415
15:00	1534	1510	3044	1179	1248	2427	5471
16:00	1628	1725	3353	1285	1667	2952	6305
17:00	1655	1751	3406	1453	1844	3297	6703
18:00	1273	1119	2392	1073	1259	2332	4724
19:00	914	666	1580	814	723	1537	3117
20:00	770	486	1256	662	479	1141	2397
21:00	629	346	975	536	382	918	1893
22:00	419	205	624	361	208	569	1193
23:00	321	123	444	313	140	453	897
Total	19418	16186	35604	17682	17856	35538	71142
Percentages	27.29%	22.75%	50.05%	24.85%	25.10%	49.95%	100.00%

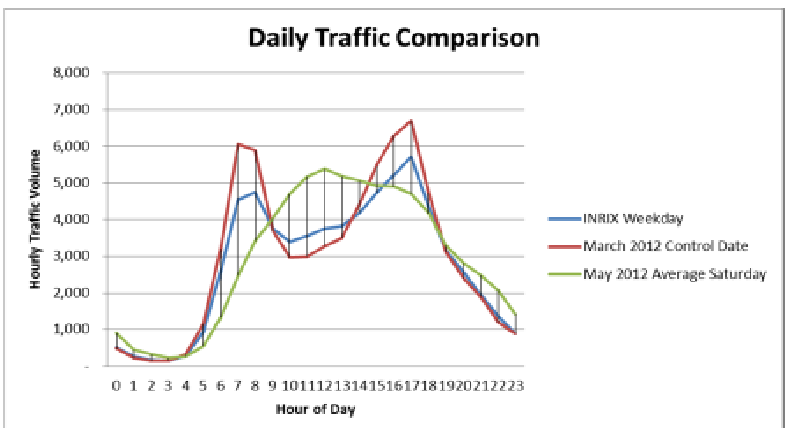
Station Name:
Site ID:000000000061
Station Num:000000009017
Description:CT 15 - AT BENHAM ROAD UNDERPASS
City:HAMDEN
County:NEW HAVEN
Start Date/Time:05-12-2012 00:00
End Date/Time:05-12-2012 23:59

	Lane 1 (North)	Lane 2 (North)	NB	Lane 3 (South)	Lane 4 (South)	SB	All Lanes
00:00	371	168	539	248	123	371	910
01:00	184	68	252	144	50	194	446
02:00	137	35	172	115	39	154	326
03:00	81	26	107	89	23	112	219
04:00	104	33	137	98	27	125	262
05:00	191	71	262	198	93	291	553
06:00	434	230	664	397	255	652	1316
07:00	765	554	1319	644	508	1152	2471
08:00	891	926	1817	838	763	1601	3418
09:00	1079	991	2070	957	1007	1964	4034
10:00	1166	1134	2300	1144	1256	2400	4700
11:00	1277	1259	2536	1192	1441	2633	5169
12:00	1319	1353	2672	1277	1438	2715	5387
13:00	1343	1264	2607	1199	1378	2577	5184
14:00	1297	1201	2498	1184	1385	2569	5067
15:00	1279	1157	2436	1159	1338	2497	4933
16:00	1249	1083	2332	1173	1394	2567	4899
17:00	1264	1078	2342	1101	1256	2357	4699
18:00	1117	963	2080	1000	1091	2091	4171
19:00	900	667	1567	885	835	1720	3287
20:00	819	609	1428	728	642	1370	2798
21:00	732	461	1193	755	532	1287	2480
22:00	622	387	1009	592	464	1056	2065
23:00	508	239	747	432	243	675	1422
Total	19129	15957	35086	17549	17581	35130	70216
Percentages	27.24%	22.73%	49.97%	24.99%	25.04%	50.03%	100.00%

Weekday to Saturday Conversion Rate Computations

Existing Traffic Volumes

Time Period	I-95 Value Pricing Study (VPS) SB	NB	Total		Average Weekday (March 15, 2012) SB	NB	Total		Average Saturday (May12, 2012) SB	NB	Total
Hour 0	214	285	498		178	304	482		371	539	910
Hour 1	124	150	274		97	123	220		194	252	446
Hour 2	80	91	171		55	81	136		154	172	326
Hour 3	76	73	149		62	89	151		112	107	219
Hour 4	158	133	291		195	135	330		125	137	262
Hour 5	572	358	930		744	400	1,144		291	262	553
Hour 6	1,482	1,089	2,571		1,887	1,291	3,178		652	664	1,316
Hour 7	2,330	2,222	4,552		3,275	2,772	6,047		1,152	1,319	2,471
Hour 8	2,456	2,294	4,749		3,027	2,866	5,893		1,601	1,817	3,418
Hour 9	1,936	1,830	3,766		1,946	1,749	3,695		1,964	2,070	4,034
Hour 10	1,716	1,679	3,396		1,485	1,486	2,971		2,400	2,300	4,700
Hour 11	1,778	1,784	3,562		1,497	1,502	2,999		2,633	2,536	5,169
Hour 12	1,882	1,868	3,749		1,598	1,680	3,278		2,715	2,672	5,387
Hour 13	1,836	1,986	3,822		1,676	1,827	3,503		2,577	2,607	5,184
Hour 14	2,044	2,143	4,186		2,190	2,225	4,415		2,569	2,498	5,067
Hour 15	2,163	2,564	4,728		2,427	3,044	5,471		2,497	2,436	4,933
Hour 16	2,536	2,701	5,237		2,952	3,353	6,305		2,567	2,332	4,899
Hour 17	2,818	2,895	5,713		3,297	3,406	6,703		2,357	2,342	4,699
Hour 18	2,144	2,196	4,340		2,332	2,392	4,724		2,091	2,080	4,171
Hour 19	1,489	1,662	3,151		1,537	1,580	3,117		1,720	1,567	3,287
Hour 20	1,238	1,323	2,561		1,141	1,256	2,397		1,370	1,428	2,798
Hour 21	953	1,001	1,953		918	975	1,893		1,287	1,193	2,480
Hour 22	637	723	1,361		569	624	1,193		1,056	1,009	2,065
Hour 23	428	472	900		453	444	897		675	747	1,422
Total	33089	33522	66611		35538	35604	71142		35130	35086	70216
Directionality	49.7%	50.3%			50.0%	50.0%			50.0%	50.0%	
Source	State Project #63-676 I-95 Value Pricing Study				CTDOT Bureau of Policy and Planning				CTDOT Bureau of Policy and Planning		



Daily Volume Comparison

	SB	NB	Total			SB	NB	Total
I-95 VPS to Ave Weekday	1.07	1.06	1.07		Ave Weekday to I-95 VPS	0.93	0.94	0.94
I-95 VPS to Ave Saturday	1.06	1.05	1.05		Ave Saturday to I-95 VPS	0.94	0.96	0.95
Ave Weekday to Ave Saturday	0.99	0.99	0.99		Ave Saturday to Ave Weekday	1.01	1.01	1.01

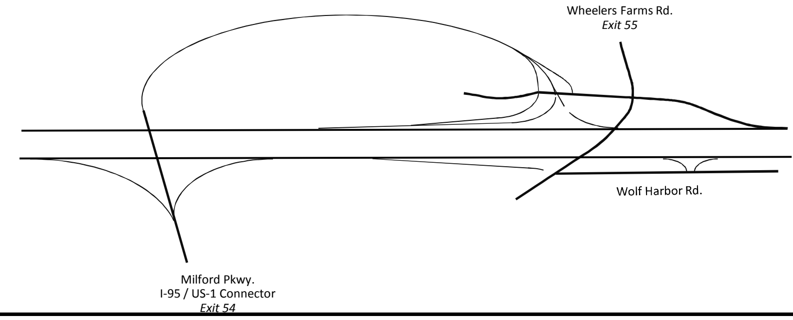
Off-Peak to Sat Peak Conversion Rate Computation*

	I-95 Value Pricing Study SB	NB	Total		Average Saturday SB	NB	Total		I-95 VPS to Average Saturday SB	NB	Total
Hour 11	1,778	1,784	3,562		2633	2536	5,169		1.48	1.42	1.45
Hour 12	1,882	1,868	3,749		2715	2672	5,387		1.44	1.43	1.44
Hour 13	1,836	1,986	3,822		2577	2607	5,184		1.40	1.31	1.36
Hour 14	2,044	2,143	4,186		2569	2498	5,067		1.26	1.17	1.21
								Average	**1.40**	**1.33**	**1.36**

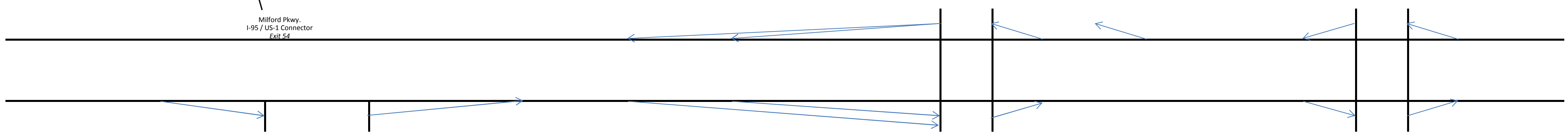
*Conversion Rate computed as Average Saturday traffic volume divided by I-95 Value Pricing Study traffic volume by direction and time.

2014 Route 15 Balanced Weekday Midday Off-Peak Profile

Milford Pkwy / I-95&US-1 Connector Exit 54	Wheelers Farms Rd/ Wolf Harbor Rd Exit 55	Rt 121 - Grassy Hill Rd. Exit 56



	SB ML	SB On	SB On	SB Off	SB Off	SB ML	SB On	SB Off	SB ML
Hour 11	**2,069**	744	89	223	42	**1,501**	78	96	**1,519**
Hour 12	**2,325**	985	118	267	65	**1,554**	101	94	**1,547**
Hour 13	**2,300**	859	92	269	53	**1,671**	114	95	**1,652**
Hour 14	**2,761**	1,166	96	310	55	**1,864**	153	92	**1,803**



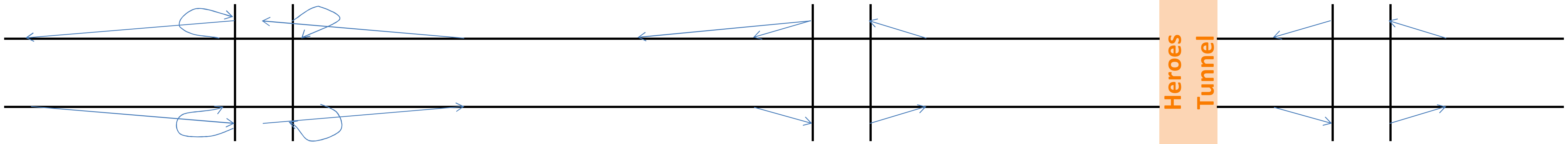
	NB ML	NB Off	NB On	NB ML	NB Off	NB Off	NB On	NB ML	NB Off	NB On	NB ML
Hour 11	**2,394**	1,146	412	**1,660**	152	18	56	**1,545**	94	73	**1,524**
Hour 12	**2,427**	1,292	413	**1,548**	152	26	69	**1,438**	101	109	**1,447**
Hour 13	**2,562**	1,360	400	**1,602**	138	23	64	**1,504**	106	100	**1,499**
Hour 14	**2,861**	1,482	529	**1,908**	173	45	83	**1,773**	145	129	**1,757**

Milford Pkwy / I-95&US-1 Connector Exit 54	Wheelers Farms Rd/ Wolf Harbor Rd Exit 55	Rt 121 - Grassy Hill Rd. Exit 56

Note: Traffic volumes for the Route 15 Balanced Weekday Midday Off-Peak Profile were taken from State Project #63-676 (I-95 Value Pricing Study) with the exception of the Exit 60-67 Ramps. Exit 60-67 Ramp data taken from CTDOT provided ATR data. Minor spot adjustments made to account for decimal rounding.

2014 Route 15 Balanced Weekday Midday Off-Peak Profile

	Rt 34 - Derby Ave Exit 57 / Exit 58					Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Rt 10 - Dixwell Ave. Exit 60		
	SB On	SB Off	SB On	*SB Off*	**SB ML**	*SB On*	*SB On*	*SB Off*	**SB ML**	*SB On*	*SB Off*	**SB ML**
Hour 11	50	171	105	143	**1,678**	143	129	372	**1,778**	439	256	**1,595**
Hour 12	34	147	102	178	**1,736**	110	186	441	**1,882**	484	268	**1,666**
Hour 13	49	150	153	164	**1,764**	143	172	385	**1,834**	489	267	**1,612**
Hour 14	56	150	208	249	**1,938**	156	190	452	**2,044**	579	254	**1,719**



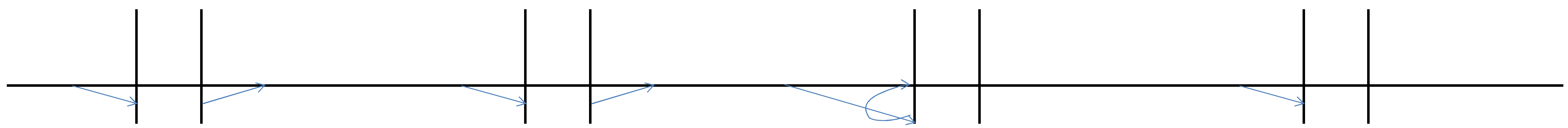
	Rt 34 - Derby Ave Exit 57 / Exit 58					Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Rt 10 - Dixwell Ave. Exit 60		
	NB Off	*NB On*	*NB Off*	*NB On*	**NB ML**		*NB Off*	*NB On*	**NB ML**	*NB Off*	*NB On*	**NB ML**
Hour 11	123	164	40	72	**1,597**		221	408	**1,784**	394	299	**1,689**
Hour 12	112	198	35	74	**1,572**		216	512	**1,868**	411	339	**1,796**
Hour 13	104	203	47	110	**1,661**		209	534	**1,986**	465	337	**1,858**
Hour 14	163	220	51	126	**1,889**		293	547	**2,143**	538	482	**2,087**

Note: Traffic volumes for the Route 15 Balanced Weekday Midday Off-Peak Profile were taken from State Project #63-676 (I-95 Value Pricing Study) with the exception of the Exit 60-67 Ramps. Exit 60-67 Ramp data taken from CTDOT provided ATR data. Minor spot adjustments made to account for decimal rounding.

CDM Smith

2014 Route 15 Balanced Weekday Midday Off-Peak Profile

Hour 11
Hour 12
Hour 13
Hour 14



	Whitney Ave. Exit 61 *NB Off*	Whitney Ave. Exit 61 *NB On*	**NB ML**	Dixwell Ave. Exit 62 *NB Off*	Dixwell Ave. Exit 62 *NB On*	**NB ML**	Route 22 Exit 63 *NB Off*	Route 22 Exit 63 *NB On*	**NB ML**	Quinnipiac St. Exit 64 *NB Off*	**NB ML**
Hour 11	228	146	**1,607**	182	94	**1,519**	271	98	**1,346**	147	**1,199**
Hour 12	240	118	**1,674**	187	94	**1,581**	304	106	**1,383**	139	**1,244**
Hour 13	248	176	**1,786**	219	100	**1,667**	321	89	**1,435**	167	**1,268**
Hour 14	248	213	**2,052**	246	99	**1,905**	369	115	**1,651**	208	**1,443**

Note: Traffic volumes for the Route 15 Balanced Weekday Midday Off-Peak Profile were taken from State Project #63-676 (I-95 Value Pricing Study) with the exception of the Exit 60-67 Ramps. Exit 60-67 Ramp data taken from CTDOT provided ATR data. Minor spot adjustments made to account for decimal rounding.

2014 Route 15 Balanced Weekday Midday Off-Peak Profile

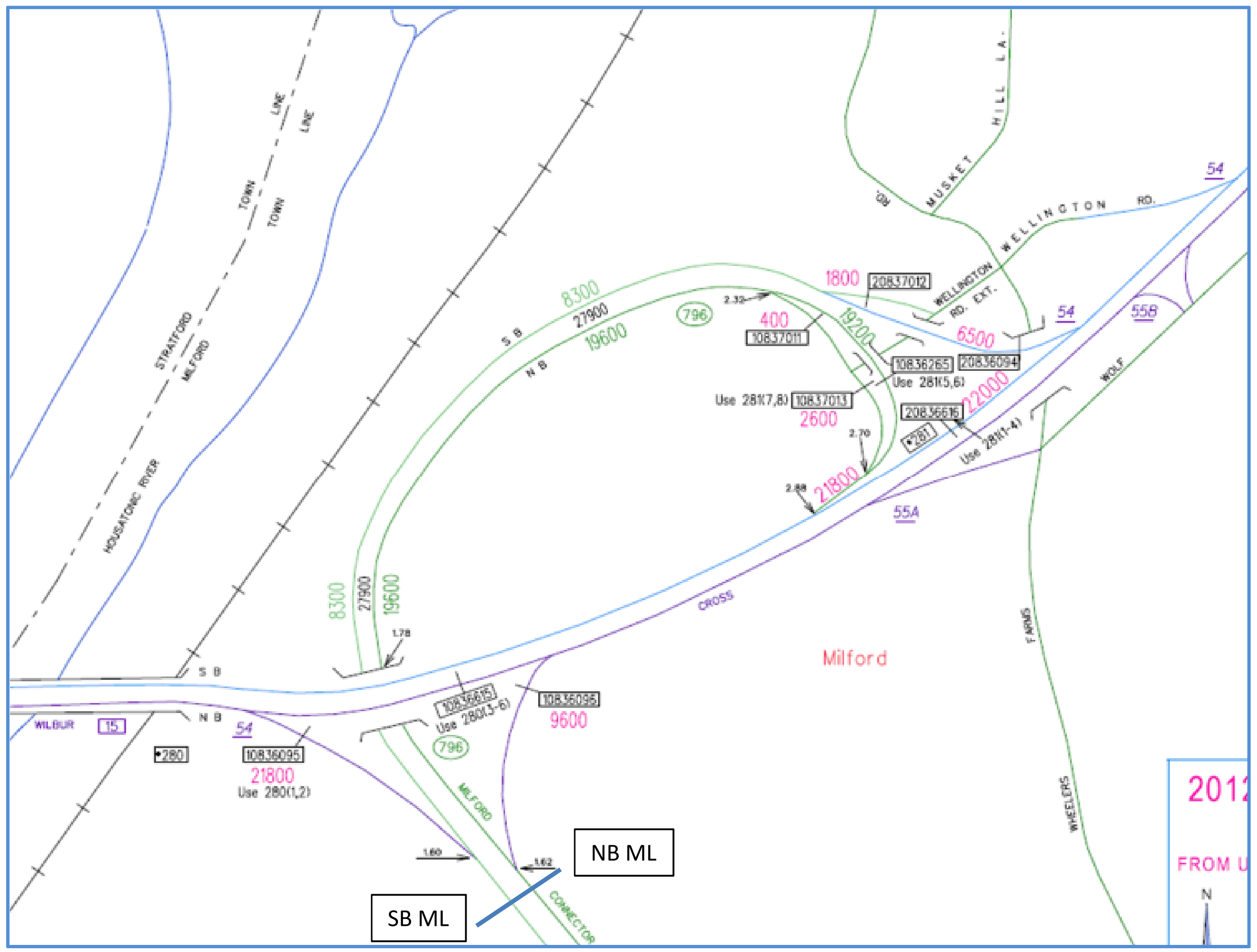
Hour 11
Hour 12
Hour 13
Hour 14

	NB Off	NB On	NB ML	NB Off	NB On	NB ML	NB Off	NB On	NB ML	NB Off	NB ML
	River Rd. Exit 65			Route 5 Exit 66			CTDOT Garage & Miller Avenue			East Main St. Exit 67	
Hour 11	110	266	**1,355**	247	339	**1,447**	65	95	**1,477**	136	**1,341**
Hour 12	101	294	**1,437**	235	439	**1,641**	118	94	**1,617**	187	**1,430**
Hour 13	99	263	**1,432**	282	466	**1,616**	107	101	**1,610**	168	**1,442**
Hour 14	145	345	**1,643**	284	480	**1,839**	121	112	**1,830**	169	**1,661**

Note: Traffic volumes for the Route 15 Balanced Weekday Midday Off-Peak Profile were taken from State Project #63-676 (I-95 Value Pricing Study) with the exception of the Exit 60-67 Ramps. Exit 60-67 Ramp data taken from CTDOT provided ATR data. Minor spot adjustments made to account for decimal rounding.

CDM Smith

2014 Milford Parkway Balanced Weekday Midday Off-Peak Profile



Milford Parkway
Milford Pkwy / Route 15

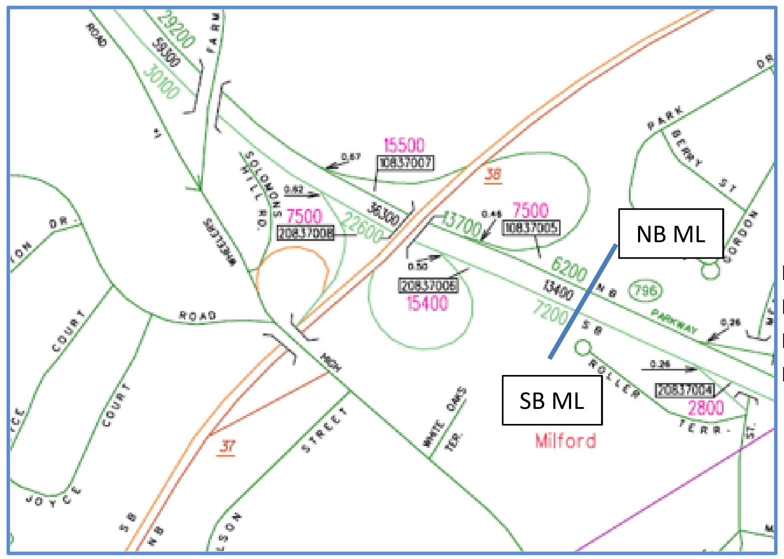
	NB Off	*NB Off*	*NB Off*	**NB ML**
Hour 11	412	20	744	1,176
Hour 12	413	24	985	1,422
Hour 13	400	24	859	1,283
Hour 14	529	25	1,166	1,720
	STA 6096	*STA 7011*	*STA 6265*	*Computed*
	From SP#63-676		*From SP#63-676*	

	SB On	*SB On*	*SB On*	**SB ML**
Hour 11	102	223	1,146	1,471
Hour 12	141	267	1,292	1,700
Hour 13	103	269	1,360	1,732
Hour 14	88	310	1,482	1,880
				Computed
	STA 7012	*STA 6094*	*STA 6095*	
		From SP#63-676	*From SP#63-676*	

Note: Traffic volumes at Station 7011 and 7012 were taken from CTDOT provided ATR data. Traffic volumes at Stations 6096, 6265, 6094, and 6095 were taken from State Project #63-676 (I-95 Value Pricing Study)

CDM Smith

2014 Milford Parkway Balanced Weekday Midday Off-Peak Profile

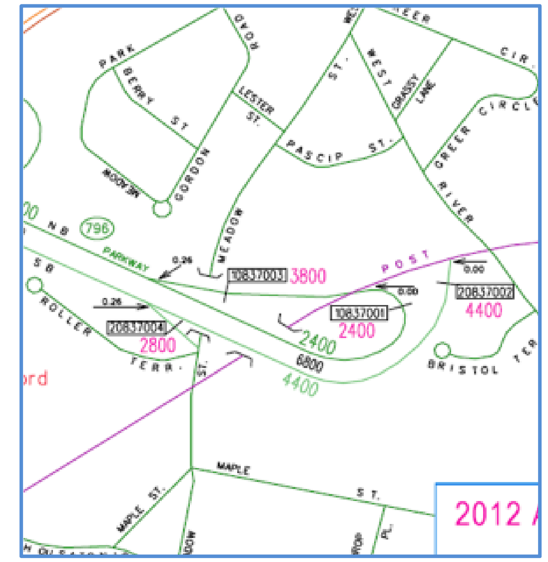


Milford Parkway

Milford Pkwy / I-95

	NB On	NB On	NB ML
Hour 11	650	246	280
Hour 12	764	312	346
Hour 13	686	277	320
Hour 14	887	414	419
	STA 7007 Balanced From SP#63-676	STA 7005 Balanced From SP#63-676	Computed

	SB Off	SB Off	SB ML
Hour 11	322	726	423
Hour 12	358	884	458
Hour 13	373	865	494
Hour 14	387	935	558
	STA 7008 Balanced From SP#63-676	STA 7006 Balanced From SP#63-676	Computed



Milford Parkway

Milford Pkwy / Route 1

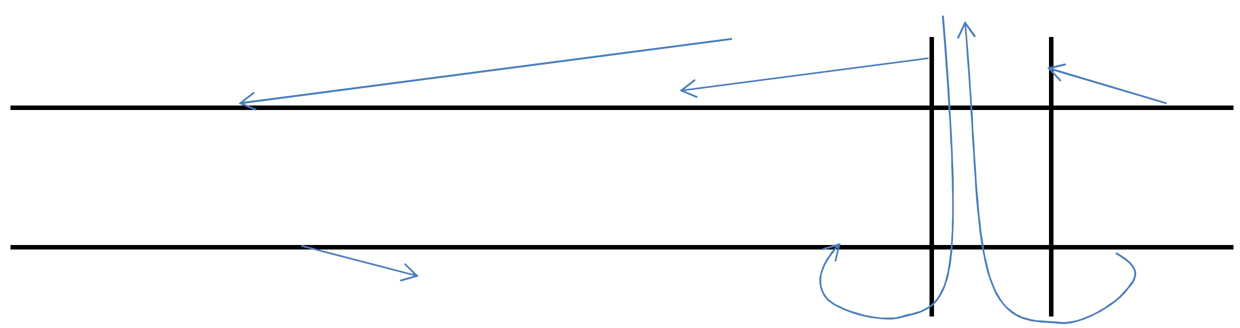
	NB On	NB On
Hour 11	184	96
Hour 12	208	138
Hour 13	195	125
Hour 14	249	170
	STA 7003 Balanced	STA 7001 Balanced

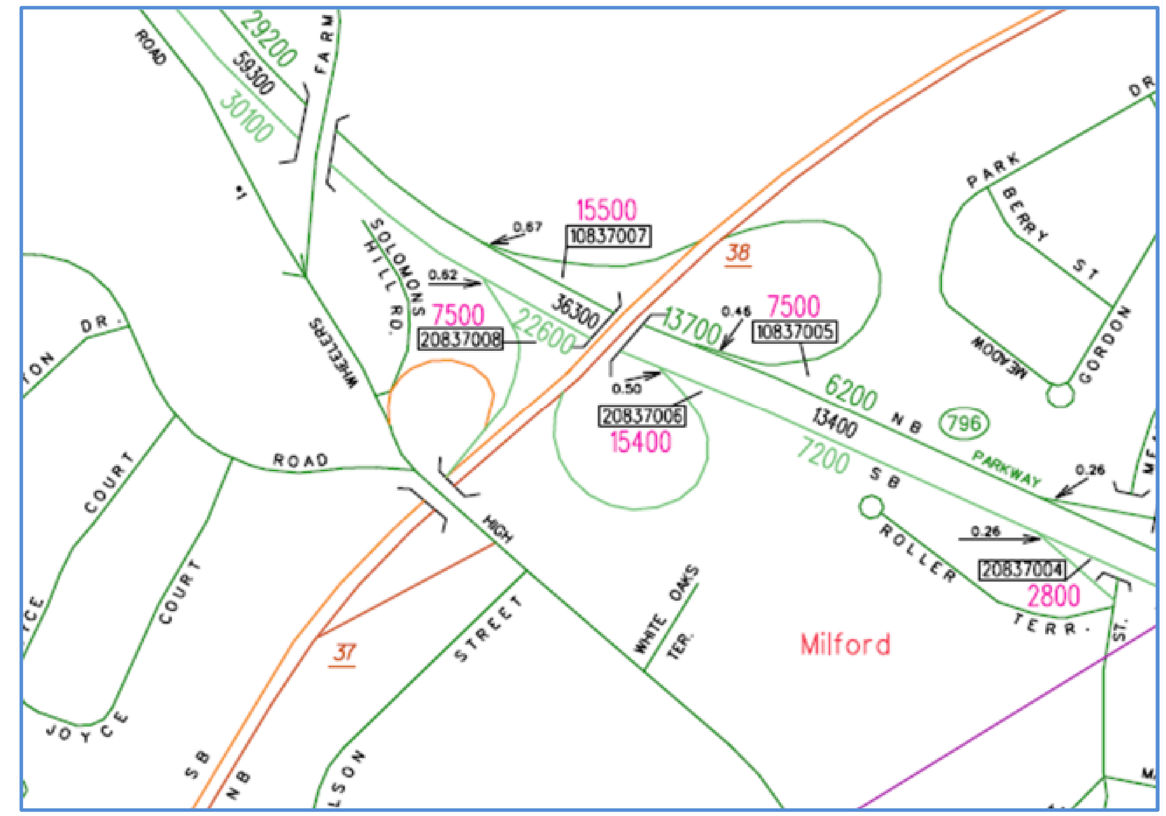
	SB Off	SB Off
Hour 11	146	277
Hour 12	167	291
Hour 13	227	267
Hour 14	252	306
	STA 7004 Balanced	STA 7002 Balanced

Note: Traffic volumes at the Milford Parkway/I-95 Interchange were taken from State Project #63-676 (I-95 Value Pricing Study). Traffic volumes at the Milford Parkway/Route 1 Interchange were taken from CTDOT provided ATR data. Traffic volumes at each interchange was adjusted proportionately from source data to balance with the Milford Parkway through volumes as assessed on the Milford Parkway Balanced Weekday Midday Off-Peak Profile at the Milford Parkway and Route 15 interchange.

2014 I-95 Balanced Weekday Midday Off-Peak Profile

		Int. 38 Wheelers Farms Rd.	Int. 38 Milford Connector		
	SB ML	*SB On*	*SB On*	*SB Off*	SB ML
Hour 11	**3,579**	128	322	650	**3,779**
Hour 12	**3,888**	117	358	764	**4,177**
Hour 13	**3,923**	138	373	686	**4,098**
Hour 14	**4,068**	138	387	887	**4,430**
	Computed				*From SP#63-676*
		STA 7148 *From SP#63-676*	***STA 7008***	***STA 7007***	





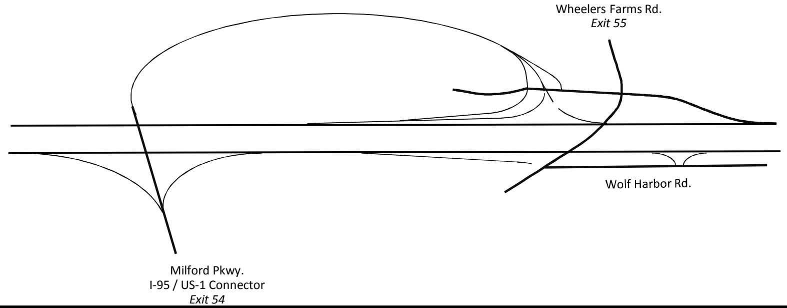
Note: Traffic volumes at Stations 7005, 7006, 7007, and 7008 were taken from the Milford Parkway Balanced Weekday Midday Off-Peak Profile. Traffic volumes at Stations 7147 and 7148, as well as the noted I-95 mainline volumes, were taken from State Project #63-676 (I-95 Value Pricing Study).

		From SP#63-676 ***STA 7147***	***STA 7006***	***STA 7005***	
Hour 11	**3,974**	169	726	246	**4,285**
Hour 12	**3,942**	159	884	312	**4,355**
Hour 13	**4,289**	182	865	277	**4,695**
Hour 14	**4,903**	212	935	414	**5,212**
	NB ML	*NB Off*	*NB On*	*NB Off*	NB ML
	From SP#63-676	High St. Int. 37	Milford Connector Int. 38		*Computed*

2014 Route 15 Balanced Saturday Midday Peak Profile

Conversion Factor: 1.4 (Southbound)

Exit 54: Milford Pkwy / I-95&US-1 Connector | Exit 55: Wheelers Farms Rd/ Wolf Harbor Rd | Exit 56: Rt 121 - Grassy Hill Rd.



	SB ML	SB On	SB On	SB Off	SB Off	SB ML	SB On	SB Off	SB ML
Hour 11	**2,897**	1,042	125	312	59	**2,101**	109	134	**2,126**
Hour 12	**3,255**	1,379	165	374	91	**2,176**	141	132	**2,167**
Hour 13	**3,220**	1,203	129	377	74	**2,339**	160	133	**2,312**
Hour 14	**3,865**	1,632	134	434	77	**2,610**	214	129	**2,525**

	NB ML	NB Off	NB On	NB ML	NB Off	NB Off	NB On	NB ML	NB Off	NB On	NB ML
Hour 11	**3,184**	1,524	548	**2,208**	202	24	74	**2,056**	125	97	**2,028**
Hour 12	**3,228**	1,718	549	**2,059**	202	35	92	**1,914**	134	145	**1,925**
Hour 13	**3,407**	1,809	532	**2,130**	184	31	85	**2,000**	141	133	**1,992**
Hour 14	**3,805**	1,971	704	**2,538**	230	60	110	**2,358**	193	172	**2,337**

Conversion Factor: 1.33 (Northbound)

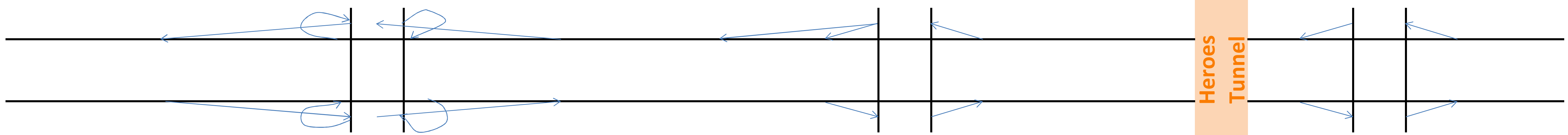
Exit 54: Milford Pkwy / I-95&US-1 Connector | Exit 55: Wheelers Farms Rd/ Wolf Harbor Rd | Exit 56: Rt 121 - Grassy Hill Rd.

Note: Respective conversion factor applied by direction to Route 15 Balanced Weekday Midday Off-Peak Profile traffic volumes.

2014 Route 15 Balanced Saturday Midday Peak Profile

Conversion Factor ***1.4***

	Rt 34 - Derby Ave Exit 57 / Exit 58					Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Rt 10 - Dixwell Ave. Exit 60		
	SB On	SB Off	SB On	*SB Off*	**SB ML**	*SB On*	*SB On*	***SB Off***	**SB ML**	*SB On*	*SB Off*	**SB ML**
Hour 11	70	239	147	200	**2,348**	200	181	520	**2,487**	615	358	**2,230**
Hour 12	48	206	143	249	**2,431**	154	260	618	**2,635**	678	375	**2,332**
Hour 13	69	210	214	230	**2,469**	200	241	540	**2,568**	685	374	**2,257**
Hour 14	78	210	291	349	**2,715**	218	266	632	**2,863**	811	356	**2,408**



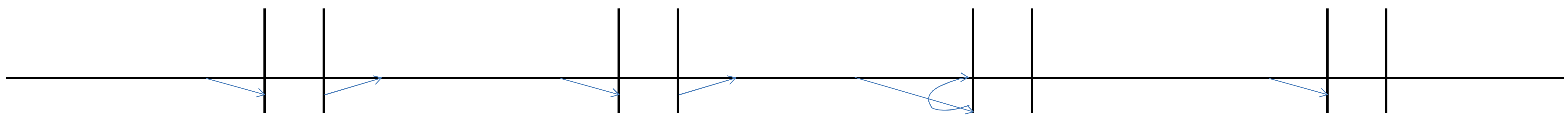
Hour 11	164	218	53	96	**2,125**	294	543	543	**2,374**	524	398	**2,248**
Hour 12	149	263	47	98	**2,090**	287	681	681	**2,484**	547	451	**2,388**
Hour 13	138	270	63	146	**2,207**	278	710	710	**2,639**	618	448	**2,469**
Hour 14	217	293	68	168	**2,513**	390	728	728	**2,851**	716	641	**2,776**
	NB Off	*NB On*	*NB Off*	*NB On*	**NB ML**	*NB Off*	*NB On*		**NB ML**	*NB Off*	*NB On*	**NB ML**
	Rt 34 - Derby Ave Exit 57 / Exit 58					Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Rt 10 - Dixwell Ave. Exit 60		

Conversion Factor ***1.33***

Note: Respective conversion factor applied by direction to Route 15 Balanced Weekday Midday Off-Peak Profile traffic volumes.

2014 Route 15 Balanced Saturday Midday Peak Profile

Hour 11
Hour 12
Hour 13
Hour 14



	NB Off	NB On	NB ML	NB Off	NB On	NB ML	NB Off	NB On	NB ML	NB Off	NB ML
Hour 11	303	194	**2,139**	242	125	**2,022**	360	130	**1,792**	196	**1,596**
Hour 12	319	157	**2,226**	249	125	**2,102**	404	141	**1,839**	185	**1,654**
Hour 13	330	234	**2,373**	291	133	**2,215**	427	118	**1,906**	222	**1,684**
Hour 14	330	283	**2,729**	327	132	**2,534**	491	153	**2,196**	277	**1,919**

Conversion Factor	***1.33***

Whitney Ave. Exit 61	Dixwell Ave. Exit 62	Route 22 Exit 63	Quinnipiac St. Exit 64

Note: Respective conversion factor applied by direction to Route 15 Balanced Weekday Midday Off-Peak Profile traffic volumes.

2014 Route 15 Balanced Saturday Midday Peak Profile

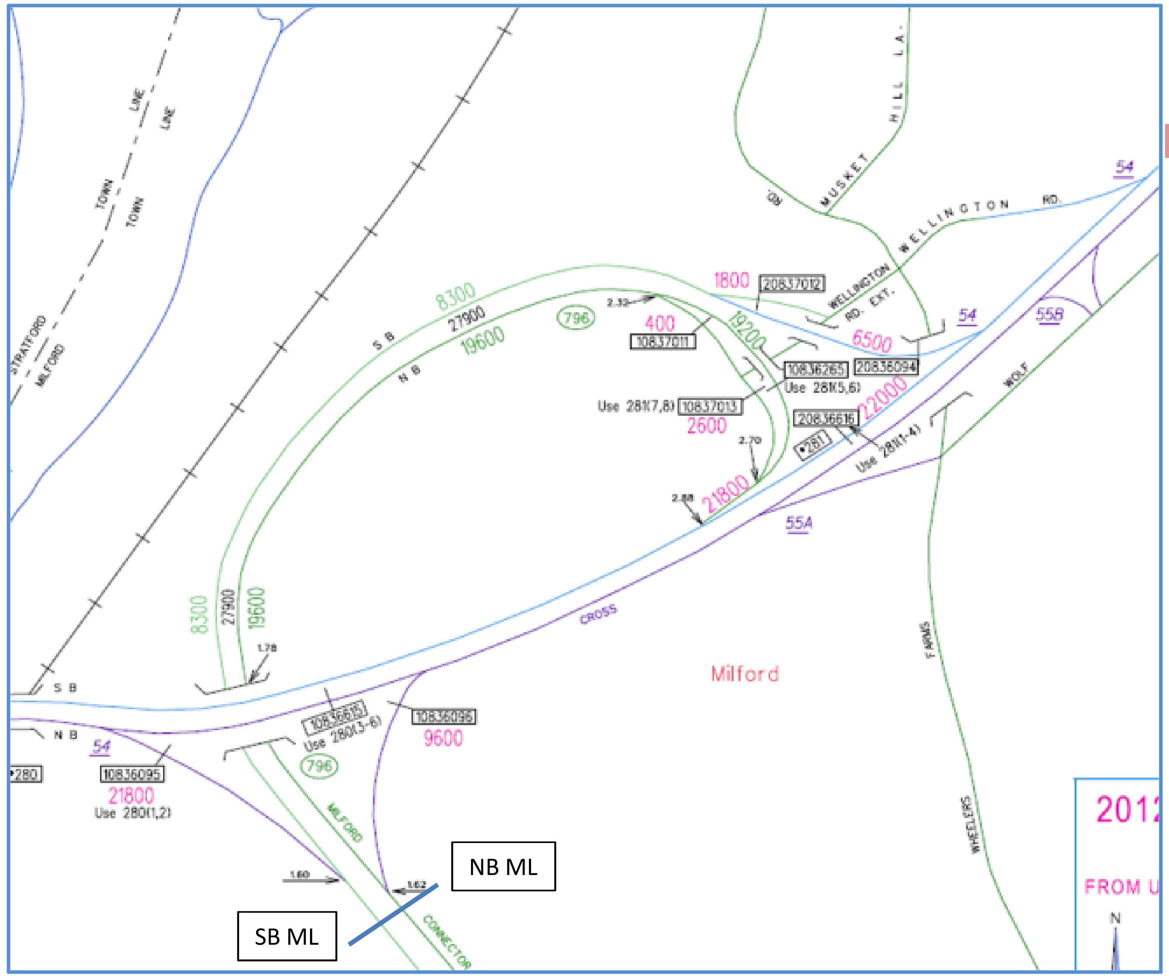
Hour 11
Hour 12
Hour 13
Hour 14

	River Rd. Exit 65 NB Off	River Rd. Exit 65 NB On	**NB ML**	Route 5 Exit 66 NB Off	Route 5 Exit 66 NB On	**NB ML**	CTDOT Garage & Miller Avenue NB Off	CTDOT Garage & Miller Avenue NB On	**NB ML**	East Main St. Exit 67 NB Off	**NB ML**
Hour 11	146	354	**1,804**	329	451	**1,926**	86	126	**1,966**	181	**1,785**
Hour 12	134	391	**1,911**	313	584	**2,182**	157	125	**2,150**	249	**1,901**
Hour 13	132	350	**1,902**	375	620	**2,147**	142	134	**2,139**	223	**1,916**
Hour 14	193	459	**2,185**	378	638	**2,445**	161	149	**2,433**	225	**2,208**

***Conversion Factor* 1.33**

Note: Respective conversion factor applied by direction to Route 15 Balanced Weekday Midday Off-Peak Profile traffic volumes.

2014 Milford Parkway Balanced Saturday Midday Peak Profile



Milford Parkway

Milford Pkwy / Route 15

NB Conversion Factor **1.33**

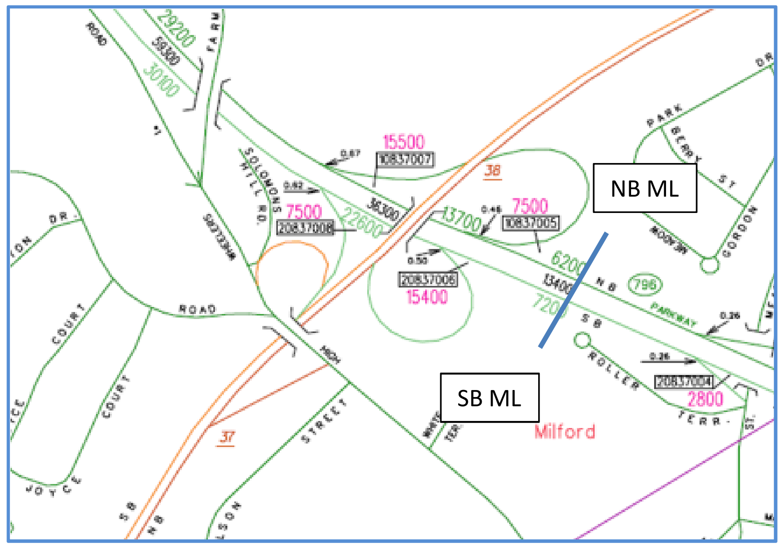
	NB Off	NB Off	NB Off	NB ML	
Hour 11	548	27	1,042	1,617	894
Hour 12	549	32	1,379	1,960	1,053
Hour 13	532	32	1,203	1,767	943
Hour 14	704	33	1,632	2,369	1,221
	STA 6096	STA 7011	STA 6265 To Southbound RT 15 Apply SB RT 15 Factor	Computed	

	SB On	SB On	SB On	SB ML
Hour 11	143	312	1,524	1,979
Hour 12	197	374	1,718	2,289
Hour 13	144	377	1,809	2,330
Hour 14	123	434	1,971	2,528
	STA 7012	STA 6094	STA 6095 From Northbound RT 15 Apply NB RT 15 Factor	Computed

SB Conversion Factor **1.4**

Note: Respective conversion factor applied by direction to Milford Parkway Balanced Weekday Midday Off-Peak Profile traffic volumes.

2014 Milford Parkway Balanced Saturday Midday Peak Profile



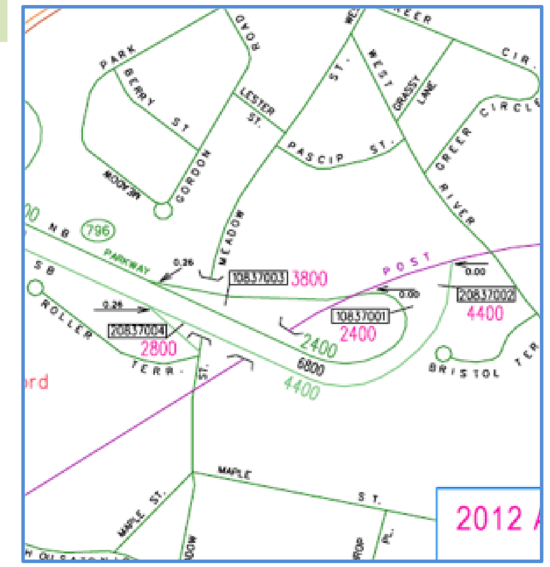
Note: Due to directional conversion factors applied to Stations 6265 and 6095 at the Milford Parkway/Route 15 interchange, traffic volumes at the I-95 and Route 1 Ramps were adjusted proportionately to balance with the Milford Parkway through volumes as assessed on the Milford Parkway Balanced Saturday Midday Peak Profile at the Milford Parkway and Route 15 interchange.

Milford Parkway

Milford Pkwy / I-95

	NB On	*NB On*	**NB ML**	
Hour 11	894	338	385	385
Hour 12	1,053	430	477	477
Hour 13	943	382	442	442
Hour 14	1,221	571	577	577
	STA 7007 Balanced	*STA 7005 Balanced*	*Computed*	

	SB Off	*SB Off*	**SB ML**
Hour 11	433	977	569
Hour 12	483	1,189	617
Hour 13	502	1,164	664
Hour 14	520	1,259	749
	STA 7008 Balanced	*STA 7006 Balanced*	*Computed*



Milford Parkway

Milford Pkwy / Route 1

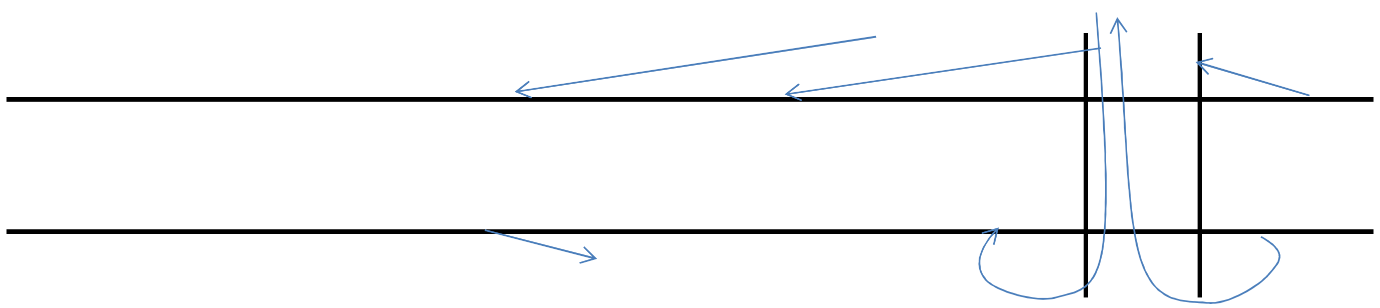
	NB On	*NB On*
Hour 11	253	132
Hour 12	286	191
Hour 13	269	173
Hour 14	343	234
	STA 7003 Balanced	*STA 7001 Balanced*

	SB Off		*SB Off*
Hour 11	196	373	373
Hour 12	225	392	392
Hour 13	305	359	359
Hour 14	338	411	411
	STA 7004 Balanced		*STA 7002 Balanced*

2014 I-95 Balanced Saturday Midday Peak Profile

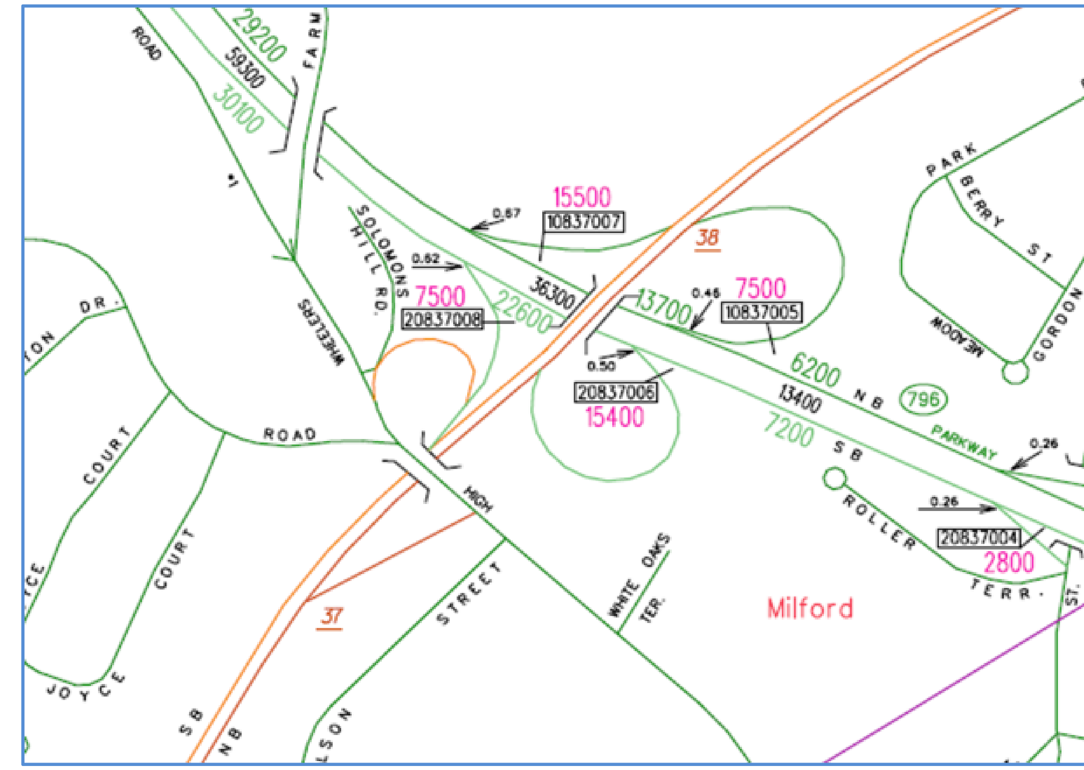
SB Conversion Factor 1.4

	SB ML	Int. 38 Wheelers Farms Rd. SB On	Int. 38 Milford Connector SB On	Int. 38 Milford Connector SB Off	SB ML
Hour 11	**5009**	179	433	894	**5,291**
Hour 12	**5442**	164	483	1053	**5,848**
Hour 13	**5489**	193	502	943	**5,737**
Hour 14	**5694**	193	520	1221	**6,202**
		STA 7148	STA 7008	STA 7007	



	NB ML	Int. 37 High St. NB Off	Int. 38 Milford Connector NB On	Int. 38 Milford Connector NB Off	NB ML
		STA 7147	STA 7006	STA 7005	
Hour 11	**5285**	225	977	338	**5,699**
Hour 12	**5243**	211	1189	430	**5,791**
Hour 13	**5704**	242	1164	382	**6,244**
Hour 14	**6521**	282	1259	571	**6,927**

NB Conversion Factor 1.33



Note: Respective conversion factor applied by direction to Route 15 Balanced Weekday Midday Off-Peak Profile traffic volumes.

B1b. Vissim Network Calibration

Saturday Midday Peak Period
Data Collection (Compiled Data)

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\existing conditions - saturday.inp
Comment:
Date: Thursday, April 10, 2014 10:12:38 AM
VISSIM: 5.40-09 [41012]

	1800-5400				5400-9000				9000-12600				12600-16200			
	Simulated	Raw	% Difference	GEH	Simulated	Raw	% Difference	GEH	Simulated	Raw	% Difference	GEH	Simulated	Raw	% Difference	GEH
Measurement 1: Data Collection Point(s) 1: 15 SB at Tunnel, 2: 15 SB at Tunnel	2482	2487	0.2%	0.1	2641	2635	-0.2%	0.1	2567	2568	0.0%	0.0	2866	2863	-0.1%	0.1
Measurement 3: Data Collection Point(s) 3: Ex 59 SB Off-Ramp	519	520	0.2%	0.0	636	618	-2.8%	0.7	518	540	4.2%	1.0	664	632	-4.8%	1.3
Measurement 4: Data Collection Point(s) 4: 15 SB Ex 59, 5: 15 SB Ex 59	1968	1967	-0.1%	0.0	1999	2017	0.9%	0.4	2056	2028	-1.4%	0.6	2196	2231	1.6%	0.7
Measurement 6: Data Collection Point(s) 6: Ex 59 SB On-Ramp	377	381	1.1%	0.2	338	414	22.5%	3.9	344	441	28.2%	4.9	303	484	59.7%	9.1
Measurement 7: Data Collection Point(s) 7: SB Rt 15 S of Ex 59, 8: SB Rt 15 S of Ex 59	2316	2348	1.4%	0.7	2338	2431	4.0%	1.9	2400	2469	2.9%	1.4	2500	2715	8.6%	4.2
Measurement 9: Data Collection Point(s) 9: SB RT 15 N OF EX 58, 10: SB RT 15 N OF EX 58	2311	2348	1.6%	0.8	2352	2431	3.4%	1.6	2389	2469	3.3%	1.6	2499	2715	8.6%	4.2
Measurement 11: Data Collection Point(s) 11: SB EX 58 OFF-RAMP	191	200	4.7%	0.6	222	249	12.2%	1.8	211	230	9.0%	1.3	320	349	9.1%	1.6
Measurement 12: Data Collection Point(s) 12: SB RT 15 EX 58, 13: SB RT 15 EX 58	2116	2148	1.5%	0.7	2129	2182	2.5%	1.1	2182	2239	2.6%	1.2	2177	2366	8.7%	4.0
Measurement 14: Data Collection Point(s) 14: SB EX 58 ON RAMP	148	147	-0.7%	0.1	143	143	0.0%	0.0	214	214	0.0%	0.0	269	291	8.2%	1.3
Measurement 15: Data Collection Point(s) 15: SB RT 15 BETWEEN 57 & 58, 16: SB RT 15 BETWEEN EX 57 & 58	2261	2295	1.5%	0.7	2271	2325	2.4%	1.1	2393	2453	2.5%	1.2	2438	2657	9.0%	4.3
Measurement 17: Data Collection Point(s) 17: SB EX 57 OFF-RAMP	216	239	10.6%	1.5	196	206	5.1%	0.7	170	210	23.5%	2.9	192	210	9.4%	1.3
Measurement 18: Data Collection Point(s) 18: SB RT 15 EX 57, 19: SB RT 15 EX 57	2042	2056	0.7%	0.3	2080	2119	1.9%	0.9	2226	2243	0.8%	0.4	2243	2447	9.1%	4.2
Measurement 20: Data Collection Point(s) 20: SB EX 57 ON-RAMP	70	70	0.0%	0.0	48	48	0.0%	0.0	69	69	0.0%	0.0	78	78	0.0%	0.0
Measurement 21: Data Collection Point(s) 21: SB RT 15 S OF EX 57, 22: SB RT 15 S OF EX 57	2108	2126	0.9%	0.4	2129	2167	1.8%	0.8	2297	2312	0.7%	0.3	2323	2525	8.7%	4.1
Measurement 23: Data Collection Point(s) 23: SB RT 15 N OF EX 56, 24: SB RT 15 N OF EX 56	2099	2126	1.3%	0.6	2133	2167	1.6%	0.7	2292	2312	0.9%	0.4	2313	2525	9.2%	4.3
Measurement 25: Data Collection Point(s) 25: SB EX 56 OFF-RAMP	116	134	15.5%	1.6	138	132	-4.3%	0.5	126	133	5.6%	0.6	119	129	8.4%	0.9
Measurement 26: Data Collection Point(s) 26: SB RT 15 EX 56, 27: SB RT 15 EX 56	1985	1992	0.4%	0.2	1995	2035	2.0%	0.9	2166	2179	0.6%	0.3	2194	2396	9.2%	4.2
Measurement 28: Data Collection Point(s) 28: SB EX 56 ON-RAMP	109	109	0.0%	0.0	141	141	0.0%	0.0	160	160	0.0%	0.0	214	214	0.0%	0.0
Measurement 29: Data Collection Point(s) 29: SB RT 15 S OF EX 56, 30: SB RT 15 S OF EX 56	2095	2101	0.3%	0.1	2137	2176	1.8%	0.8	2327	2339	0.5%	0.2	2412	2610	8.2%	4.0
Measurement 31: Data Collection Point(s) 31: SB RT 15 N OF EX 55, 32: SB RT 15 N OF EX 55	2096	2101	0.2%	0.1	2132	2176	2.1%	0.9	2317	2339	0.9%	0.5	2399	2610	8.8%	4.2
Measurement 33: Data Collection Point(s) 33: SB EX 55 OFF-RAMP	77	59	-23.4%	2.2	103	91	-11.7%	1.2	96	74	-22.9%	2.4	62	77	24.2%	1.8
Measurement 34: Data Collection Point(s) 34: SB RT 15 EX 55, 35: SB RT 15 EX 55	2022	2042	1.0%	0.4	2025	2085	3.0%	1.3	2226	2265	1.8%	0.8	2336	2533	8.4%	4.0
Measurement 36: Data Collection Point(s) 36: SB EX 54 OFF-RAMP	312	312	0.0%	0.0	386	374	-3.1%	0.6	360	377	4.7%	0.9	395	434	9.9%	1.9
Measurement 37: Data Collection Point(s) 37: SB RT 15 EX 54, 38: SB RT 15 EX 54	1716	1730	0.8%	0.3	1629	1711	5.0%	2.0	1869	1888	1.0%	0.4	1939	2099	8.3%	3.6
Measurement 39: Data Collection Point(s) 39: WELLINGTON RD ON-RAMP TO SB RT 15	125	125	0.0%	0.0	165	165	0.0%	0.0	129	129	0.0%	0.0	134	134	0.0%	0.0
Measurement 40: Data Collection Point(s) 40: MC ON-RAMP TO SB RT 15	1114	1042	-6.5%	2.2	1347	1379	2.4%	0.9	1262	1203	-4.7%	1.7	1603	1632	1.8%	0.7
Measurement 41: Data Collection Point(s) 41: SB ON-RAMP TO RT 15	1238	1167	-5.7%	2.0	1512	1544	2.1%	0.8	1392	1332	-4.3%	1.6	1732	1766	2.0%	0.8
Measurement 42: Data Collection Point(s) 42: SB RT 15 AT EX 54 ON-RAMP, 43: SB RT 15 AT EX 54 ON-RAMP	1714	1730	0.9%	0.4	1631	1711	4.9%	2.0	1862	1888	1.4%	0.6	1947	2099	7.8%	3.4
Measurement 44: Data Collection Point(s) 44: SB RT 15 S OF EX 54, 45: SB RT 15 S OF EX 54, 46: SB RT 15 S OF EX 54	2941	2897	-1.5%	0.8	3144	3255	3.5%	2.0	3260	3220	-1.2%	0.7	3673	3865	5.2%	3.1
Measurement 47: Data Collection Point(s) 47: WELLINGTON RD ON-RAMP TO MC	143	143	0.0%	0.0	197	197	0.0%	0.0	144	144	0.0%	0.0	123	123	0.0%	0.0
Measurement 48: Data Collection Point(s) 48: SB ON-RAMP TO MC	455	312	-31.4%	7.3	583	374	-35.8%	9.6	502	377	-24.9%	6.0	520	434	-16.5%	3.9
Measurement 49: Data Collection Point(s) 49: MC OFF-RAMP TO WELLINGTON RD	27	27	0.0%	0.0	45	32	-28.9%	2.1	29	32	10.3%	0.5	42	33	-21.4%	1.5
Measurement 50: Data Collection Point(s) 50: MC OFF-RAMP TO RT 15 SB	1112	1042	-6.3%	2.1	1353	1379	1.9%	0.7	1254	1203	-4.1%	1.5	1608	1632	1.5%	0.6
Measurement 51: Data Collection Point(s) 51: NB MC OFF-RAMP TO RT 15 SB & WELLINGTON RD	1140	1069	-6.2%	2.1	1401	1411	0.7%	0.3	1281	1235	-3.6%	1.3	1649	1665	1.0%	0.4
Measurement 52: Data Collection Point(s) 52: NB RT 15 S OF EX 54, 53: NB RT 15 S OF EX 54, 54: NB RT 15 S OF EX 54	3191	3184	-0.2%	0.1	3228	3228	0.0%	0.0	3406	3407	0.0%	0.0	3798	3805	0.2%	0.1
Measurement 55: Data Collection Point(s) 55: EX 54 NB OFF-RAMP	1528	1524	-0.3%	0.1	1721	1718	-0.2%	0.1	1821	1809	-0.7%	0.3	1923	1971	2.5%	1.1
Measurement 56: Data Collection Point(s) 56: NB RT 15 EX 54, 57: NB RT 15 EX 54	1663	1660	-0.2%	0.1	1492	1510	1.2%	0.5	1543	1598	3.6%	1.4	1764	1834	4.0%	1.7
Measurement 58: Data Collection Point(s) 58: EX 54 NB ON-RAMP	530	548	3.4%	0.8	501	549	9.6%	2.1	509	532	4.5%	1.0	711	704	-1.0%	0.3
Measurement 59: Data Collection Point(s) 59: NB RT 15 N OF EX 54, 60: NB RT 15 N OF EX 54, 61: NB RT 15 N OF EX 54	2184	2208	1.1%	0.5	1991	2059	3.4%	1.5	2058	2130	3.5%	1.6	2477	2538	2.5%	1.2
Measurement 62: Data Collection Point(s) 62: EX 55 NB OFF-RAMP AT WHEELERS FARM RD	189	202	6.9%	0.9	192	202	5.2%	0.7	156	184	17.9%	2.1	221	230	4.1%	0.6
Measurement 63: Data Collection Point(s) 63: NB RT 15 EX 55 AT WHEELERS FARM RD, 64: NB RT 15 EX 55 AT WHEELERS FARM RD	1995	2006	0.6%	0.2	1805	1857	2.9%	1.2	1903	1946	2.3%	1.0	2255	2308	2.4%	1.1
Measurement 65: Data Collection Point(s) 65: EX 55 NB OFF-RAMP TO WOLF HARBOR RD	16	24	50.0%	1.8	38	35	-7.9%	0.5	23	31	34.8%	1.5	49	60	22.4%	1.5
Measurement 66: Data Collection Point(s) 66: NB RT 15 EX 55 WOLF HARBOR RD, 67: NB RT 15 EX 55 WOLF HARBOR RD	1974	1982	0.4%	0.2	1770	1822	2.9%	1.2	1881	1915	1.8%	0.8	2202	2248	2.1%	1.0
Measurement 68: Data Collection Point(s) 68: EX 55 NB ON-RAMP	74	74	0.0%	0.0	92	92	0.0%	0.0	85	85	0.0%	0.0	110	110	0.0%	0.0
Measurement 69: Data Collection Point(s) 69: NB RT 15 N OF EX 55, 70: NB RT 15 N OF EX 55	2045	2056	0.5%	0.2	1864	1914	2.7%	1.2	1967	2000	1.7%	0.7	2308	2358	2.2%	1.0
Measurement 71: Data Collection Point(s) 71: NB RT 15 S OF EX 56, 72: NB RT 15 S OF EX 56	2032	2056	1.2%	0.5	1880	1914	1.8%	0.8	1958	2000	2.1%	0.9	2293	2358	2.8%	1.3
Measurement 73: Data Collection Point(s) 73: EX 56 NB OFF-RAMP	117	125	6.8%	0.7	136	134	-1.5%	0.2	145	141	-2.8%	0.3	187	193	3.2%	0.4
Measurement 74: Data Collection Point(s) 74: EX 56 NB ON-RAMP	97	97	0.0%	0.0	144	145	0.7%	0.1	134	133	-0.7%	0.1	171	172	0.6%	0.1
Measurement 75: Data Collection Point(s) 75: NB RT 15 EX 56, 76: NB RT 15 EX 56	1911	1931	1.0%	0.5	1746	1780	1.9%	0.8	1809	1859	2.8%	1.2	2107	2165	2.8%	1.3
Measurement 77: Data Collection Point(s) 77: NB RT 15 N OF EX 56, 78: NB RT 15 N OF EX 56	2006	2028	1.1%	0.5	1890	1925	1.9%	0.8	1943	1992	2.5%	1.1	2279	2337	2.5%	1.2
Measurement 79: Data Collection Point(s) 79: NB RT 15 S OF EX 57, 80: NB RT 15 S OF EX 57	2005	2028	1.1%	0.5	1887	1925	2.0%	0.9	1960	1992	1.6%	0.7	2262	2337	3.3%	1.6
Measurement 81: Data Collection Point(s) 81: EX 57 NB OFF-RAMP	166	164	-1.2%	0.2	161	149	-7.5%	1.0	142	138	-2.8%	0.3	230	217	-5.7%	0.9
Measurement 82: Data Collection Point(s) 82: NB RT 15 EX 57, 83: NB RT 15 EX 57	1842	1864	1.2%	0.5	1727	1776	2.8%	1.2	1813	1854	2.3%	1.0	2031	2120	4.4%	2.0
Measurement 84: Data Collection Point(s) 84: EX 57 NB ON-RAMP	217	218	0.5%	0.1	264	263	-0.4%	0.1	270	270	0.0%	0.0	292	293	0.3%	0.1
Measurement 85: Data Collection Point(s) 85: NB RT 15 N OF EX 57, 86: NB RT 15 N OF EX 57	2062	2082	1.0%	0.4	1984	2039	2.8%	1.2	2087	2124	1.8%	0.8	2311	2413	4.4%	2.1
Measurement 87: Data Collection Point(s) 87: EX 58 NB OFF-RAMP	48	53	10.4%	0.7	30	47	56.7%	2.7	62	63	1.6%	0.1	64	68	6.3%	0.5
Measurement 88: Data Collection Point(s) 88: EX 58 NB ON-RAMP	96	96	0.0%	0.0	98	98	0.0%	0.0	146	146	0.0%	0.0	168	168	0.0%	0.0
Measurement 89: Data Collection Point(s) 89: NB RT 15 EX 58, 90: NB RT 15 EX 58	2014	2029	0.7%	0.3	1958	1992	1.7%	0.8	2026	2061	1.7%	0.8	2243	2345	4.5%	2.1
Measurement 91: Data Collection Point(s) 91: NB RT 15 N OF EX 58, 92: NB RT 15 N OF EX 58	2113	2125	0.6%	0.3	2055	2090	1.7%	0.8	2174	2207	1.5%	0.7	2404	2513	4.5%	2.2
Measurement 93: Data Collection Point(s) 93: NB RT 15 S OF EX 59, 94: NB RT 15 S OF EX 59	2093	2125	1.5%	0.7	2081	2090	0.4%	0.2	2149	2207	2.7%	1.2	2385	2513	5.4%	2.6
Measurement 95: Data Collection Point(s) 95: EX 59 NB OFF-RAMP	311	294	-5.5%	1.0	271	287	5.9%	1.0	271	278	2.6%	0.4	343	390	13.7%	2.5
Measurement 96: Data Collection Point(s) 96: NB RT 15 EX 59, 97: NB RT 15 EX 59	1783	1831	2.7%	1.1	1812	1803	-0.5%	0.2	1878	1929	2.7%	1.2	2041	2123	4.0%	1.8
Measurement 98: Data Collection Point(s) 98: EX 59 NB ON-RAMP	542	543	0.2%	0.0	682	681	-0.1%	0.0	710	710	0.0%	0.0	727	728	0.1%	0.0
Measurement 99: Data Collection Point(s) 99: NB RT 15 N OF EX 59, 100: NB RT 15 N OF EX 59	2328	2374	2.0%	0.9	2486	2484	-0.1%	0.0	2584	2639	2.1%	1.1	2759	2851	3.3%	1.7
Measurement 101: Data Collection Point(s) 101: SB MC S OF RT 15, 102: SB MC S OF RT 15	1994	1979	-0.8%	0.3	2300	2289	-0.5%	0.2	2324	2330	0.3%	0.1	2437	2528	3.7%	1.8
Measurement 103: Data Collection Point(s) 103: NB MC S OF RT 15, 104: NB MC S OF RT 15	1677	1617	-3.6%	1.5	1906	1960	2.8%	1.2	1798	1767	-1.7%	0.7	2344	2369	1.1%	0.5
Measurement 105: Data Collection Point(s) 105: NB MC N OF I95, 106: NB MC N OF I95	1683	1617	-3.9%	1.6	1908	1960	2.7%	1.2	1791	1767	-1.3%	0.6	2342	2369	1.2%	0.6
Measurement 107: Data Collection Point(s) 107: SB MC N OF I95, 108: SB MC N OF I95	2010	1979	-1.5%	0.7	2300	2289	-0.5%	0.2	2312	2330	0.8%	0.4	2435	2528	3.8%	1.9
Measurement 109: Data Collection Point(s) 109: SB I-95 OFF-RAMP	949	894	-5.8%	1.8	1010	1053	4.3%	1.3	961	943	-1.9%	0.6	1258	1221	-2.9%	1.1
Measurement 110: Data Collection Point(s) 110: NB MC AT I-95, 111: NB MC AT I-95	734	723	-1.5%	0.4	900	907	0.8%	0.2	838	824	-1.7%	0.5	1084	1148	5.9%	1.9
Measurement 112: Data Collection Point(s) 112: SB MC AT I-95, 113: SB MC AT I-95	1554	1546	-0.5%	0.2	1830	1806	-1.3%	0.6	1791	1828	2.1%	0.9	1965	2008	2.2%	1.0
Measurement 114: Data Collection Point(s) 114: SB MC OFF-RAMP TO I-95	458	433	-5.5%	1.2	471	483	2.5%	0.5	514	502	-2.3%	0.5	473	520	9.9%	2.1
Measurement 115: Data Collection Point(s) 115: WHEELERS FARM RD ON-RAMP TO I-95	179	179	0.0%	0.0	164	164	0.0%	0.0	193	193	0.0%	0.0	193	193	0.0%	0.0
Measurement 116: Data Collection Point(s) 116: SB I-95 ON-RAMP	637	612	-3.9%	1.0	635	647	1.9%	0.5	702	695	-1.0%	0.3	671	713	6.3%	1.6
Measurement 117: Data Collection Point(s) 117: SB I-95 S OF MC, 118: SB I-95 S OF MC, 119: SB I-95 S OF MC	4968	5011	0.9%	0.6	5463	5443	-0.4%	0.3	5510	5492	-0.3%	0.2	5562	5695	2.4%	1.8
Measurement 120: Data Collection Point(s) 120: SB I-95 AT MC, 121: SB I-95 AT MC, 122: SB I-95 AT MC	4324	4399	1.7%	1.1	4843	4796	-1.0%	0.7	4791	4797	0.1%	0.1	4900	4982	1.7%	1.2
Measurement 123: Data Collection Point(s) 123: SB I-95 N OF MC, 124: SB I-95 N OF MC, 125: SB I-95 N OF MC	5275	5291	0.3%	0.2	5853	5848	-0.1%	0.1	5760	5737	-0.4%	0.3	6154	6202	0.8%	0.6
Measurement 126: Data Collection Point(s) 126: NB I-95 S OF HIGH ST, 127: NB I-95 S OF HIGH ST, 128: NB I-95 S OF HIGH ST	5295	5285	-0.2%	0.1	5242	5243	0.0%	0.0	5690	5704	0.2%	0.2	5870	6521	11.1%	8.3
Measurement 129: Data Collection Point(s) 129: I-95 EX 37 NB OFF-RAMP	225	225	0.0%	0.0	197	211	7.1%	1.0	241	242	0.4%	0.1	245	282	15.1%	2.3
Measurement 130: Data Collection Point(s) 130: NB I-95 S OF MC, 131: NB I-95 S OF MC, 132: NB I-95 S OF MC	5065	5060	-0.1%	0.1	5043	5032	-0.2%	0.2	5449	5462	0.2%	0.2	5616	6239	11.1%	8.1
Measurement 133: Data Collection Point(s) 133: I-95 NB ON-RAMP FROM MC	947	977	3.2%	1.0	1238	1189	-4.0%	1.4	1128	1164	3.2%	1.1	1253	1259	0.5%	0.2
Measurement 134: Data Collection Point(s) 134: NB I-95 AT MC, 135: NB I-95 AT MC, 136: NB I-95 AT MC, 137: NB I-95 AT MC	6015	6037	0.4%	0.3	6280	6221	-0.9%	0.7	6579	6626	0.7%	0.6	6802	7498	10.2%	8.2
Measurement 138: Data Collection Point(s) 138: I-95 NB OFF-RAMP TO MC	350	338	-3.4%	0.6	430	430	0.0%	0.0	391	382	-2.3%	0.5	507	571	12.6%	2.8
Measurement 139: Data Collection Point(s) 139: NB I-95 N OF MC, 140: NB I-95 N OF MC, 141: NB I-95 N OF MC	5658	5699	0.7%	0.5	5855	5791	-1.1%	0.8	6180	6244	1.0%	0.8	6296	6927	10.0%	7.8
Measurement 142: Data Collection Point(s) 142: SB MC S OF I-95, 143: SB MC S OF I-95	603	569	-5.6%	1.4	589	617	4.8%	1.1	663	664	0.2%	0.0	706	749	6.1%	1.6
Measurement 144: Data Collection Point(s) 144: NB MC S OF I-95, 145: NB MC S OF I-95	386	385	-0.3%	0.1	472	477	1.1%	0.2	447	442	-1.1%	0.2	574	577	0.5%	0.1
Measurement 146: Data Collection Point(s) 146: SB RT 1 ON-RAMP TO NB MC	253	253	0.0%	0.0	285	286	0.4%	0.1	270	269	-0.4%	0.1	343	343	0.0%	0.0
Measurement 147: Data Collection Point(s) 147: NB RT 1 ON RAMP TO NB MC	132	132	0.0%	0.0	190	191	0.5%	0.1	174	173	-0.6%	0.1	234	234	0.0%	0.0
Measurement 148: Data Collection Point(s) 148: SB MC OFF-RAMP TO NB RT 1, 149: SB MC OFF-RAMP TO NB RT 1	395	373	-5.6%	1.1	375	392	4.5%	0.9	368	359	-2.4%	0.5	375	411	9.6%	1.8
Measurement 150: Data Collection Point(s) 150: SB MC OFF-RAMP TO SB RT 1	208	196	-5.8%	0.8	212	225	6.1%	0.9	296	305	3.0%	0.5	332	338	1.8%	0.3
			Count	1			Count	1			Count	1			Count	5
			Percent Calibrated	98.9%			Percent Calibrated	98.9%			Percent Calibrated	98.9%			Percent Calibrated	94.4%
	10% Count		6		10% Count		6		10% Count		7		10% Count		12	
	Percent Calibrated		93.3%		Percent Calibrated		93.3%		Percent Calibrated		92.2%		Percent Calibrated		86.7%	

Weekday Overnight Off-Peak Period
Data Collection (Compiled Data)

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\existing conditions - weekday off-peak.inp
Comment:
Date: Friday, February 14, 2014 3:28:50 PM
VISSIM: 5.40-09 [41012]

		0-3600		3600-7200		7200-10800		10800-14400	
		Simulated	% Difference	Simulated	% Difference	Simulated	% Difference	Simulated	% Difference
Measurement	1: Data Collection Point(s) 1: Route 15 SB, 8: SB N of Exit 60	1281	0.8%	1055	-0.1%	867	-0.6%	598	0.3%
Measurement	2: Data Collection Point(s) 9: Exit 60 SB Off Ramp	222	7.5%	170	-3.7%	133	7.0%	115	-3.6%
Measurement	3: Data Collection Point(s) 2: Rt15SB Ex60, 7: Exit 60	1056	-0.5%	887	0.3%	734	-2.1%	486	0.6%
Measurement	4: Data Collection Point(s) 32: Ex 60 SB On Ramp	438	0.0%	348	0.0%	235	-0.4%	148	0.0%
Measurement	5: Data Collection Point(s) 3: Rt15 SB Post Ex 60, 10: SB Between Ex 59 & 60	1450	2.6%	1205	2.7%	949	0.4%	628	1.4%
Measurement	6: Data Collection Point(s) 4: Rt15SB Pre Ex59, 11: SB North of Exit 59	1367	8.2%	1213	2.0%	959	-0.6%	663	-4.1%
Measurement	7: Data Collection Point(s) 21: Exit 59 SB Off-Ramp	271	14.8%	237	7.1%	217	-10.2%	109	-3.8%
Measurement	8: Data Collection Point(s) 5: SB Rt15 Ex 59, 12: SB Exit 59	1095	6.5%	975	0.8%	742	1.9%	555	-4.3%
Measurement	9: Data Collection Point(s) 22: SB Exit 59 On-Ramp	277	0.0%	195	-0.5%	137	0.0%	97	0.0%
Measurement	10: Data Collection Point(s) 6: Rt 15 SB Post Ex59, 13: SB South of Exit 59	1363	5.9%	1175	0.2%	880	1.5%	651	-3.5%
Measurement	11: Data Collection Point(s) 14: NB S of Exit 59, 15: NB S of Exit 59	1460	5.8%	1183	-2.5%	884	-1.0%	672	-1.2%
Measurement	12: Data Collection Point(s) 23: Exit 59 NB Off Ramp	245	4.3%	164	5.2%	128	-9.4%	80	0.0%
Measurement	13: Data Collection Point(s) 16: NB Exit 59, 17: NB Exit 59	1210	6.5%	1023	-4.3%	753	0.7%	596	-2.1%
Measurement	14: Data Collection Point(s) 20: Exit 59 NB On Ramp	367	0.3%	343	-0.3%	242	0.0%	139	0.0%
Measurement	15: Data Collection Point(s) 18: NB N of Exit 59, 19: NB North of Exit 59	1489	10.4%	1309	1.1%	962	3.8%	720	0.4%
Measurement	16: Data Collection Point(s) 24: NB South of Exit 60, 25: NB South of Exit 60	1412	15.0%	1331	-0.6%	973	2.7%	724	-0.1%
Measurement	17: Data Collection Point(s) 26: Exit 60 NB Off-Ramp	438	18.3%	441	-5.3%	293	4.2%	173	3.9%
Measurement	18: Data Collection Point(s) 27: NB Exit 60, 28: NB Exit 60	970	13.9%	893	1.2%	678	2.3%	551	-1.5%
Measurement	19: Data Collection Point(s) 29: Exit 60 NB On-Ramp	325	0.3%	201	-0.5%	195	0.0%	100	0.0%
Measurement	20: Data Collection Point(s) 30: NB N of Exit 60, 31: NB N of Exit 60	1234	15.0%	1032	6.5%	853	4.0%	632	1.7%

B1c. Traffic Analysis

existing conditions - weekday off-peak.npe

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\existing conditions\existing conditions - weekday off-peak.inp
Comment:
Date: Monday, April 14, 2014 2:09:35 PM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Average stopped delay per vehicle [s], All Vehicle Types	0.408;
Total delay time [h], All Vehicle Types	32.590;
Total Distance Traveled [mi], All Vehicle Types	64767.399;
Number of Stops, All Vehicle Types	1391;
Number of vehicles that have left the network, All Vehicle Types	12077;
Number of vehicles in the network, All Vehicle Types	161;
Total stopped delay [h], All Vehicle Types	1.387;
Average delay time per vehicle [s], All Vehicle Types	9.587;
Average number of stops per vehicles, All Vehicle Types	0.114;
Average speed [mph], All Vehicle Types	64.477;
Total travel time [h], All Vehicle Types	1004.500;
Total Distance Traveled [mi], All Vehicle Types	64767.399;

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\existing conditions\existing conditions - saturday.inp
Comment:
Date: Monday, April 14, 2014 1:58:48 PM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Number of vehicles that have left the network, All Vehicle Types	80619;
Number of vehicles in the network, All Vehicle Types	2034;
Average delay time per vehicle [s], All Vehicle Types	44.136;
Average number of stops per vehicles, All Vehicle Types	1.320;
Average speed [mph], All Vehicle Types	55.440;
Average stopped delay per vehicle [s], All Vehicle Types	5.480;
Total delay time [h], All Vehicle Types	1013.318;
Total Distance Traveled [mi], All Vehicle Types	335322.229;
Number of Stops, All Vehicle Types	109123;
Total stopped delay [h], All Vehicle Types	125.817;
Total travel time [h], All Vehicle Types	6048.424;

Lane Group	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Lane Configurations												
Volume (vph)	0	68	11	36	44	55	725	5	33	1	44	418
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	14	11	10	10	10	10	16	12	13	10	12	10
Storage Length (ft)		0		10			100	0			160	
Storage Lanes		1		0			2	0			1	
Taper Length (ft)		25					25				25	
Right Turn on Red					Yes				Yes			
Link Speed (mph)	30		30				30					30
Link Distance (ft)	309		175				1238					566
Travel Time (s)	7.0		4.0				28.1					12.9
Confl. Peds. (#/hr)		1		5	3	1	7	3	1	7	5	
Peak Hour Factor	0.92	0.77	0.55	0.69	0.65	0.72	0.95	0.62	0.75	0.25	0.73	0.87
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	88	140	0	0	76	815	0	0	0	64	504
Turn Type		Perm	NA			Perm	NA			Split	Split	NA
Protected Phases	5		5				3			1	1	1
Permitted Phases		5				3						2
Detector Phase	5	5	5			3	3			1	1	1
Switch Phase												
Minimum Initial (s)	5.0	5.0	5.0			9.0	9.0			5.0	5.0	5.0
Minimum Split (s)	10.0	10.0	10.0			14.0	14.0			10.0	10.0	10.0
Total Split (s)	12.0	12.0	12.0			16.0	16.0			10.0	10.0	10.0
Total Split (%)	14.1%	14.1%	14.1%			18.8%	18.8%			11.8%	11.8%	11.8%
Yellow Time (s)	3.0	3.0	3.0			3.0	3.0			3.0	3.0	3.0
All-Red Time (s)	2.0	2.0	2.0			2.0	2.0			2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0			0.0	0.0				0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0			5.0	5.0				5.0	5.0
Lead/Lag						Lead	Lead			Lead	Lead	Lead
Lead-Lag Optimize?						Yes	Yes					
Recall Mode	None	None	None			None	None			None	None	None
v/c Ratio		0.62	0.74			0.55	1.04				0.48	0.81
Control Delay		51.1	47.1			45.4	65.1				45.3	32.0
Queue Delay		0.0	0.0			0.0	0.0				0.0	0.0
Total Delay		51.1	47.1			45.4	65.1				45.3	32.0
Queue Length 50th (ft)		29	32			24	112				21	138
Queue Length 95th (ft)		#105	56			#82	#364				#70	#480
Internal Link Dist (ft)	229		95				1158					486
Turn Bay Length (ft)						100	100				160	
Base Capacity (vph)		143	189			137	786				133	624
Starvation Cap Reductn		0	0			0	0				0	0
Spillback Cap Reductn		0	0			0	0				0	0
Storage Cap Reductn		0	0			0	0				0	0
Reduced v/c Ratio		0.62	0.74			0.55	1.04				0.48	0.81

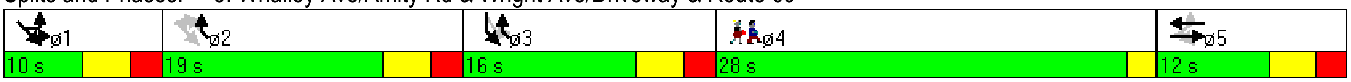
Intersection Summary	
Area Type:	CBD
Cycle Length: 85	
Actuated Cycle Length: 62.6	

Lane Group	SER	NWL	NWT	NWR	NWR2	ø4
Lane Configurations						
Volume (vph)	13	5	400	419	7	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	
Lane Width (ft)	12	12	12	12	13	
Storage Length (ft)	0	0		0		
Storage Lanes	0	0		1		
Taper Length (ft)		25				
Right Turn on Red	Yes				Yes	
Link Speed (mph)			30			
Link Distance (ft)			442			
Travel Time (s)			10.0			
Confl. Peds. (#/hr)	1	1		7	5	
Peak Hour Factor	0.55	0.63	0.93	0.85	0.88	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	0	0	438	501	0	
Turn Type		custom	NA	custom		
Protected Phases				2 3		4
Permitted Phases		2	2			
Detector Phase		2	2	2 3		
Switch Phase						
Minimum Initial (s)		15.0	15.0			1.0
Minimum Split (s)		20.0	20.0			28.0
Total Split (s)		19.0	19.0			28.0
Total Split (%)		22.4%	22.4%			33%
Yellow Time (s)		3.0	3.0			2.0
All-Red Time (s)		2.0	2.0			0.0
Lost Time Adjust (s)			0.0			
Total Lost Time (s)			5.0			
Lead/Lag		Lag	Lag			Lag
Lead-Lag Optimize?		Yes	Yes			Yes
Recall Mode		Min	Min			None
v/c Ratio			1.13	0.65		
Control Delay			114.4	16.6		
Queue Delay			0.0	0.0		
Total Delay			114.4	16.6		
Queue Length 50th (ft)			~170	79		
Queue Length 95th (ft)			#514	#335		
Internal Link Dist (ft)			362			
Turn Bay Length (ft)						
Base Capacity (vph)			387	774		
Starvation Cap Reductn			0	0		
Spillback Cap Reductn			0	0		
Storage Cap Reductn			0	0		
Reduced v/c Ratio			1.13	0.65		

Intersection Summary

Natural Cycle: 95
Control Type: Actuated-Uncoordinated
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 3: Whalley Ave/Amity Rd & Wright Ave/Driveway & Route 69



Movement	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Lane Configurations												
Volume (vph)	0	68	11	36	44	55	725	5	33	1	44	418
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	14	11	10	10	10	10	16	12	13	10	12	10
Total Lost time (s)		5.0	5.0			5.0	5.0				5.0	5.0
Lane Util. Factor		1.00	1.00			1.00	0.97				1.00	1.00
Frpb, ped/bikes		1.00	0.95			1.00	1.00				1.00	1.00
Flpb, ped/bikes		1.00	1.00			1.00	1.00				1.00	1.00
Frt		1.00	0.87			1.00	0.99				1.00	0.99
Flt Protected		0.95	1.00			0.95	0.96				0.95	1.00
Satd. Flow (prot)		1566	1326			1514	3550				1624	1583
Flt Permitted		0.76	1.00			0.48	0.96				0.95	1.00
Satd. Flow (perm)		1248	1326			765	3550				1624	1583
Peak-hour factor, PHF	0.92	0.77	0.55	0.69	0.65	0.72	0.95	0.62	0.75	0.25	0.73	0.87
Adj. Flow (vph)	0	88	20	52	68	76	763	8	44	4	60	480
RTOR Reduction (vph)	0	0	39	0	0	0	148	0	0	0	0	2
Lane Group Flow (vph)	0	88	101	0	0	76	667	0	0	0	64	502
Confl. Peds. (#/hr)		1		5	3	1	7	3	1	7	5	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		Perm	NA			Perm	NA			Split	Split	NA
Protected Phases	5		5				3			1	1	1
Permitted Phases		5				3						2
Actuated Green, G (s)		7.2	7.2			11.3	11.3				5.1	19.5
Effective Green, g (s)		7.2	7.2			11.3	11.3				5.1	19.5
Actuated g/C Ratio		0.11	0.11			0.18	0.18				0.08	0.31
Clearance Time (s)		5.0	5.0			5.0	5.0				5.0	5.0
Vehicle Extension (s)		2.0	2.0			2.0	2.0				2.0	2.0
Lane Grp Cap (vph)		140	149			135	628				129	607
v/s Ratio Prot			c0.08				c0.19				0.04	c0.07
v/s Ratio Perm		0.07				0.10						0.25
v/c Ratio		0.63	0.68			0.56	1.06				0.50	0.83
Uniform Delay, d1		27.0	27.2			24.0	26.2				28.1	20.6
Progression Factor		1.00	1.00			1.00	1.00				1.00	1.00
Incremental Delay, d2		6.2	9.2			3.2	53.5				1.1	8.6
Delay (s)		33.2	36.4			27.2	79.7				29.2	29.2
Level of Service		C	D			C	E				C	C
Approach Delay (s)	0.0		35.2				75.2					29.2
Approach LOS	A		D				E					C

Intersection Summary			
HCM 2000 Control Delay	57.4	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.95		
Actuated Cycle Length (s)	63.8	Sum of lost time (s)	22.0
Intersection Capacity Utilization	85.0%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Movement	SER	NWL	NWT	NWR	NWR2
Lane Configurations					
Volume (vph)	13	5	400	419	7
Ideal Flow (vphpl)	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	13
Total Lost time (s)			5.0	5.0	
Lane Util. Factor			1.00	1.00	
Frpb, ped/bikes			1.00	1.00	
Flpb, ped/bikes			1.00	1.00	
Frt			1.00	0.85	
Flt Protected			1.00	1.00	
Satd. Flow (prot)			1708	1454	
Flt Permitted			0.99	1.00	
Satd. Flow (perm)			1687	1454	
Peak-hour factor, PHF	0.55	0.63	0.93	0.85	0.88
Adj. Flow (vph)	24	8	430	493	8
RTOR Reduction (vph)	0	0	0	60	0
Lane Group Flow (vph)	0	0	438	441	0
Confl. Peds. (#/hr)	1	1		7	5
Heavy Vehicles (%)	0%	0%	0%	0%	0%
Turn Type		custom	NA	custom	
Protected Phases				2 3	
Permitted Phases		2	2		
Actuated Green, G (s)			14.4	30.7	
Effective Green, g (s)			14.4	30.7	
Actuated g/C Ratio			0.23	0.48	
Clearance Time (s)			5.0		
Vehicle Extension (s)			2.0		
Lane Grp Cap (vph)			380	699	
v/s Ratio Prot				0.30	
v/s Ratio Perm			c0.26		
v/c Ratio			1.15	0.63	
Uniform Delay, d1			24.7	12.3	
Progression Factor			1.00	1.00	
Incremental Delay, d2			94.6	1.4	
Delay (s)			119.3	13.7	
Level of Service			F	B	
Approach Delay (s)			63.0		
Approach LOS			E		

Intersection Summary

Lane Group	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	311	466	0	527	629	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	16	12	12	16	16	12
Link Speed (mph)	30			30	30	
Link Distance (ft)	321			1238	178	
Travel Time (s)	7.3			28.1	4.0	
Confl. Peds. (#/hr)	2					
Peak Hour Factor	0.87	0.94	0.85	0.85	0.90	0.90
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%
Shared Lane Traffic (%)						
Lane Group Flow (vph)	853	0	0	620	699	0
Sign Control	Stop			Free	Free	

Intersection Summary	
Area Type:	Other
Control Type: Unsignalized	

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (veh/h)	311	466	0	527	629	0
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Peak Hour Factor	0.87	0.94	0.85	0.85	0.90	0.90
Hourly flow rate (vph)	357	496	0	620	699	0
Pedestrians					2	
Lane Width (ft)					16.0	
Walking Speed (ft/s)					4.0	
Percent Blockage					0	
Right turn flare (veh)						
Median type				Raised	Raised	
Median storage veh)				1	1	
Upstream signal (ft)				1238	313	
pX, platoon unblocked	0.83	0.83	0.83			
vC, conflicting volume	1321	699	699			
vC1, stage 1 conf vol	699					
vC2, stage 2 conf vol	622					
vCu, unblocked vol	1283	530	530			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)	5.4					
tF (s)	3.5	3.3	2.2			
p0 queue free %	0	0	100			
cM capacity (veh/h)	303	457	865			

Direction, Lane #	EB 1	NB 1	SB 1
Volume Total	853	620	699
Volume Left	357	0	0
Volume Right	496	0	0
cSH	377	1700	1700
Volume to Capacity	2.26	0.36	0.41
Queue Length 95th (ft)	1613	0	0
Control Delay (s)	600.2	0.0	0.0
Lane LOS	F		
Approach Delay (s)	600.2	0.0	0.0
Approach LOS	F		

Intersection Summary			
Average Delay	235.8		
Intersection Capacity Utilization	85.6%	ICU Level of Service	E
Analysis Period (min)	15		

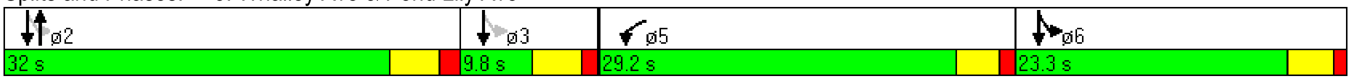
Lane Group	WBL	WBR	NBT	NBR	SBL	SBT	ø3
Lane Configurations							
Volume (vph)	50	108	503	404	275	576	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	
Lane Width (ft)	11	11	10	10	10	11	
Right Turn on Red		Yes		Yes			
Link Speed (mph)	30		30			30	
Link Distance (ft)	415		135			335	
Travel Time (s)	9.4		3.1			7.6	
Confl. Peds. (#/hr)	7	1		11	11		
Peak Hour Factor	0.69	0.90	0.87	0.83	0.82	0.87	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	
Shared Lane Traffic (%)							
Lane Group Flow (vph)	192	0	1065	0	335	662	
Turn Type	NA		NA		custom	NA	
Protected Phases	5		2		6	2 3 6	3
Permitted Phases					2 3		
Detector Phase	5		2		6	2 3 6	
Switch Phase							
Minimum Initial (s)	6.0		25.0		9.0		5.0
Minimum Split (s)	15.2		30.0		15.3		9.8
Total Split (s)	29.2		32.0		23.3		9.8
Total Split (%)	31.0%		33.9%		24.7%		10%
Yellow Time (s)	3.0		3.5		3.3		3.5
All-Red Time (s)	1.2		1.5		1.0		1.3
Lost Time Adjust (s)	0.0		0.0		0.0		
Total Lost Time (s)	4.2		5.0		4.3		
Lead/Lag	Lead				Lag		
Lead-Lag Optimize?	Yes				Yes		
Recall Mode	None		Min		None		None
v/c Ratio	0.62		0.86		0.70	0.47	
Control Delay	21.8		27.8		23.0	5.2	
Queue Delay	0.0		0.0		0.0	0.0	
Total Delay	21.8		27.8		23.0	5.2	
Queue Length 50th (ft)	29		202		81	85	
Queue Length 95th (ft)	50		#341		163	184	
Internal Link Dist (ft)	335		55			255	
Turn Bay Length (ft)							
Base Capacity (vph)	622		1237		527	1387	
Starvation Cap Reductn	0		0		0	0	
Spillback Cap Reductn	0		0		0	0	
Storage Cap Reductn	0		0		0	0	
Reduced v/c Ratio	0.31		0.86		0.64	0.48	

Intersection Summary

Area Type: Other
Cycle Length: 94.3
Actuated Cycle Length: 76.7
Natural Cycle: 75
Control Type: Semi Act-Uncoord
95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 5: Whalley Ave & Pond Lily Ave



Movement	WBL	WBR	NBT	NBR	SBL	SBT
Lane Configurations						
Volume (vph)	50	108	503	404	275	576
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width	11	11	10	10	10	11
Total Lost time (s)	4.2		5.0		4.3	5.0
Lane Util. Factor	1.00		0.95		1.00	1.00
Frpb, ped/bikes	0.99		0.98		1.00	1.00
Flpb, ped/bikes	1.00		1.00		1.00	1.00
Frt	0.92		0.93		1.00	1.00
Flt Protected	0.98		1.00		0.95	1.00
Satd. Flow (prot)	1636		3088		1685	1837
Flt Permitted	0.98		1.00		0.12	1.00
Satd. Flow (perm)	1636		3088		221	1837
Peak-hour factor, PHF	0.69	0.90	0.87	0.83	0.82	0.87
Adj. Flow (vph)	72	120	578	487	335	662
RTOR Reduction (vph)	113	0	147	0	0	0
Lane Group Flow (vph)	79	0	918	0	335	662
Confl. Peds. (#/hr)	7	1		11	11	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%
Turn Type	NA		NA		custom	NA
Protected Phases	5		2		6	2 3 6
Permitted Phases					2 3	
Actuated Green, G (s)	9.2		27.1		54.0	58.3
Effective Green, g (s)	9.2		27.1		49.0	54.0
Actuated g/C Ratio	0.12		0.35		0.64	0.71
Clearance Time (s)	4.2		5.0		4.3	
Vehicle Extension (s)	3.0		3.5		3.0	
Lane Grp Cap (vph)	196		1093		464	1296
v/s Ratio Prot	c0.05		c0.30		c0.16	c0.36
v/s Ratio Perm					0.30	
v/c Ratio	0.41		0.84		0.72	0.51
Uniform Delay, d1	31.1		22.7		16.0	5.2
Progression Factor	1.00		1.00		1.00	1.00
Incremental Delay, d2	1.4		6.1		5.5	0.4
Delay (s)	32.5		28.8		21.4	5.6
Level of Service	C		C		C	A
Approach Delay (s)	32.5		28.8			10.9
Approach LOS	C		C			B

Intersection Summary			
HCM 2000 Control Delay	21.2	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.73		
Actuated Cycle Length (s)	76.5	Sum of lost time (s)	18.3
Intersection Capacity Utilization	63.3%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	NBL2	NBL	NBT	NBR	SBL	SBT	SBR	SBR2	SEL	SET	SER	SER2
Lane Configurations												
Volume (vph)	85	85	704	85	224	644	55	1	132	65	12	11
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	11	13	12	14	12	12	10	11	11
Storage Length (ft)		0		0	84		0		0		0	
Storage Lanes		1		1	1		0		0		0	
Taper Length (ft)		25			25				25			
Right Turn on Red				Yes				Yes				Yes
Link Speed (mph)			30			30				30		
Link Distance (ft)			334			671				589		
Travel Time (s)			7.6			15.3				13.4		
Peak Hour Factor	0.92	0.89	0.91	0.69	0.92	0.91	0.69	0.25	0.69	0.75	0.90	0.77
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	188	774	123	243	792	0	0	0	305	0	0
Turn Type	Prot	Prot	NA	custom	Prot	NA			Split	NA		
Protected Phases	1	1	6	6	5	2			4	4		
Permitted Phases				7								
Detector Phase	1	1	6	6	5	2			4	4		
Switch Phase												
Minimum Initial (s)	2.0	2.0	10.0	10.0	5.0	10.0			5.0	5.0		
Minimum Split (s)	9.0	9.0	20.0	20.0	11.0	20.0			28.0	28.0		
Total Split (s)	11.0	11.0	22.0	22.0	13.0	24.0			28.0	28.0		
Total Split (%)	12.9%	12.9%	25.9%	25.9%	15.3%	28.2%			32.9%	32.9%		
Yellow Time (s)	3.0	3.0	3.0	3.0	3.0	3.0			3.0	3.0		
All-Red Time (s)	3.0	3.0	3.0	3.0	3.0	3.0			3.0	3.0		
Lost Time Adjust (s)		0.0	0.0	0.0	0.0	0.0				0.0		
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Lead/Lag	Lead	Lead	Lag	Lag	Lead	Lag						
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes						
Recall Mode	None	None	Min	Min	None	Min			None	None		
v/c Ratio		1.63	1.05	0.18	1.46	0.97				0.48		
Control Delay		353.0	82.0	2.6	268.8	58.9				29.2		
Queue Delay		0.0	0.0	0.0	0.0	0.0				0.0		
Total Delay		353.0	82.0	2.6	268.8	58.9				29.2		
Queue Length 50th (ft)		~153	~259	0	~188	~248				68		
Queue Length 95th (ft)		#276	#372	9	#330	#365				85		
Internal Link Dist (ft)			254			591				509		
Turn Bay Length (ft)					84							
Base Capacity (vph)		115	735	693	166	814				907		
Starvation Cap Reductn		0	0	0	0	0				0		
Spillback Cap Reductn		0	0	0	0	0				0		
Storage Cap Reductn		0	0	0	0	0				0		
Reduced v/c Ratio		1.63	1.05	0.18	1.46	0.97				0.34		

Intersection Summary

Area Type: Other

Cycle Length: 85

Actuated Cycle Length: 78.6

Natural Cycle: 85

Lane Group	NWL2	NWT	NWR
Lane Configurations			
Volume (vph)	120	304	202
Ideal Flow (vphpl)	1900	1900	1900
Lane Width (ft)	14	12	14
Storage Length (ft)			0
Storage Lanes			1
Taper Length (ft)			
Right Turn on Red			Yes
Link Speed (mph)		30	
Link Distance (ft)		251	
Travel Time (s)		5.7	
Peak Hour Factor	0.77	0.92	0.89
Heavy Vehicles (%)	0%	0%	0%
Shared Lane Traffic (%)			
Lane Group Flow (vph)	156	330	227
Turn Type	Split	NA	Prot
Protected Phases	7	7	7
Permitted Phases			
Detector Phase	7	7	7
Switch Phase			
Minimum Initial (s)	10.0	10.0	10.0
Minimum Split (s)	22.0	22.0	22.0
Total Split (s)	22.0	22.0	22.0
Total Split (%)	25.9%	25.9%	25.9%
Yellow Time (s)	3.0	3.0	3.0
All-Red Time (s)	3.0	3.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	6.0
Lead/Lag			
Lead-Lag Optimize?			
Recall Mode	None	None	None
v/c Ratio	0.41	0.89	0.44
Control Delay	33.2	60.0	7.5
Queue Delay	0.0	0.0	0.0
Total Delay	33.2	60.0	7.5
Queue Length 50th (ft)	74	175	0
Queue Length 95th (ft)	110	#330	55
Internal Link Dist (ft)		171	
Turn Bay Length (ft)			
Base Capacity (vph)	396	390	534
Starvation Cap Reductn	0	0	0
Spillback Cap Reductn	0	0	0
Storage Cap Reductn	0	0	0
Reduced v/c Ratio	0.39	0.85	0.43

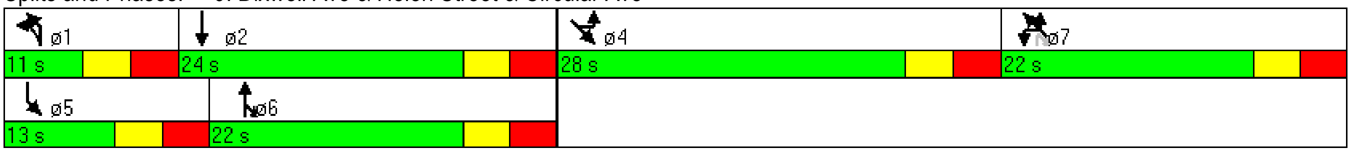
Intersection Summary

Control Type: Semi Act-Uncoord

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 9: Dixwell Ave & Helen Street & Circular Ave



Movement	NBL2	NBL	NBT	NBR	SBL	SBT	SBR	SBR2	SEL	SET	SER	SER2
Lane Configurations												
Volume (vph)	85	85	704	85	224	644	55	1	132	65	12	11
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	11	13	12	14	12	12	10	11	11
Total Lost time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Lane Util. Factor		1.00	0.95	1.00	1.00	0.95				0.95		
Frt		1.00	1.00	0.85	1.00	0.98				0.99		
Flt Protected		0.95	1.00	1.00	0.95	1.00				0.97		
Satd. Flow (prot)		1787	3574	1546	1847	3518				3192		
Flt Permitted		0.95	1.00	1.00	0.95	1.00				0.97		
Satd. Flow (perm)		1787	3574	1546	1847	3518				3192		
Peak-hour factor, PHF	0.92	0.89	0.91	0.69	0.92	0.91	0.69	0.25	0.69	0.75	0.90	0.77
Adj. Flow (vph)	92	96	774	123	243	708	80	4	191	87	13	14
RTOR Reduction (vph)	0	0	0	73	0	1	0	0	0	4	0	0
Lane Group Flow (vph)	0	188	774	50	243	791	0	0	0	301	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
Turn Type	Prot	Prot	NA	custom	Prot	NA			Split	NA		
Protected Phases	1	1	6	6	5	2			4	4		
Permitted Phases				7								
Actuated Green, G (s)		5.1	16.2	31.6	7.1	18.2				15.7		
Effective Green, g (s)		5.1	16.2	31.6	7.1	18.2				15.7		
Actuated g/C Ratio		0.07	0.21	0.40	0.09	0.23				0.20		
Clearance Time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Vehicle Extension (s)		1.0	2.0	2.0	1.0	3.0				1.0		
Lane Grp Cap (vph)		116	738	623	167	816				639		
v/s Ratio Prot		0.11	0.22	0.02	c0.13	c0.22				c0.09		
v/s Ratio Perm				0.02								
v/c Ratio		1.62	1.05	0.08	1.46	0.97				0.47		
Uniform Delay, d1		36.7	31.1	14.4	35.7	29.8				27.7		
Progression Factor		1.00	1.00	1.00	1.00	1.00				1.00		
Incremental Delay, d2		315.2	46.6	0.0	234.8	24.0				0.2		
Delay (s)		351.9	77.7	14.5	270.5	53.8				27.9		
Level of Service		F	E	B	F	D				C		
Approach Delay (s)			118.1			104.7				27.9		
Approach LOS			F			F				C		

Intersection Summary			
HCM 2000 Control Delay	86.7	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.90		
Actuated Cycle Length (s)	78.4	Sum of lost time (s)	24.0
Intersection Capacity Utilization	75.2%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

Movement	NWL2	NWT	NWR
Lane Configurations			
Volume (vph)	120	304	202
Ideal Flow (vphpl)	1900	1900	1900
Lane Width	14	12	14
Total Lost time (s)	6.0	6.0	6.0
Lane Util. Factor	1.00	1.00	1.00
Frt	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00
Satd. Flow (prot)	1925	1900	1723
Flt Permitted	0.95	1.00	1.00
Satd. Flow (perm)	1925	1900	1723
Peak-hour factor, PHF	0.77	0.92	0.89
Adj. Flow (vph)	156	330	227
RTOR Reduction (vph)	0	0	182
Lane Group Flow (vph)	156	330	45
Heavy Vehicles (%)	0%	0%	0%
Turn Type	Split	NA	Prot
Protected Phases	7	7	7
Permitted Phases			
Actuated Green, G (s)	15.4	15.4	15.4
Effective Green, g (s)	15.4	15.4	15.4
Actuated g/C Ratio	0.20	0.20	0.20
Clearance Time (s)	6.0	6.0	6.0
Vehicle Extension (s)	1.0	1.0	1.0
Lane Grp Cap (vph)	378	373	338
v/s Ratio Prot	0.08	c0.17	0.03
v/s Ratio Perm			
v/c Ratio	0.41	0.88	0.13
Uniform Delay, d1	27.5	30.6	26.0
Progression Factor	1.00	1.00	1.00
Incremental Delay, d2	0.3	20.7	0.1
Delay (s)	27.8	51.4	26.1
Level of Service	C	D	C
Approach Delay (s)		38.2	
Approach LOS		D	

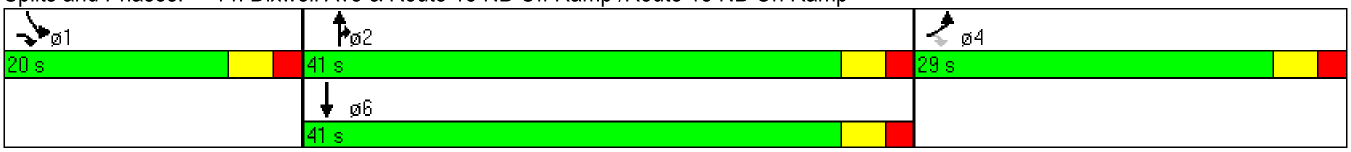
Intersection Summary

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	344	0	245	0	0	0	0	1241	376	106	1271	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	11	12	12	11	12	11
Storage Length (ft)	0		215	0		0	0		240	0		0
Storage Lanes	2		1	0		0	0		1	1		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		409			488			632			296	
Travel Time (s)		9.3			11.1			14.4			6.7	
Confl. Peds. (#/hr)			2						4	4		
Peak Hour Factor	0.83	0.25	0.92	0.92	0.92	0.92	0.25	0.86	0.96	0.88	0.95	0.25
Heavy Vehicles (%)	0%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	414	0	266	0	0	0	0	1443	392	120	1338	0
Turn Type	Prot		custom					NA	Prot	Prot	NA	
Protected Phases	4		1					2	2	1	6	
Permitted Phases			4									
Detector Phase	4		1					2	2	1	6	
Switch Phase												
Minimum Initial (s)	7.0		7.0					15.0	15.0	7.0	15.0	
Minimum Split (s)	12.0		12.0					31.0	31.0	12.0	21.0	
Total Split (s)	29.0		20.0					41.0	41.0	20.0	41.0	
Total Split (%)	32.2%		22.2%					45.6%	45.6%	22.2%	45.6%	
Yellow Time (s)	3.0		3.0					3.0	3.0	3.0	3.0	
All-Red Time (s)	2.0		2.0					2.0	2.0	2.0	2.0	
Lost Time Adjust (s)	0.0		0.0					0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None		None					Min	Min	None	Min	
v/c Ratio	0.67		0.52					0.83	0.40	0.52	0.76	
Control Delay	34.5		19.3					23.0	3.6	39.2	20.3	
Queue Delay	0.0		0.0					0.0	0.0	0.0	0.0	
Total Delay	34.5		19.3					23.0	3.6	39.2	20.3	
Queue Length 50th (ft)	91		79					278	6	52	244	
Queue Length 95th (ft)	130		137					#475	58	105	414	
Internal Link Dist (ft)		329			408			552			216	
Turn Bay Length (ft)			215						240			
Base Capacity (vph)	1139		624					1744	975	354	1762	
Starvation Cap Reductn	0		0					0	0	0	0	
Spillback Cap Reductn	0		0					0	0	0	0	
Storage Cap Reductn	0		0					0	0	0	0	
Reduced v/c Ratio	0.36		0.43					0.83	0.40	0.34	0.76	

Intersection Summary	
Area Type:	Other
Cycle Length: 90	
Actuated Cycle Length: 74.2	

Natural Cycle: 60
Control Type: Semi Act-Uncoord
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 14: Dixwell Ave & Route 15 NB Off Ramp /Route 15 NB On Ramp



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	344	0	245	0	0	0	0	1241	376	106	1271	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	12	12	11	12	12	11	12	11
Total Lost time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Lane Util. Factor	0.97		1.00					0.95	1.00	1.00	0.95	
Frpb, ped/bikes	1.00		0.99					1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00		1.00					1.00	1.00	1.00	1.00	
Frt	1.00		0.85					1.00	0.85	1.00	1.00	
Flt Protected	0.95		1.00					1.00	1.00	0.95	1.00	
Satd. Flow (prot)	3502		1602					3574	1615	1745	3610	
Flt Permitted	0.95		1.00					1.00	1.00	0.95	1.00	
Satd. Flow (perm)	3502		1602					3574	1615	1745	3610	
Peak-hour factor, PHF	0.83	0.25	0.92	0.92	0.92	0.92	0.25	0.86	0.96	0.88	0.95	0.25
Adj. Flow (vph)	414	0	266	0	0	0	0	1443	392	120	1338	0
RTOR Reduction (vph)	0	0	17	0	0	0	0	0	187	0	0	0
Lane Group Flow (vph)	414	0	249	0	0	0	0	1443	205	120	1338	0
Confl. Peds. (#/hr)			2						4	4		
Heavy Vehicles (%)	0%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
Turn Type	Prot		custom					NA	Prot	Prot	NA	
Protected Phases	4		1					2	2	1	6	
Permitted Phases			4									
Actuated Green, G (s)	13.1		22.9					36.2	36.2	9.8	36.2	
Effective Green, g (s)	13.1		22.9					36.2	36.2	9.8	36.2	
Actuated g/C Ratio	0.18		0.31					0.49	0.49	0.13	0.49	
Clearance Time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Vehicle Extension (s)	2.0		2.0					3.0	3.0	2.0	3.0	
Lane Grp Cap (vph)	619		603					1746	788	230	1763	
v/s Ratio Prot	c0.12		0.05					c0.40	0.13	c0.07	0.37	
v/s Ratio Perm			0.10									
v/c Ratio	0.67		0.41					0.83	0.26	0.52	0.76	
Uniform Delay, d1	28.5		20.3					16.3	11.1	30.0	15.4	
Progression Factor	1.00		1.00					1.00	1.00	1.00	1.00	
Incremental Delay, d2	2.1		0.2					3.4	0.2	1.0	1.9	
Delay (s)	30.6		20.4					19.6	11.3	31.0	17.3	
Level of Service	C		C					B	B	C	B	
Approach Delay (s)		26.6			0.0			17.8			18.5	
Approach LOS		C			A			B			B	

Intersection Summary			
HCM 2000 Control Delay	19.6	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.74		
Actuated Cycle Length (s)	74.1	Sum of lost time (s)	15.0
Intersection Capacity Utilization	61.9%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	306	110	38	7	3	8	58	485	31	121	369	294
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	11	13	12	11	12	11	10	12	14	10	12	12
Storage Length (ft)	210		0	55		0	90		0	130		0
Storage Lanes	1		0	1		0	1		0	1		1
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		555			252			414			384	
Travel Time (s)		12.6			5.7			9.4			8.7	
Confl. Peds. (#/hr)	4		5	5		4	19		12	12		19
Peak Hour Factor	0.60	0.75	0.50	0.58	0.75	0.50	0.69	0.98	0.76	0.86	0.90	0.80
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	1%	0%	0%	1%	0%
Shared Lane Traffic (%)	28%											
Lane Group Flow (vph)	367	366	0	12	20	0	84	536	0	141	410	368
Turn Type	Split	NA		Split	NA		pm+pt	NA		pm+pt	NA	pt+ov
Protected Phases	9	9		8	8		5	2		1	6	6 9
Permitted Phases							2			6		
Detector Phase	9	9		8	8		5	2		1	6	6 9
Switch Phase												
Minimum Initial (s)	9.0	9.0		5.0	5.0		5.0	15.0		5.0	15.0	
Minimum Split (s)	13.6	13.6		10.4	10.4		7.9	19.8		7.9	19.8	
Total Split (s)	26.6	26.6		15.4	15.4		12.9	32.8		12.9	32.8	
Total Split (%)	24.2%	24.2%		14.0%	14.0%		11.8%	29.9%		11.8%	29.9%	
Yellow Time (s)	3.6	3.6		3.6	3.6		2.8	3.6		2.8	3.6	
All-Red Time (s)	1.0	1.0		1.8	1.8		0.1	1.2		0.1	1.2	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	
Lead/Lag							Lead	Lag		Lead	Lag	
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		None	Min		None	Min	
v/c Ratio	0.67	0.62		0.09	0.14		0.22	0.48		0.35	0.61	0.28
Control Delay	30.6	27.5		36.1	22.5		11.3	20.6		12.6	24.3	1.0
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Delay	30.6	27.5		36.1	22.5		11.3	20.6		12.6	24.3	1.0
Queue Length 50th (ft)	127	121		5	2		14	81		25	128	0
Queue Length 95th (ft)	173	220		14	18		33	158		65	272	7
Internal Link Dist (ft)		475			172			334			304	
Turn Bay Length (ft)	210			55			90			130		
Base Capacity (vph)	548	590		265	262		462	1504		456	800	1307
Starvation Cap Reductn	0	0		0	0		0	0		0	0	0
Spillback Cap Reductn	0	0		0	0		0	0		0	0	0
Storage Cap Reductn	0	0		0	0		0	0		0	0	0
Reduced v/c Ratio	0.67	0.62		0.05	0.08		0.18	0.36		0.31	0.51	0.28

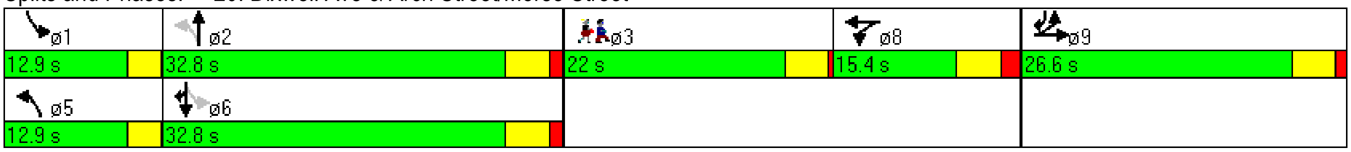
Intersection Summary	
Area Type:	Other
Cycle Length: 109.7	
Actuated Cycle Length: 67.7	

Lane Group	ø3
Lane Configurations	
Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Confl. Peds. (#/hr)	
Peak Hour Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	3
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	7.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	20%
Yellow Time (s)	3.5
All-Red Time (s)	0.5
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Natural Cycle: 90
Control Type: Semi Act-Uncoord

Splits and Phases: 20: Dixwell Ave & Arch Street/Morse Street



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	306	110	38	7	3	8	58	485	31	121	369	294
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	11	13	12	11	12	11	10	12	14	10	12	12
Total Lost time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	4.8
Lane Util. Factor	0.95	0.95		1.00	1.00		1.00	0.95		1.00	1.00	1.00
Frpb, ped/bikes	1.00	0.99		1.00	0.95		1.00	1.00		1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Frt	1.00	0.97		1.00	0.88		1.00	0.99		1.00	1.00	0.85
Flt Protected	0.95	0.98		0.95	1.00		0.95	1.00		0.95	1.00	1.00
Satd. Flow (prot)	1641	1745		1745	1593		1678	3525		1682	1881	1615
Flt Permitted	0.95	0.98		0.95	1.00		0.35	1.00		0.33	1.00	1.00
Satd. Flow (perm)	1641	1745		1745	1593		622	3525		589	1881	1615
Peak-hour factor, PHF	0.60	0.75	0.50	0.58	0.75	0.50	0.69	0.98	0.76	0.86	0.90	0.80
Adj. Flow (vph)	510	147	76	12	4	16	84	495	41	141	410	368
RTOR Reduction (vph)	0	8	0	0	16	0	0	5	0	0	0	128
Lane Group Flow (vph)	367	358	0	12	4	0	84	531	0	141	410	240
Confl. Peds. (#/hr)	4		5	5		4	19		12	12		19
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	1%	0%	0%	1%	0%
Turn Type	Split	NA		Split	NA		pm+pt	NA		pm+pt	NA	pt+ov
Protected Phases	9	9		8	8		5	2		1	6	6 9
Permitted Phases							2			6		
Actuated Green, G (s)	22.6	22.6		1.8	1.8		27.6	22.2		31.6	24.2	46.8
Effective Green, g (s)	22.6	22.6		1.8	1.8		27.6	22.2		31.6	24.2	46.8
Actuated g/C Ratio	0.32	0.32		0.03	0.03		0.38	0.31		0.44	0.34	0.65
Clearance Time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	
Vehicle Extension (s)	1.5	1.5		1.5	1.5		1.5	2.5		1.5	2.5	
Lane Grp Cap (vph)	517	550		43	39		318	1091		372	634	1054
v/s Ratio Prot	c0.22	0.21		c0.01	0.00		0.02	0.15		c0.04	c0.22	0.15
v/s Ratio Perm							0.08			0.13		
v/c Ratio	0.71	0.65		0.28	0.11		0.26	0.49		0.38	0.65	0.23
Uniform Delay, d1	21.7	21.2		34.3	34.2		14.7	20.1		12.6	20.1	5.1
Progression Factor	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Incremental Delay, d2	3.6	2.1		1.3	0.5		0.2	0.3		0.2	2.0	0.1
Delay (s)	25.3	23.3		35.6	34.6		14.8	20.4		12.8	22.1	5.2
Level of Service	C	C		D	C		B	C		B	C	A
Approach Delay (s)		24.3			35.0			19.6			13.9	
Approach LOS		C			D			B			B	

Intersection Summary			
HCM 2000 Control Delay	19.0	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.70		
Actuated Cycle Length (s)	71.7	Sum of lost time (s)	21.7
Intersection Capacity Utilization	54.0%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	240	712	4	13	604	61	2	1	3	107	1	171
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	10	11	15	15	11	11	15	15	15	14	15	8
Storage Length (ft)	150		0	0		0	0		0	0		0
Storage Lanes	1		0	0		0	0		0	0		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		709			1067			199			1402	
Travel Time (s)		16.1			24.3			4.5			31.9	
Confl. Peds. (#/hr)	6		12	12		6	4		3	3		4
Peak Hour Factor	0.25	0.88	0.61	0.25	0.88	0.61	0.50	0.25	0.38	0.92	0.25	0.93
Heavy Vehicles (%)	0%	0%	1%	2%	2%	2%	2%	2%	2%	1%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	960	816	0	0	838	0	0	16	0	0	304	0
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	1	6			2			4			4	
Permitted Phases	6			2			4			4		
Detector Phase	1	6		2	2		4	4		4	4	
Switch Phase												
Minimum Initial (s)	5.0	5.0		15.0	15.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	9.0	27.0		20.0	20.0		10.0	10.0		10.0	10.0	
Total Split (s)	10.0	30.0		20.0	20.0		27.0	27.0		27.0	27.0	
Total Split (%)	12.5%	37.5%		25.0%	25.0%		33.8%	33.8%		33.8%	33.8%	
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	0.1	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0			0.0			0.0			0.0	
Total Lost Time (s)	3.1	5.0			5.0			5.0			5.0	
Lead/Lag	Lead			Lag	Lag		Lag	Lag		Lag	Lag	
Lead-Lag Optimize?				Yes	Yes							
Recall Mode	None	Max		C-Max	C-Max		None	None		None	None	
v/c Ratio	1.08	0.34			1.58			0.05			0.82	
Control Delay	73.5	6.0			297.0			17.3			38.9	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	73.5	6.0			297.0			17.3			38.9	
Queue Length 50th (ft)	~492	71			~318			3			102	
Queue Length 95th (ft)	67	131			#421			3			11	
Internal Link Dist (ft)		629			987			119			1322	
Turn Bay Length (ft)	150											
Base Capacity (vph)	890	2429			530			476			520	
Starvation Cap Reductn	0	0			0			0			0	
Spillback Cap Reductn	0	0			0			0			0	
Storage Cap Reductn	0	0			0			0			0	
Reduced v/c Ratio	1.08	0.34			1.58			0.03			0.58	

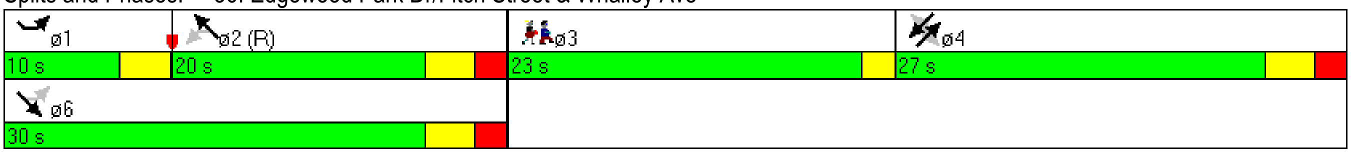
Intersection Summary	
Area Type:	Other
Cycle Length: 80	
Actuated Cycle Length: 80	

Lane Group	ø3
Lane Configurations	
Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Confl. Peds. (#/hr)	
Peak Hour Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	3
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	7.0
Minimum Split (s)	23.0
Total Split (s)	23.0
Total Split (%)	29%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	Lead
Lead-Lag Optimize?	
Recall Mode	None
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Offset: 0 (0%), Referenced to phase 2:NWTL, Start of Green
Natural Cycle: 100
Control Type: Actuated-Coordinated
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 36: Edgewood Park Dr/Fitch Street & Whalley Ave



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	240	712	4	13	604	61	2	1	3	107	1	171
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	10	11	15	15	11	11	15	15	15	14	15	8
Total Lost time (s)	3.1	5.0			5.0			5.0			5.0	
Lane Util. Factor	1.00	0.95			0.95			1.00			1.00	
Frpb, ped/bikes	1.00	1.00			1.00			0.99			0.99	
Flpb, ped/bikes	1.00	1.00			1.00			1.00			1.00	
Frt	1.00	1.00			0.98			0.93			0.92	
Flt Protected	0.95	1.00			1.00			0.99			0.98	
Satd. Flow (prot)	1684	3484			3333			1870			1851	
Flt Permitted	0.22	1.00			0.83			0.90			0.87	
Satd. Flow (perm)	392	3484			2763			1710			1638	
Peak-hour factor, PHF	0.25	0.88	0.61	0.25	0.88	0.61	0.50	0.25	0.38	0.92	0.25	0.93
Adj. Flow (vph)	960	809	7	52	686	100	4	4	8	116	4	184
RTOR Reduction (vph)	0	0	0	0	13	0	0	7	0	0	78	0
Lane Group Flow (vph)	960	816	0	0	825	0	0	9	0	0	226	0
Confl. Peds. (#/hr)	6		12	12		6	4		3	3		4
Heavy Vehicles (%)	0%	0%	1%	2%	2%	2%	2%	2%	2%	1%	0%	0%
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	1	6			2			4			4	
Permitted Phases	6			2			4			4		
Actuated Green, G (s)	55.8	55.8			15.0			14.2			14.2	
Effective Green, g (s)	55.8	55.8			15.0			14.2			14.2	
Actuated g/C Ratio	0.70	0.70			0.19			0.18			0.18	
Clearance Time (s)	3.1	5.0			5.0			5.0			5.0	
Vehicle Extension (s)	1.0	0.2			0.2			1.0			1.0	
Lane Grp Cap (vph)	882	2430			518			303			290	
v/s Ratio Prot	c0.51	0.23										
v/s Ratio Perm	0.25				c0.30			0.01			c0.14	
v/c Ratio	1.09	0.34			1.59			0.03			0.78	
Uniform Delay, d1	16.6	4.8			32.5			27.2			31.4	
Progression Factor	1.00	1.00			1.00			1.00			1.00	
Incremental Delay, d2	57.3	0.4			275.7			0.0			11.4	
Delay (s)	73.9	5.2			308.2			27.2			42.8	
Level of Service	E	A			F			C			D	
Approach Delay (s)		42.3			308.2			27.2			42.8	
Approach LOS		D			F			C			D	

Intersection Summary			
HCM 2000 Control Delay	118.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.17		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	15.1
Intersection Capacity Utilization	74.5%	ICU Level of Service	D
Analysis Period (min)	15		

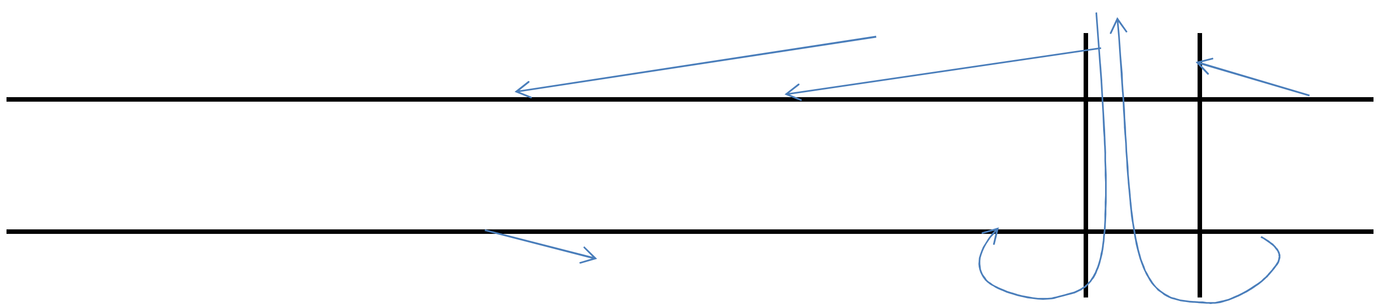
c Critical Lane Group

B2. 2019 Future Conditions Without Construction

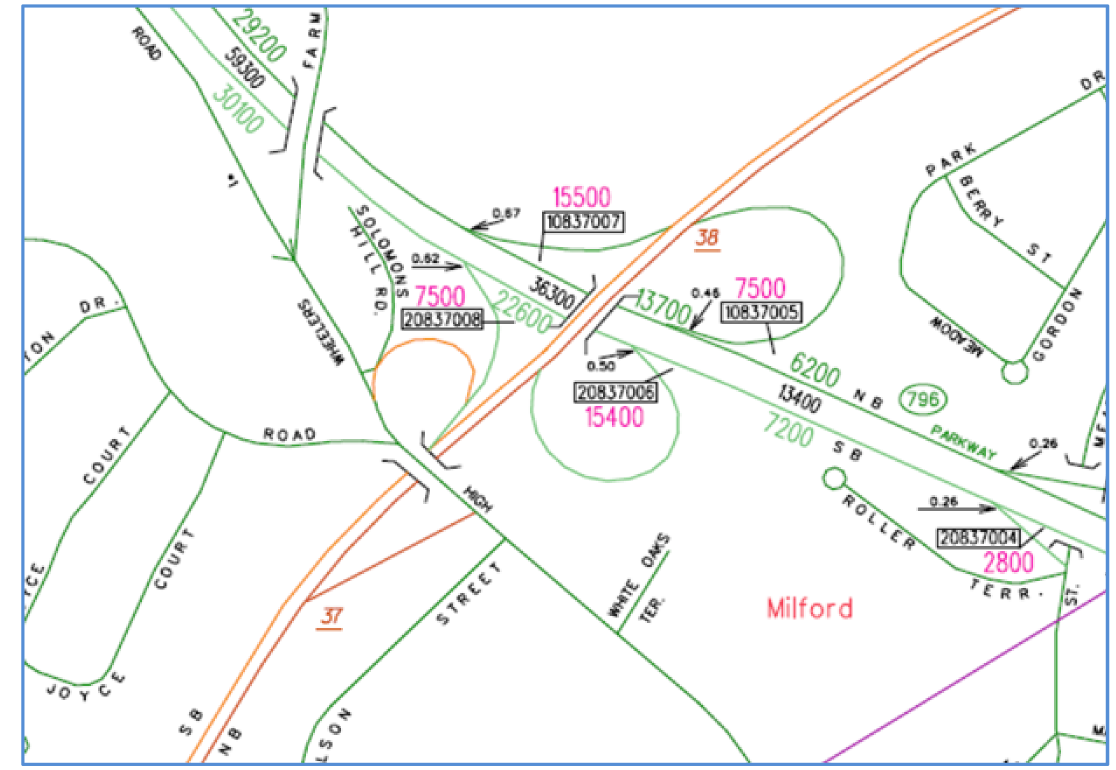
B2a. Balanced Traffic Volume Profiles

2019 I-95 Balanced Saturday Midday Peak Profile

		Int. 38 Wheelers Farms Rd.	Int. 38 Milford Connector		
	SB ML	*SB On*	*SB On*	*SB Off*	**SB ML**
Hour 11	**5135**	184	444	917	**5,424**
Hour 12	**5579**	168	495	1080	**5,996**
Hour 13	**5628**	198	515	967	**5,882**
Hour 14	**5838**	198	533	1252	**6,359**
		STA 7148	***STA 7008***	***STA 7007***	

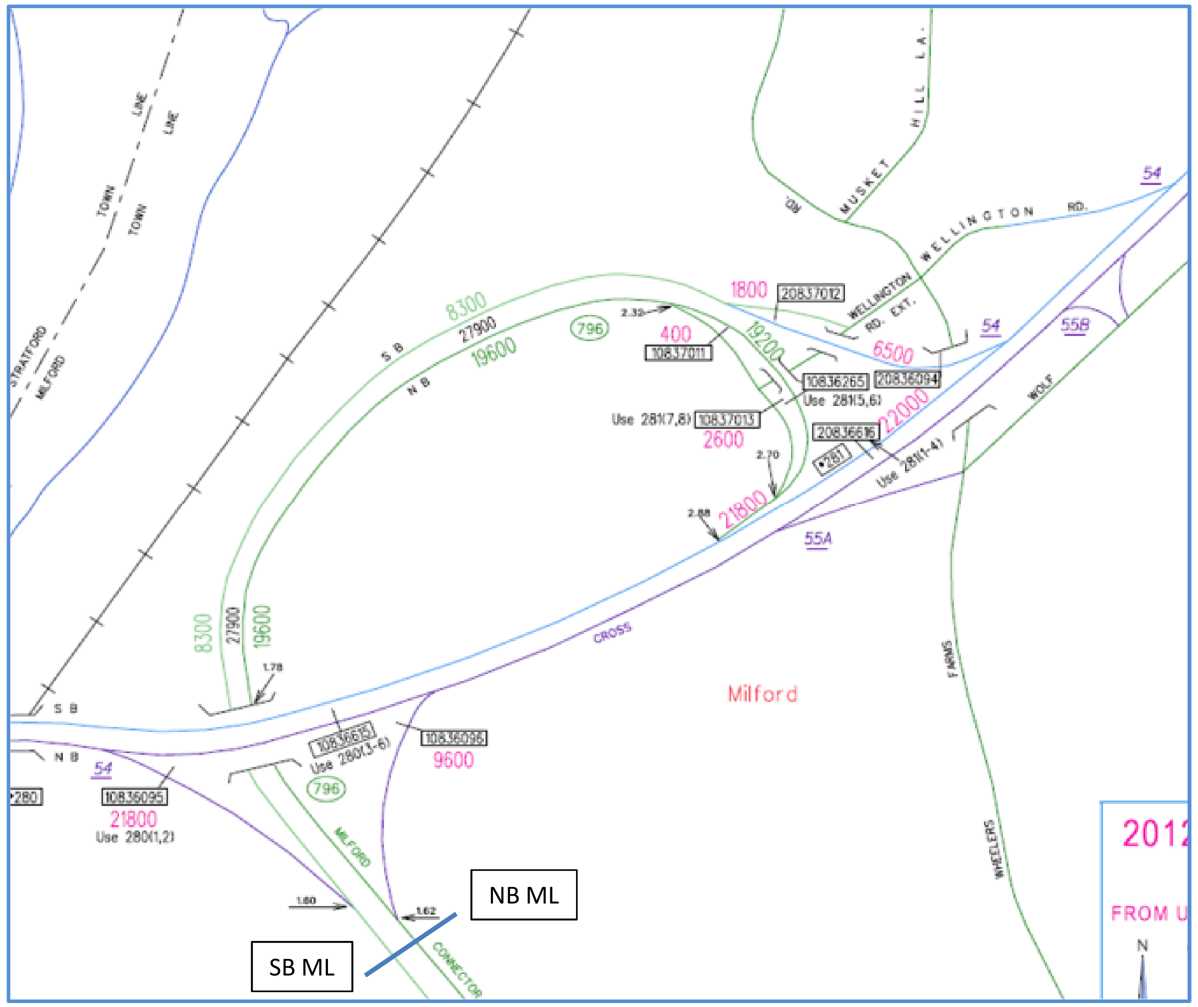


		STA 7147	***STA 7006***	***STA 7005***	
Hour 11	**5418**	231	1002	347	**5,842**
Hour 12	**5375**	216	1219	441	**5,937**
Hour 13	**5848**	248	1193	392	**6,401**
Hour 14	**6686**	289	1291	585	**7,103**
	NB ML	*NB Off*	*NB On*	*NB Off*	**NB ML**
		High St. Int. 37	Milford Connector Int. 38		



Note: 0.5% Per year annual growth rate applied to 2014 I-95 Balanced Saturday Midday Peak Profile traffic volumes.

2019 Milford Parkway Balanced Saturday Midday Peak Profile



Milford Parkway

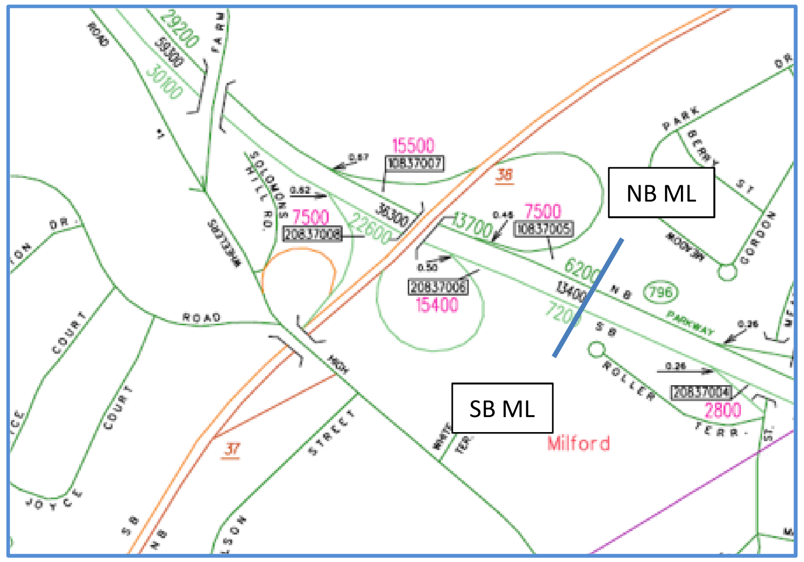
Milford Pkwy / Route 15

	NB Off	NB Off	NB Off	NB ML
Hour 11	562	28	1,068	1,658
Hour 12	563	33	1,414	2,010
Hour 13	545	33	1,233	1,811
Hour 14	722	34	1,673	2,429
	STA 6096	STA 7011	STA 6265	Computed

	SB On	SB On	SB On	SB ML
Hour 11	147	320	1,562	2,029
Hour 12	202	383	1,761	2,346
Hour 13	148	387	1,855	2,390
Hour 14	126	445	2,021	2,592
	STA 7012	STA 6094	STA 6095	Computed

Note: 0.5% Per year annual growth rate applied to 2014 Milford Parkway Balanced Saturday Midday Peak Profile traffic volumes.

2019 Milford Parkway Balanced Saturday Midday Peak Profile

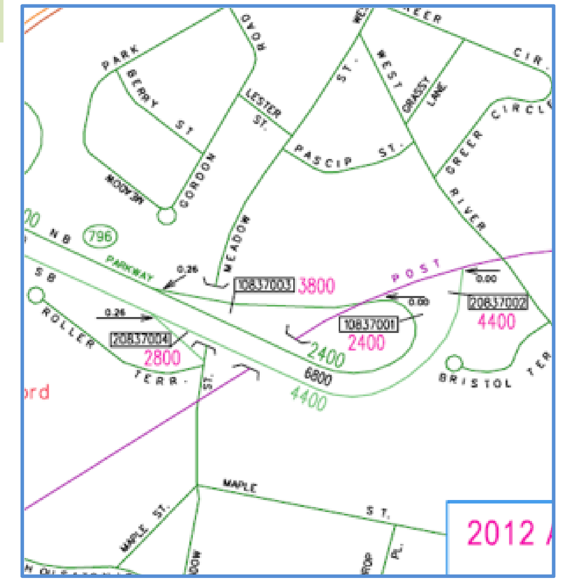


Milford Parkway

Milford Pkwy / I-95

	NB On	*NB On*	**NB ML**
Hour 11	917	347	394
Hour 12	1,080	441	489
Hour 13	967	392	452
Hour 14	1,252	585	592
	STA 7007 Balanced	*STA 7005 Balanced*	*Computed*

	SB Off	*SB Off*	**SB ML**
Hour 11	444	1,002	583
Hour 12	495	1,219	632
Hour 13	515	1,193	682
Hour 14	533	1,291	768
	STA 7008 Balanced	*STA 7006 Balanced*	*Computed*



Milford Parkway

Milford Pkwy / Route 1

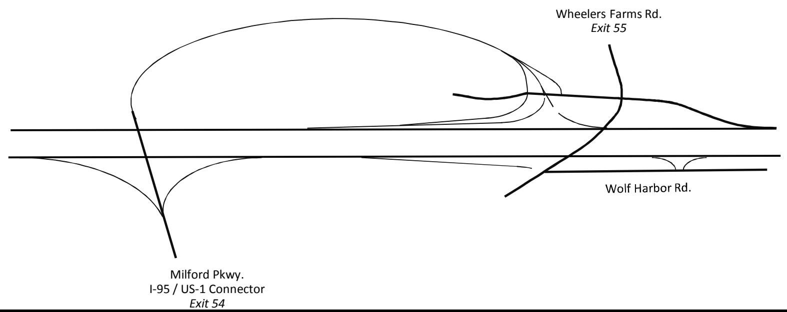
	NB On	*NB On*
Hour 11	259	135
Hour 12	293	196
Hour 13	275	177
Hour 14	352	240
	STA 7003 Balanced	*STA 7001 Balanced*

	SB Off	*SB Off*
Hour 11	201	382
Hour 12	231	401
Hour 13	313	369
Hour 14	347	421
	STA 7004 Balanced	*STA 7002 Balanced*

Note: 0.5% Per year annual growth rate applied to 2014 Milford Parkway Balanced Saturday Midday Peak Profile traffic volumes.

2019 Route 15 Balanced Saturday Midday Peak Profile

Milford Pkwy / I-95&US-1 Connector — Exit 54 | Wheelers Farms Rd/ Wolf Harbor Rd — Exit 55 | Rt 121 - Grassy Hill Rd. — Exit 56



	SB ML	SB On	SB On	SB Off	SB Off	SB ML	SB On	SB Off	SB ML
Hour 11	**2,970**	1,068	128	320	60	**2,154**	112	137	**2,179**
Hour 12	**3,337**	1,414	169	383	93	**2,230**	145	135	**2,220**
Hour 13	**3,301**	1,233	132	387	76	**2,399**	164	136	**2,371**
Hour 14	**3,963**	1,673	137	445	79	**2,677**	219	132	**2,590**

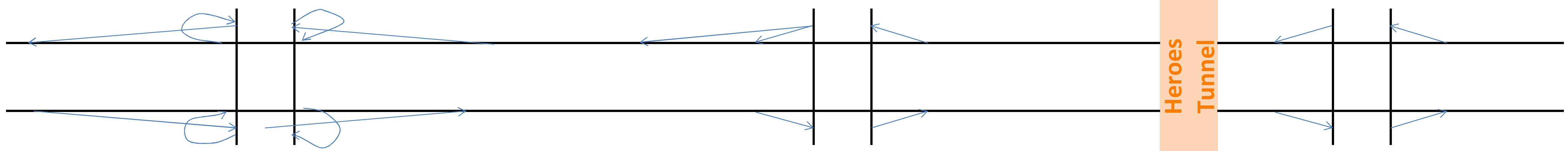
	NB ML	NB Off	NB On	NB ML	NB Off	NB Off	NB On	NB ML	NB Off	NB On	NB ML
Hour 11	**3,264**	1,562	562	**2,264**	207	25	76	**2,108**	128	99	**2,079**
Hour 12	**3,310**	1,761	563	**2,112**	207	36	94	**1,963**	137	149	**1,975**
Hour 13	**3,493**	1,855	545	**2,183**	189	32	87	**2,049**	145	136	**2,040**
Hour 14	**3,901**	2,021	722	**2,602**	236	62	113	**2,417**	198	176	**2,395**

Milford Pkwy / I-95&US-1 Connector — Exit 54 | Wheelers Farms Rd/ Wolf Harbor Rd — Exit 55 | Rt 121 - Grassy Hill Rd. — Exit 56

Note: 0.5% Per year annual growth rate applied to 2014 Route 15 Balanced Saturday Midday Peak Profile traffic volumes.

2019 Route 15 Balanced Saturday Midday Peak Profile

	Rt 34 - Derby Ave Exit 57 / Exit 58					Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Rt 10 - Dixwell Ave. Exit 60		
	SB On	SB Off	SB On	*SB Off*	**SB ML**	*SB On*	*SB On*	***SB Off***	**SB ML**	*SB On*	*SB Off*	**SB ML**
Hour 11	72	245	151	205	**2,406**	205	186	533	**2,548**	631	367	**2,284**
Hour 12	49	211	147	255	**2,490**	158	267	634	**2,699**	695	384	**2,388**
Hour 13	71	215	219	236	**2,532**	205	247	554	**2,634**	702	383	**2,315**
Hour 14	80	215	298	358	**2,785**	224	273	648	**2,936**	831	365	**2,470**

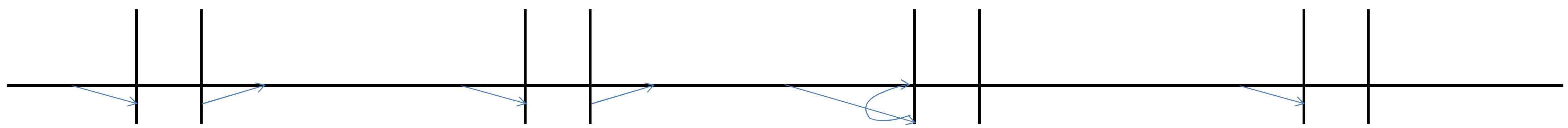


	Rt 34 - Derby Ave Exit 57 / Exit 58					Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Rt 10 - Dixwell Ave. Exit 60		
	NB Off	*NB On*	*NB Off*	*NB On*	**NB ML**		*NB Off*	*NB On*	**NB ML**	*NB Off*	*NB On*	**NB ML**
Hour 11	168	224	54	98	**2,179**		301	557	**2,435**	537	408	**2,306**
Hour 12	153	270	48	100	**2,144**		294	698	**2,548**	561	462	**2,449**
Hour 13	141	277	65	150	**2,261**		285	728	**2,704**	634	459	**2,529**
Hour 14	222	300	70	172	**2,575**		400	746	**2,921**	734	657	**2,844**

Note: 0.5% Per year annual growth rate applied to 2014 Route 15 Balanced Saturday Midday Peak Profile traffic volumes.

2019 Route 15 Balanced Saturday Midday Peak Profile

Hour 11
Hour 12
Hour 13
Hour 14

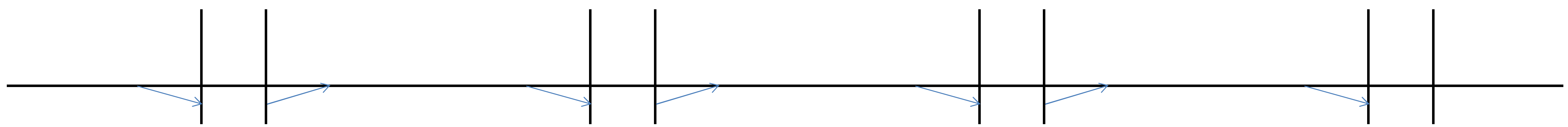


	Whitney Ave. Exit 61 NB Off	Whitney Ave. Exit 61 NB On	NB ML	Dixwell Ave. Exit 62 NB Off	Dixwell Ave. Exit 62 NB On	NB ML	Route 22 Exit 63 NB Off	Route 22 Exit 63 NB On	NB ML	Quinnipiac St. Exit 64 NB Off	NB ML
Hour 11	311	199	**2,194**	248	128	**2,074**	369	133	**1,838**	201	**1,637**
Hour 12	327	161	**2,283**	255	128	**2,156**	414	145	**1,887**	190	**1,697**
Hour 13	338	240	**2,431**	298	136	**2,269**	438	121	**1,952**	228	**1,724**
Hour 14	338	290	**2,796**	335	135	**2,596**	503	157	**2,250**	284	**1,966**

Note: 0.5% Per year annual growth rate applied to 2014 Route 15 Balanced Saturday Midday Peak Profile traffic volumes.

2019 Route 15 Balanced Saturday Midday Peak Profile

Hour 11
Hour 12
Hour 13
Hour 14



	River Rd. Exit 65 NB Off	River Rd. Exit 65 NB On	**NB ML**	Route 5 Exit 66 NB Off	Route 5 Exit 66 NB On	**NB ML**	CTDOT Garage & Miller Avenue NB Off	CTDOT Garage & Miller Avenue NB On	**NB ML**	East Main St. Exit 67 NB Off	**NB ML**
Hour 11	150	363	**1,850**	337	462	**1,975**	88	129	**2,016**	186	**1,830**
Hour 12	137	401	**1,961**	321	599	**2,239**	161	128	**2,206**	255	**1,951**
Hour 13	135	359	**1,948**	384	636	**2,200**	146	137	**2,191**	229	**1,962**
Hour 14	198	471	**2,239**	388	654	**2,505**	165	153	**2,493**	231	**2,262**

Note: 0.5% Per year annual growth rate applied to 2014 Route 15 Balanced Saturday Midday Peak Profile traffic volumes.

B2b. Traffic Analysis

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\2019 future conditions - no construction\2019 future conditions - weekday off-peak.inp
Comment:
Date: Monday, April 14, 2014 2:25:54 PM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Average delay time per vehicle [s], All Vehicle Types	9.770
Average number of stops per vehicles, All Vehicle Types	0.117
Average speed [mph], All Vehicle Types	64.425
Average stopped delay per vehicle [s], All Vehicle Types	0.410
Total delay time [h], All Vehicle Types	33.900
Total Distance Traveled [mi], All Vehicle Types	65908.300
Number of Stops, All Vehicle Types	1461
Number of vehicles in the network, All Vehicle Types	157
Number of vehicles that have left the network, All Vehicle Types	12334
Total stopped delay [h], All Vehicle Types	1.424
Total travel time [h], All Vehicle Types	1023.021

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\2019 future conditions - no construction\2019 future conditions - nc - saturday peak.inp
Comment:
Date: Monday, April 14, 2014 4:02:57 PM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Total Distance Traveled [mi], All Vehicle Types	341526.021;
Average delay time per vehicle [s], All Vehicle Types	49.420;
Average number of stops per vehicles, All Vehicle Types	1.498;
Average speed [mph], All Vehicle Types	54.331;
Average stopped delay per vehicle [s], All Vehicle Types	6.656;
Total delay time [h], All Vehicle Types	1157.968;
Number of Stops, All Vehicle Types	126357;
Number of vehicles in the network, All Vehicle Types	2183;
Number of vehicles that have left the network, All Vehicle Types	82169;
Total stopped delay [h], All Vehicle Types	155.949;
Total travel time [h], All Vehicle Types	6286.079;

Lane Group	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Lane Configurations												
Volume (vph)	0	70	11	37	45	56	743	5	34	1	45	429
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	14	11	10	10	10	10	16	12	13	10	12	10
Storage Length (ft)		0		10			100	0			160	
Storage Lanes		1		0			2	0			1	
Taper Length (ft)		25					25				25	
Right Turn on Red					Yes				Yes			
Link Speed (mph)	30		30				30					30
Link Distance (ft)	309		175				1238					566
Travel Time (s)	7.0		4.0				28.1					12.9
Confl. Peds. (#/hr)		1		5	3	1	7	3	1	7	5	
Peak Hour Factor	0.92	0.77	0.55	0.69	0.65	0.72	0.95	0.62	0.75	0.25	0.73	0.87
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	91	143	0	0	78	835	0	0	0	66	517
Turn Type		Perm	NA			Perm	NA			Split	Split	NA
Protected Phases	5		5				3			1	1	1
Permitted Phases		5				3						2
Detector Phase	5	5	5			3	3			1	1	1
Switch Phase												
Minimum Initial (s)	5.0	5.0	5.0			9.0	9.0			5.0	5.0	5.0
Minimum Split (s)	10.0	10.0	10.0			14.0	14.0			10.0	10.0	10.0
Total Split (s)	12.0	12.0	12.0			16.0	16.0			10.0	10.0	10.0
Total Split (%)	14.1%	14.1%	14.1%			18.8%	18.8%			11.8%	11.8%	11.8%
Maximum Green (s)	7.0	7.0	7.0			11.0	11.0			5.0	5.0	5.0
Yellow Time (s)	3.0	3.0	3.0			3.0	3.0			3.0	3.0	3.0
All-Red Time (s)	2.0	2.0	2.0			2.0	2.0			2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0			0.0	0.0				0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0			5.0	5.0				5.0	5.0
Lead/Lag						Lead	Lead			Lead	Lead	Lead
Lead-Lag Optimize?						Yes	Yes					
Vehicle Extension (s)	2.0	2.0	2.0			2.0	2.0			2.0	2.0	2.0
Recall Mode	None	None	None			None	None			None	None	None
Walk Time (s)												
Flash Dont Walk (s)												
Pedestrian Calls (#/hr)												
v/c Ratio		0.64	0.76			0.58	1.06				0.50	0.83
Control Delay		52.7	49.5			47.2	72.9				46.1	33.5
Queue Delay		0.0	0.0			0.0	0.0				0.0	0.0
Total Delay		52.7	49.5			47.2	72.9				46.1	33.5
Queue Length 50th (ft)		30	33			24	~119				22	143
Queue Length 95th (ft)		#110	#59			#86	#377				#72	#496
Internal Link Dist (ft)	229		95				1158					486
Turn Bay Length (ft)						100	100				160	
Base Capacity (vph)		143	188			135	786				133	624
Starvation Cap Reductn		0	0			0	0				0	0
Spillback Cap Reductn		0	0			0	0				0	0
Storage Cap Reductn		0	0			0	0				0	0

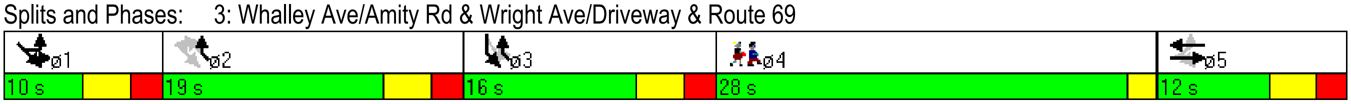
Lane Group	SER	NWL	NWT	NWR	NWR2	ø4
Lane Configurations						
Volume (vph)	13	5	410	430	7	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	
Lane Width (ft)	12	12	12	12	13	
Storage Length (ft)	0	0		0		
Storage Lanes	0	0		1		
Taper Length (ft)		25				
Right Turn on Red	Yes				Yes	
Link Speed (mph)			30			
Link Distance (ft)			442			
Travel Time (s)			10.0			
Confl. Peds. (#/hr)	1	1		7	5	
Peak Hour Factor	0.55	0.63	0.93	0.85	0.88	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	0	0	449	514	0	
Turn Type		custom	NA	custom		
Protected Phases				2 3		4
Permitted Phases		2	2			
Detector Phase		2	2	2 3		
Switch Phase						
Minimum Initial (s)		15.0	15.0			1.0
Minimum Split (s)		20.0	20.0			28.0
Total Split (s)		19.0	19.0			28.0
Total Split (%)		22.4%	22.4%			33%
Maximum Green (s)		14.0	14.0			26.0
Yellow Time (s)		3.0	3.0			2.0
All-Red Time (s)		2.0	2.0			0.0
Lost Time Adjust (s)			0.0			
Total Lost Time (s)			5.0			
Lead/Lag		Lag	Lag			Lag
Lead-Lag Optimize?		Yes	Yes			Yes
Vehicle Extension (s)		2.0	2.0			3.0
Recall Mode		Min	Min			None
Walk Time (s)						7.0
Flash Dont Walk (s)						19.0
Pedestrian Calls (#/hr)						16
v/c Ratio			1.16	0.66		
Control Delay			124.6	17.2		
Queue Delay			0.0	0.0		
Total Delay			124.6	17.2		
Queue Length 50th (ft)			~178	82		
Queue Length 95th (ft)			#528	#350		
Internal Link Dist (ft)			362			
Turn Bay Length (ft)						
Base Capacity (vph)			387	774		
Starvation Cap Reductn			0	0		
Spillback Cap Reductn			0	0		
Storage Cap Reductn			0	0		

Lane Group	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Reduced v/c Ratio		0.64	0.76			0.58	1.06				0.50	0.83

Intersection Summary	
Area Type:	CBD
Cycle Length: 85	
Actuated Cycle Length: 62.6	
Natural Cycle: 95	
Control Type: Actuated-Uncoordinated	

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 3: Whalley Ave/Amity Rd & Wright Ave/Driveway & Route 69



Lane Group	SER	NWL	NWT	NWR	NWR2	ø4
Reduced v/c Ratio			1.16	0.66		

Intersection Summary

Movement	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Lane Configurations												
Volume (vph)	0	70	11	37	45	56	743	5	34	1	45	429
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	14	11	10	10	10	10	16	12	13	10	12	10
Total Lost time (s)		5.0	5.0			5.0	5.0				5.0	5.0
Lane Util. Factor		1.00	1.00			1.00	0.97				1.00	1.00
Frpb, ped/bikes		1.00	0.95			1.00	1.00				1.00	1.00
Flpb, ped/bikes		1.00	1.00			1.00	1.00				1.00	1.00
Frt		1.00	0.87			1.00	0.99				1.00	0.99
Flt Protected		0.95	1.00			0.95	0.96				0.95	1.00
Satd. Flow (prot)		1566	1325			1514	3550				1624	1583
Flt Permitted		0.76	1.00			0.47	0.96				0.95	1.00
Satd. Flow (perm)		1248	1325			755	3550				1624	1583
Peak-hour factor, PHF	0.92	0.77	0.55	0.69	0.65	0.72	0.95	0.62	0.75	0.25	0.73	0.87
Adj. Flow (vph)	0	91	20	54	69	78	782	8	45	4	62	493
RTOR Reduction (vph)	0	0	38	0	0	0	148	0	0	0	0	2
Lane Group Flow (vph)	0	91	105	0	0	78	687	0	0	0	66	515
Confl. Peds. (#/hr)		1		5	3	1	7	3	1	7	5	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		Perm	NA			Perm	NA			Split	Split	NA
Protected Phases	5		5				3			1	1	1
Permitted Phases		5				3						2
Actuated Green, G (s)		7.2	7.2			11.3	11.3				5.1	19.5
Effective Green, g (s)		7.2	7.2			11.3	11.3				5.1	19.5
Actuated g/C Ratio		0.11	0.11			0.18	0.18				0.08	0.31
Clearance Time (s)		5.0	5.0			5.0	5.0				5.0	5.0
Vehicle Extension (s)		2.0	2.0			2.0	2.0				2.0	2.0
Lane Grp Cap (vph)		140	149			133	628				129	607
v/s Ratio Prot			c0.08				c0.19				0.04	c0.07
v/s Ratio Perm		0.07				0.10						0.26
v/c Ratio		0.65	0.70			0.59	1.09				0.51	0.85
Uniform Delay, d1		27.1	27.3			24.1	26.2				28.2	20.8
Progression Factor		1.00	1.00			1.00	1.00				1.00	1.00
Incremental Delay, d2		8.0	11.6			4.2	64.2				1.4	10.3
Delay (s)		35.0	38.9			28.3	90.4				29.6	31.0
Level of Service		D	D			C	F				C	C
Approach Delay (s)	0.0		37.4				85.1					30.9
Approach LOS	A		D				F					C

Intersection Summary			
HCM 2000 Control Delay	63.2	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.98		
Actuated Cycle Length (s)	63.8	Sum of lost time (s)	22.0
Intersection Capacity Utilization	86.6%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Movement	SER	NWL	NWT	NWR	NWR2
Lane Configurations					
Volume (vph)	13	5	410	430	7
Ideal Flow (vphpl)	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	13
Total Lost time (s)			5.0	5.0	
Lane Util. Factor			1.00	1.00	
Frpb, ped/bikes			1.00	1.00	
Flpb, ped/bikes			1.00	1.00	
Frt			1.00	0.85	
Flt Protected			1.00	1.00	
Satd. Flow (prot)			1708	1454	
Flt Permitted			0.99	1.00	
Satd. Flow (perm)			1687	1454	
Peak-hour factor, PHF	0.55	0.63	0.93	0.85	0.88
Adj. Flow (vph)	24	8	441	506	8
RTOR Reduction (vph)	0	0	0	60	0
Lane Group Flow (vph)	0	0	449	454	0
Confl. Peds. (#/hr)	1	1		7	5
Heavy Vehicles (%)	0%	0%	0%	0%	0%
Turn Type		custom	NA	custom	
Protected Phases				2 3	
Permitted Phases		2	2		
Actuated Green, G (s)			14.4	30.7	
Effective Green, g (s)			14.4	30.7	
Actuated g/C Ratio			0.23	0.48	
Clearance Time (s)			5.0		
Vehicle Extension (s)			2.0		
Lane Grp Cap (vph)			380	699	
v/s Ratio Prot				0.31	
v/s Ratio Perm			c0.27		
v/c Ratio			1.18	0.65	
Uniform Delay, d1			24.7	12.5	
Progression Factor			1.00	1.00	
Incremental Delay, d2			105.6	1.6	
Delay (s)			130.3	14.1	
Level of Service			F	B	
Approach Delay (s)			68.2		
Approach LOS			E		

Intersection Summary

Lane Group	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	319	478	0	540	645	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	16	12	12	16	16	12
Link Speed (mph)	30			30	30	
Link Distance (ft)	321			1238	178	
Travel Time (s)	7.3			28.1	4.0	
Confl. Peds. (#/hr)	2					
Peak Hour Factor	0.87	0.94	0.85	0.85	0.90	0.90
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%
Shared Lane Traffic (%)						
Lane Group Flow (vph)	876	0	0	635	717	0
Sign Control	Stop			Free	Free	

Intersection Summary	
Area Type:	Other
Control Type: Unsignalized	

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (veh/h)	319	478	0	540	645	0
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Peak Hour Factor	0.87	0.94	0.85	0.85	0.90	0.90
Hourly flow rate (vph)	367	509	0	635	717	0
Pedestrians					2	
Lane Width (ft)					16.0	
Walking Speed (ft/s)					4.0	
Percent Blockage					0	
Right turn flare (veh)						
Median type				Raised	Raised	
Median storage veh)				1	1	
Upstream signal (ft)				1238	313	
pX, platoon unblocked	0.82	0.82	0.82			
vC, conflicting volume	1354	717	717			
vC1, stage 1 conf vol	717					
vC2, stage 2 conf vol	637					
vCu, unblocked vol	1321	541	541			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)	5.4					
tF (s)	3.5	3.3	2.2			
p0 queue free %	0	0	100			
cM capacity (veh/h)	294	445	848			

Direction, Lane #	EB 1	NB 1	SB 1
Volume Total	875	635	717
Volume Left	367	0	0
Volume Right	509	0	0
cSH	367	1700	1700
Volume to Capacity	2.39	0.37	0.42
Queue Length 95th (ft)	1710	0	0
Control Delay (s)	655.8	0.0	0.0
Lane LOS	F		
Approach Delay (s)	655.8	0.0	0.0
Approach LOS	F		

Intersection Summary			
Average Delay	257.7		
Intersection Capacity Utilization	87.6%	ICU Level of Service	E
Analysis Period (min)	15		

Lane Group	WBL	WBR	NBT	NBR	SBL	SBT	ø3
Lane Configurations							
Volume (vph)	51	111	516	414	282	591	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	
Lane Width (ft)	11	11	10	10	10	11	
Right Turn on Red		Yes		Yes			
Link Speed (mph)	30		30			30	
Link Distance (ft)	415		135			335	
Travel Time (s)	9.4		3.1			7.6	
Confl. Peds. (#/hr)	7	1		11	11		
Peak Hour Factor	0.69	0.90	0.87	0.83	0.82	0.87	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	
Shared Lane Traffic (%)							
Lane Group Flow (vph)	197	0	1092	0	344	679	
Turn Type	NA		NA		custom	NA	
Protected Phases	5		2		6	2 3 6	3
Permitted Phases					2 3		
Detector Phase	5		2		6	2 3 6	
Switch Phase							
Minimum Initial (s)	6.0		25.0		9.0		5.0
Minimum Split (s)	15.2		30.0		15.3		9.8
Total Split (s)	29.2		32.0		23.3		9.8
Total Split (%)	31.0%		33.9%		24.7%		10%
Maximum Green (s)	25.0		27.0		19.0		5.0
Yellow Time (s)	3.0		3.5		3.3		3.5
All-Red Time (s)	1.2		1.5		1.0		1.3
Lost Time Adjust (s)	0.0		0.0		0.0		
Total Lost Time (s)	4.2		5.0		4.3		
Lead/Lag	Lead				Lag		
Lead-Lag Optimize?	Yes				Yes		
Vehicle Extension (s)	3.0		3.5		3.0		0.2
Recall Mode	None		Min		None		None
Walk Time (s)	10.0				10.0		
Flash Dont Walk (s)	1.0				1.0		
Pedestrian Calls (#/hr)	4				4		
v/c Ratio	0.63		0.89		0.72	0.49	
Control Delay	22.3		30.2		24.3	5.5	
Queue Delay	0.0		0.0		0.0	0.0	
Total Delay	22.3		30.2		24.3	5.5	
Queue Length 50th (ft)	32		214		87	91	
Queue Length 95th (ft)	53		#360		171	196	
Internal Link Dist (ft)	335		55			255	
Turn Bay Length (ft)							
Base Capacity (vph)	620		1231		524	1381	
Starvation Cap Reductn	0		0		0	0	
Spillback Cap Reductn	0		0		0	0	
Storage Cap Reductn	0		0		0	0	
Reduced v/c Ratio	0.32		0.89		0.66	0.49	

Intersection Summary	
Area Type:	Other

Cycle Length: 94.3
Actuated Cycle Length: 77.1
Natural Cycle: 75
Control Type: Semi Act-Uncoord
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 5: Whalley Ave & Pond Lily Ave

Movement	WBL	WBR	NBT	NBR	SBL	SBT
Lane Configurations						
Volume (vph)	51	111	516	414	282	591
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width	11	11	10	10	10	11
Total Lost time (s)	4.2		5.0		4.3	5.0
Lane Util. Factor	1.00		0.95		1.00	1.00
Frpb, ped/bikes	0.99		0.98		1.00	1.00
Flpb, ped/bikes	1.00		1.00		1.00	1.00
Frt	0.92		0.93		1.00	1.00
Flt Protected	0.98		1.00		0.95	1.00
Satd. Flow (prot)	1636		3088		1685	1837
Flt Permitted	0.98		1.00		0.12	1.00
Satd. Flow (perm)	1636		3088		221	1837
Peak-hour factor, PHF	0.69	0.90	0.87	0.83	0.82	0.87
Adj. Flow (vph)	74	123	593	499	344	679
RTOR Reduction (vph)	112	0	146	0	0	0
Lane Group Flow (vph)	85	0	946	0	344	679
Confl. Peds. (#/hr)	7	1		11	11	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%
Turn Type	NA		NA		custom	NA
Protected Phases	5		2		6	2 3 6
Permitted Phases					2 3	
Actuated Green, G (s)	9.4		27.1		54.2	58.5
Effective Green, g (s)	9.4		27.1		49.2	54.2
Actuated g/C Ratio	0.12		0.35		0.64	0.70
Clearance Time (s)	4.2		5.0		4.3	
Vehicle Extension (s)	3.0		3.5		3.0	
Lane Grp Cap (vph)	199		1088		466	1294
v/s Ratio Prot	c0.05		c0.31		c0.16	c0.37
v/s Ratio Perm					0.31	
v/c Ratio	0.43		0.87		0.74	0.52
Uniform Delay, d1	31.2		23.2		16.5	5.3
Progression Factor	1.00		1.00		1.00	1.00
Incremental Delay, d2	1.5		7.7		6.0	0.4
Delay (s)	32.7		31.0		22.6	5.8
Level of Service	C		C		C	A
Approach Delay (s)	32.7		31.0			11.4
Approach LOS	C		C			B

Intersection Summary			
HCM 2000 Control Delay	22.5	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.75		
Actuated Cycle Length (s)	76.9	Sum of lost time (s)	18.3
Intersection Capacity Utilization	64.7%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	NBL2	NBL	NBT	NBR	SBL	SBT	SBR	SBR2	SEL	SET	SER	SER2
Lane Configurations												
Volume (vph)	87	87	722	87	230	660	56	1	135	67	12	11
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	11	13	12	14	12	12	10	11	11
Storage Length (ft)		0		0	84		0		0		0	
Storage Lanes		1		1	1		0		0		0	
Taper Length (ft)		25			25				25			
Right Turn on Red				Yes				Yes				Yes
Link Speed (mph)			30			30				30		
Link Distance (ft)			334			671				589		
Travel Time (s)			7.6			15.3				13.4		
Peak Hour Factor	0.92	0.89	0.91	0.69	0.92	0.91	0.69	0.25	0.69	0.75	0.90	0.77
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	193	793	126	250	810	0	0	0	312	0	0
Turn Type	Prot	Prot	NA	custom	Prot	NA			Split	NA		
Protected Phases	1	1	6	6	5	2			4	4		
Permitted Phases				7								
Detector Phase	1	1	6	6	5	2			4	4		
Switch Phase												
Minimum Initial (s)	2.0	2.0	10.0	10.0	5.0	10.0			5.0	5.0		
Minimum Split (s)	9.0	9.0	20.0	20.0	11.0	20.0			28.0	28.0		
Total Split (s)	11.0	11.0	22.0	22.0	13.0	24.0			28.0	28.0		
Total Split (%)	12.9%	12.9%	25.9%	25.9%	15.3%	28.2%			32.9%	32.9%		
Maximum Green (s)	5.0	5.0	16.0	16.0	7.0	18.0			22.0	22.0		
Yellow Time (s)	3.0	3.0	3.0	3.0	3.0	3.0			3.0	3.0		
All-Red Time (s)	3.0	3.0	3.0	3.0	3.0	3.0			3.0	3.0		
Lost Time Adjust (s)		0.0	0.0	0.0	0.0	0.0				0.0		
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Lead/Lag	Lead	Lead	Lag	Lag	Lead	Lag						
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes						
Vehicle Extension (s)	1.0	1.0	2.0	2.0	1.0	3.0			1.0	1.0		
Recall Mode	None	None	Min	Min	None	Min			None	None		
Walk Time (s)									7.0	7.0		
Flash Dont Walk (s)									15.0	15.0		
Pedestrian Calls (#/hr)									36	36		
v/c Ratio		1.69	1.08	0.18	1.52	1.00				0.48		
Control Delay		373.5	91.7	2.6	289.7	65.2				29.4		
Queue Delay		0.0	0.0	0.0	0.0	0.0				0.0		
Total Delay		373.5	91.7	2.6	289.7	65.2				29.4		
Queue Length 50th (ft)		~158	~270	0	~196	~260				71		
Queue Length 95th (ft)		#283	#384	9	#339	#377				87		
Internal Link Dist (ft)			254			591				509		
Turn Bay Length (ft)					84							
Base Capacity (vph)		114	732	697	165	811				903		
Starvation Cap Reductn		0	0	0	0	0				0		
Spillback Cap Reductn		0	0	0	0	0				0		
Storage Cap Reductn		0	0	0	0	0				0		
Reduced v/c Ratio		1.69	1.08	0.18	1.52	1.00				0.35		

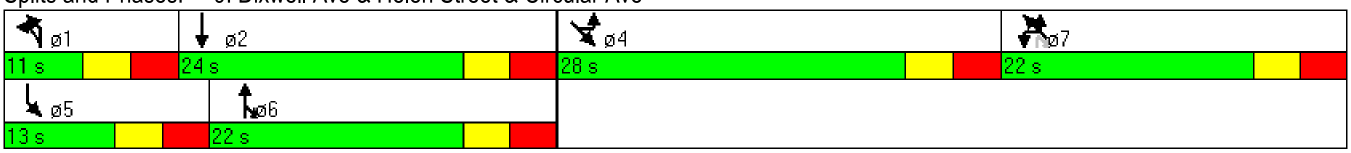
Lane Group	NWL2	NWT	NWR
Lane Configurations			
Volume (vph)	123	312	207
Ideal Flow (vphpl)	1900	1900	1900
Lane Width (ft)	14	12	14
Storage Length (ft)			0
Storage Lanes			1
Taper Length (ft)			
Right Turn on Red			Yes
Link Speed (mph)		30	
Link Distance (ft)		251	
Travel Time (s)		5.7	
Peak Hour Factor	0.77	0.92	0.89
Heavy Vehicles (%)	0%	0%	0%
Shared Lane Traffic (%)			
Lane Group Flow (vph)	160	339	233
Turn Type	Split	NA	Prot
Protected Phases	7	7	7
Permitted Phases			
Detector Phase	7	7	7
Switch Phase			
Minimum Initial (s)	10.0	10.0	10.0
Minimum Split (s)	22.0	22.0	22.0
Total Split (s)	22.0	22.0	22.0
Total Split (%)	25.9%	25.9%	25.9%
Maximum Green (s)	16.0	16.0	16.0
Yellow Time (s)	3.0	3.0	3.0
All-Red Time (s)	3.0	3.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	6.0
Lead/Lag			
Lead-Lag Optimize?			
Vehicle Extension (s)	1.0	1.0	1.0
Recall Mode	None	None	None
Walk Time (s)	5.0	5.0	5.0
Flash Dont Walk (s)	11.0	11.0	11.0
Pedestrian Calls (#/hr)	0	0	0
v/c Ratio	0.42	0.90	0.44
Control Delay	33.2	62.2	7.4
Queue Delay	0.0	0.0	0.0
Total Delay	33.2	62.2	7.4
Queue Length 50th (ft)	76	180	0
Queue Length 95th (ft)	113	#341	56
Internal Link Dist (ft)		171	
Turn Bay Length (ft)			
Base Capacity (vph)	394	389	538
Starvation Cap Reductn	0	0	0
Spillback Cap Reductn	0	0	0
Storage Cap Reductn	0	0	0
Reduced v/c Ratio	0.41	0.87	0.43

Intersection Summary	
Area Type:	Other
Cycle Length: 85	
Actuated Cycle Length: 78.9	
Natural Cycle: 95	
Control Type: Semi Act-Uncoord	

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 9: Dixwell Ave & Helen Street & Circular Ave



Movement	NBL2	NBL	NBT	NBR	SBL	SBT	SBR	SBR2	SEL	SET	SER	SER2
Lane Configurations												
Volume (vph)	87	87	722	87	230	660	56	1	135	67	12	11
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	11	13	12	14	12	12	10	11	11
Total Lost time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Lane Util. Factor		1.00	0.95	1.00	1.00	0.95				0.95		
Frt		1.00	1.00	0.85	1.00	0.98				0.99		
Flt Protected		0.95	1.00	1.00	0.95	1.00				0.97		
Satd. Flow (prot)		1787	3574	1546	1847	3518				3192		
Flt Permitted		0.95	1.00	1.00	0.95	1.00				0.97		
Satd. Flow (perm)		1787	3574	1546	1847	3518				3192		
Peak-hour factor, PHF	0.92	0.89	0.91	0.69	0.92	0.91	0.69	0.25	0.69	0.75	0.90	0.77
Adj. Flow (vph)	95	98	793	126	250	725	81	4	196	89	13	14
RTOR Reduction (vph)	0	0	0	75	0	1	0	0	0	4	0	0
Lane Group Flow (vph)	0	193	793	51	250	809	0	0	0	308	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
Turn Type	Prot	Prot	NA	custom	Prot	NA			Split	NA		
Protected Phases	1	1	6	6	5	2			4	4		
Permitted Phases				7								
Actuated Green, G (s)		5.0	16.2	31.8	7.1	18.3				15.8		
Effective Green, g (s)		5.0	16.2	31.8	7.1	18.3				15.8		
Actuated g/C Ratio		0.06	0.21	0.40	0.09	0.23				0.20		
Clearance Time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Vehicle Extension (s)		1.0	2.0	2.0	1.0	3.0				1.0		
Lane Grp Cap (vph)		113	735	624	166	818				640		
v/s Ratio Prot		0.11	0.22	0.02	c0.14	c0.23				c0.10		
v/s Ratio Perm				0.02								
v/c Ratio		1.71	1.08	0.08	1.51	0.99				0.48		
Uniform Delay, d1		36.9	31.2	14.5	35.8	30.1				27.8		
Progression Factor		1.00	1.00	1.00	1.00	1.00				1.00		
Incremental Delay, d2		353.2	56.5	0.0	256.4	28.5				0.2		
Delay (s)		390.1	87.8	14.5	292.2	58.6				28.0		
Level of Service		F	F	B	F	E				C		
Approach Delay (s)			132.0			113.7				28.0		
Approach LOS			F			F				C		

Intersection Summary			
HCM 2000 Control Delay	94.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.92		
Actuated Cycle Length (s)	78.7	Sum of lost time (s)	24.0
Intersection Capacity Utilization	76.6%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

Movement	NWL2	NWT	NWR
Lane Configurations			
Volume (vph)	123	312	207
Ideal Flow (vphpl)	1900	1900	1900
Lane Width	14	12	14
Total Lost time (s)	6.0	6.0	6.0
Lane Util. Factor	1.00	1.00	1.00
Frt	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00
Satd. Flow (prot)	1925	1900	1723
Flt Permitted	0.95	1.00	1.00
Satd. Flow (perm)	1925	1900	1723
Peak-hour factor, PHF	0.77	0.92	0.89
Adj. Flow (vph)	160	339	233
RTOR Reduction (vph)	0	0	187
Lane Group Flow (vph)	160	339	46
Heavy Vehicles (%)	0%	0%	0%
Turn Type	Split	NA	Prot
Protected Phases	7	7	7
Permitted Phases			
Actuated Green, G (s)	15.6	15.6	15.6
Effective Green, g (s)	15.6	15.6	15.6
Actuated g/C Ratio	0.20	0.20	0.20
Clearance Time (s)	6.0	6.0	6.0
Vehicle Extension (s)	1.0	1.0	1.0
Lane Grp Cap (vph)	381	376	341
v/s Ratio Prot	0.08	c0.18	0.03
v/s Ratio Perm			
v/c Ratio	0.42	0.90	0.14
Uniform Delay, d1	27.6	30.8	26.0
Progression Factor	1.00	1.00	1.00
Incremental Delay, d2	0.3	23.5	0.1
Delay (s)	27.9	54.3	26.1
Level of Service	C	D	C
Approach Delay (s)		39.5	
Approach LOS		D	

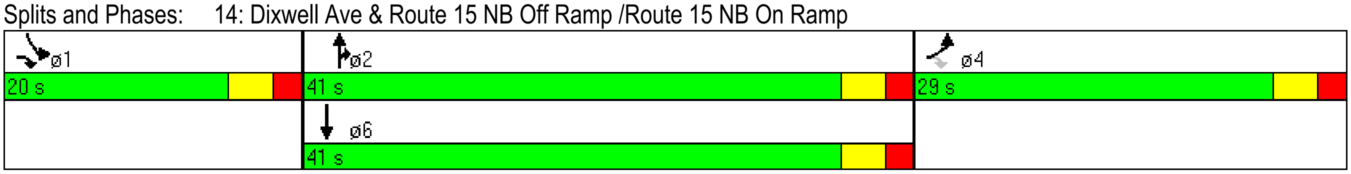
Intersection Summary

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	353	0	251	0	0	0	0	1272	385	109	1303	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	11	12	12	11	12	11
Storage Length (ft)	0		215	0		0	0		240	0		0
Storage Lanes	2		1	0		0	0		1	1		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		409			488			632			296	
Travel Time (s)		9.3			11.1			14.4			6.7	
Confl. Peds. (#/hr)			2						4	4		
Peak Hour Factor	0.83	0.25	0.92	0.92	0.92	0.92	0.25	0.86	0.96	0.88	0.95	0.25
Heavy Vehicles (%)	0%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	425	0	273	0	0	0	0	1479	401	124	1372	0
Turn Type	Prot		custom					NA	Prot	Prot	NA	
Protected Phases	4		1					2	2	1	6	
Permitted Phases			4									
Detector Phase	4		1					2	2	1	6	
Switch Phase												
Minimum Initial (s)	7.0		7.0					15.0	15.0	7.0	15.0	
Minimum Split (s)	12.0		12.0					31.0	31.0	12.0	21.0	
Total Split (s)	29.0		20.0					41.0	41.0	20.0	41.0	
Total Split (%)	32.2%		22.2%					45.6%	45.6%	22.2%	45.6%	
Maximum Green (s)	24.0		15.0					36.0	36.0	15.0	36.0	
Yellow Time (s)	3.0		3.0					3.0	3.0	3.0	3.0	
All-Red Time (s)	2.0		2.0					2.0	2.0	2.0	2.0	
Lost Time Adjust (s)	0.0		0.0					0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)	2.0		2.0					3.0	3.0	2.0	3.0	
Recall Mode	None		None					Min	Min	None	Min	
Walk Time (s)								15.0	15.0			
Flash Dont Walk (s)								1.0	1.0			
Pedestrian Calls (#/hr)								4	4			
v/c Ratio	0.68		0.53					0.85	0.41	0.53	0.78	
Control Delay	34.7		19.4					24.6	3.8	39.6	21.4	
Queue Delay	0.0		0.0					0.0	0.0	0.0	0.0	
Total Delay	34.7		19.4					24.6	3.8	39.6	21.4	
Queue Length 50th (ft)	94		82					294	8	54	257	
Queue Length 95th (ft)	135		141					#503	63	108	#478	
Internal Link Dist (ft)		329			408			552			216	
Turn Bay Length (ft)			215						240			
Base Capacity (vph)	1132		627					1733	970	352	1751	
Starvation Cap Reductn	0		0					0	0	0	0	
Spillback Cap Reductn	0		0					0	0	0	0	
Storage Cap Reductn	0		0					0	0	0	0	

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Reduced v/c Ratio	0.38		0.44					0.85	0.41	0.35	0.78	

Intersection Summary	
Area Type:	Other
Cycle Length: 90	
Actuated Cycle Length: 74.6	
Natural Cycle: 60	
Control Type: Semi Act-Uncoord	
# 95th percentile volume exceeds capacity, queue may be longer.	
Queue shown is maximum after two cycles.	

Splits and Phases: 14: Dixwell Ave & Route 15 NB Off Ramp /Route 15 NB On Ramp



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	353	0	251	0	0	0	0	1272	385	109	1303	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	12	12	11	12	12	11	12	11
Total Lost time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Lane Util. Factor	0.97		1.00					0.95	1.00	1.00	0.95	
Frpb, ped/bikes	1.00		0.99					1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00		1.00					1.00	1.00	1.00	1.00	
Frt	1.00		0.85					1.00	0.85	1.00	1.00	
Flt Protected	0.95		1.00					1.00	1.00	0.95	1.00	
Satd. Flow (prot)	3502		1602					3574	1615	1745	3610	
Flt Permitted	0.95		1.00					1.00	1.00	0.95	1.00	
Satd. Flow (perm)	3502		1602					3574	1615	1745	3610	
Peak-hour factor, PHF	0.83	0.25	0.92	0.92	0.92	0.92	0.25	0.86	0.96	0.88	0.95	0.25
Adj. Flow (vph)	425	0	273	0	0	0	0	1479	401	124	1372	0
RTOR Reduction (vph)	0	0	16	0	0	0	0	0	187	0	0	0
Lane Group Flow (vph)	425	0	257	0	0	0	0	1479	214	124	1372	0
Confl. Peds. (#/hr)			2						4	4		
Heavy Vehicles (%)	0%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
Turn Type	Prot		custom					NA	Prot	Prot	NA	
Protected Phases	4		1					2	2	1	6	
Permitted Phases			4									
Actuated Green, G (s)	13.4		23.4					36.2	36.2	10.0	36.2	
Effective Green, g (s)	13.4		23.4					36.2	36.2	10.0	36.2	
Actuated g/C Ratio	0.18		0.31					0.49	0.49	0.13	0.49	
Clearance Time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Vehicle Extension (s)	2.0		2.0					3.0	3.0	2.0	3.0	
Lane Grp Cap (vph)	629		609					1734	783	233	1751	
v/s Ratio Prot	c0.12		0.06					c0.41	0.13	c0.07	0.38	
v/s Ratio Perm			0.10									
v/c Ratio	0.68		0.42					0.85	0.27	0.53	0.78	
Uniform Delay, d1	28.6		20.2					16.9	11.4	30.1	15.9	
Progression Factor	1.00		1.00					1.00	1.00	1.00	1.00	
Incremental Delay, d2	2.3		0.2					4.3	0.2	1.2	2.4	
Delay (s)	30.8		20.4					21.2	11.6	31.3	18.3	
Level of Service	C		C					C	B	C	B	
Approach Delay (s)		26.8			0.0			19.1			19.4	
Approach LOS		C			A			B			B	

Intersection Summary			
HCM 2000 Control Delay	20.5	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.76		
Actuated Cycle Length (s)	74.6	Sum of lost time (s)	15.0
Intersection Capacity Utilization	63.1%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

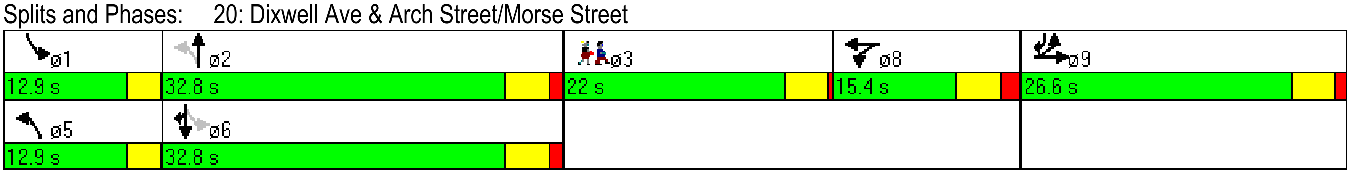
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	314	113	39	7	3	8	59	497	32	124	378	301
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	11	13	12	11	12	11	10	12	14	10	12	12
Storage Length (ft)	210		0	55		0	90		0	130		0
Storage Lanes	1		0	1		0	1		0	1		1
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		555			252			414			384	
Travel Time (s)		12.6			5.7			9.4			8.7	
Confl. Peds. (#/hr)	4		5	5		4	19		12	12		19
Peak Hour Factor	0.60	0.75	0.50	0.58	0.75	0.50	0.69	0.98	0.76	0.86	0.90	0.80
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	1%	0%	0%	1%	0%
Shared Lane Traffic (%)	28%											
Lane Group Flow (vph)	377	375	0	12	20	0	86	549	0	144	420	376
Turn Type	Split	NA		Split	NA		pm+pt	NA		pm+pt	NA	pt+ov
Protected Phases	9	9		8	8		5	2		1	6	6 9
Permitted Phases							2			6		
Detector Phase	9	9		8	8		5	2		1	6	6 9
Switch Phase												
Minimum Initial (s)	9.0	9.0		5.0	5.0		5.0	15.0		5.0	15.0	
Minimum Split (s)	13.6	13.6		10.4	10.4		7.9	19.8		7.9	19.8	
Total Split (s)	26.6	26.6		15.4	15.4		12.9	32.8		12.9	32.8	
Total Split (%)	24.2%	24.2%		14.0%	14.0%		11.8%	29.9%		11.8%	29.9%	
Maximum Green (s)	22.0	22.0		10.0	10.0		10.0	28.0		10.0	28.0	
Yellow Time (s)	3.6	3.6		3.6	3.6		2.8	3.6		2.8	3.6	
All-Red Time (s)	1.0	1.0		1.8	1.8		0.1	1.2		0.1	1.2	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	
Lead/Lag							Lead	Lag		Lead	Lag	
Lead-Lag Optimize?												
Vehicle Extension (s)	1.5	1.5		1.5	1.5		1.5	2.5		1.5	2.5	
Recall Mode	None	None		None	None		None	Min		None	Min	
Walk Time (s)												
Flash Dont Walk (s)												
Pedestrian Calls (#/hr)												
v/c Ratio	0.69	0.64		0.09	0.14		0.23	0.48		0.36	0.62	0.29
Control Delay	31.8	28.5		36.3	22.5		11.3	20.6		12.6	24.4	1.0
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Delay	31.8	28.5		36.3	22.5		11.3	20.6		12.6	24.4	1.0
Queue Length 50th (ft)	135	128		5	2		15	84		26	131	0
Queue Length 95th (ft)	177	227		14	18		34	163		66	280	7
Internal Link Dist (ft)		475			172			334			304	
Turn Bay Length (ft)	210			55			90			130		
Base Capacity (vph)	544	585		263	260		456	1492		452	794	1306
Starvation Cap Reductn	0	0		0	0		0	0		0	0	0
Spillback Cap Reductn	0	0		0	0		0	0		0	0	0
Storage Cap Reductn	0	0		0	0		0	0		0	0	0

Lane Group	ø3
Lane Configurations	
Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Confl. Peds. (#/hr)	
Peak Hour Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	3
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	7.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	20%
Maximum Green (s)	18.0
Yellow Time (s)	3.5
All-Red Time (s)	0.5
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Vehicle Extension (s)	3.0
Recall Mode	None
Walk Time (s)	5.0
Flash Dont Walk (s)	11.0
Pedestrian Calls (#/hr)	0
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Reduced v/c Ratio	0.69	0.64		0.05	0.08		0.19	0.37		0.32	0.53	0.29

Intersection Summary	
Area Type:	Other
Cycle Length: 109.7	
Actuated Cycle Length: 68.2	
Natural Cycle: 90	
Control Type: Semi Act-Uncoord	

Splits and Phases: 20: Dixwell Ave & Arch Street/Morse Street



Lane Group	ø3
Reduced v/c Ratio	

Intersection Summary

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	314	113	39	7	3	8	59	497	32	124	378	301
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	11	13	12	11	12	11	10	12	14	10	12	12
Total Lost time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	4.8
Lane Util. Factor	0.95	0.95		1.00	1.00		1.00	0.95		1.00	1.00	1.00
Frpb, ped/bikes	1.00	0.99		1.00	0.95		1.00	1.00		1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Frt	1.00	0.97		1.00	0.88		1.00	0.99		1.00	1.00	0.85
Flt Protected	0.95	0.98		0.95	1.00		0.95	1.00		0.95	1.00	1.00
Satd. Flow (prot)	1641	1745		1745	1593		1679	3525		1682	1881	1615
Flt Permitted	0.95	0.98		0.95	1.00		0.34	1.00		0.33	1.00	1.00
Satd. Flow (perm)	1641	1745		1745	1593		604	3525		577	1881	1615
Peak-hour factor, PHF	0.60	0.75	0.50	0.58	0.75	0.50	0.69	0.98	0.76	0.86	0.90	0.80
Adj. Flow (vph)	523	151	78	12	4	16	86	507	42	144	420	376
RTOR Reduction (vph)	0	8	0	0	16	0	0	5	0	0	0	130
Lane Group Flow (vph)	377	367	0	12	4	0	86	544	0	144	420	246
Confl. Peds. (#/hr)	4		5	5		4	19		12	12		19
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	1%	0%	0%	1%	0%
Turn Type	Split	NA		Split	NA		pm+pt	NA		pm+pt	NA	pt+ov
Protected Phases	9	9		8	8		5	2		1	6	6 9
Permitted Phases							2			6		
Actuated Green, G (s)	22.6	22.6		1.8	1.8		28.0	22.6		32.0	24.6	47.2
Effective Green, g (s)	22.6	22.6		1.8	1.8		28.0	22.6		32.0	24.6	47.2
Actuated g/C Ratio	0.31	0.31		0.02	0.02		0.39	0.31		0.44	0.34	0.65
Clearance Time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	
Vehicle Extension (s)	1.5	1.5		1.5	1.5		1.5	2.5		1.5	2.5	
Lane Grp Cap (vph)	514	546		43	39		315	1104		369	641	1057
v/s Ratio Prot	c0.23	0.21		c0.01	0.00		0.02	0.15		c0.04	c0.22	0.15
v/s Ratio Perm							0.09			0.13		
v/c Ratio	0.73	0.67		0.28	0.11		0.27	0.49		0.39	0.66	0.23
Uniform Delay, d1	22.1	21.5		34.5	34.4		14.7	20.1		12.6	20.2	5.1
Progression Factor	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Incremental Delay, d2	4.6	2.6		1.3	0.5		0.2	0.3		0.2	2.2	0.1
Delay (s)	26.7	24.1		35.8	34.8		14.8	20.4		12.8	22.3	5.2
Level of Service	C	C		D	C		B	C		B	C	A
Approach Delay (s)		25.4			35.2			19.6			14.0	
Approach LOS		C			D			B			B	

Intersection Summary			
HCM 2000 Control Delay	19.4	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.72		
Actuated Cycle Length (s)	72.1	Sum of lost time (s)	21.7
Intersection Capacity Utilization	54.8%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

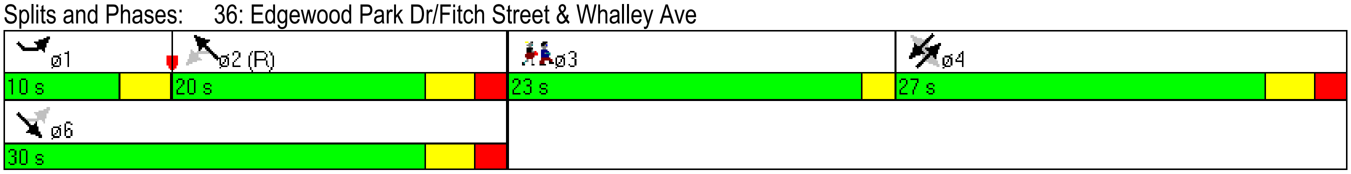
Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	246	730	4	13	619	63	2	1	3	110	1	175
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	10	11	15	15	11	11	15	15	15	14	15	8
Storage Length (ft)	150		0	0		0	0		0	0		0
Storage Lanes	1		0	0		0	0		0	0		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		709			1067			199			1402	
Travel Time (s)		16.1			24.3			4.5			31.9	
Confl. Peds. (#/hr)	6		12	12		6	4		3	3		4
Peak Hour Factor	0.25	0.88	0.61	0.25	0.88	0.61	0.50	0.25	0.38	0.92	0.25	0.93
Heavy Vehicles (%)	0%	0%	1%	2%	2%	2%	2%	2%	2%	1%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	984	837	0	0	858	0	0	16	0	0	312	0
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	1	6			2			4			4	
Permitted Phases	6			2			4			4		
Detector Phase	1	6		2	2		4	4		4	4	
Switch Phase												
Minimum Initial (s)	5.0	5.0		15.0	15.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	9.0	27.0		20.0	20.0		10.0	10.0		10.0	10.0	
Total Split (s)	10.0	30.0		20.0	20.0		27.0	27.0		27.0	27.0	
Total Split (%)	12.5%	37.5%		25.0%	25.0%		33.8%	33.8%		33.8%	33.8%	
Maximum Green (s)	6.9	25.0		15.0	15.0		22.0	22.0		22.0	22.0	
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	0.1	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0			0.0			0.0			0.0	
Total Lost Time (s)	3.1	5.0			5.0			5.0			5.0	
Lead/Lag	Lead			Lag	Lag		Lag	Lag		Lag	Lag	
Lead-Lag Optimize?				Yes	Yes							
Vehicle Extension (s)	1.0	0.2		0.2	0.2		1.0	1.0		1.0	1.0	
Recall Mode	None	Max		C-Max	C-Max		None	None		None	None	
Walk Time (s)												
Flash Dont Walk (s)												
Pedestrian Calls (#/hr)												
v/c Ratio	1.12	0.35			1.62			0.05			0.83	
Control Delay	88.3	6.3			313.3			17.0			39.0	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	88.3	6.3			313.3			17.0			39.0	
Queue Length 50th (ft)	~524	75			~330			3			106	
Queue Length 95th (ft)	70	137			#433			3			12	
Internal Link Dist (ft)		629			987			119			1322	
Turn Bay Length (ft)	150											
Base Capacity (vph)	880	2408			530			479			520	
Starvation Cap Reductn	0	0			0			0			0	
Spillback Cap Reductn	0	0			0			0			0	
Storage Cap Reductn	0	0			0			0			0	

Lane Group	ø3
Lane Configurations	
Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Confl. Peds. (#/hr)	
Peak Hour Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	3
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	7.0
Minimum Split (s)	23.0
Total Split (s)	23.0
Total Split (%)	29%
Maximum Green (s)	21.0
Yellow Time (s)	2.0
All-Red Time (s)	0.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	Lead
Lead-Lag Optimize?	
Vehicle Extension (s)	0.2
Recall Mode	None
Walk Time (s)	7.0
Flash Dont Walk (s)	14.0
Pedestrian Calls (#/hr)	0
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Reduced v/c Ratio	1.12	0.35			1.62			0.03			0.60	

Intersection Summary	
Area Type:	Other
Cycle Length: 80	
Actuated Cycle Length: 80	
Offset: 0 (0%), Referenced to phase 2:NWTL, Start of Green	
Natural Cycle: 100	
Control Type: Actuated-Coordinated	
~ Volume exceeds capacity, queue is theoretically infinite. Queue shown is maximum after two cycles.	
# 95th percentile volume exceeds capacity, queue may be longer. Queue shown is maximum after two cycles.	

Splits and Phases: 36: Edgewood Park Dr/Fitch Street & Whalley Ave



Lane Group	ø3
Reduced v/c Ratio	

Intersection Summary

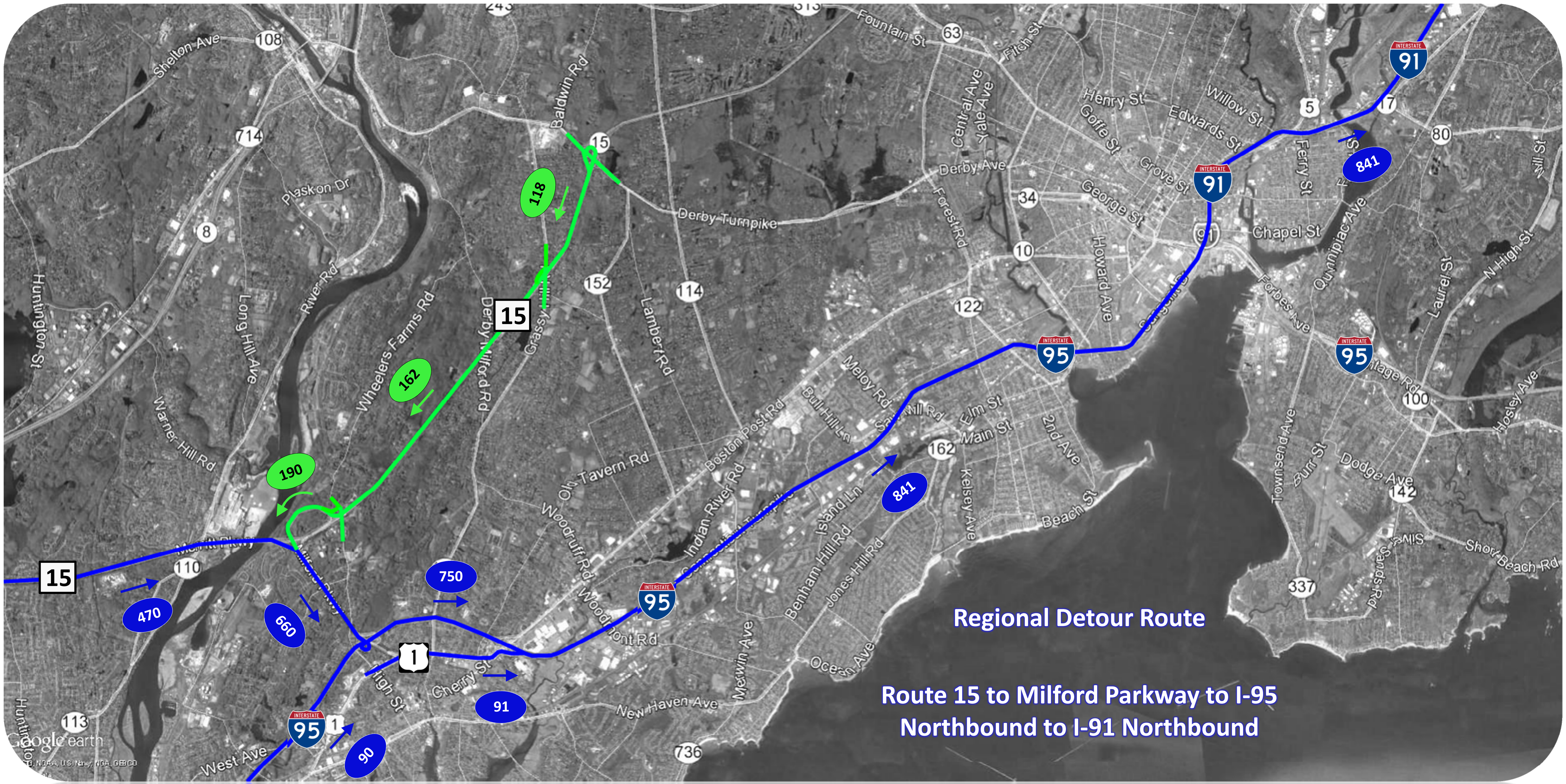
Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	246	730	4	13	619	63	2	1	3	110	1	175
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	10	11	15	15	11	11	15	15	15	14	15	8
Total Lost time (s)	3.1	5.0			5.0			5.0			5.0	
Lane Util. Factor	1.00	0.95			0.95			1.00			1.00	
Frpb, ped/bikes	1.00	1.00			1.00			0.99			0.99	
Flpb, ped/bikes	1.00	1.00			1.00			1.00			1.00	
Frt	1.00	1.00			0.98			0.93			0.92	
Flt Protected	0.95	1.00			1.00			0.99			0.98	
Satd. Flow (prot)	1684	3484			3333			1870			1852	
Flt Permitted	0.22	1.00			0.83			0.91			0.87	
Satd. Flow (perm)	392	3484			2759			1719			1637	
Peak-hour factor, PHF	0.25	0.88	0.61	0.25	0.88	0.61	0.50	0.25	0.38	0.92	0.25	0.93
Adj. Flow (vph)	984	830	7	52	703	103	4	4	8	120	4	188
RTOR Reduction (vph)	0	0	0	0	13	0	0	7	0	0	77	0
Lane Group Flow (vph)	984	837	0	0	845	0	0	9	0	0	235	0
Confl. Peds. (#/hr)	6		12	12		6	4		3	3		4
Heavy Vehicles (%)	0%	0%	1%	2%	2%	2%	2%	2%	2%	1%	0%	0%
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	1	6			2			4			4	
Permitted Phases	6			2			4			4		
Actuated Green, G (s)	55.3	55.3			15.0			14.7			14.7	
Effective Green, g (s)	55.3	55.3			15.0			14.7			14.7	
Actuated g/C Ratio	0.69	0.69			0.19			0.18			0.18	
Clearance Time (s)	3.1	5.0			5.0			5.0			5.0	
Vehicle Extension (s)	1.0	0.2			0.2			1.0			1.0	
Lane Grp Cap (vph)	871	2408			517			315			300	
v/s Ratio Prot	c0.52	0.24										
v/s Ratio Perm	0.26				c0.31			0.01			c0.14	
v/c Ratio	1.13	0.35			1.63			0.03			0.78	
Uniform Delay, d1	16.8	5.0			32.5			26.8			31.1	
Progression Factor	1.00	1.00			1.00			1.00			1.00	
Incremental Delay, d2	72.8	0.4			294.2			0.0			11.7	
Delay (s)	89.6	5.4			326.7			26.8			42.8	
Level of Service	F	A			F			C			D	
Approach Delay (s)		50.9			326.7			26.8			42.8	
Approach LOS		D			F			C			D	

Intersection Summary			
HCM 2000 Control Delay	128.6	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.20		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	15.1
Intersection Capacity Utilization	76.1%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

B3. Regional and Local Detours

B3a. Regional Detour



PEAK REDISTRIBUTED TRAFFIC VOLUMES ALONG DETOUR

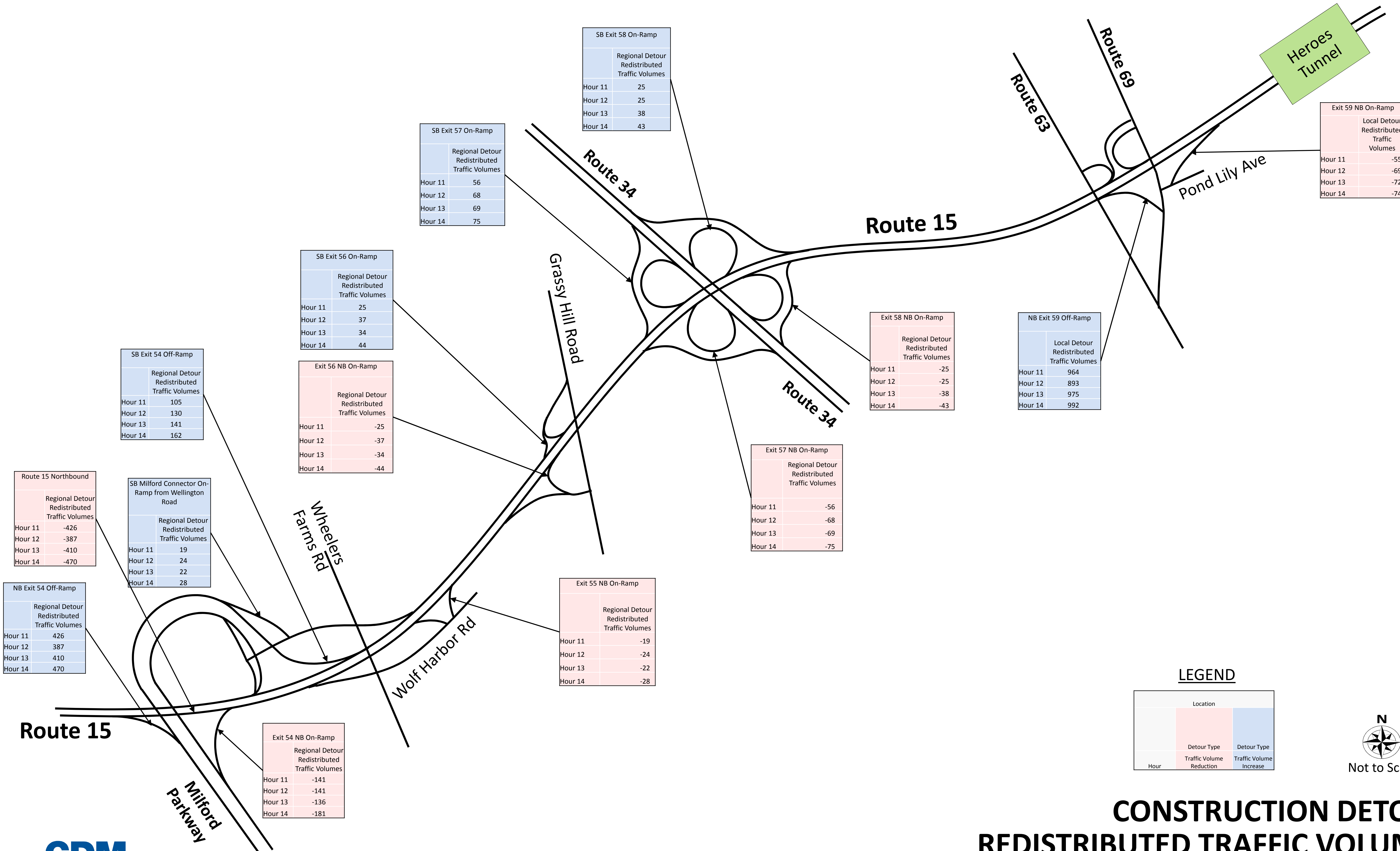
- XX ROUTE 15 SOUTHBOUND
- XX REGIONAL NORTHBOUND

N
Not to Scale

CDM Smith

REGIONAL CONSTRUCTION DETOUR

CONSTRUCTION DETOUR REDISTRIBUTED TRAFFIC VOLUMES



SB Exit 58 On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	25
Hour 12	25
Hour 13	38
Hour 14	43

SB Exit 57 On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	56
Hour 12	68
Hour 13	69
Hour 14	75

Exit 59 NB On-Ramp	Local Detour Redistributed Traffic Volumes
Hour 11	-557
Hour 12	-698
Hour 13	-728
Hour 14	-746

SB Exit 56 On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	25
Hour 12	37
Hour 13	34
Hour 14	44

Exit 58 NB On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	-25
Hour 12	-25
Hour 13	-38
Hour 14	-43

NB Exit 59 Off-Ramp	Local Detour Redistributed Traffic Volumes
Hour 11	964
Hour 12	893
Hour 13	975
Hour 14	992

SB Exit 54 Off-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	105
Hour 12	130
Hour 13	141
Hour 14	162

Exit 56 NB On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	-25
Hour 12	-37
Hour 13	-34
Hour 14	-44

Exit 57 NB On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	-56
Hour 12	-68
Hour 13	-69
Hour 14	-75

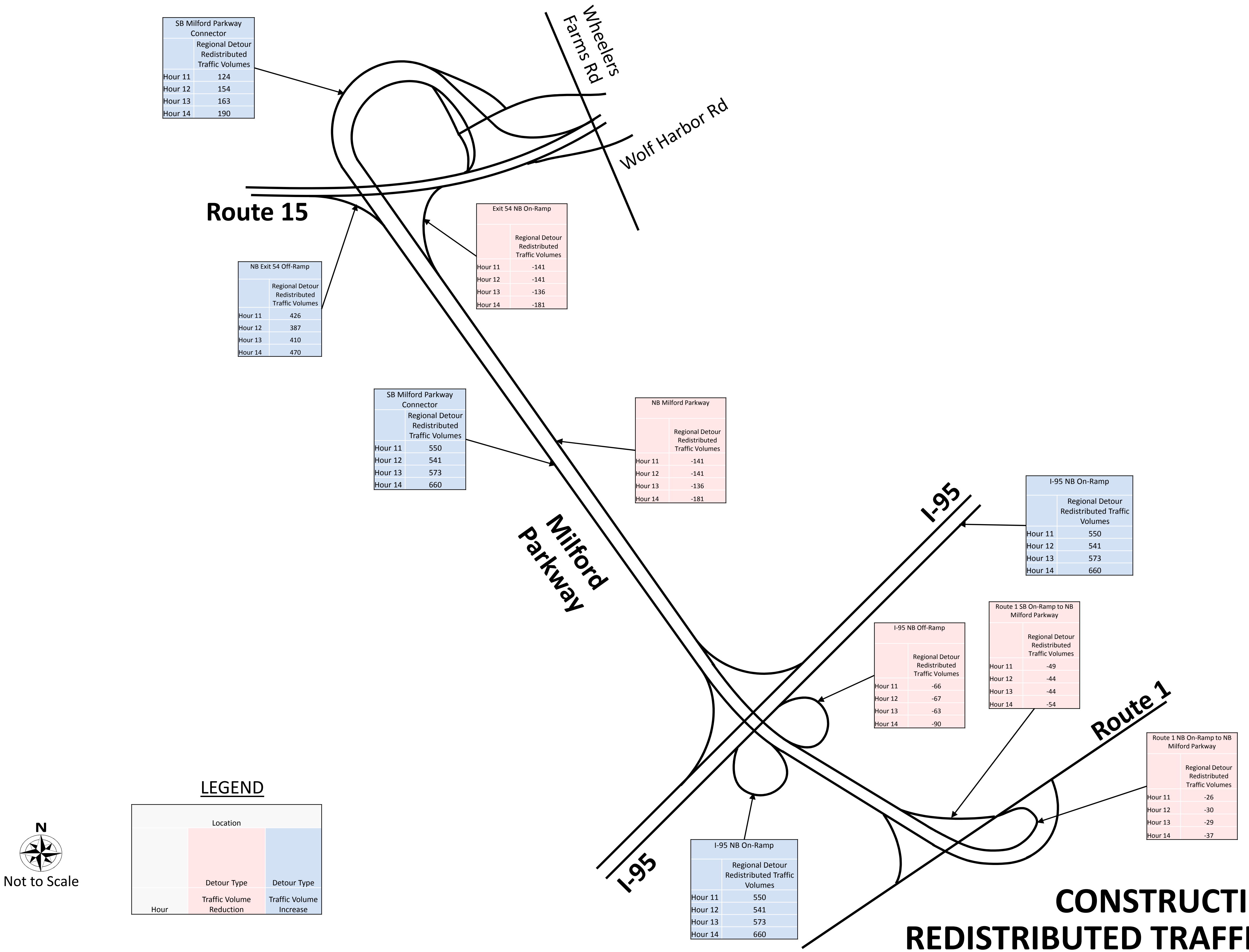
Route 15 Northbound	Regional Detour Redistributed Traffic Volumes
Hour 11	-426
Hour 12	-387
Hour 13	-410
Hour 14	-470

SB Milford Connector On-Ramp from Wellington Road	Regional Detour Redistributed Traffic Volumes
Hour 11	19
Hour 12	24
Hour 13	22
Hour 14	28

NB Exit 54 Off-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	426
Hour 12	387
Hour 13	410
Hour 14	470

Exit 55 NB On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	-19
Hour 12	-24
Hour 13	-22
Hour 14	-28

Exit 54 NB On-Ramp	Regional Detour Redistributed Traffic Volumes
Hour 11	-141
Hour 12	-141
Hour 13	-136
Hour 14	-181



SB Milford Parkway Connector	
	Regional Detour Redistributed Traffic Volumes
Hour 11	124
Hour 12	154
Hour 13	163
Hour 14	190

Exit 54 NB On-Ramp	
	Regional Detour Redistributed Traffic Volumes
Hour 11	-141
Hour 12	-141
Hour 13	-136
Hour 14	-181

NB Exit 54 Off-Ramp	
	Regional Detour Redistributed Traffic Volumes
Hour 11	426
Hour 12	387
Hour 13	410
Hour 14	470

SB Milford Parkway Connector	
	Regional Detour Redistributed Traffic Volumes
Hour 11	550
Hour 12	541
Hour 13	573
Hour 14	660

NB Milford Parkway	
	Regional Detour Redistributed Traffic Volumes
Hour 11	-141
Hour 12	-141
Hour 13	-136
Hour 14	-181

I-95 NB On-Ramp	
	Regional Detour Redistributed Traffic Volumes
Hour 11	550
Hour 12	541
Hour 13	573
Hour 14	660

Route 1 SB On-Ramp to NB Milford Parkway	
	Regional Detour Redistributed Traffic Volumes
Hour 11	-49
Hour 12	-44
Hour 13	-44
Hour 14	-54

I-95 NB Off-Ramp	
	Regional Detour Redistributed Traffic Volumes
Hour 11	-66
Hour 12	-67
Hour 13	-63
Hour 14	-90

Route 1 NB On-Ramp to NB Milford Parkway	
	Regional Detour Redistributed Traffic Volumes
Hour 11	-26
Hour 12	-30
Hour 13	-29
Hour 14	-37

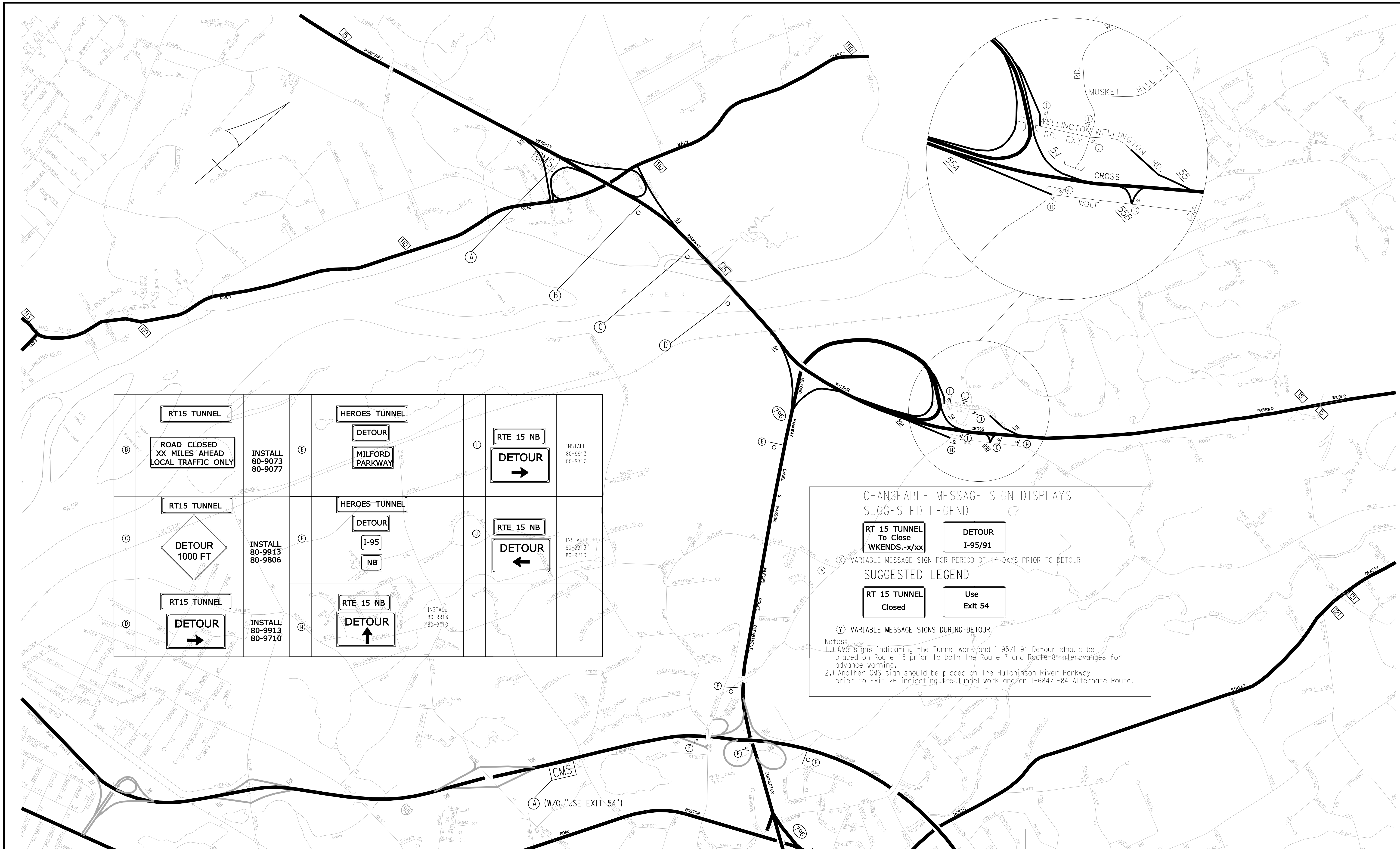
I-95 NB On-Ramp	
	Regional Detour Redistributed Traffic Volumes
Hour 11	550
Hour 12	541
Hour 13	573
Hour 14	660

LEGEND

Location		
	Detour Type	Detour Type
Hour	Traffic Volume Reduction	Traffic Volume Increase

CONSTRUCTION DETOUR REDISTRIBUTED TRAFFIC VOLUMES

CDM Smith



(B)	RT15 TUNNEL ROAD CLOSED XX MILES AHEAD LOCAL TRAFFIC ONLY	INSTALL 80-9073 80-9077	(E)	HEROES TUNNEL DETOUR MILFORD PARKWAY		(I)	RTE 15 NB DETOUR →	INSTALL 80-9913 80-9710
(C)	RT15 TUNNEL DETOUR 1000 FT	INSTALL 80-9913 80-9806	(F)	HEROES TUNNEL DETOUR I-95 NB		(J)	RTE 15 NB DETOUR ←	INSTALL 80-9913 80-9710
(D)	RT15 TUNNEL DETOUR →	INSTALL 80-9913 80-9710	(H)	RTE 15 NB DETOUR ↑	INSTALL 80-9913 80-9710			

CHANGEABLE MESSAGE SIGN DISPLAYS
SUGGESTED LEGEND

RT 15 TUNNEL To Close WKENDS.-x/xx	DETOUR I-95/91

(X) VARIABLE MESSAGE SIGN FOR PERIOD OF 14 DAYS PRIOR TO DETOUR

(A) SUGGESTED LEGEND

RT 15 TUNNEL Closed	Use Exit 54

(Y) VARIABLE MESSAGE SIGNS DURING DETOUR

Notes:
1.) CMS signs indicating the Tunnel work and I-95/I-91 Detour should be placed on Route 15 prior to both the Route 7 and Route 8 interchanges for advance warning.
2.) Another CMS sign should be placed on the Hutchinson River Parkway prior to Exit 26 indicating the Tunnel work and an I-684/I-84 Alternate Route.

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: 6/25/2014

DESIGNER/DRAFTER: DS
CHECKED BY: EYC
NOT TO SCALE

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: Heroestunnel_Detour.dgn

GARG CONSULTING SERVICES
2096A SILAS DEANE HIGHWAY
ROCKY HILL, CT 06067
TEL:(860)563-0582

PROJECT TITLE:

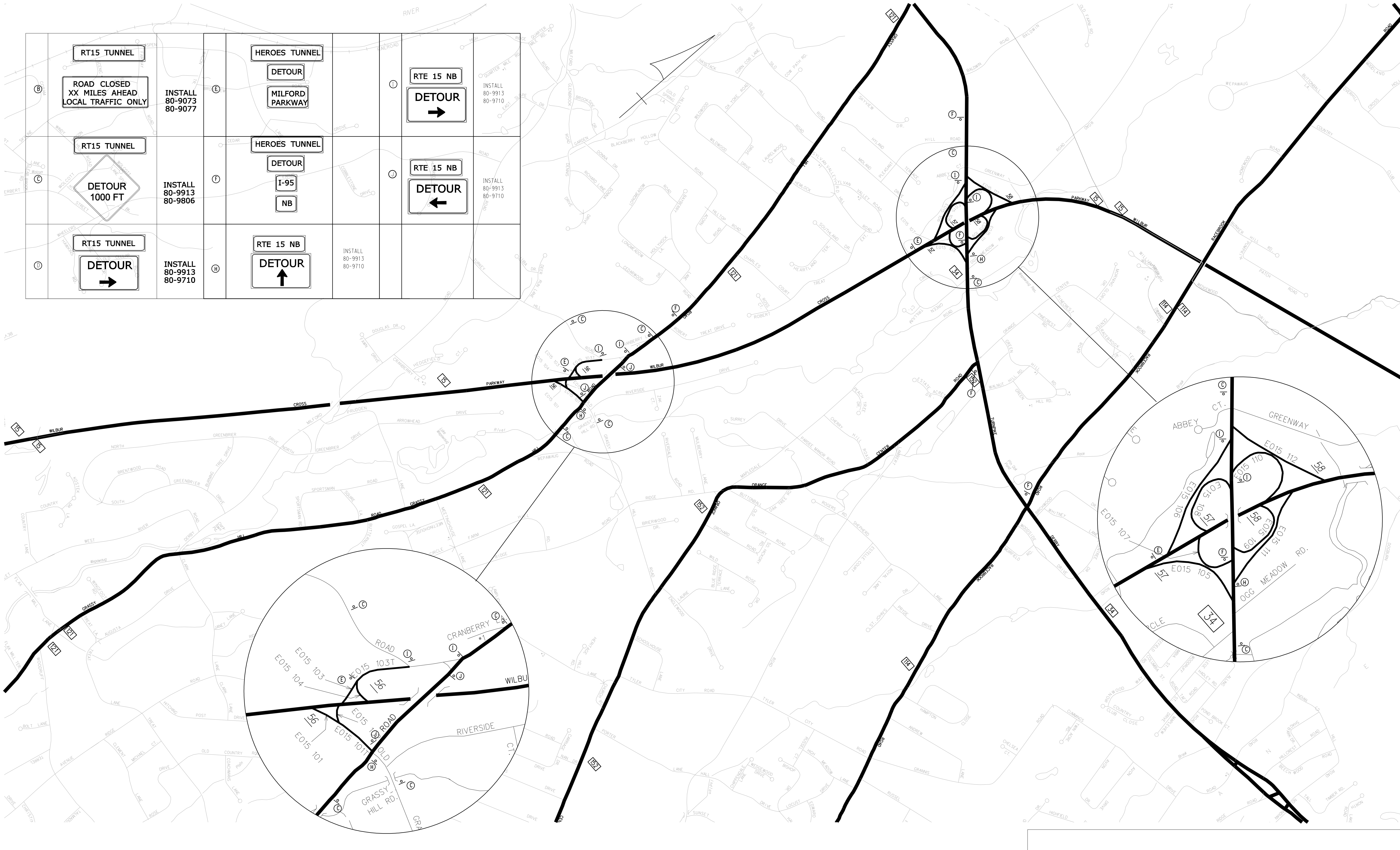
TOWN:

DRAWING TITLE: **REGIONAL DETOUR - 1**

PROJECT NO.

DRAWING NO. **DP-1**

SHEET NO.



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: 6/25/2014

DESIGNER/DRAFTER: DS

CHECKED BY: EYC

NOT TO SCALE

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: Heroestunnel_Detour.dgn

GARG CONSULTING SERVICES
2096A SILAS DEANE HIGHWAY
ROCKY HILL, CT 06067
TEL:(860)563-0582

PROJECT TITLE:

TOWN:

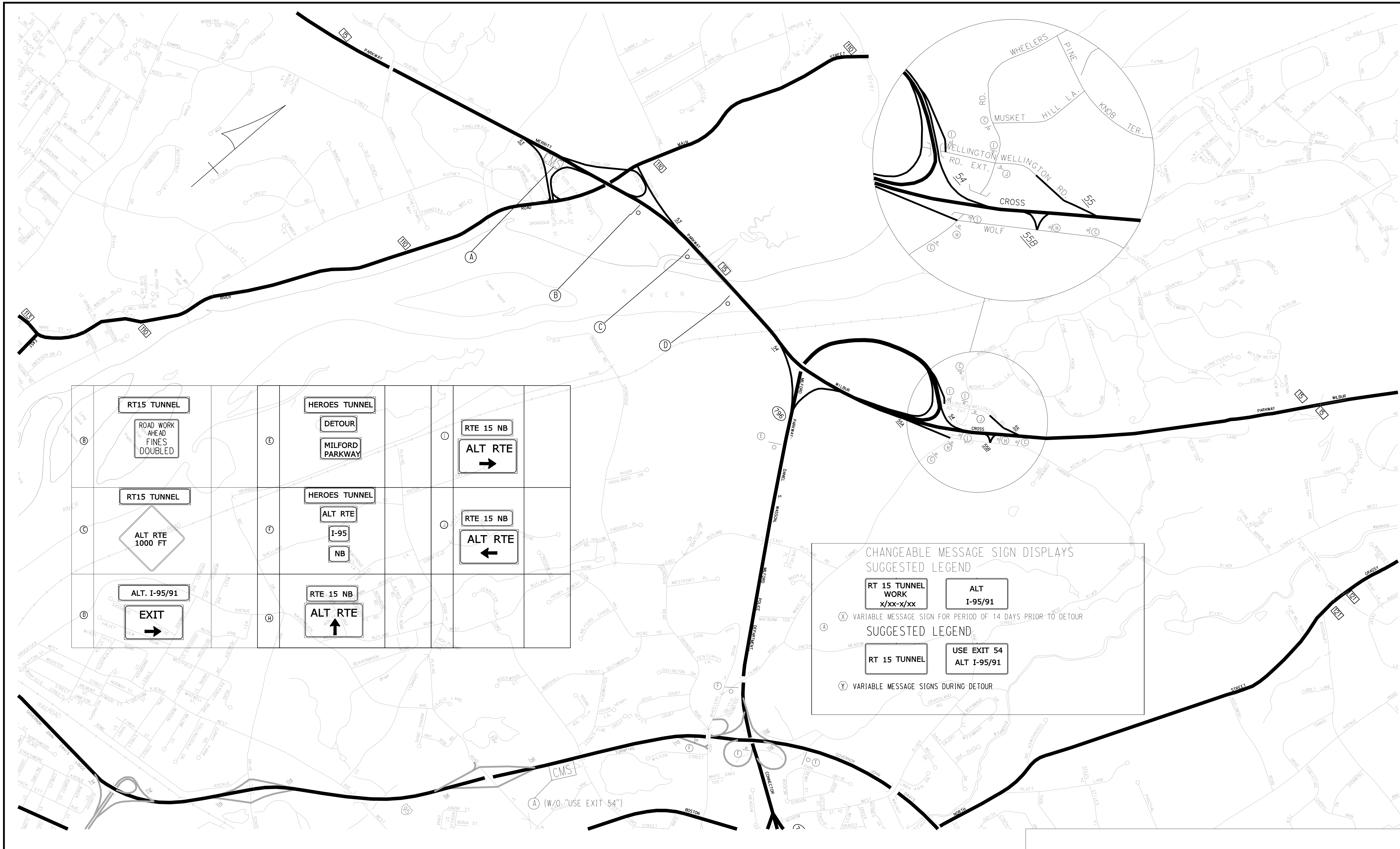
DRAWING TITLE:

REGIONAL DETOUR - 2

PROJECT NO.

DRAWING NO.
DP-2

SHEET NO.



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: 6/25/2014

DESIGNER/DRAFTER: DS

CHECKED BY: EYC

NOT TO SCALE

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: Heroestunnel_Detour.dgn

GARG CONSULTING SERVICES
2096A SILAS DEANE HIGHWAY
ROCKY HILL, CT 06067
TEL:(860)563-0582

PROJECT TITLE:

TOWN:

DRAWING TITLE: **ALTERNATE ROUTE-1**

PROJECT NO.

DRAWING NO. **ALT.-1**

SHEET NO.

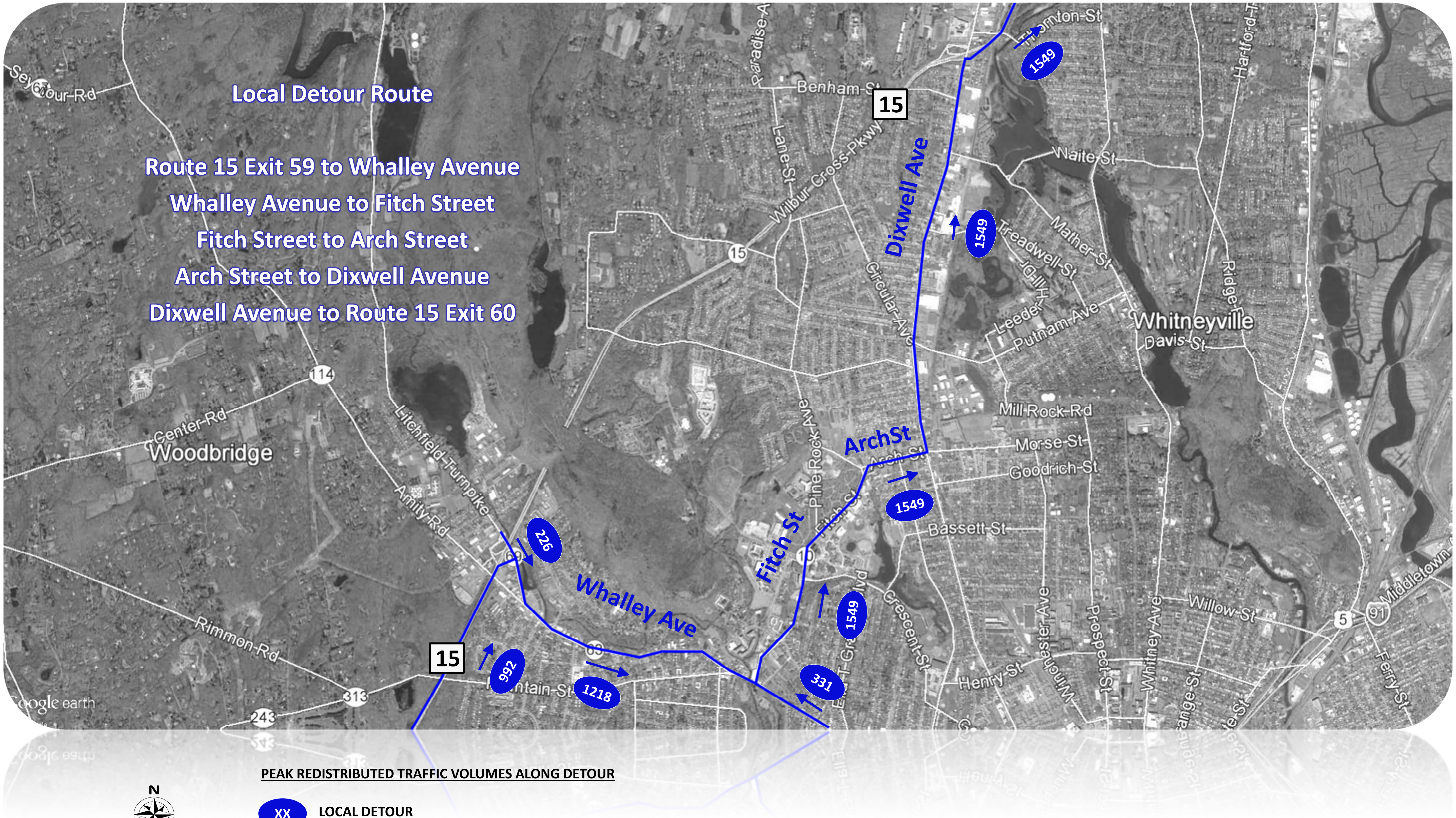
B3b. Local Detour

N
Not to Scale

● STUDY INTERSECTION

LOCAL CONSTRUCTION DETOUR STUDY INTERSECTIONS

CDM Smith



LOCAL CONSTRUCTION DETOUR

	Sign	Note		Sign	Note		Sign	Note
(C)	RT15 TUNNEL / ROAD CLOSED AHEAD	INSTALL 80-9913 80-3014	(F)	DO NOT ENTER	INSTALL 31-0552	(I)	RTE 15 NB / DETOUR →	INSTALL 80-9913 80-9710
(D)	RT15 TUNNEL / DETOUR 1000 FT	INSTALL 80-9913 80-9806	(G)	ROAD CLOSED	INSTALL 80-9080	(J)	RTE 15 NB / DETOUR ←	INSTALL 80-9913 80-9710
(E)	RT15 TUNNEL / DETOUR →	INSTALL 80-9913 80-9710	(H)	RTE 15 NB / DETOUR ↑	INSTALL 80-9913 80-9710	(K)	END DETOUR	INSTALL 80-9708

(A)

CHANGEABLE MESSAGE SIGN DISPLAYS

SUGGESTED LEGEND

RT 15 TUNNEL To Close WKENDS.-x/xx	BEGIN X/XX THRU X/XX	DETOUR RTE 10

(X) VARIABLE MESSAGE SIGN FOR PERIOD OF 14 DAYS PRIOR TO DETOUR

SUGGESTED LEGEND

RT 15 TUNNEL Closed	Exit 59 FOLLOW DETOUR

(Y) VARIABLE MESSAGE SIGNS DURING DETOUR

(B)

CHANGEABLE MESSAGE SIGN DISPLAYS

SUGGESTED LEGEND

RT 15 NB To Close SAT.-x/xx	DETOUR RTE 10

(X) VARIABLE MESSAGE SIGN FOR PERIOD OF 14 DAYS PRIOR TO DETOUR

SUGGESTED LEGEND

RT 15 NB Closed	FOLLOW DETOUR

(Y) VARIABLE MESSAGE SIGNS DURING DETOUR

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: 6/25/2014

DESIGNER/DRAFTER: DS

CHECKED BY: EYC

NOT TO SCALE

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: Heroestunnel_Detour.dgn

GARG CONSULTING SERVICES
2096A SILAS DEANE HIGHWAY
ROCKY HILL, CT 06067
TEL:(860)563-0582

PROJECT TITLE:

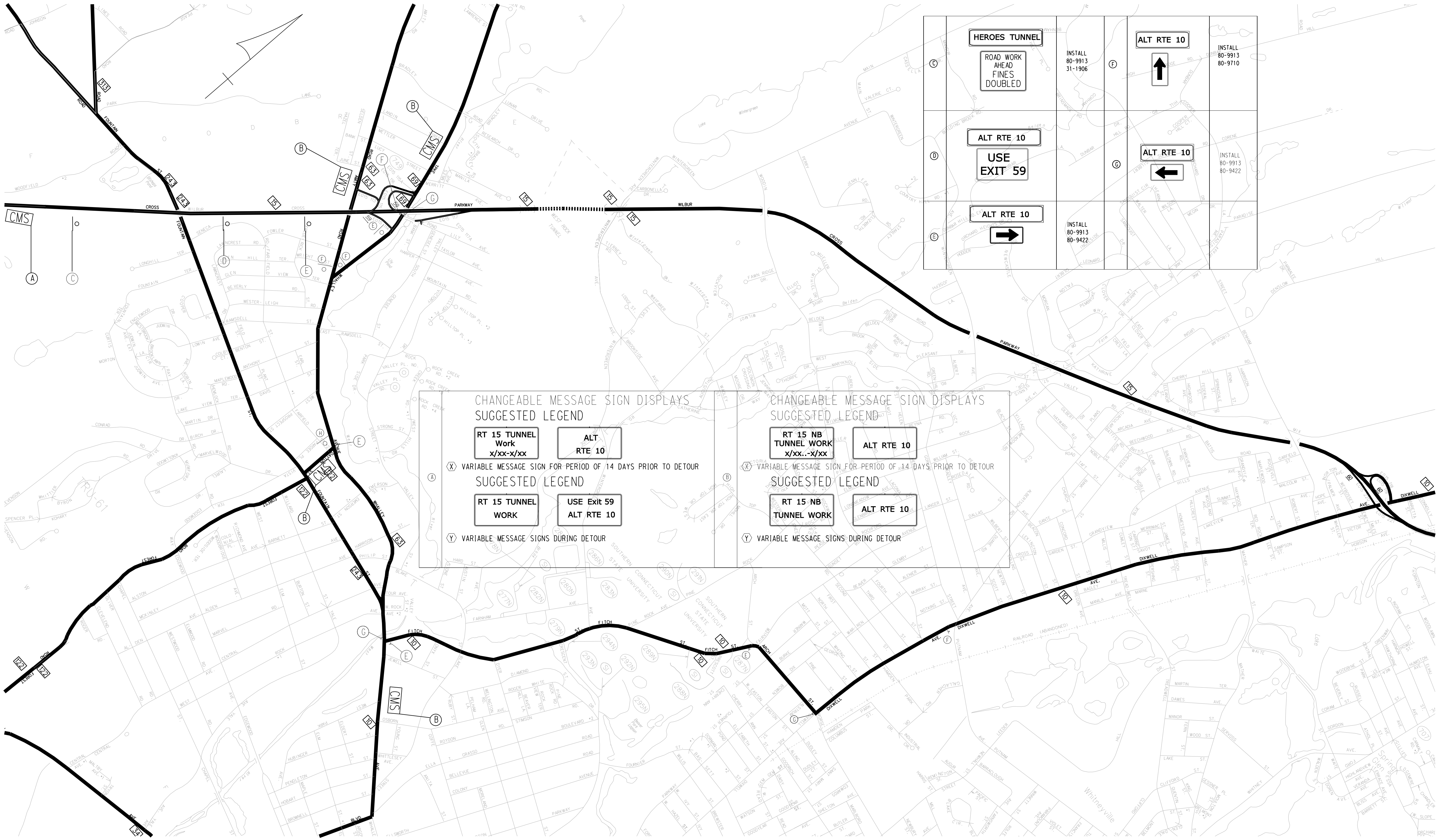
TOWN:

DRAWING TITLE: **LOCAL DETOUR**

PROJECT NO.

DRAWING NO. **DP-3**

SHEET NO.



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: 6/25/2014

DESIGNER/DRAFTER: DS
CHECKED BY: EYC
NOT TO SCALE

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

Filename: Heroestunnel_Detour.dgn

GARG CONSULTING SERVICES
2096A SILAS DEANE HIGHWAY
ROCKY HILL, CT 06067
TEL:(860)563-0582

PROJECT TITLE:

TOWN:

DRAWING TITLE: ALTERNATING-2

PROJECT NO.

DRAWING NO. ALT-2

SHEET NO.

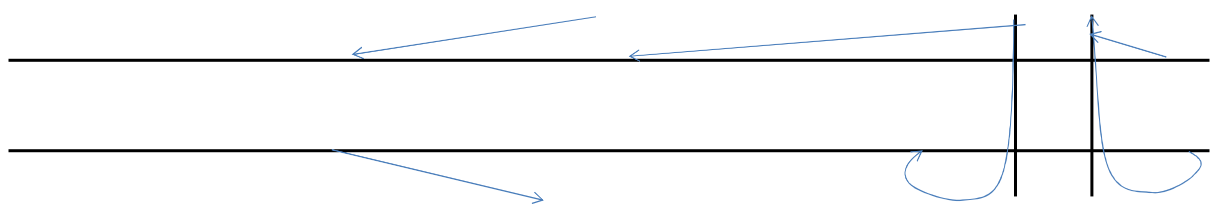
B4. 2019 Future Conditions During Construction

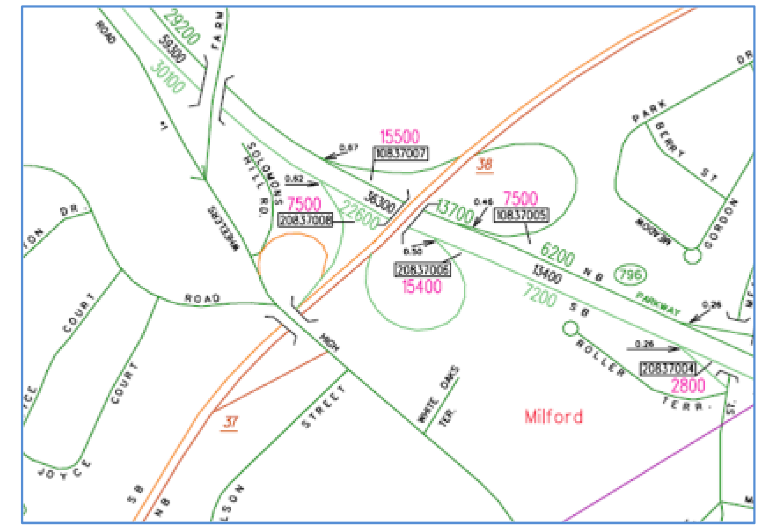
B4a. Balanced Traffic Volume Profiles

CDM Smith

2019 I-95 Detour Condition Profile
Saturday Midday Peak Period

	SB ML	Int. 38 Wheelers Farms Rd. SB On	Int. 38 Milford Connector SB On	Int. 38 Milford Connector SB Off	SB ML
Hour 11	**5135**	184	444	917	**5,424**
Hour 12	**5579**	168	495	1080	**5,996**
Hour 13	**5628**	198	515	967	**5,882**
Hour 14	**5838**	198	533	1252	**6,359**
		STA 7148	*STA 7008*	*STA 7007*	





		STA 7147		*STA 7006*			*STA 7005*				
				Existing	Redistributed Traffic Volumes (A+L+K+M+N)	Total Traffic Volumes During Detour (Existing + A+K+L+M+N)	Existing	Prorated amount of cars not using Milford Pkwy (V)	Existing - V	Existing	**Detour Thru Volumes**
Hour 11	**5418**	231	5187	1,002	550	1,552	347	66	281	**5,842**	**6,458**
Hour 12	**5375**	216	5159	1,219	541	1,760	441	67	374	**5,937**	**6,544**
Hour 13	**5848**	248	5600	1,193	572	1,765	392	63	329	**6,401**	**7,036**
Hour 14	**6686**	289	6397	1,291	660	1,951	585	90	495	**7,103**	**7,853**
	NB ML	*NB Off*			*NB On*			*NB Off*		**NB ML**	
		High St. Int. 37			**Milford Connector Int. 38**						

Note: Regional detour volumes from Rte-15 enter I-95 from Milford Pkwy through STA 7006. A prorated number of cars from all of those entering Milford Pkwy NB (V) will not use STA 7005. Prorated values are calculated on '2019 Mpwy Sat Detour Network' tab.
Note: Vehicles redistributed based on the following guidelines:

Vehicles travelling NB along Route 15 south of Exit 54 and from the Milford Parkway			
	Exit Prior to Tunnel	**Exit North of Tunnel**	**Reach I-91**
	(No Detour Required)	(Local Detour)	(Regional Detour)
Percent of Traffic	*45%*	*30%*	*25%*

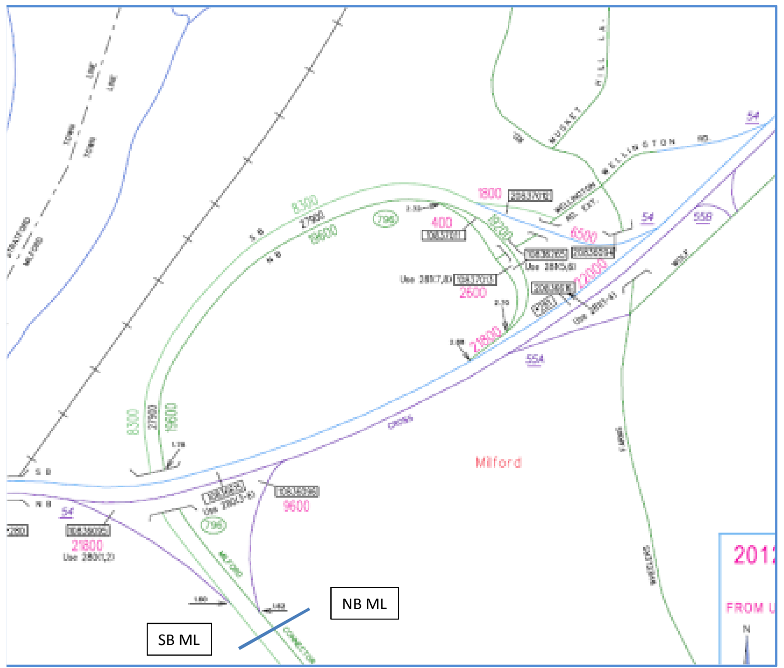
Vehicles entering Route 15 NB from Exits 55-58			
	Use Other Local Roads	**Exit North of Tunnel**	**Reach I-91**
	(Will not Enter Route 15)	(Local Detour)	(Regional Detour)
Percent of Traffic	*45%*	*30%*	*25%*

Vehicles entering Route 15 NB from Exit 59 will follow the local detour.
Vehicles entering Route 15 NB from Exits 60-67 will not be required to follow

CDM Smith

2019 Milford Parkway Detour Condition Profile
Saturday Midday Peak Period

Milford Parkway
Milford Pkwy / Route 15



	NB Off (STA 6096) Existing	NB Off (STA 6096) Detour Volumes (Existing - T) remaining after 25% shift from Milford Pkwy	NB Off (STA 7011)	NB Off (STA 6265)	NB Off (STA 6265)	NB ML Existing	NB ML Total Traffic Volumes During Detour
Hour 11	562	422	28	1,068	1,096	**1,658**	**1,518**
Hour 12	563	422	33	1,414	1,447	**2,010**	**1,869**
Hour 13	545	409	33	1,233	1,266	**1,811**	**1,675**
Hour 14	722	542	34	1,673	1,707	**2,429**	**2,249**
	STA 6096		STA 7011	STA 6265		Computed	

	SB On (STA 7012) Existing	SB On (STA 7012) N Redistributed Traffic Volumes (25% of Existing Exit 55 NB On-	SB On (STA 7012) Total Traffic Volumes During Detour (Existing + N)	SB On (STA 6094) Existing	SB On (STA 6094) Regional Detour shift (Existing + K + L + M)	SB On (STA 6094) Detour Volumes	SB On (STA 6095) Existing	SB On (STA 6095) A Redistributed Traffic Volumes	SB On (STA 6095) Detour Volumes (Existing + A) 25% shift from Rte 15 NB	SB ML Existing	SB ML Total Traffic Volumes During Detour
Hour 11	147	19	166	320	105	425	1,562	426	1,988	**2,029**	**2,579**
Hour 12	202	24	226	383	130	513	1,761	387	2,148	**2,346**	**2,887**
Hour 13	148	22	170	387	141	528	1,855	410	2,265	**2,390**	**2,962**
Hour 14	126	28	154	445	162	607	2,021	470	2,491	**2,592**	**3,252**
	STA 7012			STA 6094			STA 6095			Computed	

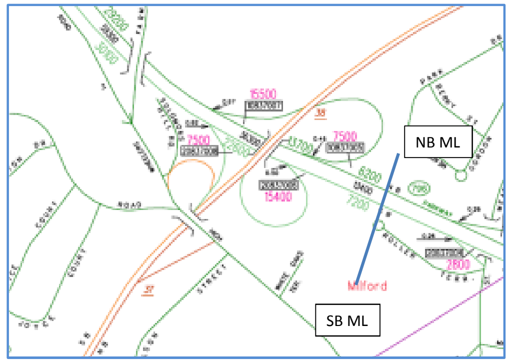
Note: Vehicles redistributed based on the following guidelines:

Vehicles travelling NB along Route 15 south of Exit 54 and from the Milford Parkway			
	Exit Prior to Tunnel	**Exit North of Tunnel and Prior**	**Reach I-91**
	(No Detour Required)	(Local Detour)	(Regional Detour)
Percent of Traffic	*45%*	*30%*	*25%*

Vehicles entering Route 15 NB from Exits 55-58			
	Use Other Local Roads	**Exit North of Tunnel**	**Reach I-91**
	(Will not Enter Route 15)	(Local Detour)	(Regional Detour)
Percent of Traffic	*45%*	*30%*	*25%*

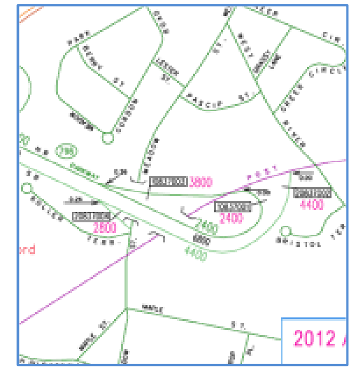
Vehicles entering Route 15 NB from Exit 59 will follow the local detour. Vehicles entering Route 15 NB from Exits 60-67 will not be

2019 Milford Parkway Detour Condition Profile
Saturday Midday Peak Period



Milford Parkway
Milford Pkwy / I-95

	NB On (STA 7007, Balanced)	NB On (STA 7005, Balanced): Existing	α % of total traffic entering 7001, 7003, 7005	V Redistributed Traffic Volumes (T*α)	Total Traffic Volumes During Detour (Existing - V)	NB ML (Computed): Existing	NB ML (Computed): Total Traffic Volumes During Detour
Hour 11	917	347	47%	66	281	**394**	**319**
Hour 12	1,080	441	47%	67	374	**489**	**415**
Hour 13	967	392	46%	63	329	**452**	**379**
Hour 14	1,252	585	50%	90	495	**592**	**501**



Milford Parkway
Milford Pkwy / Route 1

	NB On (STA 7003, Balanced): Existing	β % of total traffic entering 7001, 7003, 7005	V Redistributed Traffic Volumes (T*β)	Total Traffic Volumes During Detour	NB On (STA 7001, Balanced): Existing	μ % of total traffic entering 7001, 7003, 7005	V Redistributed Traffic Volumes (T*μ)	Total Traffic Volumes During Detour (Existing - W)
Hour 11	259	35%	49	210	135	18%	26	109
Hour 12	293	32%	44	249	196	21%	30	166
Hour 13	275	33%	44	231	177	21%	29	148
Hour 14	352	30%	54	298	240	20%	37	203

	SB Off (STA 7008, Balanced)		SB Off (STA 7006, Balanced): Existing	Redistributed Traffic Volumes (A+L+K+M+N)	Total Traffic Volumes During Detour (Existing + A)	SB ML (Computed): Existing	SB ML (Computed): Total Traffic Volumes During Detour
Hour 11	444	2,135	1,002	550	1552	**583**	**583**
Hour 12	495	2,392	1,219	541	1760	**632**	**632**
Hour 13	515	2,447	1,193	573	1766	**682**	**681**
Hour 14	533	2,719	1,291	660	1951	**768**	**768**

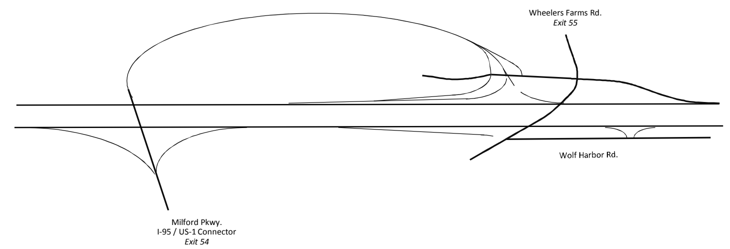
	SB Off (STA 7004, Balanced)	SB Off (STA 7002, Balanced)
Hour 11	201	382
Hour 12	231	401
Hour 13	313	368
Hour 14	347	421

CDM Smith

2019 Route 15 Detour Condition Profile
Saturday Midday Peak Period

Milford Pkwy / I-95&US-1 Connector — Exit 54

Wheelers Farms Rd/ Wolf Harbor Rd — Exit 55



Southbound

	SB ML	SB On	SB On		SB Off Existing	SB Off Redistributed Traffic Volumes (K+L+M)	SB Off Total Traffic Volumes During Detour (Existing +K+L+M)		SB Off	SB ML Existing	SB ML Total Traffic Volumes During Detour (Existing +K+L+M)
Hour 11	**2970**	1,068	128	*1,774*	320	105	425	*2,199*	60	**2,154**	**2,259**
Hour 12	**3337**	1,414	169	*1,754*	383	130	513	*2,267*	93	**2,230**	**2,360**
Hour 13	**3301**	1,233	132	*1,936*	387	141	528	*2,464*	76	**2,399**	**2,540**
Hour 14	**3963**	1,673	137	*2,153*	445	162	607	*2,760*	79	**2,677**	**2,839**

Northbound — Exit 54 (Milford Pkwy / I-95&US-1 Connector)

	NB ML: Regional Detour Redistributed Traffic Volumes	NB ML: Existing	NB Off: Existing	NB Off: Redistributed Traffic Volumes (A) (25% to shift to exit 54)	NB Off: Total Traffic Volumes During Detour (Existing + A)	NB ML: Existing Cars Continuing NB on Rte 15	NB ML: Redistributed Traffic Volumes (A) (25% to shift to exit 54)	NB ML: Total Traffic Volumes During Detour (Existing - A)	NB On: Existing	NB On: Redistributed Traffic Volumes (T) (25% of NB on-ramp)	NB On: Total Traffic Volumes During Detour (Existing - T)	NB ML: Existing	NB ML: Total Traffic Volumes During Detour (Existing - A - T)
Hour 11	141	**3,264**	1,562	391	1,988	1,702	426	1,277	562	141	422	2,264	**1,698**
Hour 12	141	**3,310**	1,761	440	2,148	1,549	387	1,162	563	141	422	2,112	**1,584**
Hour 13	136	**3,493**	1,855	464	2,265	1,638	410	1,229	545	136	409	2,183	**1,637**
Hour 14	181	**3,901**	2,021	505	2,491	1,880	470	1,410	722	181	542	2,602	**1,952**

Northbound — Exit 55 (Wheelers Farms Rd/ Wolf Harbor Rd)

	NB Off: Existing		NB Off: Existing		NB On: Existing	NB On: Redistributed Traffic Volumes (45% will not enter)	NB On: N Redistributed Traffic Volumes (25% regional detour)	NB On: Total Traffic Volumes During Detour (Existing-45%-25%)	NB ML: Existing	NB ML: Total Traffic Volumes During Detour (Existing - A - T - G)
Hour 11	207	1,491	25	1,466	76	34	19	23	2,108	**1,489**
Hour 12	207	1,377	36	1,341	94	42	24	28	1,963	**1,369**
Hour 13	189	1,448	32	1,416	87	39	22	26	2,049	**1,442**
Hour 14	236	1,716	62	1,654	113	51	28	34	2,417	**1,687**

Note: Vehicles redistributed based on the following guidelines:

Vehicles travelling NB along Route 15 south of Exit 54 and from the Milford Parkway

	Exit Prior to Tunnel	Exit North of Tunnel and Prior to I-91	Reach I-91
	(No Detour Required)	(Local Detour)	(Regional Detour)
Percent of Traffic	*45%*	*30%*	*25%*

Vehicles entering Route 15 NB from Exits 55-58

	Use Other Local Roads	Exit North of Tunnel and Prior to I-91	Reach I-91
	(Will not Enter Route 15)	(Local Detour)	(Regional Detour)
Percent of Traffic	*45%*	*30%*	*25%*

Vehicles entering Route 15 NB from Exit 59 will follow the local detour. Vehicles entering Route 15 NB from Exits 60-67 will not be required to follow a detour.

2019 Route 15 Detour Condition Profile
Saturday Midday Peak Period

Rt 121 - Grassy Hill Rd.
Exit 56

	SB On: Existing	SB On: Redistributed Traffic Volumes (M)	SB On: Total Traffic Volumes During Detour (Existing + M)	SB Off	SB Off	SB ML: Existing	SB ML: Total Traffic Volumes During Detour (Existing +K+L)
Hour 11	112	25	137	*2,123*	137	**2,179**	**2,260**
Hour 12	145	37	182	*2,178*	135	**2,220**	**2,313**
Hour 13	164	34	198	*2,342*	136	**2,371**	**2,478**
Hour 14	219	44	263	*2,576*	132	**2,590**	**2,708**

	SB On: Existing	SB On: Redistributed Traffic Volumes	SB On: Total Traffic Volumes During Detour		SB Off		SB On: Existing	SB On: Redistributed Traffic Volumes (K)	SB On: Total Traffic Volumes During Detour (Existing + K)	SB Off	SB ML
Hour 11	72	56	128	**2,132**	245	2,377	151	25	176	205	**2,406**
Hour 12	49	68	117	**2,196**	211	2,407	147	25	172	255	**2,490**
Hour 13	71	69	140	**2,338**	215	2,553	219	38	257	236	**2,532**
Hour 14	80	75	155	**2,553**	215	2,768	298	43	341	358	**2,785**

	NB Off: Existing		NB On: Existing	NB On: Redistributed Traffic Volumes (45% will not enter)	NB On: M Redistributed Traffic Volumes (25% regional detour)	NB On: Total Traffic Volumes During Detour (Existing-45%-25%))	NB ML: Existing	NB ML: Total Traffic Volumes During Detour (Existing - A - T - G - H)
Hour 11	128	1,361	99	45	25	30	**2,079**	**1,391**
Hour 12	137	1,232	149	67	37	45	**1,975**	**1,277**
Hour 13	145	1,297	136	61	34	41	**2,040**	**1,338**
Hour 14	198	1,489	176	79	44	53	**2,395**	**1,542**

	NB Off		NB On: Existing	NB On: Redistributed Traffic Volumes (45% will not enter)	NB On: L Redistributed Traffic Volumes (25% regional detour)	NB On: Total Traffic Volumes During Detour (Existing-45%-25%))		NB Off: Existing		NB On: Existing	NB On: Redistributed Traffic Volumes (45% will not enter)	NB On: K Redistributed Traffic Volumes (25% regional detour)	NB On: Total Traffic Volumes During Detour (Existing-45%-25%))	NB ML: Existing	NB ML: Total Traffic Volumes During Detour (Existing - A - T - G - H - I - J)
Hour 11	168	1,223	224	101	56	67	1,290	54	1,236	98	44	25	29	**2,179**	**1,265**
Hour 12	153	1,124	270	122	68	81	1,205	48	1,157	100	45	25	30	**2,144**	**1,187**
Hour 13	141	1,197	277	125	69	83	1,280	65	1,215	150	68	38	45	**2,261**	**1,260**
Hour 14	222	1,320	300	135	75	90	1,410	70	1,340	172	77	43	52	**2,575**	**1,392**

Rt 121 - Grassy Hill Rd.
Exit 56

2019 Route 15 Detour Condition Profile
Saturday Midday Peak Period

CDM Smith

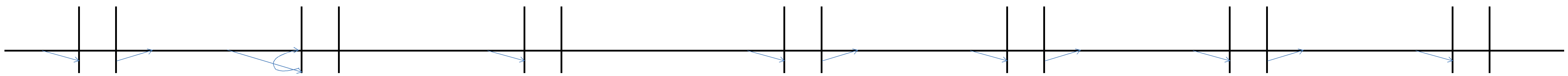
	Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59				Heroes Tunnel	Rt 10 - Dixwell Ave. Exit 60		
	SB On	SB On	SB Off	SB ML		SB On	SB Off	SB ML
Hour 11	205	186	533	**2,548**		631	367	**2,284**
Hour 12	158	267	634	**2,699**		695	384	**2,388**
Hour 13	205	247	554	**2,634**		702	383	**2,315**
Hour 14	224	273	648	**2,936**		831	365	**2,470**

	NB Off				NB On		NB ML		NB Off	NB On			NB ML	NB Off	NB On	NB ML
	Total Traffic Volumes During Detour	Existing	Total Traffic Volumes During Detour		Existing	Total Traffic Volumes During Detour	Existing	Total Traffic Volumes During Detour		Existing	Redistributed Traffic Volumes From Local Detour	Total Traffic Volumes During Detour				
Hour 11	1,265	301	964	1,521	557	0	2,435	0	537	408	1,521	1,929	**1,392**	311	199	**1,280**
Hour 12	1,187	294	893	1,591	698	0	2,548	0	561	462	1,591	2,053	**1,492**	327	161	**1,326**
Hour 13	1,260	285	975	1,703	728	0	2,704	0	634	459	1,703	2,162	**1,528**	338	240	**1,430**
Hour 14	1,392	400	992	1,738	746	0	2,921	0	734	657	1,738	2,395	**1,661**	338	290	**1,613**

Rt.69- Litchfield Tpke/ Rt63-Amity Rd Exit 59 | Rt 10 - Dixwell Ave. Exit 60 | Whitney Ave. Exit 61

2019 Route 15 Detour Condition Profile
Saturday Midday Peak Period

Hour 11
Hour 12
Hour 13
Hour 14



	Dixwell Ave. Exit 62			Route 22 Exit 63			Quinnipiac St. Exit 64			River Rd. Exit 65			Route 5 Exit 66			CTDOT Garage & Miller Avenue			East Main St. Exit 67		
	NB Off	*NB On*	**NB ML**	*NB Off*	*NB On*	**NB ML**	*NB Off*		**NB ML**	*NB Off*	*NB On*	**NB ML**	*NB Off*	*NB On*	**NB ML**	*NB Off*	*NB On*	**NB ML**	*NB Off*		**NB ML**
Hour 11	248	128	**1,160**	369	133	**924**	201		**723**	150	363	**936**	337	462	**1,061**	88	129	**1,102**	186		**916**
Hour 12	255	128	**1,199**	414	145	**930**	190		**740**	137	401	**1,004**	321	599	**1,282**	161	128	**1,249**	255		**994**
Hour 13	298	136	**1,268**	438	121	**951**	228		**723**	135	359	**947**	384	636	**1,199**	146	137	**1,190**	229		**961**
Hour 14	335	135	**1,413**	503	157	**1,067**	284		**783**	198	471	**1,056**	388	654	**1,322**	165	153	**1,310**	231		**1,079**

Local Intersection Network Profile Development

		SB					WB					NB					EB/SEB				
		Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left
1 Route 15 NB off ramp at Route 69	Existing Peak Hour			629										527				466		311	
2 Route 69 at Pond Lily Avenue				576	275			108		50			404	503			0	0	0	0	0
3 Whalley Avenue at Route 63		33	5	725	55		44	36	11	68			7	419	400	5	13	418		44	1
4 Route 10 (Fitch St) at Route 63 (Whalley Ave)			171	1	107			61	604	13			3	1	2			4	712	240	
6 Route 10 (Dixwell Ave) at Arch St			294	369	121			8	3	7			31	485	58			38	110	306	
7 Route 10 (Dixwell Ave) at Putnam Ave		1	55	644	224		202	224	80	120			85	704	85	85	11	12		65	132
8 Route 15 NB ramps at Route 10 (Dixwell Ave)				1271	106								376	1241				145		344	

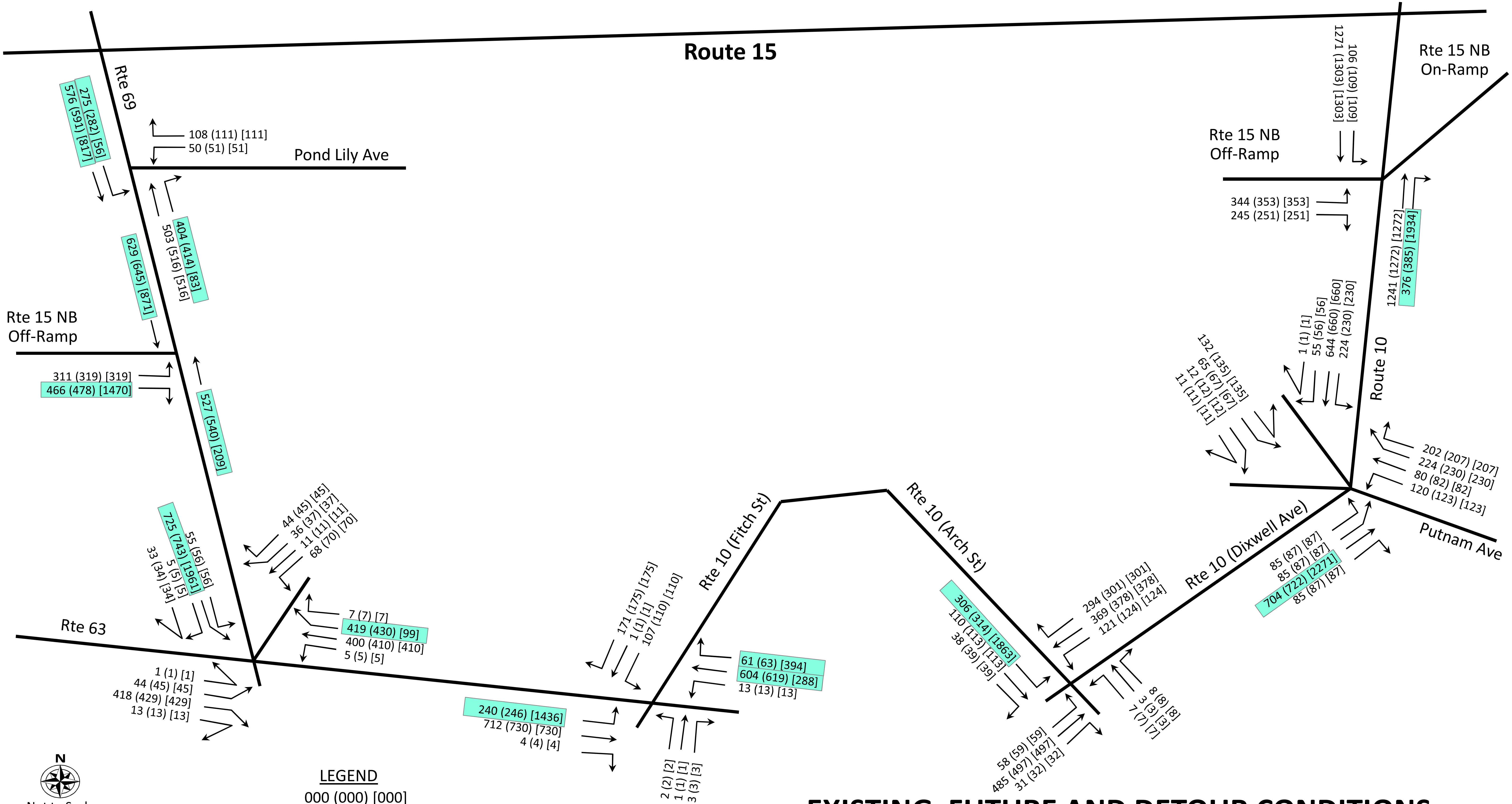
		SB					WB					NB					EB/SEB				
		Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left
1 Route 15 NB off ramp at Route 69	2019 Peak Hour	0	0	645	0	0	0	0	0	0	0	0	0	540	0	0	0	478	0	319	0
2 Route 69 at Pond Lily Avenue		0	0	591	282	0	0	111	0	51	0	0	414	516	0	0	0	0	0	0	0
3 Whalley Avenue at Route 63		34	5	743	56	0	45	37	11	70	0	0	7	430	410	5	13	429	0	45	1
4 Route 10 (Fitch St) at Route 63 (Whalley Ave)		0	175	1	110	0	0	63	619	13	0	0	3	1	2	0	0	4	730	246	0
6 Route 10 (Dixwell Ave) at Arch St		0	301	378	124	0	0	8	3	7	0	0	32	497	59	0	0	39	113	314	0
7 Route 10 (Dixwell Ave) at Putnam Ave		1	56	660	230	0	207	230	82	123	0	0	87	722	87	87	11	12	0	67	135
8 Route 15 NB ramps at Route 10 (Dixwell Ave)		0	0	1303	109	0	0	0	0	0	0	0	385	1272	0	0	0	149	0	353	0

Rte 15 NB Local Detour Volumes	Rte 69 SB RT shift	Rte 69 NB RT shift	Rte 69 SB RT shift - remainder	Rte 69 NB RT shift - remainder	Exit 59 NB On-ramp
992	226	331	56	83	557

		SB					WB					NB					EB/SEB				
		Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left	Hard Right	Right	Thru	Left	Hard Left
1 Route 15 NB off ramp at Route 69	2019 Detour Peak Hour	0	0	871	0	0	0	0	0	0	0	0	0	209	0	0	0	1470	0	319	0
2 Route 69 at Pond Lily Avenue		0	0	817	56	0	0	111	0	51	0	0	83	516	0	0	0	0	0	0	0
3 Whalley Avenue at Route 63		34	5	1961	56	0	45	37	11	70	0	0	7	99	410	5	13	429	0	45	1
4 Route 10 (Fitch St) at Route 63 (Whalley Ave)		0	175	1	110	0	0	394	288	13	0	0	3	1	2	0	0	4	730	1464	0
6 Route 10 (Dixwell Ave) at Arch St		0	301	378	124	0	0	8	3	7	0	0	32	497	59	0	0	39	113	1863	0
7 Route 10 (Dixwell Ave) at Putnam Ave		1	56	660	230	0	207	230	82	123	0	0	87	2271	87	87	11	12	0	67	135
8 Route 15 NB ramps at Route 10 (Dixwell Ave)		0	0	1303	109	0	0	0	0	0	0	0	1934	1272	0	0	0	149	0	353	0

1.025251253 = Growth Rate

Assume 0.5 % per year for 5 years (2014-2019)



LEGEND

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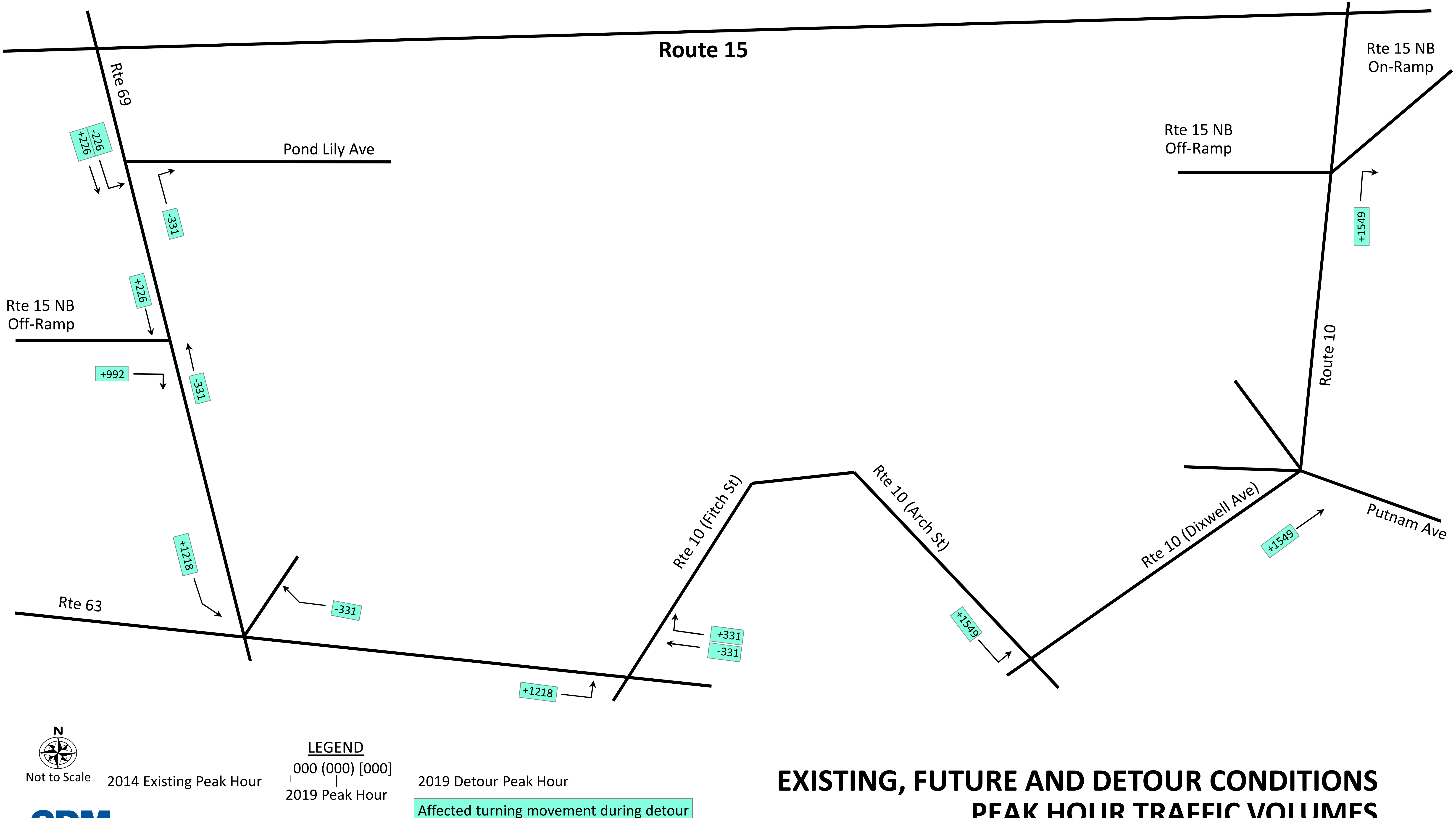
2014 Existing Peak Hour — 2019 Peak Hour — 2019 Detour Peak Hour

Affected turning movement during detour

EXISTING, FUTURE AND DETOUR CONDITIONS PEAK HOUR TRAFFIC VOLUMES

CDM Smith



EXISTING, FUTURE AND DETOUR CONDITIONS
PEAK HOUR TRAFFIC VOLUMES

CDM Smith

B4a. Traffic Analysis

2019 future conditions - weekday off-peak.npe

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\2019 future conditions - during construction\2019 future conditions - weekday off-peak.inp
Comment:
Date: Monday, April 14, 2014 5:04:04 PM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Average delay time per vehicle [s], All Vehicle Types	14.904;
Average number of stops per vehicles, All Vehicle Types	0.229;
Average speed [mph], All Vehicle Types	63.331;
Average stopped delay per vehicle [s], All Vehicle Types	0.829;
Total delay time [h], All Vehicle Types	51.768;
Total Distance Traveled [mi], All Vehicle Types	65949.739;
Number of Stops, All Vehicle Types	2867;
Number of vehicles in the network, All Vehicle Types	164;
Number of vehicles that have left the network, All Vehicle Types	12340;
Total stopped delay [h], All Vehicle Types	2.879;
Total travel time [h], All Vehicle Types	1041.349;

2019 future conditions - during construction - saturday peak.npe

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\2019 future conditions - during construction\2019 future conditions - during construction - saturday peak.inp
Comment:
Date: Tuesday, April 29, 2014 11:26:59 AM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Total Distance Traveled [mi], All Vehicle Types	312304.708;
Average delay time per vehicle [s], All Vehicle Types	121.312;
Average number of stops per vehicles, All Vehicle Types	3.535;
Average speed [mph], All Vehicle Types	42.704;
Average stopped delay per vehicle [s], All Vehicle Types	13.543;
Total delay time [h], All Vehicle Types	2623.607;
Number of Stops, All Vehicle Types	275233;
Number of vehicles in the network, All Vehicle Types	2362;
Number of vehicles that have left the network, All Vehicle Types	75495;
Total stopped delay [h], All Vehicle Types	292.902;
Total travel time [h], All Vehicle Types	7313.254;

Lane Group	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Lane Configurations												
Volume (vph)	0	70	11	37	45	56	1961	5	34	1	45	429
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	14	11	10	10	10	10	16	12	13	10	12	10
Storage Length (ft)		0		10			100	0			160	
Storage Lanes		1		0			2	0			1	
Taper Length (ft)		25					25				25	
Right Turn on Red					Yes				Yes			
Link Speed (mph)	30		30				30					30
Link Distance (ft)	309		175				1238					566
Travel Time (s)	7.0		4.0				28.1					12.9
Confl. Peds. (#/hr)		1		5	3	1	7	3	1	7	5	
Peak Hour Factor	0.92	0.77	0.55	0.69	0.65	0.72	0.95	0.62	0.75	0.25	0.73	0.87
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	91	143	0	0	78	2117	0	0	0	66	517
Turn Type		Perm	NA			Perm	NA			Split	Split	NA
Protected Phases	5		5				3			1	1	1
Permitted Phases		5				3						2
Detector Phase	5	5	5			3	3			1	1	1
Switch Phase												
Minimum Initial (s)	5.0	5.0	5.0			9.0	9.0			5.0	5.0	5.0
Minimum Split (s)	10.0	10.0	10.0			14.0	14.0			10.0	10.0	10.0
Total Split (s)	12.0	12.0	12.0			16.0	16.0			10.0	10.0	10.0
Total Split (%)	14.1%	14.1%	14.1%			18.8%	18.8%			11.8%	11.8%	11.8%
Yellow Time (s)	3.0	3.0	3.0			3.0	3.0			3.0	3.0	3.0
All-Red Time (s)	2.0	2.0	2.0			2.0	2.0			2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0			0.0	0.0				0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0			5.0	5.0				5.0	5.0
Lead/Lag						Lead	Lead			Lead	Lead	Lead
Lead-Lag Optimize?						Yes	Yes					
Recall Mode	None	None	None			None	None			None	None	None
v/c Ratio		0.64	0.76			0.40	2.68				0.50	0.83
Control Delay		52.7	49.5			33.8	775.0				46.1	33.5
Queue Delay		0.0	0.0			0.0	0.0				0.0	0.0
Total Delay		52.7	49.5			33.8	775.0				46.1	33.5
Queue Length 50th (ft)		30	33			23	~634				22	143
Queue Length 95th (ft)		#110	#59			67	#1160				#72	#496
Internal Link Dist (ft)	229		95				1158					486
Turn Bay Length (ft)						100	100				160	
Base Capacity (vph)		143	188			193	791				133	624
Starvation Cap Reductn		0	0			0	0				0	0
Spillback Cap Reductn		0	0			0	0				0	0
Storage Cap Reductn		0	0			0	0				0	0
Reduced v/c Ratio		0.64	0.76			0.40	2.68				0.50	0.83

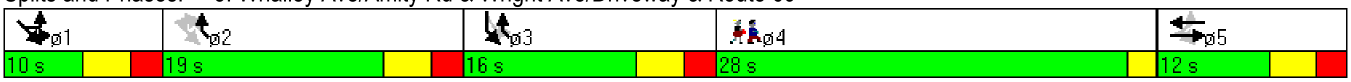
Intersection Summary	
Area Type:	CBD
Cycle Length: 85	
Actuated Cycle Length: 62.6	

Lane Group	SER	NWL	NWT	NWR	NWR2	ø4
Lane Configurations						
Volume (vph)	13	5	410	99	7	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	
Lane Width (ft)	12	12	12	12	13	
Storage Length (ft)	0	0		0		
Storage Lanes	0	0		1		
Taper Length (ft)		25				
Right Turn on Red	Yes				Yes	
Link Speed (mph)			30			
Link Distance (ft)			442			
Travel Time (s)			10.0			
Confl. Peds. (#/hr)	1	1		7	5	
Peak Hour Factor	0.55	0.63	0.93	0.85	0.88	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	0	0	449	124	0	
Turn Type		custom	NA	custom		
Protected Phases				2 3		4
Permitted Phases		2	2			
Detector Phase		2	2	2 3		
Switch Phase						
Minimum Initial (s)		15.0	15.0			1.0
Minimum Split (s)		20.0	20.0			28.0
Total Split (s)		19.0	19.0			28.0
Total Split (%)		22.4%	22.4%			33%
Yellow Time (s)		3.0	3.0			2.0
All-Red Time (s)		2.0	2.0			0.0
Lost Time Adjust (s)			0.0			
Total Lost Time (s)			5.0			
Lead/Lag		Lag	Lag			Lag
Lead-Lag Optimize?		Yes	Yes			Yes
Recall Mode		Min	Min			None
v/c Ratio			1.16	0.16		
Control Delay			124.6	4.4		
Queue Delay			0.0	0.0		
Total Delay			124.6	4.4		
Queue Length 50th (ft)			~178	1		
Queue Length 95th (ft)			#528	33		
Internal Link Dist (ft)			362			
Turn Bay Length (ft)						
Base Capacity (vph)			387	774		
Starvation Cap Reductn			0	0		
Spillback Cap Reductn			0	0		
Storage Cap Reductn			0	0		
Reduced v/c Ratio			1.16	0.16		

Intersection Summary

Natural Cycle: 95
Control Type: Actuated-Uncoordinated
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 3: Whalley Ave/Amity Rd & Wright Ave/Driveway & Route 69



Movement	EBT	WBL	WBT	WBR	WBR2	SBL2	SBL	SBR	SBR2	SEL2	SEL	SET
Lane Configurations												
Volume (vph)	0	70	11	37	45	56	1961	5	34	1	45	429
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	14	11	10	10	10	10	16	12	13	10	12	10
Total Lost time (s)		5.0	5.0			5.0	5.0				5.0	5.0
Lane Util. Factor		1.00	1.00			1.00	0.97				1.00	1.00
Frpb, ped/bikes		1.00	0.95			1.00	1.00				1.00	1.00
Flpb, ped/bikes		1.00	1.00			1.00	1.00				1.00	1.00
Frt		1.00	0.87			1.00	1.00				1.00	0.99
Flt Protected		0.95	1.00			0.95	0.95				0.95	1.00
Satd. Flow (prot)		1566	1325			1513	3569				1624	1583
Flt Permitted		0.76	1.00			0.68	0.95				0.95	1.00
Satd. Flow (perm)		1248	1325			1079	3569				1624	1583
Peak-hour factor, PHF	0.92	0.77	0.55	0.69	0.65	0.72	0.95	0.62	0.75	0.25	0.73	0.87
Adj. Flow (vph)	0	91	20	54	69	78	2064	8	45	4	62	493
RTOR Reduction (vph)	0	0	38	0	0	0	148	0	0	0	0	2
Lane Group Flow (vph)	0	91	105	0	0	78	1969	0	0	0	66	515
Confl. Peds. (#/hr)		1		5	3	1	7	3	1	7	5	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		Perm	NA			Perm	NA			Split	Split	NA
Protected Phases	5		5				3			1	1	1
Permitted Phases		5				3						2
Actuated Green, G (s)		7.2	7.2			11.3	11.3				5.1	19.5
Effective Green, g (s)		7.2	7.2			11.3	11.3				5.1	19.5
Actuated g/C Ratio		0.11	0.11			0.18	0.18				0.08	0.31
Clearance Time (s)		5.0	5.0			5.0	5.0				5.0	5.0
Vehicle Extension (s)		2.0	2.0			2.0	2.0				2.0	2.0
Lane Grp Cap (vph)		140	149			191	632				129	607
v/s Ratio Prot			c0.08				c0.55				0.04	c0.07
v/s Ratio Perm		0.07				0.07						0.26
v/c Ratio		0.65	0.70			0.41	3.12				0.51	0.85
Uniform Delay, d1		27.1	27.3			23.3	26.2				28.2	20.8
Progression Factor		1.00	1.00			1.00	1.00				1.00	1.00
Incremental Delay, d2		8.0	11.6			0.5	956.1				1.4	10.3
Delay (s)		35.0	38.9			23.8	982.3				29.6	31.0
Level of Service		D	D			C	F				C	C
Approach Delay (s)	0.0		37.4				948.3					30.9
Approach LOS	A		D				F					C

Intersection Summary			
HCM 2000 Control Delay	604.7	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.52		
Actuated Cycle Length (s)	63.8	Sum of lost time (s)	22.0
Intersection Capacity Utilization	125.2%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

Movement	SER	NWL	NWT	NWR	NWR2
Lane Configurations					
Volume (vph)	13	5	410	99	7
Ideal Flow (vphpl)	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	13
Total Lost time (s)			5.0	5.0	
Lane Util. Factor			1.00	1.00	
Frpb, ped/bikes			1.00	1.00	
Flpb, ped/bikes			1.00	1.00	
Frt			1.00	0.85	
Flt Protected			1.00	1.00	
Satd. Flow (prot)			1708	1454	
Flt Permitted			0.99	1.00	
Satd. Flow (perm)			1687	1454	
Peak-hour factor, PHF	0.55	0.63	0.93	0.85	0.88
Adj. Flow (vph)	24	8	441	116	8
RTOR Reduction (vph)	0	0	0	60	0
Lane Group Flow (vph)	0	0	449	64	0
Confl. Peds. (#/hr)	1	1		7	5
Heavy Vehicles (%)	0%	0%	0%	0%	0%
Turn Type		custom	NA	custom	
Protected Phases				2 3	
Permitted Phases		2	2		
Actuated Green, G (s)			14.4	30.7	
Effective Green, g (s)			14.4	30.7	
Actuated g/C Ratio			0.23	0.48	
Clearance Time (s)			5.0		
Vehicle Extension (s)			2.0		
Lane Grp Cap (vph)			380	699	
v/s Ratio Prot				0.04	
v/s Ratio Perm			c0.27		
v/c Ratio			1.18	0.09	
Uniform Delay, d1			24.7	9.0	
Progression Factor			1.00	1.00	
Incremental Delay, d2			105.6	0.0	
Delay (s)			130.3	9.0	
Level of Service			F	A	
Approach Delay (s)			104.0		
Approach LOS			F		

Intersection Summary

Lane Group	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (vph)	319	1470	0	209	871	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	16	12	12	16	16	12
Link Speed (mph)	30			30	30	
Link Distance (ft)	321			1238	178	
Travel Time (s)	7.3			28.1	4.0	
Confl. Peds. (#/hr)	2					
Peak Hour Factor	0.87	0.94	0.85	0.85	0.90	0.90
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%
Shared Lane Traffic (%)						
Lane Group Flow (vph)	1931	0	0	246	968	0
Sign Control	Stop			Free	Free	

Intersection Summary	
Area Type:	Other
Control Type: Unsignalized	

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Volume (veh/h)	319	1470	0	209	871	0
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Peak Hour Factor	0.87	0.94	0.85	0.85	0.90	0.90
Hourly flow rate (vph)	367	1564	0	246	968	0
Pedestrians					2	
Lane Width (ft)					16.0	
Walking Speed (ft/s)					4.0	
Percent Blockage					0	
Right turn flare (veh)						
Median type				Raised	Raised	
Median storage veh)				1	1	
Upstream signal (ft)				1238	313	
pX, platoon unblocked	0.65	0.65	0.65			
vC, conflicting volume	1216	968	968			
vC1, stage 1 conf vol	968					
vC2, stage 2 conf vol	248					
vCu, unblocked vol	1063	682	682			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)	5.4					
tF (s)	3.5	3.3	2.2			
p0 queue free %	0	0	100			
cM capacity (veh/h)	269	295	599			

Direction, Lane #	EB 1	NB 1	SB 1
Volume Total	1930	246	968
Volume Left	367	0	0
Volume Right	1564	0	0
cSH	290	1700	1700
Volume to Capacity	6.67	0.14	0.57
Queue Length 95th (ft)	Err	0	0
Control Delay (s)	Err	0.0	0.0
Lane LOS	F		
Approach Delay (s)	Err	0.0	0.0
Approach LOS	F		

Intersection Summary			
Average Delay	6139.3		
Intersection Capacity Utilization	160.9%	ICU Level of Service	H
Analysis Period (min)	15		

Lane Group	WBL	WBR	NBT	NBR	SBL	SBT	ø3
Lane Configurations							
Volume (vph)	51	111	516	83	56	817	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	
Lane Width (ft)	11	11	10	10	10	11	
Right Turn on Red		Yes		Yes			
Link Speed (mph)	30		30			30	
Link Distance (ft)	415		135			335	
Travel Time (s)	9.4		3.1			7.6	
Confl. Peds. (#/hr)	7	1		11	11		
Peak Hour Factor	0.69	0.90	0.87	0.83	0.82	0.87	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	
Shared Lane Traffic (%)							
Lane Group Flow (vph)	197	0	693	0	68	939	
Turn Type	NA		NA		custom	NA	
Protected Phases	5		2		6	2 3 6	3
Permitted Phases					2 3		
Detector Phase	5		2		6	2 3 6	
Switch Phase							
Minimum Initial (s)	6.0		25.0		9.0		5.0
Minimum Split (s)	15.2		30.0		15.3		9.8
Total Split (s)	29.2		32.0		23.3		9.8
Total Split (%)	31.0%		33.9%		24.7%		10%
Yellow Time (s)	3.0		3.5		3.3		3.5
All-Red Time (s)	1.2		1.5		1.0		1.3
Lost Time Adjust (s)	0.0		0.0		0.0		
Total Lost Time (s)	4.2		5.0		4.3		
Lead/Lag	Lead				Lag		
Lead-Lag Optimize?	Yes				Yes		
Recall Mode	None		Min		None		None
v/c Ratio	0.64		0.61		0.11	0.67	
Control Delay	22.5		24.2		3.2	8.3	
Queue Delay	0.0		0.0		0.0	0.0	
Total Delay	22.5		24.2		3.2	8.3	
Queue Length 50th (ft)	32		140		6	162	
Queue Length 95th (ft)	53		210		17	354	
Internal Link Dist (ft)	335		55			255	
Turn Bay Length (ft)							
Base Capacity (vph)	612		1149		654	1366	
Starvation Cap Reductn	0		0		0	0	
Spillback Cap Reductn	0		0		0	0	
Storage Cap Reductn	0		0		0	0	
Reduced v/c Ratio	0.32		0.60		0.10	0.69	

Intersection Summary	
Area Type:	Other
Cycle Length: 94.3	
Actuated Cycle Length: 78.1	
Natural Cycle: 75	
Control Type: Semi Act-Uncoord	

Splits and Phases: 5: Whalley Ave & Pond Lily Ave

Movement	WBL	WBR	NBT	NBR	SBL	SBT
Lane Configurations						
Volume (vph)	51	111	516	83	56	817
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width	11	11	10	10	10	11
Total Lost time (s)	4.2		5.0		4.3	5.0
Lane Util. Factor	1.00		0.95		1.00	1.00
Frpb, ped/bikes	0.99		0.99		1.00	1.00
Flpb, ped/bikes	1.00		1.00		1.00	1.00
Frt	0.92		0.98		1.00	1.00
Flt Protected	0.98		1.00		0.95	1.00
Satd. Flow (prot)	1636		3279		1681	1837
Flt Permitted	0.98		1.00		0.29	1.00
Satd. Flow (perm)	1636		3279		512	1837
Peak-hour factor, PHF	0.69	0.90	0.87	0.83	0.82	0.87
Adj. Flow (vph)	74	123	593	100	68	939
RTOR Reduction (vph)	112	0	13	0	0	0
Lane Group Flow (vph)	85	0	680	0	68	939
Confl. Peds. (#/hr)	7	1		11	11	
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%
Turn Type	NA		NA		custom	NA
Protected Phases	5		2		6	2 3 6
Permitted Phases					2 3	
Actuated Green, G (s)	9.5		26.7		55.3	59.6
Effective Green, g (s)	9.5		26.7		50.3	55.3
Actuated g/C Ratio	0.12		0.34		0.64	0.71
Clearance Time (s)	4.2		5.0		4.3	
Vehicle Extension (s)	3.0		3.5		3.0	
Lane Grp Cap (vph)	199		1120		608	1300
v/s Ratio Prot	c0.05		0.21		0.03	c0.51
v/s Ratio Perm					0.05	
v/c Ratio	0.42		0.61		0.11	0.72
Uniform Delay, d1	31.8		21.3		5.6	6.8
Progression Factor	1.00		1.00		1.00	1.00
Incremental Delay, d2	1.5		1.0		0.1	2.1
Delay (s)	33.2		22.3		5.7	8.9
Level of Service	C		C		A	A
Approach Delay (s)	33.2		22.3			8.7
Approach LOS	C		C			A

Intersection Summary			
HCM 2000 Control Delay	16.2	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.74		
Actuated Cycle Length (s)	78.1	Sum of lost time (s)	18.3
Intersection Capacity Utilization	60.4%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	NBL2	NBL	NBT	NBR	SBL	SBT	SBR	SBR2	SEL	SET	SER	SER2
Lane Configurations												
Volume (vph)	87	87	2271	87	230	660	56	1	135	67	12	11
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	11	13	12	14	12	12	10	11	11
Storage Length (ft)		0		0	84		0		0		0	
Storage Lanes		1		1	1		0		0		0	
Taper Length (ft)		25			25				25			
Right Turn on Red				Yes				Yes				Yes
Link Speed (mph)			30			30				30		
Link Distance (ft)			334			671				589		
Travel Time (s)			7.6			15.3				13.4		
Peak Hour Factor	0.92	0.89	0.91	0.69	0.92	0.91	0.69	0.25	0.69	0.75	0.90	0.77
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	193	2496	126	250	810	0	0	0	312	0	0
Turn Type	Prot	Prot	NA	custom	Prot	NA			Split	NA		
Protected Phases	1	1	6	6	5	2			4	4		
Permitted Phases				7								
Detector Phase	1	1	6	6	5	2			4	4		
Switch Phase												
Minimum Initial (s)	2.0	2.0	10.0	10.0	5.0	10.0			5.0	5.0		
Minimum Split (s)	9.0	9.0	20.0	20.0	11.0	20.0			28.0	28.0		
Total Split (s)	11.0	11.0	22.0	22.0	13.0	24.0			28.0	28.0		
Total Split (%)	12.9%	12.9%	25.9%	25.9%	15.3%	28.2%			32.9%	32.9%		
Yellow Time (s)	3.0	3.0	3.0	3.0	3.0	3.0			3.0	3.0		
All-Red Time (s)	3.0	3.0	3.0	3.0	3.0	3.0			3.0	3.0		
Lost Time Adjust (s)		0.0	0.0	0.0	0.0	0.0				0.0		
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Lead/Lag	Lead	Lead	Lag	Lag	Lead	Lag						
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes						
Recall Mode	None	None	Min	Min	None	Min			None	None		
v/c Ratio		1.69	3.41	0.18	1.52	1.00				0.48		
Control Delay		373.5	1103.8	3.1	289.7	65.2				29.4		
Queue Delay		0.0	0.0	0.0	0.0	0.0				0.0		
Total Delay		373.5	1103.8	3.1	289.7	65.2				29.4		
Queue Length 50th (ft)		~158	~1279	2	~196	~260				71		
Queue Length 95th (ft)		#283	#1416	11	#339	#377				87		
Internal Link Dist (ft)			254			591				509		
Turn Bay Length (ft)					84							
Base Capacity (vph)		114	732	691	165	811				903		
Starvation Cap Reductn		0	0	0	0	0				0		
Spillback Cap Reductn		0	0	0	0	0				0		
Storage Cap Reductn		0	0	0	0	0				0		
Reduced v/c Ratio		1.69	3.41	0.18	1.52	1.00				0.35		

Intersection Summary	
Area Type:	Other
Cycle Length: 85	
Actuated Cycle Length: 78.9	
Natural Cycle: 95	

Lane Group	NWL2	NWT	NWR
Lane Configurations			
Volume (vph)	123	312	207
Ideal Flow (vphpl)	1900	1900	1900
Lane Width (ft)	14	12	14
Storage Length (ft)			0
Storage Lanes			1
Taper Length (ft)			
Right Turn on Red			Yes
Link Speed (mph)		30	
Link Distance (ft)		251	
Travel Time (s)		5.7	
Peak Hour Factor	0.77	0.92	0.89
Heavy Vehicles (%)	0%	0%	0%
Shared Lane Traffic (%)			
Lane Group Flow (vph)	160	339	233
Turn Type	Split	NA	Prot
Protected Phases	7	7	7
Permitted Phases			
Detector Phase	7	7	7
Switch Phase			
Minimum Initial (s)	10.0	10.0	10.0
Minimum Split (s)	22.0	22.0	22.0
Total Split (s)	22.0	22.0	22.0
Total Split (%)	25.9%	25.9%	25.9%
Yellow Time (s)	3.0	3.0	3.0
All-Red Time (s)	3.0	3.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	6.0
Lead/Lag			
Lead-Lag Optimize?			
Recall Mode	None	None	None
v/c Ratio	0.42	0.90	0.44
Control Delay	33.2	62.2	7.4
Queue Delay	0.0	0.0	0.0
Total Delay	33.2	62.2	7.4
Queue Length 50th (ft)	76	180	0
Queue Length 95th (ft)	113	#341	56
Internal Link Dist (ft)		171	
Turn Bay Length (ft)			
Base Capacity (vph)	394	389	538
Starvation Cap Reductn	0	0	0
Spillback Cap Reductn	0	0	0
Storage Cap Reductn	0	0	0
Reduced v/c Ratio	0.41	0.87	0.43

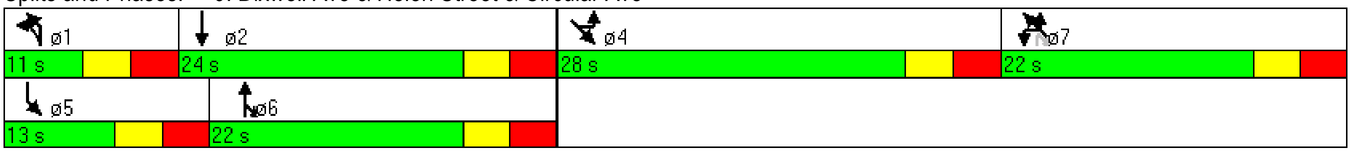
Intersection Summary

Control Type: Semi Act-Uncoord

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 9: Dixwell Ave & Helen Street & Circular Ave



Movement	NBL2	NBL	NBT	NBR	SBL	SBT	SBR	SBR2	SEL	SET	SER	SER2
Lane Configurations												
Volume (vph)	87	87	2271	87	230	660	56	1	135	67	12	11
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	11	13	12	14	12	12	10	11	11
Total Lost time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Lane Util. Factor		1.00	0.95	1.00	1.00	0.95				0.95		
Frt		1.00	1.00	0.85	1.00	0.98				0.99		
Flt Protected		0.95	1.00	1.00	0.95	1.00				0.97		
Satd. Flow (prot)		1787	3574	1546	1847	3518				3192		
Flt Permitted		0.95	1.00	1.00	0.95	1.00				0.97		
Satd. Flow (perm)		1787	3574	1546	1847	3518				3192		
Peak-hour factor, PHF	0.92	0.89	0.91	0.69	0.92	0.91	0.69	0.25	0.69	0.75	0.90	0.77
Adj. Flow (vph)	95	98	2496	126	250	725	81	4	196	89	13	14
RTOR Reduction (vph)	0	0	0	69	0	1	0	0	0	4	0	0
Lane Group Flow (vph)	0	193	2496	57	250	809	0	0	0	308	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
Turn Type	Prot	Prot	NA	custom	Prot	NA			Split	NA		
Protected Phases	1	1	6	6	5	2			4	4		
Permitted Phases				7								
Actuated Green, G (s)		5.0	16.2	31.8	7.1	18.3				15.8		
Effective Green, g (s)		5.0	16.2	31.8	7.1	18.3				15.8		
Actuated g/C Ratio		0.06	0.21	0.40	0.09	0.23				0.20		
Clearance Time (s)		6.0	6.0	6.0	6.0	6.0				6.0		
Vehicle Extension (s)		1.0	2.0	2.0	1.0	3.0				1.0		
Lane Grp Cap (vph)		113	735	624	166	818				640		
v/s Ratio Prot		0.11	c0.70	0.02	c0.14	0.23				c0.10		
v/s Ratio Perm				0.02								
v/c Ratio		1.71	3.40	0.09	1.51	0.99				0.48		
Uniform Delay, d1		36.9	31.2	14.5	35.8	30.1				27.8		
Progression Factor		1.00	1.00	1.00	1.00	1.00				1.00		
Incremental Delay, d2		353.2	1081.6	0.0	256.4	28.5				0.2		
Delay (s)		390.1	1112.9	14.5	292.2	58.6				28.0		
Level of Service		F	F	B	F	E				C		
Approach Delay (s)			1014.2			113.7				28.0		
Approach LOS			F			F				C		

Intersection Summary			
HCM 2000 Control Delay	612.5	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.60		
Actuated Cycle Length (s)	78.7	Sum of lost time (s)	24.0
Intersection Capacity Utilization	119.4%	ICU Level of Service	H
Analysis Period (min)	15		
c Critical Lane Group			

Movement	NWL2	NWT	NWR
Lane Configurations			
Volume (vph)	123	312	207
Ideal Flow (vphpl)	1900	1900	1900
Lane Width	14	12	14
Total Lost time (s)	6.0	6.0	6.0
Lane Util. Factor	1.00	1.00	1.00
Frt	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00
Satd. Flow (prot)	1925	1900	1723
Flt Permitted	0.95	1.00	1.00
Satd. Flow (perm)	1925	1900	1723
Peak-hour factor, PHF	0.77	0.92	0.89
Adj. Flow (vph)	160	339	233
RTOR Reduction (vph)	0	0	187
Lane Group Flow (vph)	160	339	46
Heavy Vehicles (%)	0%	0%	0%
Turn Type	Split	NA	Prot
Protected Phases	7	7	7
Permitted Phases			
Actuated Green, G (s)	15.6	15.6	15.6
Effective Green, g (s)	15.6	15.6	15.6
Actuated g/C Ratio	0.20	0.20	0.20
Clearance Time (s)	6.0	6.0	6.0
Vehicle Extension (s)	1.0	1.0	1.0
Lane Grp Cap (vph)	381	376	341
v/s Ratio Prot	0.08	c0.18	0.03
v/s Ratio Perm			
v/c Ratio	0.42	0.90	0.14
Uniform Delay, d1	27.6	30.8	26.0
Progression Factor	1.00	1.00	1.00
Incremental Delay, d2	0.3	23.5	0.1
Delay (s)	27.9	54.3	26.1
Level of Service	C	D	C
Approach Delay (s)		39.5	
Approach LOS		D	

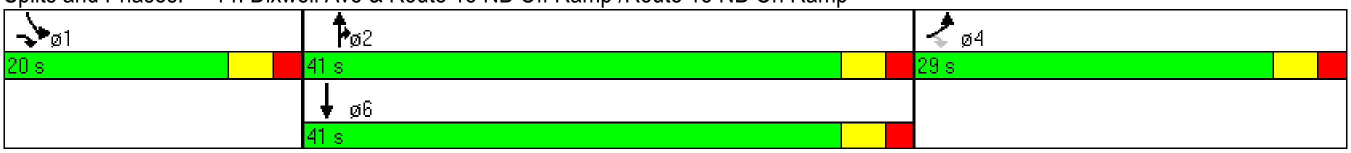
Intersection Summary

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	353	0	251	0	0	0	0	1272	1934	109	1303	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12	11	12	12	11	12	11
Storage Length (ft)	0		215	0		0	0		240	0		0
Storage Lanes	2		1	0		0	0		1	1		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		409			488			632			296	
Travel Time (s)		9.3			11.1			14.4			6.7	
Confl. Peds. (#/hr)			2						4	4		
Peak Hour Factor	0.83	0.25	0.92	0.92	0.92	0.92	0.25	0.86	0.96	0.88	0.95	0.25
Heavy Vehicles (%)	0%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	425	0	273	0	0	0	0	1479	2015	124	1372	0
Turn Type	Prot		custom					NA	Prot	Prot	NA	
Protected Phases	4		1					2	2	1	6	
Permitted Phases			4									
Detector Phase	4		1					2	2	1	6	
Switch Phase												
Minimum Initial (s)	7.0		7.0					15.0	15.0	7.0	15.0	
Minimum Split (s)	12.0		12.0					31.0	31.0	12.0	21.0	
Total Split (s)	29.0		20.0					41.0	41.0	20.0	41.0	
Total Split (%)	32.2%		22.2%					45.6%	45.6%	22.2%	45.6%	
Yellow Time (s)	3.0		3.0					3.0	3.0	3.0	3.0	
All-Red Time (s)	2.0		2.0					2.0	2.0	2.0	2.0	
Lost Time Adjust (s)	0.0		0.0					0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None		None					Min	Min	None	Min	
v/c Ratio	0.68		0.53					0.85	1.66	0.53	0.78	
Control Delay	34.7		19.4					24.6	318.8	39.6	21.4	
Queue Delay	0.0		0.0					0.0	0.0	0.0	0.0	
Total Delay	34.7		19.4					24.6	318.8	39.6	21.4	
Queue Length 50th (ft)	94		82					294	~1171	54	257	
Queue Length 95th (ft)	135		141					#503	#1602	108	#478	
Internal Link Dist (ft)		329			408			552			216	
Turn Bay Length (ft)			215						240			
Base Capacity (vph)	1132		627					1733	1211	352	1751	
Starvation Cap Reductn	0		0					0	0	0	0	
Spillback Cap Reductn	0		0					0	0	0	0	
Storage Cap Reductn	0		0					0	0	0	0	
Reduced v/c Ratio	0.38		0.44					0.85	1.66	0.35	0.78	

Intersection Summary	
Area Type:	Other
Cycle Length: 90	
Actuated Cycle Length: 74.6	

Natural Cycle: 100
Control Type: Semi Act-Uncoord
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 14: Dixwell Ave & Route 15 NB Off Ramp /Route 15 NB On Ramp



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	353	0	251	0	0	0	0	1272	1934	109	1303	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	12	12	11	12	12	11	12	11
Total Lost time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Lane Util. Factor	0.97		1.00					0.95	1.00	1.00	0.95	
Frpb, ped/bikes	1.00		0.99					1.00	1.00	1.00	1.00	
Flpb, ped/bikes	1.00		1.00					1.00	1.00	1.00	1.00	
Frt	1.00		0.85					1.00	0.85	1.00	1.00	
Flt Protected	0.95		1.00					1.00	1.00	0.95	1.00	
Satd. Flow (prot)	3502		1602					3574	1615	1745	3610	
Flt Permitted	0.95		1.00					1.00	1.00	0.95	1.00	
Satd. Flow (perm)	3502		1602					3574	1615	1745	3610	
Peak-hour factor, PHF	0.83	0.25	0.92	0.92	0.92	0.92	0.25	0.86	0.96	0.88	0.95	0.25
Adj. Flow (vph)	425	0	273	0	0	0	0	1479	2015	124	1372	0
RTOR Reduction (vph)	0	0	16	0	0	0	0	0	428	0	0	0
Lane Group Flow (vph)	425	0	257	0	0	0	0	1479	1587	124	1372	0
Confl. Peds. (#/hr)			2						4	4		
Heavy Vehicles (%)	0%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
Turn Type	Prot		custom					NA	Prot	Prot	NA	
Protected Phases	4		1					2	2	1	6	
Permitted Phases			4									
Actuated Green, G (s)	13.4		23.4					36.2	36.2	10.0	36.2	
Effective Green, g (s)	13.4		23.4					36.2	36.2	10.0	36.2	
Actuated g/C Ratio	0.18		0.31					0.49	0.49	0.13	0.49	
Clearance Time (s)	5.0		5.0					5.0	5.0	5.0	5.0	
Vehicle Extension (s)	2.0		2.0					3.0	3.0	2.0	3.0	
Lane Grp Cap (vph)	629		609					1734	783	233	1751	
v/s Ratio Prot	c0.12		0.06					0.41	c0.98	c0.07	0.38	
v/s Ratio Perm			0.10									
v/c Ratio	0.68		0.42					0.85	2.03	0.53	0.78	
Uniform Delay, d1	28.6		20.2					16.9	19.2	30.1	15.9	
Progression Factor	1.00		1.00					1.00	1.00	1.00	1.00	
Incremental Delay, d2	2.3		0.2					4.3	466.4	1.2	2.4	
Delay (s)	30.8		20.4					21.2	485.6	31.3	18.3	
Level of Service	C		C					C	F	C	B	
Approach Delay (s)		26.8			0.0			289.0			19.4	
Approach LOS		C			A			F			B	

Intersection Summary			
HCM 2000 Control Delay	185.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.47		
Actuated Cycle Length (s)	74.6	Sum of lost time (s)	15.0
Intersection Capacity Utilization	134.6%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	1863	113	39	7	3	8	59	497	32	124	378	301
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	11	13	12	11	12	11	10	12	14	10	12	12
Storage Length (ft)	210		0	55		0	90		0	130		0
Storage Lanes	1		0	1		0	1		0	1		1
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		555			252			414			384	
Travel Time (s)		12.6			5.7			9.4			8.7	
Confl. Peds. (#/hr)	4		5	5		4	19		12	12		19
Peak Hour Factor	0.60	0.75	0.50	0.58	0.75	0.50	0.69	0.98	0.76	0.86	0.90	0.80
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	1%	0%	0%	1%	0%
Shared Lane Traffic (%)	46%											
Lane Group Flow (vph)	1677	1657	0	12	20	0	86	549	0	144	420	376
Turn Type	Split	NA		Split	NA		pm+pt	NA		pm+pt	NA	pt+ov
Protected Phases	9	9		8	8		5	2		1	6	6 9
Permitted Phases							2			6		
Detector Phase	9	9		8	8		5	2		1	6	6 9
Switch Phase												
Minimum Initial (s)	9.0	9.0		5.0	5.0		5.0	15.0		5.0	15.0	
Minimum Split (s)	13.6	13.6		10.4	10.4		7.9	19.8		7.9	19.8	
Total Split (s)	26.6	26.6		15.4	15.4		12.9	32.8		12.9	32.8	
Total Split (%)	24.2%	24.2%		14.0%	14.0%		11.8%	29.9%		11.8%	29.9%	
Yellow Time (s)	3.6	3.6		3.6	3.6		2.8	3.6		2.8	3.6	
All-Red Time (s)	1.0	1.0		1.8	1.8		0.1	1.2		0.1	1.2	
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Lost Time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	
Lead/Lag							Lead	Lag		Lead	Lag	
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		None	Min		None	Min	
v/c Ratio	3.08	2.84		0.09	0.14		0.23	0.48		0.36	0.62	0.29
Control Delay	957.5	849.2		36.3	22.5		11.3	20.6		12.6	24.4	1.0
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Delay	957.5	849.2		36.3	22.5		11.3	20.6		12.6	24.4	1.0
Queue Length 50th (ft)	~1273	~1267		5	2		15	84		26	131	0
Queue Length 95th (ft)	#1206	#1563		14	18		34	163		66	280	7
Internal Link Dist (ft)		475			172			334			304	
Turn Bay Length (ft)	210			55			90			130		
Base Capacity (vph)	544	583		263	260		456	1492		452	794	1306
Starvation Cap Reductn	0	0		0	0		0	0		0	0	0
Spillback Cap Reductn	0	0		0	0		0	0		0	0	0
Storage Cap Reductn	0	0		0	0		0	0		0	0	0
Reduced v/c Ratio	3.08	2.84		0.05	0.08		0.19	0.37		0.32	0.53	0.29

Intersection Summary	
Area Type:	Other
Cycle Length: 109.7	
Actuated Cycle Length: 68.2	

Lane Group	ø3
Lane Configurations	
Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Confl. Peds. (#/hr)	
Peak Hour Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	3
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	7.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	20%
Yellow Time (s)	3.5
All-Red Time (s)	0.5
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

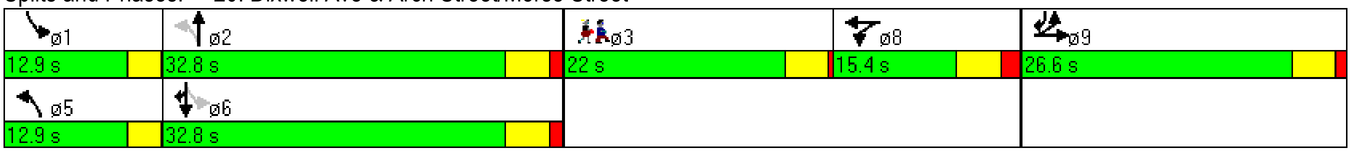
Natural Cycle: 100

Control Type: Semi Act-Uncoord

~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 20: Dixwell Ave & Arch Street/Morse Street



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	1863	113	39	7	3	8	59	497	32	124	378	301
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	11	13	12	11	12	11	10	12	14	10	12	12
Total Lost time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	4.8
Lane Util. Factor	0.95	0.95		1.00	1.00		1.00	0.95		1.00	1.00	1.00
Frpb, ped/bikes	1.00	1.00		1.00	0.95		1.00	1.00		1.00	1.00	1.00
Flpb, ped/bikes	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Frt	1.00	0.99		1.00	0.88		1.00	0.99		1.00	1.00	0.85
Flt Protected	0.95	0.96		0.95	1.00		0.95	1.00		0.95	1.00	1.00
Satd. Flow (prot)	1641	1756		1745	1593		1679	3525		1682	1881	1615
Flt Permitted	0.95	0.96		0.95	1.00		0.34	1.00		0.33	1.00	1.00
Satd. Flow (perm)	1641	1756		1745	1593		604	3525		577	1881	1615
Peak-hour factor, PHF	0.60	0.75	0.50	0.58	0.75	0.50	0.69	0.98	0.76	0.86	0.90	0.80
Adj. Flow (vph)	3105	151	78	12	4	16	86	507	42	144	420	376
RTOR Reduction (vph)	0	1	0	0	16	0	0	5	0	0	0	130
Lane Group Flow (vph)	1677	1656	0	12	4	0	86	544	0	144	420	246
Confl. Peds. (#/hr)	4		5	5		4	19		12	12		19
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	1%	0%	0%	1%	0%
Turn Type	Split	NA		Split	NA		pm+pt	NA		pm+pt	NA	pt+ov
Protected Phases	9	9		8	8		5	2		1	6	6 9
Permitted Phases							2			6		
Actuated Green, G (s)	22.6	22.6		1.8	1.8		28.0	22.6		32.0	24.6	47.2
Effective Green, g (s)	22.6	22.6		1.8	1.8		28.0	22.6		32.0	24.6	47.2
Actuated g/C Ratio	0.31	0.31		0.02	0.02		0.39	0.31		0.44	0.34	0.65
Clearance Time (s)	4.6	4.6		5.4	5.4		2.9	4.8		2.9	4.8	
Vehicle Extension (s)	1.5	1.5		1.5	1.5		1.5	2.5		1.5	2.5	
Lane Grp Cap (vph)	514	550		43	39		315	1104		369	641	1057
v/s Ratio Prot	c1.02	0.94		c0.01	0.00		0.02	0.15		c0.04	c0.22	0.15
v/s Ratio Perm							0.09			0.13		
v/c Ratio	3.26	3.01		0.28	0.11		0.27	0.49		0.39	0.66	0.23
Uniform Delay, d1	24.7	24.7		34.5	34.4		14.7	20.1		12.6	20.2	5.1
Progression Factor	1.00	1.00		1.00	1.00		1.00	1.00		1.00	1.00	1.00
Incremental Delay, d2	1023.2	909.5		1.3	0.5		0.2	0.3		0.2	2.2	0.1
Delay (s)	1048.0	934.2		35.8	34.8		14.8	20.4		12.8	22.3	5.2
Level of Service	F	F		D	C		B	C		B	C	A
Approach Delay (s)		991.4			35.2			19.6			14.0	
Approach LOS		F			D			B			B	

Intersection Summary			
HCM 2000 Control Delay	674.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.85		
Actuated Cycle Length (s)	72.1	Sum of lost time (s)	21.7
Intersection Capacity Utilization	97.7%	ICU Level of Service	F
Analysis Period (min)	15		

c Critical Lane Group

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	1464	730	4	13	288	394	2	1	3	110	1	175
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (ft)	10	11	15	15	11	11	15	15	15	14	15	8
Storage Length (ft)	150		0	0		0	0		0	0		0
Storage Lanes	1		0	0		0	0		0	0		0
Taper Length (ft)	25			25			25			25		
Right Turn on Red			Yes			Yes			Yes			Yes
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		709			1067			199			1402	
Travel Time (s)		16.1			24.3			4.5			31.9	
Confl. Peds. (#/hr)	6		12	12		6	4		3	3		4
Peak Hour Factor	0.25	0.88	0.61	0.25	0.88	0.61	0.50	0.25	0.38	0.92	0.25	0.93
Heavy Vehicles (%)	0%	0%	1%	2%	2%	2%	2%	2%	2%	1%	0%	0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	5856	837	0	0	1025	0	0	16	0	0	312	0
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	1	6			2			4			4	
Permitted Phases	6			2			4			4		
Detector Phase	1	6		2	2		4	4		4	4	
Switch Phase												
Minimum Initial (s)	5.0	5.0		15.0	15.0		5.0	5.0		5.0	5.0	
Minimum Split (s)	9.0	27.0		20.0	20.0		10.0	10.0		10.0	10.0	
Total Split (s)	10.0	30.0		20.0	20.0		27.0	27.0		27.0	27.0	
Total Split (%)	12.5%	37.5%		25.0%	25.0%		33.8%	33.8%		33.8%	33.8%	
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		3.0	3.0	
All-Red Time (s)	0.1	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0			0.0			0.0			0.0	
Total Lost Time (s)	3.1	5.0			5.0			5.0			5.0	
Lead/Lag	Lead			Lag	Lag		Lag	Lag		Lag	Lag	
Lead-Lag Optimize?				Yes	Yes							
Recall Mode	None	Max		C-Max	C-Max		None	None		None	None	
v/c Ratio	6.65	0.35			1.19			0.05			0.83	
Control Delay	2553.6	6.3			114.2			17.0			39.0	
Queue Delay	0.0	0.0			0.0			0.0			0.0	
Total Delay	2553.6	6.3			114.2			17.0			39.0	
Queue Length 50th (ft)	~5803	75			~218			3			106	
Queue Length 95th (ft)	#1360	137			#325			3			12	
Internal Link Dist (ft)		629			987			119			1322	
Turn Bay Length (ft)	150											
Base Capacity (vph)	880	2408			864			479			520	
Starvation Cap Reductn	0	0			0			0			0	
Spillback Cap Reductn	0	0			0			0			0	
Storage Cap Reductn	0	0			0			0			0	
Reduced v/c Ratio	6.65	0.35			1.19			0.03			0.60	

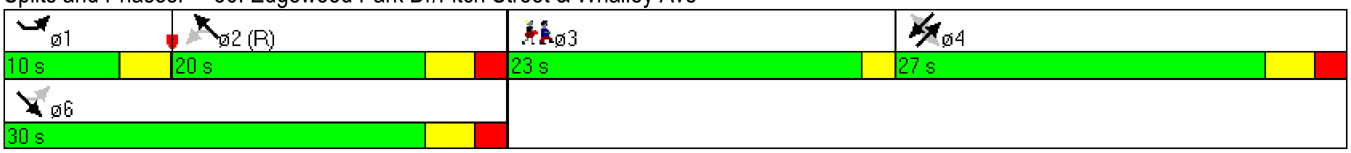
Intersection Summary	
Area Type:	Other
Cycle Length: 80	
Actuated Cycle Length: 80	

Lane Group	ø3
Lane Configurations	
Volume (vph)	
Ideal Flow (vphpl)	
Lane Width (ft)	
Storage Length (ft)	
Storage Lanes	
Taper Length (ft)	
Right Turn on Red	
Link Speed (mph)	
Link Distance (ft)	
Travel Time (s)	
Confl. Peds. (#/hr)	
Peak Hour Factor	
Heavy Vehicles (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	3
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	7.0
Minimum Split (s)	23.0
Total Split (s)	23.0
Total Split (%)	29%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	Lead
Lead-Lag Optimize?	
Recall Mode	None
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Offset: 0 (0%), Referenced to phase 2:NWTL, Start of Green
Natural Cycle: 100
Control Type: Actuated-Coordinated
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 36: Edgewood Park Dr/Fitch Street & Whalley Ave



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (vph)	1464	730	4	13	288	394	2	1	3	110	1	175
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	10	11	15	15	11	11	15	15	15	14	15	8
Total Lost time (s)	3.1	5.0			5.0			5.0			5.0	
Lane Util. Factor	1.00	0.95			0.95			1.00			1.00	
Frpb, ped/bikes	1.00	1.00			0.98			0.99			0.99	
Flpb, ped/bikes	1.00	1.00			1.00			1.00			1.00	
Frt	1.00	1.00			0.91			0.93			0.92	
Flt Protected	0.95	1.00			1.00			0.99			0.98	
Satd. Flow (prot)	1684	3484			3019			1870			1852	
Flt Permitted	0.22	1.00			0.84			0.91			0.87	
Satd. Flow (perm)	392	3484			2547			1719			1637	
Peak-hour factor, PHF	0.25	0.88	0.61	0.25	0.88	0.61	0.50	0.25	0.38	0.92	0.25	0.93
Adj. Flow (vph)	5856	830	7	52	327	646	4	4	8	120	4	188
RTOR Reduction (vph)	0	0	0	0	388	0	0	7	0	0	77	0
Lane Group Flow (vph)	5856	837	0	0	637	0	0	9	0	0	235	0
Confl. Peds. (#/hr)	6		12	12		6	4		3	3		4
Heavy Vehicles (%)	0%	0%	1%	2%	2%	2%	2%	2%	2%	1%	0%	0%
Turn Type	pm+pt	NA		Perm	NA		Perm	NA		Perm	NA	
Protected Phases	1	6			2			4			4	
Permitted Phases	6			2			4			4		
Actuated Green, G (s)	55.3	55.3			15.0			14.7			14.7	
Effective Green, g (s)	55.3	55.3			15.0			14.7			14.7	
Actuated g/C Ratio	0.69	0.69			0.19			0.18			0.18	
Clearance Time (s)	3.1	5.0			5.0			5.0			5.0	
Vehicle Extension (s)	1.0	0.2			0.2			1.0			1.0	
Lane Grp Cap (vph)	871	2408			477			315			300	
v/s Ratio Prot	c3.12	0.24										
v/s Ratio Perm	c1.52				0.25			0.01			c0.14	
v/c Ratio	6.72	0.35			1.34			0.03			0.78	
Uniform Delay, d1	16.8	5.0			32.5			26.8			31.1	
Progression Factor	1.00	1.00			1.00			1.00			1.00	
Incremental Delay, d2	2577.9	0.4			165.1			0.0			11.7	
Delay (s)	2594.7	5.4			197.6			26.8			42.8	
Level of Service	F	A			F			C			D	
Approach Delay (s)		2270.9			197.6			26.8			42.8	
Approach LOS		F			F			C			D	

Intersection Summary			
HCM 2000 Control Delay	1915.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	5.85		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	15.1
Intersection Capacity Utilization	138.7%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

B5. Alternate Analysis

2019 future conditions - during construction - saturday peak.npe

Network Performance

File: c:\users\gieldm\desktop\projects\heroes tunnel\vissim\2019 future conditions - during construction - ctdot 20% reduction\2019 future conditions - during construction - saturday peak.inp
Comment:
Date: Friday, May 09, 2014 4:18:51 PM
VISSIM: 5.40-09 [41012]

Simulation time from 1800.0 to 16200.0.

Parameter	Value
Total Distance Traveled [mi], All Vehicle Types	308336.251
Average delay time per vehicle [s], All Vehicle Types	59.953
Average number of stops per vehicles, All Vehicle Types	1.684
Average speed [mph], All Vehicle Types	52.160
Average stopped delay per vehicle [s], All Vehicle Types	6.686
Total delay time [h], All Vehicle Types	1281.452
Number of Stops, All Vehicle Types	129613
Number of vehicles in the network, All Vehicle Types	2092
Number of vehicles that have left the network, All Vehicle Types	74855
Total stopped delay [h], All Vehicle Types	142.904
Total travel time [h], All Vehicle Types	5911.337

Appendix C

Highway Design

C1. Plans Showing Geometry of Option 1 and Crossovers Constructed to Shift Traffic

C2. Profile Showing Proposed Tunnel Grade for Option 1 Relative to Existing Grade

C3. Plans Showing Geometry of Option 2 and Crossovers Constructed to Shift Traffic

C4. Profile Showing Proposed Tunnel Grade for Option 2 Relative to Existing Grade

C5. Plans Showing Geometry of Route 40 Interchange Improvements

C6. Profile Showing Route 40 Interchange Improvements

C7. Map of General Locations of State and Federal Listed Species and Significant Natural Communities in New Haven and Hamden, CT

Natural Diversity Data Base Areas

HAMDEN, CT

June 2014

State and Federal Listed Species & Significant Natural Communities

Town Boundary

NOTE: This map shows general locations of State and Federal Listed Species and Significant Natural Communities. Information on listed species is collected and compiled by the Natural Diversity Data Base (NDDB) from a number of data sources. Exact locations of species have been buffered to produce the general locations. Exact locations of species and communities occur somewhere in the shaded areas, not necessarily in the center. A new mapping format is being employed that more accurately models important riparian and aquatic areas and eliminates the need for the upstream/downstream searches required in previous versions.

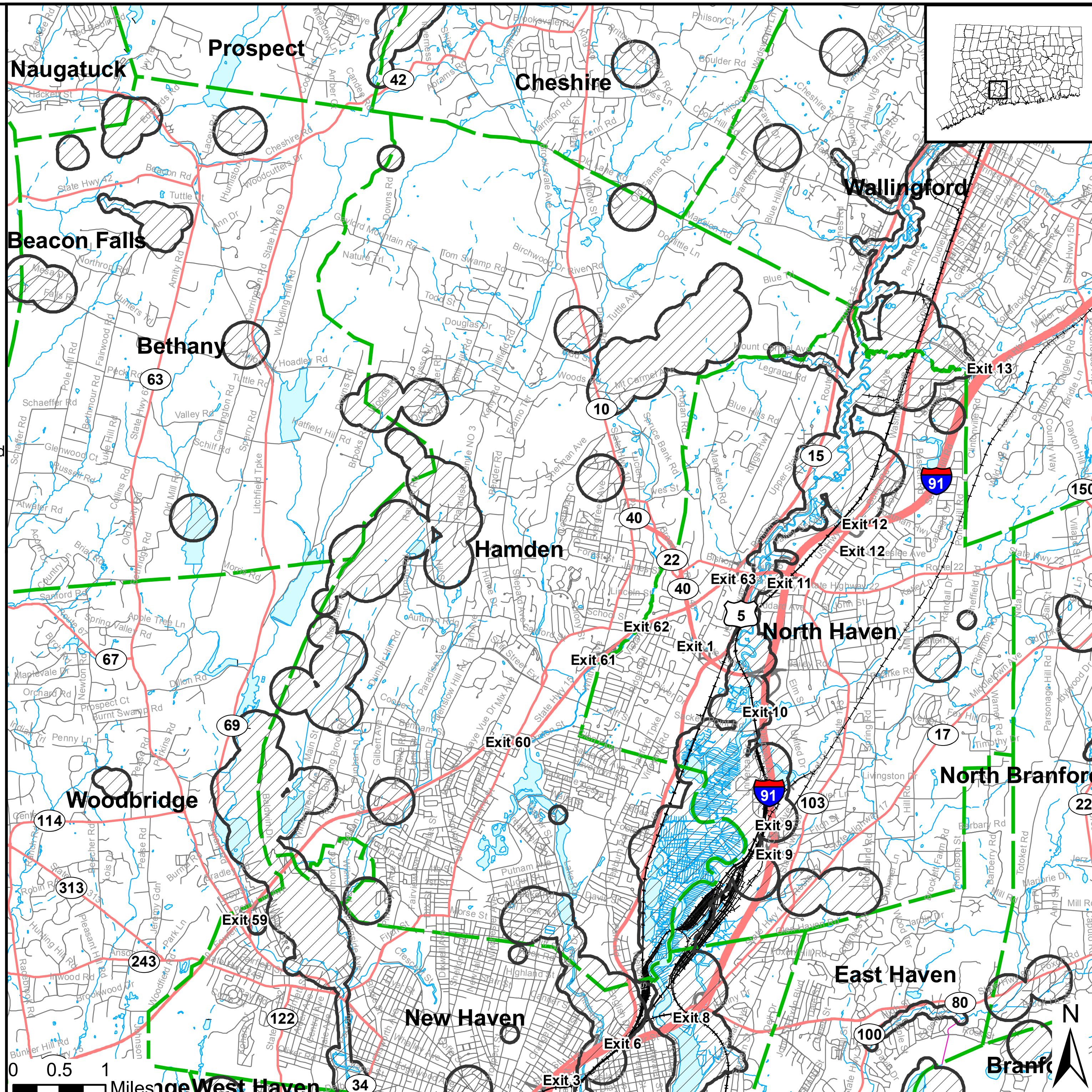
This map is intended for use as a preliminary screening tool for conducting a Natural Diversity Data Base Review Request. To use the map, locate the project boundaries and any additional affected areas. If the project is within a shaded area there may be a potential conflict with a listed species. For more information, complete a Request for Natural Diversity Data Base State Listed Species Review form (DEP-APP-007), and submit it to the NDDB along with the required maps and information. More detailed instructions are provided with the request form on our website.

www.ct.gov/deep/nddbrequest

This file has PDF Layers. Look for the Layers tab on the left. Expand the layers and use the "eye" icons to change visibility.

QUESTIONS: Department of Energy and Environmental Protection (DEEP)
79 Elm St., Hartford CT 06106
Phone (860) 424-3011

Connecticut Department of Energy & Environmental Protection
Bureau of Natural Resources
Wildlife Division

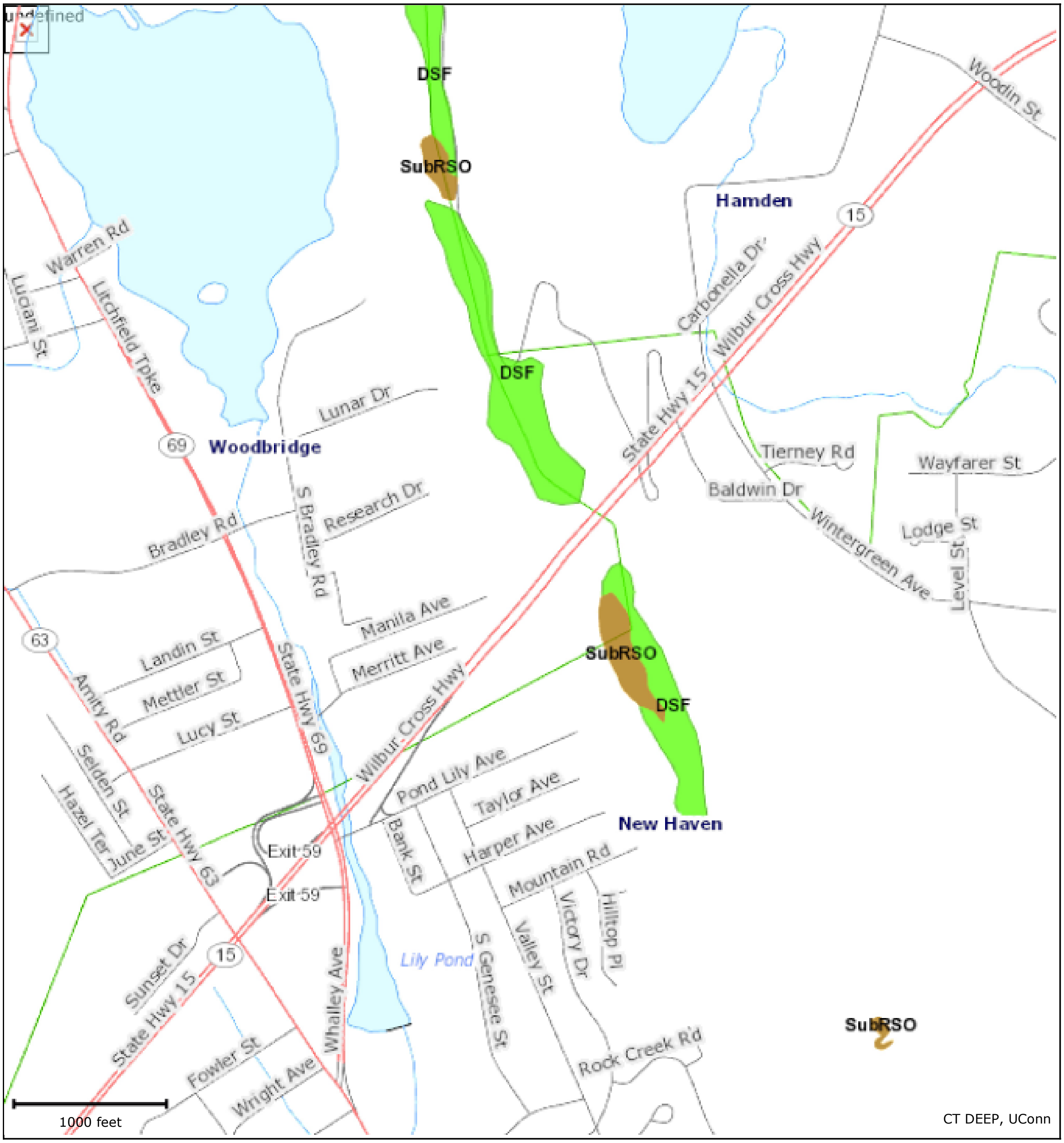


C8. Map of Critical Habitat Locations within the Project Area

CTECO Connecticut Environmental Conditions Online

Maps and Geospatial Data for Planning, Management, Education and Research

Critical Habitats



This map is intended for general planning, management, education, and research purposes only. Data shown on this map may not be complete or current. The data shown may have been compiled at different times and at different map scales, which may not match the scale at which the data is shown on this map.

CT ECO Connecticut Environmental Conditions Online
Maps and Geospatial Data for Planning, Management, Education and Research

Critical Habitats

CONNECTICUT CRITICAL HABITATS

Estuarine

Beachshore - Subtype Salt	B
Intertidal Marsh	IM

Palustrine Forested

Acidic Atlantic White Cedar Swamp	AAWCS
Acidic Red/Black Spruce Basin Swamp	AcR/BSS
Circumneutral Northern White Cedar Swamp	CirNWCS
Floodplain Forest	FF

Palustrine Non-Forested

Beachshore - Subtype Riverine	B
Circumneutral Spring Fen	CirSF
Floodplain Forest - Subtype Alluvial Marsh	FF
Freshwater Aquatic	FA
Medium Fen	MF
Poor Fen	PF
Rich Fen	RF
Sea Level Fen	SFL

Terrestrial Forested

Coastal Woodland/Shrubland	CWS
Dry Acidic Forest	DAF
Dry Circumneutral Forest	DCF
Dry Subacidic Forest	DSF
Old Growth Forest	OGF
Subacidic Cold Talus Forest/Woodland	SubCTFW

Terrestrial Non-Forested

Acidic Rocky Summit Outcrop	AcRSO
Alluvial Grassland/Outcrop	AllG/O
Circumneutral Rocky Summit Outcrop	CirRSO
Coastal Bluffs and Headlands	CBH
Coastal Grassland	CG
Sand Barren	SB
Subacidic Rocky Summit Outcrop	SubRSO

More information:
Basic Data Guide
http://cteco.uconn.edu/guides/Critical_Habitat.htm
Complete Resource Guide
http://cteco.uconn.edu/guides/resource/CT_ECO_Resource_Guide_Critical_Habitat.pdf

Connecticut Base Map

Transportation

Airport

Railroad

Interstate

US Route

State Route

Ramp

Street

Ferry

Hydrography

Water

Water

Coast or Shore line

Dam

Water Connector

Political Boundaries

State

Town

Color Photos

2006 NAIP Color Orthophotos

2008 NAIP Color Orthophotos

2010 NAIP Color Orthophotos

Black & White Photos

2004 Black & White Orthophotos

CT ECO - www.cteco.uconn.edu

6/24/2014

Appendix D

Vehicle Height Warning Systems – System Specifications for Optoelectric Sensors

Appendix D

Vehicle Height Warning Systems – System Specifications for Optoelectric Sensors

Table A1: System specifications for optoelectric sensors (from Smithfield, 2010)

Company	Model	2-way detection	Speed Parameters	Width Range	Temperature Parameters	Backup Warning System	Video Capability	Power	Enviromentally sealed	Internal thermostat
ASTI Transportation Systems		0	0	200 ft.	(-) 25F to 150F	0	0	10 - 30 V DC	0	0
Autotron	LRML	0	0	35 ft.	(-) 40F to 55F	0	0	12 V DC or 120 V AC	yes	yes
Banner Engineering	Magnet-resistive	0	0	0	0	0	0	0	0	0
	QS30	0	0	0	0	0	0	0	0	0
	A-gage Mini Array	0	0	55 ft.	0	0	0	0	0	0
Coeval Group		0	0	165 ft.	0	0	0	0	0	0
Internaltional Road Dynamics Inc.		yes	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	yes	24 V DC or 115 V AC	yes	yes
Measurement Devices Ltd.	Laser Ace IM	0	1 to 75 (mph)	500 ft.	14F to 140F	0	yes	9 - 24 V DC	yes	0
IDT		yes	1 to 75 (mph)	65 ft.	5F to 150F	yes	yes	UK mains	yes	no
Peter Berghaus GmbH		yes	0	200 ft.	(-)4F	0	0	12 V DC or 230 V AC	yes	yes
Schuh & Co.		yes	1 to 75 (mph)	100 ft.	(-) 10F to 140F	yes	yes	24 V DC	yes	yes
TEC Traffic Systems		0	1 to 75 (mph)	100 ft.	0	0	0	0	no	no
Sick Maihak		no	1 to 75 (mph)	300 ft.	(-) 25F to 150F	yes	no	24 V to 240 V UC	yes	no
Trigg Industries Inc.	Z-Pattern	yes	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	yes	24 V DC or 115 V AC	yes	yes
	Double Eye	yes	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	yes	24 V DC or 115 V AC	yes	yes
	Single Eye	no	1 to 75 (mph)	200 ft.	(-) 40F to 135F	yes	0	24 V DC or 115 V AC	yes	yes
	Metro Economy	no	1 to 75 (mph)	200 ft.	0	no	0	24 V DC or 115 V AC	yes	no

Appendix E

Advanced Traffic Data Collection Systems – Description of Technologies

Appendix E

Advanced Traffic Data Collection Systems – Description of Technologies

E.1 In-roadway Sensors

An in-roadway sensor is one that is either embedded in the pavement or subgrade of the roadway or adhered to the surface of the roadway. In-roadway sensors function by detecting an induced electric field (inductive loop detector), the perturbation of a magnetic field (magnetic sensors), induced voltage through a piezoelectric material (piezoelectric sensors), or physical deflection (bending plate sensors) when a vehicle passes over the section of the roadway. These sensors can be used to measure vehicle speed, weight, and presence as well as lane occupancy, but cannot measure length or height. The drawbacks of in-roadway sensors are that they require disruption of traffic for installation and repair and can fail if not installed properly. In addition, when roadways are resurfaced or they are damaged due to wear and tear from the stresses of traffic and temperature they have to be reinstalled. These installation and maintenance costs can significantly increase the life cycle costs of in-roadway sensors.

E.1.1 Pneumatic Road Tube

Pneumatic road tube sensors produce an electrical signal when a vehicle's tire passes over the tube, sending a burst of air pressure that closes an air switch. Road tubes are generally used for short-term traffic counting for planning and research studies. Though they are inexpensive and quick to install, they are not designed for long term wear-and-tear (Mimbela and Klein, 2007).

E.1.2 Inductive Loop Detectors

Inductive loop detectors are the most common sensor used in traffic management applications. Inductive loop sensors involve one or more turns of insulated wire buried in a roadway, a cable that runs from the roadside to a controller cabinet, and an electronics unit in the controller cabinet. Vehicles that pass through or stop over the loop decreases the inductance of the loop, which is detected by the controller. Inductive loops can sense vehicle passage, presence, count, and lane occupancy. Speed can be determined using a two-loop speed trap or using data from single loop with an algorithm that estimates speed based on the loop length and an average vehicle length. Newer inductive loop sensors can classify vehicles by the frequency of loop excitation, which correlates to specific metal portions under various types of vehicles (Mimbela and Klein, 2007).

Inductive loop sensors generally have lower equipment costs than over-roadway sensors but require disruption of traffic for installation and repair. Life cycle costs must factor in reinstallation during resurfacing of roadways as well as wear and tear due to traffic and temperature stresses.

E.1.3 Magnetic Sensors

Magnetic sensors employ disruption of the Earth's magnetic field or an installed device's magnetic field to detect an object containing iron passing over the sensor. Magnetic sensors can count vehicles but must be used in tandem to determine speed and lane occupancy. Magnetic sensors may be less susceptible to wear-and-tear from traffic than inductive loops but like loops, generally require disruption of traffic for installation and repair (Mimbela and Klein, 2007).

E.1.4 Piezoelectric Sensors

Piezoelectric sensors employ special materials that generate an electrical signal when deflected. The voltage generated is proportional to the degree of deflection, and so piezoelectric sensors can measure vehicle weight in addition to counting vehicles, counting axles, and determining speed (when multiple sensors are deployed). Piezoelectric sensors are commonly used in weigh-in-motion systems. Piezoelectric sensors are marginally more expensive than inductive loops, but provide better accuracy in speed measurement as well as the axle spacing and weight data that loops do not provide. For WIM applications, piezoelectric WIM systems generally have the lowest equipment costs and can be used at higher speed ranges (up to 70 mph) but have lower accuracy than other WIM systems. The drawbacks to piezoelectric sensors are similar to those of inductive loop sensors – traffic disruption and wear-and-tear failtures. Piezoelectric sensors may be sensitive to temperature and vehicle speed (Mimbela and Klein, 2007).

E.1.5 Bending Plate Sensors

Bending plate sensors employ strain gauges to calculate the weight of a passing load in WIM systems. Bending plate sensors are typically integrated with two inductive loop detectors to determine the speed of the passing vehicle, which is required in order to determine the vehicle weight by the bending plate sensor. Bending plate WIM systems are generally more accurate than piezoelectric WIM systems but are considerably more expensive. Bending plate WIM systems are generally lower cost than load cell WIM systems (Mimbela and Klein, 2007).

E.1.6 Load Cell

Load cell WIM sensors use hydraulic scales to detect vehicle weight. Like bending plate sensors, they are integrated with two inductive loop detectors to alert the system of an approaching vehicle and to determine axle spacing and vehicle speed. While load cell systems are among the most accurate WIM systems, they are also the most expensive in terms of equipment and maintenance costs (Mimbela and Klein, 2007).

E.1.7 Capacitance Mat

Capacitance mat WIM systems consists of two metal sheets sandwiching a dielectric material. When the spacing between the plates decreases during loading, the capacitance of the mat changes proportionally to the axle weight. Capacitance mat WIM systems are not as accurate as other WIM systems but are similar in cost to load cell WIM systems (Mimbela and Klein, 2007).

E.2 Over-Roadway Sensors

An over-roadway sensor is one that is mounted above or alongside the roadway. Various types of sensors in this category are summarized in this section. Radar-based systems are considered to be the most robust technologies in this category.

E.2.1 Video Image Processing Systems

Video image processing systems consist of one or more cameras mounted over or on the side of the roadway and a microprocessor-based computer for digitizing and processing. The captured image data is interpreted by software to produce traffic flow data, such as vehicle count, speed, length category, and lane changes. Some vendors include Econolite Control Products, Traficon, Itiris, Peek

Traffic, Sumitomo Electric Industries, and Quixote Traffic Corp (Mimbela and Klein, 2007). Video image processing systems can be vulnerable to sightline obstructions (including from inclement weather, water droplets, salt, grime, icicles, and cobwebs), shadows; vehicle projection into adjacent lanes, shifts in lighting from day to night, road contrast, and camera motion due to strong winds.

Video image processing systems are not designed to measure vehicle height nor to work at highway speeds, so they are not appropriate for the Heroes Tunnel application.

E.2.2 Radar Systems

Electromagnetic waves in the radio or microwave ranges are emitted from an overhead antenna towards the roadway. When the beam is interrupted by a vehicle, a portion of the beam is reflected back towards a mounted receiver, which is detected and used to calculate lane vehicle volume, vehicle speed, lane occupancy, and vehicle length. Vendors include SpeedInfo, Electronic Integrated Systems Inc. (EIS), Wavetronix, Fortran Traffic Systems, GMH Engineering, and ASIM Technologies, now part of Xtralis (Mimbela and Klein, 2007). Microwave radar systems are insensitive to inclement weather. Wavetronix is the major manufacturer in this category. One of Wavetronix's customers in Alabama is using a Wavetronix radar-based matrix sensor to determine vehicle length integrated with a laser-based sensor to determine vehicle height.

E.2.3 Infrared Systems

Similar to radar traffic detectors, infrared sensors mounted overhead provide vehicle presence at traffic signals, lane vehicle volume, vehicle speed measurement, vehicle length, queue measurement, and vehicle classification and can be passive or active.

Passive infrared sensors detect energy emitted from vehicles and other objects using a sensitive detector element to detect vehicle presence. Sometimes these passive infrared sensors are used to trigger other types of sensors to turn on, in order to extend the transmitter life of other sensors (such as radar or ultrasonic sensors). Passive infrared sensors can also be configured as an array, which allows for vehicle counting, vehicle length and speed, stopline presence detection, lane occupancy detection, queue detection, and vehicle classification (by length). Vendors include Eltec, Siemens ITS, and ASIM Technologies, now part of Xtralis (Mimbela and Klein, 2007).

Active infrared sensors emit a beam or zone of infrared energy that is scattered by passing vehicles and detected by a detector, much like those that are used in the active overheight vehicle detection systems that are based on infrared technology. Systems that transmit two or more beams allow vehicle speed to be recorded by detecting when the vehicle scatters each sequential beam. Infrared laser sensors using an array of beams can produce two- and three-dimensional images in order to classify vehicles. Vendors include OSI Laserscan, EFKON, and Laser Technology Inc. (Mimbela and Klein, 2007). If both overheight and traffic data functionalities are desired, such as potentially in the Heroes Tunnel application, a system using entirely infrared sensors could be employed. It is important to note, however, that a dedicated infrared sensor would be used for the overheight detection component, along with two or more additional infrared sensors for the traffic data component. So, in essence, combining the two functionalities requires combining a dedicated overheight detection system with a dedicated traffic data system – there is not a single sensor that can do both functionalities.

Infrared traffic sensors can be sensitive to sunlight, particulates, and inclement weather, especially fog. An additional drawback for using infrared sensors for collecting traffic data is that at least two sensors are required, which results in potentially higher cost as well as multiple points of failure. The operating principle of infrared sensors is the detection of a vehicle that interrupts and/or reflects a single, narrow infrared beam. Multiple beams and sensors spaced apart are necessary to be able to detect length, speed, etc. Radar-based systems are based on detection of the scattered reflection of the emitted beam, allowing for detection of length, speed, etc. using a single emitter and detector.

E.2.4 Ultrasonic Systems

Ultrasonic sensors use the transmission of and detection of reflected sound waves to determine vehicle count, presence, and lane occupancy information. (Vehicular speed can be calculated when two or more ultrasonic sensors are spaced at a known distance apart.) Sometimes ultrasonic sensors are used in conjunction with other sensor technologies to enhance presence and queue detection, vehicle counting, and height and distance discrimination. Vendors include Sumitomo Electric and Microwave Sensors (Mimbela and Klein, 2007). Ultrasonic sensors can be impacted by changes in temperature or extreme air turbulence. Lane occupancy measurement is difficult for vehicles traveling at moderate to high speeds. Because of these drawbacks, ultrasonic sensors are not advised for the Heroes Tunnel application.

E.2.5 Passive Acoustic Systems

Passive acoustic sensors detect vehicles by detecting the audible sounds produced by a vehicle as it passes through a detection zone using a microphone. Arrays of acoustic sensors can determine vehicle speed by assuming an average vehicle length. Vendors include SmartSonic, International Road Dynamics, and SmarTek Systems (Mimbela and Klein, 2007). Passive acoustic sensors can be impacted by cold temperatures and are not recommended with slow moving vehicles in stop and go traffic. Because of these drawbacks, ultrasonic sensors are not advised for the Heroes Tunnel application.

Appendix F

Cost Estimates

F1. Option 1 - Roadway Realignment Cost Estimate – Not Include New Tunnel Bore, Construction and Existing Tunnel Repair

CONCEPTUAL-1 COST ESTIMATE
NOT INCLUDE NEW TUNNEL BORE , CONSRTUCTION AND EXISTING TUNNEL REPAIR

PROGRESS ESTIMATE

DONE BY: D.SHI Date : 11/26/14
CHECKED BY:

ITEM NO.		DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT
0202100		ROCK EXCAVATION	C.Y.	11,000	$75.00	$825,000.00
0202000		EARTH EXCAVATION	C.Y.	11,000	$16.80	$184,800.00
0202529		SAWCUT BITUMINOUS CONCRETE PAVEMENT	L.F.	2,100	$1.80	$3,780.00
0209001		FORMATION OF SUBGRADE	SQ .Y	11,000	$2.40	$26,400.00
0210100		ANTI TRACKING PAD	SQ .Y	120	$16.20	$1,944.00
0219001		SEDIMENTATION CONTROL SYSTEM	L.F.	3,700	$4.40	$16,280.00
0304002		PROCESSED AGGREGATE BASE	C.Y.	1,120	$40.00	$44,800.00
0406002		TEMPORARY PAVEMENT	S.Y.	10,680	$24.20	$258,456.00
0406170		HMA S1	TON	2,150	$90.80	$195,220.00
0406173		HMA S0.5	TON	1,610	$79.60	$128,156.00
0212000		SUBBASE	C.Y.	2,750	$38.60	$106,150.00
0406236		MATERIAL FOR TACK COAT	GAL.	700	$2.00	$1,400.00
0406286		MILLING FOR PAVEMENT TRANSITIONS	S.Y.	700	$8.20	$5,740.00
0821502		F-SHAPE PRECAST CONCRETE BARRIER CURB	L.F.	1,000	$99.20	$99,200.00
0911001		METAL BEAM RAIL (TYPE R-B 350)	L.F.	1,000	$31.20	$31,200.00
0913001		4' CHAIN LINK FENCE	L.F.	2,100	$22.80	$47,880.00
0913911		12' CHAIN LINK DOUBLE GATE 4' HIGH	EA.	1	$1,500.00	$1,500.00
0943001		WATER FOR DUST CONTROL	M. GAL	730	$1.80	$1,314.00
0944000		FURNISHING AND PLACING TOPSOIL	S.Y.	11,700	$7.20	$84,240.00
0950005		TURF ESTABLISHMENT	S.Y.	11,700	$1.40	$16,380.00
0930001		SODDING	S.Y.	11,700	$10.80	$126,360.00
0969015		CONSTRUCTION FIELD OFFICE (TYPE C)	EST.	1	$90,000.00	$90,000.00
0970006		TRAFFICPER (MUNICIPAL POLICE OFFICER)	EST	1	$200,000.00	$200,000.00
0976002		BARRICADE WARNING LIGHTS-HIGH INTENSITY	DAY	2,000	$1.00	$2,000.00
0978002		TRAFFIC DRUM	EA.	400	$67.00	$26,800.00
0979003		CONSTRUCTION BARRICADE TYPE III	EA.	40	$132.80	$5,312.00
0105111		PORTABLE VARIABLE MESSAGE SIGN	EA.	8	$50,000.00	$400,000.00
1207012		SIGN FACE - SHEET ALUMINUM	S.F.	2,000	$37.00	$74,000.00
		(TYPE III REFLECTIVE SHEETING)				
1210101		4" EXPOXY RESIN PAVEMENT MARKINGS WHITE	L.F.	16,000	$0.40	$6,400.00
1201102		4" EXPOXY RESIN PAVEMENT MARKINGS YELLOW	L.F.	2,400	$0.40	$960.00
		CONSTRUCTION SIGNS-TYPE III REFLECTIVE SHEETING	S.F.	4,000	$20.00	$80,000.00

			SUB-TOTAL (ROADWAY)=		**$3,091,672.00**
HWY BRIDGE DECK SQ. FT	**SQ.FT.**	**3600.00**		**493.00**	**$1,774,800.00**
RETAING WALL & HEAD WALL	**SQ.FT.**	**2080.00**		**120.00**	**$249,600.00**
			TOTAL		**$5,116,072**
RIGHT OF WAY (ACQUISITION)	**SQ.FT.**	**208895.00**		**4.00**	**$835,580.00**

F2. Option 2 - Roadway Realignment Cost Estimate - Not Include New Tunnel Bore, Construction and Existing Tunnel Repair

CONCEPTUAL-2 COST ESTIMATE
NOT INCLUDE NEW TUNNEL BORE , CONSRTUCTION AND EXISTING TUNNEL REPAIR

PROGRESS ESTIMATE

DONE BY: D.SHI Date : 11/26/14
CHECKED BY:

ITEM NO.		DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT
0202100		ROCK EXCAVATION	C.Y.	19,600	$75.00	$1,470,000.00
0202000		EARTH EXCAVATION	C.Y.	19,600	$16.80	$329,280.00
0202529		SAWCUT BITUMINOUS CONCRETE PAVEMENT	L.F.	3,150	$1.80	$5,670.00
0209001		FORMATION OF SUBGRADE	SQ .Y	22,000	$2.40	$52,800.00
0210100		ANTI TRACKING PAD	SQ .Y	120	$16.20	$1,944.00
0219001		SEDIMENTATION CONTROL SYSTEM	L.F.	3,700	$4.40	$16,280.00
0304002		PROCESSED AGGREGATE BASE	C.Y.	1,540	$40.00	$61,600.00
0406002		TEMPORARY PAVEMENT	S.Y.	10,680	$24.20	$258,456.00
0406170		HMA S1	TON	2,950	$90.80	$267,860.00
0406173		HMA S0.5	TON	2,220	$79.60	$176,712.00
0212000		SUBBASE	C.Y.	3,000	$38.60	$115,800.00
0406236		MATERIAL FOR TACK COAT	GAL.	1,100	$2.00	$2,200.00
0406286		MILLING FOR PAVEMENT TRANSITIONS	S.Y.	1,100	$8.20	$9,020.00
0821502		F-SHAPE PRECAST CONCRETE BARRIER CURB	L.F.	1,000	$99.20	$99,200.00
0911001		METAL BEAM RAIL (TYPE R-B 350)	L.F.	1,000	$31.20	$31,200.00
0913001		4' CHAIN LINK FENCE	L.F.	2,100	$22.80	$47,880.00
0913911		12' CHAIN LINK DOUBLE GATE 4' HIGH	EA.	1	$1,500.00	$1,500.00
0943001		WATER FOR DUST CONTROL	M. GAL	5,745	$1.80	$10,341.00
0944000		FURNISHING AND PLACING TOPSOIL	S.Y.	11,700	$7.20	$84,240.00
0950005		TURF ESTABLISHMENT	S.Y.	11,700	$1.40	$16,380.00
0930001		SODDING	S.Y.	11,700	$10.80	$126,360.00
0969015		CONSTRUCTION FIELD OFFICE (TYPE C)	EST.	1	$90,000.00	$90,000.00
0970006		TRAFFICPER (MUNICIPAL POLICE OFFICER)	EST	1	$200,000.00	$200,000.00
0976002		BARRICADE WARNING LIGHTS-HIGH INTENSITY	DAY	2,000	$1.00	$2,000.00
0978002		TRAFFIC DRUM	EA.	400	$67.00	$26,800.00
0979003		CONSTRUCTION BARRICADE TYPE III	EA.	40	$132.80	$5,312.00
0105111		PORTABLE VARIABLE MESSAGE SIGN	EA.	8	$50,000.00	$400,000.00
1207012		SIGN FACE - SHEET ALUMINUM	S.F.	2,000	$37.00	$74,000.00
		(TYPE III REFLECTIVE SHEETING)				
1210101		4" EXPOXY RESIN PAVEMENT MARKINGS WHITE	L.F.	16,000	$0.40	$6,400.00
1201102		4" EXPOXY RESIN PAVEMENT MARKINGS YELLOW	L.F.	2,400	$0.40	$960.00
		CONSTRUCTION SIGNS-TYPE III REFLECTIVE SHEETING	S.F.	4,000	$20.00	$80,000.00

			SUB-TOTAL (ROADWAY)=	**$4,070,195.00**
HWY BRIDGE DECK SQ. FT	**SQ.FT.**	**4950.00**	**493.00**	**$2,440,350.00**
RETAING WALL & HEAD WALL	**SQ.FT.**	**2080.00**	**120.00**	**$249,600.00**
			TOTAL	**$6,760,145**
RIGHT OF WAY (ACQUISITION)	**SQ.FT.**	**228095.00**	**4.00**	**$912,380.00**

F3. Alternative Construction Options Cost Estimate Summaries

HEROES TUNNEL OPTION 1 - Drill and Blast

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$19,688,177.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$5,125,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$19,688,177.00	$5,125,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$5,706,717.97	$1,485,507.25	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$856,007.70	$222,826.09	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$285,335.90	$74,275.36	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$1,997,351.29	$519,927.54	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$28,533,589.86	$7,427,536.23	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$8,560,076.96	$2,228,260.87	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$4,280,038.48	$1,114,130.43	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$41,373,705.29**	**$10,769,927.54**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$8,274,741.06	$2,153,985.51	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$49,648,446.35**	**$12,923,913.04**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$70,641,924.61**				

HEROES TUNNEL OPTION 1 - Closed Face TBM

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$43,038,308.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$5,125,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$43,038,308.00	$5,125,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$12,474,871.88	$1,485,507.25	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$1,871,230.78	$222,826.09	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$623,743.59	$74,275.36	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$4,366,205.16	$519,927.54	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$62,374,359.42	$7,427,536.23	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$18,712,307.83	$2,228,260.87	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$9,356,153.91	$1,114,130.43	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$90,442,821.16**	**$10,769,927.54**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$18,088,564.23	$2,153,985.51	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$108,531,385.39**	**$12,923,913.04**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$129,524,863.65**				

HEROES TUNNEL OPTION 1 - Main Beam TBM

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$42,513,771.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$5,125,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$42,513,771.00	$5,125,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$12,322,832.17	$1,485,507.25	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$1,848,424.83	$222,826.09	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$616,141.61	$74,275.36	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$4,312,991.26	$519,927.54	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$61,614,160.87	$7,427,536.23	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$18,484,248.26	$2,228,260.87	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$9,242,124.13	$1,114,130.43	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$89,340,533.26**	**$10,769,927.54**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$17,868,106.65	$2,153,985.51	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$107,208,639.91**	**$12,923,913.04**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$128,202,118.17**				

HEROES TUNNEL OPTION 1 - Road Header

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	ESTIMATED COST				
TUNNEL	$23,007,014.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$5,125,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$23,007,014.00	$5,125,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$6,668,699.71	$1,485,507.25	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$1,000,304.96	$222,826.09	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$333,434.99	$74,275.36	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$2,334,044.90	$519,927.54	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$33,343,498.55	$7,427,536.23	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$10,003,049.57	$2,228,260.87	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$5,001,524.78	$1,114,130.43	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$48,348,072.90**	**$10,769,927.54**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$9,669,614.58	$2,153,985.51	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$58,017,687.48**	**$12,923,913.04**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$79,011,165.74**				

HEROES TUNNEL OPTION 2 - Drill and Blast

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$23,763,995.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$6,790,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$23,763,995.00	$6,790,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$6,888,114.49	$1,968,115.94	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$1,033,217.17	$295,217.39	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$344,405.72	$98,405.80	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$2,410,840.07	$688,840.58	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$34,440,572.46	$9,840,579.71	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$10,332,171.74	$2,952,173.91	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$5,166,085.87	$1,476,086.96	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$49,938,830.07**	**$14,268,840.58**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$9,987,766.01	$2,853,768.12	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$59,926,596.09**	**$17,122,608.70**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$85,118,770.00**				

HEROES TUNNEL OPTION 2 - Closed Face TBM

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$51,308,340.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$6,790,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$51,308,340.00	$6,790,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$14,871,982.61	$1,968,115.94	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$2,230,797.39	$295,217.39	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$743,599.13	$98,405.80	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$5,205,193.91	$688,840.58	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$74,359,913.04	$9,840,579.71	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$22,307,973.91	$2,952,173.91	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$11,153,986.96	$1,476,086.96	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$107,821,873.91**	**$14,268,840.58**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$21,564,374.78	$2,853,768.12	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$129,386,248.70**	**$17,122,608.70**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$154,578,422.61**				

HEROES TUNNEL OPTION 2 - Main Beam TBM

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$51,726,724.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$6,790,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$51,726,724.00	$6,790,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$14,993,253.33	$1,968,115.94	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$2,248,988.00	$295,217.39	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$749,662.67	$98,405.80	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$5,247,638.67	$688,840.58	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$74,966,266.67	$9,840,579.71	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$22,489,880.00	$2,952,173.91	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$11,244,940.00	$1,476,086.96	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$108,701,086.67**	**$14,268,840.58**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$21,740,217.33	$2,853,768.12	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$130,441,304.00**	**$17,122,608.70**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$155,633,477.91**				

HEROES TUNNEL OPTION 2 - Road Header

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$34,443,307.00				
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$6,790,000.00			
RIGHT OF WAY			$1,000,000.00		
ABANDON VENT SHAFT				$200,000.00	
CTDOT MAINTENANCE SHED					$2,000,000.00
TOTAL CONTRACT ITEMS	$34,443,307.00	$6,790,000.00	$1,000,000.00	$200,000.00	$2,000,000.00
MINOR ITEM ALLOWANCE (20%)	$9,983,567.25	$1,968,115.94	$289,855.07	$57,971.01	$579,710.14
CLEARING AND GRUBBING (3%)	$1,497,535.09	$295,217.39	$43,478.26	$8,695.65	$86,956.52
CONSTRUCTION STAKING (1%)	$499,178.36	$98,405.80	$14,492.75	$2,898.55	$28,985.51
MOBILIZATION (7%)	$3,494,248.54	$688,840.58	$101,449.28	$20,289.86	$202,898.55
BASE ESTIMATE	$49,917,836.23	$9,840,579.71	$1,449,275.36	$289,855.07	$2,898,550.72
CONTINGENCY (30%)	$14,975,350.87	$2,952,173.91	$434,782.61	$86,956.52	$869,565.22
INCIDENTALS (15%)	$7,487,675.43	$1,476,086.96	$217,391.30	$43,478.26	$434,782.61
SUBTOTAL	**$72,380,862.54**	**$14,268,840.58**	**$2,101,449.28**	**$420,289.86**	**$4,202,898.55**
INFLATION (5 YEARS @ 4%)	$14,476,172.51	$2,853,768.12	$420,289.86	$84,057.97	$840,579.71
ITEM TOTAL	**$86,857,035.04**	**$17,122,608.70**	**$2,521,739.13**	**$504,347.83**	**$5,043,478.26**
CONSTRUCTION TOTAL	**$112,049,208.96**				

HEROES TUNNEL OPTION 3

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	ESTIMATED COST		
TUNNEL	$26,573,913.00		
ROADWAY FEATURES (OUTSIDE OF TUNNEL)		$800,000.00	
ABANDON VENT SHAFT			$200,000.00
TOTAL CONTRACT ITEMS	$26,573,913.00	$800,000.00	$200,000.00
MINOR ITEM ALLOWANCE (20%)	$7,702,583.48	$231,884.06	$57,971.01
CLEARING AND GRUBBING (3%)	$1,155,387.52	$34,782.61	$8,695.65
CONSTRUCTION STAKING (1%)	$385,129.17	$11,594.20	$2,898.55
MOBILIZATION (7%)	$2,695,904.22	$81,159.42	$20,289.86
BASE ESTIMATE	$38,512,917.39	$1,159,420.29	$289,855.07
CONTINGENCY (30%)	$11,553,875.22	$347,826.09	$86,956.52
INCIDENTALS (15%)	$5,776,937.61	$173,913.04	$43,478.26
SUBTOTAL	**$55,843,730.22**	**$1,681,159.42**	**$420,289.86**
INFLATION (5 YEARS @ 4%)	$11,168,746.04	$336,231.88	$84,057.97
ITEM TOTAL	**$67,012,476.26**	**$2,017,391.30**	**$504,347.83**
CONSTRUCTION TOTAL	**$69,534,215.39**		

HEROES TUNNEL OPTION 4

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**				
TUNNEL	$8,968,751.00				
ROADWAY FEATURES (INSIDE TUNNEL)		$311,000.00			
MAINTENANCE & PROTECTION OF TRAFFIC (DETOUR)			$900,000.00		
MECHANICAL (VENTILATION/LIGHTING)				$180,000.00	
ABANDON VENT SHAFT					$200,000.00
TOTAL CONTRACT ITEMS	$8,968,751.00	$311,000.00	$900,000.00	$180,000.00	$200,000.00
MINOR ITEM ALLOWANCE (20%)	$2,599,637.97	$90,144.93	$260,869.57	$52,173.91	$57,971.01
CLEARING AND GRUBBING (3%)	$389,945.70	$13,521.74	$39,130.43	$7,826.09	$8,695.65
CONSTRUCTION STAKING (1%)	$129,981.90	$4,507.25	$13,043.48	$2,608.70	$2,898.55
MOBILIZATION (7%)	$909,873.29	$31,550.72	$91,304.35	$18,260.87	$20,289.86
BASE ESTIMATE	$12,998,189.86	$450,724.64	$1,304,347.83	$260,869.57	$289,855.07
CONTINGENCY (30%)	$3,899,456.96	$135,217.39	$391,304.35	$78,260.87	$86,956.52
INCIDENTALS (15%)	$1,949,728.48	$67,608.70	$195,652.17	$39,130.43	$43,478.26
SUBTOTAL	**$18,847,375.29**	**$653,550.72**	**$1,891,304.35**	**$378,260.87**	**$420,289.86**
INFLATION (5 YEARS @ 4%)	$3,769,475.06	$130,710.14	$378,260.87	$75,652.17	$84,057.97
ITEM TOTAL	**$22,616,850.35**	**$784,260.87**	**$2,269,565.22**	**$453,913.04**	**$504,347.83**
CONSTRUCTION TOTAL	**$26,628,937.30**				

HEROES TUNNEL OPTION 4 (NO DETOUR)

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**			
TUNNEL	$8,968,751.00			
ROADWAY FEATURES (INSIDE TUNNEL)		$311,000.00		
MECHANICAL (VENTILATION/LIGHTING)			$180,000.00	
ABANDON VENT SHAFT				$200,000.00
TOTAL CONTRACT ITEMS	$8,968,751.00	$311,000.00	$180,000.00	$200,000.00
MINOR ITEM ALLOWANCE (20%)	$2,759,615.69	$95,692.31	$55,384.62	$61,538.46
MAINTENANCE & PROTECTION OF TRAFFIC (4%)	$551,923.14	$19,138.46	$11,076.92	$12,307.69
CLEARING AND GRUBBING (3%)	$413,942.35	$14,353.85	$8,307.69	$9,230.77
CONSTRUCTION STAKING (1%)	$137,980.78	$4,784.62	$2,769.23	$3,076.92
MOBILIZATION (7%)	$965,865.49	$33,492.31	$19,384.62	$21,538.46
BASE ESTIMATE	$13,798,078.46	$478,461.54	$276,923.08	$307,692.31
CONTINGENCY (30%)	$4,139,423.54	$143,538.46	$83,076.92	$92,307.69
INCIDENTALS (15%)	$2,069,711.77	$71,769.23	$41,538.46	$46,153.85
SUBTOTAL	**$20,007,213.77**	**$693,769.23**	**$401,538.46**	**$446,153.85**
INFLATION (5 YEARS @ 4%)	$4,001,442.75	$138,753.85	$80,307.69	$89,230.77
ITEM TOTAL	**$24,008,656.52**	**$832,523.08**	**$481,846.15**	**$535,384.62**
CONSTRUCTION TOTAL	**$25,858,410.37**			

HEROES TUNNEL OPTION 5

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONTRACT ITEMS	**ESTIMATED COST**			
TUNNEL	$10,595,924.00			
ROADWAY FEATURES (INSIDE TUNNEL)		$311,000.00		
MECHANICAL (VENTILATION/LIGHTING)			$180,000.00	
ABANDON VENT SHAFT				$200,000.00
TOTAL CONTRACT ITEMS	$10,595,924.00	$311,000.00	$180,000.00	$200,000.00
MINOR ITEM ALLOWANCE (20%)	$3,071,282.32	$90,144.93	$52,173.91	$57,971.01
CLEARING AND GRUBBING (3%)	$460,692.35	$13,521.74	$7,826.09	$8,695.65
CONSTRUCTION STAKING (1%)	$153,564.12	$4,507.25	$2,608.70	$2,898.55
MOBILIZATION (7%)	$1,074,948.81	$31,550.72	$18,260.87	$20,289.86
BASE ESTIMATE	$15,356,411.59	$450,724.64	$260,869.57	$289,855.07
CONTINGENCY (30%)	$4,606,923.48	$135,217.39	$78,260.87	$86,956.52
INCIDENTALS (15%)	$2,303,461.74	$67,608.70	$39,130.43	$43,478.26
SUBTOTAL	**$22,266,796.81**	**$653,550.72**	**$378,260.87**	**$420,289.86**
INFLATION (5 YEARS @ 4%)	$4,453,359.36	$130,710.14	$75,652.17	$84,057.97
ITEM TOTAL	**$26,720,156.17**	**$784,260.87**	**$453,913.04**	**$504,347.83**
CONSTRUCTION TOTAL	**$28,462,677.91**			

HEROES TUNNEL CONSTRUCTION SCENARIOS

CONCEPTUAL COST ESTIMATE

TOTAL COST SUMMARY

CONSTRUCTION OPTION COMPONENTS		ESTIMATED COST
CONSTRUCTION SCENARIO A		
OPTION 1		$70,641,924.61
OPTION 4 (NO DETOUR)		$25,323,025.75
	TOTAL	$95,964,950.36
CONSTRUCTION SCENARIO B1		
OPTION 2		$85,118,770.00
OPTION 4 (NO DETOUR) - 1 TUNNEL ONLY		$12,393,820.57
	TOTAL	$97,512,590.57
CONSTRUCTION SCENARIO B2		
OPTION 2		$85,118,770.00
OPTION 4 (NO DETOUR)		$25,323,025.75
	TOTAL	$110,441,795.75
CONSTRUCTION SCENARIO C		
OPTION 3		$69,534,215.39
OPTION 4 (NO DETOUR) - 1 TUNNEL ONLY		$12,393,820.57
	TOTAL	$81,928,035.96
CONSTRUCTION SCENARIO D		
OPTION 4		$26,628,937.30
	TOTAL	$26,628,937.30
CONSTRUCTION SCENARIO E		
OPTION 5		$28,462,677.91
	TOTAL	$28,462,677.91
CTDOT ALTERNATIVE CONSTRUCTION SCENARIO		
OPTION 2		$85,118,770.00
OPTION 3		$69,029,867.57
OPTION 4 (NO DETOUR) - 1 TUNNEL ONLY		$12,393,820.57
	TOTAL	$166,542,458.13